Wetland Functional Assessment and Impact Analysis

Master Plan Update Improvements Seattle-Tacoma International Airport

Port of Seattle

Parametrix, Inc.
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WETLAND FUNCTIONAL ASSESSMENT AND IMPACT ANALYSIS

MASTER PLAN UPDATE IMPROVEMENTS
SEATTLE-TACOMA INTERNATIONAL AIRPORT

Prepared for

PORT OF SEATTLE
Seattle-Tacoma International Airport
Seattle, Washington 98158

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

APPENDICES

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (CONTINUED)

ACRONYM LIST

ACDP	*Air Cargo Development Plan*
ACOE	U.S. Army Corps of Engineers
AHFS	Aircraft Hydrant Fueling System
AMA	Aircraft movement area
AOA	Airport operating area
ASDE	Airport Surface Detection Equipment
BA	Biological Assessment
BMPs	Best management practices
BOD	Biochemical Oxygen Demand
cfs	Cubic feet per second
CIP	Capital Improvement Project
CMA	Calcium Magnesium Acetate
CPMPNAS	Committee on Protection and Management of Pacific Northwest Anadromous Salmonids
cy	Cubic yards
DO	Dissolved Oxygen
DOC	Dissolved organic carbon
DNL	Day/night level
DNR	Department of Natural Resources
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FEIS	*Final Environmental Impact Statement*
FSEIS	*Final Supplemental Environmental Impact Statement*
ft	Foot/feet
GIS	Geographic Information System
HGM	Hydrogeomorphic classification
HPA	Hydraulic Project Approval
HSPF	Hydrologic Simulation Program – FORTRAN
in	Inches
IVA	Indicator Value Assessment
IWS	Industrial Wastewater System
IWSB	

ACRONYM LIST (CONTINUED)

IWTP	Industrial Wastewater Treatment Plant
LWD	Large woody debris
MSE	Mechanically stabilized earth
NEPA	National Environmental Policy Act
NEPL	North Employees Parking Lot
NPDES	National Pollutant Discharge Elimination System
NRMP	*Natural Resource Mitigation Plan*
NTU	Nephelometric Turbidity Units
PC	Prior converted
PGIS	Pollution-generating impervious surfaces
Port	Port of Seattle
PSW	Puget Sound Wetlands and Stormwater Management Research Program
RDF	Regional Detention Facility
RSA	Runway Safety Area
RTA	Regional Transit Authority
SASA	South Aviation Support Area
SDS	Storm Drain System
SEIS	Supplemental Environmental Impact Statement
SEPA	State Environmental Policy Act
SMP	*Preliminary Comprehensive Stormwater Management Plan*
Sound Transit	Central Puget Sound Regional Transit Authority
SPCCCP	*Spill Prevention Control and Countermeasure Plan*
SR	State route
STIA	Seattle-Tacoma International Airport
SWPPP	*Stormwater Pollution Prevention Plan*
TESC	Temporary Erosion and Sedimentation Control
TPH	Total petroleum hydrocarbons
TSS	Total suspended solids
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
VWFDR	Vegetation, Wildlife, and Fisheries Discipline Report
WDR	*Wetland Discipline Report*
WET	Wetland Evaluation Technique
WHMP	*Wildlife Hazard Management Plan*
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

The Seattle-Tacoma International Airport (STIA) has updated its Master Plan to meet future aviation needs. This report describes the impact of Master Plan development projects on wetlands and wetland functions. The report updates earlier wetland analyses completed in support of the National Environmental Policy Act (NEPA)/State Environmental Policy Act (SEPA), Final Environmental Impact Statement (FEIS), and Final Supplemental Environmental Impact Statement (FSEIS) for the Master Plan. Master Plan Update improvements that affect wetlands and streams include:

- Runway safety area (RSA) extensions for existing runways
- A new 8,500-ft-long runway
- Relocation of South 154th Street around the north end of the RSAs of existing and proposed runways
- Development of on-site borrow sources to provide fill material for the third runway
- Cargo and maintenance facilities in the South Aviation Support Area (SASA)
- Various utility improvements and expansions to service new facilities

Proposed construction projects will result in permanent impacts[1] to 18.37 acres of wetlands and temporary impacts to 2.05 acres. About 9.05 acres of Category II wetlands, 7.31 acres of Category III wetlands, and 2.01 acres of Category IV wetlands will be permanently impacted by the proposed project. In addition, 980 linear ft of Miller Creek and 1,290 linear ft of drainage channels (ditches) will be filled.

Wetland functions are the physical, chemical, and biological processes and interactions that occur in a wetland. Impacts to wetland functions were assessed for nine wetland functions typically performed by wetlands. The habitat functions evaluated were habitat for fish, passerine birds, waterfowl, amphibians, and small mammals. Physical functions evaluated were export of carbon, groundwater exchange, and water quality (nutrient and sediment trapping). The functions were assessed by classifying wetlands into hydrogeomorphic groups (slope, depression, and riparian) and habitat groups (forest, shrub, and emergent). For these groups, the wetland attributes that are typically recognized as indicators of wetland functions for western Washington wetlands were identified and evaluated. Based on the presence of these indicators and professional judgement, each wetland for each function was rated using a "high," "medium," or "low" rating system. The approach to rating the wetlands was to consider the likely importance of the wetland functions to the local watershed, and as a result, the ratings are somewhat higher than if the wetland and functions were compared to undisturbed wetlands in the region.

With respect to biological functions, overall wildlife use of the study area and its associated wetlands is largely limited to species that are tolerant to human disturbance. The area is fragmented

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[1] These permanent impacts include direct filling and potential indirect impacts that could eliminate wetlands.

by urban development, and faunal diversity is limited because wetlands are too small to meet habitat requirements for many wildlife populations. However, when compared to other urban wetlands, some larger wetlands that support native shrub and forest vegetation provide moderate to high function for songbirds, amphibians, and small mammals.

With respect to physical functions, the riparian wetlands located on groundwater seeps adjacent to Miller and Des Moines Creeks provide base flow support functions and may enhance (i.e., reduce) stream temperatures during summer months. Most of the wetlands on-site have limited stormwater storage capacity due to their small size, lack of direct connections to the streams, or topographic conditions that limit water detention. The existing groundwater recharge function is also limited because most wetlands appear to be underlain by relatively compact soils that limit rates of groundwater infiltration. Wetlands that occur on relatively flat areas and receive runoff from urban areas function to improve water quality.

Temporary impacts to wetlands during construction include removal of wetland vegetation (native and non-native), soil disturbance, and potential sedimentation. Vegetation removal and soil disturbance result from constructing temporary erosion and sediment control stormwater collection swales and ponds, and construction staging in wetlands. Because temporary impacts may occur for more than one construction season, a temporal loss of their function occurs.

The wetland losses that could result from indirect impacts are also included in the impact area of 18.37 acres and fully replaced by mitigation at ratios in excess of 3:1. About 2.4 acres of indirect wetland impacts could occur in certain locations where changes to wetland hydrology, shading, or fragmentation result in loss of wetland functions. While these indirect impacts could result in the loss of some wetland functions from an area, they may not necessarily remove all wetland functions.

Potential indirect impacts to the hydrology of wetlands adjacent to construction projects are expected to be minimal because the project design allows groundwater and runoff to continue to flow to downslope wetlands. Indirect impacts resulting from noise and human disturbance are expected to be minor because most wetlands are already subject to aircraft noise, traffic noise, and human disturbances, and because the wildlife species present in these wetlands are common in urban environments and tolerant of these activities.

Other indirect impacts to wetlands that could affect their function include noise and human disturbance, changes in water quality impacts, and changes in surface hydrology. These indirect impacts could alter or reduce the level of some functions, but will not eliminate the wetlands themselves. These indirect impacts will be mitigated because, in most cases, land use conditions that have degraded these wetlands will be removed, and restoration actions are implemented to improve their functional performance (see Section 4 of the *Natural Resources Mitigation Plan; Parametrix 2001a*).

Overall, the Master Plan Update improvement design and mitigation will protect wetlands and aquatic resources. The substantial mitigation will compensate for identified impacts to hydrology (peak flow and low flow), water quality, wetlands (temporary, permanent filling, and indirect), and streams. Planned mitigation will also prevent cumulative impacts attributable to the proposed actions.

1. INTRODUCTION

Implementation of the updated Seattle-Tacoma International Airport (STIA) Master Plan Update will result in unavoidable filling of wetlands; relocation of a 980-ft section of Miller Creek, and replacement of 1,290 ft of drainage channels. This report describes the impacts of the proposed improvements on wetlands.[2] The report updates wetland analysis completed in support of the National Environmental Policy Act (NEPA)/State Environmental Policy Act (SEPA), Final Environmental Impact Statement (FEIS), and Final Supplemental Environmental Impact Statement (FSEIS) for the Master Plan Update improvements. This report also addresses wetland impacts within project areas that were not identified in the previous documents EIS when the Port of Seattle (Port) did not have access to some properties during the earlier analysis.

The report is organized into four sections. Section 1 describes the project, the study area, and the results of a comprehensive wetland delineation of the project site (see *Wetland Delineation Report, Master Plan Update Improvements, Seattle-Tacoma International Airport*, Parametrix 2000a). Section 2 describes the methodologies for evaluating project impacts to wetland area and function.[3] The results of the impact analysis are presented in Section 3. These results were used to develop on-site and off-site mitigation projects (described in *Natural Resource Mitigation Plan, Master Plan Update Improvements, Seattle-Tacoma International Airport* [NRMP]; Parametrix 2001a) to compensate for wetland impacts. Section 4 describes permanent and temporary impacts and indirect impacts resulting from the project.

1.1 PROJECT DESCRIPTION

As currently configured, STIA is unable to efficiently meet existing and future regional air travel demands. The airfield operates inefficiently during poor weather because it can accommodate only a single arrival stream. As a result, significant arrival delay occurs during poor weather. Aircraft are either held on the ground in their originating city, slowed en route, or placed in holding patterns to await clearance to land at STIA. These conditions result in inefficient operation of the existing airfield, as described in the FEIS (Federal Aviation Administration [FAA] 1996) and FSEIS (FAA 1997).

With or without airport development, airport activity will increase as a consequence of regional population growth. As aviation demand grows, aircraft operating delay will increase exponentially. The increased passenger, cargo, and aircraft operations demands will place increasing burdens on the existing terminal and support facilities. Without improvements, the roadway system, terminal

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[2] Impacts to streams, drainage channels, and floodplains are also described in the *Natural Resources Mitigation Plan*, the *Biological Assessment*, the *Final EIS*, the *Final Supplemental EIS*, and the *Stormwater Master Plan*.

[3] Wetland functions are the physical, chemical, and biological processes and interactions that occur in a wetland.

space, gates, and cargo and freight processing space will become more inefficient and congested, and the quality of service will be reduced.

The proposed Master Plan Update addresses the following needs:

- Improve poor weather operating capability to accommodate aircraft activity with an acceptable level of aircraft delay.
- Provide sufficient runway length to accommodate either warm weather operations or payloads for aircraft types operating to the Pacific Rim.
- Provide Runway Safety Areas (RSAs) that meet current FAA standards.
- Provide efficient and flexible landside facilities to accommodate future aviation demand.

1.2 KEY PROJECT ELEMENTS

The proposed Master Plan Update includes the following major components:

- Establishing standard RSAs for existing Runways 16R/34L and 16L/34R
- Adding a third parallel runway (16X/34X) with a length of 8,500 ft and associated taxiway and navigational aids
- Extending Runway 34R by 600 ft to the south
- Adding a new air traffic control tower
- Relocating South 154th Street to accommodate the extended RSAs and third runway
- Improving and expanding the main terminal and access system
- Developing new parking facilities and expanding existing facilities
- Developing a new north unit terminal, roadway system, and parking facility
- Developing the South Aviation Support Area (SASA) for cargo and/or maintenance facilities
- Relocating, redeveloping, and expanding support facilities

Airport improvements that will affect wetlands and streams are the RSA extensions and relocation of South 154th Street, the new runway, development of on-site borrow sources to provide fill for the runway, and development of a SASA.

The project area is located at and near STIA in SeaTac, Washington (Figure 1-1). Areas near the airport where construction activities could affect wetlands are discussed below. The project areas occur in the Miller Creek, Walker Creek, and Des Moines Creek drainage basins.[4] An off-site wetland mitigation project is proposed in the Green River drainage basin near Auburn (see Figure 1-1).

1.2.1 Runway Safety Areas and Relocation of South 154th Street

The RSAs at the north end of the airfield (for Runways 16L and 16R) will be extended to meet FAA regulations (Figure 1-2). These safety area extensions will require the relocation of South 154th Street about 250 ft north of its existing location.

New Third Runway

An 8,500-ft runway will be constructed about 1,000 ft west of existing Runway 34L. Construction of the third runway also requires relocation of South 154th Street north of its present location. Land for the new runway includes areas owned by the Port of Seattle (east of 12th Avenue South) and areas in private ownership (the acquisition area) west of 12th Avenue South (see Figure 1-2). The acquisition area is located between 12th Avenue South, Des Moines Memorial Drive, South 176th Street, and South 147th Street.

In addition to accommodating the new runway, the acquisition area will be used for stormwater management facilities, construction staging, and as a buffer between the airfield and residential areas farther to the west. Construction staging uses in the acquisition area could include vehicle and equipment parking, material storage, construction stormwater treatment facilities, and temporary office facilities.

1.2.3 Borrow Areas

Several areas of Port-owned property will be developed to provide fill material for construction of the new runway (see Figure 1-2). Borrow Area 1 is located east of Des Moines Creek and between South 200th Street and South 216th Street. Borrow Area 3 is located west of Des Moines Creek and between South 200th Street and 209th Street. Borrow Area 4 is located between South 196th Street and South 200th Street, near 18th Avenue South. These borrow areas will be operated during the dry season only, with disturbed areas hydroseeded or otherwise stabilized prior to late fall. Fill material will also be obtained from an elevated area located just west of the existing airfield, near the location of South 176th Street.

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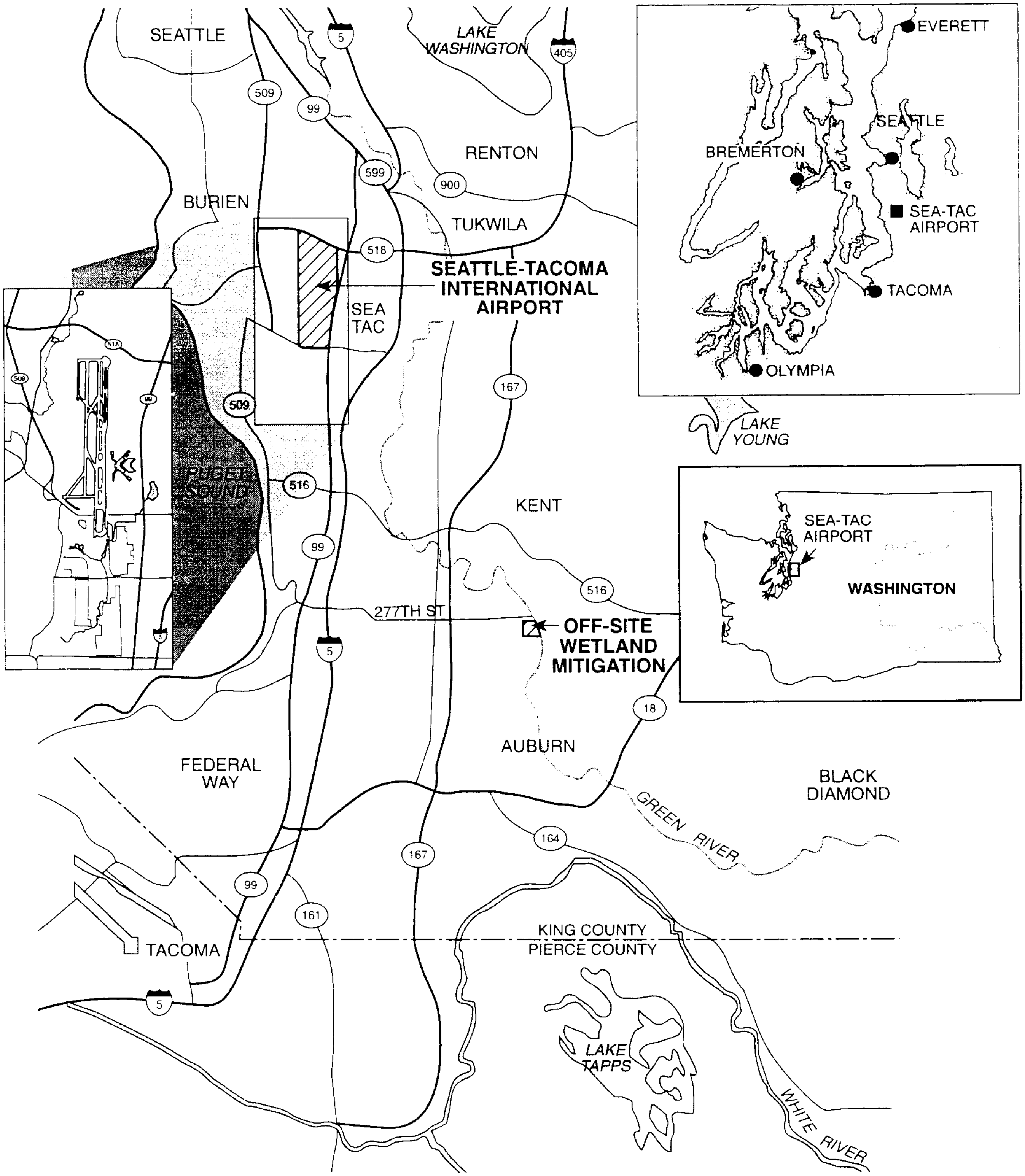
[4] Master Plan Update improvements will not add new impervious surface, alter wetlands, or alter stream channels in the Gilliam Creek drainage basin. Thus, Gilliam Creek is not considered further in this report.



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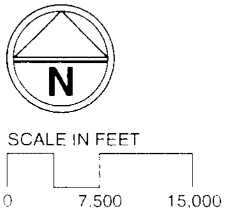

Figure 1-1
Location of Seattle-Tacoma International Airport and Off-Site Wetland Mitigation Site

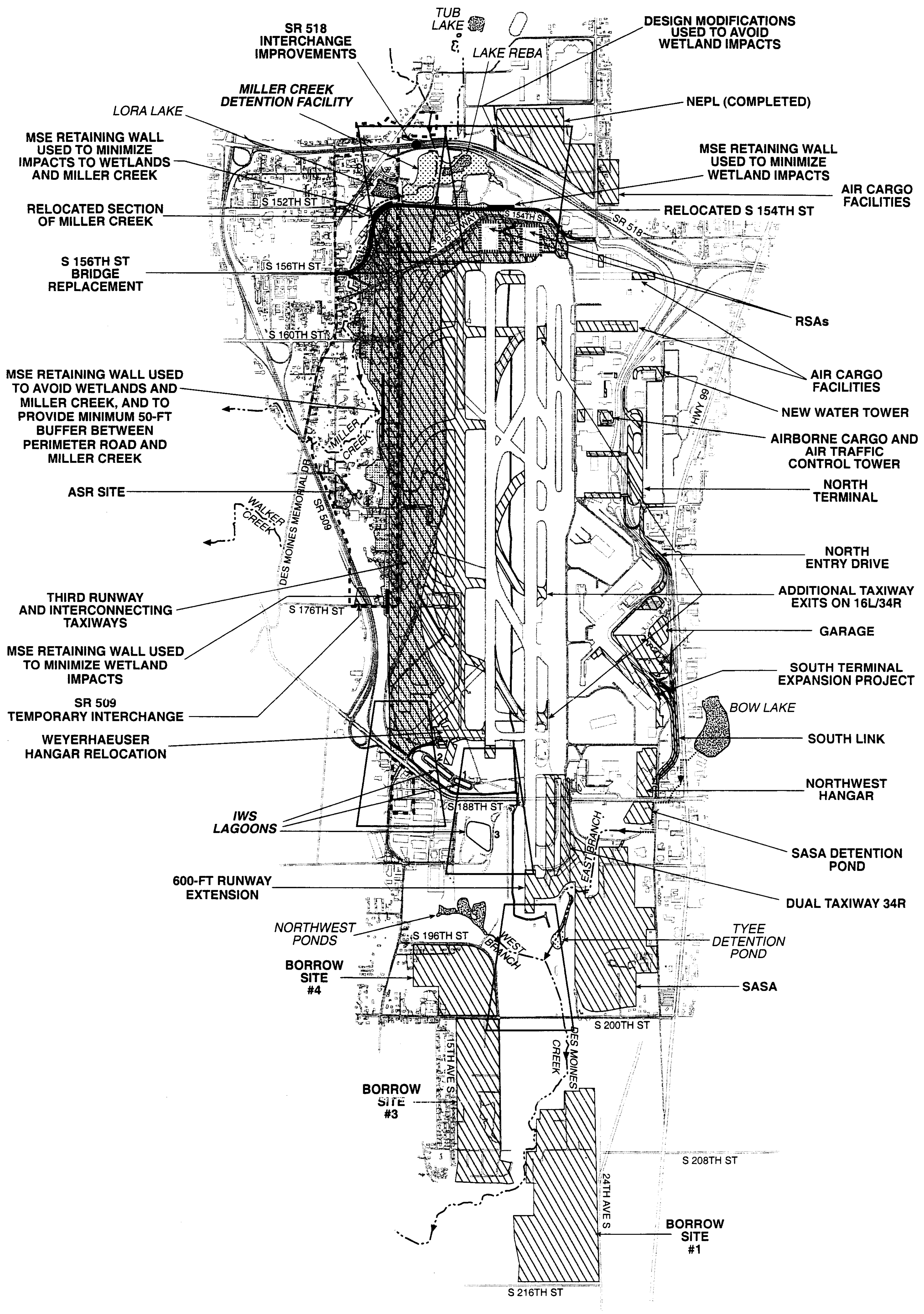

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Figure 1-2
Master Plan Update Improvement Projects at STIA

1.2.4 South Aviation Support Area

The SASA site will be developed for air cargo and maintenance facilities, and will be connected to the airfield taxiways with a bridge and taxiway. The SASA project site is located south and east of the airfield (see Figure 1-2). The site includes vacant land between South 188th Street and South 200th Street, including portions of the Tyee Valley Golf Course.

Prior to development of the SASA project, portions of this site may be used for construction staging. Construction staging uses could include vehicle and equipment parking, material storage, construction stormwater treatment facilities, and temporary office facilities.

1.2.5 Overview of the Mitigation Plan

The Master Plan Update improvement projects also include the natural resource mitigation required to mitigate adverse impacts to the natural environment (wetlands, streams, floodplains, water quality, and hydrology). These mitigation actions are evaluated as a part of the impact analysis presented in this report. They are described in detail in the *Natural Resources Mitigation Plan: Master Plan Update Improvements Seattle-Tacoma International Airport* (Parametrix 2000a). The mitigation focuses on compensatory mitigation to replace wetland and stream functions lost or impacted by the project. Key elements of the mitigation restore wetland functions such as sediment and nutrient retention (water quality), surface water storage (flood water detention and storage), aquatic habitat functions (e.g., instream aquatic habitat and riparian habitat), and organic carbon production and export. Compensatory mitigation projects are summarized in Table 1-1. In addition, the Port has made extensive efforts throughout the Master Plan Update planning process to avoid, minimize, and rectify, as well as compensate for, adverse impacts.

1.3 WETLAND DELINEATION

Wetlands in the study area[5] were identified through wetland delineation studies completed by FAA (1996), Parametrix (2000a), and U.S. Army Corps of Engineers (ACOE 2001). Studies completed by Parametrix update wetland delineations and inventories completed in support of the Environmental Impact Statement (EIS) and FSEIS. While the focus of the delineation was within the acquisition area, all project areas for the Master Plan Update were re-evaluated for the presence of wetlands.

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[5] The study area addressed in this report and the supporting wetland delineation report includes all areas where development for Master Plan Update improvements are planned as well as adjoining areas where mitigation is planned or where indirect impacts would occur (see Figure 1-2).

Table 1-1. Summary of compensatory mitigation (on and off site) for watershed, wetland, and stream impacts at Seattle-Tacoma International Airport.

Impact	Mitigation Action	Target Functions to Replace	Explanation and Key Attributes that Provide Target Functions[a]
ON-SITE MITIGATION			
Permanent Impacts			
Approximately 980 linear ft of Miller Creek channel will be filled to accommodate third runway embankment and South 154th Street relocation.	Relocate approximately 1,080 ft of Miller Creek channel. Enhance 450 ft of Miller Creek channel at Des Moines Way Nursery.	Fish and aquatic habitat Amphibian habitat Organic matter export	The channel design includes instream habitat features, including improved substrate conditions, LWD, channel diversity, and increased channel length. A buffer around the new channel will be vegetated with native trees and shrubs to provide shade and organic matter inputs to the stream.
Drainage channels will be filled near 12th Avenue South to accommodate the third runway embankment.	Create new permanent drainage channels.	Organic matter export functions Groundwater exchange functions	Approximately 1,290 ft of new permanent drainage channels will provide ecological functions by planting the channel margins with native vegetation to provide buffer functions. Functions include shade to control water temperatures and provide organic matter input. The channels will be designed to connect to the embankment drainage layer material to promote groundwater discharge. Connection to wetlands and Miller Creek will promote organic matter transport and export to the creek.
Approximately 8,500 cy of Miller Creek floodplain will be filled to accommodate third runway embankment and South 154th Street relocation.	Replace lost floodplain.	Flood storage	Approximately 9,600 cubic yards of soil will be excavated to suitable elevations that achieve storage of 5.94 acre-ft of floodwaters. Suitable grades and elevations will allow overbank and backwater flooding to occur in this floodplain.

Table 1-1. Summary of compensatory mitigation (on and off site) for watershed, wetland, and stream impacts at Seattle-Tacoma International Airport (continued).

Impact	Mitigation Action	Target Functions to Replace	Explanation and Key Attributes that Provide Target Functions[a]
Approximately 18.37 acres of wetland will be filled during construction of the third runway embankment and other construction-related projects.	Restore about 12.3 acres of prior converted cropland, farmed wetland, or other wetland on the Vacca Farm site to shrub-dominated wetlands (including removal of 1 acre of fill).	Nutrient and sediment trapping functions Organic matter export Groundwater exchange Small mammal habitat Reduced waterfowl habitat	Plowed farmland will be stabilized with dense shrub and herbaceous plantings. Overbank and backwater flooding will occur to promote organic matter export. Subsurface drainage systems will be removed to promote natural groundwater discharge and flow patterns.
	Restore about 2.8 acres of the Des Moines Way Nursery site to shrub dominated wetlands (Including removal of 2 acres of fill).		Hummocks vegetated with dense native vegetation in wetlands and buffers will be provided as habitat for small mammals. This attribute will be augmented with LWD in wetlands and buffers. Large areas of emergent vegetation, open water, or long-term flooding that could promote waterfowl use will be avoided.
	Restore wetland buffer conditions (1.81 acre) around the north and west sides of Lora Lake.	Fish, amphibian, and aquatic habitat Organic matter export Reduce wildlife attractants	Converting lawn areas to riparian buffer communities will be established by planting with native wetland and upland shrub vegetation (refer to Table 5.1-1 in Section 5). Overhanging dense shrub vegetation will improve aquatic habitat, reduce waterfowl use of shoreline areas, and promote export of organic matter from shoreline to aquatic habitats. Removal of a concrete bulkhead along the Lora Lake shoreline will improve shoreline habitat for amphibians, fish, and aquatic insects.
	Enhance approximately 10.25 acres of wetlands along Miller Creek	Nutrient and sediment trapping Small mammal habitat	Removing structures and restoring native wetland vegetation (Table 4.1-3) will enhance riparian and other wetlands. Areas of non-native vegetation will be removed and native trees and shrubs planted in the wetland.

Table 1-1. Summary of compensatory mitigation (on and off site) for watershed, wetland, and stream impacts at Seattle-Tacoma International Airport (continued).

Impact	Mitigation Action	Target Functions to Replace	Explanation and Key Attributes that Provide Target Functions[a]
	Restore wetlands on the Tyee Valley Golf Course.	Nutrient and sediment trapping Organic matter export Reduce waterfowl habitat Small mammal habitat	Dense native shrub vegetation will be planted in Des Moines Creek floodplain and riparian areas. The wetland and riparian vegetation will promote increased export of organic matter to Des Moines Creek compared to the existing turf vegetation.[b] Shrub communities will reduce waterfowl use and improve habitat for small mammals.
<u>**Temporary Impacts**</u>			
Construction of temporary stormwater management ponds and other projects may temporarily impact up to 2.05 acres of wetland.	Restore forest and shrub communities to Wetland A17. Restore approximately 125 ft of Water D. Restore wetland areas after construction is complete.	Nutrient and sediment trapping Organic matter export Groundwater exchange Small mammal habitat	Restoration of wetlands that will be temporarily filled or disturbed will restore functions that previously existed on these sites. Restoration will include establishing pre-disturbance topography, removing three culverts in Water D, and planting the area with native shrub or forest vegetation. Integration of these areas with the replacement drainage channel mitigation and the embankment drainage layer will promote restoration of pre-existing hydrologic and water quality functions.
<u>**Indirect and Cumulative Impacts**</u>			
Filled wetlands near Miller Creek will reduce aquatic habitat value of the stream.	Establish and enhance buffers along Miller Creek.	Nutrient and sediment trapping Organic matter export Small mammal habitat	Conversion of residential land uses to vegetated stream buffers will promote nutrient and sediment trapping functions and reduce pollutant loading. Greater densities of riparian vegetation will increase shade, instream habitat, and organic matter export to Miller Creek. Riparian buffer vegetation will contribute to bank stabilization, sediment, and nutrient removal. It will also provide small mammal habitat.

Table 1-1. Summary of compensatory mitigation (on and off site) for watershed, wetland, and stream impacts at Seattle-Tacoma International Airport (continued).

Impact	Mitigation Action	Target Functions to Replace	Explanation and Key Attributes that Provide Target Functions[a]
Additional development in the watersheds could result in additional cumulative impacts.	Participate in developing and implementing Miller Creek and Des Moines Creek basin plans.	Aquatic habitat Stream and/or watershed hydrology	These planning processes will identify effective, long-term solutions to restore additional fish habitat functions to Miller and Des Moines Creeks. Projects are anticipated to focus on restoring watershed hydrology through increased regional stormwater detention facilities and improved fish habitat through habitat restoration projects. The Port will contribute staffing resources and funds to support these efforts. The Port will work with other cooperating jurisdictions to plan and implement appropriate watershed restoration projects.
	Provide trust fund to watershed restoration projects.	Cumulative impacts to aquatic habitat	The Port will establish a trust fund to help promote aquatic habitat and other watershed restoration actions.
The runway fill or borrow area excavation may eliminate water sources that contribute to remaining wetlands downslope of the runway.	Design internal drainage and conveyance channels to promote and retain wetland hydrology and streamflow. Monitor wetlands adjacent to the third runway embankment and borrow areas to ensure wetland hydrology is maintained.	Groundwater exchange Organic matter export	Subsurface and surface replacement channels will continue to collect and distribute groundwater currently surfacing near 12th Avenue South to Miller Creek and associated wetlands. Surface drainage patterns and conveyance swales will be designed to collect and distribute groundwater seepage and surface runoff to wetlands downslope of the borrow areas.
OFF-SITE MITIGATION			
Permanent Impacts			
Approximately 18.37 acres of wetland wildlife (avian) habitat will be lost.	Replace high quality wetland and avian habitat functions off-site at an overall ratio of 2:1.	Passerine bird habitat Waterfowl habitat Small mammal habitat Flood storage	A variety of wetland classes and vegetation types on a large protected site will provide high quality habitat for a diverse array of birds and small mammals. Open water habitat (including vegetated aquatic beds) will support waterfowl and other bird

Table 1-1. Summary of compensatory mitigation (on and off site) for watershed, wetland, and stream impacts at Seattle-Tacoma International Airport (continued).

Impact	Mitigation Action	Target Functions to Replace	Explanation and Key Attributes that Provide Target Functions[a]
			species that require small ponds for forage or nesting.
			Waterfowl and other marsh birds will use flooded persistent and non-persistent emergent plant communities for forage and nesting. These communities will produce organic matter and aquatic insects that provide forage in open water areas.
			Shrub wetland will fringe marsh communities and provide nesting and forage habitat for songbirds as well as export organic matter to emergent areas.
			Multi-storied forest communities will provide habitat to songbirds, raptors, and small mammals.
			A densely vegetated 100-ft-wide buffer will provide additional upland habitats and protect interior upland and wetland habitats from potential disturbances if off-site areas are developed.
			Microhabitat features including LWD, vegetated hummocks, interspersion of vegetation types, and proximity to the Green River riparian corridor-will further enhance the area for wildlife.
			Excavation of portions of the site below an elevation of 45 ft and connection to the floodplain of the Green River by enhancing existing drainage channels will provide flood-storage functions.

[a] Analyses of the ecological functions provided at each wetland mitigation site are found in Tables 4-13 to 4-16. All mitigation areas (including, but not limited to, streams, wetlands, buffers, and floodplains) located within 10,000 ft of a runway shall be subject to the provisions of the Port's *Wildlife Hazard Management Plan* (USDA 2000) for the management of wildlife and wildlife attractant areas. On-site mitigation may provide replacement habitat functions for birds, but credit is not sought for this function, as management of birds pursuant to the WHMP may restrict this function.

[b] These enhancements will be coordinated with the Des Moines Creek Basin Committee's proposed RDF.

All wetlands were delineated between 1998 and 2000 using the criteria described in the ACOE *Wetlands Delineation Manual* (Environmental Laboratory 1987). The delineated boundaries were surveyed, mapped, and field verified by ACOE personnel. Incorporation of these survey data into a geographic information system (GIS) system allowed calculation of wetland areas, mapping of wetlands, and calculation of wetland impacts.

More than 117 wetlands, 12 ponds, and 8 channels (excluding Miller and Des Moines Creeks) totaling 117.9 acres have been delineated as Master Plan Update improvement sites. Additional wetlands known to exist nearby (see Section 1.4) increase the total to more than 200 acres[6] (Table 1-2, see Figures 1-3 and 1-4). Approximately 20.42 ac of wetlands could be directly affected by permanent and temporary construction[7] proposed in the Master Plan Update.

Table 1-2. Summary of wetland areas in the Seattle-Tacoma International Airport Master Plan Update area.

Wetland [a]	Classification [b]	Area (Acres)	Watershed
North Employee Parking Lot Area			
1	Forest	0.07	Miller
2	Forest	0.73	Miller
	Subtotal	**0.80**	
Runway Safety Area Extension			
3	Forest	0.56	Miller
4	Forest	5.00	Miller
5	Forest/Scrub-Shrub	4.63	Miller
6	Scrub-Shrub	0.86	Miller
	Subtotal	**11.05**	
Third Runway Project Area			
North Airfield			
7[c]	Forest/Open Water/Emergent	6.68	Miller
8	Scrub-Shrub/Emergent	4.95	Miller
9	Forest/ Emergent (40/60)	2.83	Miller
10	Scrub-Shrub	0.31	Miller
11	Forest/Emergent (80/20)	0.50	Miller
12	Forest/Emergent (20/80)	0.21	Miller
13	Emergent	0.05	Miller
14	Forest	0.19	Miller
West Airfield			
15	Emergent	0.28	Miller

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[6] This number includes 115.89 acres reported in Table 1-2 and wetlands associated with Bow Lake (25 acres), Tub Lake (19 acres), and other nearby significant wetlands (49.7 acres) as described in Section 1.4.

[7] Because many of these construction impacts exceed 1-year, mitigation includes restoration and other on-site actions (see NRMP, Parametrix 2001a)

Table 1-2. **Summary of wetland areas in the Seattle-Tacoma International Airport Master Plan Update area (continued).**

Wetland [a]	Classification [b]	Area (Acres)	Watershed
16	Emergent	0.05	Miller
17	Emergent	0.02	Miller
18	Forest/Scrub-Shrub/Emergent (50/20/30)	3.56	Miller
19	Forest	0.56	Miller
20	Scrub-Shrub/Emergent (90/10)	0.57	Miller
21	Forest	0.22	Miller
22	Scrub-Shrub/Emergent (90/10)	0.06	Miller
23	Emergent	0.77	Miller
24	Emergent	0.14	Miller
25	Forest	0.06	Miller
26	Emergent	0.02	Miller
W1	Emergent	0.10	Miller
W2	Forest/Emergent (20/80)	0.22	Miller
	Other Waters of the U.S.	0.02	Miller
Vacca Farm Site			
FW1	Farmed Wetland	0.03	Miller
FW2	Farmed Wetland	0.09	Miller
FW3	Farmed Wetland	0.59	Miller
FW5	Farmed Wetland	0.08	Miller
FW6	Farmed Wetland	0.07	Miller
FW8	Farmed Wetland	0.03	Miller
FW9	Farmed Wetland	0.01	Miller
FW10	Farmed Wetland	0.02	Miller
FW11	Farmed Wetland	0.11	Miller
A1a	Shrub	0.07	Miller
	Other Waters of the U.S.	0.02	Miller
West Acquisition Area			
35a-d	Forest/Emergent (40/60)	0.67	Miller
37a-f	Forest/Emergent (70/30)	5.73	Miller
39	Forest/Scrub-Shrub/Emergent (25/50/25)	0.90	Miller
40	Scrub-Shrub	0.03	Miller
41a and b	Emergent/Open Water	0.44	Miller
44a and b	Forest/Scrub-Shrub (70/30)	3.08	Miller
A1	Forest/Scrub-Shrub/Emergent (15/15/70)	4.59	Miller
A2	Scrub-Shrub	0.05	Miller
A3	Scrub-Shrub	0.01	Miller
A4	Scrub-Shrub	0.03	Miller
A5	Emergent	0.03	Miller
A6	Forest	0.16	Miller
A7	Forest	0.30	Miller
A8	Forest/Scrub-Shrub (30/70)	0.38	Miller
A9	Scrub-Shrub	0.04	Miller
A10	Scrub-Shrub	0.01	Miller
A11	Scrub-Shrub	0.02	Miller

Table 1-2. **Summary of wetland areas in the Seattle-Tacoma International Airport Master Plan Update area (continued).**

Wetland [a]	Classification [b]	Area (Acres)	Watershed
A12	Scrub-Shrub	0.11	Miller
A13	Forest	0.12	Miller
A14a and b	Forest/Scrub-Shrub/Emergent (50/25/25)	0.19	Miller
A15	Emergent	0.04	Miller
A16	Scrub-Shrub/Emergent (20/80)	0.09	Miller
A17	Forest/Scrub-Shrub/Emergent (20/80)	2.66	Miller
A18	Scrub-Shrub	0.01	Miller
A19	Emergent	0.04	Miller
Lora Lake	Open Water	3.06	Miller
	Other Waters of the U.S.	0.33	Miller
<u>Riparian Wetlands</u>			
R1	Emergent	0.17	Miller
R2	Scrub-Shrub/Emergent (70/30)	0.12	Miller
R3	Scrub-Shrub	0.02	Miller
R4	Emergent	0.11	Miller
R4b	Forest/Emergent (25/75)	0.11	Miller
R5	Emergent	0.05	Miller
R5b	Forest/Emergent (25/75)	0.07	Miller
R6	Forest/Emergent (25/75)	0.21	Miller
R6b	Emergent	0.09	Miller
R7	Forest/Emergent (25/75)	0.04	Miller
R7a	Emergent	0.04	Miller
R8	Scrub-Shrub/Emergent (40/60)	0.40	Miller
R9	Forest	0.38	Miller
R9a	Forest/Scrub-Shrub/Emergent (25/50/25)	0.74	Miller
R10	Scrub-Shrub	0.04	Miller
R11	Emergent	0.42	Miller
R12	Forest	0.03	Miller
R13	Emergent	0.12	Miller
R14a	Scrub-Shrub/Emergent (25/27)	0.13	Miller
R14b	Emergent	0.08	Miller
R15a	Forest/Scrub-Shrub/Emergent (25/65/10)	0.79	Miller
R15b	Forest/Emergent (25/75)	0.25	Miller
R17	Forest	0.31	Miller
	Subtotal	**51.33**	
Borrow Area 1			
32	Emergent	0.09	Des Moines
48	Forest/Emergent (20/80)	1.58	Des Moines
B1	Forest/Scrub-Shrub (30/70)	0.27	Des Moines
B4	Scrub-Shrub	0.07	Des Moines
B11	Emergent	0.18	Des Moines
B12 [d]	Scrub-Shrub	0.63	Des Moines
B14	Scrub-Shrub/Emergent (70/30)	0.78	Des Moines
B15 a and b [d]	Scrub-Shrub	2.05	Des Moines

Table 1-2. Summary of wetland areas in the Seattle-Tacoma International Airport Master Plan Update area (continued).

Wetland[a]	Classification[b]	Area (Acres)	Watershed
	Other Waters of U.S.	0.01	Des Moines
	Subtotal	**5.66**	
Borrow Area 3			
29	Forest	0.74	Des Moines
30	Forest/Scrub-Shrub (80/20)	0.88	Des Moines
B5	Forest/Scrub-Shrub (40/60)	0.08	Des Moines
B6	Forest/Scrub-Shrub (30/70)	0.55	Des Moines
B7	Forest/Scrub-Shrub (30/70)	0.03	Des Moines
B9	Forest	0.05	Des Moines
B10	Forest	0.02	Des Moines
	Subtotal	**2.35**	
South Aviation Support Area (SASA)/Tyee Valley Golf Course			
28[d]	Scrub-Shrub/Emergent/Open Water (50/30/20)	35.45	Des Moines
52	Forest/Scrub-Shrub/Emergent (80/20/20)	4.70	Des Moines
53	Forest	0.60	Des Moines
G1	Emergent	0.05	Des Moines
G2	Emergent	0.02	Des Moines
G3	Emergent	0.06	Des Moines
G4	Emergent	0.04	Des Moines
G5	Emergent	0.87	Des Moines
G6	Emergent	0.01	Des Moines
G7	Forest/Scrub-Shrub (30/70)	0.50	Des Moines
G8	Emergent	0.04	Des Moines
WH	Open Water	0.25	Des Moines
DMC	Forest/Scrub-Shrub/Emergent	1.08	Des Moines
	Subtotal	**43.67**	
Industrial Waste System (IWS) Area[c]			
IWS a and b	Forest	0.67	Des Moines
	Subtotal	**0.67**	
South Aviation Support Area - Detention Pond			
E1	Forest	0.23	Des Moines
E2	Forest	0.04	Des Moines
E3	Forest	0.06	Des Moines
	Subtotal	**0.33**	**Des Moines**
TOTAL		**115.86**	

[a] The wetland labeling protocol is as follows:

- Wetlands with numbered designations (e.g., Wetland 35 or Wetland 44) are described in the FEIS and FSEIS (FAA 1996, 1997).
- Wetlands with an 'A' designation (e.g., Wetland A5 or A10) are wetlands occurring within the west acquisition area delineated after 1997.

Table 1-2. Summary of wetland areas in the Seattle-Tacoma International Airport Master Plan Update area (continued).

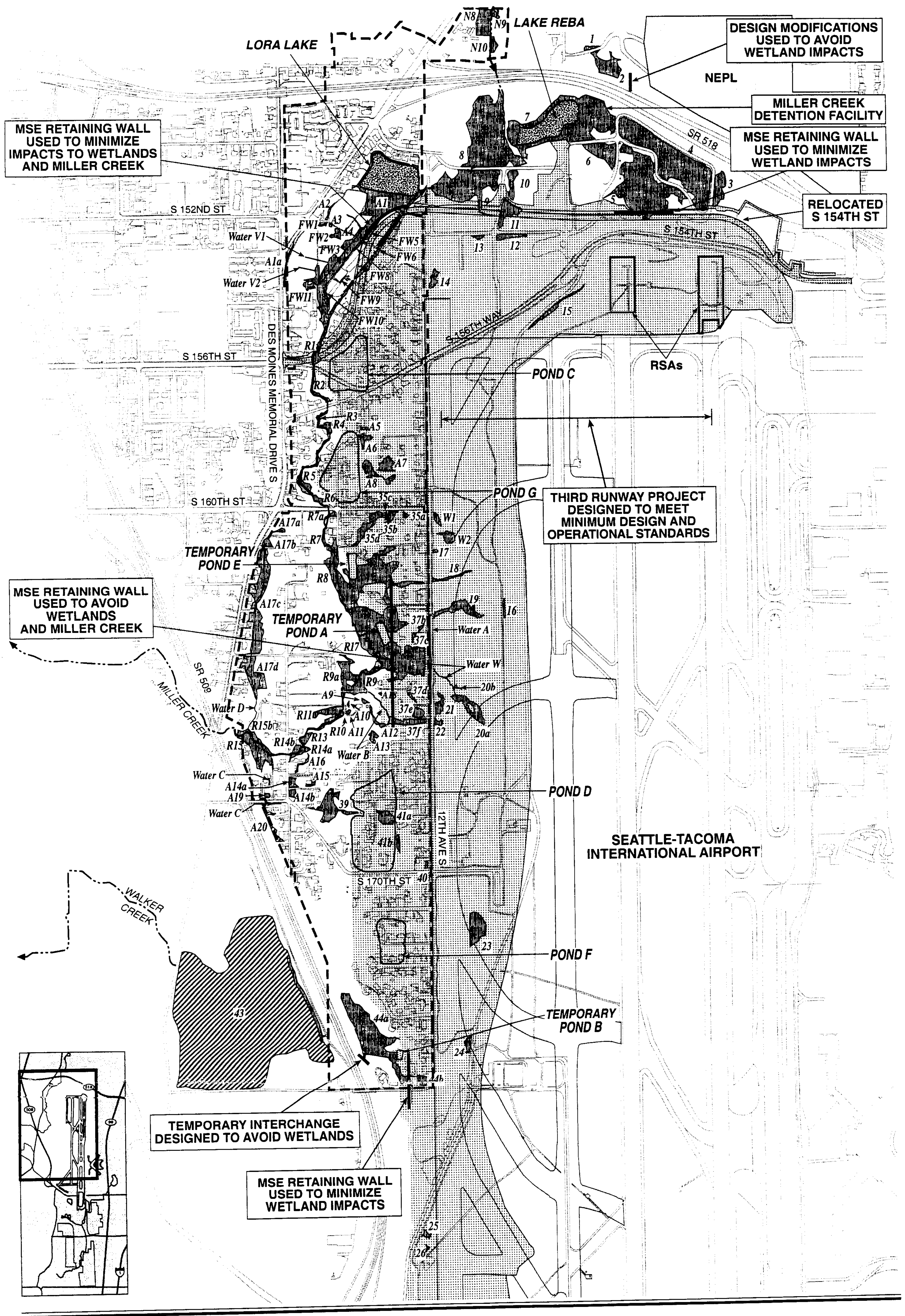
- Wetlands with an 'R' designation (e.g., Wetland R5 or R6) are new riparian wetlands occurring within the west acquisition area.
- Wetlands with a 'W' designation (e.g., Wetland W1 or W2) are new wetlands occurring within the west airfield area.
- Wetlands with a 'G' designation (e.g., Wetland G5 or G6) are new wetlands occurring within the Tyee Valley Golf Course or the SASA areas.
- Wetlands with an 'E' designation (e.g., Wetland E1 or E2) are new wetlands occurring within the SASA detention pond area.
- Wetlands with an 'IWS' designation (e.g., IWSa and IWSb) are new wetlands occurring near the IWS lagoon.
- Wetlands with a 'B' designation (e.g., Wetland B5 or B10) are new wetlands occurring within the borrow sites.
- Wetland numbers followed by a small case letter designate subsections of a wetland (i.e., Wetland 35a or 35b) where constructed features (i.e., driveways) fragment a larger wetland.

[b] Numbers indicate approximate percentage of cover by respective wetland classes (Cowardin et al. 1979).

[c] Includes Lake Reba.

[d] Portions of the wetland area are estimated.

[e] The IWS collects stormwater from the terminal, air cargo, hangars, maintenance, and parking areas. Wetlands occur near IWS treatment lagoons.



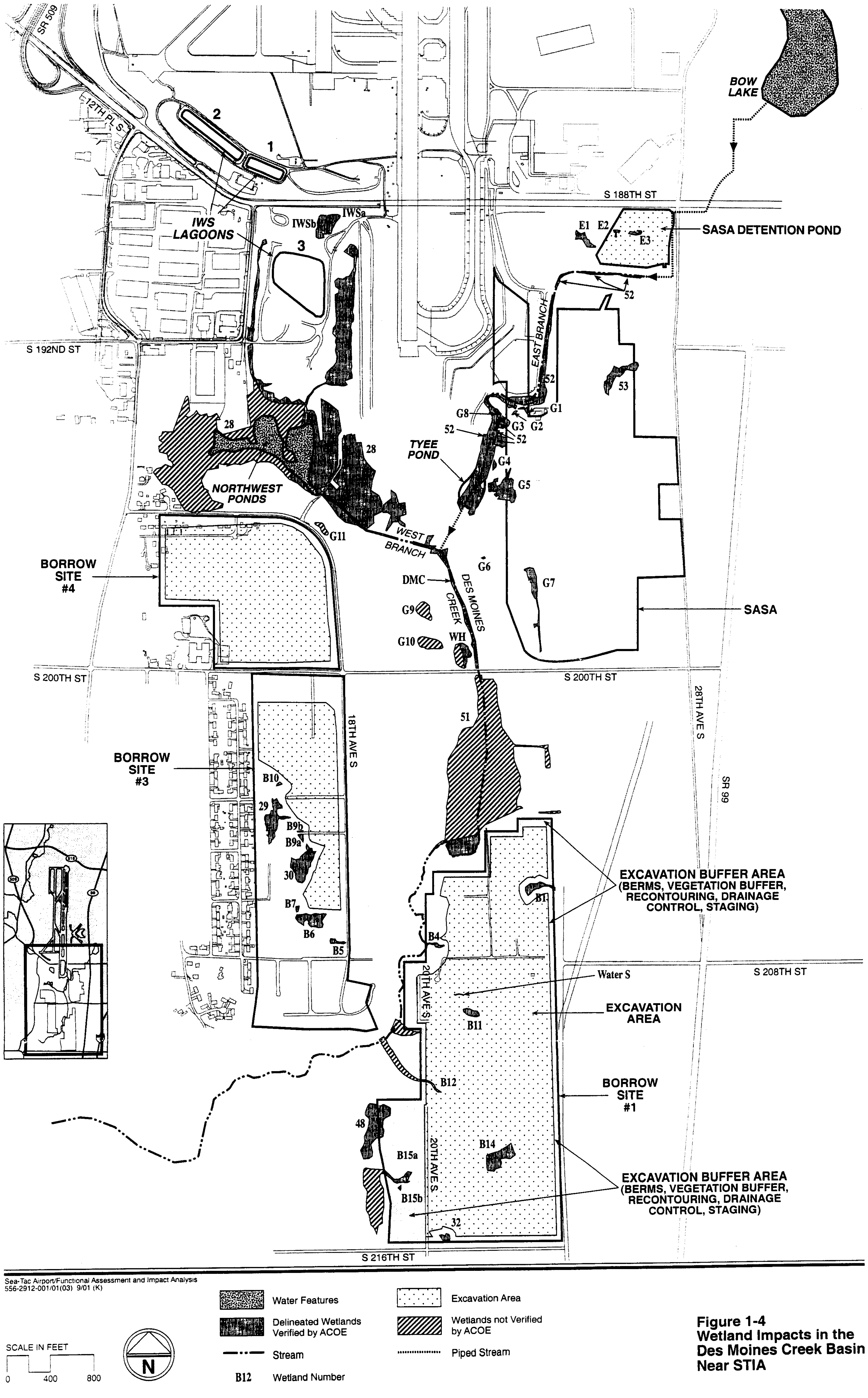
Sea-Tac Airport/Functional Assessment and Impact Analysis
556-2912-001/01(03) 11/01 (K)

▨	Wetlands not Verified by ACOE	▒	Water Features
■	Delineated Wetlands Verified by ACOE	░	Construction Area (Fill and Grading for Third Runway, Runway Safety Areas, and S 154th Street Relocation)
—··—	Stream		
– – –	Acquisition Area Boundary	*41a*	Wetland Number

SCALE IN FEET
0 400 800

N

**Figure 1-3
Wetland Impacts in the Miller Creek Basin Near STIA**



Sea-Tac Airport/Functional Assessment and Impact Analysis
556-2912-001/01(03) 9/01 (K)

Figure 1-4
Wetland Impacts in the Des Moines Creek Basin Near STIA

1.4 SIGNIFICANT WETLANDS AVOIDED BY MASTER PLAN IMPROVEMENTS

Over 200 acres of wetland are known to exist on or near STIA, and it is likely that additional un-inventoried wetlands exist on property elsewhere in the watershed where detailed studies have not been completed. Un-inventoried wetlands are likely to include numerous small wetlands in developed and partially developed residential areas, as was discovered in residential areas west of STIA (Parametrix 2000a). These wetlands are likely to be similar in character and function to many of the smaller wetlands occurring within the acquisition area.

While a number of small wetlands would be impacted or eliminated by the proposed Master Plan Update improvements, several large wetland complexes both on-site and nearby would not be affected by the improvements. These wetlands contain physical and biological features that indicate they provide a variety of wetland functions within Miller and Des Moines Creek watersheds at moderate to high levels. These wetlands (Table 1-3) are discussed briefly below.

Table 1-3. Other significant wetlands near the Seattle-Tacoma International Airport project area.

Wetland	Classification [a]	Approximate Area (Acres)	Watershed
43	Forest/Scrub-Shrub/Emergent (25/50/25)	33.4	Miller
Tub Lake	Forest/Shrub/Emergent/Open Water (30/40/10/20)	19	Miller
Bow Lake	Scrub-Shrub/ Open Water (40/60)	25	Des Moines
51	Forest/Scrub-Shrub (30/70)	16.0	Des Moines
A20	Emergent	0.3	Miller
	Total	**91.4**	

[a] Numbers indicate approximate percentage of cover by respective wetland classes (Cowardin et al. 1979).

A 30-acre wetland (Wetland 43, see Table 1-2 and Figure 1-3) occurs between Des Moines Memorial Drive and State Route (SR) 509 immediately north of South 176th Street. This wetland contains a diversity of vegetation types, including forested, shrub, emergent, and open water wetland classes. The diversity of plant types, the presence of permanent open water, and hydrologic connections to Walker Creek indicate the wetland provides moderate to high biological functions for a variety of wildlife groups (resident fish, passerine birds, small mammals, amphibians, and waterfowl). The wetland is the source of Walker Creek. Topographic conditions in the depression the wetland occupies, the presence of adjacent developments, hydrologic observations, and the large size of the wetland suggest it also provides substantial base flow support, surface runoff storage, sediment trapping, and water quality benefits.

A 19-acre bog wetland (see Figure 1-2) occurs north of SR 518 and includes Tub Lake (about one acre). This wetland contains forest, shrub, emergent, and open water wetland habitats, and Miller Creek flows through the wetland. The diversity of wetland classes, the presence of permanent open water, connections to other undeveloped land, and hydrologic connections to stream habitat result in moderate to high biologic function for a variety of wildlife groups (resident fish, passerine birds, small mammals, amphibians, and waterfowl). The location near the headwaters of Miller Creek, presence of upslope development, and topography of the basin indicate the wetland provides major base flow support, surface runoff storage, sediment trapping, and water quality benefits.

Bow Lake is a 25-acre wetland (see Figure 1-4) located east of 28th Avenue South and north of South 188th Street. This wetland contains open water and shrub vegetation classes, and forms the headwaters of the east branch of Des Moines Creek. The biological functions of the wetland are limited by the proximity of adjacent commercial and residential development; however, the wetland likely provides moderate biological function for passerine birds, small mammals, waterfowl, and amphibians. Physical functions likely provided by the wetland include groundwater recharge, storage of runoff, and water quality benefits.

Wetland 28 (see Table 1-2 and Figure 1-4) is adjacent to the west side of Tyee Valley Golf Course and is about 35 acres. The wetland is composed of open water, emergent, and shrub wetland habitat. A tributary of Des Moines Creek flows through the wetland. The presence of open water, habitat diversity, and hydrologic connections to stream habitat result in moderate to high function for a variety of wildlife groups (resident fish, passerine birds, small mammals, amphibians, and waterfowl). The wetland is headwaters of the west branch of Des Moines Creek and is located downslope of developed areas. Because of this topographic setting, it provides base flow support, surface runoff storage, sediment trapping, and water quality benefits.

A series of wetlands (Wetlands 3, 4, 5[8], 6, 7, 8, and 9; see Table 1-1 and Figure 1-3) totaling about 25 acres comprise the Miller Creek detention facility. The wetlands consist of open water, emergent, shrub, and forested wetlands that are hydrologically connected to Miller Creek. The diversity of wetland classes, permanent open water, and hydrologic connections to stream habitat indicate the wetlands provide moderate to high biological function to a variety of wildlife groups (resident fish, passerine birds, small mammals, amphibians, and waterfowl). The location near the headwaters, presence of adjacent developments, and topographic conditions suggest the wetland complex also provides physical functions such as base flow support, surface runoff storage, and sediment trapping.

Wetland 51 (see Table 1-3 and Figure 1-4) is located in Des Moines Creek Park, south of South 200th Street. It will not be altered by the improvements. The wetland provides forest and shrub habitat to wildlife using the area. The area appears to be a zone of groundwater discharge, and would thus provide base flow support to Des Moines Creek.

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[8] Minor (0.14 acre) fill impacts would occur in Wetland 5. Because of the small area affected, location upslope of the floodplain, and proximity to other disturbance, the overall functions provided by the wetland will not be significantly affected.

2. METHODS

Methods used to analyze impacts to wetlands are described in this section. The methods for evaluating impacts to wetland acreage affected by the project are described in Section 2.1. Impacts to the ecological functions provided by wetlands are described in Section 2.2.

2.1 IMPACTS TO WETLAND AREA

2.1.1 Direct Impacts

Direct impacts were considered to occur in those areas where wetlands would be filled by project development. These areas were calculated using engineering design data and survey maps of delineated wetland boundaries. These data were incorporated into GIS map layers, from which fill impacts were calculated.

Permanent direct impacts occur where fill is permanently placed in wetlands. **Temporary direct impacts** occur where, on a temporary basis, fill or other activities occur in wetlands during a portion of the construction period. In these areas, following construction, and per the Council of Environmental Quality regulations (40CFR 1508.20), the impact is rectified by restoring the affected environment.

Temporary[9] construction impacts result primarily from the need for temporary erosion and sediment control facilities (including sediment fencing, drainage swales, and stormwater management ponds) during the construction period. The duration of temporary impacts is variable, depending on project area and specific activity. Additional temporary impacts result from implementing mitigation projects. The duration and nature of these impacts are evaluated in Section 4.2.

2.1.2 Indirect Impacts

Indirect wetland impacts are defined as potential wetland impacts (excluding filling) that could affect the existence and ecological function of wetlands located near areas developed as part of the Master Plan. The general methodology for evaluating these impacts was to consider the changes to wetland conditions or characteristics that could occur from the project, and evaluate what effect these changes could have on wetland functions (see Section 2.2).

Examples of indirect impacts include alteration of surface or groundwater hydrology, changes in water quality, construction and operational noise, human disturbance, and landscape changes. For

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[9] The NRMP proposes wetland mitigation for all significant wetland impacts. Because the duration of temporary impacts exceed 1-year, mitigation for these temporary impacts includes restoration of the affected area and restoration of Wetland A17 (2.85 acres of wetland and 8.6 acres of upland) (see NRMP Parametrix 2001a).

this analysis, indirect impacts were grouped as **temporary** (short term during project construction) and **operational** (those that occur throughout the life of the project). Temporary impacts include wildlife disturbance during construction and potential water quality impacts due to stormwater runoff during construction. Operational impacts include wildlife disturbance from airport operations and potential hydrologic modifications to the wetlands located downslope of the project, or fragmentation of larger wetlands, such that the remaining fragment could no longer continue to provide functions at levels similar to the existing condition.

Fragmentation impacts were evaluated independent of size by considering if, given the remaining fragment of wetland and the future project condition, the wetland would be capable of providing the suite of biological and physical functions it currently does. For habitat functions, where the remaining wetland would, as a result of mitigation, be incorporated into enhanced and protected buffers, it would remain functional because it will remain connected to other wetlands and riparian areas. If, however, a wetland fragment were to remain isolated from other more significant habitat, its functions would be impaired, and the indirect impact was considered significant. In these cases, the area of the wetland fragment was added to the amount of direct impacts. For physical functions, the changes in hydrologic, runoff, disturbance, and other conditions were evaluated to determine if additional indirect impacts would reduce and fragment wetlands.

2.2 IMPACTS TO WETLAND FUNCTIONS

2.2.1 Background

In addition to determining wetland areas affected and potentially affected by the project, impacts to wetland functions were also evaluated. Wetlands perform numerous ecological functions. However, for the purposes of this analysis, and consistent with implementation of Clean Water Act Sections 404 and 401, this study focused on beneficial biological and physical (hydrologic and water quality) functions that wetlands provide to their watersheds.

Several functional assessment methodologies are available to estimate wetland functions; these include the *Wetland Evaluation Technique* (WET) (Adamus et al. 1987), *Hydrogeomorphic Classification for Wetlands* (Brinson 1993), and the *Wetland Values: Concepts and Methods for Wetland Evaluation* (Reppert et al. 1979). Functional assessment methodologies for wetlands typically identify and evaluate physical and biological attributes that provide predictive rather than direct measurements of specific ecological functions (Reimold 1994; Waterways Experiment Station 1994). Due to the limitations of many of the available functional analysis methods, expert opinion is also important when assessing wetlands for indicators of functions (Washington State Department of Ecology [Ecology] 1996; Solomon and Sexton 1994).

Assessment methodologies typically do not recognize local variations in small wetlands on a scale such as the Master Plan Update improvement study area. Many of these methods emphasize the importance of waterfowl and flood control functions of wetlands (Adamus et al. 1987), but they do not address functions of smaller wetlands that lack aquatic habitat (typical of many wetlands within the Master Plan Update improvement study area) (Ecology 1996).

Because of the diversity of wetland systems nationwide, functional assessment procedures may not recognize regional variations in wetland functions. To address this gap in assessment methodologies, Hruby et al. (1995) developed a numeric assessment methodology (Indicator Value Assessment, or IVA) that establishes relative functional performance scores for wetlands within a limited geographic region. This system is based on assignment of the importance of functional indicators and the use of a numeric model (developed for the specific analysis area) to calculate the performance score. However, these models do not exist for most wetland types found in the project area. The Washington Department of Ecology has developed a wetland functional assessment models for a variety of wetland types in western Washington (Ecology 1999). However, these models were not available at the time this study was conducted and do not model functions of slope or non-riverine riparian wetland types.

Regional studies of urbanization impacts to wetlands in King County completed by the Puget Sound Wetlands and Stormwater Management Research Program (PSW) (Azous and Horner 2001) attempt to characterize natural and modified conditions in the depressional, impounding hydrogeomorphic (HGM) wetland class. With a few exceptions, these studies are not appropriate to assessing wetland functions and impacts for the Master Plan Update Projects because wetlands affected near STIA are of different HGM classes and not subjected to new stormwater discharges, which was a major focus of the PSW program.

The commonly recognized functions provided by wetlands in Puget Sound were evaluated in this study, and include:

- **Supports resident and anadromous fish.** Wetlands can provide direct habitat for fish, or provide indirect support to fish habitat by a number of processes.
- **Provides habitat for songbirds.** A variety of avian species use wetlands for foraging and nesting habitat.
- **Provides waterfowl habitat.** Wetlands frequently provide aquatic and semi-aquatic habitat used by waterfowl for nesting and foraging.
- **Provides amphibian habitat.** Wetlands with seasonal ponding may be breeding and rearing habitat for amphibians, which then disperse to adjacent upland areas.
- **Provides small mammal habitat.** A variety of small mammals forage in and adjacent to wetlands. Some small mammals (American beaver [*Castor canadensis*] and muskrat [*Ondatra zibenthicus*]) live in certain types of wetlands.
- **Exports organic matter.** Organic matter produced in wetlands (live or dead plant material, aquatic or terrestrial insects, etc.) can be exported to downslope waters and may serve as food resources for other aquatic organisms. Carbon export can be in dissolved or particulate forms.
- **Maintains groundwater exchange.** Wetlands can be areas where groundwater is discharged and enters surface water drainage systems. Less frequently, they are areas where surface water collects and recharges groundwater aquifers.

- **Provides flood-storage and runoff desynchronization.** Wetlands in floodplains store floodwater and can reduce downstream flooding. Other wetlands slow surface water runoff rates, which can also reduce peak runoff rates in streams.
- **Enhances nutrient retention and sediment trapping.** Wetlands that reduce water velocities are areas where sedimentation occurs. Nutrients and pollutants are often attached to these sediments. Chemical and biochemical processes in wetlands can also remove nutrients and other chemical pollutants from surface water. These processes can improve the quality of surface water flowing through a wetland.

2.2.2 Assessment Methodology

Due to the limitations of assessment methods described above, a combined approach was used to assess wetland functions for this project. Biological and physical functions of wetlands were determined by evaluating a variety of wetland attributes (Tables 2-1 and 2-2) that are correlated to wetland function. These attributes were identified using best professional judgement, as well as those recognized in regional and national functional assessment methodologies (e.g., Hruby et al. 1995; Adamus et al. 1987; Smith et al. 1995; Reppert et al. 1979; Solomon and Sexton 1994; Ecology 1993). The attributes indicate the quality of functions provided within the wetland, its buffer, and its associated watershed. For biological functions, the attributes examined focused on structural complexity, hydrological connectivity to other aquatic habitat, hydrodynamics, habitat quality, and the degree of human disturbance. For physical functions, the attributes examined focused on hydrodynamics, hydrologic connectivity, the degree of disturbance, topographic conditions, as well as potential sediment transport. The presence, absence, and nature of these attributes helped determine the functions provided by the wetlands.

Table 2-1. Wetland attributes considered in evaluating biological functions of wetlands impacted by the proposed Master Plan Update improvements.

	Function				
Wetland Attribute	**Resident/ Anadromous Fish**	**Passerine Birds**	**Waterfowl**	**Amphibians**	**Small Mammals**
Wetland Physical Attributes					
Size of wetland		X	X	X	X
Wetland is hydrologically isolated		X	X	X	X
Wetland is hydrologically connected to fish-bearing stream	X	X	X	X	X
Wetland ditched or drained		X	X	X	X
Connection of wetland to other natural areas		X	X	X	X
Seasonality, frequency, and amount of flooding in wetland	X	X	X	X	X
Depth and area of seasonal open water		X	X	X	X
Depth and area of permanent open water		X	X	X	X
Hummocks/islands present in wetland		X	X	X	X
Wetland cultivated		X	X	X	X

Table 2-1. **Wetland attributes considered in evaluating biological functions of wetlands impacted by the proposed Master Plan Update improvements (continued).**

	Function				
Wetland Attribute	**Resident/ Anadromous Fish**	**Passerine Birds**	**Waterfowl**	**Amphibians**	**Small Mammals**
Evidence of impacts from excess nutrients, toxic materials, or sediments				X	
Buffer attributes					
Amount of impervious surface within watershed	X	X		X	
Buffer is discontinuous by crops, pasture, or urban yard	X	X	X	X	X
Amount of buffer in forest, shrub, or undisturbed grass communities	X	X		X	X
Upland/wetland edge irregular (W:L ratio >2:1)	X	X	X	X	X
Vegetation Attributes					
Number of vegetation classes (vertical habitat diversity)		X	X		X
Interspersion of vegetation classes		X	X	X	X
Amount, diversity, and size of forested communities		X	X	X	X
Evidence of seasonal ponding in forest vegetation classes		X	X	X	
Areas of aquatic bed vegetation		X	X	X	
Areas permanently ponded with emergent vegetation		X	X	X	X
Areas seasonally ponded with emergent vegetation		X	X	X	X
Interspersion of water and emergent vegetation		X	X	X	X
Ratio of native to non-native vegetation		X	X	X	X
Amount and diversity of shrub communities		X			X
Buffer vegetation is deciduous, coniferous, or mixed	X	X		X	X
Avian perch sites adjacent to or above water		X			
Large woody debris present	X	X		X	X
Standing dead trees >12" diameter within wetland and buffer		X		X	X
Stream Attributes					
Documented evidence of use by fish (within 3 yrs)	X			X	
Stream channel sinuous	X			X	
Evidence of erosion and high stream velocities	X				
Pools and riffles present	X	X	X		X
Spawning gravels present	X				
Presence of undercut banks	X			X	
Stream channel shaded by vegetation	X	X			X
Presence of seeps and springs	X	X		X	

Table 2-2. Wetland attributes considered in evaluating physical functions of wetlands impacted by the proposed Master Plan Update improvements.

	Function			
Wetland Attribute	**Exports Carbon**	**Groundwater Exchange**	**Flood Storage**	**Nutrient / Sediment Trapping**
Wetland ditched or drained	X	X	X	X
Wetland contains seasonal open water	X	X	X	X
Wetland contains permanent open water		X	X	X
Multiple channels within wetland	X			X
Wetland discharging to stream	X	X	X	X
Receives storm flood water	X		X	X
Wetland has fluctuating water levels throughout year		X	X	X
Interspersion of vegetation and open water areas	X			X
Evidence of beaver dams	X	X	X	X
Amount of vegetation present in flooded portions of wetland	X			X
Direct evidence of sediment trapping				X
Outflow present during summer but no inlet	X	X		
Topography of wetland relative to outlet	X		X	X
Wetland has no inlet and no outlet	X	X		X
Wetland has outlet but no inlet	X	X		
Wetland has inlet but no outlet	X	X	X	X
Presence of organic soils	X			X
Underlying soil is clay, till, or hardpan		X		
Wetland in pasture or cultivation	X			X
Amount and type of human activities in upstream watershed			X	X
Man-made detention			X	X

Five biological functions were examined. These functions determine the degree to which the wetland: (1) supports resident and anadromous fish, (2) provides passerine bird habitat, (3) provides waterfowl habitat, (4) provides amphibian habitat, and (5) provides small mammal habitat (see Table 2-1). This assessment relied heavily on the factors incorporated into Ecology's wetland rating system (Ecology 1993) as indicators of significant wildlife habitat (i.e., Category I and Category II wetlands).

Four physical functions provided by wetlands were also examined. These functions examined the wetlands' ability to: (1) export organic matter to downslope systems, (2) maintain groundwater exchange, (3) provide flood storage, and (4) enhance nutrient retention and sediment trapping (see Table 2-2). Wetlands with similar landscape positions, water sources, and hydrologic fluctuation (i.e., the same hydrogeomorphic classification [Smith et al. 1995]) were compared. Wetland groupings in the study area were determined to be:

- **Riparian.** Wetlands directly adjacent to Miller, Walker, or Des Moines Creeks.
- **Slope.** Wetlands that are generally free draining because they are on a hillside or slope.
- **Depression.** Wetlands that occur in topographic depressions, with or without restricted drainage outlets.

The functional assessment was completed on all wetlands directly impacted by the proposed Master Plan Update improvements and is discussed in Section 3. Where impacts occur to a portion of a larger diverse wetland (e.g., Wetlands 5, 9, A1, 18, 37, 44, and B12), the assessment focused on the functional attributes provided by the portion of wetland directly affected by Master Plan Update Projects.[10]

To help summarize project impacts on wetland functions, the wetlands were grouped according to their physical and biological similarities. The primary attributes that control the biological functions are the plant communities present, their vegetation structure, and the amount of habitat connectivity (particularly with other aquatic habitats). The primary attribute that accounts for physical (hydrologic and water quality) functions is whether the wetlands are riparian, slope, or depression (i.e., their hydrogeomorphic classification [HGM]). For these reasons, the wetlands were characterized by the vegetation classes that would be impacted (palustrine emergent, palustrine shrub, and palustrine forested) as well as their topographic occurrence in riparian, slope, or depression areas (i.e., its hydrogeomorphic position).

The functional performance of each wetland was determined based on evaluations of the physical and biological indicators of wetland function observed in each wetland, knowledge of other wetland ecosystems in the Puget Sound region (urban and non-urban), and professional judgement. Functional performance ratings were assigned as follows:

- **High.** The wetland contains several important characteristics required to perform the function, and lacks attributes that limit or prohibit the function from occurring in the wetland.
- **Moderate.** The wetland contains one or more characteristics required to perform the function; however, several of these may be secondary indicators. The wetland may contain one or more characteristics that interfere with or prevent optimal performance of the function in question.
- **Low.** The wetland lacks significant attributes that the wetland could perform the function in question. One or more characteristics indicating the wetland does not perform the function are typically present.

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[10] An assessment of indirect impacts considered how the project might alter the extent or functions of wetland areas located adjacent to construction areas.

This approach is consistent with permitting guidelines and available methods. Despite the significant amount of wetland research that has occurred over the past several decades, there are few if any wetlands where the suite of ecological functions provided has been quantitatively documented through direct measurements. The scientific literature documenting, for most wetland functions generally consists of a relatively small number of direct measurements of function taken in a relatively small number of wetlands. From this data, attempts are made to characterize various physical and ecological attributes that would indicate the functional performance of other wetlands, but there are no standard assessment methods that are applicable to the range of wetlands types found in Washington State or the project area.

3. FUNCTIONS OF WETLANDS IN THE PROJECT AREA

Design of the STIA Master Plan Update improvements has focused, to the extent feasible and practical, on avoiding impacts to wetlands and streams. However, because of the design and siting criteria for the various elements of the Master Plan Update improvements and the proximity of over 200 acres of wetlands near STIA, not all wetland impacts can be avoided. Based on the wetland delineation data (Parametrix 2000a) and project design and planning reports (Appendices A and B; FAA 1997; HNTB et al. 1999; Parametrix 2000c), approximately 18.37 acres of wetland will be permanently impacted by the project (Table 3-1; see Figures 1-3 and 1-4) and about 2.05 acres will be subject to direct temporary impacts during construction (Table 3-2). Implementation of wetland mitigation, both on the project site and at the off-site mitigation site, will improve and protect over 86 acres of wetlands and 92 acres of upland buffers to restore wetland functions to the Miller, Walker, and Des Moines Creek watersheds and to compensate wildlife habitat impacts off-site.

Functions provided by wetlands impacted by the Master Plan Update improvements are generally described in Section 3.1. In Section 3.2, a detailed description of the functions provided by wetlands in the various project areas is provided. The analysis of impacts to these wetland functions due to the Master Plan Update improvements is provided in Section 4.

3.1 SUMMARY OF WETLAND FUNCTIONS

Wetlands located within the construction areas provide a variety of functions as defined in Section 2. This section provides a general description of existing functions provided by these wetlands. The performance ratings for these functions that were assigned to each wetland are summarized in Table 3-3. The acreage impacts to wetlands providing these functions are tabulated in Table 3-4.

Impacted wetlands range from small, highly modified wetlands subject to ongoing human disturbance to wetlands that have been historically modified but are gradually recovering from past logging or farming activities. Moderate to high habitat function occurs in larger wetlands (for example, Wetlands 30, 37, and A1) where native vegetation is recovering from past disturbances. Lower habitat functions typically occur in many of the smaller wetlands that are subjected to ongoing disturbance and rarely contain surface water. Hydrologic and water quality functions of wetlands vary depending on their landscape position and numerous site-specific factors. Several wetlands (Wetlands 37, 44, and 52) appear to provide groundwater discharge functions that enhance base flow in adjacent streams. Wetlands A1 and 28 provide high function for reducing flood flow and for water quality enhancement. The biological and physical functions of impacted wetlands are discussed further below.

Table 3-1. Summary of permanent fill impacts to wetlands in the proposed Master Plan Update improvement area (in acres).

Wetland	Ecology Rating	HGM Class	Classification	Fill Impact	Vegetation Types Impacted: Forest	Shrub	Emergent
Runway Safety Area							
5	III	Slope	Scrub-shrub	0.14	0.07	0.07	0.00
			Subtotal	0.14	0.07	0.07	0.00
New Third Runway							
9	III	Slope	Forest/Emergent	0.03	0.01	0.00	0.02
11	III	Slope	Forest/Emergent	0.50	0.40	0.00	0.10
12	III	Slope	Forest/Emergent	0.21	0.04	0.00	0.17
13	III	Slope	Emergent	0.05	0.00	0.00	0.05
14	III	Slope	Forest	0.19	0.19	0.00	0.00
15	III	Slope	Emergent	0.28	0.00	0.00	0.28
16	III	Depression	Emergent	0.05	0.00	0.00	0.05
17	III	Depression	Emergent	0.02	0.00	0.00	0.02
18	II	Slope	Forest/Scrub-shrub/Emergent	2.84	1.28	0.75	0.81
19	III	Slope	Forest	0.56	0.56	0.00	0.00
20	II	Slope	Scrub-shrub/Emergent	0.57	0.00	0.51	0.06
21	III	Slope	Forest	0.22	0.22	0.00	0.00
22	III	Slope	Emergent/Scrub-shrub	0.06	0.00	0.01	0.05
23	IV	Depression	Emergent	0.77	0.00	0.00	0.77
24	III	Depression	Emergent	0.14	0.00	0.00	0.14
25	III	Depression	Forest	0.06	0.06	0.00	0.00
26	IV	Depression	Emergent	0.02	0.00	0.00	0.02
W1	III	Depression	Forest/Emergent	0.10	0.00	0.00	0.10
W2	III	Depression	Forest/Emergent	0.22	0.04	0.00	0.18
35a-d	III	Slope	Forest/Emergent	0.67	0.27	0.00	0.40
37a-f	II	Slope	Forest/Emergent	4.09	2.84	0.00	1.25
40	III	Depression	Forest	0.03	0.00	0.03	0.00
41a and b	III	Depression	Emergent [a]	0.44	0.00	0.00	0.44
44a and b	II	Slope	Forest	0.26	0.18	0.08	0.00
A1	II	Depression, Riparian	Forest/Scrub-shrub/Emergent	0.59	0.09	0.09	0.41
A5	IV	Depression	Emergent	0.03	0.00	0.00	0.03
A6	III	Slope	Forest	0.16	0.16	0.00	0.00
A7	III	Slope	Forest	0.30	0.30	0.00	0.00
A8	III	Slope	Forest/Scrub-shrub	0.38	0.07	0.31	0.00
A12	III	Slope	Scrub-shrub	0.08	0.00	0.08	0.00
A18	III	Slope	Scrub-shrub	0.01	0.00	0.01	0.00

Table 3-1. Summary of permanent fill impacts to wetlands in the proposed Master Plan Update improvement area (in acres) (continued).

Wetland	Ecology Rating	HGM Class	Classification	Fill Impact	Vegetation Types Impacted		
					Forest	Shrub	Emergent
FW5 and 6	IV	Depression, Riparian	Farmed Wetland	0.15	0.00	0.00	0.15
R1	III	Riparian	Emergent	0.13	0.00	0.00	0.13
			Subtotal	**14.23**	**6.73**	**1.87**	**5.63**
South Aviation Support Area (SASA)							
52	II	Slope	Forest/Scrub-shrub/Emergent	0.54	0.54	0.00	0.00
53	III	Depression	Forest	0.60	0.60	0.00	0.00
E2	III	Slope	Scrub-shrub	0.04	0.04	0.00	0.00
E3	III	Slope	Scrub-shrub	0.06	0.06	0.00	0.00
G1	IV	Slope	Scrub-shrub	0.05	0.00	0.05	0.00
G2	IV	Slope	Emergent	0.02	0.00	0.00	0.02
G3	IV	Slope	Emergent	0.06	0.00	0.00	0.06
G4	IV	Slope	Emergent	0.04	0.00	0.00	0.04
G5	IV	Slope	Emergent	0.87	0.00	0.00	0.87
G7	III	Slope	Forest/Scrub-shrub	0.50	0.13	0.37	0.00
			Subtotal	**2.78**	**1.37**	**0.42**	**0.99**
Borrow Area and Haul Road							
28	II	Depression, Riparian	Emergent	0.07	0.00	0.00	0.07
B11	III	Depression	Emergent	0.18	0.00	0.00	0.18
B12[b]	II	Depression	Emergent	0.07	0.00	0.07	0.00
B14	III	Depression	Scrub-shrub	0.78	0.00	0.55	0.23
			Subtotal	**1.10**	**0.00**	**0.62**	**0.48**
Mitigation (Auburn)							
Area 7	III	Depression	Emergent	0.02	0.00	0.00	0.02
Area 9	III	Depression	Emergent	0.03	0.00	0.00	0.03
Area 10	III	Depression	Emergent	0.07	0.00	0.00	0.07
			Subtotal	**0.12**	**0.00**	**0.00**	**0.12**
TOTAL				**18.37**	**8.17**	**2.98**	**7.22**

[a] Includes 0.18 acre of open water habitat.

[b] These wetlands extend off-site.

Table 3-2. **Summary of direct temporary construction impacts to wetlands in the proposed Master Plan Update improvement area.**

Wetland	Duration	Area (acres)	Vegetation Types (acres) Forest	Shrub	Emergent	Impacts
Runway Safety Area Extension						
4	1 year	0.20	0.20	0.00	0.00	Temporary construction disturbance could occur in the portion of the wetlands that borders the construction area. These impacts could include minor soil disturbance or siltation caused by installation and removal of erosion control fences. Small amounts of shrub or herbaceous vegetation could be trimmed during installation or maintenance of the fences.
5	1 year	0.20	0.10	0.10	0.00	
Third Runway						
9	1 year	0.16	0.11	0.00	0.05	Construction activity and noise could disturb wildlife during portions of the construction period.
A1	1.5 years	0.05	0.01	0.01	0.03	
18	3 years	0.22	0.04	0.07	0.11	The temporary erosion and sediment control (TESC) collection swales and a collection pond in Wetland 37 would eliminate water quality and habitat functions during the construction period. (Note: Permanent stormwater management facilities will be located outside of wetland areas. Impacts of temporary Pond E have been considered permanent.)
37	2 years	0.71	0.14	0.18	0.39	
A12	3 years	0.03	0.00	0.03	0.00	
A13	3 years	0.01	0.01	0.00	0.00	A narrow band of temporary disturbance could result from installation of erosion control fences adjacent to the fill footprint and the security road. This disturbance will be within 30 ft of Miller Creek for about 100 linear ft. These impacts could include minor soil disturbance or siltation caused by installation and removal of erosion control fences. Small amounts of shrub or herbaceous vegetation could be trimmed during installation or maintenance of the fences. Construction activity and noise could cause disturbance to wildlife.
44a	0.5 year	0.00				**SR 509** - Temporary Interchange - Construction activity and noise could disturb wildlife during portions of the construction period.
	3 years	0.28	0.18	0.10	0.00	**Embankment TESC** - The TESC pond would eliminate habitat and water quality functions during the construction period. Construction activity and noise could disturb wildlife during portions of the construction period
South Aviation Support Area						
52	2 years	0.17	0.00	0.05	0.12	Temporary construction disturbance could occur in the portion of the wetlands that borders the bridge construction area. These impacts could include minor soil disturbance or siltation caused by installation and removal of erosion control fences. Small amounts of shrub or herbaceous vegetation could be trimmed during installation or maintenance of the fences Construction activity and noise could disturb wildlife during the construction period.
TOTAL		**2.05**	**0.79**	**0.54**	**0.72**	

Table 3-3. Ratings for wetland functions impacted by fill for construction of Master Plan Update improvements.

Wetland	Resident/ Anadromous Fish	Passerine Birds	Waterfowl	Amphibians	Small Mammals	Exports Organic Carbon	Groundwater Exchange	Flood Storage	Nutrient/ Sediment Trapping
5	Low	Low	Low	Low-Moderate	Moderate-High	Low-Moderate	High	Low	Moderate
9	Low	Moderate-High	Low	Low-Moderate	Moderate-High	Low-Moderate	Low	High	Moderate
11	Low	Moderate-High	Low	Low	Low-Moderate	Low	Low	Low	Moderate
12	Low	Moderate-High	Low	Low	Low	Low	Low	Low	Low
13	Low	Low-Moderate	Low	Low	Low	Low	Low	Low	Low
14	Low	Moderate-High	Low	Low	Low	Low	Moderate	Low	Low
15	Low	Low-Moderate	Low	Low-Moderate	Low	Low	High	Low	Moderate
16	Low	Low-Moderate	Low	Low	Low	Low	Low	Low	Low
17	Low	Low-Moderate	Low	Low	Low-Moderate	Low	Low	Low	Moderate
18	Moderate	High	Low	Moderate	Moderate	High	High	Moderate	Moderate
19	Low	Moderate-High	Low	Moderate	Moderate	Moderate	High	Low	Moderate
20	Low	High	Low	Moderate	Moderate-High	High	High	Low	Low
21	Low	Moderate-High	Low	Low-Moderate	Low-Moderate	Low-Moderate	Low	Low	Low
22	Low	Moderate-High	Low	Low-Moderate	Low-Moderate	Low-Moderate	Low	Low	Low
23	Low	Low-Moderate	Low	Low	Low	Low	Low	Low-Moderate	High
24	Low	Low-Moderate	Low	Low	Low	Low	Low	Low-Moderate	High
25	Low	Moderate-High	Low	Low	Low	Low	Low	Low-Moderate	High
26	Low	Low-Moderate	Low	Low	Low	Low	Moderate	Low-Moderate	High
28	High	Low-Moderate	High	Moderate	High	Low	High	High	High
35	Low	Low	Low	Low	Low	Low	Moderate	Low	High
37	High	High	Low	Moderate	Moderate-High	High	High	Low	Moderate-High
40	Low	Moderate	Low	Low-Moderate	Low	Low	Low	Low-Moderate	High
41	Low	Low-Moderate	Low	Low	Low	Low	Low	Low-Moderate	High
44	Low-Moderate	Moderate-High	Low	Moderate	Moderate-High	High	High	Low	Moderate-High
48	Low	Low-Moderate	Low	Low-Moderate	Low-Moderate	Low-Moderate	Moderate	Low	Low-Moderate
52	Moderate-High	Low-Moderate	Low	Low-Moderate	Moderate-High	High	High	Moderate	Moderate-High
53	Low	Moderate-High	Low	Low	Moderate	Low	Low	Low-Moderate	High

Table 3-3. Ratings for wetland functions impacted by fill for construction of Master Plan Update improvements (continued).

Wetland	Resident/ Anadromous Fish	Passerine Birds	Waterfowl	Amphibians	Small Mammals	Exports Organic Carbon	Groundwater Exchange	Flood Storage	Nutrient/ Sediment Trapping
A1	High	Moderate	Moderate	Low	Moderate-High	High	Moderate	High	High
A12, A18	Low-Moderate	Low	Low	Low	Moderate	Low- Moderate	Moderate	Low	Low
A5	Low	Low	Low	Low	Low	Low	Low	Low	Low
A6	Low	Moderate-High	Low	Low	Moderate	Low	Moderate	Low	Low-Moderate
A7	Low	Moderate-High	Low	Low	Moderate	Low	Moderate	Low	Low-Moderate
A8	Low	Low-Moderate	Low	Low	Moderate	Low	Moderate	Low	Low-Moderate
B11	Low	Low-Moderate	Low	Low	Low-Moderate	Low	Low	Low-Moderate	High
B12	Low-Moderate	Moderate-High	Low	Moderate	Moderate	Low-Moderate	Moderate	Low	Low-Moderate
B14	Low	Low	Low	Low	Moderate	Low	Low	Low-Moderate	High
B15	Low-Moderate	Low	Low	Low	Moderate	Low-Moderate	Moderate	Low	Low-Moderate
E2	Low	Low	Low	Low	Low	Low	Moderate	Low	Low
E3	Low	Low	Low	Low	Low	Low	Moderate	Low	Low
FW5, 6	Low	Low	Moderate	Low	Low	Low	Low	High	High
G1, G2	Low	Low	Low-Moderate	Low	Low	Low	Moderate	Low	Low-Moderate
G3	Low	Low	Low-Moderate	Low	Low	Low	Moderate	Low	Low-Moderate
G4	Low	Low	Low-Moderate	Low	Low	Low	Moderate	Low	Low-Moderate
G5	Low	Low	Low-Moderate	Low	Low	Low	Moderate	Low	Low-Moderate
G7	Low	Moderate	Low	Low	Low	Low	High	Low	Low-Moderate
R1	Low	Low-Moderate	Low	Low	Moderate	High	Moderate-High	High	Moderate-High
W1	Low	Low	Low	Low	Low	Low	Low	Low-Moderate	High
W2	Low	Moderate	Low	Low	Moderate	Low	Low	Low-Moderate	High

Table 3-4. Wetland acreage impacts by wetland function.

Wetland Function	Acres of Impact[a]	Rating Threshold and Comments
Resident/ Anadromous Fish	8.6	Most wetlands rated for this function do not provide direct habitat for fish or aquatic organisms. These wetlands were rated at least low-moderate when at least indirect support of fish habitat through organic matter export, hydrologic functions, or other water quality functions would be expected.
Passerine Birds	14.9	Generally, areas providing nesting and foraging habitat for some birds were rated at least low-moderate. These ratings reflect the fact that even disturbed wetland areas in urban areas provide some habitat for birds when trees or shrubs are present in or near the wetlands.
Waterfowl	1.9	Wetlands that provide areas of forage (wetlands on the golf course and Vacca Farm) or emergent wetlands with nesting habitat were rated at least low-moderate.
Amphibians	9.8	When forest or shrub habitat occurred in wetlands or their buffers, they were rated at least low-moderate for this function.
Small Mammals	13.2	Generally, wetlands with shrub or forest cover provide some habitat to small mammals, and were rated at least low-moderate. These ratings reflect the fact that the small and disturbed wetland areas, even in urban environments are used by small mammal species.
Exports Organic Matter	10.9	Wetlands with surface water connections to streams or channels were generally rated at least low-moderate for this function.
Ground Water Exchange	13.0	Wetlands where groundwater discharges (perennial or seasonal) were observed were rated at least low-moderate for this function.
Flood Storage	4.6	Wetlands in floodplains or those formed in shallow depressions were rated at least low to moderate for this function.
Nutrient/Sediment Trapping	16.3	Wetlands in floodplains, in shallow depressions, or on slopes where channelized inflow was absent, were rated at least low-moderate for this function.

[a] If functional assessment for a wetland was rated greater than low, the impact acreage is included in this table.

3.1.1 Biological Functions

Wildlife use of the study area and its associated wetlands is largely limited to small mammal species tolerant of disturbance. The study area is fragmented by urban development, which limits access to the area for most large mammals (McDonnell et al. 1993, Gardner et al. 1993). Faunal diversity is frequently limited in wetlands because they are too small to meet habitat requirements for many wildlife populations and the high amount of urbanization within the area may limit the numbers and diversity of wildlife and amphibians present (Richter and Azous 1995). No federal or state-listed threatened or endangered wildlife species use the areas planned for Master Plan Update improvements (FAA 1996). Coho salmon (*Oncorhynchus kisutch*), a federal candidate species, occurs in Miller and Des Moines Creeks downstream of development areas (Williams et al. 1975). An analysis of project impacts to listed species is provided in the *Biological Assessment* (FAA 2000), a National Marine Fisheries Service Concurrence Letter (NMFS) (2001a and b), and USFWS (2001) Biological Opinion.

The forested wetlands within the study area lack true aquatic habitat (i.e., areas with extended periods of inundation), and do not support species dependent on aquatic habitat. Thus, the wildlife function of these wetlands is similar to that of upland areas with comparable vegetation communities (Table 3-5). Small passerine birds (such as varied thrushes [*Ixoreus naevius*], orange-crowned warblers [*Vermivora celata*], black-capped chickadees [*Parus atricapillus*], and song sparrows [*Melospiza melodia*]) use forested habitat in the study area for nesting and feeding (Ehrlich et al. 1988). Forested areas are also used by small mammals (including mountain beaver [*Aplodontia rufa*], raccoon [*Procyon lotor*], Virginia opossum [*Didelphis virginian*], Douglas squirrel [*Tamiasciurus hudsonicus*], and deer mouse [*Peromyscus maniculatus*]) for breeding and cover. Some amphibians (including northwestern salamander [*Ambystona gracile*], Pacific chorus frog [*Pseudacris regilla*], and rough-skinned newt [*Taricha granulosa*]) may use portions of the wetlands for resting, foraging, and breeding (Nussbaum et al. 1983).

As shown in Table 3-6, the habitat functions of shrub wetlands include nest and cover habitat for songbirds (such as Swainson's thrush [*Catharus ustulatus*], Bewick's wren [*Thryomanus bewickii*], and ruby-crowned kinglets [*Reguus calendula*]) and small mammals (including the water shrew [*Sorex palustris*], raccoon, Virginia opossum, and Norway rat [*Rattus norvegicus*]) (Richter and Azous 1995). Shallow areas of seasonal ponding in shrub wetlands are uncommon, but when present they provide habitat for amphibian breeding. Shrub wetlands lack the woody debris that is desirable to terrestrial amphibians such as ensatina (*Ensatina eschscholtzii*).

Emergent wetlands in the study area provide habitat to songbird species (such as red-winged blackbirds [*Agelaius phoeniceus*] and marsh wrens [*Cistothorus palustris*], which use portions of wetlands A1, 28, and 43) where the vegetation provides for nesting and foraging habitat (Table 3-7). Small mammals (water shrew) forage on emergent vegetation. In certain wetlands (Wetland A1) amphibian species (including long-toed salamander [*Ambystoma macrodactylum*], western toad [*Bufo boreas*], and Pacific chorus frog) may use emergent vegetation that occurs in standing water for egg mass attachment. Many of the emergent wetlands in the study area are small,

Table 3-5. Rating of habitat functions of forested wetlands impacted by the proposed Master Plan Update improvements.

Function	Rating	Rationale
Supports Resident and Anadromous Fish	Low to Moderate	Most forested wetland habitat (Wetlands 11, 14, 21, 25, 39, 40, and 53) are isolated from streams and other fish habitat. These areas contain small amounts of standing water during winter and spring months and are thus unable to provide this function. Some forested wetlands (Wetlands 18, 19, 37, and 52) have intermittent connections or border Miller or Des Moines Creeks. These wetlands provide shade, buffer, and food resources to resident or migratory fish species.
Provides Songbird Habitat	Moderate to High	Several larger forested wetland habitat areas (Wetlands 3, 4, 5, 19, 29, 37, 51, 52, and 53) contain habitat for breeding birds. These habitat attributes include more than one wetland class, the presence of snags or logs, understory shrub and herbaceous vegetation, and forested buffers connecting to other habitat types. Some of the forested wetlands in the impact area are dominated by willow (*Salix, spp.*), red alder (*Alnus rubra*), and black cottonwood (*Populus balsamifera*) (Wetlands 11, 19, 37, 39, and 53) that are too young to provide cavity nesting habitat. The lack of dense coniferous forest habitat in all forested wetlands also reduces their habitat function for some bird species.
Provides Amphibian Habitat	Low to Moderate	Soil in forested wetland habitat is typically saturated but lacks significant amounts of standing water during the late spring and summer months. This condition limits the diversity of amphibians that can breed in the forested wetlands. Where extended seasonal ponding is present near forested wetlands, (Wetlands 3, 4, 5, 37, 40, and 52), Pacific chorus frog, red-legged frog (*Rana aurora*), and long-toed salamander may be present.
Provides Small Mammal Habitat	Moderate	Forested wetland vegetation provides habitat to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals are absent from the project area due to the lack of large, undeveloped areas of native vegetation.
Provides Waterfowl Habitat	Low	Forested wetland habitat lacks open water or open areas that allow foraging, nesting, or resting by waterfowl. The forested wetlands in the impact area generally lack significant open water or standing water during the breeding season, limiting their function as waterfowl breeding habitat.

AR 030114

Table 3-6. Rating of habitat functions of shrub wetlands impacted by the proposed Master Plan Update improvements.

Function	Rating	Rationale
Supports Resident and Anadromous Fish	Low to Moderate	Most shrub wetland habitat (Wetlands 20, A8, B14, and B15) is isolated from streams and other fish habitat. These wetlands lack standing water and are thus unable to provide fish habitat. Some wetlands (Wetlands 18 and 52) have intermittent connections to, or border Miller or Des Moines Creeks. These wetlands provide shade, buffer, and food resources to resident or migratory fish species.
Provides Songbird Habitat	Low to High	Several larger wetlands (Wetlands 18, 20, 37, and 52) contain shrub communities with high habitat function for breeding birds. Their attributes include more than one wetland class, the presence of snags or logs, understory shrub and herbaceous vegetation, and forested buffers connecting to other habitat types. Most shrub-dominated areas are small (Wetlands 5, 22, 40, A12, B12, B15, E2, and E3), frequently dominated by Himalayan blackberry (*Rubus discolor*), and do not provide significant habitat functions.
Provides Amphibian Habitat	Low	Shrub wetlands are typically saturated but lack standing water during the late spring and summer months. This condition limits the diversity of amphibians that can breed in the wetlands.
Provides Small Mammal Habitat	Moderate	Shrub wetlands provide habitat to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals are absent from the project area due to the lack of large, undeveloped areas of native vegetation.
Provides Waterfowl Habitat	Low	These wetlands lack open water or emergent vegetation that would allow foraging by waterfowl. Shrub habitat in the impacted area generally lacks significant open water or standing water during the breeding season, limiting its function as waterfowl breeding habitat.

Table 3-7. **Rating of habitat functions of emergent wetlands impacted by the proposed Master Plan Update improvements.**

Function	Rating	Rationale
Supports Resident and Anadromous Fish	Low	Most emergent wetlands (including Wetlands 15, 16, 17, 23, 24, and 32) do not provide fish habitat function because they are isolated from streams and other fish habitat and have only small amounts of standing water during winter and spring months. Some emergent wetlands have intermittent connections or are adjacent to streams (Wetlands 18, 35, 44, 52, and G7). These hydrologic connections provide a potential export of food into fish habitat; however, these connections provide no significant habitat to fish, nor do they allow fish to access suitable aquatic habitat within the wetlands.
Provides Songbird Habitat	Low to Moderate	Emergent wetlands are typically small, ranging in size from less than 0.1 acre to about 1 acre. Due to their small size and location in shallow, seasonally wet depressions, these wetlands lack many of the habitat attributes associated with high function for breeding birds. Emergent wetlands lack significant open water or standing water during the breeding season. They are often vegetated by reed canarygrass (*Phalaris arundinacea*), velvet-grass (*Holcus lanatus*), or other emergent plant species that offer limited breeding, feeding, and resting habitat to birds such as the marsh wren, red-winged blackbird, song sparrows, and common yellowthroat. Emergent wetlands that have associated forest or shrub wetland classes and buffers (Wetlands A1, 20, 18, 37, 28, 52, and G7) provide habitat for a greater variety of breeding birds, including thrushes and flycatchers. In these wetlands, red alder and cottonwood provide nest and perch sites for birds, although many trees are too young to provide cavity nesting habitat.
Provides Amphibian Habitat	Low to Moderate	Soil in emergent wetlands is typically saturated, but lacks significant amounts of standing water during the late spring and summer months. In addition, there is a large percentage of developed land near these wetlands. These conditions limit the diversity of amphibians that can breed in the wetlands. Where water is present for extended periods (portions of Wetlands A1 and 37), Pacific chorus frog and red-legged frog may be present.
Provides Small Mammals Habitat	Low to Moderate	Emergent wetlands, especially when bordered by forest or shrub communities (Wetlands A1, 36, 37, 39, and 52), are likely to provide habitat to small mammals. However, the small size of most of these wetlands, and the lack of diverse habitat structure within them, limit the use of these wetlands by small mammals. Species likely to inhabit the wetlands include deer mice, voles, and species tolerant of human activity.
Provides Waterfowl Habitat	Low	Emergent wetlands affected by the proposed airport improvements lack significant open water or meadow areas suitable for waterfowl. They may provide breeding sites for mallards when located near other water features (Wetland A1).

isolated, and recently disturbed by human activities. Wetlands located within the current airport operating area (AOA) and Tyee Valley Golf Course are mowed several to many times per year. This mowing and other disturbance limits their function as wildlife habitat. Most emergent wetlands occur on seasonally saturated soil and lack intermittent surface flows or seasonal standing water, a condition which also limits habitat diversity and their overall habitat function.

The wildlife habitat functions are generally significant to the local vicinity (rather than to a larger landscape or watershed) because urban development isolates the area for many terrestrial species of wildlife (Gavareski 1976). Wildlife use and diversity are limited because many of the wetlands are smaller than the habitat requirements of many native mammal and bird species (Brown 1985; Johnson and O'Neil 2001). The biological functions of many of the wetlands are further limited by the lack of permanent open water, the short duration of seasonal ponding or soil saturation, the amount of non-native plant species, and the fragmented habitats. The wildlife habitat function increases where trees and/or shrubs are adjacent to the grass-dominated emergent areas (see Tables 3-5 and 3-6).

3.1.2 Physical Functions

Wetlands affected by the Master Plan Update improvements are grouped by HGM classification (i.e., riparian, slope, and depression) because the levels of hydrologic function these wetlands perform are generally similar within each HGM class (Tables 3-8, 3-9, and 3-10).

Several riparian wetlands located in areas of groundwater seeps are adjacent to Miller and Des Moines Creeks and function to support stream base flows by providing seasonal or perennial sources of water. These groundwater sources may also help lower summer stream temperatures, benefiting fish and other aquatic life. Fill in several wetlands where this function occurs will require mitigation to assure downslope wetlands and stream habitats are not impacted.

Wetlands associated with the Miller Creek detention facility temporarily store floodwaters, which may reduce downstream flooding and stream bank erosion (Booth 1991; Childers and Gosselink 1990). Other riparian wetlands help reduce peak flows by collecting and storing storm runoff, thereby reducing the rate and volume of water that reaches the stream systems during storms (Reinelt and Horner 1990, 1991; Mitsch and Gosselink 2000). The on-site wetland areas affected by the project have a limited ability to provide stormwater storage functions due to their small size, lack of connections to streams, or topographic conditions that limit the amount and duration of detained stormwater. However, fill in Wetland A1 (and adjacent farmland) would occur in the floodplain of Miller Creek, and flood storage functions would be lost.

The existing groundwater recharge function of the on-site wetlands appears to be limited because many of them occur on low permeability till soils (Alderwood Series). These wetlands have formed in shallow depressions or gentle slopes where a perched water table has developed. Due to the low soil permeability, evapotranspiration, and the short duration of soil saturation, it is unlikely these small wetlands contribute significantly to recharge of groundwater (FAA 1997). Other wetlands occur in groundwater discharge areas, and as such, recharge would not be expected.

Table 3-8. Rating of physical and chemical functions of riparian wetlands impacted by the proposed Master Plan Update improvements.

Function	Rating	Rationale
Exports Organic Matter	High	Most riparian wetlands contain deciduous and woody vegetation that overhang Miller Creek or Des Moines Creek. Coarse and fine particulate matter from plants and insects fall from this vegetation into the stream that supports food chains in the aquatic ecosystem.
Maintains Groundwater Exchange	Moderate to High	Most riparian wetlands that border Miller and Des Moines Creeks occur where groundwater surfaces (i.e., they are groundwater discharge sites). Groundwater discharge in portions of other non-riparian wetlands (Wetlands A1, 37, and 52) occurs during most times of the year.
Provides Flood Storage/ Desynchronization	High	Portions of riparian wetlands are in the Miller or Des Moines Creek floodplain where they convey and/or store floodwater. The topography and hydrologic roughness of these systems help retain and detain floodwater. These functions are especially high in the Miller Creek detention facility, where engineering modifications have enhanced this function.
Enhances Nutrient Retention/ Sediment Trapping	Moderate to High	Riparian wetlands occur on alluvial soils, indicating sedimentation is present. Certain nutrients (i.e., phosphorus) and other chemicals that adsorb to particulate matter are likely to accumulate here. The long-term saturation also creates environments that promote denitrification. During periods of high streamflow, the riparian wetlands may act as a sediment source due to bank erosion.

Table 3-9. Ratings of physical and chemical functions of depressional wetlands impacted by the proposed Master Plan Update improvements.

Function	Rating	Rationale
Exports Organic Matter	Low	These wetlands have no outlet and no opportunity to perform this function.
Maintains Groundwater Exchange	Low	Many of the depressional wetlands occur on till soils, where groundwater recharge rates are low due to low soil permeability. However, they likely perform some groundwater discharge function during the wet season and some recharge function while they remain saturated.
Provides Flood Storage/ Desynchronization	Low to Moderate	These wetlands typically occur in shallow depressions with little surface water storage capacity. They likely play some role in desynchronizing runoff, thus reducing peak storm flows.
Maintains Nutrient Retention/ Sediment Trapping	High	Without surface water outlets, most depressional wetlands are likely to retain sediments and the nutrients that may be adsorbed to them. They would also remove dissolved nutrient or other contaminants that enter stormwater runoff. Wetlands 40 and 41 are proximate to runoff from roads or pastures and are likely to be effective in this regard.

Table 3-10. Ratings of physical and chemical functions of slope wetlands impacted by the proposed Master Plan Update improvements

Function	Rating	Rationale
Exports Organic Matter	Low to Moderate	While there is seasonal flow on some slope wetlands, but they generally do not export organic matter to downslope systems due to low water volumes. Exceptions are wetlands connected by seasonal flow to Wetlands 37. These wetlands (Wetlands 19 and 20) provide detritus to Wetland 37 and Miller Creek, especially during the winter months when the greatest flows are present.
Maintains Groundwater Exchange	Low to High	Some slope wetlands (Wetlands 3, 4, 5, 18, 37, 44, and 52) appear to be areas where groundwater seasonally surfaces. Depending on the duration of the flow into the summer months, this flow enhances the base flows of Miller or Des Moines Creek. Most slope wetlands are discharge/recharge systems, where shallow groundwater temporarily surfaces in the wetland, yet infiltrates downslope near the edge of the wetland.
Provides Flood Storage/ Desynchronization	Low	These wetlands do not occur in floodplains. The wetlands could reduce peak flows by slowing runoff rates to Miller or Des Moines Creek.
Enhances Nutrient Retention/Sediment Trapping	Low to Moderate	The limited input of surface water or sediments to these wetlands allows little opportunity for this function to occur. However, some wetlands (Wetlands 18, 35, 37, 44, and A1) receive storm runoff from streets. These wetlands provide biofiltration.

3.1.3 Water Quality (Organic Carbon Export, Nutrient and Sediment Trapping)

The effectiveness of wetlands in providing organic carbon export and improved water quality functions to downslope waters are closely related to the sources and amounts of water flow, and the presence or absence of a hydrologic connection to other water bodies. These functions are also controlled by the types of vegetation present in the wetland and by local topography.

3.1.3.1 Organic Carbon Export

Riparian wetlands, lacustrine wetlands, and other wetlands with seasonal water flow can export particulate matter (typically leaves, branches, and other plant parts) to adjacent water bodies. The organic matter may serve as an energy source to or provide habitat to aquatic organisms in the adjacent system (Allan 1995). Particulate organic matter would not be exported from the small depression wetlands that lack surface connections to downstream areas. For other wetlands (slope and riparian) export would occur from areas located near seasonal or perennial flow (generally, sources of organic matter to streams occur within 100 ft of the channel (Knutson and Naef 1997), so portions of wetlands located farther away would contribute little if any particulate organic matter.

In addition to exporting particulate organic matter, wetlands can also export dissolved organic matter to adjacent systems. Dissolved organic carbon (DOC) export can occur in both surface and groundwater discharges. Organic matter export functions would be expected to be greatest in organic soils that remain anaerobic for long periods of time. Under these conditions, decomposition results in soluble organic compounds (versus carbon dioxide generated from aerobic decomposition). In highly anaerobic soils, organic matter is also likely to accumulate in the soil and particulate and dissolved compounds (Ford 1993).

The ecological significance of DOC to stream energetics is not well understood (Allan 1995; Ford 1993). The role or significance of dissolved organic matter in contributing to the productivity the higher trophic levels of a stream ecosystem, and ultimately invertebrate or fish production is not understood (Allan 1995).

Dissolved organic matter export is likely to be high from several of the slope wetlands that receive ground water inputs and contain organic soils. The presence of organic soils indicates anaerobic decomposition, and the presence of groundwater provides an export pathway.

There are relatively high levels of DOC in Miller Creek (see pages 7-19 through 7-22 of the *Biological Assessment* (FAA 2000) for the project) and this DOC affects water chemistry, including metal toxicity. The high levels of DOC are found upstream and downstream of wetlands to be filled by the project. The large areas of peat and muck soil located in the upper portion of the basins (at Tub Lake –about 15 acres; at the Vacca Farm area and other wetlands located north of the existing airfield –39 acres, and other riparian wetlands such as are present at the Des Moines Way Nursery site[11]) are a likely source of DOC to the creek.

3.1.3.2 Water Quality

Slope wetlands in the project area are frequently supported by groundwater seeps with inputs of sediment or pollutants from surface water (frequently stormwater) sources. Those slope wetlands that receive storm runoff from streets or other sources provide biofiltration functions (Wetlands 18, 35, 37, and 44), but the rate of water flow through these wetlands may be too rapid for optimal removal of nutrients or pollutants.

In contrast to slope wetlands, depressional wetlands typically provide more significant water quality benefits if sediment or other pollutant sources enter them because of increased hydrologic retention times (Ecology 1996; Mitsch and Gosslink 2000). When no outlet is present, depressional wetlands retain all sediments as well as the nutrients adsorbed to the sediments. Denitrification can also occur in wetlands, especially where organic soils are saturated for long periods (Mitsch and Gosslink 2000).

Riparian wetlands are likely to receive sediment from upslope sources and overbank flow. Nutrients such as phosphorus and other chemical pollutants that adsorb to particulate matter are likely to accumulate in riparian wetlands. In addition, these wetlands are sites for denitrification when soil is saturated for long periods. The riparian areas of Wetland A1, and those in the Miller Creek detention facility (Wetlands 4 and 6-10) would rate high for this function. Riparian wetlands may also act as a sediment source due to bank erosion that often occurs during periods of high streamflow.

Undeveloped upland soils also have a large capacity to remove pollutants, through infiltration and overland flow processes, as indicated by the BMPs for stormwater treatment that use this approach (Ecology 2001a).

3.2 FUNCTIONS PROVIDED BY WETLANDS IN MASTERPLAN UPDATE PROJECT AREAS

To facilitate understanding how the Master Plan Update improvements would directly affect various wetlands and wetland functions; the following sections describe the functions currently provided by wetlands in each of proposed Master Plan improvements. These descriptions include analysis of the existing wetland functions provided by wetlands in the Master Plan Update improvement areas (Section 3.2.1) and in each mitigation site (Section 3.2.2). The specific project areas are:

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[11] The Des Moines Way Nursery site is described in Appendix N of the NRMP (Parametrix 2001a).

- Wetlands impacted by RSA extensions
- Wetlands impacted by the third runway embankment area located generally west of the existing airfield, north of South 170th Street, including wetlands in the vicinity of the retaining wall
- Wetlands impacted by the third runway in the Walker Creek Watershed
- Wetlands impacted by the SASA development
- Wetlands impacted by development of Borrow Area 1
- Wetlands impacted by on-site mitigation
- Wetlands impacted by off-site mitigation in Auburn

The impacts to these wetlands and wetland functions are evaluated in Section 4.

3.2.1 Wetland Impact Areas

The impacts of Master Plan Update Projects on wetland functions are discussed below. Except where indicated, the wetland functions described generally pertain to the portions of the listed wetlands where fill impacts will modify them. In some cases, wetland areas outside the area of impact may provide somewhat different functions.

3.2.1.1 Wetlands Impacted by RSAs, Third Runway, and 154th Street Relocation

The functions provided by impacted wetlands (or portions of them) near the north end of the airfield are analyzed in Table 3-11. This analysis pertains to RSA (Wetland 5), third runway, and South 154th Street relocation impacts (Wetlands 9, 11, 12, 13, 14, 15, R1, A1, FW5, and FW6).

Table 3-11. Summary of the ecological functions provided by wetlands impacted by RSA extensions and the northwest portion of the third runway embankment.

Function	Analysis
Resident/Anadromous Fish Habitat:	With the exception of Wetland A1, the wetlands lack habitat for fish. Wetland A1 includes portions of Miller Creek and adjacent riparian areas that support fish habitat. The *FEIS, FSEIS, NRMP*, and *Biological Assessment* (BA) discuss fish use in Miller Creek.
Passerine Bird Habitat:	These wetlands generally provide variable habitat functions for passerine birds. The habitat function is typically limited by the young age of the forest and shrub habitats, and by the presence of non-native species in the understory. Within the construction areas, these wetlands lack special habitat features for birds. Bird species using the wetlands are expected to occur in many urban habitats. These migratory (and resident) birds disperse widely and also use the large amounts of urban habitat available for breeding or migration. Wetland A1 contains a creek channel and drainage ditch that provide some flooded emergent wetland habitat not found in other wetlands.
Waterfowl Habitat:	Wetlands A1, FW5, and FW6 provide moderate function for waterfowl because they contain emergent wetland or farmed habitat with suitable forage. Wetland A1 contains limited areas of open water suitable for nesting by mallard ducks. Other wetlands lack waterfowl habitat because of their isolation from water and the presence of woody vegetation.

Table 3-11. Summary of the ecological functions provided by wetlands impacted by RSA extensions and the northwest portion of the third runway embankment (continued).

Function	Analysis
Amphibian Habitat:	These wetlands generally contain low to moderate habitat for amphibians because they lack suitable breeding areas (i.e., sufficient areas of standing water from late fall through late spring). Wetland A1 provides some breeding habitat within an agricultural drainage ditch. Since these wetlands except Wetland 15 have some habitat connection to the aquatic habitat areas of Miller Creek, they provide habitat for non-breeding amphibians.
Small Mammal Habitat:	Most of these wetlands provide shrub or forest habitat to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals (except coyote [*Canis latrans*]) are absent from the project area due to the lack of large, undeveloped areas of native vegetation.
Organic Matter Export:	While there may be limited periods of seasonal flow from some wetlands, these wetlands generally do not export organic matter to downslope systems due to low water volumes and gentle topography. Exceptions are Wetland A1 and R1, where floodwaters transport detritus and other organic matter, and where riparian vegetation contributes organic matter directly to the creek. Wetlands 5, 14 and 15 have seasonal connections to drainage channels, and may contribute organic carbon to downslope systems during runoff periods.
Groundwater Exchange:	These wetlands appear to be areas where groundwater seasonally surfaces. In Wetland 5, seepage water is present year round. Depending on the duration of the flow into the summer months, this flow may help maintain other downslope wetlands or enhance the low flow of Miller Creek. Wetlands 13 and 14 are discharge/recharge systems, where shallow groundwater seasonally surfaces in the wetland, yet infiltrates near the downslope edges of the wetlands.
Flood Storage/ Desynchronization:	Affected portions of Wetlands A1, FW5, FW6, and R1 occur in the floodplain of Miller Creek. The remaining areas of wetland fill do not occur in floodplains. However, the wetlands that are not in the floodplain could reduce peak flows by slowing runoff rates to Miller Creek.
Nutrient Retention/ Sediment Trapping:	The limited input of surface water or sediments to the affected portions of most of these wetlands allows little opportunity for this function to occur. However, some wetlands receive storm runoff from streets, lawns, or farmland (i.e., Wetlands A1, FW5, and FW6) and they would be expected to provide biofiltration functions.

3.2.1.2 Wetlands Impacted by the Third Runway Embankment West of the Existing Airfield

Functions provided by impacted wetlands (or portions of them) located south of South 154th Street, north of South 170th Street, and between the airfield and Miller Creek are assessed in this section. The wetlands or portions of wetlands that are subject to project impacts are evaluated in Table 3-12. This analysis pertains to Wetlands 16, 17, 18, 19, 20, 21, 22, 35, 37, 40, 41, A5, A6, A7, A8, A12, and A18. The two drainage channels, Water A and Water W, are also included in this analysis.

Table 3-12. Summary of the ecological functions provided by wetlands impacted by third runway embankment construction on the west side of the existing airfield.

Function	Analysis
Resident/ Anadromous Fish Habitat:	Wetlands 18 and 37 are adjacent to Miller Creek and its aquatic habitat. Downslope of the project, the wetlands could provide some fish habitat during flood events, when their riparian portions are flooded. Aside from the stream channel itself, the wetlands lack fish habitat during normal flow periods. Other wetlands do not contain fish habitat. The EIS, Supplemental Environmental Impact Statement (SEIS), NRMP, and BA discuss fish use in Miller Creek.
Passerine Bird Habitat:	Several of these wetlands (18, 19, 20, 21, 22, 35, 37, 40, A6, and A7) provide moderate to high habitat functions for passerine birds. However, in these wetlands and most others, the habitat function is somewhat limited by the young age of the forest and shrub habitats, and by the presence of non-native species in the understory. Residential land uses also limit this function to species tolerant of moderate to high levels of human disturbance. Birds expected in these wetlands are common in urban areas. The migratory (and resident) birds disperse widely and use the large amounts of urban habitat in the area for breeding and migration. Other wetlands (Wetlands 16, 17, A5, A8, A12, and A13) provide lower habitat functions due to their proximity to human disturbance, less complex vegetation structure, and/or lack of substantial buffers.
Waterfowl Habitat:	Because of a lack of open water, flooded emergent vegetation, large expanses of lawn, or other conditions, the wetlands do not provide habitat for waterfowl.
Amphibian Habitat:	These wetlands generally contain low to moderate habitat for most amphibian species because they lack suitable breeding areas (i.e., areas of standing water from late fall through late spring). Since most of these wetlands have some habitat connection to the aquatic habitat areas of Miller Creek, they may provide habitat for non-breeding amphibians. This is especially true of forested portions of Wetlands 18, 19, 20, and 37. The presence of shallow standing water (up to 6 inches) in portions of Wetland 35 provides breeding habitat for Pacific chorus frog and western redback salamander (*Plethodon vehiculum*).
Small Mammal Habitat:	Most of these wetlands provide low to moderate habitat to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals (except coyote) are absent from the project area due to the lack of large, undeveloped areas of native vegetation and presence of extensive urban development.
Organic Matter Export:	The forested riparian areas of Wetlands 18 and 37 are expected to provide plant and insect detritus to Miller Creek, and rank high for this function. Wetlands 19 and 20, which is connected to Wetland 37 and Miller Creek through natural and artificial channels (Water W and Water A), is also rated high for this function. Wetlands 35, A12 and A18 contribute seasonal flow to downslope wetlands, and are rated low to moderate for this function. Other wetlands are rated low for this function, based on their isolation from streams, ditches or other drainage channels.
Groundwater Exchange:	Several wetlands (Wetlands 18, 19, 20, and 37) are formed in areas of groundwater discharge, and they thus contribute to the base flow of Miller Creek and are rated high for this function. Natural and artificial channels (Water A and Water W) help convey this water to the creek. Wetlands 35, A6, A7, A8, and A12 are rated moderate for this function because during the winter and spring months, the perched water collects in them and discharges to downslope areas. Other wetlands (Wetlands 16, 17, 21, 22, 40, 41, and A5) occur on low permeability till soils where shallow depressions or gentle slopes collect rainwater during the winter months. These wetlands were rated low for this function because groundwater discharge is not present and seepage to groundwater is restricted by soil conditions.
Flood Storage/ Desynchronization:	Portions of Wetlands 18 and 37 impacted by the project are outside the Miller Creek floodplain. (Downslope areas occur in the floodplain of Miller Creek and provide flood storage or flood conveyance functions.) The remaining wetlands do not occur in floodplains, but they could reduce peak flows by slowing runoff rates to Miller Creek. Wetlands 40 and 41 are rated medium for this function because they are small depressions that pond water during the winter

Table 3-12. Summary of the ecological functions provided by wetlands impacted by third runway embankment construction on the west side of the existing airfield (continued).

Function	Analysis
	months and provide detention for stormwater runoff. Other wetlands are rated low because they are not in floodplains and lack active storage.
Nutrient Retention/ Sediment Trapping:	Surface water runoff from streets and residential development enter most of the wetlands located west of 12th Avenue South, and these wetlands are rated moderate or high for this function. Sediments, nutrients, and other chemicals are likely removed from runoff by these wetlands due to topographic, hydrologic, and vegetation conditions. Removal of sediments and nutrients would be somewhat reduced in wetlands with channelized flow (Wetlands 18, 35, 37, and A18) compared to other wetlands where channelized flow is absent. For wetlands east of 12th Avenue South, moderate to high water quality functions could be expected; however, these wetlands do not receive surface water runoff from developed areas, and they are therefore rated low for this function.

3.2.1.3 Wetlands Impacted by the Third Runway Embankment within the Walker Creek Sub-Basin.

Functions provided by the portion of Wetland 44 and the several wetland depressions at the south end of the existing airfield (Wetlands 23, 24, 25, and 26) that are subject to project impacts are evaluated in Table 3-13.

Table 3-13. Summary of the ecological functions provided by wetlands impacted by third runway embankment construction south of 170th Street.

Function	Analysis
Resident/ Anadromous Fish Habitat:	Wetlands on the airfield and the affected portion Wetland 44 do not contain fish habitat.
Passerine Bird Habitat:	Wetland 44 provides moderate-high habitat functions for passerine birds. However, the wetlands habitat function is somewhat limited by the young age of the forest and shrub habitats, and by the presence of non-native species in the understory. Residential land uses also limit the function to species tolerant of moderate to high levels of human disturbance. Wetlands on the airfield provide limited functions to birds because of their small size and on-going vegetation management. Birds using the wetlands are dispersed over the landscape and occur in many urban habitats. These migratory (and resident) birds use the large amounts of urban habitat available for breeding and migration.
Waterfowl Habitat:	Because of a lack of open water, flooded emergent vegetation, large expanses of lawn, or other conditions, Wetland 44 does not provide habitat for waterfowl. Waterfowl periodically use mowed wetland areas on the airfield (Wetland 23), but hazing or removal as part of the wildlife hazard management necessary to maintain aviation safety discourages this use.
Amphibian Habitat:	Wetland 44 generally contains moderate habitat for amphibians because it lacks suitable breeding areas (i.e., areas of standing water from late fall through late spring), yet the area may provide habitat for non-breeding amphibians. The wetland is connected to the aquatic habitat areas of Wetland 43, where breeding habitat is present. The depressions on the airfield are unlikely to be used by amphibians because of vegetation maintenance, lack of breeding habitat, and isolation from other habitat areas.

Table 3-13. Summary of the ecological functions provided by wetlands impacted by third runway embankment construction near Wetland 44 and wetlands on the existing airfield (continued).

Function	Analysis
Small Mammal Habitat:	Most of these wetlands provide habitat to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. However, for wetlands on the airfield, their small size, vegetation management, and isolation from other habitats limit this function, and they are thus rated low for this function. The affected portions of Wetland 44 are part of a larger habitat area and the wetland is thus rated moderate to high for this function. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals (except coyote) are absent from the project area due to the lack of large, undeveloped areas of native vegetation.
Organic Matter Export:	Wetland 44, downslope of the project, would provide plant and insect detritus export to Wetland 43 because several small perennial stream channels provide a mechanism for organic matter export. The intermittent channel located in the construction area could provide this function during the winter months, when flowing water is present. The isolated depressions on the airfield would not be expected to provide this carbon export function, and they were therefore rated low.
Groundwater Exchange:	Wetland 44, downslope of the permanent fill, is an area of perennial groundwater discharge. In the area of permanent fill, the wetland is seasonally saturated by perched water and stormwater runoff that supports intermittent streamflow. Therefore, the area rates moderate to high for this function. In contrast, the wetland depressions located on the airfield are areas where rainwater and stormwater runoff seasonally perches. They may provide limited groundwater recharge functions, but probably less than non-wetland portions of the airfield where soil permeability is higher. They are thus rated low for this function.
Flood Storage/ Desynchronization:	Filled portions of Wetland 44 are located upslope of floodplains and on a slope. While the area provides stormwater conveyance functions, it does not store stormwater. The wetlands on the airfield have some capacity to store stormwater runoff, but this is small due to their shallow depth and small size.
Nutrient Retention/ Sediment Trapping:	Surface water runoff from streets and residential development enter Wetland 44 from 12th Avenue South, South 176th Street and adjacent areas. Sediments, nutrients, and other chemicals are likely removed from runoff by the wetland, but channelized flow may limit this function; therefore, the wetland is rated moderate to high for this function. Wetlands on the airfield, as closed depressions, are expected to have relatively high capacities for sediment trapping and nutrient removal functions.

Walker Creek Functions

Walker Creek[12] drains an approximately 2.5-mi^2 subbasin of the Miller Creek watershed. The creek originates in a 30-acre wetland (Wetland 43) located between Des Moines Memorial Drive and SR 509. The stream flows through both residential and commercial development before its confluence

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[12] Direct alterations to Walker Creek do not result from Master Plan Update improvements. Potential indirect impacts to the creek include impacts from wetland filling, stormwater runoff, and low flow impacts.

with Miller Creek approximately 300 ft upstream from Puget Sound. Much of the riparian areas adjacent to the creek have been eliminated or altered by adjacent development.

Walker Creek parallels Miller Creek for roughly one-half its length and they share similar effects from urbanization. KCSWM (1987) reports several problems in the Miller/Walker Creek watershed created by urbanization; these include excessive runoff from streets, parking lots, and commercial areas that have increased the volume and rate of storm flows. These increased flows have lead to mass wasting and stream erosion, flooding, and loss of habitat. Runoff from this development has also reduced water quality and impaired fish usage.

The presence of a large wetland (Wetland 43) as headwaters to the creek, and perennial groundwater discharge to this wetland from subsurface drains associated with SR 509 and seeps in Wetland 44 appear to provide a relatively constant flow to the creek. Wetland 43 also provides storage capacity to buffer against stormwater runoff from upslope impervious surfaces.

The large surface area of Wetland 43, and the presence of open water (variably affected by the presence of beaver that dam its downstream end) probably causes elevated water temperatures in down stream areas during the summer months. This lack of suitable riparian condition along much of the creek channel would also contribute in increased temperature along much of the creek length.

3.2.1.4 Wetlands Impacted by the SASA Development

Functions provided by impacted wetlands (or portions of them) located in the footprint of the SASA project are evaluated in Table 3-14. This analysis pertains to Wetlands 52, 53, E2, E3, G1, G2, G3, G4, G5, and G7.

Table 3-14. Summary of the ecological functions provided by wetland areas impacted by the SASA development.

Function	Analysis
Resident/ Anadromous Fish Habitat:	Wetland 52 is a slope wetland with portions that are riparian to a constructed channel of Des Moines Creek. (The channel was constructed in the early 1970s.) The wetland itself does not provide fish habitat because it is elevated above the stream channel. However, other functions (groundwater exchange and organic matter export functions) that the wetland provides would enhance adjacent instream habitat and therefore Wetland 52 is rated moderate to high. Other wetlands are isolated from the stream and do not provide habitat for fish. Fish use of Des Moines Creek is described in the FEIS, FSEIS, NRMP, and BA.
Passerine Bird Habitat:	Wetland 52 and 53 provide forested habitat for passerine birds. The habitat function for birds in Wetlands 52 and 53 is somewhat limited by the young age of the forest habitats and by the presence of non-native species in the understory. Nearby commercial land uses also limit the function to species tolerant of moderate to high levels of human disturbance. The impacted portion of Wetland 52 is rated low to moderate for this function because of the wetland's proximity to disturbances and the presence of shrub and lower quality emergent vegetation. Wetland 53 is rated somewhat higher (moderate to high) because of forest vegetation. Other wetlands are dominated by Himalayan blackberry shrubs or are mowed portions of the Tyee Valley Golf Course and provide low habitat function for birds. Migratory (and resident) birds expected in these wetlands disperse widely and use the large amounts of urban habitat available for breeding and migration.

Table 3-14. Summary of the ecological functions provided by wetland areas impacted by the SASA development (continued).

Function	Analysis
Waterfowl Habitat:	Because of a lack of open water and flooded emergent vegetation, the wetlands do not provide breeding habitat for waterfowl. Limited waterfowl forage habitat, especially during the winter months, occurs in emergent wetlands (G1-G5, and G7), but this use is restricted by year-round operation of the golf course.
Amphibian Habitat:	These wetlands lack suitable breeding areas (i.e., areas of standing water from late fall through late spring). Wetlands E2, E3, G1, G2, G3, G4, G5, and G7 do not provide non-breeding habitat for amphibians because they are isolated from other aquatic areas or are mowed turfgrass. Wetland 52 has a habitat connection to the aquatic habitat areas of Des Moines Creek and the forested portions provide habitat for non-breeding amphibians.
Small Mammal Habitat:	Most of these wetlands provide some habitat value to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals (except coyote) are absent from the project area due to the lack of large, undeveloped areas of native vegetation. Wetlands on the golf course are rated low because they receive limited use by small mammals primarily during nocturnal hours. Wetland 52 and 53 are rated moderate and moderate to high because of the presence of shrub and forest vegetation, respectively, that provide habitat for foraging and denning animals. The small size and isolated condition of Wetlands E2 and E3 restrict use by small mammals, and these areas are thus rated low.
Organic Matter Export:	The forested riparian areas of Wetland 52 are expected to provide plant and insect detritus to Des Moines Creek, and it thus ranks high for this function. Other wetlands are rated low for this function because they are isolated from surface waters.
Groundwater Exchange:	Several wetlands (Wetlands E2, E3, G1, G2, G3, G4, G5, and G7) occur on gentle slopes in areas where groundwater discharge occurs during the late winter and spring months. These wetlands were rated moderate for this function. Groundwater discharge in portions of Wetland 52 is perennial and flows downslope to Des Moines Creek; therefore, the wetland was rated high for the function. Wetland 53 is a shallow depression where rainwater collects during the winter months. Wetland 53 was rated low for this function because it is located on till soils that restrict surface/groundwater exchanges.
Flood Storage/ Desynchronization:	Most wetlands do not provide flood storage functions because they are not part of the creek floodplain. Impacted areas of Wetland 52 are elevated above the high water mark of the channel and do not provide this function. Portions of Wetland 52 are part of a detention facility, flood periodically, and are rated high for this function. Wetland 53 could reduce peak flows by slowing runoff rates to Des Moines Creek due to a limited amount of storage capacity. Other wetlands are rated low for this function.
Nutrient Retention/ Sediment Trapping:	Topographic and runoff conditions could result in Wetlands 52 and 53, and these wetlands are rated moderate to high for this function. Other wetlands are rated low for this function because of their small size and lack of surface flows. Wetlands on the golf course may be a net source of nutrients and other chemicals due to golf course maintenance and their occurrence on a seasonally saturated slope, which promotes runoff.

3.2.1.5 Wetlands Impacted by the Borrow Area 1 Excavation

Functions provided by impacted wetlands (or portions of them) located in the footprint of Borrow Area 1 are evaluated in Table 3-15. This analysis pertains to Wetlands B11, B12, and B14.

Table 3-15. Summary of the ecological functions provided by wetlands impacted by excavation activities in Borrow Area 1.

Function	Analysis
Resident/ Anadromous Fish Habitat:	Wetlands B11, B12, and B14 do not provide fish habitat. Wetland B12 connects to Des Moines Creek and may provide indirect habitat support functions to the stream; therefore, Wetland B12 is rated low to moderate for this function. Other wetlands are rated low.
Passerine Bird Habitat:	Wetland B12 provides habitat for passerine birds and is rated moderate to high because the portion of the wetland located downslope of the borrow area is forested and located in the riparian area of Des Moines Creek. The isolated wetlands B11 and B14 provide low to moderate habitat for birds. Their habitat value is limited by a dominance by non-native vegetation and a lack of habitat diversity. Birds using the wetlands are dispersed widely over the landscape and occur in many urban habitats. The migratory (and resident) birds that are expected in these wetlands also use the large amounts of nearby urban habitat available for breeding and migration.
Waterfowl Habitat:	Because of a lack of open water, flooded emergent vegetation, or mowed lawn, the wetlands do not provide breeding or forage habitat for waterfowl.
Amphibian Habitat:	These wetlands lack suitable breeding areas (i.e., areas of standing water from late fall through late spring) for amphibians. They generally provide low quality habitat for non-breeding amphibians; however, Wetland B12 is connected to Des Moines Creek riparian areas, where habitat for non-breeding amphibians is rated moderate.
Small Mammal Habitat:	These wetlands are rated moderate for this function. They provide habitat to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals (except coyote) are absent from the project area due to the lack of large, undeveloped areas of native vegetation.
Organic Matter Export:	The forested riparian areas of Wetland B12, located downslope of the excavation, could contribute detritus and insects to Des Moines Creek. The upper portion of the wetlands lacks surface flow and does not provide this function. Isolated wetlands (B11 and B14) that lack surface outflow do not provide this function.
Groundwater Exchange:	Wetland B12 is an area of seasonal groundwater discharge and therefore functions at a moderate level for this function. Wetlands B11 and B14 are closed depressions that may provide some groundwater recharge functions; however, it is likely that upland areas adjacent to the wetland, which have more permeable soils, perform this function at a higher level than the wetland. Therefore, wetlands B11 and B14 are rated low for this function.
Flood Storage/ Desychronization:	These wetlands do not provide flood storage functions because they are not part of the creek floodplain. Wetlands B11 and B14 could reduce peak flows by slowing runoff rates to Des Moines Creek because they are shallow depressions that could pond small amounts of water during large storms.
Nutrient Retention /Sediment Trapping:	The wetlands do not receive urban runoff because the adjacent residential areas have been demolished and pollutant sources have been removed. The topographic and runoff conditions in the wetland could result in a high retention of nutrients and sediments in the closed depressions of Wetland 11 and 14. Lower function would be expected for Wetland B12 because it occurs on a slope.

3.2.2 Wetland Mitigation Areas

Several areas are proposed for on- and off-site mitigation of the Master Plan Update improvement impacts to wetland area and function (see Table 1-1). These areas contain existing wetlands that will be modified and restored or enhanced as part of the mitigation plan. This section describes the functions of existing wetlands in the mitigation areas, and serves as a baseline from which the "ecological lift," or enhancement, of functions can be evaluated.

The mitigation areas include:

- **Vacca Farm Area** – This 19.69 acre area is located near the northwest corner of the proposed runway, between Des Moines Memorial Drive, South 154th Street, and South 147th Street. The Miller Creek relocation occurs on this site, as do several other wetlands to be restored and enhanced.

- **Miller Creek Buffer Area** – This 51.11 acre area includes areas adjacent to Miller Creek between South 154th Street and Des Moines Memorial Drive. Mitigation includes buffer areas and riparian wetlands that will be enhanced. Fish habitat in Miller Creek will also be improved at four enhancement sites.

- **Tyee Valley Golf Course** – This 10.46 acre area includes portions of Wetland 28 that are located on the Tyee Valley Golf Course and buffer areas adjacent to Des Moines Creek. Wetlands and buffer areas will be enhanced and restored.

- **Des Moines Way Nursery Site** – This 5.59 acre site is located near the northwest corner of the SR 518 and Des Moines Memorial Drive interchange. Mitigation at this site includes demolition of existing facilities, removal of fill from wetlands, and planting wetlands and buffers with forest and shrub vegetation.

- **Off-site location in Auburn** – This 65.38 acre site is located south of South 277th Street and west of the Green River in the City of Auburn. Wetlands will be enhanced and restored.

3.2.2.1 Wetlands at Vacca Farm

Wetland restoration, buffer enhancement, and relocation of a reach of Miller Creek will occur in an area known as Vacca Farm, as explained in Section 5.1 of the NRMP (Parametrix 2001a). This analysis pertains to Wetlands A1, A2, A3, A4, FW1, FW2 FW3, FW9, FW10, and FW11, all located on the mitigation site. This mitigation area includes Lora Lake (Part of Wetland A1) and the wetland perimeter around Lora Lake. The functions that are provided by existing wetlands located at the Vacca Farm mitigation site are evaluated in Table 3-16.

In addition to wetlands delineated and verified by ACOE (2001), 7.88 acres of prior converted (PC) wetlands were identified on Vacca Farm parcels (Appendix C, in Parametrix 2000a). Most of these PC wetlands (6.96 acres) are located within the Vacca Farm floodplain restoration area, and will be restored to wetland and stream conditions as a result of on-site mitigation (Parametrix 2000a). The remaining PC wetland (0.92-acre) is located east of Miller Creek and will be impacted by the third runway, the relocation of South 154th Street, or the relocation of Miller Creek.

Table 3-16. Functions provided by wetlands impacted by mitigation activities planned at the Vacca Farm site.

Function	Analysis
Resident/ Anadromous Fish Habitat:	With the exception of Wetland A1, the wetlands lack habitat for fish. Wetland A1 includes portions of Miller Creek, adjacent riparian areas that support fish habitat, and Lora Lake. The FEIS, FSEIS, NRMP, and BA discuss fish use in Miller Creek. The lack of natural riparian vegetation around much of Lora Lake and Miller Creek reduces the value of these areas to fish. Other wetlands occur in or adjacent to farmland are not riparian, and lack fish habitat.
Passerine Bird Habitat:	Wetlands A2, A3, A4, FW1, FW2, FW3, FW9, FW10, and FW11 generally provide low habitat functions for passerine birds because they consist of farmland with small patches of blackberry shrubs. The habitat function they provide is limited by the land uses (farming and other vegetation disturbance) that have removed vegetation, leaving plowed ground and non-native weedy species as habitat. A limited number of bird species use these wetlands for forage. The forested and willow-dominated shrub habitats of Wetland A1 support a broader array of bird species for forage and nesting, but the area also contains lower quality habitats dominated by reed canarygrass and Himalayan blackberry. A drainage ditch in Wetland A1 provides habitat for red-winged blackbirds and forage area for great blue heron. Bird species using the wetlands are common and generally dispersed over the landscape, occurring in many urban habitats. These migratory (and resident) birds use the large amounts of urban habitat for breeding and migration.
Waterfowl Habitat:	Wetland A1 and the farmed wetlands provide moderate function for waterfowl because they contain crop residue used as forage. Wetland A1 contains limited areas of open water in a ditch and Lora Lake, which is potential nesting habitat for mallard ducks (*Anas platyrhynchos*). The lawn areas around the perimeter of Lora Lake provide forage habitat for waterfowl. Wetlands A2, A3, and A4 are dominated by Himalayan blackberry and do not provide waterfowl habitat.
Amphibian Habitat:	These wetlands generally contain low quality habitat for amphibians because they lack suitable breeding areas (i.e., areas of standing water from late fall through late spring). Wetland A1 provides some breeding habitat within an agricultural drainage ditch and Lora Lake. However, the lack of riparian vegetation around much of Lora Lake reduces the value of the shoreline area for breeding and non-breeding amphibians. Since most of these wetlands have poor vegetation cover, they provide little habitat.
Small Mammal Habitat:	Small mammals that are expected in these wetlands include raccoon, Virginia opossum, squirrels, mice, and rats. Most of the farmed wetlands provide little cover or habitat, but may be used as forage habitat, especially during the night and when crop residues are present. Wetlands A1, A2, A3, and A4 provide shrub or forest cover, and could provide potential denning areas. Nearby residential areas and the lack of riparian vegetation around much of Lora Lake reduces the value of the shoreline as foraging habitat for small mammals. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals (except coyote) are absent from the project area due to the lack of large, undeveloped areas of native vegetation.
Organic Matter Export:	The riparian portions of Wetland A1 provide organic matter export functions to Miller Creek. This function is somewhat limited by the presence of herbaceous vegetation and creek channelization. While there may be limited periods of seasonal flow from some farmed wetlands, they generally do not export organic matter to the creek except during flood events. During floods, the quality and amounts of organic matter export does not mimic natural

Table 3-16. Functions provided by wetlands affected by mitigation activities planned at the Vacca Farm site (continued).

Function	Analysis
	floodplain systems because of farming.
Groundwater Exchange:	These wetlands appear to be areas where groundwater discharge occurs and then perches on low permeability substrates. The area thus contributes to base flow of Miller Creek, and the wetlands are rated high for this function.
Flood Storage/ Desynchronization:	Most wetlands are within the floodplain of Miller Creek and are rated high for this function.
Nutrient Retention/ Sediment Trapping:	While the wetlands receive storm runoff from streets, lawns, or farmland, they provide limited biofiltration functions due to their sparse vegetation cover.

3.2.2.2 Wetlands Located in the Miller Creek Buffer Mitigation Area

Mitigation in the Miller Creek buffer area, between South 154th Street and Des Moines Memorial Drive, will consist of instream aquatic habitat enhancement, upland vegetation enhancement, and wetland enhancement. The mitigation is described in detail in Section 5.2 of the NRMP (Parametrix 2001a). The functions provided by impacted wetlands in the Miller Creek Buffer enhancement area are evaluated Table 3-17. This analysis pertains to Wetlands 18, 37, A1, A9, A10, A11, A13, A16, A17, R1-R15, and R17.

Table 3-17. Functions provided by wetlands impacted by mitigation activities planned for the Miller Creek buffer mitigation area.

Function	Analysis
Resident/ Anadromous Fish Habitat:	Wetlands 18, 37, A17, Water D and the riparian wetlands (Wetlands R1-R15 and R17) are adjacent to Miller Creek and its aquatic habitat. The wetlands provide some fish habitat during flood events, when their riparian portions are flooded. Aside from the stream channel itself, the wetlands lack fish habitat during normal flow periods. Other wetlands do not contain fish habitat and are generally isolated from the creek. While the they lack fish habitat, they maintain instream habitat because of the shade they provide the stream, their overhanging vegetation that results in carbon export, and their groundwater discharge functions. They are thus rated high for this function. The FEIS, FSEIS, NRMP, and BA discuss fish use in Miller Creek.
Passerine Bird Habitat:	Most of these wetlands contain some forest or shrub habitat and provide moderate to high habitat functions for passerine birds. However, for most wetlands, the habitat function is somewhat limited by the young age of forest vegetation and by the presence of non-native species in the understory. Residential land uses significantly limit the function to species tolerant of moderate to high levels of human disturbance. Birds using the wetlands are dispersed over the landscape and occur in many urban habitats. The migratory (and resident) birds use the large amounts of urban habitat in the area for breeding and migration.
Waterfowl Habitat:	Mallard ducks have been observed in the emergent vegetation found in Wetlands 18 and 37. Because of a lack of open water, flooded emergent vegetation, large expanses of lawn, or other conditions, the wetlands do not provide significant habitat for waterfowl, and are rated low for this function.
Amphibian Habitat:	These wetlands generally contain low to moderate habitat for amphibians because they lack suitable breeding areas (i.e., areas of standing water from late fall through late spring). Since most of these wetlands have some habitat connection to the aquatic habitat areas of Miller

Table 3-17. Functions provided by wetlands impacted by mitigation activities planned for the Miller Creek buffer mitigation area (continued).

Function	Analysis
	Creek, they may provide habitat for non-breeding amphibians. This function is limited by residential land uses and other human disturbances. However, Wetland 37 is rated moderate to high for amphibians because of the presence of shallow standing water that red-backed salamander and Pacific chorus frog could use for breeding and rearing.
Small Mammal Habitat:	Most of these wetlands provide some habitat to small mammals such as raccoon, Virginia opossum, squirrels, mice, and rats. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals (except coyote) are absent from the project area due to the lack of large, undeveloped areas of native vegetation and extensive urban development. Despite their location in residential areas, the presence of water and varying amounts of creek-side vegetation provide habitat and travel corridors and the wetlands generally provide moderate to high small mammal habitat functions.
Organic Matter Export:	The forested riparian portions of the wetlands (including Wetland A17 and Water D) export plant and insect detritus to Miller Creek, and rank high for this function. Vegetation management in the riparian zone (i.e., mowing or removing downed logs or overhanging vegetation) often reduces this function. Other wetlands (Wetlands A9, A10, A11, A13, and A16) are rated low for this function because they are isolated from surface waters.
Groundwater Exchange:	Wetlands 18, 37, A1, A9, 39, and R9 are generally formed in areas of groundwater discharge, and are rated high for this function. In addition, their proximity to Miller Creek means most wetlands contribute, at least seasonally, to the base flow of the stream.
Flood Storage/ Desynchronization:	Portions of the riparian wetlands that occur in the Miller Creek floodplain (Wetlands 18, 37, A1, A9, 39, and R9) and Wetland A17 and Water D provide flood conveyance and storage functions. Non-riparian wetlands (Wetlands A9, A10, A11, A13, and A16) occur on slopes where they have limited capacity to store runoff and reduce peak flows.
Nutrient Retention/ Sediment Trapping:	Surface water runoff from streets and residential development enters most of the wetlands located west of 12th Avenue South. Sediments, nutrients, and other chemicals are likely removed from runoff by these wetlands. Removal of sediments and nutrients would be somewhat lower in wetlands with channelized flow (portions of Wetlands 18 and 37) compared to other wetlands where channelized flow is absent.

3.2.2.3 Wetlands Impacted by the Tyee Golf Course Mitigation Project

Portions of Wetland 28 occur on the Tyee Valley Golf Course and consist of turfgrass. As part of the wetland mitigation explained in Section 5.3 of the NRMP, these wetlands and adjacent Des Moines Creek buffers will be enhanced. The functions that are provided by Wetland 28 within the footprint of the Tyee Valley Golf Course Mitigation site are analyzed in Table 3-18.

Table 3-18. Functions provided by wetlands impacted by mitigation activities planned at the Tyee Golf Course mitigation site.

Function	Analysis
Resident/Anadromous Fish Habitat:	The wetland mitigation area is riparian to a channelized segment of Des Moines Creek. The wetland itself does not provide fish habitat because it is elevated above the creek channel; however, during flood events it could receive some use by fish. Because of the lack of significant woody vegetation and shade, the wetland areas provide little indirect support to fish habitat. Fish use of Des Moines Creek is described in the FEIS, FSEIS, NRMP, and BA.
Passerine Bird Habitat:	The mitigation area consists of mowed portions of the Tyee Valley Golf Course, with a few trees present. These conditions result in low habitat for birds. During wet periods, or within

Table 3-18. Functions provided by wetlands impacted by mitigation activities planned at the Tyee Golf Course mitigation site (continued).

Function	Analysis
	emergent vegetation fringing Des Moines Creek, great blue heron (*Ardea herodias*) could forage, and red-winged blackbird nest and forage. Migratory (and resident) birds expected in these wetlands disperse widely and use the large amounts of urban habitat available for breeding and migration.
Waterfowl Habitat:	This portion of Wetland 28 lacks open water and native emergent vegetation so it does not provide breeding habitat for waterfowl. Waterfowl forage, especially during the winter months, occurs on the golf course, but year-round operation of the golf course and hazing of wildlife for safety purposes restrict this use. This area is thus rated low for waterfowl habitat.
Amphibian Habitat:	Except for the Des Moines Creek channel, the wetland mitigation area lacks suitable breeding areas (i.e., areas of standing water from late fall through late spring) for amphibians. The fringe of the wetland bordering Des Moines Creek could provide limited breeding and rearing habitat for some amphibian species. The wetland generally does not provide other habitat for amphibians because it lacks sufficient vegetation or other suitable conditions, and is frequently mowed.
Small Mammal Habitat:	The wetland mitigation area provides low quality habitat for small mammals. Some use of the habitat by mammals (such as raccoon, Virginia opossum, squirrels, mice, and rats) is expected during the night when players are off the golf course. The wetland generally does not support burrowing animals due to seasonally saturated soils; however, some use by moles could occur during the summer months when soils are dry. Large mammals (except coyote) are absent from the project area due to the lack of large, undeveloped areas of native vegetation and presence of urban development.
Organic Matter Export:	The riparian fringe of the wetland provides some carbon export function to Des Moines Creek, but mowing reduces the level of function provided. The remaining portion of the mitigation site provides low export functions due to mowing, removal of vegetation, and limited hydrologic connectivity.
Groundwater Exchange:	The wetland mitigation site appears to be an area where rainfall and flooding result in a seasonally high groundwater table. Groundwater discharge or recharge at this location may not be significant.
Flood Storage/ Desynchronization:	This wetland mitigation area is largely within the Des Moines Creek floodplain, and is rated high for this function.
Nutrient Retention /Sediment Trapping:	Topographic and runoff conditions in the mitigation area, coupled with dense turfgrass, result in high ratings for this function. However, the golf course may be a net source of nutrients and other chemicals due to maintenance applications of fertilizers or chemicals.

3.2.2.4 Wetlands Located on the Des Moines Way Nursery Site

Mitigation at the Des Moines Way Nursery site will consist of demolition of existing buildings and pavement, wetland restoration, wetland enhancement, upland vegetation enhancement, and placement of LWD in Miller Creek. The mitigation is described in detail in Appendix N of the NRMP (Parametrix 2001a). The functions provided by impacted wetlands on the Des Moines Way Nursery site are evaluated Table 3-17. This analysis pertains to Wetlands N8, N9, and N10, which occur on the property.

Table 3-19. Functions provided by wetlands impacted by mitigation activities planned for the Des Moines Way Nursery mitigation area.

Function	Analysis
Resident/ Anadromous Fish Habitat:	The riparian wetlands are adjacent to Miller Creek and its aquatic habitat. The wetlands do not provide direct fish habitat because they are non-flooded and occur outside the floodplain and lack inundated areas. Portions of N8 and most of N9 enhance instream habitat because of the shade they provide the stream, their overhanging vegetation that results in carbon export, and their groundwater discharge functions. They are thus rated high for this function.
Passerine Bird Habitat:	Wetland N8 and N9 contain some forest or shrub habitat that provides low to moderate habitat functions for passerine birds. The habitat function is somewhat limited by the young age of forest vegetation, by the presence of non-native species in the understory, the general lack of undisturbed buffers, and adjacent land uses. Adjoining commercial and recreational land uses limit use to species tolerant of moderate to high levels of human disturbance. Birds using the wetlands are dispersed over the landscape and occur in many urban habitats. The migratory (and resident) birds use the large amounts of urban habitat in the area for breeding and migration. Mowed areas of Wetland N10 provide foraging habitat for some birds that forage on the ground in urban environments.
Waterfowl Habitat:	Mallard ducks could use open areas along the creek as forage habitat. Because the wetlands lack open water, flooded emergent vegetation, or other habitat features, they do not provide significant habitat for waterfowl, and are rated low for this function.
Amphibian Habitat:	The wetlands generally contain low quality for amphibians because they lack suitable breeding areas (i.e., areas of standing water from late fall through late spring). The wetlands are riparian, but to Miller Creek but the mowed riparian areas and log culverted sections located upstream and downstream limit the value of the area to amphibians.
Small Mammal Habitat:	The wetlands provide limited habitat to small mammals, but raccoon, Virginia opossum, squirrels, mice, and rats would be expected to use them. The wetlands typically do not support burrowing animals due to seasonally saturated soils. Large mammals are absent from the project area due to the lack of large, undeveloped areas of native vegetation and extensive development. The presence of dogs on the site is likely to further limit use of the wetlands by small mammals.
Organic Matter Export:	The forested riparian portions of Wetland N8 and N9 export plant and insect detritus to Miller Creek, and rank high for this function. Vegetation management in the riparian zone (i.e., mowing or removing downed logs or overhanging vegetation) in portions of N* and Wetland N10 reduces this function by removing organic matter from the riparian area, limiting the quality of organic matter.
Groundwater Exchange:	Wetlands N8, N9, and N10 are generally formed in areas of seasonal groundwater discharge, and are rated high for this function. In addition, their proximity to Miller Creek means most wetlands contribute, at least seasonally, to the base flow of the stream.
Flood Storage/ Desynchronization:	The wetlands appear to be elevated above the typical floodplain of the creek, and property owners have indicated the creek banks do not overtop during wet periods. The wetlands are therefore rated low for this function.
Nutrient Retention/ Sediment Trapping:	Surface water runoff from streets, lawns, and/or commercial areas enters Wetland N8 and N10. Sediments, nutrients, and other chemicals are likely removed from runoff by these wetlands. The high density of grass vegetation and general lack of channelized flow is likely to promote a relatively efficient removal of sediments, nutrients, and other contaminants from runoff waters.

3.2.2.5 Wetlands Impacted by Mitigation in Auburn

The off-site mitigation area in Auburn contains about 19.5 acres of emergent wetlands on abandoned agricultural land. The functions provided by wetlands at the off-site mitigation project in Auburn are analyzed in Table 3-20. This analysis pertains to the emergent wetlands that make up part of the abandoned agricultural land on the site.

Table 3-20. Functions provided by wetlands at the mitigation project site in Auburn.

Function	Analysis
Resident/ Anadromous Fish Habitat:	There is no fish habitat on the site. No perennial or intermittent streams occur on the site and the wetland is thus rated low for this function.
Passerine Bird Habitat:	The emergent wetlands, dominated by non-native pasture grasses, provide relatively limited habitat functions for a variety of bird species (see Table 7.2-6 in the NRMP). Because of the lack of tree or shrub habitat on the site, most bird activity is limited to foraging, and the diversity of birds is limited to those that nest or forage in open habitats.
Waterfowl Habitat:	The lack of standing water on the site and the presence of un-mowed grass prevent significant nesting or forage by waterfowl species.
Amphibian Habitat:	The emergent wetlands provide low habitat conditions for amphibians (see Table 7.2-6 in the NRMP). The lack of standing or open water during the winter and spring months prevents amphibian breeding. There is no nearby high quality breeding habitat, so there is little opportunity for juveniles and adults to disperse to the area, and the lack of forest and shrub habitat provides poor habitat conditions for most adults.
Mammal Habitat:	The emergent wetlands provide habitat functions for large and small mammals (see Table 7.2-6 in the NRMP). Because of the lack of forest and shrub habitats, the diversity of animals is limited to those that use open habitats and that do not rely on woody debris for cover or nesting. In addition to use by small mammals, deer and coyote would also use the area for foraging.
Organic Matter Export:	The lack of perennial or intermittent flow in or near the wetland results in a low assessment for this function. During wet periods, some organic matter export to other ditch systems may occur.
Groundwater Exchange:	Wetlands on the site occur in areas where low permeability surface soils perch groundwater during the winter and spring months. Seepage through these soils provides some recharge to a subsurface aquifer.
Flood Storage/ Desynchronization:	A small portion of the northwest corner of the site is within the 100-year floodplain of the Green River, but due to its elevation near the upper end of the flood limit, the storage provided is insignificant. The emergent wetlands may reduce peak runoff rates, but this reduction is unlikely significant compared to the large volumes of floodwater in the adjacent Green River.
Nutrient Retention/ Sediment Trapping:	During wet periods, runoff from adjacent agricultural land to the south enters a portion of the emergent wetland. The wetland is likely effective in removing sediment, nutrients, or chemical runoff from these waters.

4. IMPACT ANALYSIS

Permanent, temporary, and indirect impacts the biological and physical functions that will be impacted by the proposed airport improvements are described in this section. Permanent impacts are considered to result from direct filling of wetlands (Section 4.1). Temporary impacts are the shorter-term[13] impacts resulting from construction in or near wetlands that will end or be removed when construction is complete (Appendix A, and Section 4.2). Potential indirect impacts (Section 4.3) are largely associated with possible changes to wetland hydrology, increased noise or human disturbance impacts to wildlife, and potential changes to water quality.

4.1 PERMANENT IMPACTS

Permanent impacts will occur to forest, shrub, and emergent wetlands within the Master Plan Update improvement area (Table 4-1; also see Table 3-1). These impacts are generally limited to the physical footprint of planned areas of fill, excavation, or other project development.

Table 4-1. Summary of permanent wetland impacts by project and wetland category[a] (in acres).

Project	Category II	Category III	Category IV	Total
RSA	0.00	0.14	0.00	**0.14**
Third Runway	8.37	4.89	0.97	**14.23**
Borrow Area 1 and Haul Rd.	0.14	0.96	0.00	**1.10**
SASA	0.54	1.20	1.04	**2.78**
Off-site Mitigation[b]	0.00	0.12	0.00	**0.12**
TOTAL	**9.05**	**7.31**	**2.01**	**18.37**

[a] Ecology (1993).

[b] Impacts result from an access road in an emergent wetland at the Auburn mitigation project.

Permanent impacts also include indirect impacts (See Section 4.3) that could eliminate functions from 2.40 acres of wetlands. These impacts could include elevations to wetland hydrology, fragmentation, and shading (from a planned bridge spanning wetlands at SASA).

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[13] Temporary impacts occur for varying lengths of time during the construction period. The duration of these impacts is discussed further in Section 4.2.

4.1.1 Runway Safety Areas

Biological Functions

Permanent wetland impacts associated with extension of the RSAs for existing runways and relocation of South 154th Street are limited to about 0.14 acre of Wetland 5 (see Figure 1-3). Forest and shrub vegetation that provides habitat for small mammals and songbirds will be removed from a Category III wetland. These habitat functions will be lost from the impacted area. The direct impacts of filling wetlands (or portions of them) near the north end of the airfield are analyzed in Table 4-2. This analysis pertains to Wetland 5, and does not consider the mitigation for these impacts discussed in Section 4.2.3.5.

Table 4-2. Impacts to the ecological functions of wetlands affected by RSA construction.

Function	Analysis
Resident/Anadromous Fish Habitat	Fill of portions of the wetlands could indirectly impact fish habitat by altering other wetland functions (organic matter export, groundwater exchange, etc.) that indirectly influence fish habitat.
Passerine Bird Habitat:	Passerine bird habitat would be eliminated from the area. This would result in a reduction in the localized population of some species. Since no unique or rare habitat type would be lost, it is unlikely that the diversity of bird species occurring in the area or watershed would be reduced. Because large amounts of similar habitat are available regionally, significant changes to regional populations of passerine birds would not occur.
Waterfowl Habitat:	No impact to waterfowl habitat would occur.
Amphibian Habitat:	Fill of these wetlands would eliminate some potential breeding habitat (within Wetland A1) and some habitat for non-breeding adults. These reductions could reduce prey availability for some birds and small mammals.
Small Mammal Habitat:	Small mammal habitat would be eliminated from the area. This would result in a reduction in the localized population of some species. Since no unique or rare habitat type would be lost, it is unlikely that the diversity of species occurring in the area would be reduced. Because large amounts of similar habitat are available regionally, significant changes to regional populations or diversity of small mammals would not occur. Coyote would experience some loss of habitat, but would be expected to remain in the area, as they are likely to use upland habitats for most needs.
Organic Matter Export:	This function would be lost from filled portions of the wetland. Because fill would occur in an area hydrologically connected to downslope areas, some organic matter transport to downslope wetland areas would be lost.
Groundwater Exchange:	Fill of wetlands, could eliminate areas where seasonal or perennial saturation supports wetlands. The fill would probably not alter the general discharge of groundwater from upslope areas to Miller Creek because the permeability of the fill would allow continued groundwater movement to the wetlands. New areas of groundwater discharge could develop near the base of the fill, which would ultimately reach Miller Creek.
Flood Storage/ Desynchronization:	No filling would occur in a floodplain. Filled portions of the wetland occur on a slope and do not store flood or stormwater runoff.
Nutrient Retention/ Sediment Trapping:	For the portion of wetland being filled, the moderate slope and channelized flow likely prevent significant nutrient removal from occurring.

Physical Functions

The impacted portion of Wetland 5 is on a moderate slope where groundwater discharge occurs throughout most of the year. Due to the slope of the wetland, this area does not detain or store stormwater. The groundwater discharge supports wetland hydrology in downslope portions of the wetland, and ultimately contributes to base flow in Miller Creek. Design of retaining walls to avoid fill in Wetlands 3 and 4, and to minimize fill in Wetland 5, will incorporate internal drainage systems that allow groundwater to continue to discharge in this area, and this function will not be lost or significantly diminished (see Section 4.3.13 and Appendix B). The addition of best management practices (BMPs) for stormwater management (i.e., stormwater detention and water quality treatment facilities) will maintain or improve water quality conditions in the wetlands, which currently receive untreated runoff.

4.1.2 Third Runway

The embankment needed to support the third runway will impact about 14.23 acres of wetlands (see Figure 1-3 and Table 4-1). These wetlands vary from lower quality Category IV farmed wetlands to higher quality Category II riparian wetlands adjacent to Miller Creek. The impacts to the ecological functions provided by wetlands (or portions of them) located between the airfield and Miller Creek are evaluated in Table 4-3. This analysis pertains to Wetlands 9, 11, 12, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 35, 37, 40, 41, 44, R1, FW5, FW6, W1, W2, A1, A5, A6, A7, A8, A12, A13, and A18. Two drainage channels, Water A and Water W, are also included in this analysis. This impact analysis does not consider the mitigation designed to compensate lost wetland functions, as discussed in Section 4.2.3.5.

Fill and embankment construction will alter ditch and drainage channels (Water A and Water W, Figure 4-1) that are connected to Wetland 37 via a culvert under 12th Avenue South. Water A is a ditch constructed adjacent to 12th Avenue South. Water in drainage Channel A flows south from Wetland 19 and north from Wetland 21. Water in drainage Water W flows from Wetland 20 to Channel A. The two water channels converge and are then culverted under 12th Avenue South and discharged into Wetland 37. Channelized flow continues through Wetland 37 to Miller Creek.

Biological Functions

About 8.37 acres of Category II wetlands will be impacted by the runway, including portions of Wetlands 18, 20, 37, 39, and 44. These wetlands typically contain a mix of early successional forest (alder and black cottonwood trees), Himalayan blackberry- and willow-dominated shrub, and non-native emergent wetland plant communities. All or portions of the wetlands are also subjected to ongoing human disturbances, including noise, stormwater runoff, and/or vegetation impacts. The wetlands support a variety of wildlife, as described in Section 3.1 and these wildlife habitat functions will be lost from the filled areas.

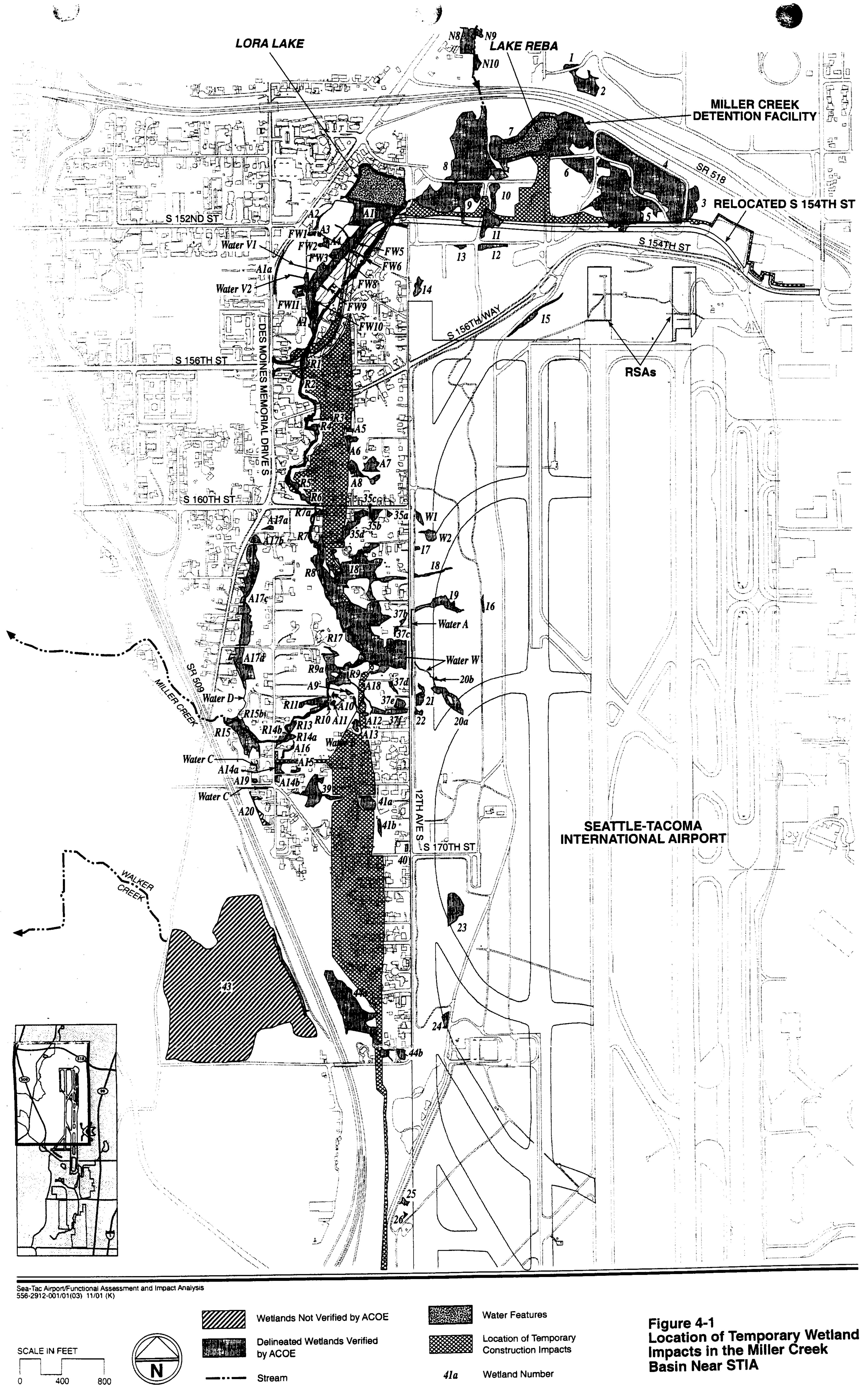
With the exception of Wetlands 18 and 37, these wetlands are not riparian. The riparian portions of Wetlands 18 and 37 protect and provide fish habitat in Miller Creek through shade and detrital input that supports invertebrate food production within the stream. Only a portion of the riparian functions provided by Wetlands 18 and 37 will be lost because only portions of the wetlands are forested with trees greater than 50 feet, and fill of these wetlands is limited to areas generally greater than 50 ft from the stream. Thus the most critical portions of the wetlands aquatic habitat support functions would remain, and there would be little or no loss of shade. Regardless of this condition, all impacts to wetlands 18 and 37 are fully mitigated (Parametrix 2001a).

Table 4-3. Impacts to the ecological functions of wetlands impacted by embankment construction west of the existing airfield.

Function	Analysis
Resident/ Anadromous Fish Habitat:	Filling portions of Wetland A1 will result in direct and indirect impacts to fish habitat. The impacts could include physical alteration of the stream channel, loss of shade, and changes in food resources. No direct impacts to fish habitat functions will occur as a result of fill placement in the wetlands. Indirect impacts to habitat conditions resulting from wetland fill (i.e., water quality and export of organic carbon) are addressed below.
Passerine Bird Habitat:	Passerine bird habitat will generally be eliminated from the areas of wetland fill, and non-paved portions of the new embankment will provide different habitat for a less diverse array of bird species. Because of the significant portion of the Miller Creek riparian areas that would remain (regardless of the planned mitigation), all bird species using the project area will continue to find habitat.
	Birds using these habitats are distributed over the landscape and expected to occur in many urban habitats. Because they disperse widely and use urban habitat for breeding and migration, migration corridors will not be eliminated. A large amount of urban habitat suitable for their use will remain following Master Plan Update improvements. Since urban habitats similar to those being eliminated are common in Puget Sound and the STIA vicinity, significant impacts on the local diversity regional populations of birds are unlikely.
Waterfowl Habitat:	The waterfowl habitat functions of Wetlands A1, FW5, and FW6 will be lost. This will result in some reduction in forage habitat for waterfowl during the winter period, and loss of a small amount of nesting habitat for mallard ducks. This loss of foraging and breeding habitat will be very small compared to the large amount of habitat available regionally, and impacts to the regional population are not expected.
	Filling of other wetlands will not eliminate significant waterfowl habitat. Waterfowl (mallard ducks) are occasionally observed in pasture and riparian areas of Wetland 18.
Amphibian Habitat:	Fill of these wetlands will eliminate habitat for amphibians. These reductions could reduce prey availability for some birds and small mammals. Because of the significant portions of the Miller Creek riparian areas that remain following project construction (regardless of the proposed habitat enhancement of this area), amphibian species potentially occurring in the area are expected to remain.
Small Mammal Habitat:	Small mammal habitat will be eliminated from the areas of wetland fill. This will result in a reduction in the localized population of some species. Since no unique or rare habitat types will be lost, it is unlikely the numbers of species occurring in the area will be reduced. The remaining portion of the Miller Creek riparian area (regardless of the proposed enhancements) will contain adequate habitat of similar quality to the wetlands being filled, and support populations of species that are currently in the area.
	Because large amounts of similar habitat are available regionally, significant changes to regional populations of small mammals will not occur. Coyote will experience some loss of habitat, but are expected to remain in the area, as they likely use upland habitats for most needs.
Organic Matter Export:	A reduction in carbon export from riparian areas to Miller Creek will occur due to the loss of portions of Wetland A1. A reduction in carbon export to Miller Creek will occur due to the loss of drainage channels (Water A and Water W). This reduction could alter or reduce the

Table 4-3. Impacts to the ecological functions of wetlands impacted by embankment construction west of the existing airfield (continued).

Function	Analysis
	type and availability of aquatic insects available for fish in the creek. If food availability is reduced, fish populations or growth rates could decline. The forested riparian areas of Wetlands 18 and 37 provide plant and insect detritus to Miller Creek, and they rank high for this function. The most critical portions of these wetlands that provide this function (i.e., those areas within 25 to 50 ft of the creek channel) will remain largely intact.
Groundwater Exchange:	Fill of wetlands will eliminate areas where seasonal or perennial saturation supports wetlands. The fill will probably not alter the general discharge of groundwater from upslope areas to Miller Creek because the permeability of the fill will allow continued groundwater movement. New areas of groundwater discharge could develop near the base of the fill, which could ultimately reach Miller Creek.
Flood Storage/ Desynchronization:	Fill in Wetland A1, R1, FW5, and FW6 will result in a loss of floodplain to Miller Creek. This loss could result in increased flood stages downstream, increased peak velocities, and channel scour. These changes could degrade habitat for fish and other biota. Elimination of floodplain areas could also reduce the export of organic matter to the creek, affecting the type and amount of aquatic insects that are available to fish and other aquatic organisms. If food availability is reduced, fish populations or growth rates could decline. It is expected that the fill of some wetland depressions and other areas that may reduce runoff rates will be balanced by the hydrologic properties of the fill (which tends to reduce runoff rates) and stormwater management systems (which store stormwater generated from impervious surfaces).
Nutrient Retention/ Sediment Trapping:	The nutrient and sediment trapping functions of the wetlands will be eliminated. In some areas (i.e., FW5 and FW6) the potential for the wetland to generate sediments and nutrient runoff from recently plowed earth will be reduced. No significant consequence of losing this function to Miller Creek or adjacent wetlands is expected because coincident with wetland filling, potential sources of sediment and uncontrolled urban runoff from 12th Avenue South and adjacent residential areas will be removed.



Sea-Tac Airport/Functional Assessment and Impact Analysis
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▨ Wetlands Not Verified by ACOE

■ Delineated Wetlands Verified by ACOE

—··— Stream

▩ Water Features

▦ Location of Temporary Construction Impacts

41a Wetland Number

SCALE IN FEET
0 400 800

N

Figure 4-1
Location of Temporary Wetland Impacts in the Miller Creek Basin Near STIA

About 2.4 million cubic yards of fill material will be obtained through excavation (i.e., a "cut") at the south end of the third runway. This area has been evaluated for wetland impacts, and includes construction or excavation impacts near Wetlands 23, 24, 25, and 26 (Table 4-4). Analysis of Wetland 44, also located at the south end of the third runway, is included in Table 4-4. This analysis does not include the benefits of the compensatory mitigation described in Section 4.2.3.5.

Table 4-4. Impacts to the ecological functions of Wetland 44 and other wetlands on the existing airfield filled by embankment construction.

Function	Analysis
Resident/Anadromous Fish Habitat:	No direct impacts to fish habitat functions will occur as a result of fill placement in the wetlands. Indirect impacts to habitat conditions resulting from wetland fill (i.e., water quality and export of organic carbon) are addressed below.
Passerine Bird Habitat:	Passerine bird habitat will generally be eliminated from the areas of wetland fill, and non-paved portions of the new embankment will provide different habitat for a less diverse array of bird species. Birds using these habitats are expected to be distributed over the landscape and to occur in many urban habitats. Because they disperse widely and use urban habitat for breeding and migration, migration corridors will not be eliminated. A large amount of urban habitat suitable for their use will remain following Master Plan Update improvements. Since urban habitats similar to those being eliminated are common in Puget Sound and the STIA vicinity, significant impacts on the local diversity or regional populations of birds are unlikely.
Waterfowl Habitat:	Mowed wetlands on the airfield that are used by foraging and loafing waterfowl will be removed. Because of active wildlife management on the airfield, wildlife use of these areas is not significant, and the impact on waterfowl populations that have many other forage areas available will be minor.
Amphibian Habitat:	Fill in Wetland 44 will eliminate habitat for non-breeding amphibians. No loss in breeding habitat will occur. The reduction could reduce prey availability for some birds and small mammals. Because of the large areas of Wetland 44 and Wetland 43 that will remain following project construction, amphibian species occurring in the local area are expected to remain.
Small Mammal Habitat:	Small mammal habitat will be eliminated from the areas of wetland fill. This will result in a localized reduction in the populations of some species. Since no unique or rare habitat types will be lost, it is unlikely that the numbers of species occurring in the area will be reduced. The remaining portion of Wetland 44 and adjacent areas will contain adequate habitat of similar quality to the wetlands being filled, and support species that are currently in the area. Because large amounts of similar habitat are available regionally, significant changes to the local diversity or regional populations of small mammals will not occur.
Organic Matter Export:	Fill in the upper portion of Wetland 44 could result in a minor reduction of detritus that is exported during the winter and spring months to downslope areas, including Walker Creek. Because of its distance from Walker Creek and the large capacity of Wetland 43 to contribute organic carbon to the creek, this change is expected to be minor. No impact on fish populations in Walker Creek is expected.
Groundwater Exchange:	Fill of wetlands will occur in areas where seasonal saturation supports wetlands. The fill will not alter the general discharge of ground from upslope areas to Wetland 44, Wetland 43, or Walker Creek because the permeability of the fill will allow groundwater to continue to surface and move downslope to Wetland 44. New areas of groundwater discharge could develop near the base of the fill, which could ultimately reach the wetlands and creek.
Flood Storage/	Impacted portions of Wetland 44 occur on a slope and do not store floodwaters. No losses in

Table 4-4. Impacts to the ecological functions of Wetland 44 and other wetlands on the existing airfield filled by embankment construction (continued).

Function	Analysis
Desynchronization:	the flood storage or conveyance functions of the wetland will occur. The fill of the wetland depressions on the airfield that may reduce runoff rates will be balanced by the hydrologic properties of the fill (which also tends to reduce runoff rates) and stormwater detention facilities (which store stormwater generated from impervious surfaces).
Nutrient Retention/ Sediment Trapping:	The nutrient and sediment trapping functions of the wetlands will be eliminated. No significant consequence of losing this function to downslope wetlands or Walker Creek is expected because coincident with wetland filling, potential sources of sediment and uncontrolled urban runoff from 12th Avenue South and adjacent residential areas will be removed.

Several Category III wetlands (see Table 4-1) will be impacted by the runway embankment. Young deciduous forest, Himalayan blackberry and willow shrubs, or non-native emergent plant species typically dominate these wetlands. The wetlands provide habitat to birds and small mammals, but because they are generally small in size, poorly buffered, and subjected to past or ongoing disturbance (vegetation clearing, human use, and/or stormwater), they represent lower quality habitat than the Category II wetlands. The wildlife habitat functions of these wetlands will be lost.

Several Category IV wetlands (Wetlands 23, 26, A5, FW5, and FW6) are dominated by non-native grasses or cultivated crops. Wetlands FW5 and FW6 provide habitat for a limited array of wildlife (waterfowl, pigeons, and crows). Most other Category IV wetlands are mowed lawn, and support small mammals and birds that are typical of disturbed urban environments (robin, sparrow, starling, etc.).

Physical Functions

Wetlands impacted by the third runway embankment occur on gentle slopes, shallow depressions, and riparian areas along Miller Creek. Their geomorphic positions control, in part, the hydrologic functions these wetlands provide, and some of their functions will be eliminated by the fill for the third runway embankment.

Most slope and depression wetlands are saturated during the winter and spring months (e.g., A5-A13, 35, 44a, W1, W2, and 16 through 24) when rainwater appears to perch on till soils (FAA 1997). These wetlands delay some runoff and thus provide winter base flow support to Miller Creek; they do not support low summer base flows because they are dry by late summer and early autumn. Slope and depression wetlands provide some detention and desynchronize stormwater runoff by reducing runoff rates. This function is limited by the small water storage volume provided by the shallow depressions or the lack of storage in slope wetlands.

Slope and depression wetlands also provide water quality functions in that they receive untreated runoff from adjacent streets and lawns and potentially remove pollutants. Depression wetlands are likely to provide higher water quality treatment functions due to longer storage times that promote contaminant removal when compared to slope wetlands. Slope wetlands have short retention times and thus provide fewer water quality benefits.

Several slope wetlands are areas of groundwater discharge (Wetlands 15, 18, and 37) that are saturated throughout the year. These wetlands convey groundwater downslope to Miller Creek. The presence of surface water in the wetlands throughout much of the summer indicates that the wetlands support base flow in Miller Creek.

Retaining walls will be constructed at four locations along the fill for the RSAs, relocated South 154th Street, and the third runway embankment to avoid impacts to riparian wetlands and to Miller Creek (see Figure 1-2). The fill embankment and the retaining walls have been designed with a drainage layer (i.e., an underdrain) constructed of coarse rock that is placed over the existing soil surface. The underdrain enables discharge of groundwater that infiltrates into the embankment from above. This water is then conveyed downgradient to discharge into wetlands located between the embankment and Miller Creek. This water will maintain wetlands located west of the embankment and support base flows in Miller Creek (see Section 4.3.2.4).

4.1.3 Borrow Areas

Borrow Areas 1, 3, and 4 were formerly developed residential areas or farmland prior to their purchase by the Port of Seattle for noise abatement. There are no wetlands in Borrow Area 4, and excavation of wetlands in Borrow Area 3 is avoided. Wetlands in Borrow Area 1 are isolated depressions and groundwater-fed slope or depressional wetlands located along the western perimeter of the borrow area.

The impacts to functions provided by wetlands (or portions of them) in Borrow Area 1 are discussed in Table 4-5. This analysis pertains to Wetlands B11, B12, and B14. This analysis does not include the benefits of compensatory mitigation discussed in Section 4.2.3.5.

Table 4-5. Impacts to the ecological functions of wetlands impacted by excavation activities in Borrow Area 1.

Function	Analysis
Resident/ Anadromous Fish Habitat:	No direct impacts to fish habitat functions will occur as a result of excavating Borrow Area 1.
Passerine Bird Habitat:	Passerine bird habitat will generally be eliminated from the areas of excavation, although some species will likely use the areas following excavation as they became revegetated with herbaceous cover. Since no unique or rare habitat type will be lost, it is unlikely that the diversity of bird species occurring in the area will be reduced. Because large amounts of similar habitat are available regionally, significant changes to regional populations of passerine birds will not occur.
Waterfowl Habitat:	No impacts to waterfowl habitat or populations will occur because it is not present in the affected wetlands.
Amphibian Habitat:	The loss of some non-breeding habitat for amphibians will occur. No loss in breeding habitat will occur. These reductions could reduce amphibian populations and prey availability for some birds and small mammals. Because the Des Moines Creek riparian area will remain adjacent to the borrow area, amphibian species potentially occurring in the area are expected

Table 4-5. **Impacts to the ecological functions of wetlands impacted by excavation activities in Borrow Area 1 (continued).**

Function	Analysis
	to remain.
Small Mammal Habitat:	Small mammal habitat will be eliminated from the areas of excavation. Since no unique or rare habitat types will be lost, the diversity of species occurring in the area will not be reduced. The Des Moines Creek riparian area contains adequate habitat of similar quality to the wetlands being filled, and supports populations of species that are currently in the area. Because large amounts of similar habitat are available regionally, significant changes to regional populations of small mammals will not occur.
Organic Matter Export:	No significant changes to this function are expected because the impacted wetland areas do not provide organic matter export.
Groundwater Exchange:	No significant change in this function is expected. Following excavation, Wetland B12 is expected to continue to seasonally convey shallow groundwater to the creek. Overall, it is anticipated that greater amounts of surface water will infiltrate into the borrow area compared to the existing condition because till soils will be removed.
Flood Storage/ Desynchronization:	No losses in the flood storage or conveyance functions of Des Moines Creek will occur because the impacted wetlands do not provide this function. Excavation of the shallow depressions that contain Wetlands B11 and B14 will result in a loss of area that seasonally saturates, stores small amounts of water, and reduces runoff rates.
Nutrient/Sediment Trapping:	The nutrient and sediment trapping functions of the wetlands will be eliminated. No significant consequence of losing this function to Des Moines Creek or adjacent wetlands is expected because urban runoff is not currently directed to the wetlands.

Biological Functions

About 0.07 acre of Category II wetlands will be impacted in Borrow Area 1 (Wetland B12). The easternmost lobe of this slope wetland extends from near the western edge of the borrow area west to connect with Des Moines Creek. Shrub vegetation in these wetlands and adjacent forested areas provide habitat for passerine birds, amphibians, and small mammals. A portion of this habitat will be lost due to construction.

About 0.96 acre of Category III wetlands will be impacted in Borrow Area 1. Two isolated depressions (Wetlands B11 and B14) with emergent and shrub vegetation that provide habitat for small mammals and passerine birds will be filled, and these functions lost.

Physical Functions

The wetlands being impacted by development in Borrow Area 1 provide limited hydrologic functions. A hydrologic functions that the slope wetland (B12) provide is the conveyance of water downslope to Des Moines Creek. The depression wetlands (B11 and B14) have limited ability to desynchronize stormwater runoff and provide some water quality benefits. Potential indirect impacts to a small portion of Wetland B12 (0.04 acre) may occur from potential changes to the hydrology of the upper portion of the wetland due to nearby grading.

4.1.4 South Aviation Support Area

Wetland impacts at the SASA site include filling 2.78 acres of wetlands on the Tyee Valley Golf Course. This impact area includes a stormwater detention facility for the SASA development that will require filling of 0.10 acre of Wetlands E1 and E2. The remaining impacts result from placing fill on them to create the SASA site and a connection to the airfield. A bridge across Des Moines Creek will be constructed to allow aircraft to access the SASA site from the airfield, and this bridge will shade portions of the stream and riparian wetlands.

The impacts to functions provided by wetlands (or portions of them) in the SASA project area are discussed in Table 4-6. This analysis pertains to Wetlands 52, 53, E2, E3, G1, G2, G3, G4, G5, and G7. This analysis does not include the benefits of compensatory mitigation discussed in Section 4.2.3.5.

Table 4-6. Impacts to the ecological functions of wetlands affected by the SASA development.

Function	Analysis
Resident/Anadromous Fish Habitat:	No direct impacts to fish habitat functions will occur as a result of fill placement in the wetlands. Indirect impacts to habitat conditions resulting from wetland fill (i.e., water quality and export of organic carbon) are addressed below.
Passerine Bird Habitat:	Passerine bird habitat will be eliminated from the areas of wetland fill. This will result in a reduction in the localized population of some species. Since no unique or rare habitat type will be lost, it is unlikely that the diversity of bird species occurring in the area will be reduced. Because large amounts of similar habitat are available regionally, significant changes to regional populations of passerine birds will not occur.
Waterfowl Habitat:	The grazing waterfowl habitat functions of Wetlands of Wetland G1, G2, G3, G4, and G5 will be lost. This will result in some reduction in forage habitat for waterfowl. This loss of foraging habitat will be small compared to the amount of habitat available regionally, and thus impacts to the local population are not expected.
Amphibian Habitat:	Impacts to Wetlands 52 and 53 will eliminate habitat for non-breeding amphibians. No loss of breeding habitat will occur because the impacted wetlands do not provide this function. These reductions could reduce prey availability for some birds and small mammals. Because the Des Moines Creek riparian area will remain following project construction (regardless of the proposed habitat enhancement of this area), amphibian species potentially occurring in the area are expected to remain.
Small Mammal Habitat:	Small mammal habitat will be eliminated from the areas of wetland fill, resulting in a reduction of the localized population of some species. Since no unique or rare habitat types will be lost, the diversity of species occurring in the area will not be reduced. The remaining portion of the Des Moines Creek riparian area (regardless of the proposed enhancements) will contain adequate habitat of similar quality to the wetlands being filled, and support populations of species that are currently in the area. Because large amounts of similar habitat are available regionally, significant changes to regional populations of small mammals will not occur.
Organic Matter Export:	A small reduction in carbon export to Des Moines Creek could occur as a result of increased shading and decreased plant growth and litter production that would occur beneath the bridge constructed over Des Moines Creek and Wetland 52. This shade will also reduce algal production in this reach of the creek, which could alter the type and availability of aquatic insects available for fish along a short segment of the creek. If food availability is reduced, fish populations or growth rates could decline.
Groundwater Exchange:	Fill of wetlands will eliminate areas where seasonal or perennial saturation supports wetlands. The fill will not alter the general discharge of groundwater from upslope areas to Des Moines Creek because the permeability of the fill will allow continued groundwater movement. New areas of groundwater discharge could develop near the base of the fill, which could ultimately

Table 4-6. Impacts to the ecological functions of wetlands affected by the SASA development (continued).

Function	Analysis
	reach Des Moines Creek.
Flood Storage/ Desynchronization	No losses in the flood storage or conveyance functions of Des Moines Creek will occur because these wetlands do not occur in any floodplain.
Nutrient Retention/ Sediment Trapping:	The nutrient and sediment trapping functions of the wetlands will be eliminated. No significant consequence of losing this function to Des Moines Creek or adjacent wetlands is expected because coincident with wetland filling, potential sources of nutrients and other chemicals applied to the wetlands during golf course operations will be eliminated.

Biological Functions

Wetlands in the SASA are typically dominated by early successional deciduous forests and shrub wetlands, or are emergent wetlands planted as golf course greens. The forest and shrub wetlands (Wetlands 52, 53, and G7) provide habitat functions similar to those described in Tables 3-4, 3-5, 3-6, and 3-7. The golf course wetlands (Wetland 52, G1, G2, G3, G4, G5, G6, and G8) provide habitat to foraging waterfowl and songbirds, but their value to these species, as breeding habitat is limited due to ongoing disturbance (golf course operations and maintenance). The loss of Wetlands 53, E2, E3, golf course wetlands, and shading of portions of Wetland 52 will result in the loss of bird and small mammal habitat.

Physical Functions

Most wetlands that will be affected by the SASA are slope and shallow depression wetlands that are seasonally saturated. They likely provide biofiltration to stormwater runoff. Their lack of closed depressions and restricted outlets prevent them from providing stormwater detention functions. They provide base flow support to Des Moines Creek during the winter months, but are dry during the late summer months when low flows occur, and thus do not contribute to this function. An exception to this is Wetland 52, where groundwater discharges throughout the summer. This wetland provides base flow support to the stream during low flow periods; however, project impacts to Wetland 52, are limited to a bridge crossing, and the groundwater discharge functions will not be eliminated.

4.1.5 Other Master Plan Update Improvements

Direct wetland impacts have been avoided through the design of most Master Plan Update improvements or project elements (including temporary interchanges at SR 509 and SR 518, the North Employee Parking Lot, terminal expansions, Airport Surface Detection Equipment [ASDE] radar facilities, and utility upgrades). Several other airport-related projects (such as the IWS expansion, new FAA TRACON and Tower facilities) also avoid wetlands. Where appropriate, any potential indirect impacts of these projects are addressed in Section 4.3.

4.2 TEMPORARY CONSTRUCTION IMPACTS

Temporary (construction) impacts to wetlands are discussed in this section. Specific construction activities that could impact wetlands are construction and use of temporary stormwater management ponds in wetlands, temporary disturbances from installation of construction fencing, TESC facilities, increased noise and human disturbance, and construction runoff (Appendix A; see Figure 4-1 and Tables 4-7 and 3-2). In general, these impacts could affect the water quality, hydrologic, and wildlife functions or conditions of wetlands located near construction sites.

4.2.1 Construction Runoff

The potential water quality impacts that could result from construction activities (including excavation and transport of fill) are primarily increased turbidity and sedimentation in wetlands located downslope of construction sites. The duration of these potential impacts and mitigation activities is throughout the construction period (up to a 5-year period). The mitigation actions taken at construction sites to avoid these wetland and water quality impacts are summarized in this section.

4.2.1.1 Discharge Standards

The Port's National Pollution Discharge Elimination System (NPDES) permit for construction at STIA (Ecology 1998b,c) requires that stormwater discharges meet the turbidity standard for Class AA waters[14] (WAC 173-201A-030). This standard requires that turbidity in stormwater discharges not exceed 5 Nephelometric Turbidity Units (NTU) over background when background is 50 NTU or less, or register more than a 10 percent increase in turbidity when background exceeds 50 NTU. As a numerical standard, this pollution limit is protective of aquatic life (Ecology 2001a).

4.2.1.2 Treatment Best Management Practices

A variety of treatment BMPs are applied at construction sites to ensure that discharge standards for construction water quality are met.

Construction Stormwater Treatment Systems

Advanced stormwater treatment systems (see Appendix D of the *Biological Assessment,* FAA 2000) are used by the Port to treat construction runoff when conventional BMPs do not remove sufficient turbidity to meet the required state water quality standards. Since autumn 1997, the Port has used advanced stormwater treatment systems to treat runoff from several construction sites, including the 1998 and 1999 construction phases of the third runway embankment. Since implementation of these systems, water quality monitoring at construction sites (Port of Seattle

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[14] Washington surface waters are classified as Class AA (extraordinary), Class A (excellent), Class B (good), Class C (fair), or Lake Class. Class designation is based largely on characteristic uses of the waters. As defined by WAC 173-201A-030, Class AA waters shall "markedly and uniformly exceed the requirements for all or substantially all" of the following characteristic uses: water supply; stock watering; fish and shellfish migration, rearing, spawning, and harvesting; wildlife habitat; recreation; and commerce and navigation.

1998, 1999b, 2000b) has demonstrated that stormwater discharges comply with required turbidity standards. The Port will continue to use these stormwater treatment systems on construction sites where necessary and appropriate.

Data from the 1999-2000 wet season (Table 4-7 and Appendix D of the *Biological Assessment*, FAA 2000) demonstrate that the Port's advanced stormwater treatment system is highly effective at producing clear water. Between November 8, 1999, and March 4, 2000, a total of 164 batches (the average batch size was approximately 70,000 gallons) of construction site runoff were treated. All discharged stormwater met the required Washington Water Quality Standard (WAC 173-201A) for turbidity. On average, the site discharge was 9.9 NTUs less than background measurements taken in Miller Creek, demonstrating that the construction discharge was typically clearer than the stream itself.

Table 4-7. Summary of third runway embankment stormwater treatment plant performance results from November 8, 1999 to March 4, 2000.

Number of batches treated	164
Percentage of treated batches meeting water quality standard for turbidity	100%
Average post-treatment turbidity (NTU)	2.7
Average Miller Creek turbidity on days when discharge occurred (NTU)	12.6

Source: Port of Seattle (2000b).

Potential water quality impacts from the advanced stormwater treatment BMPs include changes to pH and the potential toxicity of treatment compounds. The Port has used both organic polymers (such as CatFloc) and inorganic compounds (such as alum) in stormwater treatment systems. Aquatic bioassay testing of treatment system effluent has demonstrated that the effluent is not toxic (FAA 2000). Aquatic toxicity testing of the polymer compounds has demonstrated that effective treatment concentrations are several orders of magnitude below toxic concentrations (Calgon 1997). These potential impacts have been evaluated and the treatment system has been found to be environmentally safe. The BMP has been used safely for more than 3 years at STIA and several construction sites (e.g., several Washington State Department of Transportation [WSDOT] projects and Microsoft construction sites in Redmond) with Ecology's review and approval (Ecology 1998a). The *Stormwater Management Manual for Western Washington* (the Ecology Manual) (Ecology 2001a) includes a BMP for construction stormwater chemical treatment.

When applied, advanced treatment would consist of Ecology-approved alum or polymer flocculation systems. All chemical treatment facilities would operate in accordance with the conditions of BMP C250, Construction Stormwater Treatment, as it appears in the Ecology Stormwater Manual Update. The Ecology Manual provides the following criteria the Port will follow for polymer product use:

- Polymer-treated stormwater discharged from construction sites must be nontoxic to aquatic organisms.
- Petroleum-based polymers are prohibited.

- Prior to authorization for field use, jar tests must demonstrate that the turbidity reduction necessary to meet the receiving water criteria can be achieved. Test conditions, including but not limited to, raw water quality and jar test procedures should be indicative of field conditions.
- Prior to authorization for field use, the polymer-treated stormwater must be tested for aquatic toxicity. Applicable procedures defined in Chapter 173-205 WAC, Whole Effluent Toxicity Testing, and Limits, will be used. Testing will use (a) stormwater from the construction site at which the polymer is proposed for use or (b) a water solution using soil from the proposed site.
- Testing must show that the dosage at which the polymer becomes toxic is at least twice the anticipated operational dose.
- The approval of a proposed coagulant or flocculent aid will be conditional, subject to the full-scale bioassay monitoring of treated stormwater required by Ecology. The Port will use only polymer products that have been evaluated and are currently approved for use.

Other Construction Stormwater Best Management Practices

In addition to the construction stormwater treatment systems described above, sedimentation from Master Plan Update construction sites will not impact wetlands or downstream habitat because implementation of other construction BMPs will prevent sediment discharges from construction sites to wetlands or streams. These BMPs further ensure construction runoff meets water quality standards. Construction erosion control measures will protect surface water quality and meet Ecology's water quality standards. To ensure that these measures will be properly implemented and maintained, the following protection measures will be used:

- Funding independent third-party oversight of construction erosion control and stormwater management and compliance
- Writing and implementing construction stormwater pollution prevention plans (SWPPPs) and monitoring plans for individual Master Plan Update improvement activities
- Supervising contractor erosion control compliance with a full-time erosion control and stormwater engineer
- Monitoring construction stormwater runoff whenever it rains
- Additionally monitoring construction stormwater runoff when rainfall exceeds 0.5 inch in a 24-hour period

The BMPs listed in Table 4-8 will be applied as specified in the Ecology Manual (Ecology 2001a) or the King County Surface Water Design Manual (King County Department of Natural Resources [DNR] 1998). Detailed information on erosion and sediment control for the third runway embankment construction is provided in Appendix D of the *Biological Assessment* (FAA 2000).

Table 4-8. **Summary of the Ecology Manual BMPs generally applicable to Master Plan construction sites.**

Category	Applicable BMPs
Temporary cover practices	Temporary seeding, straw mulch, bonded fiber matrices, and clear plastic covering
Permanent cover practices	Preserving natural vegetation, maintaining buffer zones, and seeding and planting following construction
Structural erosion control BMPs	Stabilized construction entrance, tire wash, construction road, stabilization, dust control, interceptor dike and swale, and check dams
Sediment retention	Filter fence, storm drain inlet protection, and sedimentation basins

A Construction Spill Control and Countermeasures Plan containing the following elements will be implemented on each site:

- Spill control measures, including designated fueling areas
- Secondary containment of spillable substances
- Use of drip pans and pads
- Contractor education
- Labeling and proper storage of spillable substances
- Designated spill containment procedures
- Proper notification and cleanup procedures

4.2.2 Other Potential Construction Water Quality Impacts

Sediment ponds store stormwater runoff for treatment, and during storage, water temperature could be altered due to solar warming. Storage of stormwater that results in increases in water temperature above levels in downstream waters or water quality standards could be detrimental to fish. This is unlikely to occur downstream of Master Plan Update improvements because storms that would result in several days of water storage generally do not occur during warm weather or during low flow periods when such discharges could be quantitatively significant. The Port has observed little or no runoff from embankment construction areas during smaller, summer-season storms when temperature impacts are of greatest concern. For example, 1998 and 1999 observations in treatment facilities show the construction sites did not generate sufficient runoff to require operation of the treatment system until mid-November. By October and November, temperature impacts from stormwater would not occur due to the cool air temperatures (Table 4-9), lack of solar radiation, cool stream water, and high streamflows. Similarly, by April 1999, stormwater runoff quantities from construction sites had decreased to the point where treatment plant operation and discharge was discontinued, thus eliminating discharges during the warmer months (see Table 4-9).

Table 4-9. Temperature ranges and sky conditions for the warmest months when extended storage of stormwater at the Seattle-Tacoma International Airport is expected.

Parameter	November	April
Average Maximum Temperature[a]	49.6°F	58.2°F
Average Minimum Temperature	38.1°F	40.1°F
Average Temperature	43.9°F	49.2°F
Highest Temperature	65°F	77°F
Lowest Temperature	23°F	30°F
Number of clear days	3	3
Number of partly cloudy days	4	7

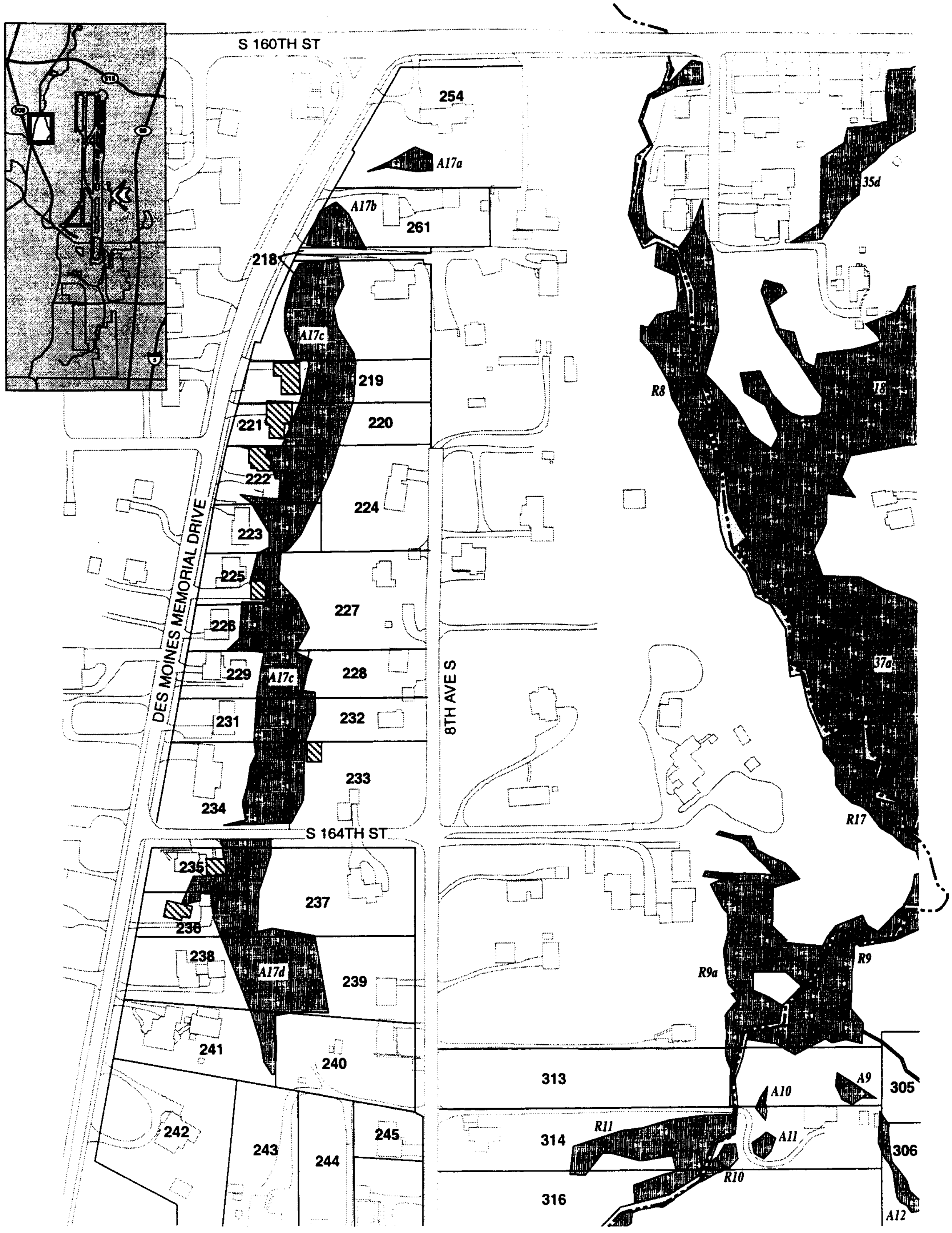
Source: WSU (1968).

[a] Salmon undergo stress if water temperatures are generally above 17° C (64.3° F) (Groot et al. 1995 and McCullough 1999). Since maximum temperatures are low and little solar radiation occurs during months when significant stormwater is likely to be held and released, temperature impacts that could affect fish are unlikely.

4.2.3 Wetland Alterations During Construction

Temporary construction impacts that will occur in wetlands near construction sites are described below. Temporary construction impacts are anticipated to occur in up to 2.05 acres (Table 3-2). The temporary construction impacts will occur in areas that may be used for temporary access roads, temporary sediment and erosion control ponds, staging areas, and stockpiling areas.

Other minor temporary impacts to wetlands may occur as a result of demolition (Figure 4-2). Demolition of houses and other buildings at several locations (Table 4-10) within the west-side acquisition area requires operating equipment and temporarily placing demolition debris on lawns and yards that are also wetlands. Demolition on Parcels 314 and 321 may also require Hydraulic Project Approval (HPA) review prior to reinforcement of existing Miller Creek crossings (a small bridge on Parcel 321 and a culvert on Parcel 321) so trucks can haul out demolition debris. During construction and demolition, all practicable efforts will be made to avoid and minimize impacts to wetlands within this temporary construction impact zone (e.g., flagging and protecting wetlands with barrier fencing and sediment fencing, locating access roads and staging areas wherever possible outside of wetlands, implementing TESC BMPs).



Sea-Tac Airport/Functional Assessment and Impact Analysis
556-2912-001/01(03) 11/01 (K)

SCALE IN FEET
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243	Parcel Number
R9a	Wetland Number
▨	Building Demolition Near Wetlands
▓	Wetlands

Figure 4-2
Potential Temporary Impacts to Wetlands Resulting from Building Demolition

Table 4-10. Description of temporary impacts to wetlands from the Seattle-Tacoma International Airport Master Plan Update improvements.

Wetlands	Temporary Impacts
Runway Safety Areas and Relocation of South 154th Street	
Wetlands 3, 6, 7, and 10	Wildlife could be disturbed by construction noise near Wetlands 3, 6, 7, and 10; however, wildlife in the area is already tolerant of air traffic and roadway (SR 518 and South 154th Street) noise.
Wetlands 3, 4, and 5	Temporary construction disturbance could occur in the portion of the wetlands that borders the construction area. These impacts could include disturbance to wildlife and minor soil disturbance or siltation caused by installation of silt fences.
Third Runway	
Wetlands 9 and 11	A small portion of Wetland 9 and the remaining portion of Wetland 11 that is not permanently impacted could be disturbed. Soil disturbance and minor siltation could occur along the southern portion of Wetland 9 and the remaining portion of Wetland 11 where silt fences are installed. Construction activity and noise could disturb wildlife.
Wetlands R1 and R2	Minor soil disturbance and siltation could cause impacts to remaining wetlands adjacent to the new South 154th Street bridge.
Wetlands R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, and R17	Construction activity and noise could disturb wildlife.
Wetlands A1, A9, A10, A11, A12, A13, and 39	Temporary construction disturbance could occur in portions of Wetland A1 adjacent to the embankment fill. Temporary disturbance is possible to small portions of Wetlands A12 and A13 outside the footprint of fill slope and perimeter road. Minor soil disturbance and siltation is possible within portions of Wetlands A12, A13, and 39 that are immediately adjacent to the footprint of fill slope, perimeter road, or other construction areas. Construction activity and noise could cause disturbance to wildlife in Wetlands A9, A10, A11, A13, and 39.
Wetlands 18 and 37	These wetlands are subjected to 0.93 acre of temporary impact. Disturbance is possible from the construction of temporary stormwater management facilities (e.g., TESC collection swales in Wetland 18 and 37 and a collection pond in Wetland 37). (Note: Permanent stormwater management facilities will be located outside of wetland areas. Impacts of temporary Pond E are considered permanent.) A narrow band of temporary disturbance is likely immediately adjacent to the fill footprint and the security road (outside of temporary stormwater facility areas). This disturbance will be within 30 ft of Miller Creek for about 100 linear ft. There may be limited areas of siltation within Wetlands 18 and 37. Construction activity and noise could cause disturbance to wildlife.

Table 4-10. **Description of temporary impacts to wetlands from the Seattle-Tacoma International Airport Master Plan Update improvements (continued).**

Wetlands	Temporary Impacts
	Temporary disturbance is possible to wetland drainage patterns/hydrology in Wetland 37 due to the construction of the temporary stormwater management facilities.
Wetland 44	Temporary disturbance to wetlands adjacent to construction areas include: • Soil and vegetation disturbance related to the placement of silt fences and construction of stormwater management facilities (TESC collection swales and Pond B). • Construction activity and noise could cause disturbance to wildlife.
Demolition	Demolition of several houses and other buildings within the west-side acquisition area requires operating equipment and temporarily placing demolition debris on lawns and yards that are also wetlands. These occur in Wetland A17 (Parcels 219, 221, 222, 225, 235, and 236), Wetland R13 (Parcels 317 and 321), Wetland R15 (Parcel 243), Wetland A16 (Parcel 322), Wetland A15 (Parcel 325), and Wetland 52 (golf course storage shed). Demolition on Parcels 314 and 321 may also require HPA approval to improve existing Miller Creek crossings so trucks can haul out demolition debris.
Staging Areas	No temporary impacts are expected. Staging areas will be a minimum of 50 ft from Miller Creek and placed outside of wetland areas. In wetlands bordering intended staging areas, activity and noise during construction of each staging location may disturb wildlife.
Borrow Area 1	
Wetlands B1, B4, and 32	Excavation will be avoided in Wetlands B1, B4, and 32; all other wetlands will be permanently impacted by excavation or dewatering. Interruption in hydrology for Wetlands B1, B4, and 32 is not anticipated; 50-ft buffers will maintain seasonal perched water regime. Excavation activities and noise will disturb wildlife.
Wetlands 48 and B15	Surface flows to these wetlands will not be affected because the upslope watershed of the wetlands (which extends east of the stormwater drainage system located along 20th Avenue South) will not be altered.
Borrow Area 3	
Wetlands 29, 30, B5, B6, B7, B9, and B10	All wetlands are being avoided and a 50-ft buffer maintained. Wetland hydrology will be maintained by preserving conditions in the watershed basin upgradient and immediately surrounding each wetland. To ensure wetland hydrology is maintained, a drainage swale will be constructed along the upslope face of the borrow cut that will direct seepage water to Wetland 29 (Appendix C). Excavation activity and noise will disturb wildlife.
South Aviation Support Area	
Wetland 52	Construction activity and noise will disturb wildlife. Minor soil disturbance and siltation may occur along the perimeter of construction due to the installation of silt fences.

Table 4-10. **Description of temporary impacts to wetlands from the Seattle-Tacoma International Airport Master Plan Update improvements (continued).**

Wetlands	Temporary Impacts
IWS Lagoon Expansion[a]	
Wetland 28	No filling or construction occurs in this wetland. Wetlands were protected by TESC BMPs including silt fences, stormwater treatment systems, etc.

[a] This project is not a Master Plan Update (FAA 1996, 1997) improvement, and would be completed independent of Master Plan projects. There are no direct impacts to wetlands from the expansion project. Information on the potential indirect and temporary impacts to wetlands is included at the request of several reviewers.

In general, the duration of these temporary impacts will be approximately from one to four construction seasons. While the overall construction period for the Master Plan Update improvements will extend over several years, near any given wetland, the construction period will be shorter. Temporary construction impacts are generally anticipated to occur early in construction sequencing, and as construction proceeds, it would move away from wetland areas.

Restoring wetland functions to temporarily disturbed areas will mitigate temporary construction impacts associated with Master Plan Update improvements.[15] Wetlands temporarily impacted by construction clearing and filling will be restored by removing all temporary fill material, re-establishing pre-disturbance conditions, aerating compacted soils, and planting with native forest and shrub vegetation. Removing sediment fencing and construction debris will restore wetlands subjected to minor disturbances when clearing of vegetation or filling has not occurred (e.g., sediment fences placed along edge of wetland, demolition of adjacent buildings, etc.).

Most wetlands subject to significant temporary construction impacts are adjacent to the third runway embankment and planned mitigation sites. Upon restoration, these areas will remain part of larger undisturbed wetlands, and in many cases be incorporated into a larger mitigation area that includes wetland buffers and wetland enhancement actions. These actions ensure that the functions of the restored (as well as remaining) wetlands are maintained at pre-project levels.

4.2.3.1 Runway Safety Areas and Relocation of South 154th Street

Wetlands 3, 4, and 5 are located near the north end of the existing runways where required RSA extensions will be built. As part of the RSA extensions, South 154th Street will be relocated up to several hundred ft north and west of its present location and will lie adjacent to Wetlands 3, 4, and 5. Temporary disturbance to small portions of these wetlands (about 0.14 acre) could result from

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[15] The NRMP (Parametrix 2001b) proposes wetland mitigation for temporary wetland impacts. Mitigation of temporary impacts includes, at a minimum, restoration of the affected areas. This mitigation includes converting 1.26 acres of the existing shrub and pasture wetlands to forested wetlands (see Section 5.2.4 of the NRMP).

placement of silt fences and required TESC actions. Minor siltation could occur within the 0.14-acre disturbance area during construction.[16]

During the relocation of South 154th Street, temporary disturbance to wildlife is likely to occur in Wetlands 3, 4, and 5. Wildlife in these wetlands are tolerant of aircraft noise from existing runways and roadway noise from SR 518 and South 154th Street. Additional disturbance to wildlife is likely to be minor, and limited to the south edges of the wetlands.

4.2.3.2 Third Runway

Wetlands A1, 9, and 11 are located near the northern end of the proposed third runway. Relocation of South 154th Street is required for runway construction. During the relocation of South 154th Street, small portions of Wetland A1 (0.05 acre) and Wetland 9 (0.16 acre) will be temporarily impacted. Minor siltation within these wetlands during construction could occur. Wildlife will likely be disturbed near the south edge of Wetland 9 by construction activity and noise.

These construction activities include potential temporary impacts to six small and isolated wetlands located near the edge of fill for the third runway embankment (Wetlands A5 and A9 through A13). In addition, two larger riparian wetlands (Wetlands 18 and 37) and a third sizable wetland (Wetland 44) that drains into a wetland complex west of SR 509 could experience temporary impacts. Temporary disturbance will occur in portions of Wetlands A12 (0.03 acre), A13 (0.01 acre), 18 (0.22 acre), 37 (0.71 acre), and 44 (0.28 acre), which are located west of the construction footprint for the embankment and the perimeter road.

Minor siltation could occur in limited portions of these wetlands as a result of installing silt fences and upslope construction. No physical disturbance to Wetlands A9, A10, A11, and A13 is proposed, although temporary disturbance to wildlife could result from construction activity and noise.

Temporary impacts to Wetlands 18, 37a, and 44a include disturbance from the construction of temporary stormwater management facilities, including detention ponds, during the construction phase of the third runway project.[17] These stormwater facilities will be removed and the wetland

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[16] TESC BMPs will be implemented prior to construction of all Master Plan Update improvement projects (see Section 4.2.2), and their effectiveness will be strictly monitored. SWPPP construction specifications are provided in Appendix R of the SMP (Parametrix 2000b). The adequacy of these BMPs is reviewed by Ecology through approval of Stormwater Pollution Prevention Plans prior to implementation. During 1998-1999 embankment construction, no water quality violations (including excess turbidity or sediment discharge to wetlands) occurred.

[17] These stormwater collection ponds must be located in wetlands because the wetlands are topographically at the lowest point, and the point where construction runoff will drain to for collection (See Appendix A). Without these facilities, some untreated runoff from construction areas could enter wetlands and Miller Creek. The size of the treatment facilities has been designed based on predicted runoff events, storage needs, and pump capacities, and include a safety factor.

area restored after the placement of the third runway embankment fill. Permanent stormwater facilities will be located outside of wetland areas.

Ten small wetlands (Wetlands R1 through R10) lie immediately adjacent to Miller Creek along the western periphery of the third runway project area. Temporary impacts from runway construction are not expected because the riparian wetlands are distant from the embankment construction and because they will be incorporated into the Miller Creek buffer. However, temporary disturbances to riparian wetlands will occur in two limited areas: at the proposed South 156th Street bridge crossing (affecting the southern edge of Wetland R1 and the northern edge of Wetland R2) and at a stormwater outfall that will lie adjacent to Wetland R6. Minor siltation could occur in the temporarily disturbed portions of Wetlands R1 and R2.

Disturbance to wildlife from construction activity and noise could occur in all riparian wetlands, but is most likely in Wetlands R1, R2, and R6 because in these areas, construction will occur near the wetland edge, and in the case of Wetland R1, some will occur within the wetland. In the case of Wetlands R4, R5, R6, and 39, nearby construction and operation of stormwater detention ponds could temporarily disturb wildlife.

4.2.3.3 Borrow Areas

Borrow Area 1

Within Borrow Area 1, Wetlands B1, B4, and 32 will be avoided and protected with a minimum 50-ft buffer. Temporary impacts to wildlife using these Category III wetlands may occur during project construction.

Wetlands 15 and 48 will not be affected by excavation, and their upslope watersheds will be protected to ensure that the areas remain as wetland. The watersheds for these wetlands extend east from the wetland edge upslope to 20th Avenue South. Along 20th Avenue South, existing stormwater ditches and drainage facilities are located along the street from the eastern edge of the watershed for these wetlands. Therefore, to prevent temporary or permanent indirect impacts to wetland hydrology, Borrow Area 1 excavation does not extend west of this street.

Impacts to Des Moines Creek are not anticipated from Borrow Area 1 excavation because it will generally be 200 ft or more east of the stream. All excavation will occur east of the top of the stream ravine. In a small area (about 0.5 acre) near 20th Avenue South and the associated abandoned residential property, borrow excavation will occur 150 ft east of the stream. Another small area (about 0.2 acre) will be excavated about 175 ft east of the stream.

Borrow Area 3

All direct impacts to wetlands in Borrow Area 3 are avoided by limiting the area of excavation to provide a minimum 50-ft buffer around wetlands. Hydrogeologic studies indicate that perched groundwater intersecting the ground surface in the central and northwestern part of Borrow Area 3 creates an area of surface seepage, forming Wetland 29. Other wetlands in Borrow Area 3 occur below this zone of seepage and are formed in shallow surface depressions that perch water. Precipitation and runoff from upslope areas west and north of the wetlands maintain these wetlands.

Borrow Area 3 excavation can be completed without disrupting the upgradient sources of water needed to maintain these wetlands. The plan for excavating Borrow Area 3 would preserve a 50-ft undisturbed buffer around the downslope (east) side of the wetlands and would not impact their upslope watersheds (see Appendix C) located to the west and northwest.

Limiting the excavation of soil to areas more than 50 ft north and east of the wetland edges would not disrupt wetland hydrology because of the low permeability soils that perch water. Water loss from the wetland is controlled by the low permeability of the soil boundary layer immediately beneath the wetland itself. The lateral thickness of soils or soil conditions more than 50 ft away would not control groundwater movement. Therefore, excavation of soil more than 50 ft away from the wetland edge would not increase the permeability of the boundary layer that maintains wetland hydrology. Thus, wetland hydrology would not change.

Temporary impacts to wildlife using Category II Wetlands (29 and 30) and Category III wetlands (B5, B6, B7, B9, and B10) could result from construction noise and other human activity. Excavation in the borrow area will be more than 150 to 200 ft from Des Moines Creek and will thus avoid impacts to the stream or riparian buffers.

Borrow Area 4

Borrow Area 4 is located between 100 ft and 400 ft south of Wetland 28. Wetland 28 is maintained by several water sources, including groundwater that emanates from beneath the existing airfield, runoff from wetlands located west of Des Moines Memorial Drive, and runoff from surrounding developments. Some water infiltrating into Borrow Area 4 may also reach the south and southeastern portion of Wetland 28; however, unlike the Borrow Area 3 excavation, Borrow Area 4 will not be excavated deep enough to reach the groundwater table. Excavation of the borrow area would thus not alter groundwater flows that may reach Wetland 28, and no indirect impacts of the excavation on this wetland are likely.

4.2.3.4 South Aviation Support Area

Wetland 52, a Category II riparian and slope wetland adjacent to the SASA, would be temporarily affected by construction. Impacts to this wetland would include temporary disturbance to wildlife due to construction noise and other human activities. Construction impacts to the wetland could also include minor sedimentation or soil disturbance resulting from construction of the taxiway bridge connecting the SASA to the airfield.

4.2.3.5 Mitigation Impacts

Wetland and stream mitigation projects are summarized in Section 1.2.5. To construct these projects and ultimately derive the intended ecological benefits, some wetlands that occur on the mitigation sites will be temporarily impacted (Table 4-11). In general, these impacts include Category II, III, and IV wetlands that are farmed or dominated by non-native vegetation. These impacts are described in this section.

Table 4-11. **Summary of wetlands subject to mitigation activities.**

				Vegetation Type Impacted		
Wetland	**Rating**	**Vegetation Types**	**Total**	**Forest**	**Shrub**	**Emergent**
Miller Creek Buffer/Vacca Farm Mitigation Projects (on-site)						
FW 1, 2, 3, 8, 9, 10, and 11	IV	Farmed Wetlands	0.88	0.00	0.00	0.88
18	II	Forest/Shrub/Emergent	1.27	1.27	0.00	0.00
37a	II	Forest/Emergent	1.96	1.50	0.00	0.46
A1	II	Forest/Shrub/Emergent	4.08	0.90	0.56	2.62
A2	IV	Shrub	0.05	0.00	0.05	0.00
A3	IV	Shrub	0.01	0.00	0.01	0.00
A4	IV	Shrub	0.03	0.00	0.03	0.00
A9	III	Shrub	0.04	0.00	0.04	0.00
A10	IV	Shrub	0.01	0.00	0.01	0.00
A11	III	Shrub	0.02	0.00	0.02	0.00
A13	III	Forest	0.12	0.12	0.00	0.00
A16	III	Shrub/Emergent	0.05	0.00	0.00	0.05
A17, Water D	II	Forest/Shrub/Emergent	2.85	0.27	0.53	2.05
R1	III	Emergent	0.04	0.00	0.00	0.04
R2	III	Shrub/Emergent	0.12	0.00	0.06	0.06
R3	III	Shrub	0.02	0.00	0.02	0.00
R4	III	Emergent	0.11	0.00	0.00	0.11
R4b	III	Forest/Emergent	0.11	0.03	0.00	0.08
R5	III	Emergent	0.05	0.00	0.00	0.05
R5b	III	Forest/Emergent	0.07	0.02	0.00	0.05
R6	III	Forest/Emergent	0.21	0.05	0.00	0.16
R6b	III	Emergent	0.09	0.00	0.00	0.09
R7	III	Forest/Emergent	0.04	0.04	0.00	0.00
R7a	III	Emergent	0.04	0.04	0.00	0.00
R8	II	Shrub/Emergent	0.40	0.00	0.20	0.20
R9	III	Forest	0.38	0.38	0.00	0.00
R9a	II	Forest/Shrub/Emergent	0.30	0.30	0.00	0.00
R10	III	Shrub	0.04	0.04	0.00	0.00
R11	II	Emergent	0.42	0.00	0.00	0.42
R12	III	Forest	0.03	0.03	0.00	0.00
R13	III	Emergent	0.12	0.00	0.00	0.12
R14a	III	Shrub/Emergent	0.13	0.13	0.00	0.00
R14b	III	Emergent	0.08	0.00	0.00	0.08
R15a	II	Forest/Shrub/Emergent	0.79	0.25	0.40	0.14
R15b	III	Forest/Emergent	0.25	0.06	0.00	0.19

Table 4-11. Summary of wetlands subject to mitigation activities (continued).

Wetland	Rating	Vegetation Types	Total	Vegetation Type Impacted		
				Forest	Shrub	Emergent
R17	II	Forest	0.31	0.31	0.00	0.00
Waters B, V1, and V2	III	Open Water	0.05	0.00	0.00	0.05
		Subtotal	**15.57**	**5.74**	**1.93**	**7.90**
Tyee Valley Golf Course Mitigation Project (on-site)						
28	II	Emergent	**4.50**	**0.00**	**0.00**	**4.50**
Des Moines Way Nursery Mitigation Project						
N8, N9, N10	III	Forest/Emergent	**0.86**	**0.08**	**0.00**	**0.78**
Auburn Mitigation Project (off-site)						
Auburn	III	Emergent	**23.27**	**0.00**	**0.00**	**23.27**
	TOTAL		**44.20**	**5.82**	**1.93**	**36.45**

Since the affected areas will be incorporated into the mitigation design, no loss of wetland will occur.[18] Following implementation of the mitigation projects, wetland areas will be restored to higher quality wetlands. Because of the physical and biological attributes of the mitigated wetlands (including increased hydrologic connectivity, greater structural diversity, etc.) the mitigation actions result in restoring or establishing Category II wetlands from Category III or IV wetlands. These Category II wetlands will typically have extended wetland hydroperiods and greater diversity of plant community types that improve hydrologic and habitat functions.

Vacca Farm Wetland Restoration Site

Mitigation at the Vacca Farm restoration site (Figure 4-3) will result in modification of existing shrub or emergent wetland (Wetlands A1, A2, A3, and A4), farmed wetlands (FW1, FW2 FW3, FW9, FW10, and FW11), and prior converted cropland (Table 4-12). Relocation of the Miller Creek channel will result in channel excavation, grading, and construction in 2.21 acres of wetland. Creation of channel banks will require fill placement in 1.79 acres of wetland. Finally, excavation of new floodplain in currently farmed areas will modify 1.56 acres of wetland. The mitigation results in an improvement of wetland functions. The changes in wetland function as a result of mitigation are summarized in Table 4-12.

Table 4-12. Summary of changes to wetland functions resulting from mitigation at the Vacca Farm mitigation site.

Function	Analysis
Resident/Anadromous Fish Habitat	The relocation of Miller Creek will replace fish habitat lost by channel filling. The quality of the new habitat will increase as a result of greater habitat diversity due to improved channel morphology, LWD, substrate, and riparian vegetation. Removal of bulkheads along Lora Lake and converting lawn to vegetated buffer will improve fish and aquatic habitat in the lake.
Passerine Bird Habitat:	The function of the wetlands for birds will increase as poorly vegetated areas are converted to shrub-dominated wetlands with vegetated buffers. Decreased human disturbance could also enhance bird use. Potential management of habitat (per the *Wildlife Hazard Management Plan* [WHMP]) may reduce habitat value for certain species.
Waterfowl Habitat:	The waterfowl habitat functions of the wetlands will largely be eliminated by converting open areas to shrub-dominated wetlands. This will improve wildlife hazard conditions at STIA.
Amphibian Habitat:	Amphibian habitat will increase because the new shrub-dominated wetlands with forested buffers will provide habitat for adults. Removal of bulkheads and converting lawn to vegetated buffer along Lora Lake will improve breeding habitat. Decreases in human disturbances and greater habitat connectivity to other portions of the Miller Creek riparian area (as a result of the new South 154th Street bridge that spans the floodplain) would also contribute to higher function for amphibians.
Small Mammal Habitat:	Habitat functions of the area for small mammals would increase because of the greater

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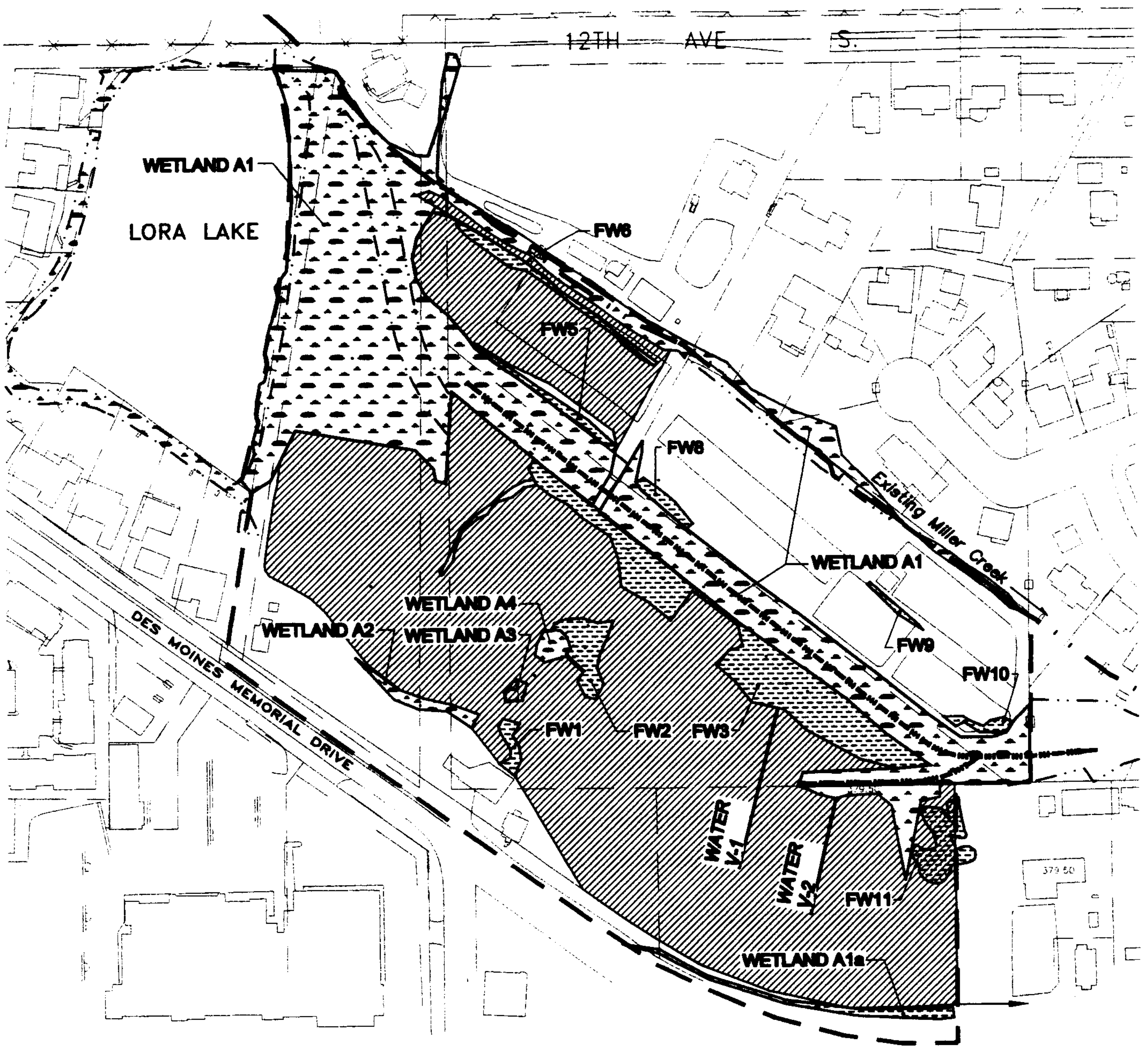
[18] A small (0.12 acre) area of emergent wetland (dominated by pasture grasses) will be filled by an access road to the Auburn mitigation site.

Table 4-12. Summary of changes to wetland functions resulting from mitigation at the Vacca Farm mitigation site (continued).

Function	Analysis
	diversity and density of vegetation cover and habitat types within the mitigation area and buffer. Increased amounts of denning habitat would be available and human disturbances would be decreased. Habitat connectivity to other portions of the Miller Creek riparian area would increase as a result of the new South 154th Street bridge that spans the creek and floodplain.
Organic Matter Export:	The increase in type and density of riparian vegetation, coupled with increased connectivity with the Miller Creek floodplain, will increase the potential for carbon export functions from the area. Removal of bulkheads along Lora Lake and restoring lawn and home sites to wetlands and buffer will increase the export of carbon from the shoreline to Lora Lake, improving aquatic habitat in the lake. Enhancement of the drainage swale and removal of a culvert between Lora Lake and Miller Creek will increase export from the lake to the stream, improving aquatic habitat in the Miller Creek. Adding LWD to Miller Creek will increase the retention and instream processing of particulate carbon. This would increase invertebrate production and food resources available for fish.
Groundwater Exchange:	Some increase in this function could occur as a result in filtration into the embankment and discharge near its base.
Flood Storage/ Desynchronization:	Flood storage functions will remain similar to the existing level. A slight increase of about 1,000 cubic yards in storage volume will be present on the site.
Nutrient Retention/ Sediment Trapping:	Removal of farming and residential land uses will reduce the amounts of sediments, nutrients, and chemicals entering wetlands, Lora Lake, and Miller Creek. The increase in vegetation density and greater connectivity between the creek and floodplain will increase the function of the site for removal of nutrients, sediments, and other pollutants.



LEGEND:

— —	Detail Area	▤	Farmed Wetlands (FW), 14 Day Inundation (Observed, 3/98)
—‖‖—	Drainage Ditch	▨	Prior Converted Wetlands
▭	Vegetated Wetlands		

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Figure 4-3
Jurisdictional Wetlands
on the Vacca Farm Site

Miller Creek Riparian Buffer

Enhancement of 10.25 acres of wetland in the Miller Creek buffer (Figure 4-4) will involve minor wetland disturbance. Hand planting trees and shrubs will redistribute small volumes of wetland soils. In some wetlands, prior to planting with native trees and shrubs, clearing and grubbing to remove existing non-native vegetation will also redistribute topsoils. In these areas, a temporary irrigation system may also disturb wetland soils. The effect of the mitigation on the functions provided by the wetlands is evaluated in Table 4-13.

Table 4-13. Summary of changes to wetland functions resulting from mitigation from the Miller Creek buffer enhancement project.

Function	Analysis
Resident/Anadromous Fish Habitat:	The Miller Creek habitat enhancement projects will increase the habitat diversity in the creek. Buffer enhancement, removal of human disturbance in and adjacent to the creek, and removing pets from the area will also improve riparian conditions and improve creek habitat.
Passerine Bird Habitat:	The function of the wetlands for birds will increase as vegetation density and the amount of woody vegetation is increased. Removal of human disturbances from the area, including pets, will also improve habitat conditions for birds. The greater connectivity of wetland and upland habitats in the buffer will also improve bird habitat. Potential management of habitat (per the WHMP) may reduce habitat value for certain species that are a risk to aircraft safety (such as raptors and flocking birds).
Waterfowl Habitat:	The low waterfowl habitat functions of the wetlands will be unchanged.
Amphibian Habitat:	Amphibian habitat functions will increase because increased amounts of shrub and forested cover will provide habitat for adults. Decreases in human disturbances, use by pets, and greater habitat connectivity to other portions of the Miller Creek riparian area (including the Vacca Farm restoration area) will also contribute to higher function for amphibians.
Small Mammal Habitat:	Habitat functions for small mammals will increase because of increased amounts of shrub and forested cover. Decreases in human disturbances, including pets, and greater habitat connectivity to other portions of the Miller Creek riparian area (including the Vacca Farm restoration area) will also contribute to a higher habitat function for small mammals. Increased amounts of denning habitat will be available, especially as the forest vegetation matures.
Organic Matter Export:	The increase in diversity and density of riparian vegetation will increase the carbon export functions from the riparian wetlands. Adding LWD to Miller Creek will increase the retention and instream processing of particulate carbon. Improving channel hydraulics and will provide more pools and other areas where organic matter will accumulate. These factors would contribute to the invertebrate productivity of the creek and increase resources available for fish.
Groundwater Exchange:	Some increase in this function may occur as water infiltrating into the embankment is gradually released to downslope areas.
Flood Storage/ Desynchronization:	No change in this function will occur.
Nutrient Retention/ Sediment Trapping:	Removal of residential land uses will reduce the amounts of sediments, nutrients, and chemicals generated from the area that enter wetlands and Miller Creek. The change in vegetation type and density could change the function of the area for storage and removal of nutrients, sediments, and other pollutants, but new pollutant sources will not be present.

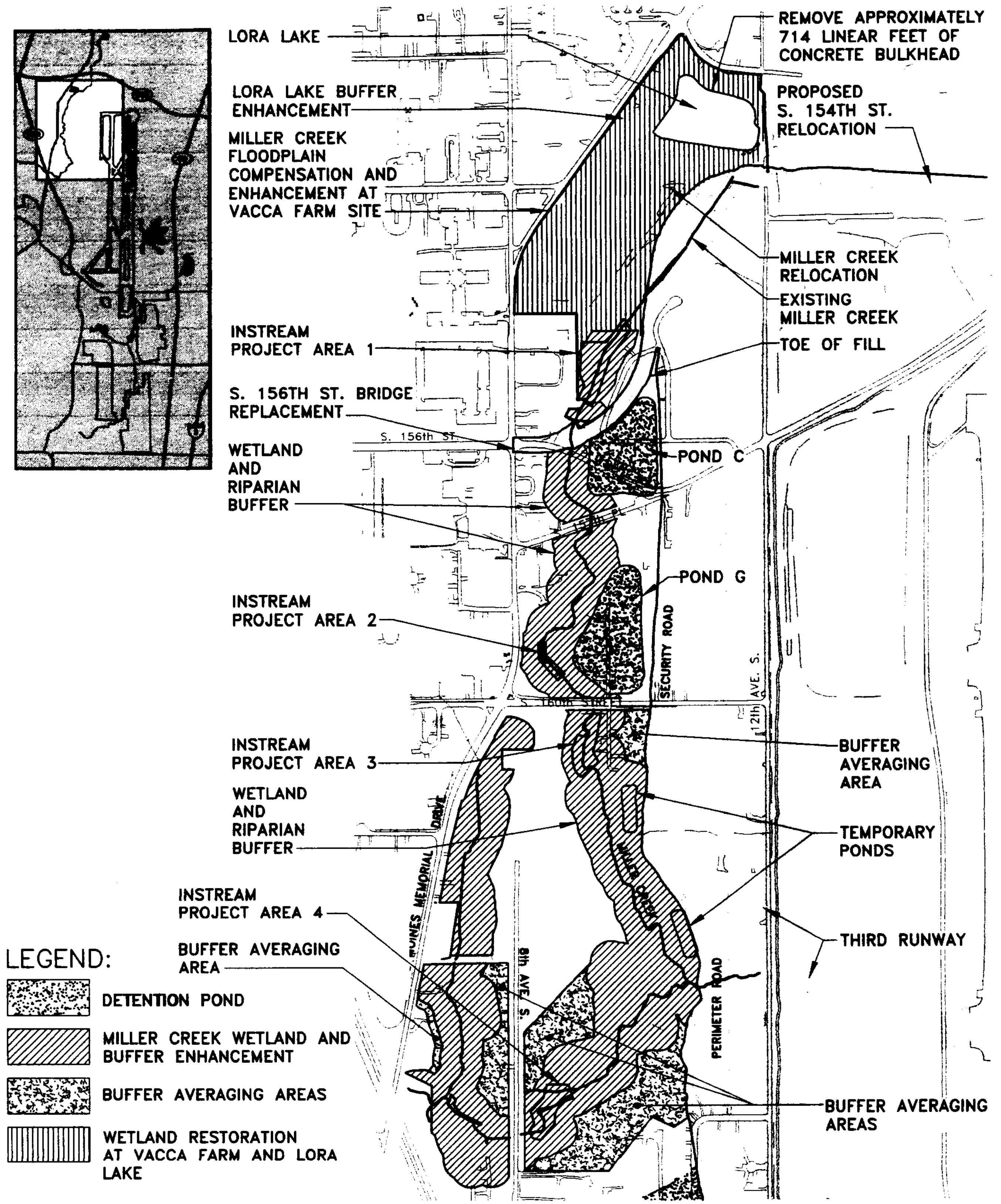

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Figure 4-4
Locations of Mitigation Projects in the Miller Creek Basin

Tyee Valley Golf Course Wetland and Des Moines Creek Buffer Mitigation

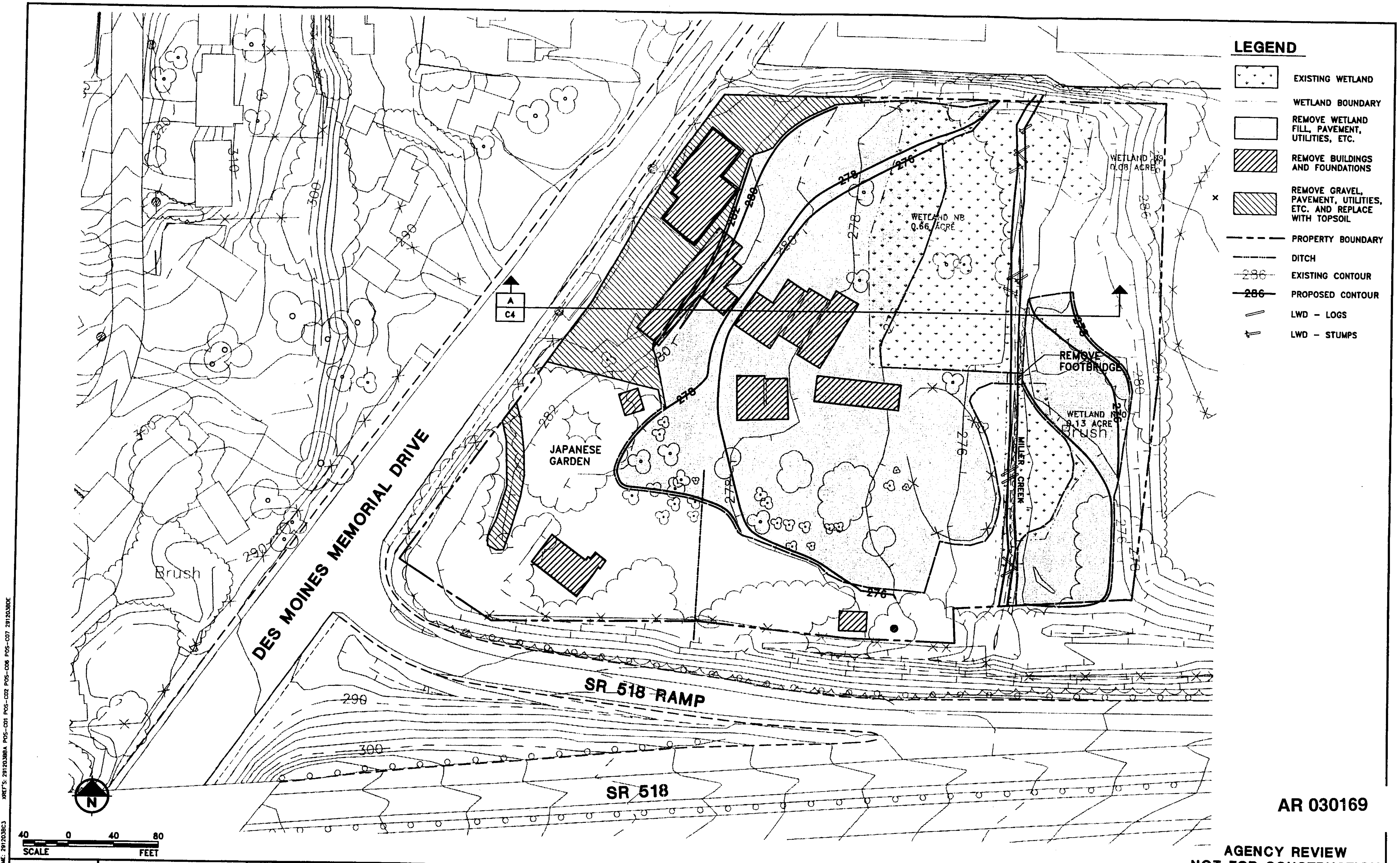
Enhancement of 5.51 acres of wetland on the 10.46 acres Tyee Valley Golf Course mitigation area (Figure 4-5) will involve minor soil disturbance during demolition of pathways and other structures located in wetlands. Planting trees and shrubs on the site will redistribute wetland soils. The effect of the mitigation on the functions provided by the wetlands is evaluated in Table 4-14.

Table 4-14. Summary of changes to wetland functions resulting from mitigation at the Tyee Valley Golf Course mitigation site.

Function	Analysis
Resident/Anadromous Fish Habitat:	This function will increase somewhat as a result of improved buffer conditions along Des Moines Creek.
Passerine Bird Habitat:	Function of the wetland for birds will increase as golf course areas are vegetated with shrub communities. Potential management of habitat (per the WHMP) may reduce habitat value for certain species.
Waterfowl Habitat:	The waterfowl habitat functions of the wetland mitigation area will be eliminated by converting open areas to shrub-dominated wetlands to improve aviation safety.
Amphibian Habitat:	Amphibian habitat will increase because the shrub-dominated wetland and buffers will provide habitat for adults. Decreases in human disturbances, reduced vegetation management, and greater habitat connectivity to other portions of Des Moines Creek and open water areas of Wetland 28 to the west will improve the function of this area for amphibians.
Small Mammal Habitat:	The function of this area for small mammals will increase because of the greater diversity and density of vegetation cover and habitat types. The decrease in human disturbances and greater connectivity to Des Moines Creek and other areas of Wetland 28 will also increase the function of the area for small mammals.
Organic Matter Export:	The increase in the type and density of riparian vegetation, coupled with connectivity to the Des Moines Creek floodplain, will increase the carbon export functions from the mitigation site. Converting turfgrass to shrub-vegetated wetlands will increase the export of carbon during periods of flooding.
Groundwater Exchange:	No change in this function will occur.
Flood Storage/ Desynchronization:	No change in this function will occur.
Nutrient Retention/ Sediment Trapping:	While the capacity of the wetland to perform this function will probably not increase, the removal of the golf course will reduce the amounts of nutrients and chemicals entering wetlands and Des Moines Creek. This could result in a net increase in water quality. Increased shading along the Des Moines Creek buffer could improve water temperatures in the creek.

Des Moines Way Nursery Mitigation Site

Enhancement of wetlands (0.86 acres), restoration of wetland (2.00 acres), and buffer enhancement at the Des Moines Way Nursery site (wetlands N8, N9, and N10, see Figure 4-4a) will involve minor wetland disturbance. Hand planting trees and shrubs will redistribute small volumes of wetland soils. In some wetlands, prior to planting with native trees and shrubs, clearing and grubbing to remove existing non-native lawn vegetation and match grades to restored wetlands will



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DRAWN BY: S. NEWELL
SCALE: 1"=40'
DATE: NOVEMBER 2001
CHECKED BY: S. HARRIS
APPROVED BY: P. FENDT

REVISIONS

NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D

PROJECT ENGINEER:
DESIGNED:
DRAWN BY:
SCALE:
DATE:
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Figure 4.4a
Des Moines Way Nursery
Site Mitigation Plan

WORK ORDER NO.
CONSULTANT'S NO. 291203BC3
PORT OF SEATTLE NO. STIA-XXXX-C3

APPENDIX F

DATE: 11/16/01 FILENAME: 291203BC3 IMAGES:
XREF'S: 291203BBA POS-C01 POS-C02 POS-C06 POS-C07 291203BDE

also remove or redistribute soil. A temporary irrigation system may also disturb wetland soils. The effect of the mitigation on the functions provided by the wetlands is evaluated in Table 4-15.

Table 4-15. Summary of changes to wetland functions resulting from mitigation from the Des Moines Way Nursery enhancement project.

Function	Analysis
Resident/Anadromous Fish Habitat:	The Miller Creek habitat will increase as a result of buffer and wetland enhancement (planting trees and shrubs) and removal of human disturbance adjacent to the creek. Placement of LWD in the creek will improve habitat diversity, trap organic matter, and enhance aquatic invertebrates.
Passerine Bird Habitat:	The function of the wetlands for birds will increase as vegetation density and the amount of woody vegetation is increased. Removal of human disturbances from the area, including pets, will also improve habitat conditions for birds. The greater connectivity of wetland and upland habitats in the buffer will also improve bird habitat. Potential management of habitat (per the WHMP) may reduce habitat value for certain species that are a risk to aircraft safety (such as raptors and flocking birds).
Waterfowl Habitat:	The low waterfowl habitat functions of the wetlands will be reduced as lawn areas are converted to shrub wetlands.
Amphibian Habitat:	Amphibian habitat functions will increase because increased amounts of shrub and forested cover will provide habitat for adults. Decreases in human disturbance and use by pets will also contribute to higher function for amphibians.
Small Mammal Habitat:	Habitat functions for small mammals will increase because of increased amounts of shrub and forested cover. Decreases in human disturbances and use by pets will also contribute to a higher habitat function for small mammals. Increased amounts of denning habitat will be available, especially as the forest vegetation matures.
Organic Matter Export:	The increase in diversity and density of wetland riparian vegetation will increase the carbon export functions from the riparian wetlands. Adding LWD to Miller Creek will increase the retention and instream processing of particulate carbon. Improving channel hydraulics and will provide more pools and other areas where organic matter will accumulate. These factors would contribute to the invertebrate productivity of the creek and increase resources available for fish.
Groundwater Exchange:	No Change to this function is expected.
Flood Storage/ Desynchronization:	No change in this function is expected. In the longer term, placement of woody debris, natural recruitment of woody debris, and channel forming processes may increase floodplain connectivity between the creek and wetland.
Nutrient Retention/ Sediment Trapping:	Removal of existing developed land uses will reduce the amounts of sediments, nutrients, and other chemicals generated from the area that enter wetlands and Miller Creek. The change in vegetation type and density could change the function of the area for storage and removal of nutrients, sediments, and other pollutants, but new pollutant sources will not be present.

Auburn Wetland Mitigation Site

Mitigation at this site will, in part, convert lower quality wetlands (Category III) to higher quality and more diverse wetland system (Category II). Temporary impacts will occur as a result of this action (Figure 4-6). Excavation as part of wetland enhancement will allow establishment of open water, flooded emergent, shrub, and forest-dominated wetlands habitat and affect about 10.39 acres of Category III wetlands.

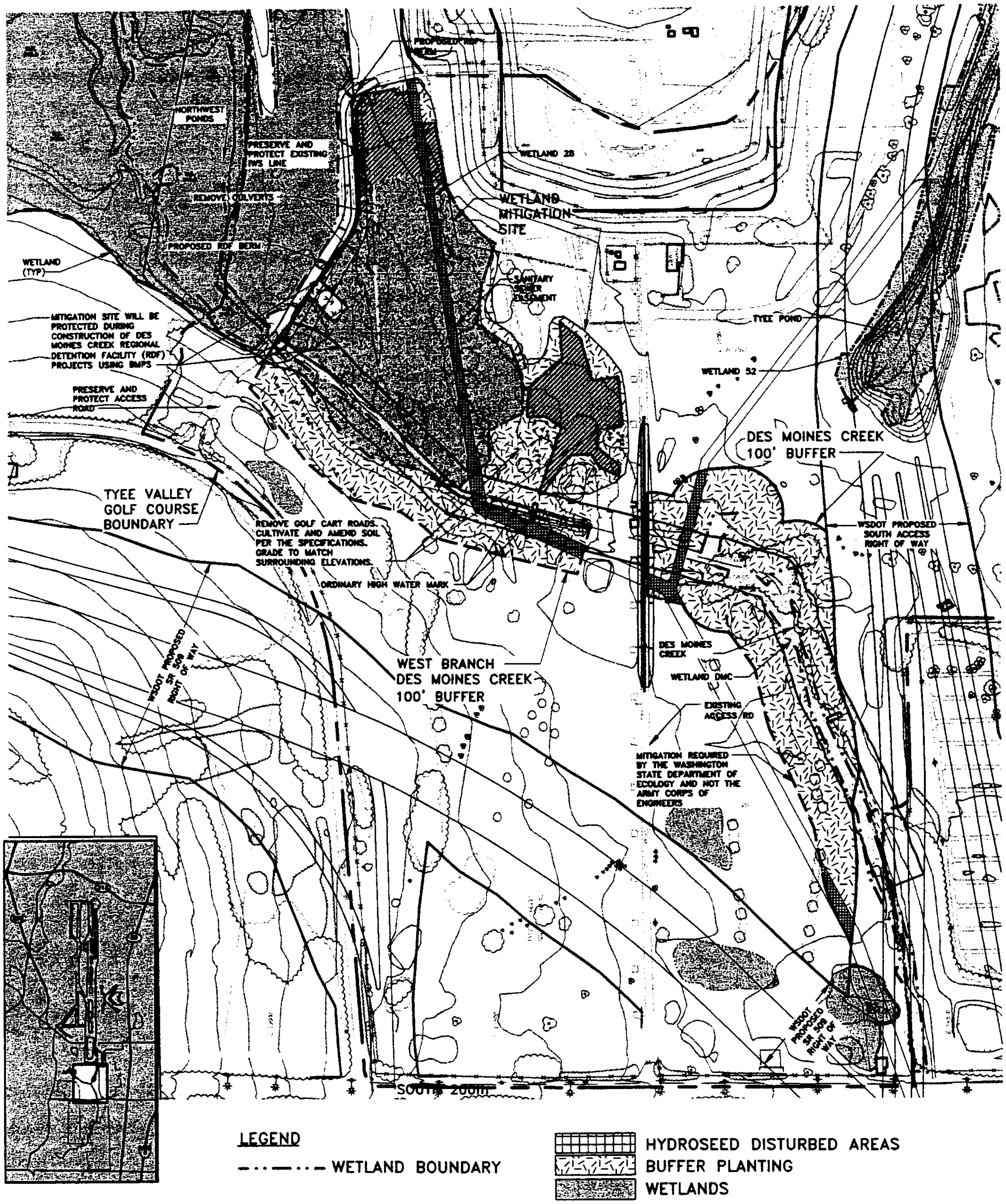

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Figure 4-5
Location of Wetland Mitigation in the Des Moines Creek Basin

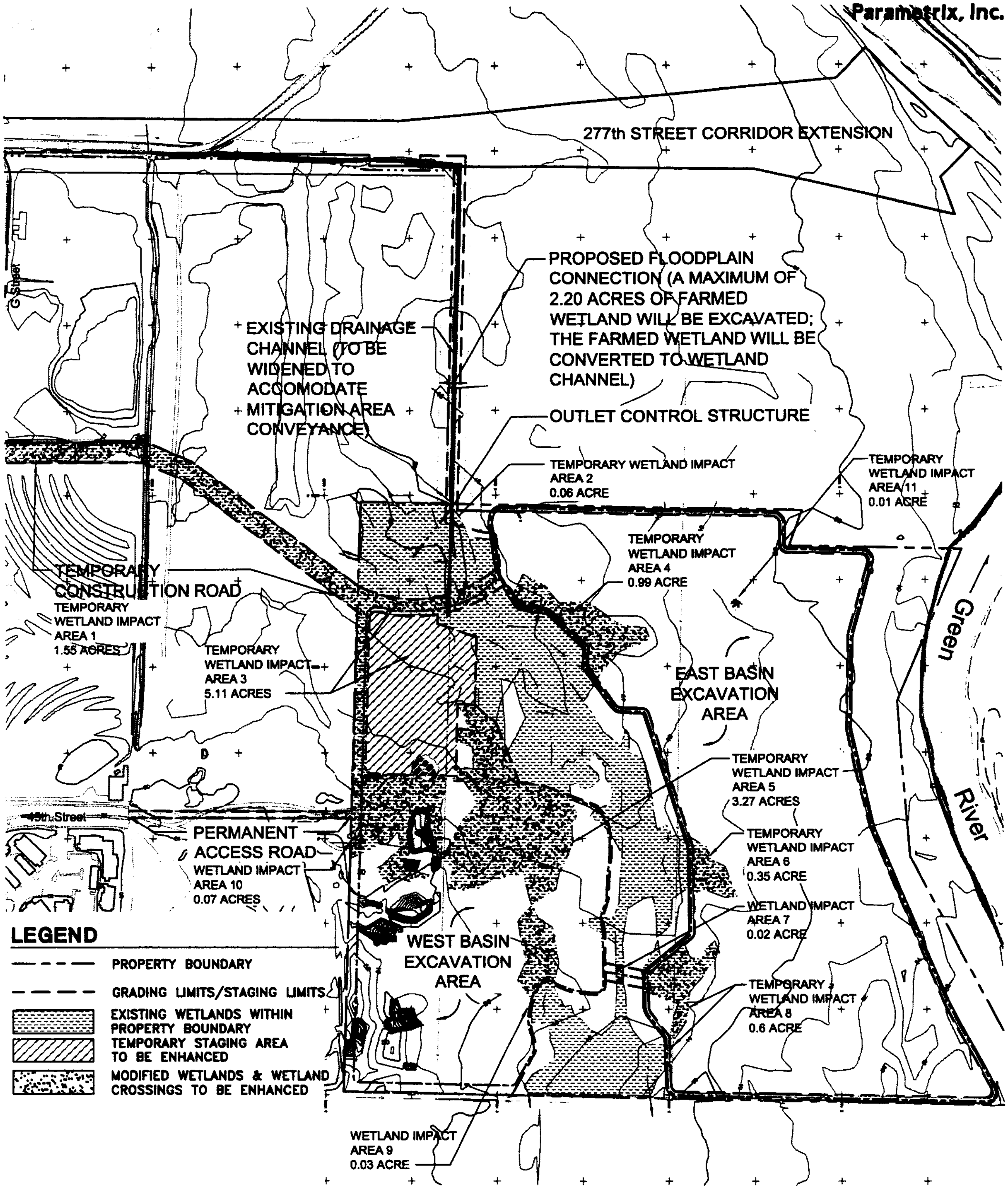

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Figure 4-6
Location of Wetland Impacts at the Auburn Mitigation Site

The wetlands will also provide floodwater storage and conveyance functions, provided by a channel excavated to connect to existing ditches. This excavation will impact about 2.2 acres of existing low quality emergent wetland.

In some wetlands, prior to planting with native trees and shrubs, clearing and grubbing to remove existing non-native vegetation will occur. This work will cause minor redistribution of soils, and will be performed to reduce the quantity of undesirable vegetation and increase the rate of colonization by desirable vegetation in wetland enhancement areas. This activity could occur in up to about 9.13 acres of low quality wetland.

A temporary construction access road to the Auburn wetland mitigation site must be constructed. This access road must cross emergent wetlands located on-site and on properties to the west. About 1.5 acres of wetland will be temporarily impacted by this access road. To minimize these impacts, the road will be constructed on geotextile fabric and a quarry rock base. While the base will allow surface water to equilibrate across the road, culverts will also be placed to convey water at existing ditches.[19]

On-site construction staging (temporary stockpiling of soil, equipment storage, contractor offices, materials storage, parking, etc.) is necessary and will occur on about 3 acres of wetland and uplands prior to enhancement. A geotextile fabric and gravel will be placed on portions of the site prior to their use for staging. Following excavation, the staging area will be removed and the existing wetlands enhanced.

Temporary access and maintenance roads and gravel paths are planned in the wetland buffer and wetlands on the mitigation site. These roads will provide access to the wetlands during the planting and monitoring period. The roads will not affect or reduce the functions provided by the mitigation site, as "infrequently used gravel or paved roads or vegetated dikes in a relatively undisturbed buffer can be ignored as a disturbance" (Ecology 1999). The temporary roads will be abandoned when vegetation performance standards are met. About 2.4 acres of maintenance roads will be in wetland buffers, while about 1.0 acres will cross wetlands. About 0.9 acres of gravel paths will occur in new wetlands.

Other activities that will occur in portions of wetlands during enhancement may include the use of vehicles to deliver plants to planting areas, soil disturbance during planting, installation of temporary irrigation[20] systems, mulching, and weed management (including mowing, plowing, and herbicide applications). The overall effect of the mitigation on the functions provided by the wetlands at the Auburn site is summarized in Table 4-15. (Section 7 of the NRMP [Parametrix 2001a] provides additional detail on the anticipated wildlife use of this site.)

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[19] Surface water, up to several inches deep, occurs in portions of the wetland for short periods following excessive rain.

[20] Temporary irrigation systems are proposed to enhance plant survival and are more fully discussed in the NRMP (Section 7.4.6).

Table 4-15. Summary of changes to wetland functions resulting from mitigation at the Auburn mitigation site.

Function	Analysis
Resident/Anadromous Fish Habitat:	No change in this function will occur.
Passerine Bird Habitat:	The habitat functions of the wetlands and uplands for passerine birds will increase substantially. The large amount and diversity of forested wetlands and protective buffers, coupled with shrub, emergent, and open water habitats will create habitat for a diverse array of species (see Table 7.2-6 in the NRMP).
Waterfowl Habitat:	The habitat functions of the site for waterfowl will increase substantially. The emergent and open water habitats will create breeding and forage habitat for a variety of waterfowl (see Table 7.2-6 in the NRMP).
Amphibian Habitat:	The habitat functions of the site for amphibians will increase substantially. The large amount of forested, shrub, and emergent habitats will provide habitat for non-breeding amphibians. LWD would also contribute to amphibian habitat. The open water areas will remain ponded during the late spring and early summer, and will provide breeding areas for several species, as identified in Table 7.2-6 of the NRMP.
Mammal Habitat:	The habitat functions of the site for mammals will increase substantially. The large amount of forested wetlands and protective buffers, coupled with shrub, emergent, and open water habitats, will create habitat for a diverse array of species (see Table 7.2-6 of the NRMP).
Organic Matter Export:	The function of the site for carbon export will increase substantially compared to the existing condition as a result of the floodplain channel that will connect the wetland to the Green River 100-year floodplain and to ditches located along South 277th Street. Export functions will generally occur between the late fall and winter period when flooding occurs and high rainfall will result in surface flows from the site.
Groundwater Exchange:	No significant change in this function is expected. Some groundwater that currently surfaces in existing drainage ditches north of the site will surface up to several hundred ft farther south, within the constructed wetland. Low permeability soils, which will remain on the site, will continue to perch water.
Flood Storage/ Desynchronization:	The flood storage functions of the wetland will increase substantially at the east basin of the mitigation site when it is connected to the floodplain of the Green River.

4.3 INDIRECT WETLAND IMPACTS

Potential indirect impacts to wetland functions or areas may result from the long-term effects of construction and operation of the Master Plan Update improvements. These potential indirect impacts are evaluated in this section and include the following:

- Placement of fill near or adjacent to wetlands
- Placement of fill in portions of wetlands
- Stormwater management upslope of wetlands
- Disturbance of wildlife from aircraft noise
- Wildlife management activities
- Excavation for retaining wall footings

- Excavation for stormwater management ponds located upslope of wetlands
- Water quality impacts from potential stormwater discharges to wetlands at construction sites

Wetland functions potentially impacted by these activities include:

- **Wildlife habitat support**, by altering habitat conditions or wildlife use of wetlands
- **Hydrologic**, including groundwater discharge functions that occur in wetlands, by altering quantities or patterns of surface or groundwater movement
- **Water quality** impacts resulting from changes to surface water drainage patterns, changes in contaminant sources, etc.

The discussion of indirect impacts includes evaluations of the various mitigation actions taken to avoid and minimize wetland impacts during construction and operation. These mitigation actions include natural resource mitigation described in the *NRMP* (Parametrix 2000a), as well as various design modifications that reduce or eliminate potential indirect impacts to wetlands.

4.3.1 Analytical Approach

The analytical approach to evaluating potential indirect impacts to wetland functions by Master Plan Update improvement construction is discussed in this section. Potential indirect impacts to five wetland biological functions were examined, including:

- Resident and anadromous fish support
- Songbird habitat support
- Waterfowl habitat support
- Amphibian habitat support
- Small mammal habitat support

Potential indirect impacts to four wetland physical functions were also examined, including:

- Organic matter export to downslope systems
- Maintenance of groundwater exchange
- Flood storage
- Nutrient retention and sediment trapping

In the following discussions these functions are analyzed and grouped as "biological impacts" and "physical impacts."

4.3.1.1 Supports Resident and Anadromous Fish

Indirect impacts to fish habitat can result from physical changes in riparian wetlands adjacent to Miller, Walker, or Des Moines Creeks that provide fish habitat. The changes that could alter adjacent aquatic environments and the functions riparian wetlands provide in supporting fish and fish habitat include:

- Increased turbidity and sediment runoff above water quality standards
- Degradation of water quality such as increases in temperature, chemical content, or reductions in dissolved oxygen
- Changes to wetland vegetation that affect stream habitat conditions, including shade and export of organic matter
- Changes to wetland hydrology that may affect the ability of a wetland to provide base flow to streams

4.3.1.2 Provides Habitat for Song (Passerine) Birds

Indirect impacts to songbird habitat can result from:

- Increased noise and human disturbance
- Changes in hydrology that eliminate special habitat conditions (i.e., hydrologic changes eliminate standing water that might be used by certain bird species)
- Changes in hydrology that alter the dominant vegetation types in the wetlands

4.3.1.3 Provides Waterfowl Habitat

Indirect impacts to characteristics of wetlands that provide waterfowl habitat functions could occur from changes to the amount of flooding in a wetland. These changes could alter the habitat wetland vegetation provides to waterfowl or the occurrence and duration of flooded habitat these species use.

4.3.1.4 Provides Amphibian Habitat

Indirect impacts to amphibian habitat functions could occur from changes in habitat conditions discussed above for fish, passerine birds, and waterfowl.

4.3.1.5 Provides Small Mammal Habitat

Indirect impacts to small mammal[21] habitat functions could occur from changes in habitat conditions discussed above for passerine birds and waterfowl.

4.3.1.6 Exports Organic Matter

Indirect impacts to this function could occur from the alteration of flow patterns in wetlands that transport organic matter to adjacent streams, changes in hydrologic conditions (rates or timing), or modification of riparian areas where organic production is produced and falls into streams.

4.3.1.7 Maintains Groundwater Exchange

Indirect impacts to this function could result from significant changes in upslope groundwater recharge or alteration of groundwater discharge patterns (location and timing). Groundwater exchange functions could be altered by new impervious surfaces, soil compaction, or sediment deposition.

4.3.1.8 Provides Flood Storage and Runoff Desynchronization

This function could be altered by physical modifications (filling, excavation, blocking drainageways, etc.) of wetlands that are in stream floodplains. Filling of wetland depressions that temporarily store runoff during storm events would also impact this function. These modifications are evaluated as direct impacts, and include modifications to wetland area, hydrologic connections, wetland topography, and wetland vegetation.

4.3.1.9 Enhances Nutrient and Sediment Retention

Indirect impacts that alter a wetland's ability to retain nutrients and trap sediments during the construction and operation include changes to vegetation (i.e., removal of or changes in type or density), hydrology (i.e., changing the amount of overland vs. channelized flow), and topographic conditions (which changes flow rates).

---

[21] The wetlands do not provide significant habitat for large mammals because they are too small to independently support the habitat requirements of large mammals found in western Washington. Large mammals (except coyote and red fox [*Vulpes vulpes*]) cannot use the wetlands because adjacent development and habitat fragmentation prevent access.

4.3.2 Analysis Summary

This section summarizes the indirect impact analysis for the Master Plan Update improvements. Additional analysis is presented in the following sections:

4.3.2.1 Wildlife
4.3.2.2 Wetland Fragmentation
4.3.2.3 Wetland Habitat Complexity and Biological Diversity
4.3.2.4 Impact to Wetland Hydrology and Hydroperiod
4.3.2.5 Stormwater Management during Operation
4.3.2.6 Floodplain Impacts
4.3.2.7 Retaining Walls
4.3.2.8 Runway Safety Areas
4.3.2.9 Third Runway: North End
4.3.2.10 Third Runway: South of South 154th Street
4.3.2.11 Wetland 44 and Walker Creek
4.3.2.12 New Stormwater Detention Facilities
4.3.2.13 Staging Areas
4.3.2.14 Borrow Area 1
4.3.2.15 Borrow Area 3
4.3.2.16 Borrow Area 4
4.3.2.17 South Aviation Support Area
4.3.2.18 Other Areas

The calculated permanent impacts to wetlands (18.37 acres) include about 2.4 acres of indirect wetland impacts (see Tables 3-1, 3-2, and 4-16) that could occur in certain locations where changes to wetland hydrology, shading, or fragmentation of wetlands occur. While these indirect impacts could result in the loss of some wetland functions from an area, they may not necessarily remove all functions. For example, where the SASA bridge crosses Wetland 52, shading will eliminate wetland vegetation and wildlife habitat; however, the riparian corridor and hydrologic functions provided by this area will remain. In other areas, if wetland hydrology is reduced or eliminated from marginally wet areas, the existing vegetation will remain and wildlife habitat functions of a wetland will not change significantly. Thus, while indirect impacts could result in the loss of wetland functions from an area, they may not necessarily remove all functions. However, to be conservative, the 2.4 acres of indirect impacts are fully mitigated at ratios of 3:1, as explained in the NRMP (Parametrix 2000a).

Table 4-16. Summary of indirect impact analysis and wetlands partially filled by Seattle-Tacoma International Airport Master Plan Update improvements.

Wetland Number[a]	Wetland Area (acres)				Explanation and Mitigation
	Total	Fill	Indirect[b]	Remaining	
Runways Safety Areas					
3	0.56	0.00	0.00	0.56	Precipitation, the embankment drainage layer, and an existing stormwater outfall will maintain wetland hydrology in this wetland. Retrofitting existing stormwater drainage system (SDS) for water quality and quantity will enhance hydrologic conditions in the wetland.
4	5.00	0.00	0.00	5.00	Precipitation, discharge from Wetland 3, and the embankment drainage layer will maintain wetland hydrology in this wetland.
5	4.63	0.14	0.00	**4.49**	Precipitation, the embankment drainage layer, and existing stormwater outfalls will maintain wetland hydrology in this wetland. Retrofitting existing stormwater drainage system for water quality and quantity will enhance hydrologic conditions in the wetland.
Third Runway					
9	2.83	0.03	0.00	**2.80**	A small portion of this wetland will be filled. While most of the wetland receives water from the Miller Creek riparian zone, seasonal seeps along the south side of the wetland will continue because groundwater conveyance through the fill will be maintained by the embankment design (i.e., the drainage layer). The wetland will receive surface water inputs from a biofiltration swale located adjacent to the relocated South 154th Street.
11	0.50	0.34	0.16	0.00	Indirect impacts result from nearby construction of South 154th Street, runway embankment, and runway safety areas over extended time periods.
12	0.21	0.21	0.00	0.00	See wetland 11
18	3.56	2.29	0.55	**0.72**	Precipitation and the embankment drainage layer will maintain wetland hydrology in the remaining portion of the wetland. The incorporation of the wetland into the Miller Creek buffer and removal of existing nearby development will ensure that habitat functions are maintained or improved. Portions of the wetland may have indirect hydrologic impacts if channels draining the embankment do not distribute water efficiently to this wetland.
37	5.73	3.75	0.34	**1.64**	See comments for Wetland 18.
39	0.90	0.00	0.02	**0.88**	Indirect impacts could result from construction of a nearby stormwater pond. Incorporation of the wetland into the Miller Creek buffer and upslope water sources will ensure remaining portions are functional.
43	30.30	0.00	0.00	30.30	Maintenance of hydrology to Wetland 44 will ensure no significant impact to this wetland occurs.

Table 4-16. Summary of indirect impact analysis and wetlands partially filled by Seattle-Tacoma International Airport Master Plan Update improvements (continued).

Wetland Number[a]	Wetland Area (acres) Total	Fill	Indirect[b]	Remaining	Explanation and Mitigation
44	3.08	0.26	0.00	**2.82**	Hydrology from precipitation and groundwater discharge through the embankment and drainage channels will maintain wetland hydrology in the downslope portions of the wetland. The removal of existing residential development will reduce human impacts to the area and maintain or enhance wildlife habitat.
A1	4.66	0.59	0.00	**4.07**	Riparian portions of channelized Miller Creek will be filled, and the stream relocated. The new stream channel reach and restoration of the Vacca Farm mitigation area will improve the functional performance of the remaining wetland and ensure that the remaining portions of the wetland are functional.
A5	0.03	0.01	0.02	0.00	Indirect impacts attributed to proximity of wetland to embankment and stormwater management facilities.
A6	0.16	0.07	0.09	0.00	See comments for Wetland A5.
A9	0.04	0.00	0.00	0.04	Precipitation and the embankment drainage layer will maintain wetland hydrology. The incorporation of this wetland into the Miller Creek buffer and removal of existing nearby development will ensure that habitat functions are maintained or improved.
A10	0.01	0.00	0.00	0.01	See comments for Wetland A9.
A11	0.02	0.00	0.00	0.02	See comments for Wetland A9.
A12	0.11	0.02	0.06	**0.03**	If distribution of water to the wetland is inefficient, indirect impacts to hydrology could result. However, precipitation and the embankment drainage layer will maintain wetland hydrology in the remaining portion of this wetland. The incorporation of the wetland into the Miller Creek buffer and removal of existing nearby development will ensure that habitat functions are maintained or improved.
A13	0.12	0.00	0.00	0.12	A small portion of this wetland may be subjected to temporary impacts during construction of the replacement drainage channels. However, precipitation and the embankment drainage layer will maintain wetland hydrology in the wetland. The incorporation of the wetland into the Miller Creek buffer and removal of existing nearby development will ensure that habitat functions are maintained or improved.
A18	0.01	0.00	0.01	0.00	The proximity of this small wetland to construction will eliminate its hydrology and function.
R1	0.17	0.13	0.00	**0.04**	Hydrology from Miller Creek, precipitation, and groundwater will maintain wetland hydrology in the remaining portions of the wetland. The incorporation of the wetland into the Miller Creek buffer and removal of existing nearby development will ensure that riparian and habitat functions are maintained or improved.

Table 4-16. **Summary of indirect impact analysis and wetlands partially filled by Seattle-Tacoma International Airport Master Plan Update improvements (continued).**

Wetland Number[a]	Wetland Area (acres) Total	Fill	Indirect[b]	Remaining	Explanation and Mitigation
R2	0.12	0.00	0.00	0.12	Hydrology from Miller Creek, precipitation, and groundwater will maintain wetland hydrology following construction. Incorporation of the wetland into the Miller Creek buffer and removal of existing nearby development will ensure that riparian and habitat functions are maintained or improved.
R3	0.02	0.00	0.00	0.02	See comments for Wetland R2.
R9	0.38	0.00	0.00	0.38	See comments for Wetland R2.
Borrow Area 1					
48	1.58	0.00	0.00	1.58	Wetland hydrology will be maintained in this wetland through precipitation and preservation of the upslope drainage system between the wetlands and 20th Avenue South.
32	0.09	0.00	0.00	0.09	A 50-ft buffer and preservation of upslope runoff will prevent impacts to wetland hydrology.
B1	0.27	0.00	0.00	0.27	See comments for Wetland 32.
B4	0.07	0.00	0.00	0.07	Groundwater sources that support this wetland will remain. Removal of constructed drainage systems will reduce erosive flows.
B12	0.63	0.03	0.04	**0.56**	Grading may alter distribution of water to upslope portions of the wetland and result in indirect impacts to hydrologic functions. The remaining wetland area will remain functional because of groundwater and precipitation water sources and its preservation in the Des Moines Creek buffer.
B15	2.07	0.00	0.00	2.07	See comments for Wetland 48.
Borrow Area 3					
B5	0.08	0.00	0.00	0.08	Borrow Area 3 has been designed to avoid impacts to the hydrology of this wetland. Further assurance that hydrologic impacts are avoided is provided by a drainage ditch that intercepts groundwater emanating on the face of the excavation and directs it to downslope wetlands.
B6	0.55	0.00	0.00	0.55	See comments for Wetland B5.
B7	0.03	0.00	0.00	0.03	See comments for Wetland B5.
B9	0.05	0.00	0.00	0.05	See comments for Wetland B5.
B10	0.02	0.00	0.00	0.02	See comments for Wetland B5.
29	0.74	0.00	0.00	0.74	See comments for Wetland B5.
30	0.88	0.00	0.00	0.88	See comments for Wetland B5.

Table 4-16. Summary of indirect impact analysis and wetlands partially filled by Seattle-Tacoma International Airport Master Plan Update improvements (continued).

Wetland Number[a]	Wetland Area (acres) Total	Fill	Indirect[b]	Remaining	Explanation and Mitigation
Borrow Area 4 and Tyee Valley Golf Course Mitigation Area					
28	35.45	0.07	0.00	35.38	Portions of Wetland 28 will be enhanced by mitigation planned at the Tyee Valley Golf Course, where existing golf course greens will be converted to shrub-dominated wetland. Master Plan Update improvements that are located near Wetland 28 are limited to a portion of the third runway and without mitigation the new pavement could generate hydrologic and water quality impacts in the wetland. The SMP (Parametrix 2000b) addresses detention facilities and water quality BMPs that will minimize these impacts to the wetland and downstream Des Moines Creek. Excavation of Borrow Area 4, located south of Wetland 28, will not intercept groundwater flowing to the wetland or Des Moines Creek, and is thus unlikely to impact the hydrology of the wetland.
South Aviation Support Area					
G3	0.06	0.04	0.02	0.00	The SASA project may eliminate upslope runoff that may maintain hydrology in the unfilled portions of this wetland.
G4	0.04	0.00	0.04	0.00	See comments for Wetland G3.
G5	0.87	0.40	0.47	0.00	See comments for Wetland G3.
52	4.70	0.00	0.54	**4.16**	Following construction, hydrology in this wetland will be maintained by Des Moines Creek and groundwater seepage. Shading results in indirect impacts to habitat functions.
Auburn Mitigation Area					
1		0.12	0.00	19.42	Remaining wetland will be converted from Category III emergent wetland to Category II forest, shrub, and emergent wetlands.
TOTAL		**15.97**	**2.40**		

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[a] Wetland numbers in bold are partially impacted and subject to fragmentation impacts. For these wetlands (except Wetland 5), mitigation and removal of existing detrimental land uses mitigate fragmentation impacts because the remaining portions of these wetlands will be in less disturbed areas with greater connectivity to other habitat areas.

[b] The acreage of indirect wetland impacts reported in this table is included in the total wetland impacts for the Master Plan Update improvements (18.37 acres). Mitigation for the indirect impacts reported here is thus at the same mitigation ratios as provided for permanent impacts.

Potential indirect impacts to wetlands affected by various elements of the Master Plan Update improvements include the potential reductions in wetland functional performance (Table 4-17) and, in some cases, loss of wetland area (see Table 4-16). Design modifications and/or wetland mitigation actions described in the *NRMP* (Parametrix 2001a) typically mitigate potential losses of functional performance.

Other indirect impacts to wetlands that could affect their function include noise and human disturbance, changes in water quality impacts, and changes in surface hydrology. Wetlands that remain adjacent to the Master Plan Update projects are generally not expected to have indirect impacts because:

- Their hydrologic sources will be maintained.
- Wildlife use in the wetlands is currently subjected to high levels of human disturbance (air traffic, residential development, automobile traffic, etc.).
- Many wetlands are located 50 ft or more from construction areas and no physical modification of these wetlands will occur.

These impacts could alter or reduce the level of some functions, but will not eliminate wetlands. These impacts are also mitigated by the NRMP because, in most cases, land use conditions that have degraded the wetlands are removed, and restoration actions are implemented to increase wetland functions (Parametrix 2000a).

Table 4-17. Summary of potential indirect impacts to wetlands and actions taken to mitigate indirect impacts of Seattle-Tacoma International Airport Master Plan Update improvements.

Wetlands	Functions	Potential Indirect Impacts and Mitigation
Runway Safety Areas and Relocation of South 154th Street		
Wetlands 3, 4, 5, 6, 7, and 10	Wildlife Habitat	Disturbance to wildlife is minimized because new roadway is constructed on top of a retaining wall; wildlife using these areas are already tolerant of aircraft and automobile noise (from existing runways, SR 518, and South 154th Street). Aircraft noise will decrease as some take-off and landing operations are shifted to the new runway. Since aircraft noise is greater than traffic noise, the closer proximity of the road to these wetlands is unlikely to eliminate wildlife from the area. Potential wildlife disturbance from wildlife management activities will continue as a result of ongoing maintenance of emergency access roads, stormwater management facilities, and airport navigation aids.

Table 4-17. Summary of potential indirect impacts to wetlands and actions taken to mitigate indirect impacts of the STIA Master Plan Update improvements (continued).

Wetlands	Functions	Potential Indirect Impacts and Mitigation
	Hydrologic and Water Quality	Disturbance to wetland hydrology is not anticipated because the projects do not add substantial new impervious surfaces (the RSA is unpaved, and the street relocation replaces existing impervious surfaces). RSAs are unpaved, which will allow rainwater to infiltrate and discharge near the base of the RSA embankment, where this water can then enter downslope wetlands. Existing wetlands receive stormwater runoff from South 154th Street and the STIA airfield. Following project construction, stormwater from the road and airfield will be detained and treated with BMPs for water quality, as described in the SMP (Parametrix 2000b). This will improve water quality conditions in the wetland compared to the existing condition.
Third Runway		
North End		
Wetlands A1, 8, and 9	Wildlife Habitat	Disturbance to wildlife from automobiles and aircraft noise should not increase because wildlife in these wetlands are already exposed to these noises. For Wetland A1, substantial disturbances related to ongoing farm activities will be eliminated, and mitigation will be completed to restore non-habitat wetland functions on the site. This mitigation will reduce habitat conditions for waterfowl that currently feed on the farmland. Habitat for small mammals and aquatic organisms will improve. Habitat in these wetlands will continue to be subjected to potential wildlife management according to the Wildlife Hazard Management Plan (USDA 2000)
	Hydrologic and Water Quality	Disturbance to wetland hydrology is not anticipated because wetland hydrology in most of these areas is maintained by Miller Creek, and its hydrology will not be substantially altered by the project. The projects do not add substantial new impervious surfaces near these wetlands (the RSA for the new runway is unpaved, and the street relocation replaces existing impervious surfaces). RSAs are unpaved, which will allow rainwater to infiltrate and discharge near the base of the RSA embankment, where this water can then enter downslope wetlands. Existing wetlands receive stormwater runoff from South 154th Street. Following project construction, stormwater from the road and airfield will be detained and treated with BMPs for water quality, as described in the SMP. This will improve water quality conditions in the wetland compared to the existing condition.

Table 4-17. Summary of potential indirect impacts to wetlands and actions taken to mitigate indirect impacts of the STIA Master Plan Update improvements (continued).

Wetlands	Functions	Potential Indirect Impacts and Mitigation
Riparian Areas		
Wetlands R1 through R17	Wildlife Habitat	Disturbance to wildlife will be minimal because of the buffer to Miller Creek, the elimination of humans and pets from the overall area, and sparse vehicular traffic on the security road. No increased level of disturbance to wildlife is expected in Wetlands R1 and R2 at the South 156th Street bridge crossing since the roadway already crosses these two wetlands. Wildlife in the riparian area will be exposed to noise from increased air traffic; however, wildlife in the area is already tolerant of disturbance. A small area of Wetland R1 will be shaded under the new South 156th Street bridge.
	Hydrologic and Water Quality	Disturbance to wetland hydrology is not anticipated because wetland hydrology in most of these wetlands is maintained by Miller Creek, and its hydrology will not be substantially altered by the project. The projects do not add substantial new impervious surfaces near these wetlands, and removal of development, the beneficial impact of the embankment on hydrology (see Section 4.3.2.4), and establishment of wetland buffers will improve natural hydrologic processes in these wetlands. Some riparian wetlands receive stormwater runoff from adjacent developed property. Following project construction, the provision of 50- to 100-ft buffers will provide water quality functions and reduce the amount of untreated stormwater. This will improve water quality conditions in the wetland compared to the existing condition.
Central Area		
Wetlands 18, 37, 39, and 44	Wildlife Habitat	Disturbance to wetlands and their wildlife from human or domestic animal activity will be eliminated due to property access restrictions. Disturbance to wildlife from increased air traffic noise may occur; however, wildlife living in this region are already tolerant of airplane noise; therefore, no significant impacts are expected. Disturbance from sparse vehicular traffic on the security road will not adversely affect wildlife.
	Hydrologic and Water Quality	The hydrologic analysis of the embankment fill shows elimination of wetland hydrology would not occur. Following construction, temporarily disturbed areas will be restored to original topography. The embankment for the third runway will allow infiltration of water outside paved areas and an internal drainage system will convey infiltrated stormwater to discharge locations at the base of the fill pad. This water will be dispersed into or immediately adjacent to Wetlands 18 and 37 to maintain site hydrology over the long term.

Table 4-17. Summary of potential indirect impacts to wetlands and actions taken to mitigate indirect impacts of the STIA Master Plan Update improvements (continued).

Wetlands	Functions	Potential Indirect Impacts and Mitigation
Downslope Isolated Wetlands		
Wetlands A9 through A17 and A19	Wildlife Habitat	Disturbance to wetlands-associated wildlife from human or domestic animal activity will be eliminated due to access restrictions in buffer areas. Disturbance to wildlife from increased noise may occur; wildlife living in this region are tolerant of airplane and traffic noise; therefore, adverse impacts are not expected.
	Hydrologic and Water Quality	Disturbance to wetland hydrology is not anticipated. The fill embankment for the third runway will allow infiltration of rainwater into non-paved areas. The internal drainage system in the embankment will convey infiltrated water to discharge locations at the base of the fill pad; routed water will be dispersed into or immediately adjacent to existing wetland areas to maintain wetland hydrology in downslope areas. Some riparian wetlands receive stormwater runoff from adjacent developed property. Following project construction, the provision of 100-ft buffers will reduce the amount of untreated stormwater reaching riparian wetlands. This will improve water quality conditions in the wetland compared to the existing condition.
Borrow Area 1		
Wetlands B1, B4, and 32	Wildlife Habitat	Disturbance to songbirds and small mammals using these wetlands could occur during construction.
	Hydrologic and Water Quality	Interruption of water supporting Wetlands B1 and 32 is not anticipated since upslope sources and wetland buffers would maintain the seasonal perched water regime. A constructed storm drain that discharges to the incised channel that forms most of Wetland B4 will be removed, reducing erosive flows in the channel.
Borrow Area 3		
Wetlands 29, 30, B5, B6, B7, B9, and B10	Wildlife Habitat	Disturbance to wildlife from increased air traffic noise may occur; however, wildlife living in this region are already tolerant of automobile and airplane noise.
	Hydrologic and Water Quality	Potential changes to wetland hydrology are not anticipated because the upslope areas that supply runoff and groundwater to the wetlands will not be disturbed (see Appendix C).
Borrow Area 4		
Wetland 28	Wildlife Habitat	The borrow area is separated from the wetland by the Tyee Valley Golf Course and/or 196th Street South or 18th Avenue South. Noise and human intrusion from these existing impacts will reduce the potential disturbance construction activity at the borrow area could have on the existing wetland. The location of the wetland in the approach zone to runway 34L also means wildlife in the wetland are subjected to high noise levels that exceed noise generated by construction.

Table 4-17. **Summary of potential indirect impacts to wetlands and actions taken to mitigate indirect impacts of the STIA Master Plan Update improvements (continued).**

Wetlands	Functions	Potential Indirect Impacts and Mitigation
	Hydrologic and Water Quality	The borrow area will not be excavated above the elevation of seasonal groundwater (Hart Crowser 2000), and impacts to hydrologic sources of Wetland 28 will not occur.
South Aviation Support Area		
Wetland 52	Wildlife Habitat	Wildlife in the riparian area will be exposed to noise from increased air traffic; however, wildlife using this area are already tolerant of this type of disturbance.
	Hydrologic and Water Quality	No adverse impacts to water quality in riparian wetlands bordering Des Moines Creek are anticipated because stormwater runoff will not be directed toward them.
IWS Lagoon Expansion		
Wetland 28	Wildlife Habitat	Expansion of the IWS lagoon will not directly impact Wetland 28. The expansion will result in temporary impact to wetland buffers that currently consist of non-native shrub and herbaceous vegetation rooted on fill soils. Construction will clear this vegetation and soil, eventually replacing it with the fill soils of the new lagoon embankment. Wildlife using the adjacent shrub and forest habitat of the wetland (primarily songbirds and small mammals) could be temporarily disturbed by these activities. Because the wetland is in the approach departure zone of the existing runway 34L, aircraft routinely fly within several hundred ft of the wetland. This noise level exceeds the noise from construction, so wildlife use may not be reduced from existing levels.
	Hydrologic and Water Quality	The IWS lagoon construction results in a reduction in surface water runoff that enters Wetland 28 because about 5 acres of relatively compacted fill soils will be removed and converted to a lined lagoon system. Water falling on the lagoon will enter the IWS treatment system instead of Wetland 28. The lagoon system includes an underdrain that will collect groundwater from beneath the lagoon (approximately 260-ft elevation) and convey it to Wetland 28. The discharge point for the underdrain is located upslope of the major portion of Wetland 28, and distribution of water to the wetland at this location will ensure that it is available to maintain high groundwater conditions downslope and prevent dewatering of the wetland. Water quality impacts to the wetland will be prevented from occurring during the construction period by construction BMPs, as described in Section 4.2.1. The IWS lagoon design prevents potential water quality impacts. During operation, the lagoon liner will prevent untreated water stored in it from entering groundwater or Wetland 28. The lagoon volume and IWS treatment capacities are large enough to ensure that overtopping and release of untreated runoff through the emergency spillway is unlikely to occur (Parametrix 2000b).

4.3.2.1 Wildlife

Noise and Human Activity

Wildlife species exhibit a wide range of tolerances to human disturbance, including noise (Gladwin et al. 1988; Manci et al. 1988; Newman and Beattie 1985). Near commercial airports, a wide variety of wildlife frequently habituates to aircraft noise and other human disturbance (Gladwin et al. 1988; Manci et al. 1988; Conomy et al. 1998). Some wildlife species appear to be inherently tolerant of loud noise, or they can adapt to noise, as evidenced by wildlife presence at airports and the variety of wildlife frequently struck by aircraft (FAA 1997). Other less tolerant species are frequently absent from urban areas.

Studies of aviation noise impacts to wildlife have focused on areas where aircraft flight is infrequent or where aircraft disturbance is of an extreme intensity. These studies have examined low-flying military aircraft over undeveloped areas and aircraft that fly at speeds that produce sonic booms (Manci et al. 1988; Gladwin et al. 1988; Weisenberg et al. 1996; Newman and Beattie 1985). The results of these studies are not necessarily applicable to typical commercial airports such as STIA, where more constant but often lower intensity noise occurs in areas that are largely developed.

Disturbance of habitats adjacent to the new third runway at STIA due to increased aircraft noise should not be significant because the new runway will be constructed in areas that are currently subject to significant human disturbance (residential development). Existing noise, visual, and habitat disturbances within or adjacent to wetlands in the acquisition area will be removed, while aircraft noise will generally increase. However, wildlife occurring in the acquisition area are limited to those species that are tolerant of human disturbance (including aircraft noise) and have already habituated to substantial noise and human disturbance. Wildlife habitat near the new runway is also near existing runways, and thus it currently receives aircraft noise. For these reasons, the wildlife species present are likely habituated to aircraft noise, and unlikely to abandon suitable habitat upon operation of the new runway.

Most wetlands that occur adjacent to Master Plan Update improvements are subjected to substantial human disturbances, and in many cases, following construction, will be subjected to the same or less disturbance than currently exists (see Tables 4-16 and 4-17). Existing land uses and associated disturbances occurring in the acquisition area that will be removed from wetlands include mowing, clearing, plowing, chemical applications for yard maintenance and farming, uncontrolled stormwater runoff, wildlife disturbance from domestic animals, and general urban noise. Some wetlands will be somewhat closer to potential airport-generated noise disturbance, but this disturbance is not expected to eliminate wildlife from the affected wetlands for reasons explained above.

Wildlife Management

The Port and FAA are mandated to take emergency actions to protect life and property in all areas near the airport (U.S. Department of Agriculture [USDA] 2000), including the mitigation sites. This need is reflected in the restrictive covenants (see Parametrix 2000a). The WHMP for STIA (USDA 2000) identifies the Port's responsibility to restore and mitigate wetland impacts should emergency actions damage mitigation sites. Indirect impacts from wildlife management are not anticipated.

4.3.2.2 Wetland Fragmentation

The analysis of fragmentation impacts considered whether the remaining wetland areas would be capable of providing similar levels of function following Master Plan Update improvements. Where the remaining wetland was, as a result of mitigation, incorporated into enhanced and protected buffers, it typically would remain functional. If, however, a wetland fragment were to remain isolated from other more significant habitat, its functions would be impaired, and the indirect impact was considered significant. In these cases, the area of the wetland fragment was added to the amount of direct impacts. Wildlife habitat impacts that result from wetland fill are proportional to the area of wetland filled when specialized habitat requirements are not lost, and when substantial areas of adjacent habitat remain. Wildlife could be eliminated from a wetland area if (a) the remaining wetland habitat is smaller than the minimum habitat requirements of a wetland-dependent species, or (b) if unique wetland habitat features that wetland dependent species use are eliminated.

Because the existing wetlands occur in an already highly urbanized and disturbed environment, many of the wildlife species that occur in these wetlands are widespread, cosmopolitan species with wide environmental tolerances. Filling existing wetlands may reduce the amount of habitat available, but would not eliminate the habitat on which these species depend. Wildlife species with specialized wetland habitat requirements (e.g., American beaver, muskrat, and green-backed heron [*Butorides striatus*], etc.) have not been observed in the wetlands impacted by the project, and it is unlikely they are present in the project area due to the condition of existing habitat.

For the wetlands being partially impacted, no unique or special habitats will be filled that would affect the ability of a species to use the remaining portion of the wetland. For example, if breeding amphibians were present in a wetland, and all the open water breeding habitat were filled, the remaining wetland could lose its ability to support amphibians and experience an indirect impact to its wildlife diversity. This or similar cases are not present at the airport.

The typically terrestrial wildlife species using upland and wetlands partially filled by Master Plan Update improvements (Appendix M, FAA 1996) are not dependent on the wetlands for their life history functions, and these species are expected to use the remaining habitat matrix of uplands and wetlands.

Mitigation adjacent to the embankment includes protection and ecological enhancement of over 67 acres of wetland and upland that are currently degraded by past or ongoing human uses. In the landscape context, the proposed mitigation (Parametrix 2000a) will improve habitat connectivity, patch size, and quality of wildlife habitat. This positive effect will mitigate the potential for indirect impacts to habitat resulting from the Master Plan Update improvement projects. On the west side of the embankment, connecting the smaller wetlands via the riparian and wetland buffer, eliminating human and domestic animal use of the area, and enhancing the habitat through planting of native vegetation will eliminate the potential for indirect wetland impacts. Additional benefits to aquatic habitat and the Miller Creek watersheds are derived from four instream enhancement projects.

The presence of undisturbed corridors between habitat patches and groups of smaller but interconnected habitat patches can increase wildlife population persistence and species diversity (Forman and Gordon 1986). For example, the minimum 200-ft-wide by 6,500-ft-long riparian buffer along Miller Creek and the Vacca Farm restoration will lead to: (1) increased connectivity between individual wetlands, (2) increased connectivity between riparian zone wetlands and stream systems, and (3) protection of riparian habitats by upland buffers.

Finally, as discussed in Section 4.3.2.4, the runway embankment projects, with their planned mitigation, are expected to maintain or improve hydrologic conditions in downslope wetlands. Therefore, potential loss of wildlife habitat resulting from a reduction in the size and numbers of the remaining wetlands adjacent to the embankment or adjacent to other areas of project activity is not anticipated. The 18.37-acre impact value accounts for all losses of wetland and wetland habitat, including indirect losses (see Table 4-18).

4.3.2.3 Wetland Habitat Complexity and Biological Diversity

The project will not result in a loss of wetland habitat complexity or species diversity because it will not eliminate any species from the project area nor affect any rare or specialized habitat type. Genetic diversity, source populations to colonize disturbed areas, and a gene pool necessary to adapt to long-term change will not be lost because, as explained below, plants and animals in wetlands affected by the project are part of widely distributed, homogenous populations.

The existing habitat complexity and plant diversity within wetland systems affected by the project are generally low for several reasons. Historical and ongoing logging, farming, grazing, golfing, and landscaping have eliminated natural plant communities and wetland habitats. As some of these wetlands have been more or less abandoned of human activity, they have been colonized with native and non-native plants. These early successional plant communities consist of cosmopolitan plant species,[22] including native and non-native invasive grasses, forbs, and shrubs (e.g., reed canarygrass, creeping buttercup [*Ranunculus repens*], and Himalayan blackberry). Because the wetlands have generally had only a few decades or less to recover from significant disturbance,

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[22] These performance standards vary spatially within the wetland, and are based on on-site analysis of vegetation, soils, and hydrology. Near the upland wetland fringe, on inorganic soil, wetland hydrology must be present for a relatively short time period. In more central locations where organic soils or strongly reduced inorganic soils are present, the wetland hydrology must be present for much longer time periods.

[23] Cosmopolitan plant species are those that are capable of and generally do occur in a wide range of habitats and over large geographical areas. They are frequently tolerant of a wide range of soil, climate, and other habitat conditions.

there has not been enough time to establish a full diversity of native plants that might typically occur in these habitats.

Another reason existing plant diversity in the wetlands is low is because of the limited number of wetland types present. For example, most wetlands have seasonally saturated soils and lack seasonal ponding. They frequently lack saturated soil during the summer and early fall months. Given these relatively homogenous environmental conditions coupled with the existing disturbance regime, the plant communities and the variety of habitats ("niches") they provide for different species are limited and frequently similar to adjacent upland areas.

Plant species found in the wetlands are expected to be genetically similar to the larger regional population because of the relatively homogenous distribution of native plant communities in western Washington. The seed and pollen dispersal mechanisms found in these plants promote genetic homogeneity at local and regional levels. For example, many of the tree (willow, black cottonwood, red alder, and Western red cedar [*Thuja plicata*]) and shrub (willow, western hazel [*Corylus cornuta*]) species are wind-pollinated. The small pollen grains are readily dispersed hundreds of yards to tens of miles by wind. Likewise, the seeds of most of these species are similarly adapted to be dispersed significant distances by wind (many common trees and many shrubs in Washington) or animals (berry and nut producing trees and shrubs). These pollination and seed dispersal mechanisms for these common wetland plants found in the area generally prevent development of specific genotypes at the local level.

Because wind and animals readily disperse the species, seed sources that allow plants to colonize disturbed areas are typically abundant. The planned in-basin mitigation that preserves large areas of existing wetlands, maintains corridors, and restores native plant communities to over 67 acres of land near STIA will ensure that the watershed and local area are not deprived of seed sources of these wetland plants. For these reasons, a change in the resistance of the wetlands or watersheds to disturbance is not likely.

The recent plant colonization of the wetlands following various disturbances that have been ongoing for at least several decades also affects their diversity. For many species of plants that have colonized the wetlands since recent disturbance, the flora consists of a single generation of perennial plants, a condition that presents little or no opportunity for genetic divergence to occur.

4.3.2.4 Impact to Wetland Hydrology and Hydroperiod

The potential for construction of the third runway embankment and retaining walls to alter the water available to maintain adjacent wetlands and their function is addressed in this section. The hydroperiod (i.e., the depth, duration, and timing of soil saturation and flooding) of a wetland is the most important determinant for maintenance of wetland types and ecological functions (Mitsch and Gosselink 2000). For this reason, significant alterations of wetland hydrology can result in potential changes to wetland type and the functions they provide. Eliminating significant portions of a wetlands water source could convert the wetland to upland habitat. As shown in Table 4-16, where these impacts were considered possible, they were calculated as a permanent wetland impact and mitigated as such.

The wetlands adjacent to the proposed third runway embankment include forested and shrub-dominated wetlands on seepage slopes or shallow depressions (see Figure 1-3). Seasonal (fall-spring) precipitation and groundwater seepage are the dominant sources of water to these wetlands. For several wetlands (especially Wetlands 18 and 37), groundwater seepage extends the period of soil saturation to the mid-summer period, and sustains the groundwater discharge functions.

The third runway embankment has been designed with retaining walls to reduce the volume of runway fill and impervious surfaces. Design features incorporated into the project that help maintain wetlands and reduce base flow impacts include:

- A permeable rock drainage layer constructed atop existing soils, beneath the embankment footprint. This drainage layer will allow groundwater[24] that currently surfaces in the wetlands to be conveyed downslope to wetlands at the edge of the embankment.
- Drainage channels constructed along the west base of the embankment that will collect water emanating from the embankment and convey and distribute it to downslope wetlands.
- Engineered fill materials of sufficient permeability to infiltrate rainwater falling on non-paved portions of the embankment (this feature reduces the amount of surface runoff generated from the embankment and maintains shallow groundwater sources for downslope wetlands).
- Use of permeable stone columns[25] or other permeable fill as footings for retailing walls to avoid altering the patterns of groundwater movement in the vicinity of retaining walls.
- Use of retaining walls to reduce the extent of the embankment footprint, thereby reducing filling of wetlands. Retaining wall designs allow water to move vertically and laterally to prevent interruption of water flow to downslope wetlands (see Appendices B and E).

Several hydrologic modeling analyses have been conducted to evaluate the effect of the runway embankment on base flow conditions in Miller Creek and downslope wetlands (Appendix E, Appendix F, Ecology 2000, and Parametrix 2001b). These studies indicate that overall the annual groundwater base flow from the embankment area will be slightly reduced due to addition of new impervious areas. However, due to a hydraulic lag, base flow to down slope streams and wetlands will be reduced during winter and early spring months, with increased base flows to downslope wetlands during the summer months (Ecology 2000, Hart Crowser 1999, 2000, and Pacific Groundwater Group 2001).

The *SeaTac Runway Fill Hydrologic Studies Report* (Ecology 2000) identifies 1.68 acres of wetlands that could be indirectly impacted due to hydrologic changes associated with the

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[24] The sources of this water include water that infiltrates onto the existing airfield (a quantity that will remain unchanged) and water that infiltrates in undeveloped land west of the airfield.

[25] These permeable stone columns and other subgrade improvements are described in Appendices B and E.

embankment (especially the Wetland 18 and Wetland 37 complex). Further analysis of this potential impact is discussed in Sections 3.2 and 3.6 of the Ecology (2000) report. The analysis concludes (pages 7, 51, 52, and 60) that seepage into the embankment and delay in water movement through the embankment will not result in the loss of these downslope wetlands. Water will infiltrate into the embankment and eventually discharge to the downslope wetlands. Although the report identifies potential secondary impacts, it also identifies a potential net benefit to wetland hydrology during the summer months due to the delay between the time water infiltrates into the embankment and when it discharges from its base.

This analysis of potential benefit to wetland hydrology for downslope wetlands is applicable to the indirect impact analysis for the following wetlands: 3, 4, 5, 7, 8, 9, 11, A1, A11, A13, 18, 37, Channel B, and all riparian wetlands located in the west side acquisition area. Because these wetlands occur on slopes or are on the banks of the Miller Creek channel, they do not impound surface water. Increases in the wetland hydroperiod would not create surface water flooding in the wetlands that could alter the types of vegetation present. The greater amounts of water would increase soil moisture and reduce the depth to the water table. Considering the types of trees, shrubs and herbaceous vegetation that occur in these wetlands, and there adaptability to wetland conditions, increases in soil saturation of up to several weeks during the growing season is unlikely to alter the vegetation present in the wetlands.

The hydrology of riparian wetland areas, located on the east and west side of Miller Creek (see Table 4-3 and Table 4-16), will not be altered from a loss of seepage water as described in the above-referenced analysis for Master Plan Update improvements. In addition, the extensive stormwater management system will prevent increases in peak flow rates and duration of peak flows that may otherwise result in significant down cutting and bank erosion (Parametrix 2000c; see Section 4.3.2.5.)

The results of the analysis completed by Hart Crowser (2000) (Appendix E) and Pacific Groundwater Group (2001)(Appendix F) also conclude that groundwater flow rates will be similar to existing conditions. However, existing conditions are predicted to be slightly higher or lower depending on annual precipitation. This study concludes:

- Groundwater flow rates beneath the proposed embankment will generally be similar to or slightly lower than current conditions during wet years.
- Groundwater flow rates beneath the embankment will show a small increase over existing conditions during dry years.
- Although the runway project will produce slightly more surface runoff volume (especially in wet years) compared to existing conditions; the overall long-term average flows are very similar in all years.
- The longer seepage path through the embankment results in a seasonal lag, which produces a net increase in base flow to Miller Creek and adjacent wetlands in the summer and early fall.

The base flow modeling findings indicate that flows would be lower in the winter than under the current condition, and greater in summer compared to the current condition (Ecology 2000).

Ecology also noted that "flows to local wetlands and the streams will be reduced only in winter when abundant water is typically present."

A comprehensive evaluation of the potential low streamflow impacts in Miller, Walker, and Des Moines Creeks from the planned STIA improvements has been completed (Parametrix 2001b). This evaluation used an Hydrologic Simulation Program – FORTRAN (HSPF) model to evaluate the expected low flow conditions during the low flow periods of the three creeks based on 1994 land use conditions and land use conditions following all Master Plan Update improvements in 2006. This evaluation specifically addressed the following conditions:

- Late summer discharges of infiltrated water stored in the proposed third runway embankment fill.
- Changes in non-hydrologic flows within the acquisition area of the watersheds. (i.e., discontinued irrigation withdrawals from the watershed and discontinued discharge of imported water through septic system drain fields).
- Secondary recharge of runoff from pavement atop the proposed third runway embankment fills.
- Extended duration discharge from stormwater detention facilities through infiltration that will provide input to the shallow groundwater regime adjacent to Miller Creek.
- Managed release of stormwater from reserved storage to ensure that low flow discharges in streams do not fall below pre-project levels during typical low flow periods.

While analysis indicates that it is likely to be unnecessary, the groundwater hydrology of riparian and isolated wetlands adjacent to Master Plan Update improvements will be monitored for up to 15-years as described in the *NRMP* (Parametrix 2001a). The purpose of this monitoring will be to collect data that can be used to determine if hydrologic conditions in the wetlands are sufficient to maintain the existing wetland vegetation types (performance criteria for this analysis are presented in Section 5.2.4.7 and Table 5.2-12 of the NRMP).[26] If necessary, the groundwater collected in drainage channels or stormwater management systems can be redistributed to specific wetlands in amounts sufficient to maintain the desired hydrologic conditions (see Appendix D of the NRMP for details regarding replacement drainage channels).

Existing groundwater conditions in wetlands located beneath or west of the proposed embankment are discussed in Appendices B, E, and F. Based on the above analysis of groundwater movement beneath and through the embankment, the measured, post-construction groundwater elevations are

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[26] These performance standards vary spatially within the wetland, and are based on on-site analysis of vegetation, soils, and hydrology. Near the upland wetland fringe, on inorganic soil, wetland hydrology must be present for a relatively short time period. In more central locations where organic soils or strongly reduced inorganic soils are present, the wetland hydrology must be present for much longer time periods.

expected to be similar to current conditions. As a result of the delayed discharge of water infiltrating into the embankment, the occurrence of high groundwater may be extended by up to several weeks.

4.3.2.5 Stormwater Management During Operations

This section discusses the potential impacts of stormwater runoff to streams and wetlands. The analysis considers the potential for runoff generated by Master Plan Update improvements to affect aquatic habitat, and considers and describes the stormwater management facilities incorporated into project planning to protect aquatic habitat. The features of aquatic habitat protected by this mitigation include:

- Water quality (e.g., dissolved oxygen [DO], nutrients, temperature, etc.)
- substrate composition
- water quantity, depth, and velocity
- cover/shelter
- Habitat complexity (e.g., large woody debris, channel complexity, etc.)
- aquatic vegetation
- food resources
- riparian vegetation
- habitat and floodplain connectivity

These habitat features can be protected by preventing increases in peak flow discharges, protecting streams from degradation of water quality, and maintaining base flow conditions. Potential impacts and protection of water quality and hydrologic conditions are evaluated in detail in the *Comprehensive Stormwater Management Plan* (Parametrix 2000b) and the *Biological Assessment* (FAA 2000) and summarized briefly here.

Stormwater Quality and Mitigation

Overall, the Master Plan Update improvements will result in a greater volume of stormwater undergoing detention and treatment. This will be accomplished through retrofitting areas with new stormwater management facilities at STIA as well as detaining and treating all stormwater associated with new impervious surfaces from Master Plan Update improvements. A result of the retrofitting will be reductions in copper and zinc currently discharged to Miller, Walker, and Des Moines Creeks through the collection and routing of stormwater to the IWS system.[27] However, operations at STIA following implementation of the Master Plan Update improvements could still affect water quality through the discharge of conventional pollutants and chemicals used in ground and aircraft de-icing to adjacent streams and the discharge of these same chemicals to the Puget Sound in IWS effluent. However, failure or overflow of the IWS system is unlikely, as discussed in

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[27] Analysis of stormwater quality is evaluated in FAA (2000) and concludes that changes in the IWS discharges resulting from the project will not adversely affect fish habitat in Miller and Des Moines Creeks or the IWS outfall.

the *Comprehensive Stormwater Management Plan* (Parametrix 2000c). Analysis of aircraft deicing and anti-icing fluids used at STIA as well as the projected concentrations of pollutants in stormwater and IWS effluent indicates that the concentrations of these chemicals will not adversely affect wetlands and aquatic habitat in Miller, Walker, and Des Moines Creeks as discussed below.

Water quality impacts will be mitigated (to maintain or improve the existing condition) by establishing and maintaining water quality treatment BMPs. These BMPs are sufficient to protect wetlands and other surface waters and also meet or exceed the requirements of the Ecology Manual (Ecology 2001; Parametrix 2000b). Additionally, existing developed areas that currently lack water quality treatment BMPs will be retrofitted with water quality treatment BMPs to the maximum extent practicable (Parametrix 2000b). This retrofitting will further ensure wetlands and streams are protected from water quality degradation. Water quality treatment of new surfaces plus treatment retrofitting of existing surfaces will result in treatment for 189 percent of new impervious surfaces (100 percent of new facilities, plus additional areas equivalent to 89 percent of the existing facilities that do not now have treatment facilities) (FAA 2000). Additional measures to mitigate water quality impacts include source control and the operation and expansion of an IWS to treat stormwater runoff generated from high-use areas (Parametrix 2000b).

Characterization of STIA stormwater, potential effects on aquatic habitat, and mitigation measures are discussed below.

Bioassay Testing. The effect of stormwater runoff on aquatic habitat downstream of the Port discharge points has been evaluated using knowledge of stormwater toxicity as described by FAA (2000). Bioassay screening tests in Miller and Des Moines Creeks downstream of existing STIA stormwater outfalls demonstrated no toxicity to either fathead minnows (*Pimephales promelas*) or the freshwater crustacean *Daphnia pulex*. For all tests, there was 100 percent survival in the undiluted stormwater and the stormwater was thus non-toxic to the exposed test organisms.

Whole Effluent Toxicity (WET) tests performed on effluent from existing STIA stormwater outfalls, to satisfy NPDES Permit requirements (see FAA 2000), used standard and sensitive species (the *Daphnia pulex* and the *Pimephales promelas*) protocols.[28] The WET test results are conservative because they represent conditions before dilution in the receiving waters. WET samples did not account for flow through facilities such as Lake Reba, where physical, chemical, and biological processes will capture or transform dissolved pollutants.

Of the four outfalls tested, three met the WET performance standards, demonstrating an overall lack of toxicity in samples consisting of 100 percent STIA stormwater. The runoff from the three outfalls in which no toxicity was measured is most representative of runoff expected from airport activities included in the Master Plan Update, including drainage from runways, taxiways, hangers,

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[28] The invertebrate *Daphnia pulex* is more sensitive to the types of pollutants expected to cause toxicity in STIA stormwater than salmonids (USEPA 1985).

terminal facilities, cargo handling areas, etc. Only one outfall (SDN-1) demonstrated toxicity. Runoff from galvanized rooftops was identified as the source of toxicity (Port of Seattle 2000). These rooftops cover a limited area of the SDS (approximately 2 acres, or about 0.5 percent of the SDS) and are not representative of Master Plan Update improvement projects, which will not use zinc-treated roofing materials. Furthermore, the toxicity observed in SDN-1 does not result in instream toxicity, as demonstrated by the results of the instream toxicity screening (see above). The lack of toxicity is likely the result of runoff flowing through vegetated drainage channels and Lake Reba, where physical, chemical, and biological processes remove and dilute dissolved pollutants prior to entering Miller Creek. The Port is reducing or eliminating the source of zinc from the SDN-1 rooftops through the application of roof coatings or other treatments.

Although the above observations demonstrate that stormwater runoff is not toxic, May et al. (1997) conducted a comprehensive study of Puget Sound streams (including Miller and Des Moines Creeks) that concluded that chemical water quality does not represent the critical factor to biota in urban streams. Rather, they found streambed and bank stability (altered by changes in runoff volume) were determined to be the "most significant problems" in Puget Sound urban streams.

Mitigation. Water quality mitigation actions include pollutant source control, water quality treatment (including the IWS), and off-site enhancements of wetland and stream water quality functions. These actions are listed in Table 8-1 of the BA (FAA 2000) and Section 7.1.4 of the BA. As described in Section 7.1.4.4 of the BA, stormwater treatment is designed to serve 189 percent of the new impervious surface associated with the project. This level of treatment compensates for the potential inefficiencies of BMPs; therefore, no significant water quality degradation would occur.

Water Quality Treatment BMPs. All new Master Plan Update pollution-generating impervious surfaces (PGIS) in STIA subbasins will receive water quality treatment to meet or exceed the requirements of the Ecology Manual as discussed above and in the SMP (Parametrix 2000b). Existing developed areas that do not have BMPs consistent with the Ecology Manual will be retrofitted with water quality treatment BMPs to the maximum extent practicable.

The primary water quality BMPs for existing and proposed PGIS will be filter strips and bioswales. In these facilities, water quality treatment occurs as runoff from impervious surfaces sheet flows over broad, shallow-sloped grassy areas (filter strips), or is directed through grass-vegetated swales (bioswales). The gentle slopes and large surface area slow runoff rates and enhance the settling of particulate matter. Water infiltrates into the ground as it flows over the vegetated area, further filtering out particles. Removal of metals and organic compounds is also significant because these pollutants bind to trapped particles and/or the organic material in the soil and vegetation. In areas where adequate space is not available, treatment may also be provided by wet vaults, which remove particulate matter and other sorbed pollutants by settling.

Filter strips and bioswales have proven effective for most pollutants in runoff from STIA, as demonstrated by pollutant concentration data and toxicity testing at STIA outfalls. As required by the Port's NPDES Permit, ongoing monitoring will demonstrate the effectiveness of BMPs and, where necessary, will indicate where additional levels of protection may be necessary. The Port's NPDES Permit provides appropriate and effective mechanisms for monitoring BMP performance and improving BMPs when necessary.

The King County Manual (King County DNR 1998) requires that high-vehicle-use areas[29] (i.e., road intersections with high vehicle counts) have oil control treatment. The upper and lower terminal drives appear to fall under the high-use definition, and will be retrofitted with oil control treatment or runoff will be diverted to the IWS (Parametrix 2000b). The IWS meets or exceeds the requirements for oil control treatment.

Source Control. Source identification and controls used at STIA are listed in Table 4-18. Source controls include passive measures (such as warning signs on catch basins and education of airport and tenant employees) and active measures (such as sweeping near and cleaning catch basins).

Source identification is also an important part of source control. As required by its NPDES Permit, if elevated pollution levels or toxicity are measured in STIA stormwater, the Port updates its *Stormwater Pollution Prevention Plan* to eliminate or provide treatment for the source. Source control BMPs are reviewed and approved by Ecology and meet or exceed the requirements of the King County and Ecology Manuals.

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[29] The *King County Surface Water Management Manual* (King County DNR 1998) defines high-use sites as any one of the following:

- commercial or industrial site subject to average daily traffic count equal to or greater than 100 vehicles per 1,000 ft^2 of gross built area, or
- commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, or commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more diesel vehicles that are over 10 tons gross vehicle weight, or
- a road intersection with average daily traffic of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway.

- commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more diesel vehicles that are over 10 tons gross vehicle weight, or
- a road intersection with average daily traffic of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway.

Industrial Wastewater System. The IWS collects stormwater from the terminal, air cargo, hangars, maintenance, and parking areas[30]. Stormwater from these areas may be contaminated by accidental fuel spill, de-icing chemicals, and wastewater from cleaning of aircraft or ground support vehicles. The IWS system prevents runoff and pollutants from reaching Miller or Des Moines Creeks, and the critical habitat located near their mouths at Puget Sound. The IWS consists of collection piping, two primary storage lagoons (Lagoons 1 and 2), a third lagoon for additional storage (Lagoon 3), and an Industrial Wastewater Treatment Plant (IWTP).

Table 4-18. Seattle-Tacoma International Airport source control BMPs (as approved by Ecology).

Activity	BMPs
Aircraft servicing	Restrict to IWS areas or block drains Store glycol in IWS areas Confine parking of lavatory waste trucks to IWS Identify and divert potential sources of industrial pollutants to IWS Restrictions for fueling on taxiway Alpha Monitor SDS outfalls during de-icing
Aircraft Movement Area (AMA) anti-icing/de-icing	Minimize de-icing chemical use Use calcium magnesium acetate (CMA)/sand mixture for roadways
Snow storage	Operate pump stations to divert snowmelt to IWS
Spill control	Implement spill plan

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[30] The IWS lagoons detain industrial wastewater, settle solids, and equalize flows to the IWTP. The IWTP treats water by (1) flash-mixing aluminum chloride into the influent water to flocculate particulate matter and oils, (2) using dissolved air flotation to carry the floc to the surface, and (3) employing a skimmer to remove the floated contaminants. A pipe, then conveys treated water approximately 2 miles to the Midway Sewer District effluent pipe which discharges directly into Puget Sound via a 200-ft-long diffuser located 1,800 ft offshore at a depth between 156 and 178 ft below mean sea level. The discharge is permitted by the Port's NPDES Permit (Ecology 1998b). IWTP effluent is monitored continuously for flow; weekly for pH, total suspended solids (TSS), and oil/grease; and monthly for biochemical oxygen demand (BOD), glycols, and total petroleum hydrocarbons (TPH).

Table 4-18.Seattle-Tacoma International Airport source control BMPs (as approved by Ecology) (continued).

Activity	BMPs
Vehicle washing and maintenance	Prohibit vehicle washing in SDS areas Place signs in key locations Clean sumps in Taxi Yard annually Sweep Taxi Yard and control litter Maintain catch basin inserts
AMA maintenance	Sweep pavement frequently Inspect catch basin sumps annually and clean as needed Store and dispose of sediments properly Construct secondary containment for used engine fluids
Inappropriate connections and discharges	Inspect outfalls for evidence of illicit connections
Temporary storage of surplus and used materials	Store liquids in approved secondary containment or IWS areas only Control entry of surplus materials
Landscape management[a] (in developed areas)	Implement *Integrated Pest Management Plan* as appropriate, use biological methods of pest management as top priority. Use environmentally benign chemicals only when necessary. If landscape chemicals are used: Follow proper cleaning/disposal procedures Apply during dry periods Restrict use near waterways Incorporate BMPs into contractor specifications Follow Ecology guidelines for herbicide application Apply herbicides/pesticides according to instructions Fertilize shrubs and trees by hand Avoid catch basin grates when applying fertilizer or pesticides Conduct regular weeding and pruning Trim ivy-covered areas by hand (do not use herbicides) Do not use beauty bark in drainageways
Tenant activities in SDS areas	Monitor and educate tenants on source and spill control De-ice aircraft according to established procedures Encourage drip pans beneath fueling trucks if leakage is observed Sweep around dumpsters Store liquids in secondary containment Do not store used fluids or hazardous waste in SDS areas Do not maintain vehicles or equipment in SDS areas Inspect catch basin grates Require tenant water pollution control plans Enforce tenant compliance with *Port Stormwater Pollution Prevention Plan* (SWPPP) Require tenant spill control plans
Other operational BMPs	Evaluate operations and revise standard operating procedures to minimize pollution Designate an SWPPP implementation monitor Conduct regular inspections of SWPPP elements Assemble pollution prevention team Conduct SDS outfall monitoring Sign catch basins ("dump no waste – drains to salmon stream") Establish packing material source control

[a] Port of Seattle (1999)

Effluent water quality limits, established in the Port's NPDES Permit, have been met since November 1996 with one exception in July 2000[31] (Ecology 1998c).

Pollutant Removal in Lake Reba. Lake Reba, a stormwater facility constructed by the Port in 1973, collects and detains stormwater from the north end of STIA and discharges it to Miller Creek. In addition to stormwater detention provided by live storage (volume that drains dry between storms), Lake Reba has a permanent pool that allows the facility to act as a wetpond. Wetponds are water quality treatment BMPs that function by settling solids and by allowing physical, chemical, and biological mechanisms to capture and/or transform dissolved pollutants (Horner et al. 1994). Pollutants such as heavy metals and nutrients that adsorb to particulates are removed as well.

Snowmelt Facility. The Port uses a snowmelt facility to store melting snow after de-icing chemicals have been applied to the runways and taxiways. The facility drains to a pump station that diverts meltwater to the IWS. This BMP reduces the amount of BOD in runoff reaching Miller and Des Moines Creeks.

Aircraft Anti-Icing and De-Icing Within IWS. Aircraft anti-icing and de-icing is performed only within areas draining to the IWS and conforms to the operational source control BMPs for airports as identified by Ecology (2001a). This BMP minimizes glycols in stormwater runoff to Miller and Des Moines Creeks.

Emergency Response. Spill prevention, control, and response procedures are described in the Port's *Spill Prevention Control and Countermeasure Plan* (SPCCCP). The plan emphasizes prevention of spills in the SDS basins, and also includes complete control and response procedures for spills (summarized in the flowcharts that are part of the plan). Two spills in the SDS have occurred in the last 5 years, both in subbasin SDS-4. In both cases, the spill was completely contained on Port property using the SPCCCP response procedures and no TPH was detected in Des Moines Creek downstream of the spills.

Enhancement of Wetland Water Quality Functions. Existing degraded wetlands in the Miller and Des Moines Creek basins will be enhanced to restore their natural water quality functions (Parametrix 2000a).[32] As described in Mitsch and Gosselink (2000), wetlands naturally benefit water quality by:

- Increasing settling and mechanical trapping of particulates

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[31] A single TSS excursion occurred in Summer 2000 during an atypical event. Under current conditions, pumping Lagoon 3 completely empty would disturb sediment on the bottom of the lagoon. Therefore, a small amount of water normally is allowed to remain in the bottom of the lagoon. To allow for Lagoon 3 expansion construction, it was necessary to pump and treat this water. Algae concentrated in this small amount of water was sufficient to cause a TSS excursion. This excursion is a result of one-time operational conditions.

[32] No natural wetlands will receive untreated stormwater from Master Plan Update improvements.

- Removing metals and other toxins that bind to particulates
- Reducing and binding metals in humic material
- Biological removal/uptake of nutrients

Additionally, some restored wetlands will replace existing cultivated land and golf course that are current pollution sources.

Miller Creek Buffer Enhancement. Riparian buffers along approximately 6,500 linear ft of Miller Creek will be enhanced (Parametrix 2001a). Native trees, understory plants, and ground cover will replace lawns, agricultural areas, golf course, and other areas. These enhanced riparian buffers will remove pollutant sources and restore buffer quality and continuity. As described by the Committee on Protection and Management of Pacific Northwest Anadromous Salmonids (CPMPNAS) (1996) and Forman and Gordon (1986), enhanced buffers will:

- Increase biofiltration of runoff flowing into the stream from riparian areas
- Reduce erosion in riparian areas
- Shade the stream to reduce stream temperatures and increase DO

Miller Creek Stream Channel Restoration and Enhancement. Approximately 1,500 ft of the Miller Creek channel will be restored and enhanced by revegetating eroding and hardened streambanks and installing LWD in the channel (Parametrix 2001a). These restoration activities will provide water quality benefits to Miller Creek by reducing channel erosion and downstream sedimentation.

Water Quality Impacts from Filling Wetlands. Although the water quality functions of the existing wetlands will be lost when these wetlands are filled, the overall project, including the planned mitigation, is likely to result in improved water quality in Miller and Des Moines Creeks. This is true for several reasons.

First, a number of the existing wetlands that will be eliminated or impacted by Master Plan Update improvements do not provide optimal water quality treatment functions. The treatment function in some of these wetlands is sub-optimal due to a short residence time (as inferred by wetlands on slopes, small size, topography that limits ponding and storage of water, and channelized flow) and a lack of dense emergent vegetation. The above-mentioned factors are typically associated with wetlands with high function for water quality improvement.

Second, the proposed stormwater management facilities will include water quality treatment (Parametrix 2000b). This will primarily consist of biofiltration swales and filter strips, as well as wet vaults where biofiltration is not feasible. These water quality treatment facilities will be constructed to meet Ecology and NPDES requirements. These facilities will be at least partially effective in replacing the water quality functions of the wetlands to be filled.

It is noteworthy that existing wetlands (to be filled) receive untreated stormwater runoff from non-STIA areas. For example, existing wetlands downslope of 12th Avenue South receive untreated stormwater runoff from 12th Avenue South and provide treatment (at less than optimal rates) prior to discharge to Miller Creek. Treating stormwater likely degrades some of the biological functions also provided by the wetlands. Following construction of the embankment, runoff will be treated by water quality treatment BMPs (Parametrix 2000b), which should enhance the biological functions of the remaining wetlands.

Third, and perhaps most important, construction of Master Plan Update improvements and mitigation measures will improve the quality of water draining to the streams and wetlands. These include:

- For areas within development footprints, existing pollution-generating impervious areas within the acquisition area (e.g., lawns, streets and driveways) that currently lack water quality treatment facilities will be removed. These areas will be replaced with embankment and other facilities with stormwater management BMPs.
- For areas to remain undeveloped, but not specifies as mitigation, the removal of residential and commercial land-uses will eliminate pollutant sources, including failing septic tanks, fertilizer, runoff, and other potential pollutants (pesticides, pesticide residues). If redevelopment of these areas occurs, then stormwater management standards for water quality treatment and runoff rates must be met at the time of development. These standards would exceed the baseline condition (lacking any stormwater BMPs), and maintain water quality benefits compared to the current condition.
- For areas in the Vacca Farm mitigation area, the restoration of farmed areas in the Miller Creek floodplain with native wetland vegetation will reducing erosion, pollutant sources, and increase the area's water quality treatment capacity to remove nutrients and pollutants from Miller Creek and stormwater runoff from adjacent areas.
- For the Miller Creek and Wetland A17 mitigation areas, the enhancement of wetlands and buffers will eliminate pollutant sources, including failing septic tanks, fertilizer, runoff, and other potential pollutants (pesticides, pesticide residues). Planting of these areas native upland and wetland vegetation will reduce erosion, pollutant sources, and increase the area's water quality treatment capacity to remove nutrients and pollutants from Miller Creek and stormwater runoff from adjacent areas.
- For mitigation along on the Tyee Valley Golf Course and along Des Moines Creek, removal of golf course uses would remove fertilizer and pesticide runoff to the creek. Planting of these areas native upland and wetland vegetation will reduce pollutant sources and increase the area's capacity to remove nutrients and pollutants from Des Moines Creek and stormwater runoff from adjacent areas.

In addition, a $300,000 trust fund will be created to support watershed restoration projects that may improve the water quality in the streams and wetlands. The overall effect of all these changes and measures is likely to be improved water quality in Miller, Walker, and Des Moines Creeks.

Hydrologic Impacts and Mitigation

Master Plan Update improvements will increase impervious surface areas in the Miller and Des Moines Creek watersheds. Stormwater detention facilities will prevent increases in peak flow rates and erosive flows (Parametrix 2000b). The proposed detention and treatment facilities will manage runoff from both newly developed project areas and existing airport areas. The net result of flow controls for the Master Plan Update improvements will be to reduce peak flows and erosive flows in Miller, Walker, and Des Moines Creeks downstream of the STIA discharges. These actions will enhance hydrologic conditions in the streams and associated estuaries and prevent impacts to aquatic habitat.

Wetland Fill Impacts. The potential impacts to the hydrology of Miller, Des Moines, and Walker Creeks from filling 18.37 acres of wetlands are the loss of stormwater storage, groundwater recharge, and groundwater discharge. These functions are discussed below, and all wetland hydrologic functions are accounted for in the HSPF model, which assesses runoff impacts of wetlands through various input parameters and calibration.

Stormwater Storage. Most wetlands filled by the project provide limited stormwater storage because the wetlands do not occur in closed basins or basins with restricted outlets that would allow water to pond during storms, and release water slowly following storms. Most wetlands occur on moderate to gentle slopes and are therefore free-draining and seldom, if ever, store water.

Flood Storage and Peak Flow Attenuation. The riparian wetlands located in the 100-year floodplain of Miller Creek provide some flood storage functions (however, due to their generally small size and shallow depth, this function is limited). Approximately 8,455 cy of flood storage would be filled at Vacca Farm, and approximately 9,589 cy of new floodplain will be excavated adjacent to the stream. All flood storage, including that provided by wetlands, is accounted for in the calibration of the HSPF model; design of stormwater detention facilities using this model will ensure that flow mitigation is provided to account for impacted wetlands.

Groundwater Discharge. Several wetlands are sites of groundwater discharge, and thereby potentially provide base flow support to streams during all or portions of the year. Where fill occurs in these wetlands, the project has been designed to allow these discharge functions to continue. For example, the third runway embankment is designed with an internal drainage system to collect water that currently infiltrates on the airfield and discharges in wetlands near 12th Avenue South. The drainage system will also collect water that infiltrates into the new embankment, and discharge it to wetlands and Miller Creek (see Section 4.3.2.4 and Appendices F and G). Drainage systems associated with the retaining wall, which will be constructed to reduce wetland impacts, will also convey groundwater downslope to wetlands and the stream. Groundwater discharge effects on base flow are accounted for in the calibration of the HSPF model.

Groundwater Recharge. Most wetlands affected by fill are unlikely to have significant groundwater recharge functions because they occur on till soils, where layers of low-permeability till restrict groundwater recharge. The low permeability of till soils results in poor drainage conditions, which in combination with topography and surface drainage features, promotes the development of wetlands. Other wetlands occur in areas of known groundwater discharge (i.e., wetlands formed by local groundwater discharges) and thus cannot recharge groundwater. However, the HSPF model is based on the premise that all wetlands infiltrate; thus, the model conservatively accounts for potential impacts to groundwater recharge as a result of filling these wetlands. Overall, development of impervious surfaces from Master Plan Update improvements could reduce groundwater recharge and eventual groundwater discharge to streams. These functions are accounted for in the HSPF model, and mitigation for these effects is included in the activities discussed in the NRMP (Parametrix 2001a) and SMP (Parametrix 2000b).

Stormwater Peak Flow Mitigation. The Port will construct stormwater conveyance, detention, and water quality treatment facilities to manage runoff from both newly developed project areas and existing airport areas, as described below. Additional detail on the proposed stormwater controls is provided in the SMP (Parametrix 2000c). The SMP describes stormwater management for the STIA Master Plan Update improvements. The stormwater management facilities will mitigate the impacts of new impervious surfaces in the Miller, Walker, and Des Moines Creek basins, as required by current stormwater regulations and mitigation goals identified during the environmental review process. The facilities will also mitigate stormwater impacts from current development by reducing the magnitude and duration of peak flows.

Level 2 Stormwater Discharge Standards for New Master Plan Update Improvements and Retrofitting for Existing Airport Areas. To protect instream habitat, the Port has committed to achieving Level 2 flow controls. The Level 2 flow control standard, as defined by the King County (1998) Manual, requires matching or improving post-developed flow duration to pre-developed flow durations[33] for all flow magnitudes between 50 percent of the 2-year event and the full 50-year event.

The Level 2 flow control standard analysis is more protective than the Level 1 standard and current Ecology standards (Ecology 2001a). As opposed to modeling peak flows for a single design event, the Level 2 analysis requires that a continuous simulation of 50 years of rainfall be modeled, and that facilities be designed to control the duration of erosive flows as well as the peaks. Level 2 is therefore more protective of stream morphology, habitat (such as stream substrate), and hydrologic flow patterns.

The pre-developed condition for the Level 2 standard will be based on a *target flow regime* that assumes the existing watershed land cover is 10 percent impervious (or less if the existing impervious area is less than 10 percent impervious), 15 percent pervious "grass," and 75 percent pervious "forest."[34] By achieving target flows based on a theoretical basin development of 10 percent impervious,[35] Master Plan Update improvement stormwater facilities will reduce peak flows and duration, restore a more natural hydrologic regime, and stabilize stream channels.

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[33] Flow duration control refers to limiting the duration of geomorphically significant flows (i.e., those flows that initiate bedload movement) to baseline (pre-Master Plan Update) conditions.

[34] In areas where existing impervious area is less than 10 percent, the difference between actual percent impervious and the 10 percent threshold is assumed to be grass.

[35] The existing impervious areas in the Miller and Des Moines Creek watersheds are 23 percent and 32 percent, respectively.

In the Des Moines Creek basin, the target flow regime was determined in a study by the University of Washington (King County Capital Improvement Project [CIP] Design Team 1999). The flow regime determined for Des Moines Creek coincides with a target flow regime that would occur with an effective watershed impervious area of 10 percent. In studies of several Puget Sound streams, Booth and Jackson (1997) identified an approximately 10 percent impervious area threshold above which stream channel instability and habitat degradation occur.

Flow retrofitting in the watersheds will replicate a flow regime that would occur at a watershed imperviousness of 10 percent or less. That is, even though the Miller and Des Moines Creek watersheds have an existing impervious area of about 23 and 32 percent, respectively, the planned facilities will reduce flows to a level corresponding to approximately 10 percent impervious.[36,37]

Estimated Detention Storage Requirements. Proposed stormwater detention facilities for the Master Plan Update improvements were designed based on the drainage area served by each facility, the detention standard, and potential for waterfowl attraction. Approximately 344 acre-ft of new stormwater detention storage will be needed to mitigate the impacts of increased stormwater runoff associated with Master Plan Update improvements (Table 4-19). The locations of new facilities are shown in Figure 4-11.

Table 4-19. Summary of required detention facility volumes

Watershed	Hydrologic Evaluation Point	Volume Required (acre-ft)	Type of Facility[a]	Comments
Miller Creek	NEPL	13.9[b]	Vault	In addition to existing 4 ac-ft
	CARGO	4.5	Vault	
	SDN2x + SDN4x	44.4	Vault	
	SDN3/3x	25.2	Vault	
	SDN1	5.6	Vault	
	SDN3A	Pond: 14.8 / Vault: 7.0	Pond/Vault	
	SDW1A	Pond: 25.5 / Vault: 7.4	Pond/Vault	Infiltration used
	SDW1B	53.6	Pond	Infiltration used
Total Miller Creek		**171.8**		

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[36] The HSPF model was calibrated with recorded streamflow data and analysis of basin land uses prior to simulation with Level 2 flow controls. The calibration accounts for flows attributable to each land use, based on existing conditions. Flows for other land uses (10 percent impervious surfaces and conditions with Master Plan Update improvements) and Level 2 flow controls were then simulated with the HSPF model (Parametrix 2000b).

[37] This retrofit analysis applies to the basin upstream of the Miller Creek detention facility and the Des Moines RDF.

Table 4-19. **Summary of required detention facility volumes (continued)**

Watershed	Hydrologic Evaluation Point	Volume Required (acre-ft)	Type of Facility[a]	Comments
Total Walker Creek	SDW2	**10.9**	Pond	
Des Moines Creek	SASA Detention Facility	33.4 [c]	Pond	
	Interconnecting taxiway (SDS3A)	5.5	Vault	
	Third Runway South (SDS7 and 6)	21.6	Vault	
	SDS3	88.0	Vault	
	SDS4	12.9	Vault	
Total Des Moines Creek		**161.4**		

[a] Types of facilities: Vault – enclosure with multiple orifice outlets on vertical riser with overflow spillway. Pond – open earth construction with netting or other means to provide wildlife deterrent.

[b] Volume needed to retrofit existing facility.

[c] Retrofit STIA area only.

Pond and Vault Construction and Operation. The feasibility of proposed stormwater ponds and vaults is demonstrated by the recent construction of similar facilities at STIA, including the North Employees' Parking Lot (NEPL) Vault in 1997 and the Interconnecting Taxiways Vault in 1998. The SASA detention pond will displace a 0.06-acre shrub wetland, and Pond D will eliminate Wetland 41. All other on-site detention facilities will be constructed in non-wetland areas. The relation of stormwater facilities to downslope wetlands and groundwater tables is evaluated in Section 4.3.2.10.

The primary discharge from the detention facilities will be surface discharge and infiltration. Detention facilities will consist of dry ponds with live storage[38] and will not include wet ponds with dead storage.

Low Streamflow Impacts. The effects of the Master Plan Update improvements on low flows in nearby streams and groundwater discharges to downslope and riparian wetlands are discussed in Section 4.3.2.4.

Net Result of Hydrologic Mitigation. The net result of flow controls for the Master Plan Update improvements will be to reduce flows in Miller, Walker, and Des Moines Creeks to a stable flow regime downstream of STIA discharges. Level 2 facilities will retrofit existing flows to the target

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[38] Live storage is that volume of stormwater stored in a detention facility that drains following the storm. Live storage is used for hydrologic benefit to reduce flow peaks and durations.

watershed flow regime before new development in considered. The net effect of flow controls for Miller, Walker, and Des Moines Creeks (Figures 4-7, 4-8, and 4-9) will be to maintain flows below existing conditions or the target watershed flow regimes following Master Plan construction and flow mitigation, whichever is less. The target flow regime will reduce flows in the stream channels, thereby reducing erosion and improving channel stability.

4.3.2.6 Floodplain Impacts

Filling of wetlands within 100-year floodplains is limited to those in the Vacca Farm area. On-site floodplain mitigation is incorporated into restoration at the Vacca farm site (Parametrix 2001a) to replace this impacted function (see "Hydrologic Impacts and Mitigation" in Section 4.3.2.5). The mitigation consists of regrading upland areas to match elevations of filled floodplain and restoring the area with native wetland vegetation.

4.3.2.7 Retaining Walls

The Port has taken a number of important steps to avoid risk of instability or other adverse impacts from the mechanically stabilized earth (MSE) walls. These include:

- Completion of detailed explorations and in-situ tests to thoroughly and completely identify conditions in the subgrade soils that will support the MSE walls
- Replacement or improvement of subgrade soils to support the MSE walls
- Development of construction quality control specifications by specialists in MSE wall technology, and who have successfully completed more than 10 MSE walls exceeding 90 ft in height
- Use of select soil materials for construction to provide adequate drainage behind and below the walls

The design and geotechnical evaluations of the MSE stabilized earth wall are explained in *Geotechnical Engineering Report-404 Permit Support-Third Runway Embankment* (Hart Crowser 1999, Appendix B), and *Geotechnical Summary – Third Runway Embankment and MSE Retaining Walls* (Hart Crowser 2001). Additional geotechnical evaluation of subgrade conditions and the structural foundation of the MSE wall is provided in *Proposed MSE Wall Subgrade Improvements-Seattle-Tacoma International Airport* (Hart Crowser 2000; Appendix B), where the components of the MSE wall foundation and subgrade soil improvements are described.

Potential indirect impacts of the retaining wall could include an alteration of groundwater hydrology west of the embankment and alterations of the microclimate conditions near Miller Creek as a result of shading and/or increased adsorption and reflection of heat energy. The analyses of these potential impacts are based on the wall designs presented in Appendix B.

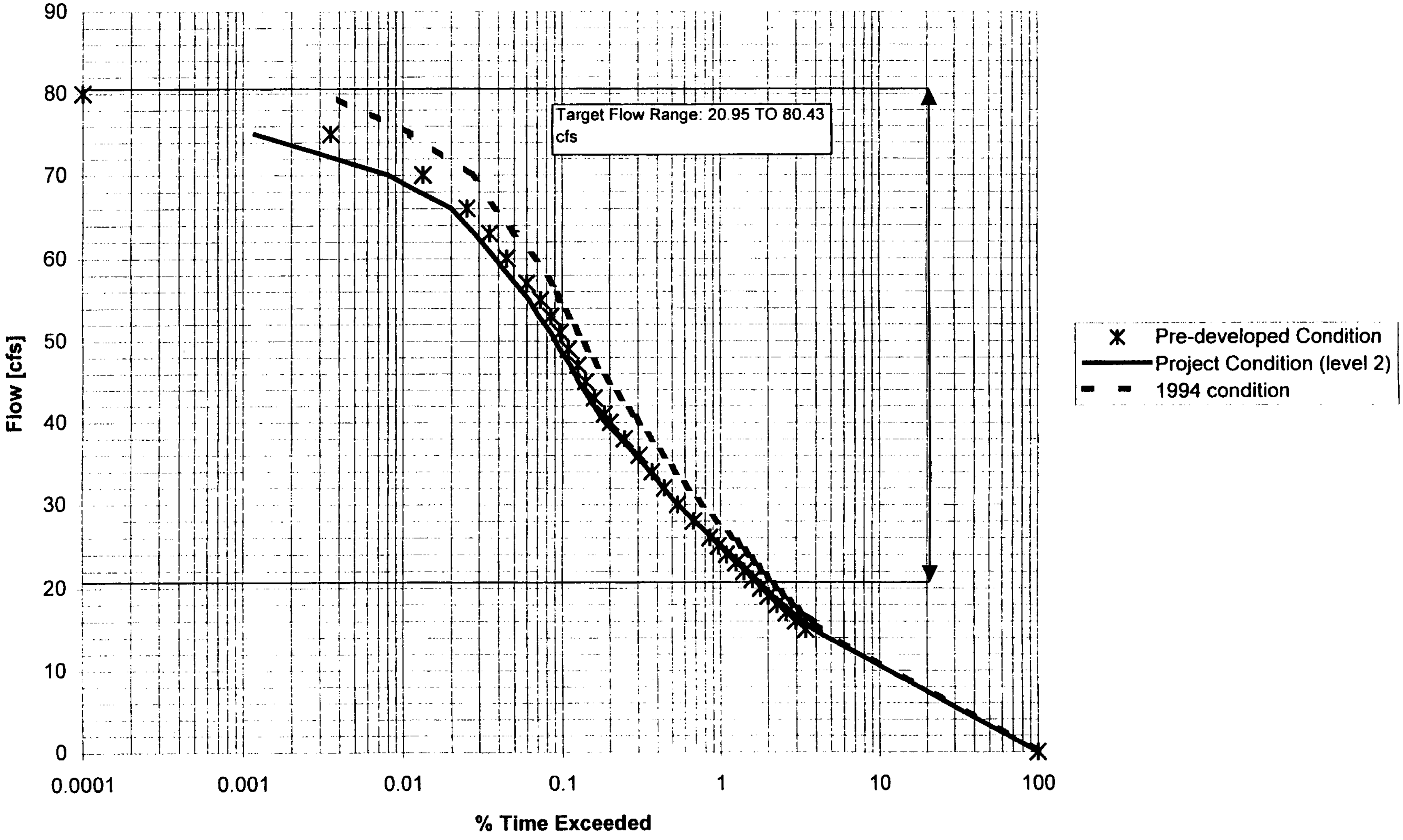


Figure 4-7
Flow Duration Curve for
Miller Creek at SR 509

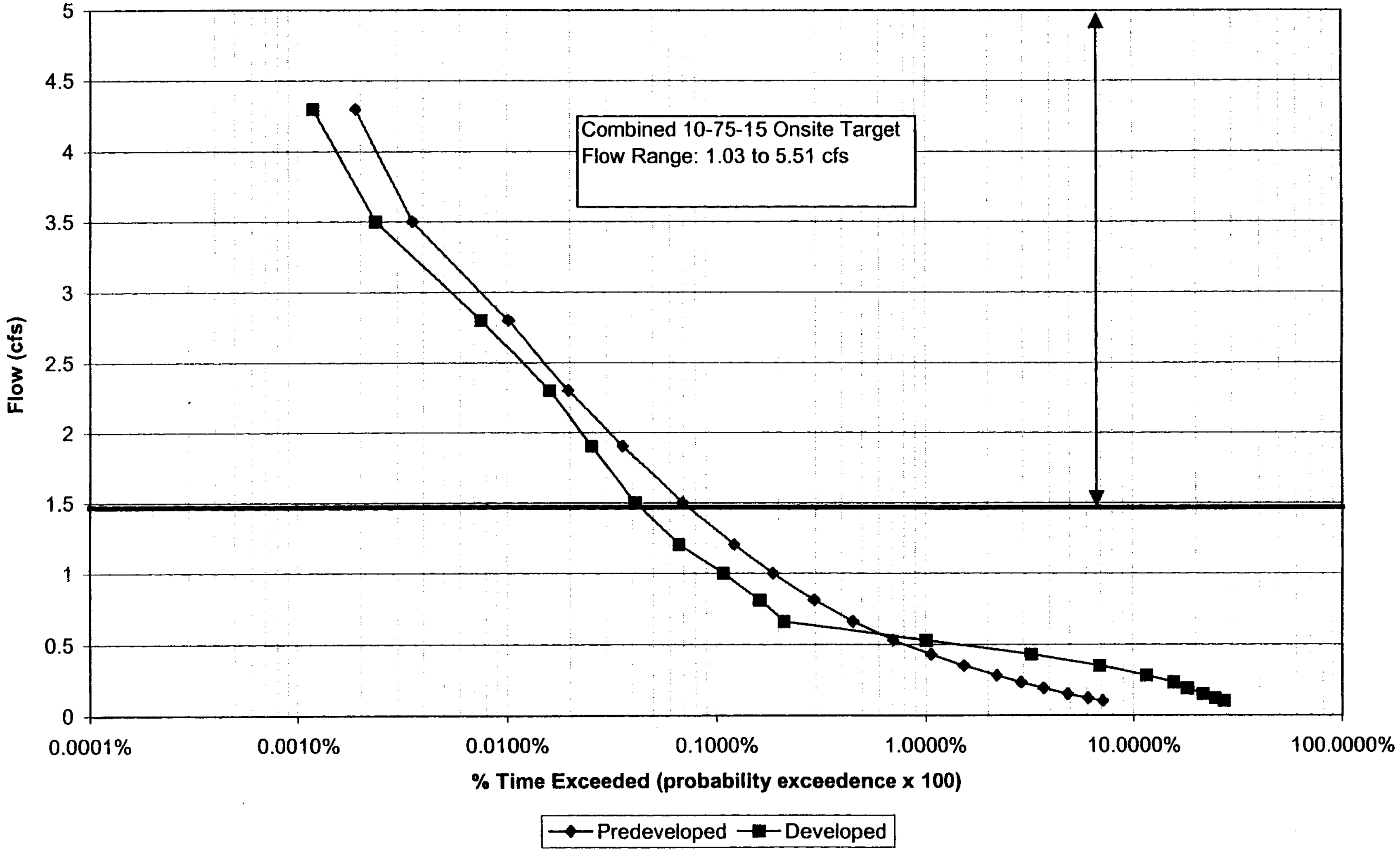


Figure 4-8
Flow Duration Curve for
Walker Creek at South 12th Street

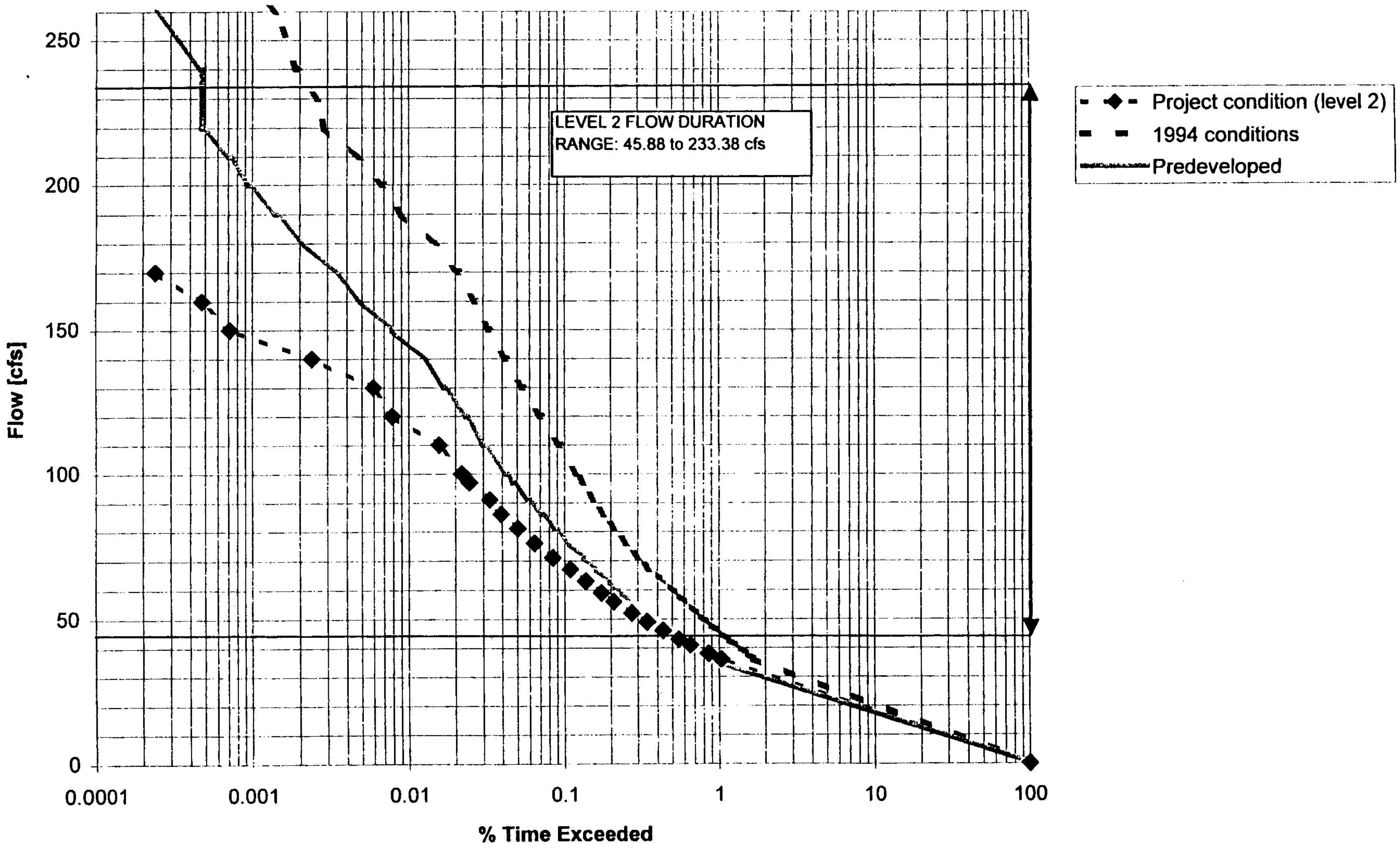


Figure 4-9
Flow Duration Curves for Des Moines Creek at South 200th Street

Hydrologic Impacts

A potential indirect impact to downslope wetland hydrology could occur if the MSE wall and its subgrade improvements significantly altered the movement of ground or surface water to wetlands. The design of MSE walls prevents impacts to groundwater movement and downslope wetlands, as explained below:

- *Removal/replacement of unsuitable subgrade soils* - Where subsoils are unsuitable for wall construction, they will be removed and backfilled with relatively free-draining structural fill. The permeability of this fill will be greater than the existing surficial soils it replaces, and will readily transmit groundwater. While the new subgrade materials are capable of transmitting groundwater at relatively high rates, the overall flow of water through the soils beneath the embankment will remain similar to existing rates. The reason flow rates will remain similar is because of the limited spatial area where unsuitable soils will be replaced and because the hydraulic conductivity of the existing subsoils will continue to control groundwater flow.
- *Stone columns* - Stone columns (Appendices B and E) would be used as subgrade improvements in some locations. Stone columns would be constructed of coarse gravel, of greater permeability than the existing silt and clay soils they are placed in. Because of their permeability and because they will occupy only about 17 percent of the soil volume, they will not impede groundwater movement.
- *Concrete bearing pad* - The bottom of the MSE wall will rest on a 6-inch-high concrete pad. This structure will not impede groundwater flow because of its small height relative to the thickness of the aquifer or perched water zones.
- *Concrete facing panels* - The MSE wall will be faced with concrete panels that are spaced with a ¾-inch gap around their perimeter. This gap allows the MSE-reinforced zone to drain through the facing, and prevents water from accumulating behind the panels.
- *Reinforced zone* - The reinforced zone itself consists of free-draining backfill reinforced with steel strips (about ¼ inch thick x 4 inches wide) that extend laterally into the backfill. The reinforcing will not impede groundwater movement because of the small area occupied by the strips relative to aquifer conditions and the high permeability of the soils in the reinforced zone.

Microclimate Impacts

There is no reason to suspect that the MSE walls would be detrimental to microclimate conditions in forest and shrub wetlands located more than 50 ft away from its base, or Miller Creek located more than 100 ft from its base. These habitats are protected since more than a third of the wall is shaded by forest vegetation and the potential for any impact to the creek is further reduced since the creek is near the wall for a very short distance (about 150 lineal ft of a 5.3-mile stream).

The plants and animals found in the project area are widely distributed across a very broad array of micro and macroclimates over their large geographical ranges. They are expected to occur from lowland areas of Puget Sound, through the Cascade foothills, and typically from northern Oregon into southern British Columbia. Many species, however, have even broader geographic ranges, extending into and over the Cascade Mountains, into warmer and more arid regions of Oregon, or into wetter and cooler regions of British Columbia. Even if minor microclimatic changes were to occur near the wall, they would not be substantial enough to affect species distributions or their biology.

The wall will increase shading of the wetlands and creek during the morning hours. This is not expected to significantly affect the wetland or creek environments. The level of shading would be expected to be of a magnitude similar to that found in natural north-south oriented ravines located nearby (such as the ravine bordering Des Moines Creek that can be seen from the paved trail adjacent to the creek. This and similar ravines support healthy biological systems that include many of the plants found riparian areas adjacent to the retaining wall.

The wetland and riparian area of Wetland 37 may receive some amphibian use due to the extended period of soil saturation and shallow (less than 2 inches deep) ponding that occurs on the site. For adults and amphibians that may breed in the area (Pacific chorus frog and red-backed salamander), shading and temperature effects will be unlikely to affect their phenology (i.e., egg development, metamorphosis, etc.) such to impact the habitat value of the areas to the species. If their phenology were delayed due to cooler temperatures, they would not be at greater risk to desiccation because the hydrologic analysis of groundwater movement into wetlands adjacent to the embankment has found that the duration of discharge to them will be extended. Further, if temperatures were cooler and egg development delayed, the cooler temperatures themselves would promote and extend the wetland hydroperiod because evapotranspiration losses by vegetation in the wetland would be reduced.

While the wall could retain, reflect, and radiate some heat, the presence of a forest and shrub canopy over wetlands and streams will block transfer of radiant and reflected heat to the wetland soil or stream. For heat that may be radiated from the wall (vs. conducted from the wall face to soil material that compose the wall itself) convection would further limit impacts as the warmer air would rise up, away from the creek and wetlands

4.3.2.8 Runway Safety Areas

Six wetlands (Wetlands 3, 4, 5, 6, 7, and 10) are near the north end of the existing airport runways. The relocation of South 154th Street to accommodate the RSAs will decrease the amount of wetland buffer, which could result in increased disturbance from traffic noise for wildlife using these wetlands. This impact is not expected to be significant because wildlife species in these wetlands are tolerant of high levels of noise from aircraft and automobile traffic on SR 518.

Other impacts could occur from changes to wetland hydrology as a result of construction near the wetlands. The retaining wall used to minimize wetland fill will include an internal drainage system that will allow groundwater to continue to enter the wetland. Stormwater runoff (water quality and quantity) conditions will be improved because the new roadway will include stormwater detention and water quality treatment, which it does not currently have.

4.3.2.9 Third Runway: North End

Wetlands 8, 9, and A1 are near the north of the new third runway. These wetlands will be subjected to greater amounts of aircraft noise, which may increase disturbance of wildlife.

The relocation of South 154th Street to accommodate the new runway embankment will decrease the amount of wetland buffer, which could result in increased disturbance to wildlife using these wetlands. This impact is not expected to be significant because wildlife species in these wetlands are tolerant of high levels of noise from aircraft and automobile traffic on SR 518.

Wildlife species occurring in these wetlands are similar to wildlife in Wetlands 3 through 7, which are beneath the flight paths of the existing runway, suggesting that wildlife use may not change significantly.

Changes to wetland hydrology could occur as a result of construction near the wetlands. However, the runway embankment design (Appendix B, E and F) will allow groundwater to continue to enter the wetlands. Stormwater runoff (water quality and quantity) conditions will be improved because the new facilities will include detention and water quality treatment in contrast to existing streets that they replace. In the event of an airfield fuel spill, design of the embankment provides an opportunity to mobilize source control and to remediate contaminated soils before the contaminants reach the stream or wetlands.

4.3.2.10 Third Runway: South of South 154th Street

Several isolated Category III wetlands (Wetlands A5, A6, and A8 through A13) and three Category II wetlands (Wetlands 18, 37, and 44) occur between Miller Creek and the edge of the new third runway. These wetlands may be subject to indirect impacts from the operation of the project.

The *SeaTac Runway Fill Hydrologic Studies Report* (Ecology 2000) identifies the potential of 1.68 acres of secondary, indirect hydrologic impacts from the embankment (especially to the Wetland 18 and Wetland 36 complex). Further analysis of this potential impact is the subject of Section 3.2 and 3.6 of the hydrologic report. The analysis concludes (pages 7, 51, 52, and 60) that seepage into the embankment and delay in water movement through the embankment would not result in the loss of these downslope wetlands. Water will infiltrate into the embankment, recharge existing subsurface aquifers, and eventually discharge to the downslope wetlands. The report identifies that some potential net benefit to wetland hydrology during the summer months is possible due to the delay in discharge to wetlands that results from the increased time of travel through the embankment fill.

Impacts to riparian Wetland R1 will occur as a result of the 154th/156th Street bridge crossings (Figure 4-10). Following construction, the small area of remaining wetland will continue to receive hydrology from Miller Creek, and thus the area will remain jurisdictional. The wetland will retain existing functions because, despite the loss of adjacent riparian wetland, remaining portions will be restored and incorporated into the buffer enhancement for the Miller Creek relocation mitigation at Vacca Farm. This action will remove lawn and nearby houses, restore native plants to the wetland and adjacent area, and ensure that the riparian and habitat functions provided by the wetland remain.

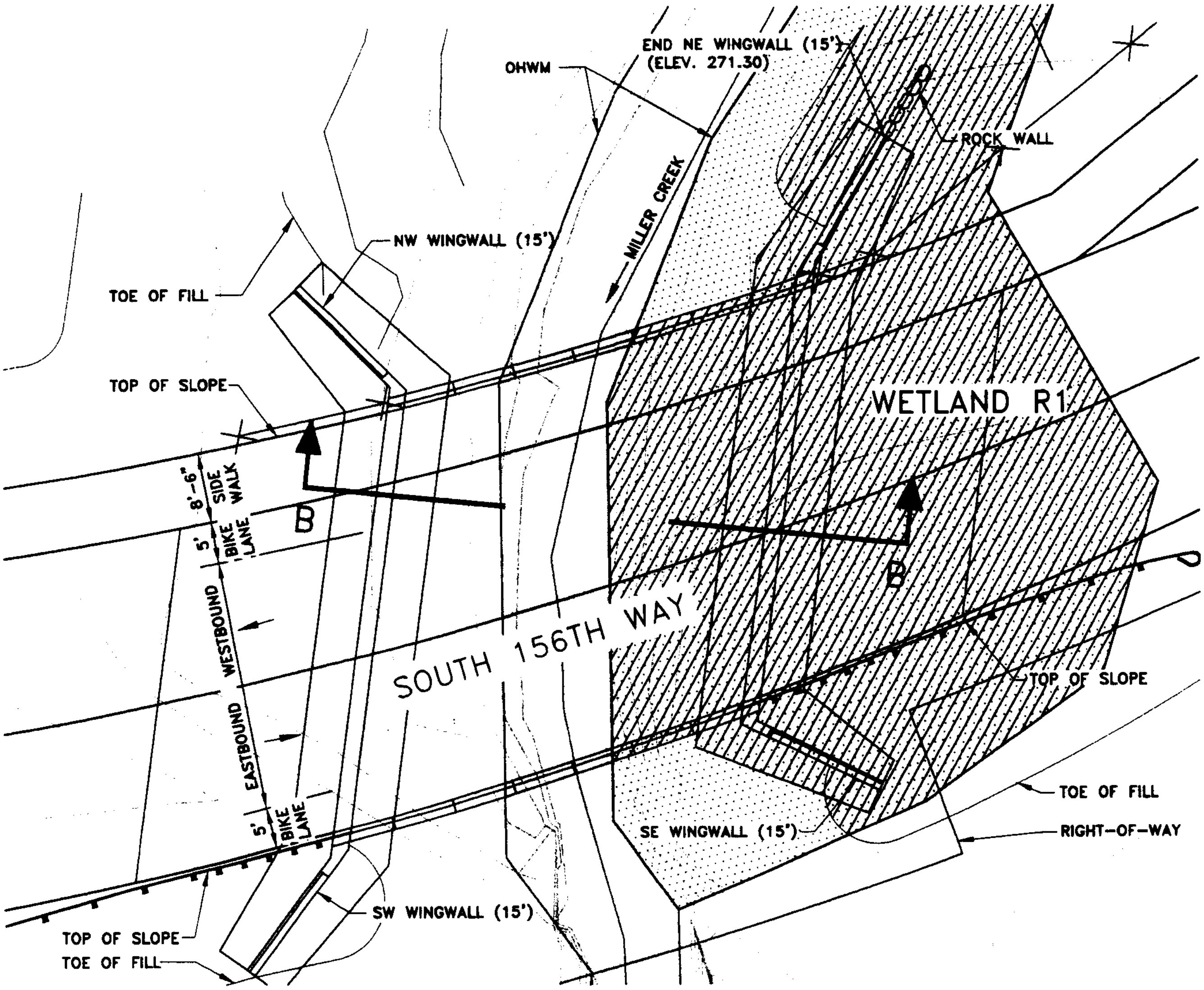
Impacts to riparian wetlands along the bank of Miller Creek will be beneficial (Ecology 2000). These wetlands will retain wetland hydrology from their association with Miller Creek and groundwater moving downslope. As discussed above, the embankment will not prevent groundwater from continuing to move downslope to support wetlands.

Impacts from humans and domestic animals will be eliminated from the overall area, which may improve the riparian area for wildlife. The sparse vehicular traffic on the safety and perimeter roads will be over 50 ft from the wetlands and thus will not adversely affect wildlife. No increased level of disturbance to wildlife is expected in Wetlands R1 and R2 at the new 156th Street bridge crossing because this new bridge will simply replace an existing bridge.

The mitigation plan shows the replacement drainage channel lengths necessary to mitigate impacts to non-wetland Waters of the U.S. and channelized flow that occurs in Wetland 37 (Parametrix 2001a). These channels will be used to distribute water to downslope wetlands. As reported in the hydrologic study, adequate water should be available to support downstream wetlands. As a contingency, if additional groundwater flow is desirable to enhance wetland hydrology, the channels could be lengthened at the north or south ends to capture additional water emanating from the embankment and to convey it to the wetlands. This would be accomplished in the upland areas immediately west of the embankment, to the north of 160th Street, and/or to the south of 166th Place.

4.3.2.11 Wetland 44 and Walker Creek

Impacts to Wetlands 43 and 44 are discussed in the *Analysis Of Indirect Impacts to Wetlands from the Temporary SR 509 Interchange – Seattle-Tacoma International Airport* (Parametrix 2000c) (Appendix H). Additional pertinent analysis is presented in the hydrologic studies completed by Ecology (2000), which demonstrate that the fill embankment design will not interrupt the water source to wetlands downslope of the embankment.



PLAN

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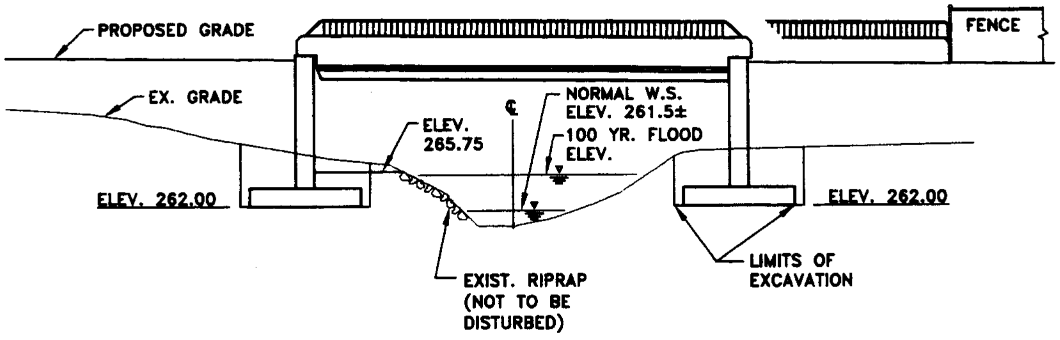

NOTE:
ALL DISTURBED AREAS WILL BE STABILIZED
USING APPROPRIATE BMPS.

SECTION - B

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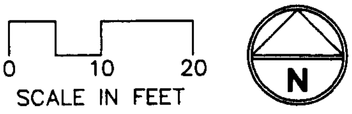


LEGEND

░ WETLAND R1
▨ WETLAND IMPACTS

Figure 4-10
Impacts to Wetland R1 from the South 156th Way Bridge Relocation

Wetland 44

Fill to construct the embankment will be placed in about 0.26 acre of Wetland 44, eliminating degraded forest and shrub wetland habitat. A retaining wall will be built at this location to minimize the direct fill impacts to the wetland. This portion of the wetland is crossed by a driveway with a 12-inch culvert. The wetland is adjacent to 12th Avenue South and South 176th Street, and receives urban runoff from these streets. In this location, stormwater runoff is concentrated in a small channel with intermittent (mostly storm) flow.

The *SeaTac Runway Fill Hydrologic Studies Report* (Ecology 2000) concludes (pages 7, 51, 52, and 60) that seepage into the embankment and delay in water movement through the embankment will not result in the loss of downslope wetlands, including Wetland 44. Water will infiltrate into the embankment, recharge existing aquifers, and eventually discharge to the downslope wetlands. The report identifies that some potential net benefit to wetland hydrology during the summer months is possible due to the delay in discharge that results from the increased travel time of water passing through the embankment.

Impacts from humans and domestic animals will be eliminated from the overall area, which will improve Wetland 44 habitat functions for wildlife

As reported in the hydrologic studies (Appendix E and F, Ecology 2000, and Parametrix 2001b), adequate water should be available to support downstream wetlands. As a contingency, if additional groundwater flow is desirable to enhance wetland hydrology, the channels could be lengthened to capture additional water emanating from the embankment and convey it to the wetland. This would be accomplished in the upland areas immediately west of the embankment, and south of the wetland.

Walker Creek

The indirect impact of filling of a small portion (0.26 acre) of Wetland 44, filling 0.99 acres of isolated wetland depressions (Wetlands 23, 24, 25, and 26), placing of embankment fill, and adding about 6 acres of impervious surface to the watershed is analyzed in this section.

Low Flow Conditions. There are no perennial headwater seeps that provide base flow to Walker Creek in the area where the embankment fill impacts Wetland 44. Fill for the runway embankment will not be placed in any perennial seep or streams that provide significant base flow to Walker Creek. One of the most significant perennial sources of water to the Walker Creek base flow is from the constructed drainage system beneath SR 509 near South 176th Street, which enters Wetland 43 on the west side of SR 509. Based on flow volume, the outlet of this drainage system may be construed to be the headwaters of Walker Creek, and it will not be affected by the project.

The fill for the embankment and drainage conditions associated with the MSE wall allow infiltration of rainwater and downward movement of water through the embankment to the existing soil surface. Upon reaching the existing soil surface, this water can infiltrate into the existing soil to recharge aquifers, or where existing soils have a low permeability, be conveyed to the drainage swales near the perimeter of the embankment, and downslope wetlands. Thus, the fill will have little impact on the hydrologic conditions in or near Wetland 44 and Walker Creek. The identified impact of a delay in discharge, as discussed above and in Appendix E and F, and Ecology (2000), is expected to provide minor benefits to low flow conditions in Walker Creek and the summertime hydrologic condition of Wetland 44.

Impervious Area and Peak Flows. The addition of about 6.2 acres of new impervious area to the Walker Creek watershed would generate increased stormwater runoff. To prevent stormwater runoff from potentially impacting habitat in Walker Creek, Wetland 44, or Wetland 43, stormwater detention facilities are proposed. These facilities will detain stormwater and release it slowly at rates below the existing peak discharge rates (see Figure 4-8 and Section 4.3.2.5). As a result, the potential impact of increased runoff from new impervious surface is mitigated, and no significant impacts to the hydrology of Walker Creek will occur.

Water Quality. The new impervious surfaces in the Walker Creek watershed could affect water quality conditions in Wetland 44, Wetland 43, and Walker Creek. To prevent water quality impacts from occurring, BMPs for water quality treatment will be employed, as discussed in Section 4.3.2.5. Further assurance against water quality impacts results from removal of residential land uses and existing streets that lack BMPs for water quality treatment. Removal of these pollution-generating activities, coupled with required water quality treatment for new facilities, will prevent impacts to Walker Creek or the associated wetlands.

Fish and Aquatic Habitat. The fish and other aquatic habitat of Walker Creek and Wetlands 44 and 43 will not be impacted by the project. As discussed above, the potential impacts of filling 0.26 acre of wetlands, adding fill to the watershed, and increasing the area of impervious surface are mitigated by the embankment drainage design and by accepted methods of stormwater management. As a result of the project design and mitigation, there is no mechanism to alter stream or wetland habitat conditions in downslope areas.

Temporary SR 509 Interchange Design. The temporary SR 509 interchange is designed to avoid direct impacts to Wetland 44 and 43 (see Appendix H). Negative impacts to wildlife in the wetlands could occur from increased construction vehicles and trucks during operation. This potential impact would be offset by elimination of humans and domestic animals from the overall area, which will improve the wetlands for wildlife.

Potential impacts to water quality in the wetlands will not occur because any stormwater runoff entering the wetlands will be treated using water quantity and water quality BMPs (see Sections 4.2.1, 4.2.2, and 4.3.5). Since the existing area lacks water quality and quantity treatment BMPs, a net improvement may occur.

4.3.2.12 New Stormwater Detention Facilities

Construction of new stormwater mitigation ponds and vaults in upland locations could result in indirect impacts to wetlands located downslope of them if excavation of these facilities intercepted significant amounts of groundwater required to support downslope wetlands. Stormwater vaults excavated in upland areas will not result in indirect impacts to wetlands even if they are excavated into a groundwater table because these sealed vaults could not collect groundwater and reduce its flow to wetlands. Stormwater detention ponds and vaults required to mitigate potential stormwater impacts (Figure 4-11) are evaluated in this section for potential impacts to downslope wetland hydrology. Plans and cross sections for new stormwater ponds are presented in Appendix I.

Potential infiltration of groundwater near stormwater management facilities could potentially extend the period downslope wetlands receive wetland hydrology. This increased soil saturation could also create new wetlands by increasing the area of soil saturation, resulting in beneficial increases in wetland functions and area. Within existing wetlands, increasing the period of soil saturation into late spring and early summer could be beneficial to wetland vegetation and functions. These potential impacts are discussed below.

Pond C

Pond C is a 14.8 acre-ft detention facility located south of the relocated South 156th Street. The pond is located about 100 ft east of Miller Creek. It is about 60 and 100 ft east of riparian Wetlands R1 and R2, respectively.

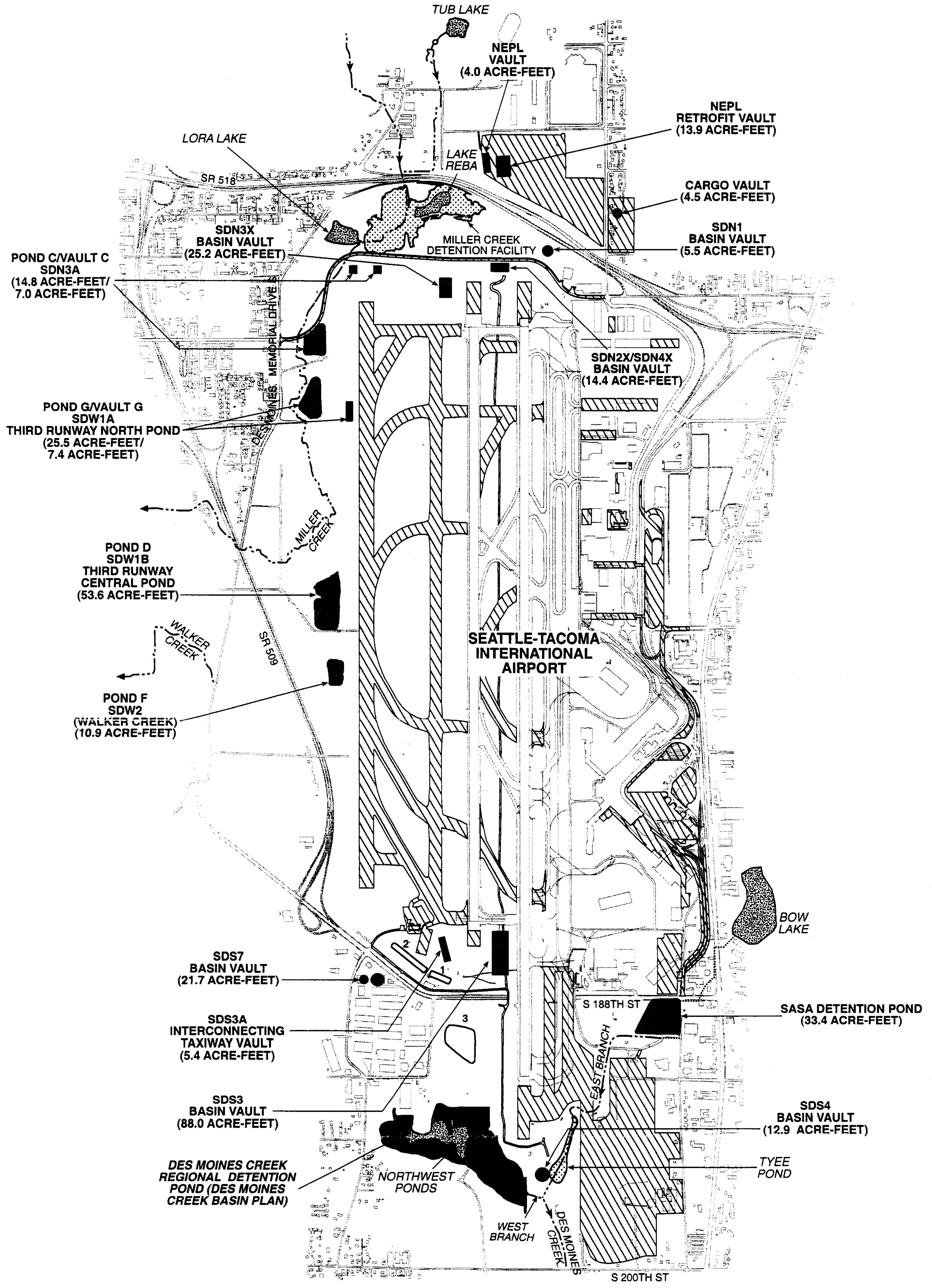
The facility will be excavated to an elevation of about 268 ft. At this elevation, the base of the pond will be 0 to 8 ft above the elevation of Wetlands R1 and R2. Excavation of a temporary pond at this location has intercepted some perched groundwater, which now discharges to existing stormwater drainage systems near wetland R1. Wetlands R1 and R2 will be monitored to verify that wetland hydrology remains in these areas following pond construction and relocation of South 156th Street. Based on the location of these wetlands next to Miller Creek, their elevation relative to the pond excavation, and the potential for infiltration to supplement groundwater, wetland hydrology is expected to remain in these wetlands, and be sufficient to support native shrub and forest wetland vegetation.

Infiltration south of this pond (Appendix J) may be feasible and, if implemented, could augment the hydrology to Wetlands R2 and R4.

Pond G

Pond G is a 25.5 acre-ft detention facility to be located north of South 160th Street. The pond is located about 60 ft east of Miller Creek. It is about 50 ft from riparian Wetlands R5 and R6. The facility will be excavated to about 246 ft, with the base of the pond about 2 ft higher than the elevation of Wetland R6. The base of the pond would be about 4 ft below the small portions of Wetland R5.

Excavation of the pond is at or above the elevation of estimated groundwater tables, and thus, hydrologic impacts to nearby wetlands are not anticipated. Infiltration north of this pond (Appendix J) may be feasible, and if implemented, could augment the hydrology to Wetland R4. Since the pond is not lined, some infiltration may occur through the bottom that could augment groundwater flow to Wetlands R5 and R6.



SCALE IN FEET
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▩ Water Features

■ Proposed Stormwater Detention Facilities (With Simulated Maximum Storage Volume)

▨ Master Plan Projects

—··— Creek

········ Piped Creek

░ Detention Facility

Figure 4-11
Proposed Detention Facilities
for Master Plan Projects

Pond D

Pond D is a 53.6 acre-ft detention facility to be located near South 170th Street. The pond is located about 700 ft southeast of Miller Creek. Construction of the pond, embankment, and security road will eliminate all of Wetland 41 (see Section 4.1), and occur east of Wetland 39. Excavation of the facility will be to about 340 ft elevation. This elevation is about 10 ft below the uppermost portion of Wetland 39. Given the close proximity of Wetland 39 to the detention pond excavation, about 0.06 acre of wetland above elevation 340 ft could be indirectly impacted by dewatering. However it is likely that water seepage through the pond bottom and bank will continue to provide water to wetland 39, as will precipitation.

To mitigate this potential impact, a discharge orifice from the pond is designed to discharge from the pond to near Wetland 39. This orifice will discharge at about elevation 334 ft, to assure water is available to the remainder of the wetland.

Hydrology in Wetland 39 will be monitored to determine if this potential impact occurs. Red alder and Himalayan blackberry dominate this portion of the wetland, plants that are capable of growing on upland soils. If indirect impacts occur to 0.06 acre of this wetland, it is unlikely that the vegetation and habitat functions of the wetland will be altered. However, if plant die-back is observed, affected areas will be replanted.

Excavation of the pond is about 55 ft above measured groundwater tables, and thus, hydrologic impacts to nearby wetlands (A11, A15, A14, and A16) are not anticipated. Infiltration north of this pond (Appendix J) may be feasible, and if implemented, could augment the hydrology to Wetlands R10 and A11. Since the pond is not lined, some infiltration may occur through the bottom that could augment groundwater flow to these wetlands as well as to Wetland 39.

Pond F

Pond F provides 10.9 acre-ft of storage and is located in the Walker Creek subbasin, near South 173rd Street. There are no wetlands near this facility (Wetland 44 is located about 250 ft to the southwest, at elevation 280 ft). The excavation of the facility to an elevation of 340 ft is at or above the seasonal high groundwater table of 335-340 ft. Thus, the pond will not intercept groundwater or alter groundwater movement (Appendix I).

SASA Detention Pond

The SASA pond will provide 33.4 acre-ft of storage to the Des Moines Creek basin. The pond is located near South 188th Street and 24th Avenue South. Construction of the facility will eliminate Wetlands E2 and E3 (0.1 acre). Following construction, no wetlands will be downslope of this facility.

4.3.2.13 Staging Areas

Construction staging for Master Plan Update improvements will not occur in wetlands. Potential indirect impacts from construction staging areas, including temporary staging areas at the SASA site (see Figure 4-11) and temporary offices near Stormwater Pond D and 170th Street South (see Figure

4-11), will not occur due to erosion control and stormwater treatment facilities. These staging activities are a temporary land use that will be removed following project construction.

4.3.2.14 Indirect Impacts of Borrow Areas to Wetlands

Direct impacts to a number of wetlands are avoided by excluding them from the limits of borrow area excavation (see Appendix C). The wetlands located near and downslope of borrow areas are potentially subjected to indirect hydrologic impacts that could result if surface or groundwater was no longer able to reach them. The following sections provide a summary of hydrologic conditions in wetlands adjacent to the three borrow areas and an analysis of how borrow site development could change hydrologic conditions in them. The overall potential indirect impact of borrow area development on local hydrology is discussed in Sections 4.3.2.15 and 4.3.2.16.

Borrow Area 1

Five wetlands in or near Borrow Area 1 (Wetlands 32, 48, B1, B4, and B13, B15) will be avoided by the excavation footprint. Wetland B14 and B 11 will be eliminated by the excavation and portions of Wetland B12 will be eliminated.

Wetland B1 is connected to a storm water drainage ditch associated with 24th Avenue South (located upslope and east of the wetland). The wetland occupies a shallow depression located on till soils. Precipitation and stormwater runoff inputs (conveyed to the wetland from the stormwater system) maintain wetland hydrology. The wetland is seasonally wet, and lacks standing water.

Water sources for Wetland B1 will not be altered by the borrow area excavation, and the area will continue to receive precipitation and stormwater runoff from upslope areas, including 24th Avenue South, that maintain the seasonally wet soils. The soils in the depression around the wetland will not be disturbed, and the 50-ft wetland setback will leave in place the low permeability till soils that restrict drainage from the depression. As a result, the seasonal hydrology of the wetland would not change.

Wetland B-4 is located at the base of a steep ravine where surface water, interflow, and shallow groundwater seeps into a seasonal drainage. The base of the ravine contains a failed stormwater discharge system, and is littered with disconnected sections of a 12-inch culvert. The culvert originally conveyed stormwater from South 208th Street to Des Moines Creek, but stormwater runoff has eroded the pipe foundation and the sections have separated. Uncontained stormwater runoff has eroded the base of the ravine. Episodic runoff and erosion also prevents the establishment of natural vegetation in the wetland. Groundwater also seeps onto the ravine slopes.

No excavation will occur within this wetland, and the primary impact of borrow area development will be to remove the stormwater drainage that reaches the wetland from the abandoned streets (South 208th Street and 22nd Avenue South). Removal of these stormwater sources could reduce peak flows in the wetland and promote increased vegetation cover in the eroded ravine that forms the wetland. Groundwater, precipitation, and interflow sources of water to the wetland will remain following excavation.

Wetland B12 is located along the base of a ravine that conveys runoff from the west perimeter of the borrow area west to Des Moines Creek. The water entering the ravine from upslope areas, groundwater discharge and precipitation are sufficient to maintain wetland conditions. Much of the surface water entering the wetland appears to originate from the stormwater drainage system still in place along 20th Avenue South.

Following excavation, about 0.07 acres of Wetland B12 will be impacted (this includes about 0.03 acres of excavation and potential indirect impacts to 0.04 acres located within 50 feet of and immediately downslope of the excavation. The sources of water from the drainage system along 20th Avenue South will not be altered, nor will groundwater discharge and precipitation sources for the wetland.

Wetland B15 and Wetland 48 are located west the borrow area and occur on a gentle slope (Wetland B15) or shallow depression (Wetland 48). Portions of the wetlands pond 1-2 inches of surface water during rainy periods. Portions of the wetlands contain disturbed soils and fill material, and they were recently (pre-1970s) used as pasture. Wetland hydrology appears to be maintained by direct precipitation that falls on relatively flat terrain that is underlain by low-permeability till soils. The wetlands' source of water appears to be supplemented by overland flow and shallow interflow from upslope areas located to east. The eastern extent of the watersheds are limited by 20th Avenue South. This abandoned street is elevated above the surrounding land and contains a stormwater drainage system. The street crown directs runoff towards drainage ditches, storm drains, and catch basins along its eastern margin. Surface flow or runoff from areas located on the east side of 20th Avenue South are unable to reach land west of the street because the drainage system intercepts this water and directs it to Wetland B12.

The watershed area for this wetland (located west of 20th Avenue South) is avoided by preventing excavation within this area. As a result, the existing precipitation and runoff sources of water to the wetlands will remain undisturbed after Borrow Area 1 has been developed.

Wetland B13 is located downslope and west of the excavation area, and is in a ravine where stormwater drainage pipes from abandoned South 210th Street and 20th Avenue South outfall. The hydrology of the wetland is similar to Wetland B12 and B1, in that it is maintained by stormwater runoff generated from abandoned streets, precipitation, interflow, and groundwater seepage.

Following construction, runoff from upslope areas would continue to flow towards the wetland, and the groundwater and precipitation sources of water would remain. Runoff from streets would be removed.

Wetland 32 is located on the NW corner of South 216th Street and 20th Avenue South. The wetland is situated in a small depression that receives runoff from the stormwater ditch servicing the north side of South 216th Street. The wetland's drainage basin also includes a small depression, which is slightly larger than the wetland itself.

The stormwater ditch that conveys runoff from South 216th Street to Wetland 32 will not be altered as a result of excavation since grading will not occur in the street right-of-way. A 50-foot buffer around the wetland will prevent impacts to the small portion of the watershed of the wetland on Port

Property. Since no changes to the watershed or hydrologic sources of water to the wetland will occur, there would be no indirect impacts.

Wetland 51 is located to the northwest of the northern part of Borrow Areas 1 and occupies a broad low-lying riparian area adjacent to Des Moines Creek. The area appears to be underlain by outwash materials. The wetland is generally near an elevation of around 230 feet, which is similar to or lower than groundwater levels measured in monitoring wells at the northernmost portion of Borrow Area 1. This indicates that this wetland is likely maintained by the water table present in the advance outwash aquifer that extends beneath the site.

A small portion of Wetland 51 is located upslope of the riparian area and is in a roadside drainage ditch north of Borrow Area 1. This area is outside the Borrow Area Development Boundary and the runoff areas that contribute to the wetland will not be affected by borrow area excavations.

The hydrology of the riparian wetland is associated with Des Moines Creek and regional groundwater discharge from the advance outwash aquifer. These hydrologic conditions will not be affected by development of the borrow areas, and indirect impacts would not occur.

Borrow Area 3 and Mitigation

All wetlands in Borrow Area 3 will be avoided and a 50-ft buffer will be maintained and the areas west and northwest of the wetlands will remain undisturbed. Wetland hydrology will be maintained by preserving conditions in the watershed basin upgradient and immediately surrounding each wetland. Groundwater analyses indicate that groundwater movement is from northwest to southeast.

Potential wetland indirect impacts at Borrow Area 3 have been evaluated, and potential losses in hydrology to wetlands avoided in Borrow Area 3 could occur without further mitigation (Hart Crowser 2000b) (Appendix C and D). A drainage channel that collects and conveys water draining to the borrow area to the adjacent wetlands is planned to mitigate indirect impacts. This contingency would prevent indirect impacts to the hydrology supporting Wetlands B5, B6, B7, B9, B10, 29, and 30.

The hydrology of downslope wetlands will be monitored by the Port to verify that these contingency measures prevent indirect hydrologic impacts to downslope wetlands, as explained in the *Natural Resource Mitigation Plan* (Parametrix 2001a) and required by the *401 Water Quality Certification #1996-4-02325(Amended-1)* (Ecology 2001b).

The drainage channel (see Appendix H, Parametrix 2001a) proposed to collect and convey groundwater that emanates from the west slope of the Borrow Area 3 excavation is unlikely to result in impacts to groundwater, or wetland hydrology. The purpose of the mitigation channel is to collect and convey the groundwater that may currently reach the wetland, but could be diverted away from the wetland if the mitigation were not constructed. The mitigation protects wetland hydrology by directing some seasonally perched water to wetlands. It does not alter or reduce the ability of the borrow area to infiltrate and recharge groundwater.

Borrow Area 4

Borrow Area 4 is located about 400 ft south of Wetland 28. Wetland 28 is maintained by several water sources, including groundwater that emanates from beneath the existing airfield, runoff from wetlands located east of it, runoff from other surrounding impervious area, and precipitation. Some water infiltrating into Borrow Area 4 may also reach the south and southeastern portion of this wetland.

Unlike Borrow Area 3, excavation in Borrow Area 4 will not reach the groundwater table, and thus is not expected to alter groundwater flow or availability for Wetland 28, and no indirect impacts are likely. Excavation of Borrow Area 4, located south of Wetland 28, will not intercept groundwater flowing to the wetland or Des Moines Creek, and is thus unlikely to impact wetland hydrology.

Portions of Wetland 28 will be enhanced by mitigation planned at the Tyee Valley Golf Course, where the existing golf course green will be converted to shrub-dominated wetland. Other Master Plan Update improvements occurring near Wetland 28 are limited to portions of the third runway, which could without mitigation generate hydrologic and water quality impacts. The stormwater report addresses detention facilities and water quality BMPs that will minimize these impacts to the wetland and downstream Des Moines Creek.

4.3.2.15 Borrow Area Impacts to Water Storage

Excavation of borrow areas is expected to change the amount of precipitation that is temporarily stored on the site through groundwater recharge/groundwater discharge processes versus stormwater runoff processes.

Evaluation by Hart Crowser (2001a, Appendix C) and Ecology (2000) show that, when compared to the existing conditions, the borrow areas will moderate the "pulses" of water that arrive as discrete precipitation and runoff events through increased groundwater recharge. The increase in groundwater recharge is discharged to the creek or other aquifers over a longer timeframe than stormwater runoff, thus moderating discharge "pulses".

These changes were evaluated in the *Sea-Tac Runway Fill Hydrologic Studies* (Ecology 2000) and found to result in a net increase in groundwater recharge by the following amounts:

• Borrow Area 1	0.03 cfs increase
• Borrow Area 3	0.006 cfs increase
• Borrow Area 4	0.01 cfs increase

A number of factors promote increased groundwater recharge and reduced stormwater runoff as summarized below. The primary factor affecting the water balance on the borrow areas is the removal of the till layer on portions of the sites. This till acts as an impediment to water recharge and groundwater storage. Excavation of the borrow areas will remove the till "cap" that exists throughout much of the borrow area site. The till cap is a less-permeable layer of material that limits infiltration and generally causes some water to move laterally to the stream rather than move vertically down into subsurface layers recharge the water table (Bauer and Mastin 1997).

Runoff

The borrow areas generally contain a mixture of residual soils (topsoil, fill) derived from the glacial till and/or other shallow soils underlain by glacial till. This condition generates moderate to high rates of direct runoff that flows overland or through the surficial soils to Des Moines Creek. Borrow Area 1, for example, has approximately 71 percent of the ground surface underlain by till. In addition, the site includes 4.2 percent impervious surfaces that include abandoned streets and driveways. The remaining area (23 percent) is underlain by recessional outwash that is relatively permeable and generates substantially less runoff.

Following excavation, the amount of till soil would be reduced to 53 percent of the area, with much of the recessional outwash and till being removed. Where till remains, lower runoff rates will occur because of the relatively flat slopes (average slope about 2 percent) in most of the excavated area. Impervious surfaces will be reduced, further reducing the amount of runoff compared to existing conditions.

Interflow

Interflow currently provides a relatively rapid pathway for a portion of the stored water perched on the till to flow downslope and into Des Moines Creek. This flow path (estimated for HSPF simulations for the Third Runway project to be typically 3 to 7 days in duration) will be interrupted by development of the borrow areas. In the developed condition, interflow is expected to result from runoff from the exposed till slopes around the excavation perimeter, which then will flow across the more gently sloped floor of the excavation (2 percent grade) where considerable infiltration will occur. The reduced topography and removal of most streets and their drainage networks would increase flow paths and reduce runoff rates.

Infiltration and Groundwater Recharge

Infiltration into the till areas will be changed by the removal of vegetation and till. Existing infiltration into till and the surficial recessional outwash soils will be replaced by infiltration into the increased area of exposed advance outwash, which will occupy approximately 45 percent of the site. Overall, rates of infiltration to the site will increase due to the increase in outwash exposure. Removal of forest vegetation will also increase the amount of water available for infiltration. Increases in infiltration and the resultant groundwater recharge (see below) will have the beneficial result of reducing runoff rates, reducing peak flows to Des Moines Creek, and increasing the amount of water stored in the aquifer that is available for release as base flow.

Based on modeling work for the third runway embankment (*Comprehensive Stormwater Master Plan* Parametrix 2000b), storage effects and slow percolation through the till is estimated to delay downward flow by around 1 to 2 months. Because infiltration into and percolation through the glacial till is limited by the till's low permeability, the quantity of water that flows through till is approximately 30 percent less than the quantity that moves through the same area of exposed outwash. On the developed site, a larger quantity of direct infiltration and percolation through the increased surface area of the exposed outwash soils will occur. This flow will recharge the water table more rapidly and the greater volume of water will serve to increase groundwater storage and the water available for baseflow discharge compared to existing conditions.

Overall, based on the change in areas of exposed soils as a result of excavation, an increase in shallow groundwater recharge equivalent to around 0.03 cfs is estimated for Borrow Area 1 (Hart Crowser 2001a, Appendic C; Ecology 2000).

4.3.2.16 Borrow Area Impacts to Water Releases

During borrow area operation, stormwater management actions will be implemented in each borrow area to prevent high rates of runoff during storm events. Stormwater management will be based on infiltration and detention facilities designed to meet King County "Level 1" (match existing stormwater peak flow) stormwater quantity control and will be based on the Des Moines Creek calibrated King County Runoff Time Series (KCRTS) method (Parametrix 2000b).

Stormwater management and site reclamation for Borrow Areas 3 and 4 are described in *Conceptual Reclamation Permit Package- Borrow Areas 3 and 4 (Draft)* (Hart Crowser 2001b) and *Sand and Gravel Stormwater Pollution Prevention Plan-Third Runway Borrow Areas 3 and 4* (Parametrix 2001e). Temporary Erosion and Sedimentation Control (TESC) and permanent, post-reclamation stormwater measures will be consistent with the NPDES Sand and Gravel General Permit, applicable portions of the *King County Surface Water Design Manual* (King County, 1998), and other applicable permits and approvals.

Post-extraction topography would drain toward the stream through approved erosion, infiltration, and sediment control structures constructed along the margins of the excavation. During excavation and site development, these would include drainage ditches and swales, stormwater detention ponds, and any stormwater BMPs required for treatment of surface water runoff.

The following is a summary of stormwater facilities planned for Borrow Areas 3 and 4 (similar facilities would also be constructed in Borrow Area 1).

- Runoff generated by Borrow Area 4 will be directed to a stormwater infiltration facility. Discharge release is through ground water conveyance, and this process will moderate "pulses" of water that could otherwise affect habitat conditions in Des Moines Creek.
- Runoff from Borrow Area 3 will also drain to an infiltration facility. Discharge release is through ground water conveyance, and this process will moderate "pulses" of water that could otherwise affect habitat conditions in Des Moines Creek.
- Where excavation of Borrow Area 3 intercepts seasonally perched groundwater, the intercepted water will be conveyed in a small channel to Wetland 29. This action will mitigate potential hydrologic impacts to the wetlands located downslope of the borrow area. Discharge of water from these wetlands is through infiltration and groundwater conveyance.
- Stormwater runoff generated by a temporary stockpile and staging area and the south half of the temporary haul road discharges to a temporary stormwater detention pond and released slowly back to an existing flow path on the Tyee Valley Golf Course. This water will eventually reach Des Moines Creek through interflow and/or groundwater conveyance.

- Runoff from the north half of the Haul Road is collected in a detention pond and released slowly as sheet flow over a short distance to Des Moines Creek.

Low Flow Hydrology

The *Sea-Tac Runway Fill Hydrologic Studies* (Ecology 2000) identified an increase in infiltration and recharge to groundwater as a result of the excavation. This increase in groundwater recharge could increase groundwater discharge to Des Moines Creek during low flow periods.

Low flow impacts due to Master Plan Update projects are evaluated in the *Low Streamflow Analysis and Summer Low Flow Impact Offset Facility* (Parametrix 2001b) report. The low-flow impacts evaluated in the report quantify the potential for Master Plan Update projects to alter stream flow in Miller, Des Moines, and Walker Creeks as a result of changing runoff characteristics that occur from the new impervious surfaces.

There are no actions proposed in the borrow areas would decrease groundwater recharge or would decrease amount of groundwater discharged to Des Moines Creek during low flow periods. Hydrologic changes from till excavation, reducing topography, and modifying vegetation cover would increase the water available to recharge groundwater and baseflow. Because no new impervious surfaces that would cause potential low flow decreases are proposed, no hydrologic modeling of stream low flow reductions are necessary and the potential benefits of excavation to groundwater discharges to the creek have not been quantified.

4.3.2.17 South Aviation Support Area

In the SASA area, indirect impacts to Wetland G5 have been considered, and the wetland or its hydrologic sources will likely be eliminated by the project. The full 0.87 acre is included in the area of permanent impact acres listed in Table 3-1. The wetland was assumed to be fully impacted because it may be maintained by stormwater runoff and interflow generated by the golf course, which will be converted to impervious surface.

The east branch of Des Moines Creek and perennial groundwater seeps support Wetland 52 in the SASA area. Wetland 52 will receive permanent impacts from an aircraft bridge that will span and shade portions of the wetland. Non-impacted portions of this wetland are expected to remain because the SASA project will not eliminate water sources for the stream or wetland.

The SASA will be designed to avoid significant impacts to Wetland 52 by avoiding much of the wetland and providing a 75-ft buffer. This wetland will be subjected to greater amounts of aircraft noise, which may increase disturbance of wildlife. This impact is not expected to be significant because wildlife species in these wetlands are tolerant of noise from aircraft.

Long-term stormwater runoff (water quality and quantity) conditions will be improved because the SASA facility will be built with water quantity and quality treatment BMPs that will replace golf course and parking areas that currently lack stormwater management facilities.

4.3.2.18 Other Areas

Impacts to riparian Wetland R1 will occur as a result of the South 154th/156th Street bridge crossings. Following construction, the areas of remaining wetland will continue to receive hydrology from Miller Creek and groundwater sources. They will continue to support existing hydric soil and wetland vegetation, and thus the areas will remain jurisdictional. The wetland will retain existing functions because, despite the loss of adjacent riparian wetland, remaining portions will be restored and incorporated into the 100-ft-wide buffer enhancement for the Miller Creek mitigation. This mitigation will include removing lawn and nearby houses, and restoring native plants to the wetland and adjacent area. These actions will ensure that riparian and habitat functions provided by these wetlands will continue to be provided.

Industrial Waste Treatment System

The Industrial Waste Treatment System expansion is not a Master Plan Update improvement, and is not included in the permit application. However, due to requests by ACOE, potential indirect impacts of this project are included in this section.

The lining of Lagoon 3 is required as a condition of the Port's NPDES permit and is intended to prevent potentially contaminated wastewater from infiltrating into groundwater. The IWS project will not fill any wetlands. The project is located on existing fill, near Wetland 28 (Appendix K). The project involves: (1) excavating and creating a berm to increase the volume of IWS Lagoon 3 from 29 to 76.5 million gallons, (2) cleaning the existing lagoon, and (3) lining the entire newly enlarged lagoon. Indirect impacts to nearby Wetland 28 are minimized by the extensive TESC methods employed to prevent sedimentation and/or construction water quality impacts to the wetland. In particular, most of the site is sloped to drain into the excavation, and the slopes around the outside of the site are surrounded by a ditch/berm system that intercepts stormwater before it enters the wetland. All collected construction runoff in the excavation and the perimeter ditch/berm system is conveyed to a stormwater treatment plant similar to the systems used for the third runway embankment and other projects at STIA.

Constructing a lined pond will create about 12.3 acres of area that will effectively act as impervious surface. This is not expected to reduce discharge to Wetland 28 or to Des Moines Creek because this is an area of groundwater discharge rather than infiltration (Kennedy Jenks 2000).

A new underdrain system beneath the lined treatment lagoons will allow groundwater beneath the lagoon to drain to Wetland 28. Thus, the liner and underdrain system will actually allow more water to reach Wetland 28 and Des Moines Creek because rainwater and upwelling groundwater that currently reaches unlined Lagoon 3 is pumped to the IWTP and discharged outside the Des Moines Creek basin. Furthermore, this may have a potential water quality benefit in that it will prevent intermingling of untreated industrial wastewater with groundwater. All water contained within the lagoon will be treated in the IWTP and discharged to Puget Sound or the King County Treatment Plant, and therefore will not affect peak flows in Des Moines Creek.

Surface runoff and seepage from the constructed embankment maintain wetland hydrology for the wetlands adjacent to Lagoon 3. Surface runoff will be unchanged. Lost seepage from the small pond area (small relative to the area providing groundwater hydrology to the wetland) is unlikely to adversely impact the adjacent wetlands.

Off-Site Mitigation

Construction of off-site wetland mitigation in Auburn includes excavation of new wetlands and restoration and enhancement of existing wetlands. To facilitate excavation, temporary soil dewatering will be performed to lower groundwater tables for the several-month construction season.

Dewatering activities on the Auburn site are not likely to impact existing wetlands located on the site or near (especially those located north and west) the site. Dewatering of the site is expected to occur from May through September, over one season in any given location. The purpose of dewatering is to increase the rate at which the water table falls during the May to September period. In May, at the time dewatering starts, the water level in the wetlands is typically about 24 inches below the ground surface, and by late May it is as much as 36 inches below the surface. Water levels in these wetlands drop to 7 to 8 ft below the ground surface during the summer months, and by late fall, they are at or near the surface. Because dewatering begins after water levels in the wetlands have already dropped below the root zone of the wetland vegetation, the wetland vegetation or hydrology will not be impacted. Dewatering will not lower the water level below the elevation it normally reaches by late summer, and thus the period of time for the water level to rise to the surface once fall rains begin will not change.

Excavation of a wetland basin adjacent to existing wetlands could, under certain conditions, dewater a portion of the existing wetlands. This would occur if the new wetland basin, constructed at a lower elevation than the existing wetland, resulted in substantial drawdown of the adjacent groundwater table. Evaluations of the excavation area, the soil permeability, and groundwater conditions show that substantial drawdown of the seasonal high water table will not occur (HWA GeoSciences 2001 [Appendix G]). Thus, dewatering impacts to adjacent wetlands will not occur.

For wetlands located off-site (north and east of the mitigation site), no impacts are expected for the reasons stated above, and because the mitigation adjacent to these off-site areas consists of wetland enhancement, and dewatering wells or excavation will not be placed near these wetlands.

4.3.2.19 Summary

The above analyses of potential permanent indirect impacts to wetlands located near or downslope of Master Plan Update improvement projects consider how a variety of project activities and alterations could indirectly affect wetlands and wetland functions. The analyses conclude that up to about 2.4 acres of wetland could be subject to indirect impacts such that wetlands or wetland functions could be lost. This area is thus included as a permanent impact of the Master Plan Update improvements on wetlands, and impacts are fully mitigated (Parametrix 2001a).

As discussed above, hydrologic analyses demonstrate that the significant wetlands located downslope of the embankment will not be eliminated or experience significant reductions in groundwater sources from embankment construction. The permanent replacement channels designed to convey water from the embankment to these downslope wetlands help assure that they will continue to provide hydrologic and biological functions to Miller Creek. The planned Miller Creek wetland and buffer mitigation (Parametrix 2001a) will enhance many of these degraded wetlands, and lift the ecological function of the area above the existing baseline conditions.

4.4 CUMULATIVE IMPACTS

Cumulative impacts are defined by the Council on Environmental Quality (1997) and 40 CFR 1508.7 as:

> "...the impact on the environment which results from incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions."

Information on other proposed projects in the vicinity of the airport is summarized in this section relative to cumulative impacts. This section identifies current environmental documentation for these projects and highlights the major findings of those documents with a particular emphasis on impacts to aquatic resources. This information is relevant to the consideration of the cumulative impacts of these other projects when combined with the impacts of the STIA Master Plan Update projects.

The background environmental documents for these projects have been provided to the Corps for consideration during its ongoing "hard look" review of the Master Plan Update project and for review by the public. This section also provides information on historical changes to wetlands and streams that has occurred as a result of past land use conditions and development.

4.4.1 Historical Changes

Historical changes in wetlands, streams, and wildlife habitats conditions in the Miller and Des Moines Creek watersheds are summarized in the report *Cumulative Impacts to Wetlands and Streams* (Parametrix 2001d). This analysis found that the historical changes in land use have occurred in the watersheds has impacted streams, wetlands, and wildlife habitat. Many of the significant land use changes that affected the ecological conditions of natural resources in the watersheds occurred prior to airport development. These changes included clearing old-growth forest (through burning and logging) and the development of agriculture lands (for grazing and crop production). These activities occurred from the time of settlement (mid to late 1800s) through the early 1900s (Parametrix 2001d). More recently (especially from the 1940s to present) the development of forest and agricultural lands for residential, commercial, and transportation (roads and airport uses) facilities has continued to impact stream, wetland, and wildlife habitats in the watersheds. Most of this historical development occurred without environmental mitigation and has contributed to cumulative losses of wetland, stream, and habitat resources.

The development of STIA has contributed to some wetland, stream, and habitat impacts at levels that appear proportionate to other development that has occurred in the watershed. While the large footprint associated with the airport facilities (developed primarily between 1946 and 1972) resulted in some wetland loss and stream modifications, such impacts were also common to many of the other private- and public-sector development projects that occurred in the watersheds prior to the establishment of environmental regulations. The need for large buffers as part of noise remedy programs near STIA has resulted in purchase by the Port of wetlands associated with agricultural and residential land uses. The removal of these land uses has resulted in the revegetation and preservation of several wetland areas.

4.4.2 Future Projects Planned by Other Agencies

Additional impacts to wetlands could occur as a result of future projects planned by project proponents in the vicinity of STIA. These projects include those sponsored by other agencies (the proposed SR 509 and South Access Road (WSDOT 1999), the Link Light Rail project (Sount Transit 1998), the Des Moines RDF (Des Moines Creek Basin Planning Committee 1999), and development planning undertaken by the City of SeaTac. In addition, STIA is planning and implementing non-Master Plan Update projects at STIA, including electrical substation upgrades, South Terminal Expansion, Satellite Transit System upgrades, upgrade and expansion of the IWS Lagoon 3, Air Cargo Development Plans, Aircraft Hydrant Fueling System, and the Part 150 Noise Compatibility Plan. These projects and their potential impacts to wetlands are discussed in this section. These projects are not expected to cause significant adverse cumulative impacts when considered independently or in relation to the potential impacts of the Master Plan Update improvements.

4.4.2.1 SR 509/South Access

WSDOT is the lead agency for the proposed extension of State Route 509 south of STIA. The SR 509/South Access Road project would extend the SR 509 freeway south from South 188th Street to a connection with Interstate 5 and improve related local traffic circulation patterns. Southern access to STIA will be provided by construction of a new roadway, the South Access Road.

Five alternatives are currently under consideration for the location the SR 509 extension. The preliminary preferred alternative is Alternative C2. Alternative C2 would cross the southern one-third of the FAA extended object-free zone at the south end of Runway 16L/34R. The roadway would continue to the southeast and encroach on the northeast corner of Des Moines Creek Park and require the acquisition of approximately 8.1 acres of parkland. Continuing toward I-5, the SR 509 main line would pass through an area of mobile homes and join I-5 near the intersection of SR 99/South 208th Street. The length of the extension would be approximately 3.3 miles.

In 1996, WSDOT published a draft environmental impact statement for the project. Between February 2000 and August 2000, WSDOT released updated information on the project in a number of *Discipline Reports* in the following areas:

Geology and Soils

Water Quality

Hazardous Waste

Historical and Archeological Preservation

Relocation

Section 4(f)—23 U.S.C. § 138 Evaluation RE: Use of Land from Public Park, Recreation Area, Wildlife or Waterfowl Refuge, or Historic Site

Social

Visual Quality

Vegetation, Wildlife and Fisheries

Wetlands

The potential impacts relating to wetlands, vegetation, wildlife, fisheries, and water quality are summarized below. Readers are referred to the *Discipline Reports* for detailed discussion of these and other potential project-related impacts.

Wetlands

Impacts to wetlands and wetland buffers vary depending on the alternative considered, and impacts could include alteration of existing wetland hydrology and water quality. Thirty-five wetlands or buffer areas lie within the cut or fill lines of the five Build alternatives. Based on the data available in April 2000, the predicted impacts are between 7.7 to 9.29 acres of wetland impacts and 14.5 to 18.56 acres of buffer impacts. The predicted impacts are described in more detail in the April 2000 *Wetland Discipline Report* (WDR) (WSDOT 2000a), pp. 57-65. Mitigation measures are discussed in WDR pp. 66-70. Wetland impacts will be avoided where possible and reduced through design changes[39]. Impacted wetlands will be rehabilitated or restored, and wetland functions will be replaced through mitigation agreement with local governments and regulatory agencies, in compliance with the Clean Water Act and local regulations that protect wetlands and streams. This wetland impact could require from 13.6 to over 21 acres of wetland mitigation to replace the wetland functions potentially affected by the project.

Vegetation, Wildlife, and Fisheries

No substantial impacts to vegetation or wildlife are anticipated. The primary effects on habitat from road construction would be the removal of vegetation and increased habitat fragmentation. Wider roads and new roads could create barriers to wildlife movements. Noise could cause wildlife to seek new foraging or nesting areas. Excavated streams would be restored and wildlife habitat would be mitigated in consultation with the FAA and other federal, state, and local agencies. Impacts to vegetation, wildlife, and fisheries vary between the alternatives and range from 113 acres to 170.8

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[39] Alternatives that construct portions of the project on bridges and use retaining walls to reduce wetland fill (to potentially less than ¼-acre) are being evaluate, and if selected as the preferred alternative, coupled with effective compensatory mitigation for impacted functions. The potential for cumulative wetland impacts is greatly reduced or eliminated.

acres of impacts to various categories of modified or natural habitat. The March 2000 *Vegetation, Wildlife and Fisheries Discipline Report* (VWFDR) (WSDOT 2000c) discusses impacts (pp. 39-47) and mitigation measures (pp. 48-50).

Water Quality

Potential impacts to water quality could occur from construction and operation of the highway (WSDOT 2000b). Construction activities include clearing vegetation, demolishing existing roads and buildings, grading the existing ground surface, installing culverts at stream crossings, handling construction materials, and operating machinery. If unmitigated, these activities have the potential to disrupt surface water flows, increase surface runoff volumes, cause erosion and sedimentation in receiving streams, and increase water temperature in streams. In addition, a variety of foreign materials could enter surface water bodies, including sediment, fuel, lubricants, paving oils, construction debris, and uncured concrete.

Activities and events that could occur during operation of the highway, such as stormwater runoff, accidental spills, sanding, de-icing, and vegetation control all have the potential to affect surface water quality. Contaminant concentrations in stormwater coming from the roadway would most likely not exceed Washington State water quality standards due to treatment by selected BMPs.

A number of measures can be taken to reduce the potential impacts on water quality, including integration of a stormwater management system into the roadway design. Also, WSDOTs Municipal NPDES permit will require mitigation of potential adverse effects from the long-term operation of the road. This mitigation includes collection of stormwater, control of flow rate, and water quality treatment in accordance with King County's 1998 Stormwater Management Guidelines, WSDOTs 1995 Stormwater Management Guidelines, and WSDOTs 1999 Endangered Species Act (ESA) Stormwater Guidelines. To minimize accumulation of sediments in streams and wetlands, WSDOT is currently considering the use of 13 wet vaults, located along the roadway as necessary, to allow collected stormwater to be discharged at natural locations in the highway's subbasins (WSDOT 2000b).

4.4.2.2 Central Link Light Rail Transit System

The cumulative impacts of the proposed light rail transit system were considered in the FSEIS, p. 5-1 through 5-8. The Central Puget Sound Regional Transit Authority (Sound Transit 1999) is proposing construction and operation of an approximately 25-mile electric light rail system known as the Central Link Light Rail Transit Project, which will connect to the eastside of the airport. The portion of the project near STIA is referred to as Segment F in the *Central Link Light Rail Transit Project, Final Environmental Impact Statement*, (Sound Transit 1999).

The preferred alternative for Segment F includes an elevated line along Tukwila International Boulevard from 152nd Street, continuing southwest to cross over SR 518, traveling west of Washington Memorial Park, and connecting to STIA proposed North End Airport Terminal or Intermodal Center. The line would then continue elevated along the west side of International Boulevard, turn southwest to cross 188th Street, and continue elevated along the east side of 28th Avenue South to South 200th Street. Three stations are proposed: North SeaTac, with a 260-, 454-, or 670-stall park-and-ride; North Central SeaTac (at the STIA Intermodal Center); and South SeaTac (*Central Link Light Rail FEIS,* p. S-5).

Potential environmental impacts of the light rail project in the vicinity of the STIA (Segment F) may include wetland and vegetation impacts.

- Four of the light rail project alternatives would require 0.60 acre of tree removal along the eastern edge of Washington Memorial Park and the loss of 0.12 acre of forested and palustrine emergent wetland and 0.21 acre of wetland buffer.
- One alternative would affect Bow Lake (AR-44) through the loss of less than 0.01 acre of scrub/shrub wetland and 0.06 acre of wetland buffer, loss of some riparian vegetation that provides wildlife habitat and water quality functions, and incremental degradation of fish habitat from in-water piers and clearing of littoral vegetation.

There are a number of options under consideration for construction of the South SeaTac station (Options A through F). South SeaTac station Option A would remove 5.0 acres and station Options B and C would remove 4.0 acres of trees and dense shrubs. South SeaTac station Options D, E, and F would remove 0.60 acre of urban songbird habitat.

No long-term impacts on wetlands or fish habitat are expected under the other alternatives in Segment F. None of these alternatives is expected to impact the bald eagle nesting territory at Angle Lake. No impacts on threatened and endangered fish species are expected to result from any of the alternatives in this segment (*Central Link Light Rail FEIS,* pp. 4-121, 4-125, and 4-126).

Water Resources

The various alternatives create up to 120,000 ft^2 of new impervious surface from trackage, 18,000 ft^2 from road improvements, and 130,600 ft^2 at the South 200th Street park-and-ride if the 950 proposed stalls are constructed. Increased impervious surface associated with the proposed South 200th Street park-and-ride facility could impact local drainage systems and water quality by increasing runoff; however, this project is not expected to have significant impacts on the East Fork of Des Moines Creek, which lies downstream from the project. Park-and-ride facilities at South 154th and South 160th are proposed at existing developed sites with 100 percent impervious surface and would decrease the total amount of impervious surface area within the Des Moines Creek watershed, although the amount of pollutant-generating impervious surface would increase.

The preferred alternative would have stations at South 154th Street, the Intermodal Center/North End Airport Terminal, and South 184th Street (possibly) and south of South 200th Street. The stations at South 154th Street, the Intermodal Center/North End Airport Terminal, and South 184th Street would decrease impervious surface. The proposed park-and-ride facility at South 200th Street would add 130,600 ft^2 of impervious surface area if the proposed 630 stalls are constructed. Trackage associated with this alternative would add an additional 80,000 ft^2 of new impervious surface along International Boulevard South, and road widening would add 7,200 ft^2 of new impervious surface.

City of SeaTac regulations, which are based upon the King County Surface Water Design Manual (1998), govern the area that would be impacted by all the alternatives in Segment F. Stormwater detention and treatment and water quality treatment would be provided at the proposed park-and-ride at International Boulevard and South 200th Street, and at 28th Avenue South and South 200th Street to meet the *King County Surface Water Manual* Level 2 requirements. Water quality treatment would be provided at the South 154th Street park-and-ride facilities (*Central Link Light Rail FEIS*, pp. 4-134 to 4-138).

4.4.2.3 Des Moines Creek Regional Detention Facility

Construction of the RDF is recommended in the Des Moines Creek Basin Plan (King County 1999), which was developed by the Des Moines Creek Basin Committee, a group comprised of the Port of Seattle, King County, and local jurisdictions. The Des Moines Creek Plan is intended to improve stormwater runoff management in the Des Moines Creek basin. During the Des Moines Creek watershed basin planning process, King County chose to rely upon regional detention facilities to mitigate existing and future development impacts.

The Des Moines RDF will be located at the head of the west branch of Des Moines Creek at the Northwest Ponds and is anticipated to provide a total of 180 acre-ft of storage. The facility would mitigate impacts of stormwater runoff from all past and future (beyond Level 1 of the King County standards) development in the Des Moines Creek watershed. The facility will reduce existing peak flood impacts in the Des Moines Creek basin. With construction of the RDF, peak flows in Des Moines Creek downstream of the RDF should decrease by 25 to 65 percent.

The three alternatives for the design of the RDF facility are described in the November 1, 1999 *Des Moines Creek Regional Capital Improvement Projects Preliminary Design Report.* On November 1, 1999, the Des Moines Creek Basin Committee also published an *Addendum to the Des Moines Creek Regional Capital Improvement Project Preliminary Design Report (Addendum).* In the *Addendum*, the Des Moines Creek Basin Committee selected the Alternative 2 design option, which is described on page 16 of the *Preliminary Design Report.*

Alternative 1 impounds the Northwest Ponds by constructing a berm at the existing outlet release control. A second berm would be constructed at the Approach Light Road with a flow release of discharge in the range of 10- to 25-year return interval flow rate. The South End Sea-Tac storm drainage (existing concrete pipe) would be rerouted to the Northwest Ponds. The flow bypass system would be connected to the Northwest Ponds at the existing outlet.

Alternative 2 impounds the Northwest Ponds by constructing a berm at the existing outlet. A second berm and flow control structure would be constructed at the Approach Light Road. Water would be released from the area at rates matching the 10- to 25-year return interval rates. The existing culverts at South 200th Street would be modified to perform flow rate control for 25- to 500-year return interval flow rates. East Fork Des Moines Creek at the Tyee Pond would be diverted to the Northwest Ponds. The South End Sea-Tac storm drainage (existing concrete pipe) would be rerouted to the Northwest Ponds, and the flow bypass system would be connected to the existing outlet (*Preliminary Design Report,* p. 16).

The berm design for Alternative 2 could require filling up to 1 acre of Wetland 28 within the golf course, depending on the final berm design and location (*Preliminary Design Report,* p. 53). This alternative would also require reconstruction of approximately 2,000 linear ft of existing channel and removal of two artificial weirs that are located within that reach. Restoration and enhancement of the stream channel would include both instream habitat features, such as LWD and boulders, as well as buffer revegetation. There would be no permanent loss of stream function or length as a result of the stream conveyance improvements.

Alternative 3 would not require construction of a berm at the outlet. Instead, the outlet would be excavated to provide an open conveyance from the Northwest Ponds to provide hydraulic control at the Approach Light Road. As with the other alternatives, a berm would be constructed at the Approach Light Road controlled discharges for storm events up to the 100-year return interval. The culverts at South 200th Street would be modified to perform flow rate control for 100- to 500-year return interval flow rates (*Preliminary Design Report,* p. 27).

Mitigation for wetland and stream impacts includes reducing water level fluctuations in adjacent forested wetlands, creating 1.8 acres of new wetland, enhancing 5 acres of wetland, and improving aquatic habitat (due to reduced peak flow) in over 2 miles of Des Moines Creek. The City of SeaTac hearing examiner (File No. CZ00-00001) found that the RDF project would result in no net loss of wetland function and area, enhance the hydrologic functions of the affected stream, and increase diversity in wetland plant species.

The Des Moines Basin Planning Committee identified a preferred alternative for the RDF in November 1999. This alternative proposes construction of a berm and hydrologic controls west of the Port's proposed wetland mitigation site on the Tyee Valley Golf Course. The proposal also includes channel reconstruction south of the Port's wetland mitigation.

Wetland Impacts

The area proposed for the RDF, the Northwest Ponds, is part of a large wetland system that includes the ponds themselves, Wetland 28, portions of the Tyee Valley Golf Course, and other areas both northeast and southwest of the ponds. To accommodate additional water storage necessary for stream protection, portions of the existing wetland will need to be modified. This modification will include construction of one or two berms and regrading approximately 11 acres of wetland area. Of this area, roughly 5 acres lie within the golf course and are dominated by turf grasses, while another 2 to 3 acres are dominated by invasive scrub-shrub species. Although the modifications will disturb some existing plant communities, the disturbed areas will remain wetlands, with the exception of the area filled for berms.

To effectively lower the water surface elevations of the ponds, the outlet channel (West Fork Des Moines Creek) must also be lowered. This will require reconstruction of approximately 2,000 linear ft of existing channel and removal of two artificial weirs within that reach. Restoration and enhancement of the stream channel will include both in-stream and habitat features such as placement of LWD and boulders, as well as buffer revegetation. As currently proposed, there will be no permanent loss of stream function or length as a result of conveyance improvements to the stream for operation of the facility (*Preliminary Design Report,* p. 54).

Compatibility of Projects Proposed on the Tyee Valley Golf Course. The Port's mitigation project has been designed to avoid areas needed for construction of the RDF, including the western edge of the mitigation project where the RDF berm is proposed, and the area along Des Moines Creek where channel excavation, grade control, and riparian restoration are planned. Furthermore, during construction of the RDF, the Port will protect the western and southern edges of the mitigation site with ecology blocks to prevent construction machinery from impacting the mitigation site. The Port will also install orange barrier fencing and TESC measures during any construction adjacent to the mitigation site to ensure that any potential impacts from construction are avoided.

The Port's proposed mitigation on Tyee Valley Golf Course is over 500 ft from the preferred alternative for SR 509. The mitigation is also over 500 ft from the preferred alternative for the South Access Freeway. In addition to this substantial distance, the drainage conditions adjacent to each proposed roadway would prevent construction runoff from entering the mitigation area. Construction noise from machinery that is located more than 500 ft away is likely to be less than noise generated from aircraft, and is thus unlikely to affect any wildlife using the mitigation site. Therefore, these projects would not impact the hydrologic or riparian functions desired for the mitigation site

The FAA and USDA Wildlife Services staff has evaluated the mitigation proposed for the Tyee Valley Golf Course for potential wildlife hazards to aviation. These agencies have determined that the mitigation results in a *decrease* in wildlife hazards near the airfield. Highway construction and operations typically reduced habitat for and use by wildlife, and therefore new roads near the mitigation site are not expected to increase wildlife hazards. New roads will not create new habitat for wildlife on the golf course; and they are unlikely to substantially affect bird movements in the area because birds of concern have habituated to vehicle and air traffic. Overall, modification of waterfowl habitat through the Port's mitigation and the proposed RDF, as well as removal of habitat through conversion of undeveloped land to roadway, should reduce wildlife hazards on the golf course.

There is no conflict between the South Access Freeway and the access bridge to SASA. The SASA access bridge will be located at airfield elevation (approximately 340 ft). The South Access Freeway will be located near existing grades (280 ft). Thus, the South Access Freeway will pass beneath the SASA bridge in an underpass.

The Port's proposed wetland mitigation is located outside the proposed RDF, and wetland hydrology of the mitigation site would not be impacted by operation of the RDF. The 100-year floodplain of Des Moines Creek (under existing conditions) is entirely within the mitigation site, and within the boundaries of Wetland 28 (see Implementation Addendum, Appendix C, Sheet C3). With the RDF in operation, the 100-year flood elevations in the mitigation site will be slightly lower than under existing conditions. Thus, increased flooding would not impact wetland vegetation. The relation of the mitigation to the 100-year floodplain, with and without the RDF, is summarized below:

	With RDF	**Without RDF**
100-year floodplain elevation	249.5 ft	250.5 ft
Area within 100-year floodplain	2.1 acres	3.1 acres

Regardless of whether the RDF is built or not, most of the area in the Port's mitigation site is existing wetland that is maintained by high groundwater and by precipitation during the winter months. Observations made during wetland delineations found high groundwater in the wetland, with water at or near the surface. This water apparently perches on a low-permeability soil layer consisting of diatomaceous earth and/or volcanic ash.

Site constraints preclude installation of extensive buffers around the mitigation site. Within the mitigation site itself, there are shrub buffers on the north side between the enhanced wetland edge and the surrounding golf course. The mitigation site will be buffered to the west by the extensive area of existing wetland (Wetland 28). On the south side, 100-ft buffers associated with Des Moines Creek will be enhanced and the mitigation site will function ecologically as a part of this important system. Wetland buffers cannot be enhanced east of the mitigation site because that area is within designated safety areas and the runway embankment. In these runway safety areas, emergency and non-emergency access, flexibility to maintain or modify vegetation, and flexibility to maintain or supplement navigation equipment or other airfield facilities must be retained. However, airport operations described above will preclude high-impact uses near the east side of the mitigation site, thereby providing an effective land use buffer.

4.4.2.4 City of SeaTac Development Planning

As a condition of the 1997 Interlocal Agreement between the Port of Seattle and the City of SeaTac, both the Port and city have agreed to coordinate development in and around the airport. The proposed Master Plan Update improvements are consistent with the City's Comprehensive Plan adopted pursuant to the state Growth Management Act.

While final designs for projects subject to the agreement are not available, each of these projects may have direct or indirect impacts to wetlands near the airport and without mitigation may result in some impact to wetland area and ecological functions. SEPA, NEPA, and Section 404 review for these projects will require evaluation of options that avoid or minimize impacts to wetlands and the aquatic environment. For unavoidable impacts to wetlands, mitigation must be provided. Mitigation provided by these projects for unavoidable wetland and stream impacts is likely to require protection of water quality conditions in streams and wetlands, replacement of wetland functions on-site, and restoration of aquatic habitat. Thus, significant cumulative impacts to wetlands are not anticipated.

Westside Plan

In November 1997, the City published the *City of SeaTac Comprehensive Plan Amendments and Zoning Changes Final Supplemental Environmental Impact Statement* (City of SeaTac 1997). This document addresses zoning classifications and development alternatives for the Westside Subarea and modifications to the City's Comprehensive Plan to be consistent with the regional Metropolitan Transportation Plan.

The SeaTac Comp Plan/Zoning FSEIS found that there would be no significant impact to water resources. Water impacts would be limited to the possible mitigatable increases in stormwater runoff in Miller Creek. King County, the City of SeaTac, and the Port have already coordinated their efforts in the Des Moines and Miller Creek watersheds to control water quantity and enhance water quality. Des Moines Creek would be unaffected by the proposed project actions.

City Center Plan

In November 1999, the city adopted the SeaTac City Center Plan as a subarea plan to SeaTac's Comprehensive Plan. The primary objectives of the City Center Plan include support for integrated development in the city center area, creation of a central business district, changes to land use designations, and location of a Sound Transit light rail station (City of SeaTac 1999).

The City and the Port of Seattle have also entered into a Joint Transportation Study that will include development of multi-modal travel simulation models to test various combinations of regional airport and city-wide development and access alternatives.

The *SeaTac City Plan FEIS* did not identify any unavoidable impacts that affect the environmental analysis provided for the Port's 404 application. For example, the *SeaTac City Plan FEIS* did not identify any additional wetland impacts, and water impacts were limited to additional stormwater runoff that will be mitigated through compliance with applicable surface water design regulations, stormwater filtration, and additional landscaping requirements (*SeaTac City Plan FEIS*, pp. 1-7 to 1-13).

4.4.3 Seattle-Tacoma International Airport Projects

The Port has a number of airport improvement projects, described below, at various stages of design and implementation. These projects are not expected to cause significant adverse cumulative impacts when considered independently or in relation to the potential impacts of the Master Plan Update improvements.

4.4.3.1 South SeaTac Electrical Substation Upgrade

This project expanded the capacity of the existing South SeaTac Substation (Port of Seattle 1999c) by constructing a new substation next to the existing one and installing approximately 1.2 miles of 115 kV high transmission lines on segments of South 188th Street and 28th Avenue South (*SEPA Determination of Non-Significance*: POS SEPA File No. 99-02, March 1, 1999).

Two shrub and forested wetlands are located 50 ft south and 50 ft east of the proposed substation site. The wetlands south of the site contain both forested and emergent wetland habitats. Groundwater seepage into the wetlands during the wet season maintains the area as a wetland. The wetlands lack any distinct surface water inlet or outlet features. The wetlands are considered Category IV using the Ecology wetland rating system because of small size, recent disturbance, and limited biological diversity. The wetlands are rated Class II under the City of SeaTac's sensitive areas code (*Substation SEPA Checklist*, pp. 7 and 8). The project was designed and constructed in accordance with City of SeaTac requirements for projects near wetlands. No structures were constructed within 65 ft of the wetlands, and measures to minimize erosion and off-site sediment transport were implemented.

4.4.3.2 South Terminal Expansion

Much of this project was analyzed under the Master Plan Update FEIS and FSEIS. Changes to the proposal were discussed in the July 19, 1999 *South Terminal Expansion SEPA Checklist* (Table 1, pp. 3 through 11) (Port of Seattle 1999d) and considered in a *Mitigated Determination of Non-Significance* dated (Port of Seattle 1999e) July 19, 1999. The project will be constructed on a previously developed portion of airport property. The facility is expected to include the following elements: Concourse A Extension, Office Tower Building, Supply Distribution Center on Concourse A, South Ground Transportation Lot, Public Transit Curb, Gate B Outbound Baggage Facility, Concourse B Operations Office, relocation of Concourse A tenants and South Satellite Office, Remain Overnight Aircraft Parking, apron paving, demolition of existing Delta Airlines hanger and construction of a new Northwest Airlines hanger on the site, Northwest Airlines flight kitchen, aircraft lavatory dump station replacement, and construction staging area. The project changes do not substantially alter the Master Plan EIS analysis of potential environmental impacts (July 19, 1999 *South Terminal Expansion SEPA Checklist*, pp. 13 through 31).

4.4.3.3 Upgrade of Airport Satellite Transit System

This proposal was analyzed in the May 13, 1997, Master Plan FSEIS (FAA 1997). The upgrade entails relocation of the existing north security checkpoint, construction of a new vertical circulation core, improvements to the satellite transit system, interior remodeling, and extension of the north end of the main terminal by approximately 75 ft. Project modifications are discussed in the August 23, 1999 SEPA Addendum. The modifications do not substantially alter the analysis of significant impacts described in the Master Plan FSEIS (August 23, 1999 SEPA Addendum, p. 3).

4.4.3.4 Upgrade and Expansion of Industrial Wastewater System Lagoon 3

This proposal is to clean, line, expand, and upgrade an existing wastewater system lagoon. The expanded lagoon will provide greater industrial wastewater storage capacity prior to treatment in the Port's Industrial Wastewater System Treatment Plant (Kennedy Jenks 2000) and allow for controlled discharge to the King County Metro sewerline. The proposal received a SEPA Determination of Non-Significance on December 22, 1999.

Two wetland complexes and a stream are located in the immediate site vicinity (Parametrix 2000a). Wetland 28, also known as the Northwest Ponds, is a large diverse Class I wetland located mostly south of Lagoon #3. The wetland is approximately 35 acres in size and consists of open water and emergent and scrub-shrub vegetation. Two arms of Wetland 28 extend north to border both the east and west sides of Lagoon #3. The west branch of Des Moines Creek originates in Wetland 28 and flows south and west into Puget Sound. Another wetland complex (IWSA/IWSB) is located north of Lagoon #3. This forested wetland is approximately 0.67 acre and is divided by a gravel access road.

The project will not involve work in the waters of Wetland 28 (see Section 4.3.2.18) or IWSA/IWSB. Work will occur adjacent to the northern arms of Wetland 28 and IWSA/IWSB. Buffer impacts resulting from the project will be reviewed by the appropriate regulatory agencies and may require mitigation such as buffer averaging or replacement (*IWS Lagoon #3 Upgrade SEPA Checklist*, p. 10). Some groundwater dewatering is expected during construction, with a maximum dry weather pumping rate of 450 gallons per minute. This groundwater is not expected to require treatment prior to discharge into the Des Moines Creek tributary east of the site. If water quality testing indicates high levels of turbidity, the water may be treated on site prior to discharge. As part of the proposed lagoon improvement, a permanent underdrain and pumping system would be installed to prevent accumulation of groundwater under the lagoon liner system. The collected water would be discharged into Des Moines Creek (*IWS Lagoon #3 Upgrade SEPA Checklist*, p. 11).

4.4.3.5 Air Cargo Development Plan

The Air Cargo Development Plan (ACDP) is a 10-year programatic development plan for facilities and actions recommended to meet the needs of existing air cargo customers at STIA. Actions tentatively planned through 2004 include purchasing airport leases to allow redevelopment in the north cargo area, constructing four aircraft hardstands in the north cargo area, constructing freight warehousing in the north cargo area, preparing a site development plan for property north of SR 518 (L-shaped parcel), and redeveloping Port building 313 for air cargo. Actions tentatively planned from 2005 through 2010 include constructing five aircraft hardstands in the north cargo area, mail processing and transfer facilities, a non-public bridge across SR 518 (adjacent to the existing 24th Avenue South bridge), and a ground support equipment storage area (*Air Cargo Development Plan SEPA* Checklist, p. 3).

There are no water bodies in the immediate vicinity of the northeast corner of STIA, where the air cargo facilities recommended in the ACDP would be located. The majority of the area is paved and already developed for airport uses. Redevelopment of airport property will have little impact on impervious surface area.

Development of the L-shaped parcel north of SR 518 will increase impervious surface area because the parcel is currently undeveloped. Site development of this parcel and an access bridge will include stormwater collection and detention facilities. Preliminary information indicates that wetlands exist on the L-shaped parcel.

Portions of this property would be developed if all of the ACDP recommendations are implemented. As the project is still in the definition phase, no wetland delineation or environmental analysis has been undertaken (*Air Cargo Development Plan SEPA Checklist*, pp. 7 through 10).

4.4.3.6 Aircraft Hydrant Fueling System

The AHFS proposal is to install a Jet A underground fuel line concurrent with the planned improvements to Concourse A. The AHFS would provide single source fuel delivery of Jet A fuel at the airport and a common infrastructure that would be used by all airlines. The AHFS would replace the current fueling operations (primarily truck deliveries) for most commercial passenger aircraft at the Airport. The AHFS would include cathodic corrosion protection for the underground pipes and a state-of-the-art leak detection system.

A SEPA determination of non-significance was issued for the project on October 6, 2000. Previously, the Port had analyzed the need to replace the existing fueling equipment in the Master Plan FEIS. Other environmental documents that discuss the proposal are listed on page three of the SEPA environmental checklist for the proposal.

The Major goals of the AHFS project include:

- Relieve congestion and increase safety on the terminal apron by significantly reducing the need for fuel truck trips;
- Improve air quality by reducing air emissions resulting from a reduction in the number of trucks;
- Deliver fuel to aircraft in a more economical and reliable manner;
- Install new equipment and dispose of existing equipment in an environmentally safe manner; and
- Provide increased environmental protection of the aircraft fuel delivery system by installing state-of-the-art pipelines and leak detection systems.

The AHFS would require removal of some of the old hydrant system piping, fuel lines, hydrants and infrastructure; installation of new aircraft hydrant fueling system, piping, fuel lines, hydrants, hydrant pump and pits. The fuel lines will be "sleeved" (placed inside another pipe) when crossing railroad tracks or highways. The AHFS would include cathodic protection and a leak detection system. Finally, the AHFS would require construction of a new fuel farm operations building (4,586 sq. ft.), a concrete pump pad facility (187 ft. x 32 ft.) and up to two new modular operations buildings (approximately 1,320 sq. ft.).

Water Resource Impacts:

The proposed operation building and pump pad would be constructed on a portion of the existing South Employee Parking Lot, which is outside of the Des Moines Creek wetland buffer area. No fill or excavation material for this project will be placed in or removed from any surface water or wetlands. The project would not cause any surface water withdrawals or diversions. Likewise, no groundwater withdraws or discharges are contemplated for this project. Most of the project area is currently paved and connected to the Port's Industrial Wastewater System ("IWS"). It is possible, though not anticipated, that some perched groundwater may be encountered during construction. *Environmental Checklist,* pp. 15-16 (October 5, 2000).

The AHFS will be connected to the IWS, which provides stormwater treatment for areas where a fuel spill could occur. All construction activity would be conducted under a construction SWPPP as required by the Port's NPDES permit. Construction runoff would be treated with BMPs (sedimentation basins, silt fences, mulching, netting, proper grading and water quality monitoring) to remove turbidity, sediment, or other materials and a construction Erosion and Sedimentation Control Plan will be created. This plan will draw on the following sources and include all required sedimentation and erosion control features of:

The project specifications:

- The Port of Seattle's Temporary Erosion and Sedimentation Control Plan;
- The Stormwater Management Manual for the Puget Sound Basin;
- The King County Surface Water Design Manual;
- Oversight by regulatory agencies; and
- The interlocal agreement between the Port of Seattle and the City of SeaTac.

Approximately 2,500 square feet of construction for the asphalt access road, fence and retaining wall (to minimize wetland impacts to the north of the access road, would be located 25 feet within the 50 foot. wetland buffer established by the City of SeaTac. The encroachment into the buffer would eliminate 2,500 square feet of grassland and blackberry. *Environmental Checklist,* pp. 15-16 (10/5/00).

4.4.3.7 Part 150 Noise Compatibility Plan

The Port issued a SEPA Determination of Non-Significance for the Part 150 Noise Compatibility Plan on October 20, 2000. The Part 150 plan consists of a series of actions to reduce noise from ground and flight operations at the airport. The Plan includes conducting additional studies including a siting study for the Ground Run-up Enclosure, a siting study for noise walls and recommended changes to runway use and flight tracks. The Plan also includes descriptions of existing conditions, aircraft operations forecasts, existing and future noise environment, facilities, operational and land use alternatives, technical reports, and a community involvement plan.

The Plan is part of the Port's Noise Remedy program, the goal of which is to reduce aircraft and ground noise at the Airport, reduce noise impacts on the greater Seattle area, and encourage land uses that are compatible with anticipated aircraft noise exposure.

The plan is anticipated to include the following components:

- Construction of noise barriers in the north cargo area
- Construction of a Ground Run-up Enclosure (GRE)
- Modifying existing maintenance regulations and noise fines
- Implementing a ground power and pre-conditioned air system
- Working with the FAA to develop noise-reducing aircraft arrival patterns, runway use, and glide slopes.
- Sound insulation of schools in the 65 DNL zone

- Acquisition of mobile home parks in the 70 DNL zone
- Working with local governments on airport noise compatible land use and building codes

Water Resource Impacts.

The project will not place or remove fill or dredge materials from surface waters or wetlands. The project would not require surface water withdrawals or diversions and would not involve the discharge of waste materials into surface waters. The development of the Ground Run-up Enclosure (GRE) and noise walls may increase the amount of impervious surface and affect the rate of stormwater runoff. About 1-acre of additional impervious surface would be developed as the base of the GRE. Runoff from the proposed GRE would flow to the Port's IWS system for treatment and subsequent discharge.

During construction the contractor will be required to have a Stormwater Prevention Plan in place that includes temporary erosion control and sedimentation measures. This plan would include best management practices such as diverting surface runoff from erosion-prone areas, mulching, netting, and proper grading.

4.4.3.8 North End Development Project

The North End Development Project (NEDP) is in the initial planning stages and would cover primarily the area north of the existing main terminal. As currently envisioned, the project builds on and includes the Master Plan Update improvements to construct a North Unit Terminal (which is currently being called the North End Terminal). The planning conducted to date for this area would include:

- Development of the North End Terminal, with a slight change over what was evaluated by the Master Plan Update
- Construction of an Transportation Center parking garage with facility for buses and other ground transportation
- Construction of a Consolidated Rental Car Facility—garage for all rental cars
- Construction of an Automated People Mover—to connect the rental car facility with the new terminal, the Transportation Center, and the main terminal.
- Relocation of displaced facilities—post office, cargo buildings, fire station
- Potential development of Port property north of SR 518 to accommodate cargo facilities (as noted in the Master Plan Update).

Although it appears unlikely at this time that there would be significant increases in either the types or intensities of environmental impacts from these facilities, planning for these concepts is at an early stage. Construction is subject to numerous contingencies including planning decisions, potential further environmental review, Port Commission adoption of a new plan for the area, permitting, and financing. If it is determined, as planning continues, that it is necessary or advisable under NEPA or SEPA to conduct additional environmental review, the FAA and/or Port will have the opportunity to conduct additional review.

4.4.3.9 North Electrical Substation

The North Electrical Substation received a SEPA Determination of Non-Significance on June 2, 2000. This DNS was amended on March 6, 2001 to reflect minor project changes. As currently envisioned, the project involves upgrading and expanding the existing Bow Lake Substation, replacing the North SeaTac Substation with a smaller facility (the North Main Service Point) and installing an 1,800-foot, 12.5 kV underground cable system between the Bow Lake Substation and the new North Main Service Point.

The Bow Lake Substation will be rebuilt on property owned by Puget Sound Energy ("PSE"). The North Main Service Point will consist of switch-gear enclosed in a 25-foot by 60-foot building that is 15 feet tall. The building will be enclosed by a 50-foot by 100-foot fence. The North Main Service Point will be located just east of the south entrance to the Airport parking garage between the entrance booth and the northbound Airport circulation road. The proposed 12.5 kV cable system will extend along the north side of South 176th St., across International Boulevard and onto Airport property.

No wetlands or water bodies are implicated in the construction of this facility. Stormwater collected at the North Main Service Point will flow either into the Port's stormwater collection system or industrial waste system. Catch basins for both systems are located in the area.

4.4.3.10 Water System Improvements

The Port proposes to construct water system improvements, including a two million-gallon reservoir, expansion of an existing booster pump station, and other improvements to the fire and domestic water distribution systems at Airport. The reservoir will be constructed on Port-owned land west of the Washington Memorial Cemetery on the east side of the Airport. This location is about 350 feet south of the existing water tower. Construction of the reservoir will involve relocating utilities and the east west portion of Host Road to a point approximately 100 feet north of the new reservoir.

The project will not result in any net increase in the amount of impervious surface over the existing 34,400 square feet. Therefore, there is no expected increase in the amount of stormwater runoff flows to the Des Moines, Green or Duwamish basins.

Rainwater from the site will be collected either in the Airport's stormwater drainage system or in the Industrial Wastewater System. The project will not require work over or in surface waters, and no fill or dredge material will be placed in or removed from surface waters or wetlands.

4.4.3.11 Miscellaneous Airport Projects

The following projects are at various stages of the design and planning process. Many have not yet undergone full environmental review. To the extent that potential environmental impacts have been identified, the Port concludes that these impacts will not have significant, adverse, environmental impacts at Sea-Tac Airport (including impacts on aquatic resources), either separately or in conjunction with the impacts identified for the Master Plan Update projects.

TRACON (Terminal Radar Approach Control) is a radar system used by the FAA to track planes while in flight from approximately 5 to 30 miles from the airport. The TRACON facility would consist of radar towers and a building to house air traffic controller radar scopes. Currently, TRACON is located in the FAA space below the tower at Sea-Tac Airport. However, the TRACON facility has outgrown available space in the tower. The FAA is currently considering relocating the TRACON to the west side of the airport below the slope of the new runway. The Master Plan Update FEIS and FSEIS evaluated this project as being located at the base of the new air traffic control tower that is under construction. Since the completion of that study, the FAA has determined that a site on-airport is not necessary and is conducting a siting evaluation, which is investigating a 19-acre potential site at 8th Ave. and 170th St.

TRACON is a FAA project, and the FAA will be responsible for construction and environmental analysis for the project. The FAA has not begun environmental analysis on the site. The target date for relocating TRACON is the end of 2004. As currently envisioned the site will house two radar antennas, a building for the air traffic controllers and a parking lot for approximately 100 vehicles. Mitigation for Master Plan Update Projects has been planned to avoid potential TRACON sites, and the TRACON Facility, as currently planned, does not fill wetlands (See Appendix J of the NRMP (Parametrix 2001a)).

ASDE (Airport Surface Detection Equipment) is radar that looks at runways and taxiways and provides a picture of location of vehicles and airplanes on the ground during periods of low visibility. The Master Plan Update EIS evaluated placing the ASDE on top of the air traffic control tower. Since that time, the FAA has learned that there are performance issues associated with locating this type of radar close to buildings. The FAA is currently conducting a siting study for this facility, which to date has determined that the location on top of the new tower could pose visibility issues. Upon selection of a final site, it is expected that the Port will conduct an additional SEPA review, and the FAA will complete a NEPA determination. Mitigation planned for Master Plan Update projects has been planned to avoid 2 potential sites for the ASDE facility. The potential sites for this facility could be developed without filling wetlands (See Appendix J of the NRMP (Parametrix 2001a)).

Temporary Aircraft Parking-Taxiway Stubs – On October 25, 2000, the Port issued a SEPA Determination of Non-Significance to allow use of some existing Taxiways for aircraft parking until the taxiways are needed for the Third Runway. No maintenance or de-icing activities will occur to aircraft parked on the taxiways, and no impacts to aquatic resources are expected to occur from this activity.

SR 518 – The Washington State Department of Transportation is in the process of studying SR518 and possible upgrades to the roadway and interchanges to improve traffic flow. The study should be available by late 2001.

4.4.4 Summary

This analysis has documented changes to land use, wetlands, streams, and wildlife habitats in the Miller and Des Moines Creek watersheds for the purpose of determining cumulative effects. The findings are summarized in Table 4-20.

Current and future development (including the STIA Master Plan Update actions must comply with a variety of environmental regulations that protect wetlands, streams, and habitat. These regulations and their substantial mitigation requirements (see the NRMP [Parametrix 2001a] and the SMP [Parametrix 2000b and Parametrix 2001d]) reduce the potential that additional cumulative impacts would occur.

For the Port's Master Plan Update projects, wetland, stream, and hydrologic mitigation improves ecosystem functions by providing wetland, stream, and buffer habitat restoration and enhancement to over 178 acre of property (FAA 2000, Parametrix 2001a). The retrofitting of previously developed areas with stormwater quality and quantity treatment facilities that meet current standards will further reduce the potential for cumulative impacts Parametrix 2000b). In addition, reductions in low stream flow are prevented as described in the low stream flow analysis report (Parametrix 2001b). As a result of this mitigation, there are no significant project impacts to wetlands or streams and thus the projects will not contribute to cumulative impacts to these resources.

The amount of known wetlands near STIA, wetland impacts, and wetland restoration actions are summarized by sub-watersheds in Table 4-21. The Master Plan Update improvements result in a loss of about 3.3 to 4.0 percent of wetland area in these sub-basins[40]. In all cases, because of the physical attributes of the mitigated wetlands, including their hydrologic connectivity, the mitigation provides Category II wetlands and buffers. These losses are compensated on-site by mitigation described in Sections 4, 5, and 7 of the NRMP, and thus an incremental (cumulative) loss of wetland functions near the airport in is avoided.

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[40] The NRMP (Parametrix 2001a) and section 3.3.2 explain how mitigation replaces wetland functions on-site and within WRIA 9.

Table 4-20 Cumulative effects analysis of wetlands, streams, and other aquatic resources in the Des Moines, Miller, and Walker Creek basins.

		Proposed Action[a]			Other
Resource	**Past Actions**	**Construction**	**Operation**	**Mitigation**	**Present and Future Actions[b]**
Wetland Area	Losses have occurred as a result of farming, commercial, residential, and airport development.	Loss of 18.37 acres would occur.	None.	Designation of over 134 acres of mitigation (67 acres on-site and over 65 acres in Auburn).	No net loss. Federal state and local regulations are increasingly protective of wetlands. Section 404 Nationwide Permits (NWPs) and Individual Permits require mitigation, typically exceeding area impacts.
Biological Wetland Functions	Losses to biological functions have occurred. In addition to filling and draining wetlands, past development and land uses have reduced the natural vegetation in and near wetlands and affected wildlife habitats. Development has affected the rates and quality of runoff, which has impacted aquatic habitat in some wetlands.	Construction will eliminate the biological functions of 18.37 acres of wetland. Without mitigation, wetland loss and buffer impacts would cause losses of biotic functions.	Without mitigation, operation impacts to wetland habitat could include habitat disturbance, wildlife management activities, and runoff impacts.	No net loss. Wetland restoration and enhancement coupled with buffer protection and enhancement will increase in-basin biotic function and connectivity of remaining wetlands. Out-of -basin mitigation creates 65 acres of high quality wetland and buffer habitats. Long-term protection and preservation of greater amounts of higher-quality wetlands balance temporal losses of habitat.	No net loss. Federal state and local regulations are increasingly protective of wetlands. Section 404 NWPs and Individual Permits require mitigation, typically exceeding area impacts. Mitigation planning increasingly focuses on replacing and enhancing functions, and local regulations protect wetland buffers.
Physical Wetland Functions	Filling of wetlands has eliminated the flood storage, water quality, and groundwater exchange functions they provide from several areas. Past development and land uses have reduced the	Construction will eliminate the physical functions of 18.37 acres of wetland. Without mitigation, wetland loss and buffer impacts would cause losses of physical	Without mitigation, operation impacts to physical wetlands functions could include decreased water quality, groundwater exchange, and stormwater storage functions.	No net loss. Wetland restoration and enhancement coupled with buffer protection and enhancement will increase in-basin biotic function and connectivity of remaining wetlands. Out-	No net loss. See above.

Table 4-20 **Cumulative effects analysis of wetlands, streams, and other aquatic resources in the Des Moines, Miller, and Walker Creek basins. (continued)**

		Proposed Action[a]			Other
Resource	**Past Actions**	**Construction**	**Operation**	**Mitigation**	**Present and Future Actions[b]**
	vegetation in and near remaining wetlands, which may reduce water quality and other functions they provide.	functions.		of-basin mitigation creates 65 acres of high-quality wetland and buffer habitats. Long-term protection and preservation of greater amounts of higher-quality wetlands balance temporal losses of habitat.	
Instream Habitat	Impacts to instream habitat have occurred from forestry, farming, and urban development. These activities have eliminated high quality in-stream habitats.	Fill of a portion of the Miller Creek stream channel would occur. Without mitigation, the loss of degraded habitat would occur.	Without mitigation, increased runoff could further degrade instream habitat.	Beneficial. Relocation and enhancement of Miller Creek, instream habitat projects, buffer enhancement, and wetland restoration improve instream habitat.	Beneficial. Sensitive areas regulations protecting streams and buffers, coupled with restoration and enhancement projects, including the planned Des Moines Creek regional detention facility, should improve habitat conditions for fish and aquatic life.
Stream Hydrology - Low Flow	Impacts to stream hydrology have occurred from forestry, farming, and urban development. Land clearing from forestry and farming activities could have increased recharge and low flows. Urban development and pavement would have decreased groundwater recharge and reduced low flows.	Construction of new impervious surfaces, without mitigation, would reduce groundwater recharge and reduce low flow.	None.	Maintain. Low flow conditions are maintained by infiltration and stormwater storage.	Degrade. Current municipal stormwater regulations do not address low flow impacts, nor require mitigation. For projects undergoing state or federal permitting, low flow mitigation may be required.
Stream Hydrology - Peak Flow	Impacts to stream hydrology have occurred from forestry, farming, and urban development. Land clearing from forestry and farming	Constructions of new impervious surface, without mitigation, would increase peak flows and degrade	None.	Beneficial. Stormwater detention facilities for new and past development will mitigate peak runoff rates and retrofit for past	Beneficial. Stormwater detention facilities for new and past development will mitigate peak runoff rates. Some projects (i.e.

Table 4-20 **Cumulative effects analysis of wetlands, streams, and other aquatic resources in the Des Moines, Miller, and Walker Creek basins. (continued)**

		Proposed Action[a]			Other
Resource	**Past Actions**	**Construction**	**Operation**	**Mitigation**	**Present and Future Actions**[b]
	activities would have increased runoff rates and peak flows. Urban development and pavement constructed without stormwater management facilities would have increased peak flows significantly.	aquatic habitat.		development.	transportation projects funded by Washington State Department of Transportation [WSDOT]) may provide detention facilities for past development. The Des Moines Creek regional detention facility should improve Des Moines Creek peak flows above the baseline level.
Floodplains	Land development and loss of flood storage has occurred in some floodplains.	Fill of floodplain and loss of flood storage would occur.	None.	Maintain. Floodplain fill will be balanced by floodplain mitigation.	Maintain. Local regulations adequately protect floodplain areas.
Water Quality	Impacts to water quality have resulted from past forestry, farming, and urban development in the watersheds. Land clearing from forestry and farming activities would have increased sediment runoff rates. Runoff from fertilizers and agricultural chemicals would have degraded water quality. Urban development has resulted in untreated stormwater runoff, which degrades water quality.	Without mitigation, sediment runoff could degrade water quality.	Without mitigation, new impervious surface could generate contaminated runoff and degrade water quality.	Maintain. New stormwater quality best management practices (BMPs) will treat runoff from new and existing impervious surfaces.	Maintain. Stormwater treatment facilities for new development will prevent significant degradation of water quality. Some projects (i.e., WSDOT-funded transportation projects) may provide treatment facilities for past development.

[a] Effects of the proposed actions on wetlands and streams are discussed in this report, the *Natural Resources Mitigation Plan* (Parametrix 2001a), the *Biological Assessment* (FAA 2000), the *Comprehensive Stormwater Management Plan* (Parametrix 2000b) ,the *FEIS* (FAA 1996), the *FSEIS* (FAA 1997), and the *Comprehensive Stormwater Management Plan* (Parametrix 2000a).

[b] Evaluated with mitigation that would be required to meet federal, state, and local regulations.

Table 4-21. Changes in wetland and aquatic habitat areas in the Miller, Walker, and Des Moines Creek basins (WRIA 9).

Watershed and Sub-Area	Area	Impact	Restoration
Miller Creek Basin			
Arbor Lake	3.7	0.00	0.00
Lake Burien	30	0.00	0.00
Riparian wetlands near S. 144th Way	2.00	0.00	0.00
Tub Lake Peatland/N. SeaTac Park Wetlands	21.01	0.00	0.00
North Employee Parking Lot Wetlands 1,2	0.81	0.00	0.00
Des Moines Way Nursery	0.86	0.00	2.00
Runway Safety Areas/North End	27.84	2.75	0.40
Vacca Farm Mitigation	8.07	0.00	6.60
Miller Creek Riparian	1.05	1.05	0.03
Third Runway Embankment	15.74	11.03	1.2
Total	**111.08**	**14.83**	**10.23**
NET CHANGE[a]: -4.5 acres -4.0%			
Walker Creek Basin			
Wetland 43	33.43	0.00	0.00
Wetland 44	3.08	0.54	0.28
Miscellaneous	0.99	0.99	0.00
Total	**37.5**	**1.53**	**0.28**
NET CHANGE[a]: -1.25 acres -3.3%			
Des Moines Creek Basin			
WSDOT Wetland B	6.60	0.00	0.00
Bow Lake Wetlands	25	0.00	0.00
SASA Area	7.22	2.95	0.17
Borrow Areas	24.24	1.04	0.00
Tyee Valley Golf Course	38.51	0.07	0.00
Total	**101.57**	**4.06**	**0.17**
NET CHANGE[a]: -3.89 acres -3.8%			
TOTAL	**250.15**	**20.42**	**10.68**
NET CHANGE -9.74 acres -3.9%			

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[a] Estimates of changes exceed actual changes, because they do not include riparian wetlands outside the project area, wetlands at the mouths of Miller, Walker, and Des Moines Creeks, or other wetlands that are likely to be present on undeveloped or developed areas. See Tables 4.1-2 and 4.1-3 in Section 4 for a summary of the mitigation planned to compensate for wetland functions associated with these changes.

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Appendix A

APPENDIX A

THIRD RUNWAY EMBANKMENT CONSTRUCTION IMPACTS TO WETLANDS

APPENDIX A

THIRD RUNWAY EMBANKMENT CONSTRUCTION IMPACTS TO WETLANDS

This appendix contains engineering reports that assess the third runway embankment design and construction methods. The information contained in the reports was used, in part, to evaluate the potential temporary construction, water quality, and indirect impacts to wetlands located adjacent or downslope of the embankment.

A-1

Temporary Construction Impacts to Wetlands

Technical Memorandum

TEMPORARY IMPACTS TO WETLANDS DURING THIRD RUNWAY EMBANKMENT CONSTRUCTION

Seattle-Tacoma International Airport
Third Runway Project

June 15, 1999

Prepared For:
The Port of Seattle, and
Parametrix, Inc.

Prepared By:
HNTB Corporation

Temporary Impacts to Wetlands during Third Runway Embankment Construction

Introduction

Construction of the Third Runway will require filling low areas west of the current airfield to raise the existing grade to approximately 400 feet MSL. This construction will require unavoidable placement of fill in existing wetlands. Temporary impacts to wetlands will result from facilities needed to meet water quality standards for construction runoff, construction dewatering, construction access, and construction staging. The facilities and activities that will result in temporary impacts to wetlands and streams are discussed below and summarized in Table 1.

Temporary construction in some of the wetlands west of the toe of the runway embankment is unavoidable because certain construction activities must occur outside (west of), but in close proximity to the footprint of the embankment where wetlands are located. Construction impacts to wetlands west of the embankment are considered temporary because following completion of construction, these impacts will be removed and the wetland areas restored to pre-construction conditions. Where feasible and consistent with FAA requirements regarding wildlife attractants, existing wetlands will be enhanced (i.e. wetlands dominated by non-native vegetation will be replanted with native species). Permanent facilities west of the runway embankment, such as storm water detention facilities, will generally be constructed outside of existing wetlands.

Storm water runoff from construction areas requires water quality treatment facilities to prevent water quality impacts to Miller Creek due to potential sedimentation. The proposed storm water treatment facilities must be constructed in low areas (which are often wetlands) and parallel to the embankment footprint (which requires crossing wetlands) to intercept construction runoff prior to entering Miller Creek. Specific storm water facilities that must be placed at the toe of the embankment slope include:

- erosion control fencing
- collection and conveyance swales
- sedimentation ponds
- pumping facilities (including power generators)
- treatment facilities (including pumps and power generators).

Additional facilities required to monitor and maintain the storm water facilities include the following. These facilities will be sited to avoid wetlands as much as possible:

- support facilities (including a trailer, parking, and material storage)
- access driveways.

In addition, the following construction activities may occur near the proposed toe of slope. These activities will also be sited to avoid wetlands, however, minor wetland impacts may occur due to temporary access roads and drainage features to support these facilities:

- contractor office space
- construction material storage
- materials testing laboratory
- concrete batch plant
- construction equipment parking and servicing

These temporary construction facilities will be removed following completion and stabilization of the embankment. Following project completion, the wetlands will be restored by:

- replacing or amending fill material with topsoil
- restoring drainage patterns and directing surface water to the wetlands
- hydroseeding disturbed areas
- replanting areas with native trees and shrubs.

Storm Water Management During Construction

This section describes the temporary drainage facilities required to meet water quality standards for the project during construction. Runoff from the embankment construction area generally flows south and west, eventually draining to one of three drainage basins. The three drainage basins within the third runway project area are:

- Miller Creek Drainage (MC)
- Walker Creek Drainage (WC) (a sub-drainage basin of Miller Creek)
- Des Moines Creek Drainage (DC)

The existing varying terrain and the proposed grading limits within the Miller Creek drainage basin require that the basin be divided into two sub-basins: Miller Creek North (MCN) and Miller Creek South (MCS). In order to manage construction runoff, temporary sedimentation ponds and treatment facilities will be constructed to serve each of the drainage basins. Plan views of the drainage basins and the conceptual construction storm water management system are depicted in Figure 1 through Figure 4.

Storm water runoff will generally be collected and conveyed to the sedimentation ponds by gravity-flow rock- or grass-lined swales. However, the lowest portions of the Miller Creek basin and the Walker Creek basin are wetlands (Wetland 37 and 44 respectively). To reduce impacts to these wetlands, construction runoff draining to these low areas will be collected in small collection ponds (sumps) and pumped to larger sedimentation ponds located upslope. The larger, upslope facilities are located in non-wetland areas to reduce wetland impacts and reduce the risk of potential encroachment into wetlands. The sumps needed to collect runoff were sized and located to reduce wetland impacts, yet provide an adequate margin of safety to prevent unauthorized storm water discharge to wetlands during emergency conditions (i.e., extreme storm events or power failures).

In order to collect runoff from the outer edge of the embankment and beyond the proposed Security Road, a temporary outer collection swale will be constructed (Figure 5-8). The swale is intended to have dual uses. First, it will collect construction runoff from the outermost portion of the embankment during the initial phases of construction and route the water to a sedimentation and treatment facility until the ground surface is established. Secondly, after establishment of the new embankment side slopes, the swale may be used as a distribution channel to direct clean runoff water to specific wetlands. Water may be distributed to wetlands using a variety of techniques, including point discharges, perforated pipe, porous rock berms, or infiltration swales. Portions of the outer swale will remain following construction to replace the conveyance functions of drainage channels filled by the project.

To service the outer collection channel during construction, as well as to provide construction access along the silt fence and the outermost fill slope, a temporary access road will be constructed (Figures 5-8). The access road will generally be constructed at or very near existing grade to minimize ground disturbance. It will not be paved and it is not intended to be used as a construction haul road.

Table 1. Temporary Construction Impacts to Wetlands Resulting From Construction of the Third Runway Embankment.

Wetland Number	Description of Facility	Purpose and Need
R2	Pond outlet pipe.	Outlet pipe from MCN-a detention pond must discharge to Miller Creek to maintain drainage basin boundary. Construction access to install pipe is required.
A5	Temporary access drive, outer collection swale, silt fence.	A swale at the edge of the construction area is necessary to collect and convey runoff to the MCN-b pond. A temporary access road will allow service and maintenance in the swale and allow installation and maintenance of a silt fence. The road, swale and fence will be removed following construction and soil stabilization.
35d	Temporary access drive, outer collection swale, silt fence, pumping facility.	A swale at the edge of the construction area is necessary to collect and convey runoff to the MCN-c holding pond. Water from the MCN-c pond will be pumped to the MCN-b pond for treatment if necessary. A temporary access road will allow service and maintenance in the swale and allow installation and maintenance of the silt fence. The road, swale and fence will be removed following construction and soil stabilization.
18	Temporary access drive, outer collection swale, holding pond (MCN-c), silt fence.	A swale at the toe of the proposed slope is necessary to collect and convey runoff to the MCN-c holding pond. The holding pond will collect construction runoff up to approximately elevation 350. Water from the pond will be pumped to the MCN-b pond for treatment if necessary. A temporary access road will allow service and maintenance in the swale and the pond, and will allow installation and maintenance of the silt fence. The road, swale, pond, and fence will be removed following construction and soil stabilization.
37a	Temporary access drive, Interim sump (MCN-d), pumping facility, silt fence.	A swale at the toe of the proposed slope is necessary to collect and convey runoff to the MCN-d sump. The sump will only collect construction runoff originating from the lowest portion of the embankment, up to approximately elevation 250. Water from the sump will be pumped to the MCN-b pond for treatment. After construction of the adjacent embankment (during the first 1-2 years of construction,) the sump will be removed and the wetland restored. A temporary access road will allow service and maintenance in the swale and the sump, and will allow installation and maintenance of the silt fence. To reduce wetland impacts, no access road will be provided in the extreme lowest portion of the embankment. The road, swale, sump, and fence will be removed following construction and soil stabilization.
Water B	Temporary access drive, outer collection swale, silt fence.	A swale at the edge of the construction area is necessary to collect and convey runoff to the MCN-c pond. A temporary access road will allow service and maintenance in the swale and allow installation and maintenance of the silt fence. The road, swale and fence will be removed following construction and soil stabilization.

Table 1. Temporary Construction Impacts to Wetlands Resulting From Construction of the Third Runway Embankment (continued).

Wetland Number	Description of Facility	Purpose and Need
A12	Temporary access drive, outer collection swale, silt fence.	A swale at the edge of the construction area is necessary to collect and convey runoff to the MCN-c pond. A temporary access road will allow service and maintenance in the swale and allow installation and maintenance of the silt fence. The road, swale and fence will be removed following construction and soil stabilization.
A13	Temporary access drive, outer collection swale, silt fence.	A swale at the toe of the proposed slope is necessary to collect and convey runoff to the MCN-c pond. A temporary access road will allow service and maintenance in the swale and allow installation and maintenance of the silt fence. The road, swale and fence will be removed following construction and soil stabilization.
41a	Temporary access drive, outer collection swale, Miller Creek South pond (MCS), silt fence.	A swale at the toe of the proposed slope is necessary to collect and convey runoff to the MCS pond. A temporary access road will allow service and maintenance in the swale and the pond and allow installation and maintenance of the silt fence. The pond is necessary for sedimentation and treatment of runoff from the southern portion of the Miller Creek drainage basin. The pond is located in the lowest area so it will collect runoff from the embankment to the east as well as staging areas to the north, west, and south.[1]
41b	Temporary access drive, outer collection swale, silt fence.	A swale at the edge of the construction area is necessary to collect and convey runoff to the MCS pond. A temporary access road will allow service and maintenance in the swale and the pond and allow installation and maintenance of the silt fence. The road, swale, pond and fence will be removed following construction and soil stabilization.
44a	Temporary access drive, outer collection swale, interim sump pond (WC-b), silt fence.	A swale at the edge of the construction area is necessary to collect and convey runoff to the WC-b sump. A temporary access road will allow service and maintenance in the swale and the pond and allow installation and maintenance of the silt fence. Access to the extreme lowest portion of the Walker Creek basin will be provided only from the south to reduce impacts to the wetland. The sump will collect water from outside the toe of the retaining wall where it will be pumped to the Walker Creek sedimentation pond (WC-a.) After the retaining wall is constructed and the surrounding ground reestablished, the sump will be removed and the ground restored.

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[1] Because this wetland will be impacted throughout the duration of runway construction (4 - 5 years, the impact is considered permanent and included in on-site and off-site mitigation plans. This wetland will not be restored following construction.

Construction Dewatering

Two types of construction dewatering will occur during construction of the runway embankment. The first involves interception of existing ground water flow and the second involves localized drawdowns of the shallow water table.

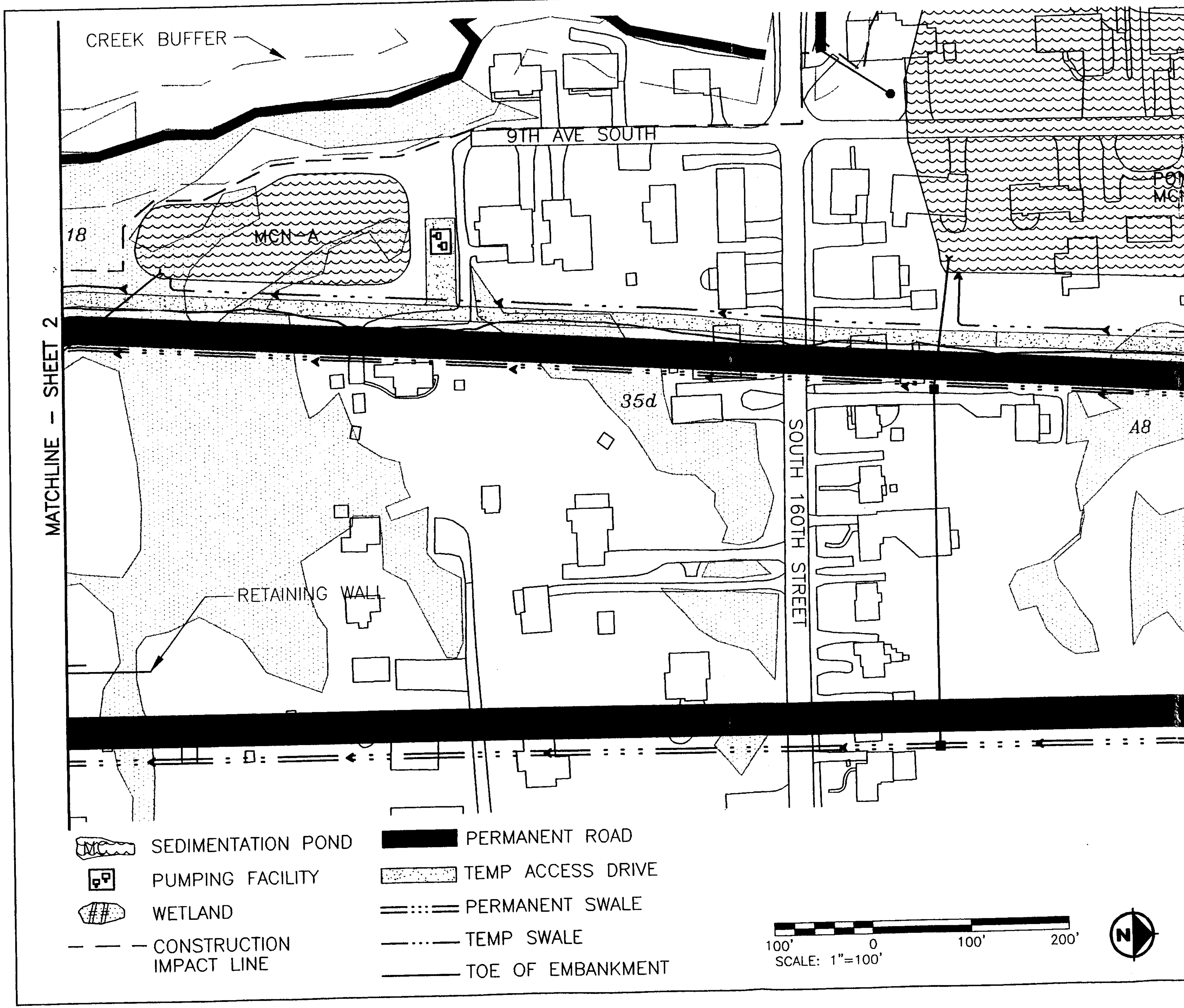
Prior to beginning construction, any existing surface flows through the work area will be routed through or around work areas via temporary piping. This will allow clean runoff water to be intercepted and discharged to the creek or wetlands and will reduce the amount of construction runoff needing water quality treatment.

Dewatering of ground water in isolated areas within the embankment will be necessary in areas where excavation of existing unsuitable material is needed. Based on preliminary geotechnical investigations, excavation of unsuitable material will be necessary for structural and seismic stability beneath the proposed retaining walls and in areas where existing soils may cause stability or settlement problems in the constructed embankment.

Removal of soft sub-soils (unsuitable material) will consist of excavating the unsuitable materials to depths where firm bearing soils are present. The excavation areas will be backfilled with structural fill or foundation material suitable for supporting the anticipated loads. Prior to excavating and backfilling, temporary wells or well points will be bored to draw down the surrounding water table. The draw down area will be localized by strategic placement of the wells, adjustment of the pump rates from the wells, or installation of temporary sheet piling. Water from the wells will be discharged to the surrounding wetlands or creek outside of the construction area as long as water quality is maintained. Hoses, sprinklers, spreaders or other methods will be utilized to distribute the water as necessary to adjacent wetlands.

The dewatering wells will be in operation at specific work areas (such as at the retaining wall areas) for as long as necessary to allow completion of any excavation of unsuitable material, foundation construction and embankment placement. The wells will be removed after the foundation is completed or the embankment grade is sufficiently above the natural ground water table that further construction activities will not be adversely affected by ground water. After removal of the wells, the ground water will be allowed to return to its natural elevation.

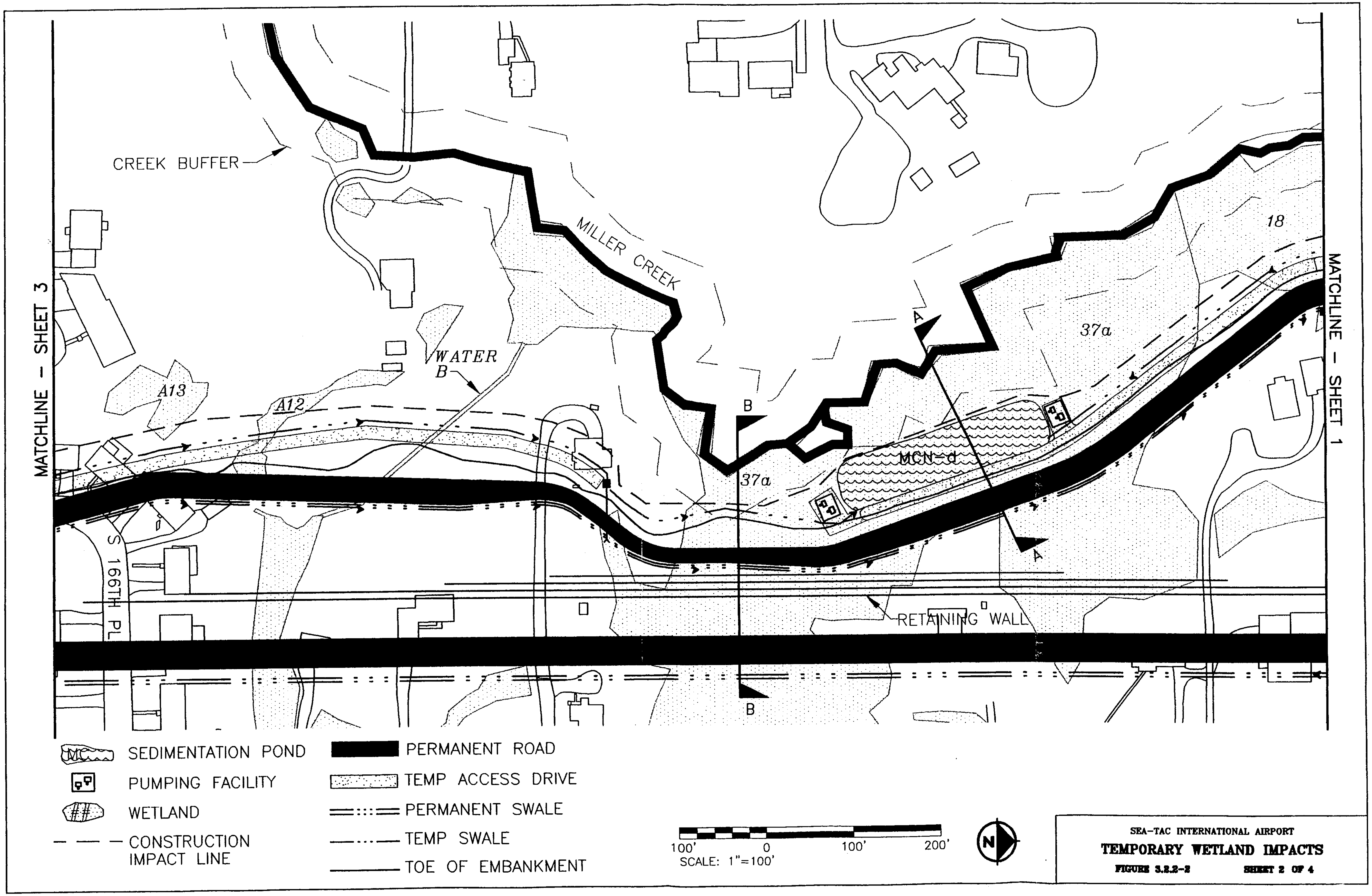
Due to the short duration of the dewatering operations coupled with the mitigating measures, significant adverse impacts to wetlands are not expected. The localization of the drawdown areas to the minimum size needed for construction, the re-distribution of groundwater to adjacent wetlands, and the routing of water from upslope areas to wetlands downslope of the construction will prevent significant dewatering impacts from occurring in downslope wetlands.



SEA-TAC INTERNATIONAL AIRPORT

TEMPORARY WETLAND IMPACTS

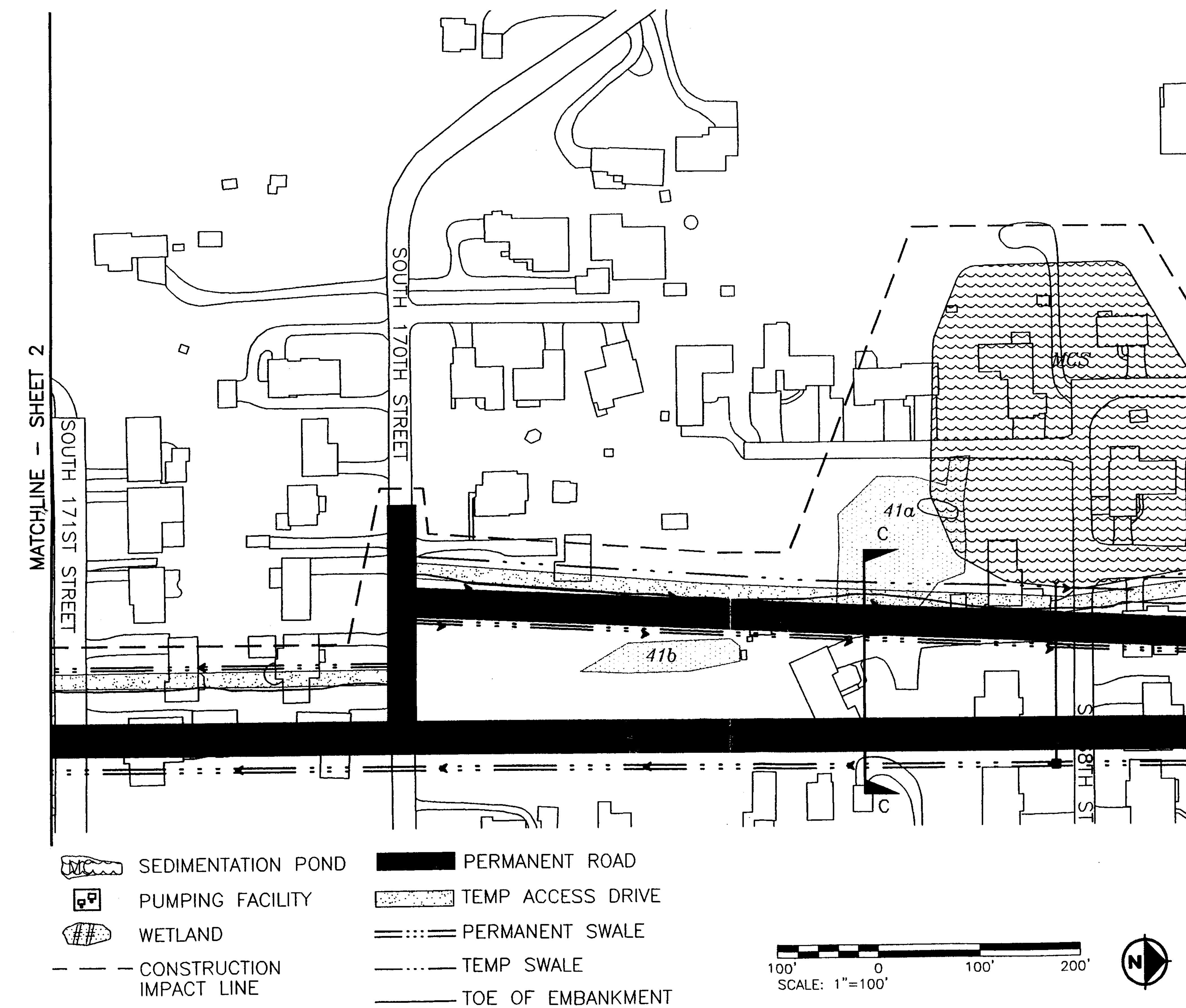
FIGURE 3.2.2-1 SHEET 1 OF 4



SEA-TAC INTERNATIONAL AIRPORT

TEMPORARY WETLAND IMPACTS

FIGURE 3.2.2-2 SHEET 2 OF 4



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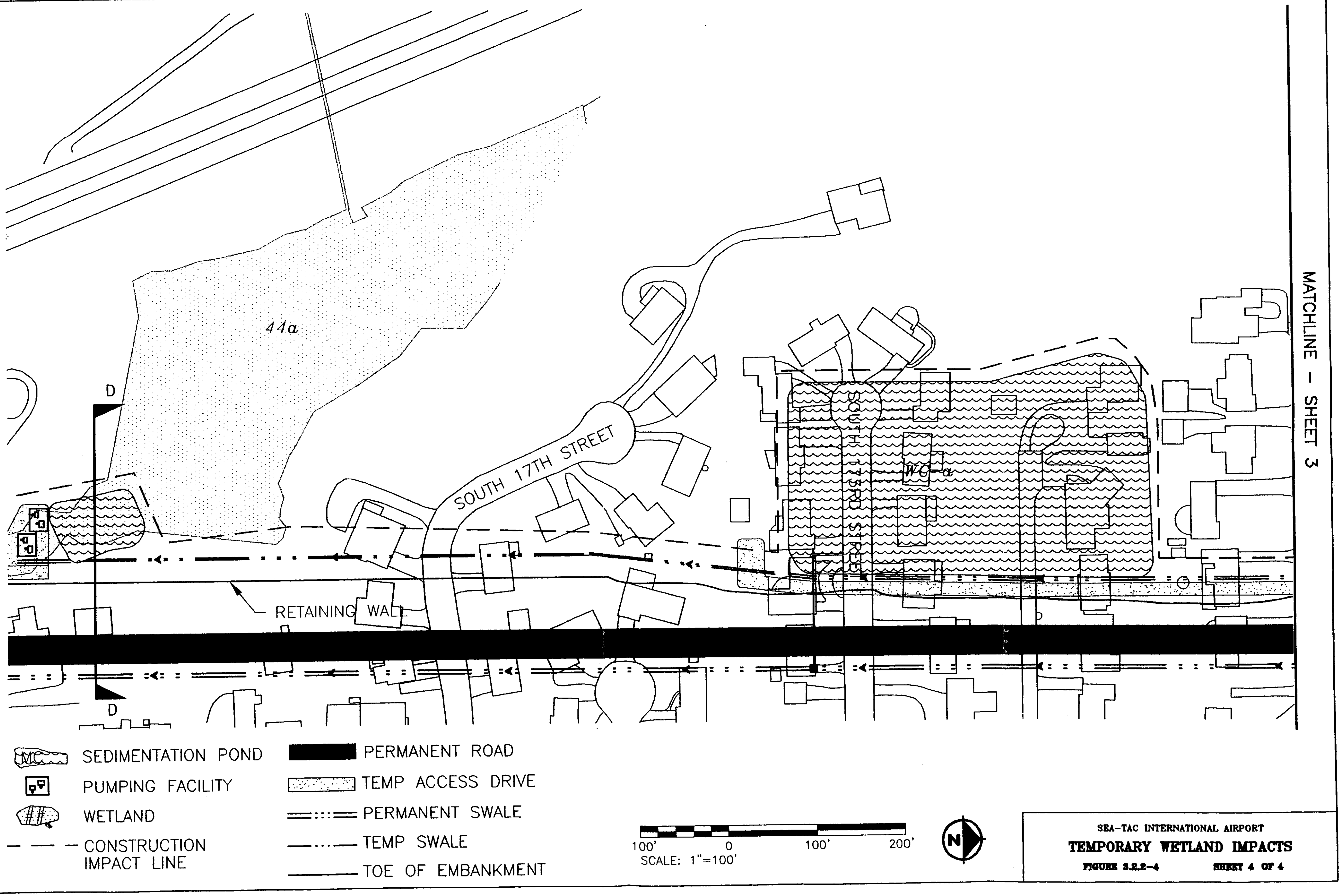
TEMPORARY WETLAND IMPACTS

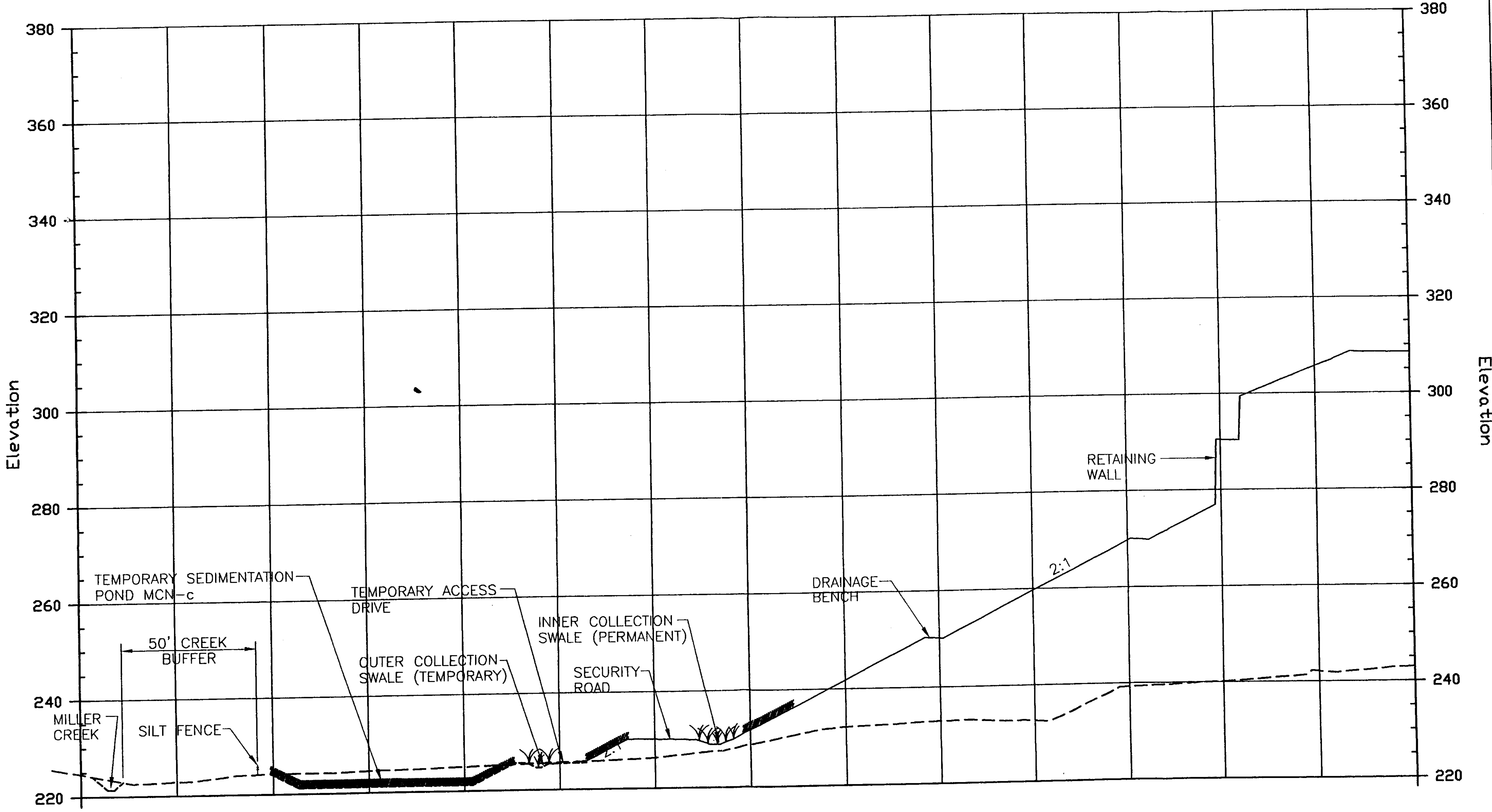
FIGURE 3.2.2-3 SHEET 3 OF 4



SEA-TAC INTERNATIONAL AIRPORT

TEMPORARY WETLAND IMPACTS

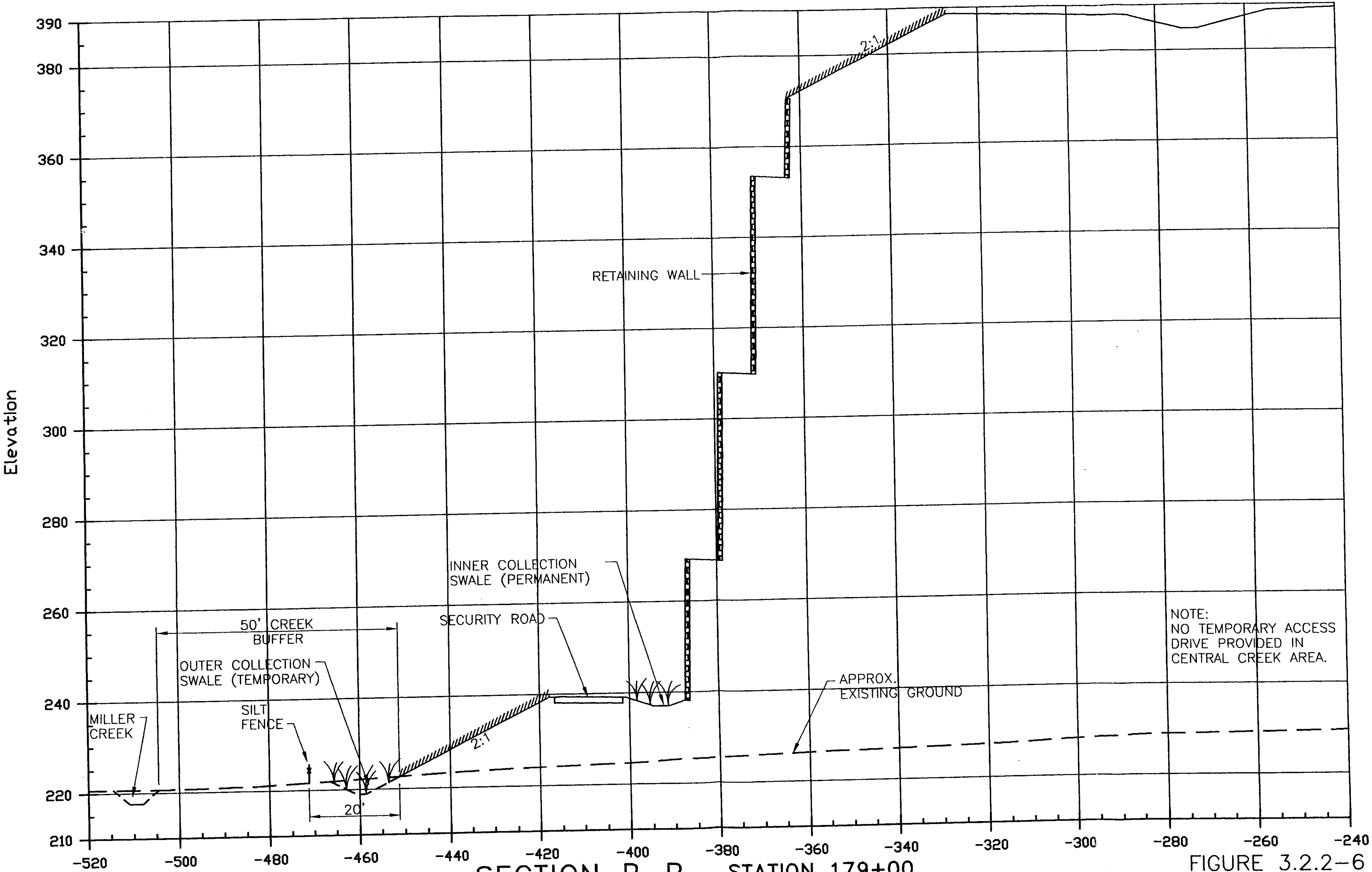
FIGURE 3.2.2-4 SHEET 4 OF 4



SECTION A–A

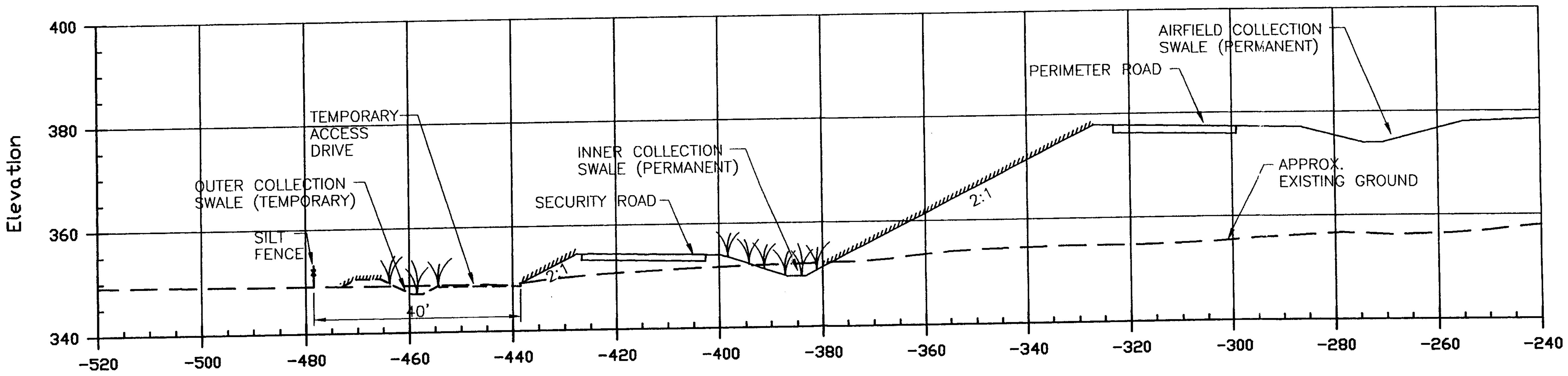
STATION 184+00 (PERPENDICULAR TO FILL SLOPE)

FIGURE 3.2.2–5



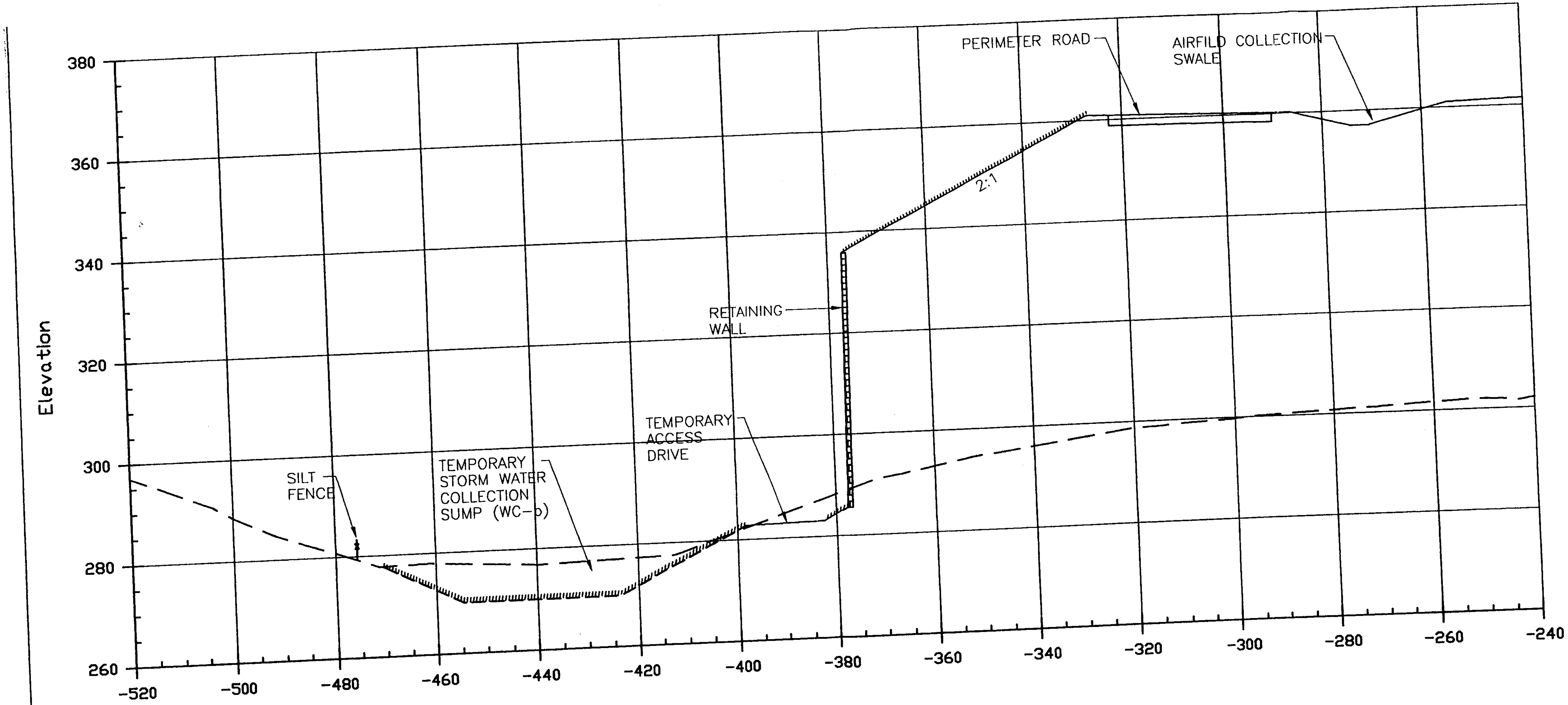
SECTION B–B STATION 179+00

FIGURE 3.2.2–6



SECTION C–C
STATION 165+00

FIGURE 3.2.2–7



SECTION D–D
STATION 143+00

FIGURE 3.2.2–8

A-2

Erosion and Sedimentation Control

Technical Memorandum

EROSION AND SEDIMENTATION CONTROL DURING THIRD RUNWAY EMBANKMENT CONSTRUCTION

Seattle-Tacoma International Airport
Third Runway Project

November 12, 1999

Prepared For:
The Port of Seattle

Prepared By:
HNTB Corporation

Erosion and Sedimentation Control During Third Runway Embankment Construction

I. Introduction

Placement of earth and gravel fill material necessary for the proposed Third Runway embankment and other construction projects associated the Seattle-Tacoma International Airport Master Plan Update will be completed over several years. During the multi-year embankment project, material placement will be completed over much of the annual periods, including the wetter months, in order meet the project schedule. Embankment construction during the wetter times of the year could generate stormwater runoff containing silt, sand, or other suspended solids in excess of permit requirements. This technical memorandum describes the approach for collection, storage, treatment, and discharge stormwater runoff during embankment construction in order to meet required water-quality standards. These or similar methods were successfully implemented during the 1998-1999 construction period. Despite wet weather construction during record periods of heavy rain, all storm water discharges were achieved.

II. Construction Stormwater Standards

The Washington State Water Quality Standards (WAC 173-201A) requires that runoff from construction projects not increase receiving stream turbidity by more than 5 NTU (Nephelometric Turbidity Units). To meet those requirements, standard BMPs will be constructed and maintained as necessary in and around the embankment construction areas. Standard BMPs can be utilized to remove most of the suspended solids in the stormwater while also providing conveyance and retention. However, due to the large scale of the proposed third runway project, combined with the proximity of the construction sites to Miller Creek, Walker Creek, and Des Moines Creek, standard BMPs alone will likely not satisfy water quality requirements for turbidity. The standard BMPs have not historically provided adequate removal of very small (colloidal) suspended particles from the embankment runoff. Even with liberal application of standard BMPs throughout the project site, experience on previous projects indicates that additional treatment of construction stormwater runoff may be necessary to meet water quality standards for turbidity.

Standard BMPs alone will not provide the level of safety desired by the Port to assure that water quality requirements will be achieved during Third Runway Embankment construction. Therefore, additional or supplemental stormwater treatment is proposed as part of the Third Runway Embankment Construction Erosion and Sedimentation Control Plan (CESCP) to provide assurance that water quality requirements will be met and wet weather construction will be allowed. Specific supplemental stormwater treatment systems are described in the 1999 Draft Ecology Stormwater Management Manual. It is anticipated that the type of supplemental stormwater treatment system described in the draft Ecology Manual will be utilized during embankment construction to control erosion and sediment. The following section summarizes the anticipated overall Third Runway

Embankment CESCP, including the use of standard and experimental BMPs during construction. Development of the Third Runway Embankment CESCP is based on experience gained on wet-weather embankment projects completed in 1998 and 1999, as well as other projects in the region.

III. 1998 and 1999 Embankment Projects

During the spring, summer, and fall of 1998 and 1999, approximately 1.8 million cubic yards of embankment was placed in the northwest corner of the existing airfield. Standard construction erosion and sedimentation controls for the 1998 and 1999 projects included the following standard BMPs:

- silt fence
- grass and rock-lined swales,
- check dams,
- sediment traps,
- a large sedimentation pond,
- a truck wheel wash,
- soil coverings (bonded fiber matrix)
- hydroseeding

In addition to the above BMPs, the top of the embankment was sloped away from the embankment face at all times during fill placement. This reduced erosion by preventing runoff from the top of the fill from flowing down the embankment face. Collection of runoff from the top at the back of the embankment also allowed flexibility in routing the runoff to gain the most benefit from the standard BMPs. In addition, only fill material containing a lower percentage of very fine particles was placed during periods of wet weather to reduce the amount of sedimentation generated in the construction stormwater runoff.

Even with the above-described controls, it was determined early in the 1998 project that standard BMPs alone would not provide the treatment necessary to consistently meet DOE stormwater quality requirements for turbidity. Potential supplemental treatment systems were evaluated to ensure that water quality discharge standards would be achieved throughout construction.

A polymer stormwater batch treatment system was selected to provide supplemental stormwater treatment prior to discharge. The treatment system developed for these embankment projects was approved as an experimental BMP by the Department of Ecology. A brief summary of the supplemental treatment system constructed for the 1998/1999 embankment projects follows.

IV. 1998/1999 Supplemental Treatment Summary

Construction runoff containing suspended solids (silt and/or sand) was intercepted in collection swales and collected in a large sedimentation pond. Under standard Department of Ecology design criteria, stormwater would normally be discharged from the sediment pond after a pre-determined "residence time" which, in theory, would result in satisfactory water quality conditions. The pond and standard BMPs helped remove the larger particles, but the polymer treatment system further cleaned the runoff water by removing the smaller suspended fine particles (colloidal particles) that the standard BMPs could not adequately remove. The polymer treatment system developed for this project involved pumping of stormwater runoff from the sedimentation pond into one of several lined treatment cells constructed adjacent to the sedimentation pond. Each treatment cell acted as an individual mixing tank/settling pond in which liquid flocculents were added at closely monitored rates. The flocculents, when properly mixed with silt-laden water, cause the suspended particles to "bind" to each other creating a heavier particle. Eventually gravity causes the flocculents and silt particles to settle to the bottom of the cell (precipitation). After testing of the water in the cell to verify quality parameters, it is pumped to a roadside storm drainage system that ultimately discharges to Miller Creek. The cell is then refilled with silt-laden water and the process started again. The sludge that accumulates at the bottom of the cells is removed with vacuum trucks as needed and disposed of at approved disposal areas off Port property.

The process was extremely successful, with stormwater discharges from the 1998 embankment site exceeding water quality standards throughout the winter of 1998/1999, a record setting season for precipitation. Much of the treated water discharge was at or below creek turbidity, and at no time was the discharge greater than 5 NTU above the creek background turbidity. The treatment system resulted in construction storm water discharges far exceeding water quality standards, which call for no *increase* of background creek turbidity greater than 5 NTU.

In accordance with the approved BMP request, water quality monitoring and testing were regularly preformed on the treated water prior to discharge. The monitoring included tests for pH, turbidity, and settleable solids, as well as bioassays to assess treated water toxicity. The bioassays were performed by a Department of Ecology accredited laboratory and test results indicated 100% conformance to Department of Ecology construction stormwater quality criteria, including toxicity, pH, and turbidity. Approximately 15 million gallons of construction stormwater were treated without incident during the winter of 1998/1999.

A similar treatment system has been used for a private development project in Redmond, WA. Through November 1997, approximately 40 million gallons of storm water had been treated and discharged without incident.

Although effective, the batch treatment process used is labor intensive. Ongoing research is being conducted to evaluate other potential supplemental treatment systems that will improve on the batch treatment system used in 1998 and 1999.

Chemical treatment of construction stormwater runoff is a relatively new application of technology that is used extensively by municipalities for drinking water and wastewater treatment. The application of this technology is fostered by increasing standards for environmental protection and the need for extended construction seasons for large projects. The Puget Sound region, in particular the Cities of Redmond and Issaquah, Washington, are national leaders in the development of chemical treatment for construction stormwater management. Chemical treatment of construction stormwater runoff is being used for a number of both public and private development projects in those cities. It is anticipated that chemical treatment of construction stormwater runoff will become more widely used due to increased scrutiny of the effectiveness of current BMPs and greater enforcement of water quality standards to protect fish and fish habitat protected under the Endangered Species Act.

V. Future Embankment Projects

This section describes a general sequence of embankment construction and the associated erosion and sedimentation control facilities anticipated for use during future construction. Contract specifications for future embankment projects will include detailed construction phasing and sequencing plans with associated stormwater runoff controls necessary for each phase of construction. The contract documents may allow the construction sequencing plan contained in the contract documents to be tailored to best suit the operations of a general contractor. However, the stormwater runoff standards and treatment approach cannot be modified by any contractor-proposed revision to the sequence of construction contained in the plans.

Conceptual Construction Sequencing & Associated Storm Water Treatment

Generally, Third Runway embankment placement is anticipated to begin in the lowest portions of the area to be filled. The lowest portion of the topography also corresponds to one of the more environmentally sensitive areas within the project boundaries (due to adjacent wetlands and proximity to Miller Creek).

Stormwater runoff naturally flows to this low point of the site. In order to reduce the impacts to wetlands in this low area, no large sedimentation pond will be constructed in this area as would typically be necessary for stormwater control. One or more collection "sumps" or small ponds will be constructed. These "sumps" are intended to collect construction runoff that flows to this low area, but are not intended to hold the runoff water for settling or supplemental treatment. Instead, runoff collected by these sumps will be pumped to larger sedimentation ponds and supplemental treatment facilities located upstream of the low point and outside of wetlands. The larger, upslope sedimentation pond and treatment facilities will be located in non-wetland areas to reduce wetland impacts and reduce the risk of potential encroachment into wetlands.

The sumps needed for runoff collection will be sized to reduce wetland impacts, yet provide an adequate margin of safety to prevent unauthorized stormwater discharge during emergency conditions (i.e. extreme storm events or power failures). The capacity of the combined sumps and pump systems will be sized to accommodate at least twice the required stormwater runoff volume.

Runoff water will be diverted directly to the upstream sedimentation pond and treatment facilities once embankment construction reaches a height that will allow runoff to gravity flow directly to the sedimentation pond(s). After settling in the sedimentation ponds and supplemental treatment as necessary, runoff water will be released to Miller Creek.

Standard BMPs will be constructed and maintained throughout the work area, including the low-point construction area. The BMPs may include, but will not be limited to, silt fence, cutoff swales, rock check dams, truck wheel washes, and fabric erosion control matting. Embankment side slopes will be covered with bonded fiber matrix, hydroseeding, and/or erosion matting as necessary as soon as possible following finish grading. Runoff water flowing into the sumps in the low portions of the site will continue to be pumped to sedimentation ponds and treatment facilities as needed ensure water quality standards are met. When the side slopes in the area have been established with vegetative growth (hydoseeding) and the runoff meets water quality standards without additional settling or treatment, pumping will cease. Water flowing into the sumps will then be allowed to flow into drainage channels and eventually to Miller Creek or the adjacent wetlands via point discharges, perforated pipe, porous rock berms, or infiltration swales as appropriate.

Runoff from construction areas outside the lowest topographical areas will be routed directly to sedimentation ponds and supplemental treatment facilities (as needed) located west of the construction zone and outside of wetlands. In general, a temporary cutoff swale will be constructed just outside (west) of the toe of the embankment prior to any site preparation or material placement. The cutoff swale will intercept construction runoff from the work area and divert it to previously constructed sedimentation ponds/treatment facilities.

To protect the outer fill slopes from erosion throughout the embankment program, fill will be placed to always slope back from the toe of the slope (to the east) as was successfully accomplished during the 1998 Embankment. A collection channel at the back of the embankment will collect stormwater runoff from the top of the fill and flow to the sedimentation ponds/treatment facilities, similar to the collection method used for the 1998 Embankment. The exposed face of the fill slope will be stabilized with hydroseeding and/or erosion matting as soon as possible following finish grading.

A conceptual storm drainage plan is shown in Figure 1, and sequential cross sections of the embankment during construction are depicted in Figures 2 and 3. Embankment will be placed in phases over several years. The exposed surface area at any given time during construction will be limited to an area equal to or less than the area of exposed surface that would generate turbid runoff in excess of the capacity of the stormwater treatment systems, less an appropriate factor of safety. Capacity of the various treatment systems (including ponds and supplemental treatment) is dependent on several varying factors and that will also influence the area of allowable exposed surface. The factors include existing soils type, fill material type, season of construction activity, and type of supplemental treatment system. On-going planning and research is being conducted to determine the construction phasing schedule and combination of treatment systems that will best meet project needs, including water quality requirements.

Special Considerations

- Pond Sizing and Overflow:
  The sedimentation ponds, sump ponds, swales, pumps, and supplemental treatment facilities necessary for a particular work area will be constructed and operational prior to fill placement. The facilities will be designed to accommodate the runoff flow that can be expected, in accordance King County and Ecology Requirements. In the unlikely event stormwater runoff volume in the ponds exceeds the design storm, pond overflow structures will be provided to allow controlled overflow discharges to minimize potential damage from the overflow. Backup power supply sources will be available for the pumping and treatment systems that require power to operate, and at least one-foot of freeboard will be provided in sedimentation ponds.

- Supplemental Treatment:
  As with the previous projects, supplemental stormwater treatment in addition to standard BMPs may be provided to ensure water quality standards are met throughout the embankment construction program. Potential supplemental treatment systems include:

  - Chemical batch treatment cells (i.e.: 1998/1999 system)
  - High-volume mechanical filtering devices, with or without chemical treatment
  - Flow-through clairifiers, with or without chemical treatment
  - Flow-through ponds, with chemical treatment

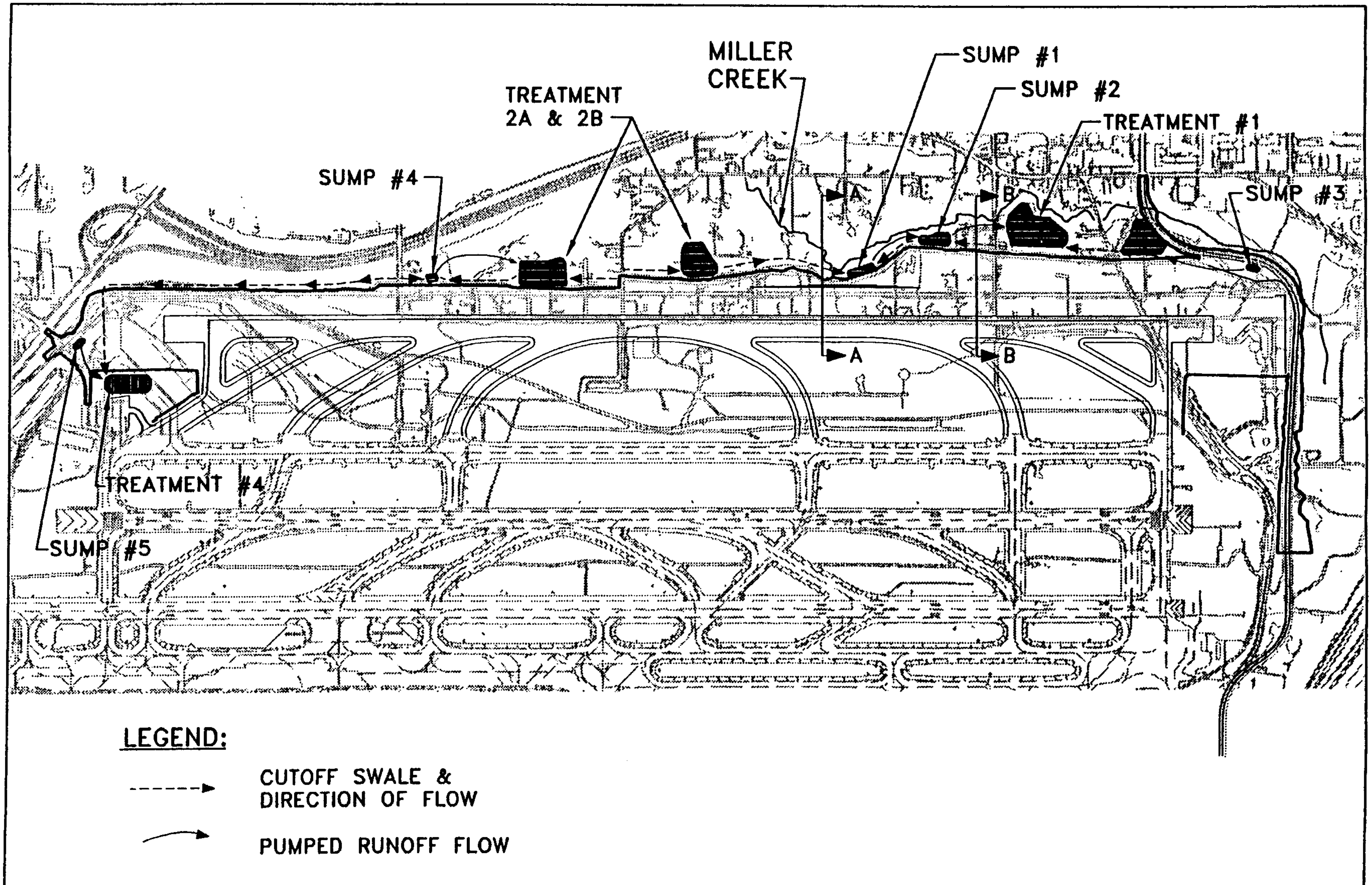
  On-going research is being conducted to develop the experimental BMPs that will achieve water quality standards and best fit the needs of the Third Runway Embankment projects. It is expected that the approved experimental BMPs will utilize one or more of the above supplemental treatment systems.

  Supplemental treatment will be provided as necessary to meet runoff water quality requirements throughout future embankment programs. The supplemental treatment system(s) will be approved for use by the Department of Ecology prior to operation. The BMP request will also include detailed description of the water testing and quality assurance program, similar to the testing program developed for the 1998/1999 batch treatment system. The specific treatment systems to be utilized for the future embankment programs will be chosen based on past experience, the ability to fulfill project requirements for performance and reliability, and DOE approval.

- Pumping:
  Pumping of stormwater runoff will allow flexibility in locating sedimentation ponds and thereby reduce wetland impacts. Pumping of stormwater was a key component of the successful 1998/1999 Embankment project. Pumping in 1998/1999 was achieved utilizing trailer-mounted portable pumps. Similar pumps are anticipated to be used during future embankment programs.

- Clean Runoff Diversion:
  During construction, runoff from undisturbed areas will be routed, as much as possible, around disturbed areas. This will reduce runoff quantities from exposed surfaces to further assure water quality standards can be met. Diversion will be accomplished using diversion swales and/or temporary piping around construction areas. Pipe outlets, level spreaders, swales, or other devices may be used to reduce erosion at the discharges of these diverted clean water flows.

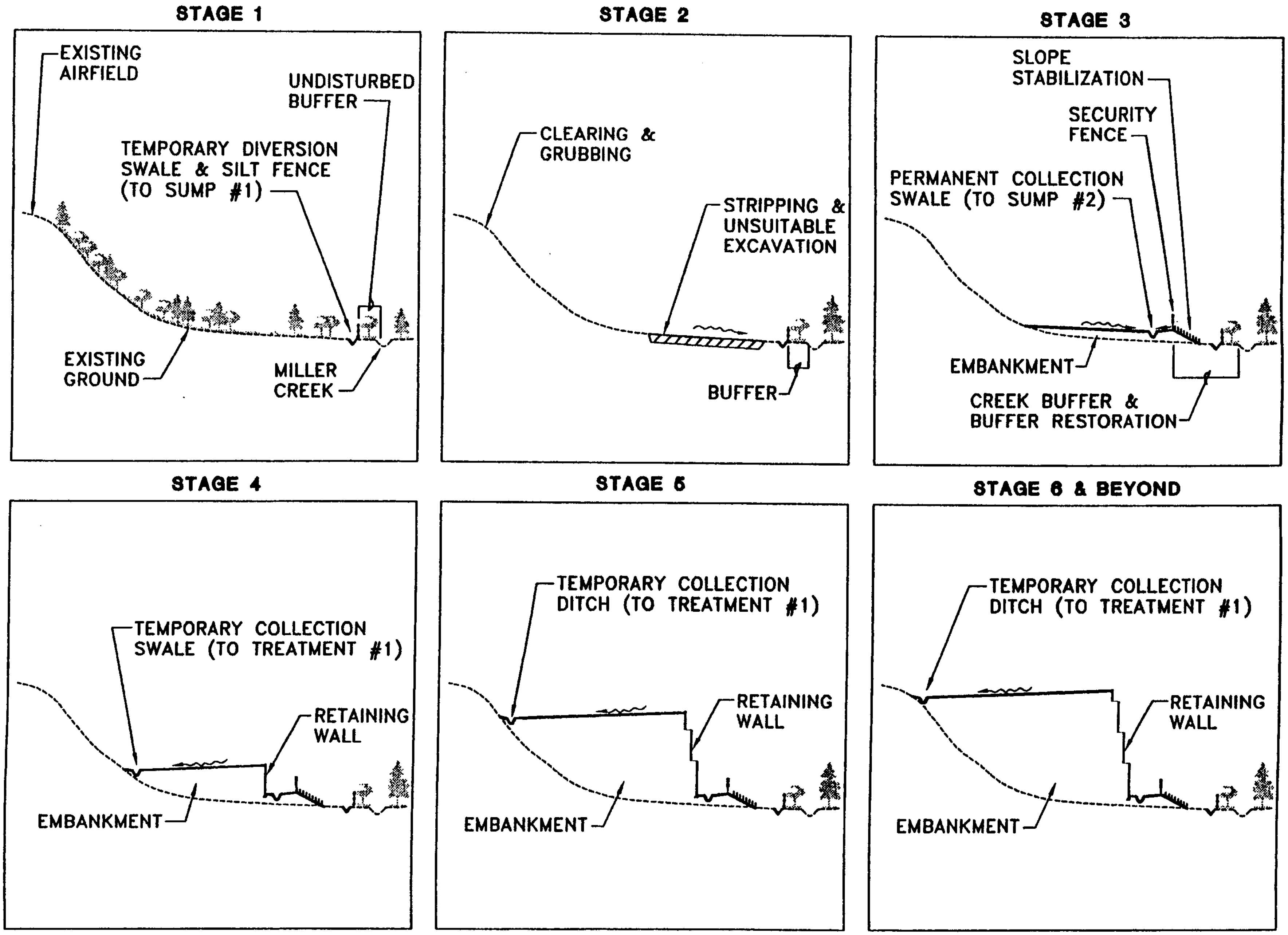
- Maintenance:
  The stormwater management facilities will be regularly maintained throughout the multi-year construction period. Maintenance may include soil and turf repair as necessary, removal of sediment accumulation from the swales and ponds, and restoration of silt fencing, pipe inlets and outfalls.



PRELIMINARY THIRD RUNWAY
CESCP

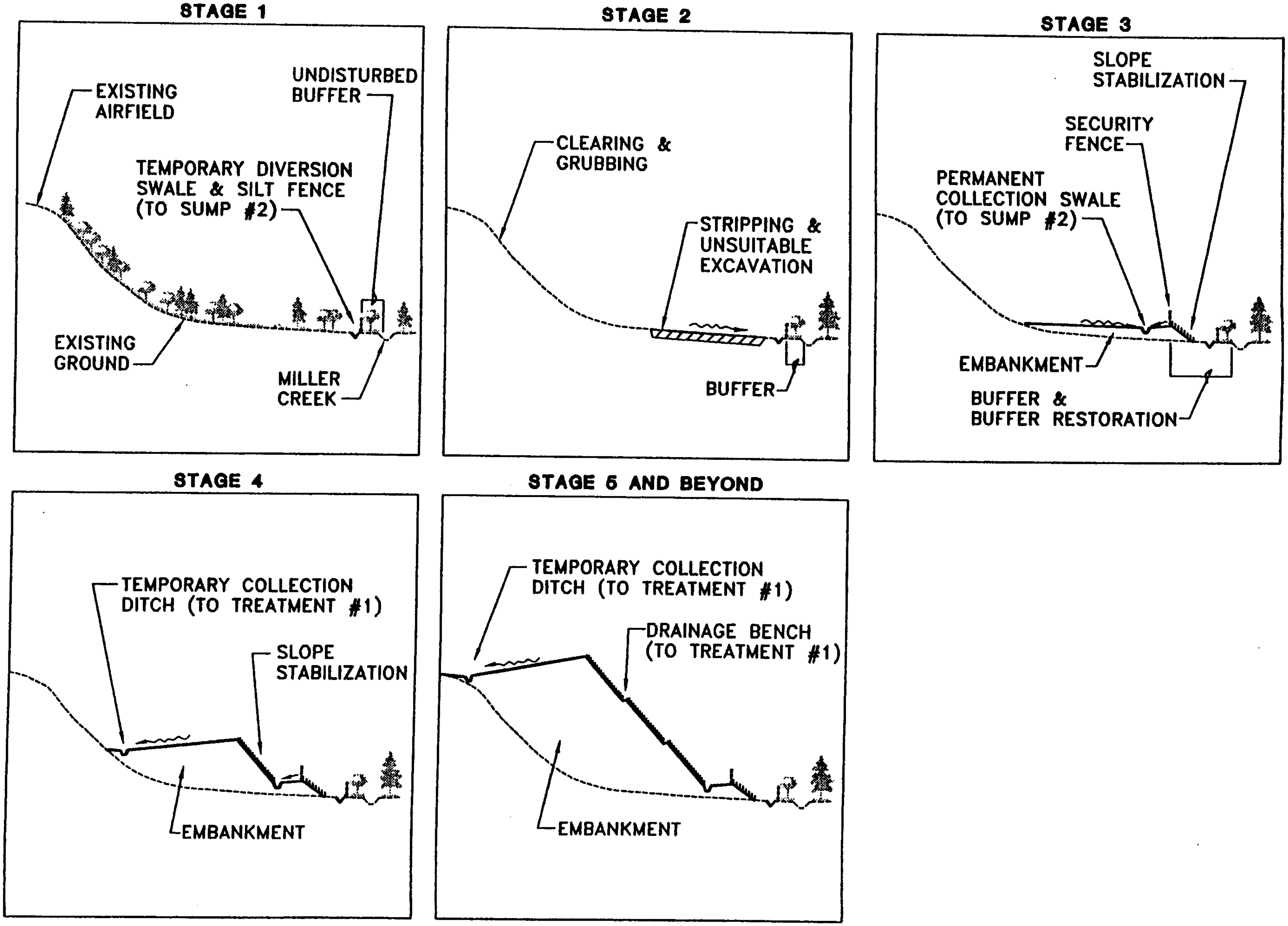
NOT TO SCALE

FIGURE



SECTION A-A

FIGURE 2
NOT TO SCALI



SECTION B-B

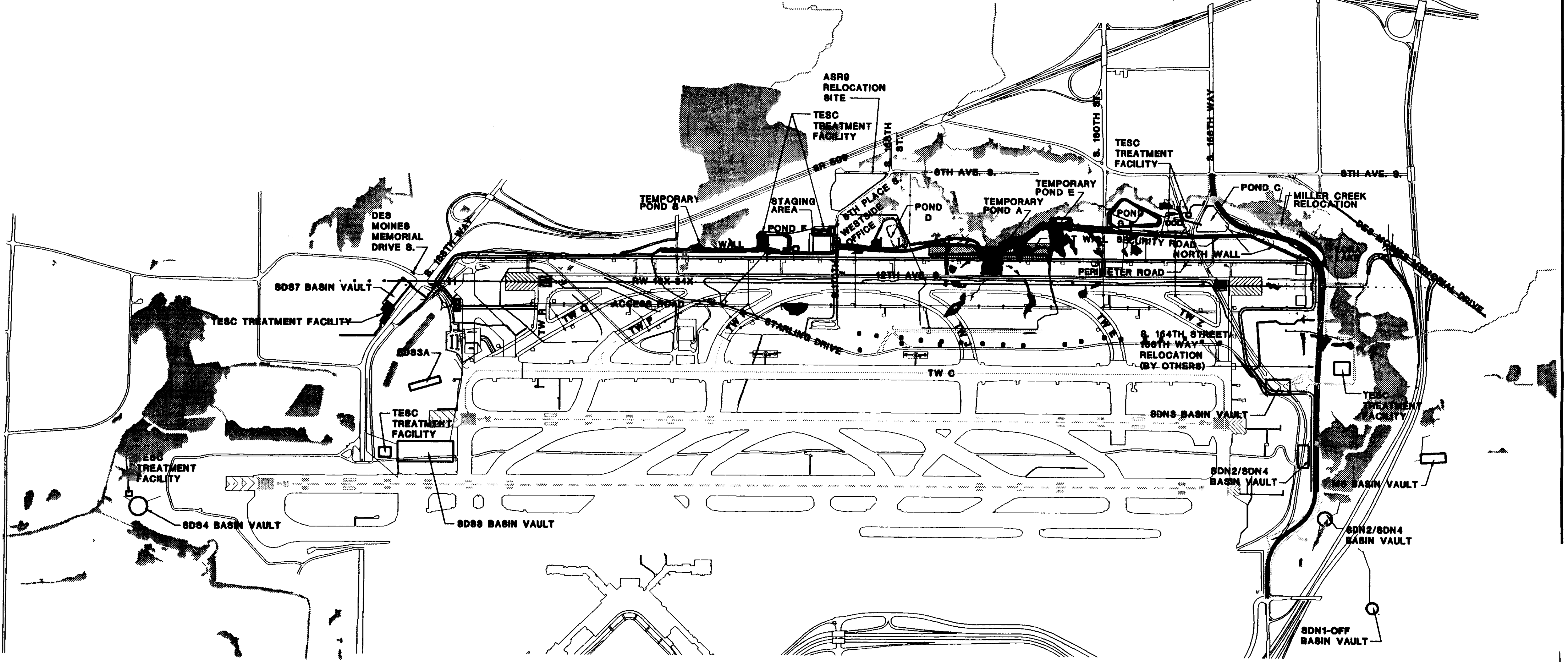
FIGURE 3
NOT TO SCALE

A-3

Erosion and Sedimentation Control Plan Figures

EROSION AND SEDIMENTATION CONTROL PLANS

Plan Ref. No.	Sheet Title
C18	EROSION AND SEDIMENTATION CONTROL LAYOUT
C19	EROSION AND SEDIMENTATION CONTROL PLAN
C20	EROSION AND SEDIMENTATION CONTROL PLAN
C21	EROSION AND SEDIMENTATION CONTROL PLAN
C22	EROSION AND SEDIMENTATION CONTROL PLAN
C23	EROSION AND SEDIMENTATION CONTROL PLAN
C24	EROSION AND SEDIMENTATION CONTROL PLAN
C25	EROSION AND SEDIMENTATION CONTROL PLAN
C26	EROSION AND SEDIMENTATION CONTROL PLAN
C27	EROSION AND SEDIMENTATION CONTROL PLAN
C28	EROSION AND SEDIMENTATION CONTROL PLAN
C29	EROSION AND SEDIMENTATION CONTROL PLAN
C30	EROSION AND SEDIMENTATION CONTROL PLAN
C31	EROSION AND SEDIMENTATION CONTROL PLAN
C32	EROSION AND SEDIMENTATION CONTROL PLAN
C33	EROSION AND SEDIMENTATION CONTROL PLAN
C34	EROSION AND SEDIMENTATION CONTROL PLAN
C35	EROSION AND SEDIMENTATION CONTROL PLAN
C36	EROSION AND SEDIMENTATION CONTROL PLAN
C37	EROSION AND SEDIMENTATION CONTROL PLAN
C38	EROSION AND SEDIMENTATION CONTROL PLAN
C39	EROSION AND SEDIMENTATION CONTROL PLAN
C40	POND B PLAN AND PROFILE - SDS7 BASIN TEMPORARY POND
C41	NOT USED
C42	POND E PLAN AND PROFILE SDW1A BASIN TEMPORARY POND 2
C43	POND A PLAN AND PROFILE SDW1A BASIN TEMPORARY POND 1



PLAN
EROSION AND SEDIMENTATION CONTROL LAYOUT
1" = 600'

N

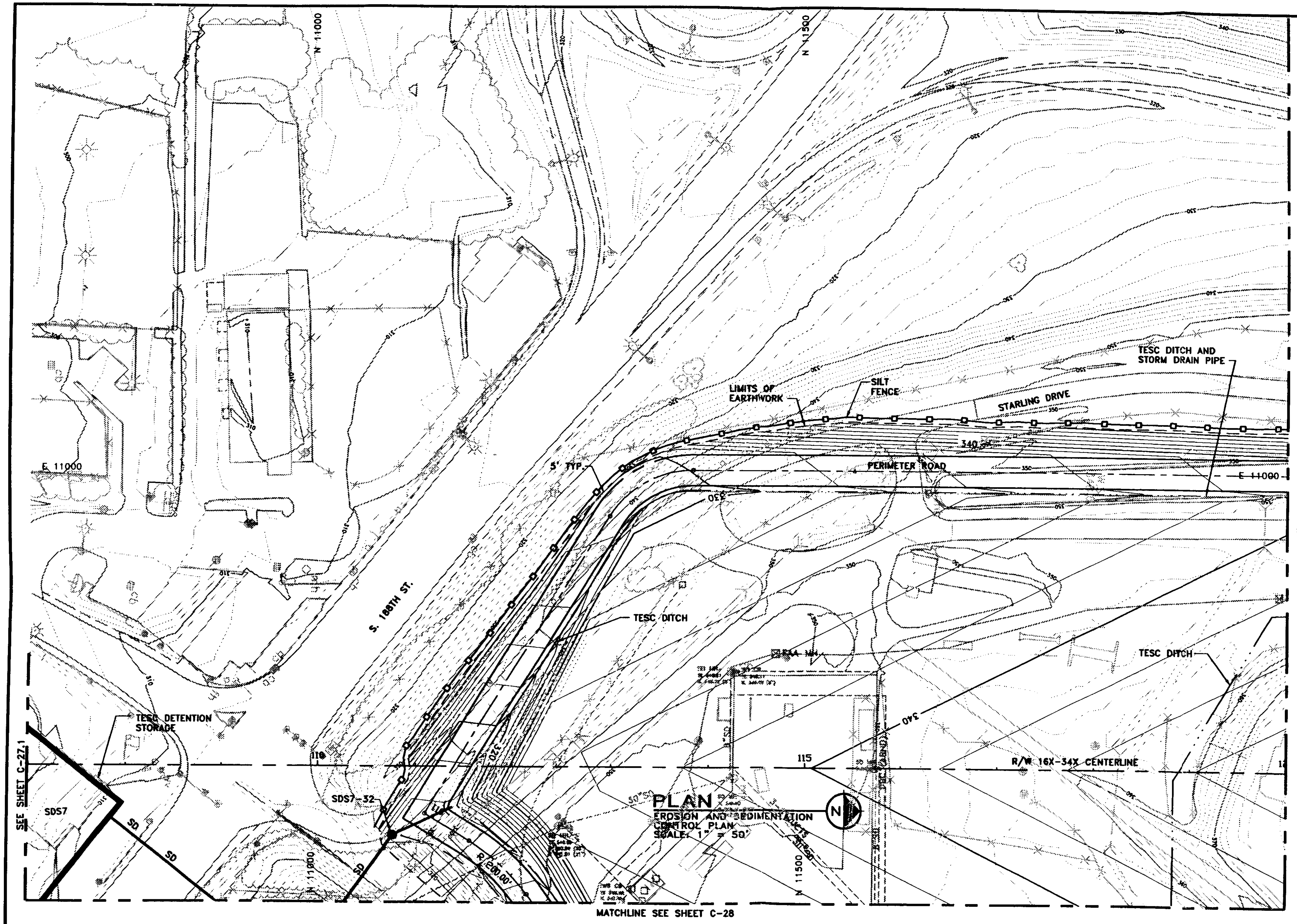
600' 0 600' 1200'
SCALE: 1"=600'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL LAYOUT**

DATE	DEC. 15, 2000
CONSULTANT'S NO.	
PORT OF SEATTLE NO.	EXHIBIT_ C18



PLAN
EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

-□—□— SILT FENCE

▨ WETLANDS

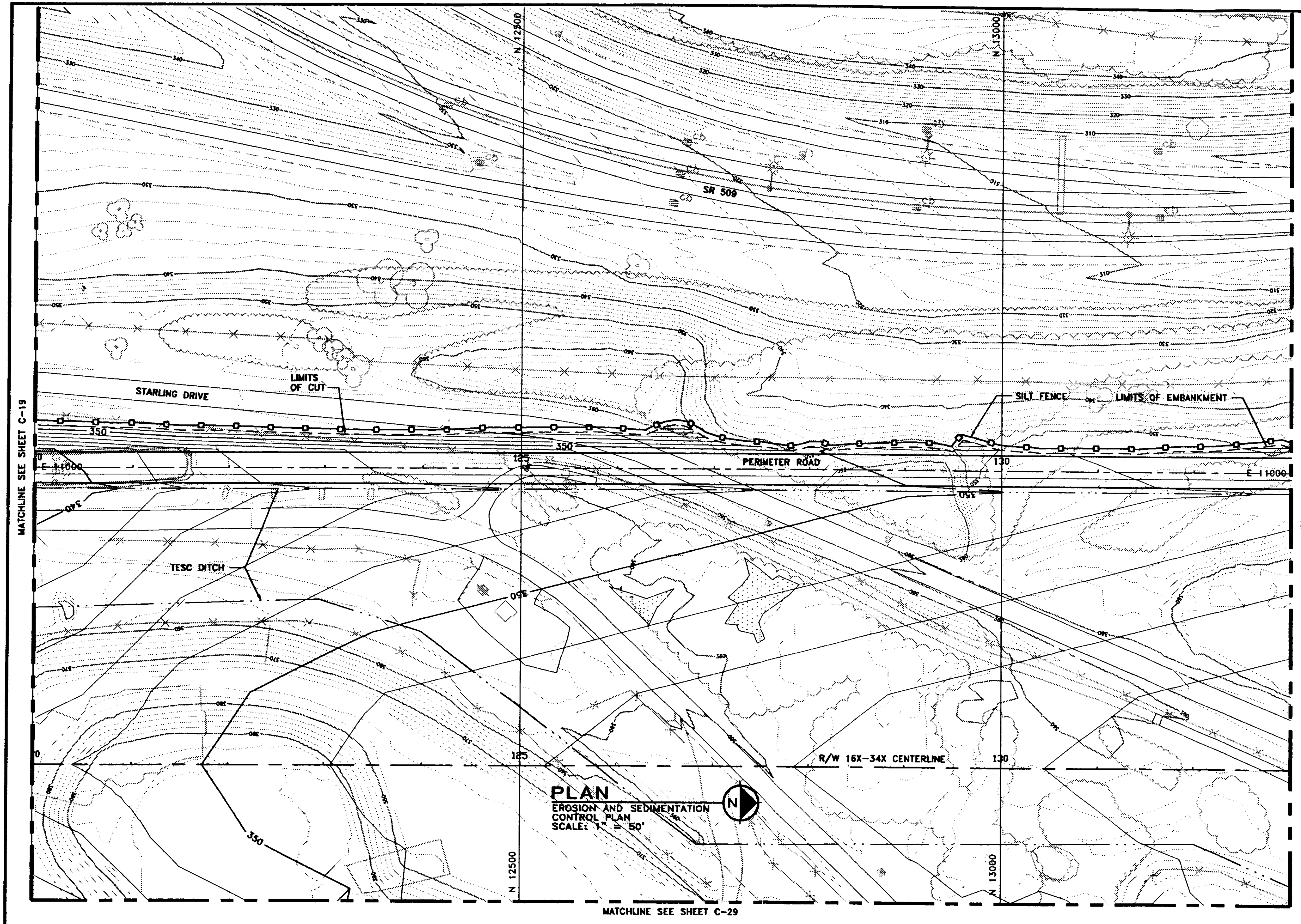
50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C19



PLAN
EROSION AND SEDIMENTATION
CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

—□—□— SILT FENCE

▨ WETLANDS

AR 030296

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000

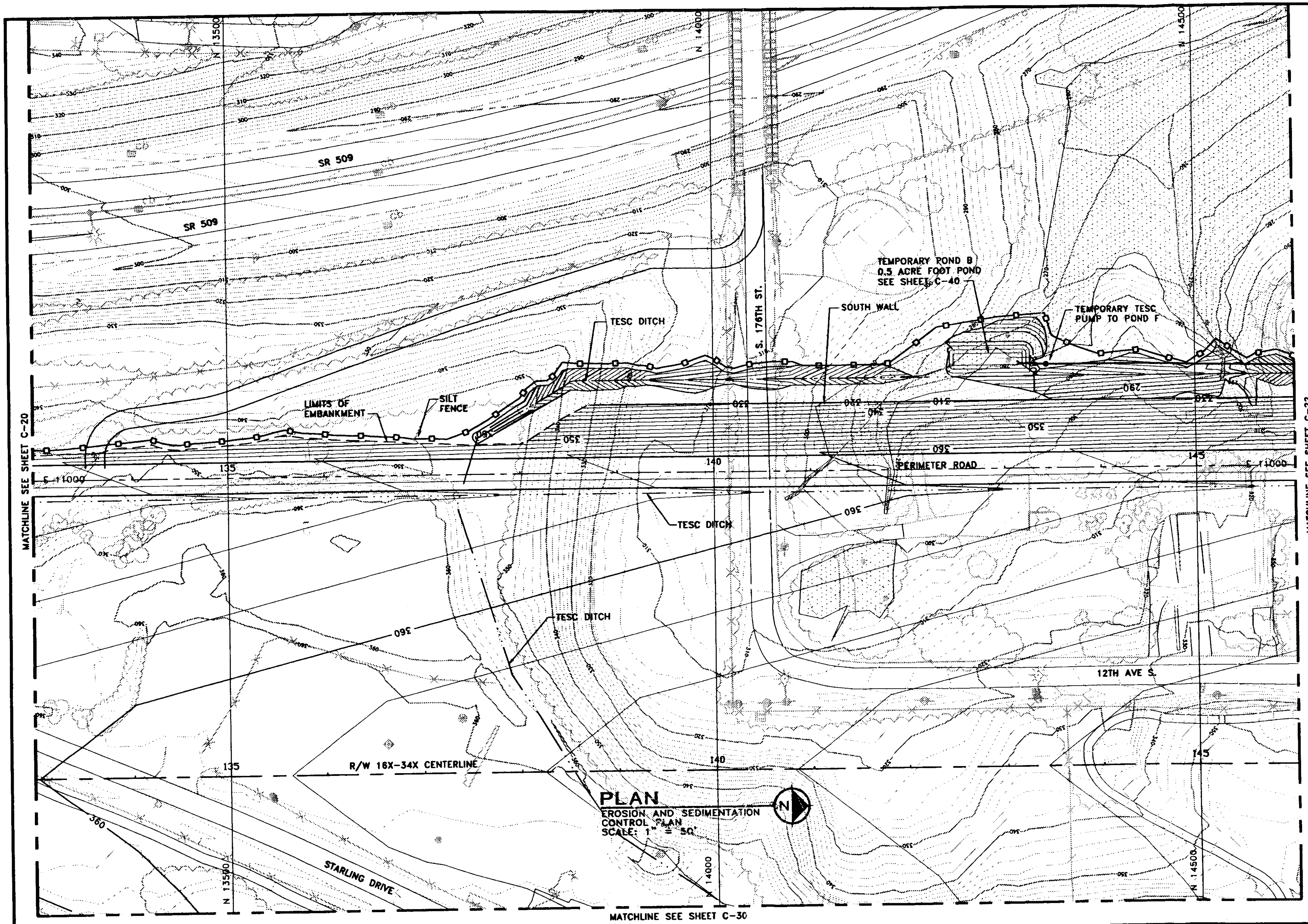
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C20

NOTES:

LEGEND:

- —□—□— SILT FENCE
- ▨ WETLANDS



PLAN

EROSION AND SEDIMENTATION
CONTROL PLAN
SCALE: 1" = 50'

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

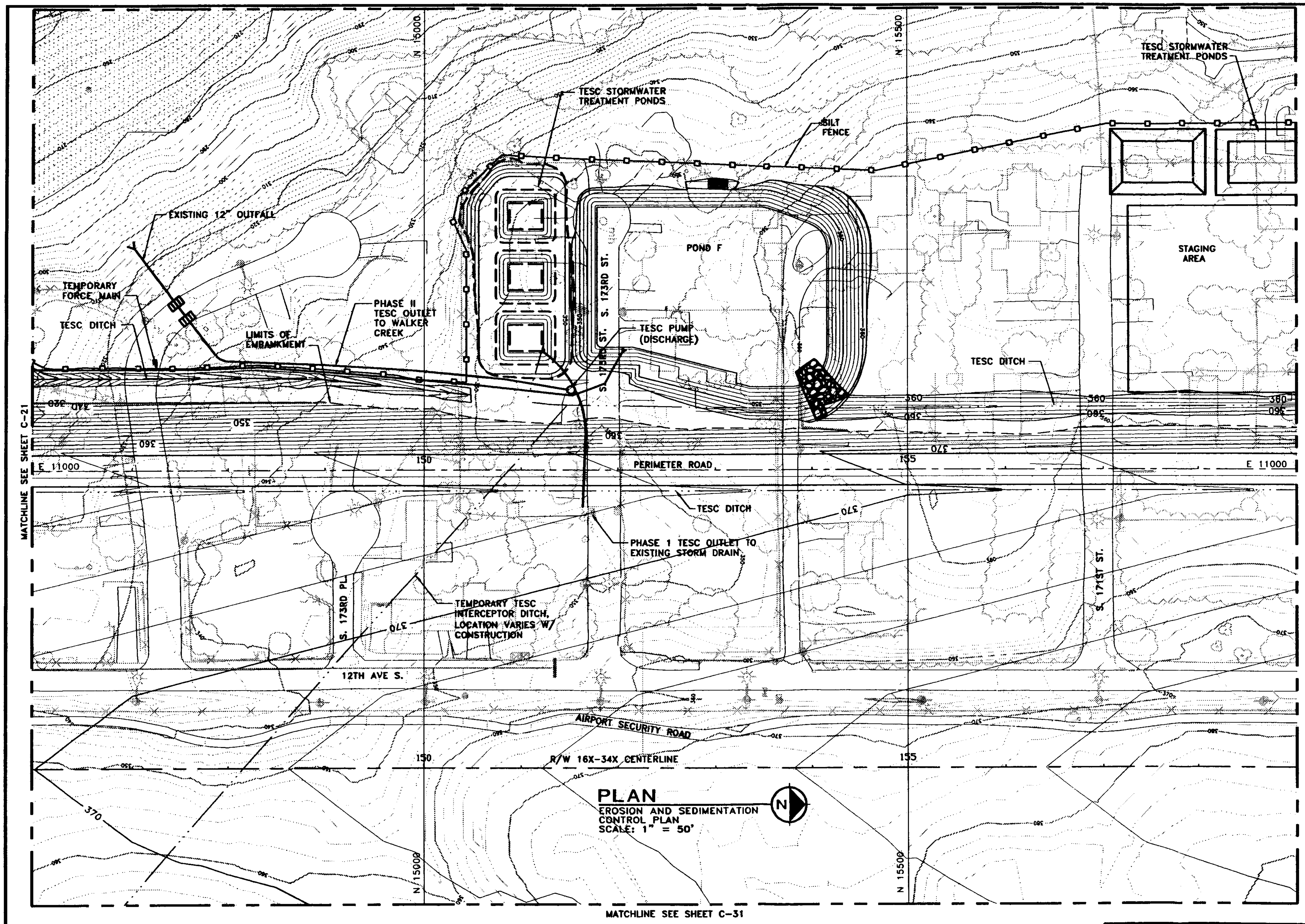
SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C21

NOTES:



PLAN

EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

LEGEND:

—□—□—	SILT FENCE
▨	WETLANDS

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

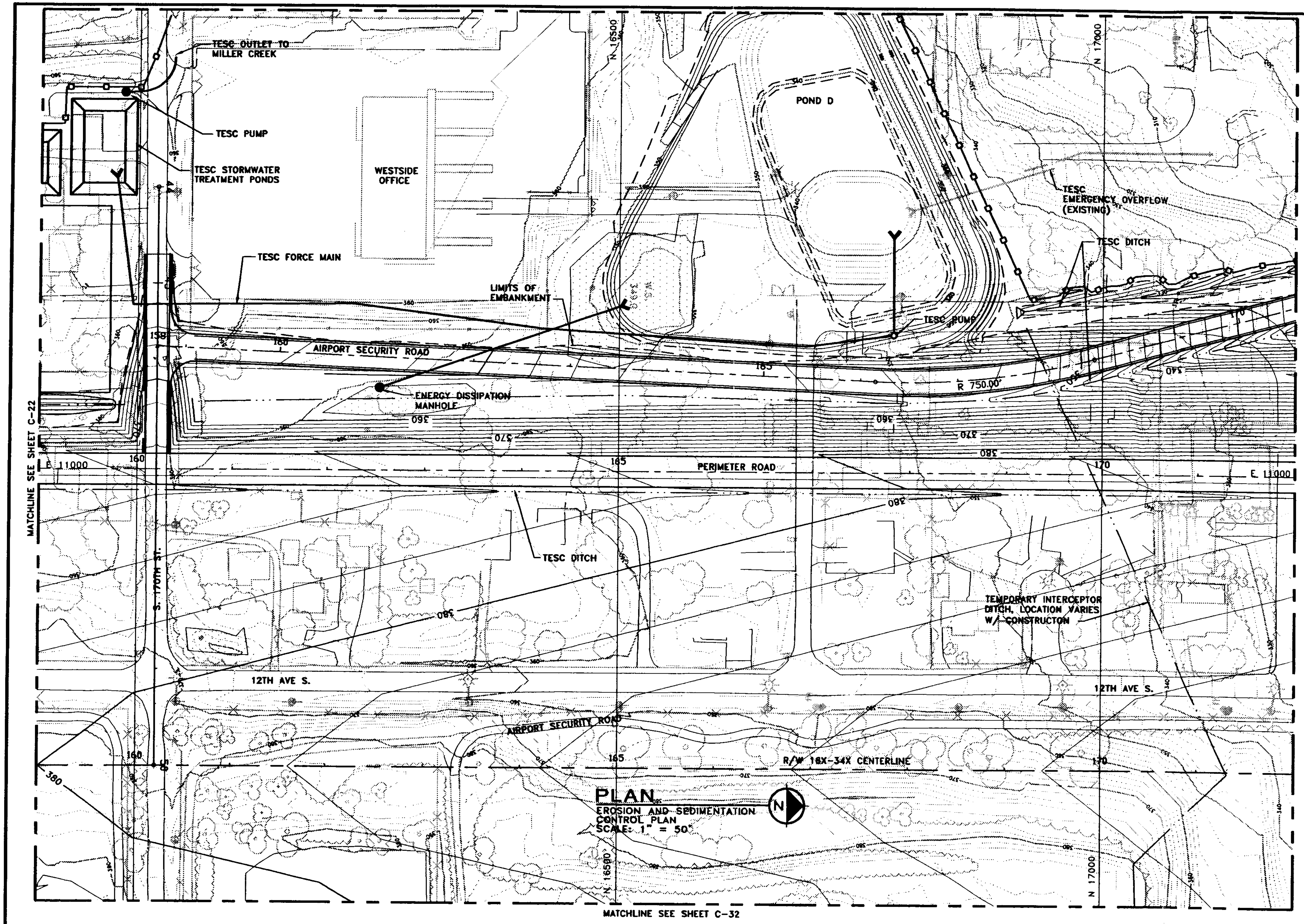
SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.

EXHIBIT_ C22



PLAN
EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

-□-□- SILT FENCE

▨ WETLANDS

AR 030299

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

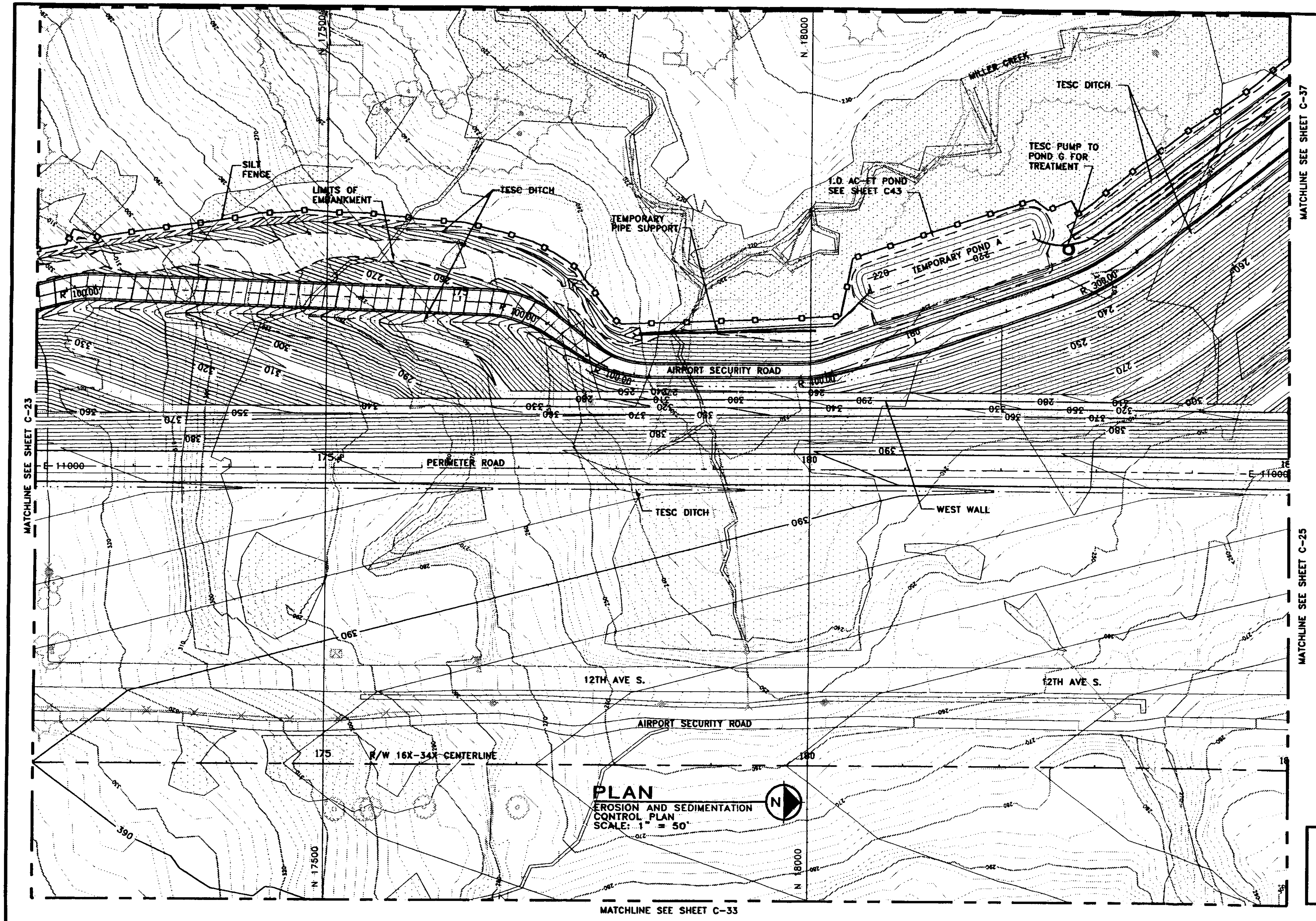
Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C23



NOTES:

LEGEND:

—□—□— SILT FENCE

▨ WETLANDS

AR 030300

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

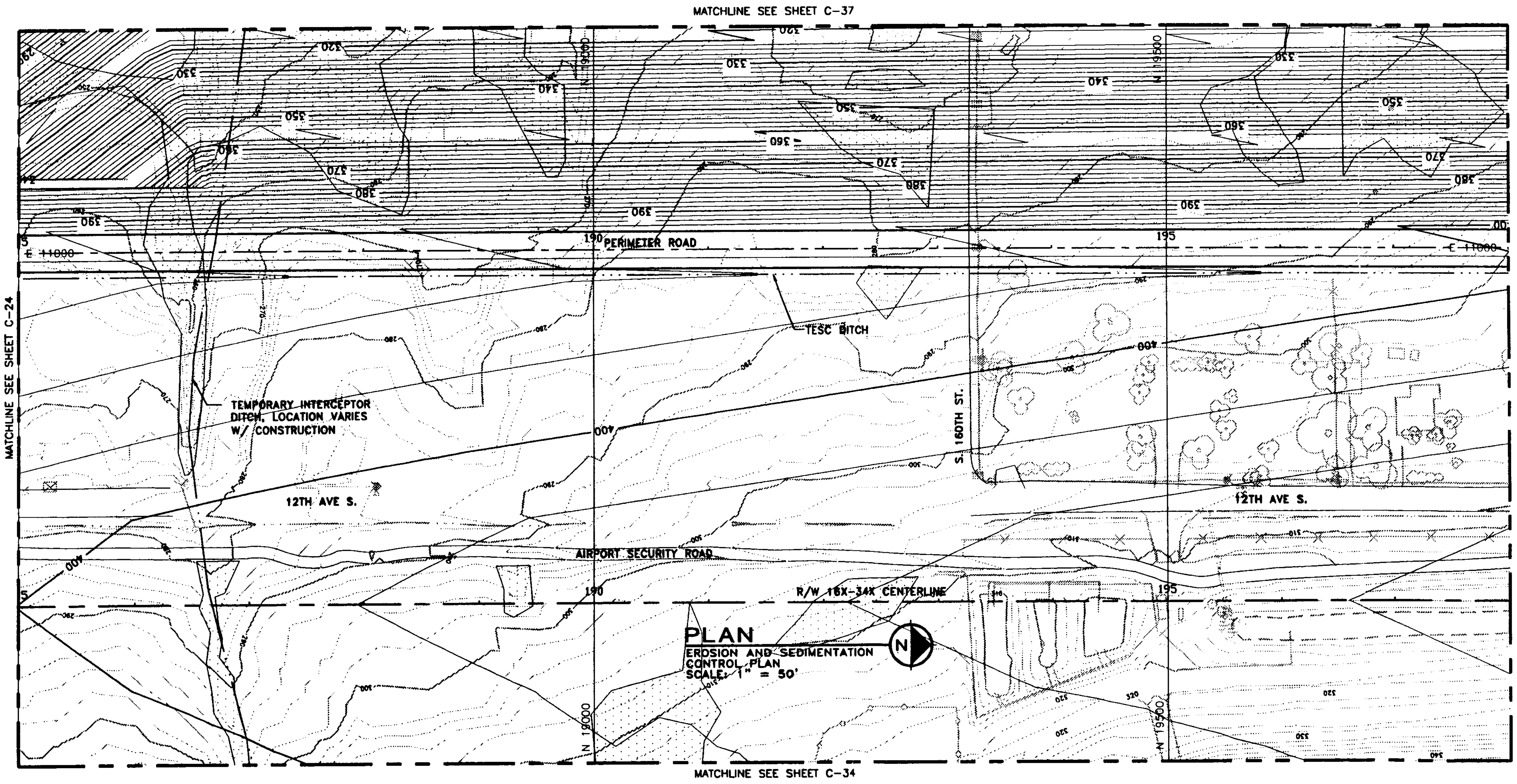
DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.

EXHIBIT_ C24

NOTES:



PLAN
ERDSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

LEGEND:

—□——□— SILT FENCE

▨ WETLANDS

50' 0 50' 100'
SCALE: 1"=50'

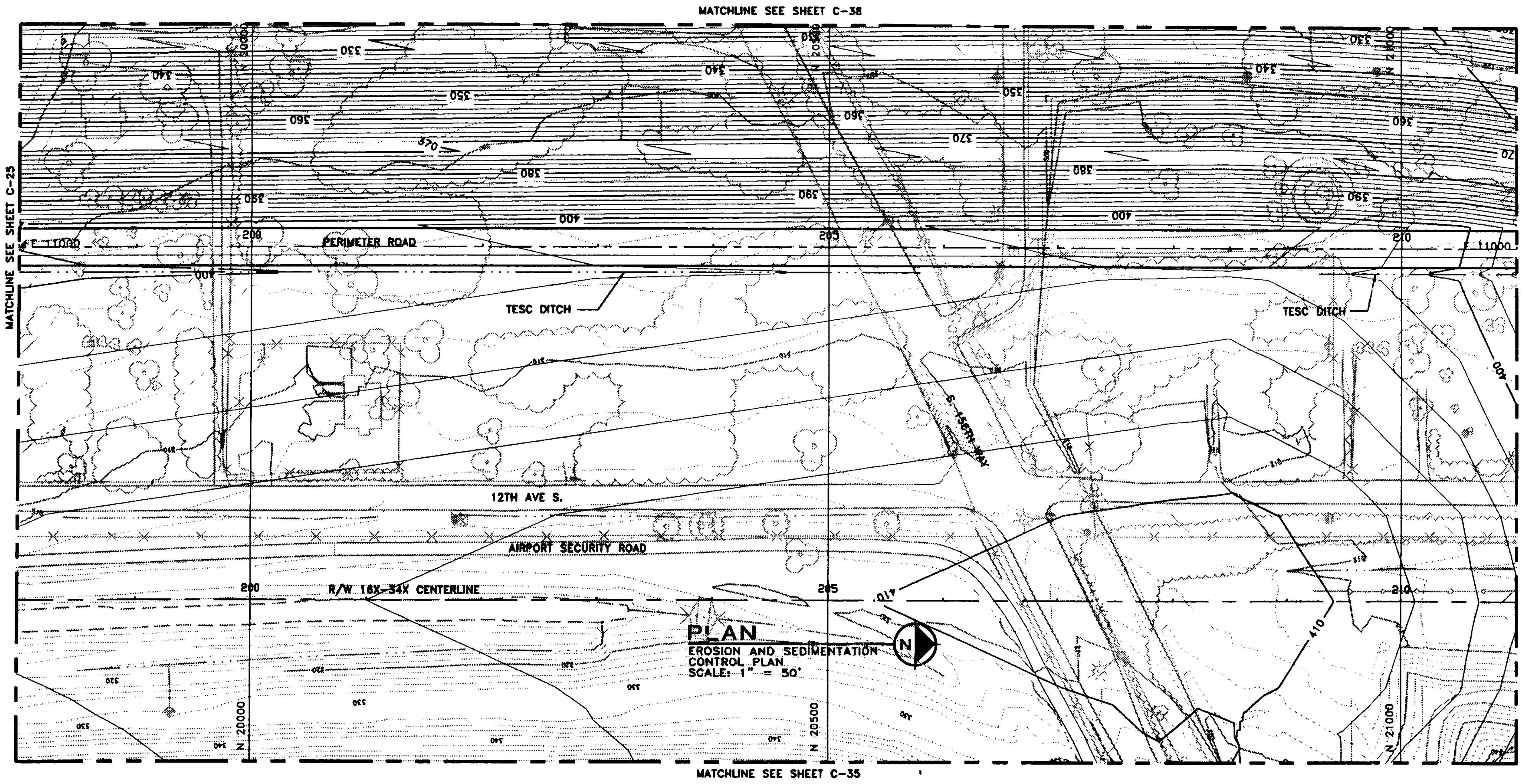
						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C25

NOTES:



PLAN
EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

LEGEND:

—□—□— SILT FENCE

▨ WETLANDS

AR 030302

50' 0 50' 100'
SCALE: 1"=50'

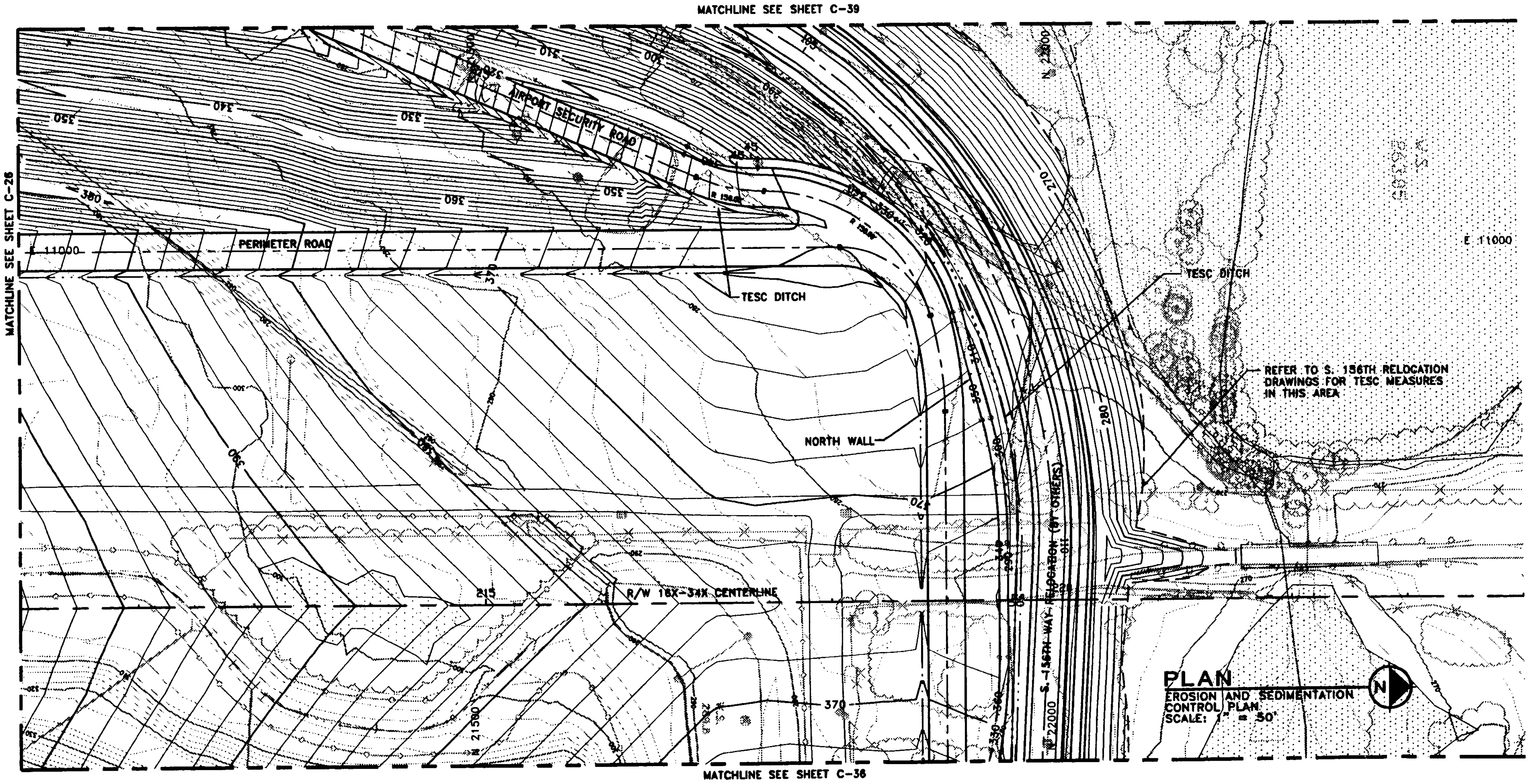
						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6
SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_C26

NOTES:



PLAN

EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

LEGEND:

—o—o—	SILT FENCE
▨	WETLANDS

AR 030303

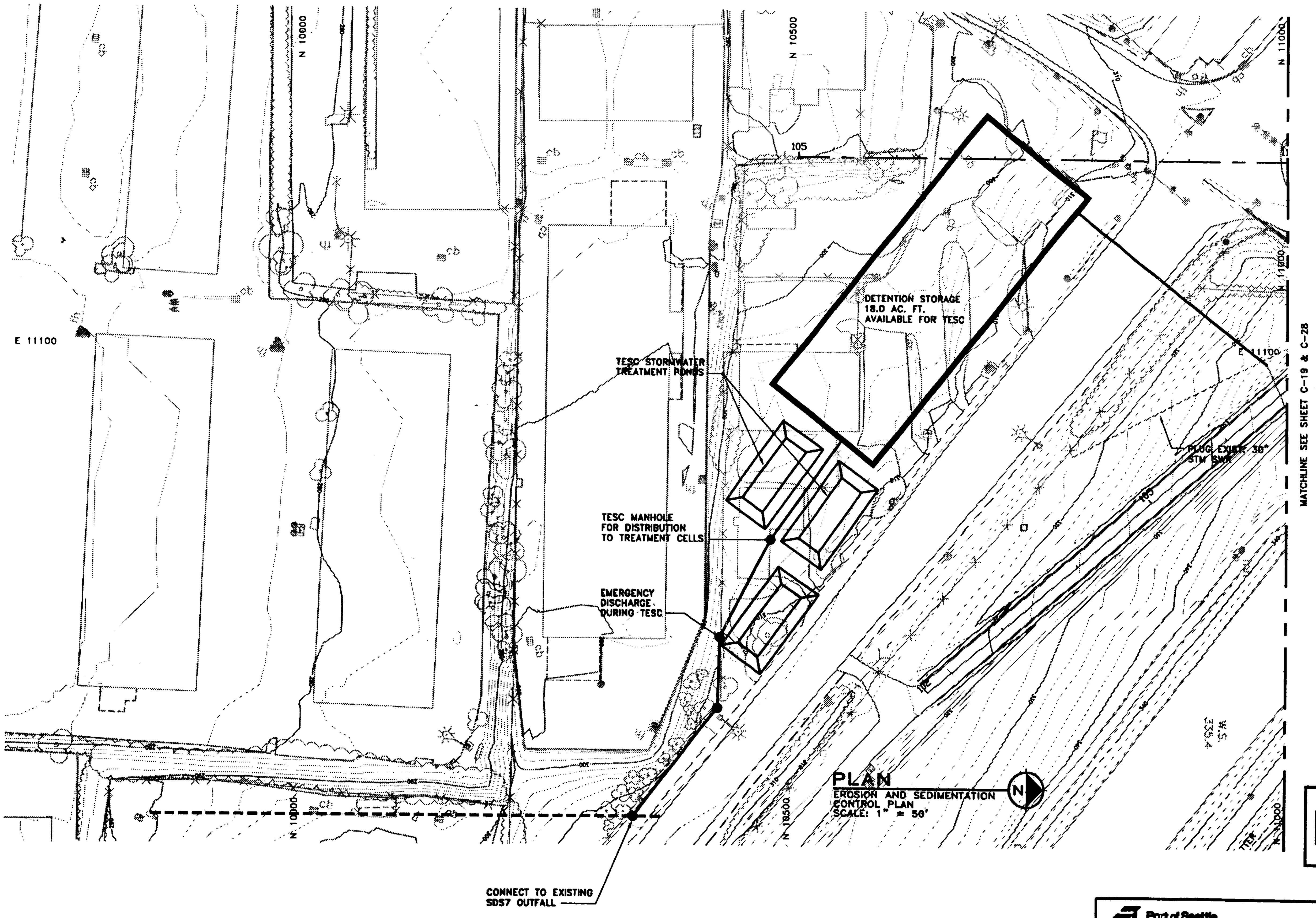
50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6
SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C27



PLAN
EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

- STORM DRAIN PIPE
- SILT FENCE
- ▨ WETLANDS

AR 030304

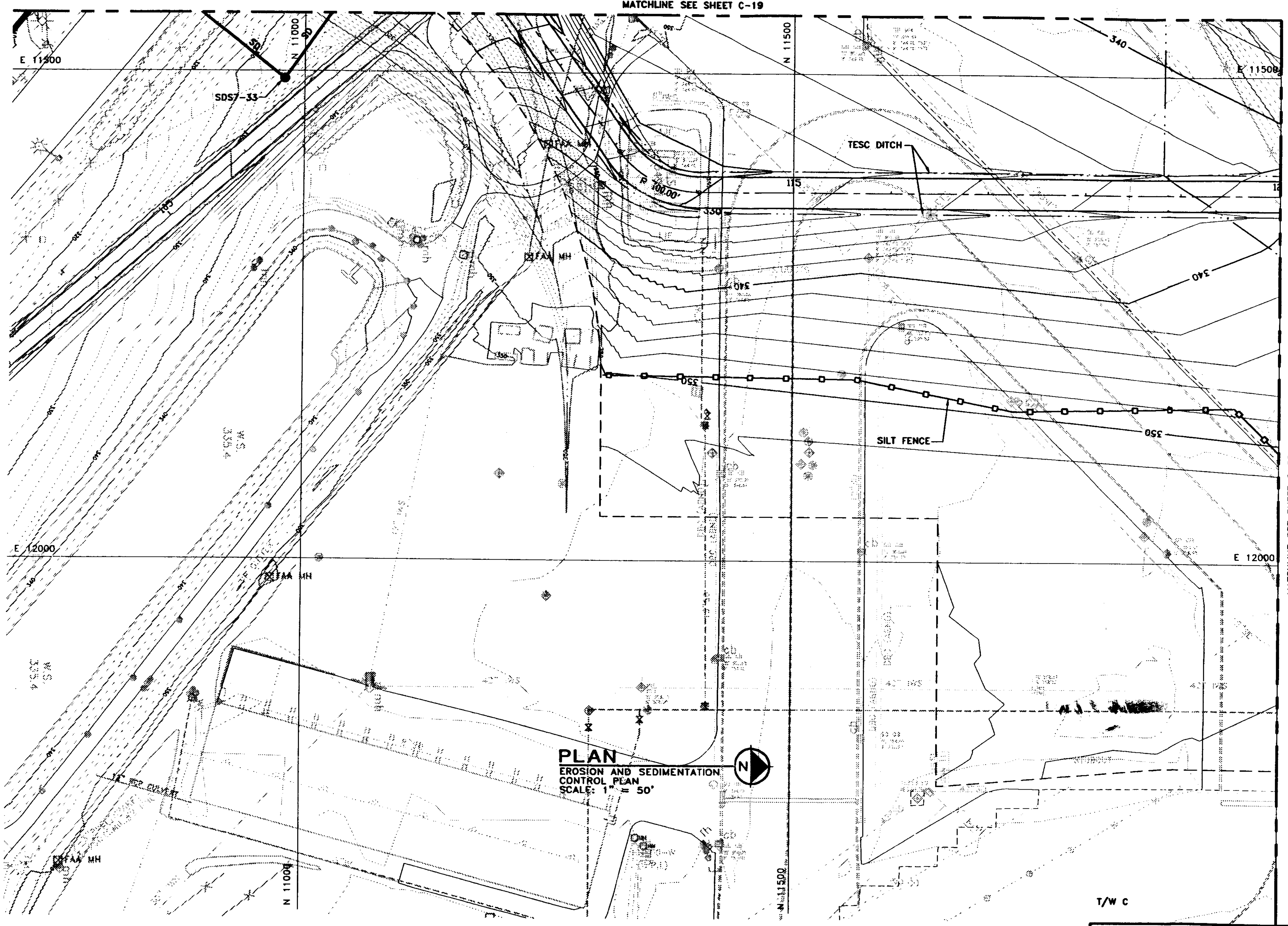
50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C27.1



NOTES:

LEGEND:

- STORM DRAIN PIPE
- ▨ WETLANDS

AR 030305

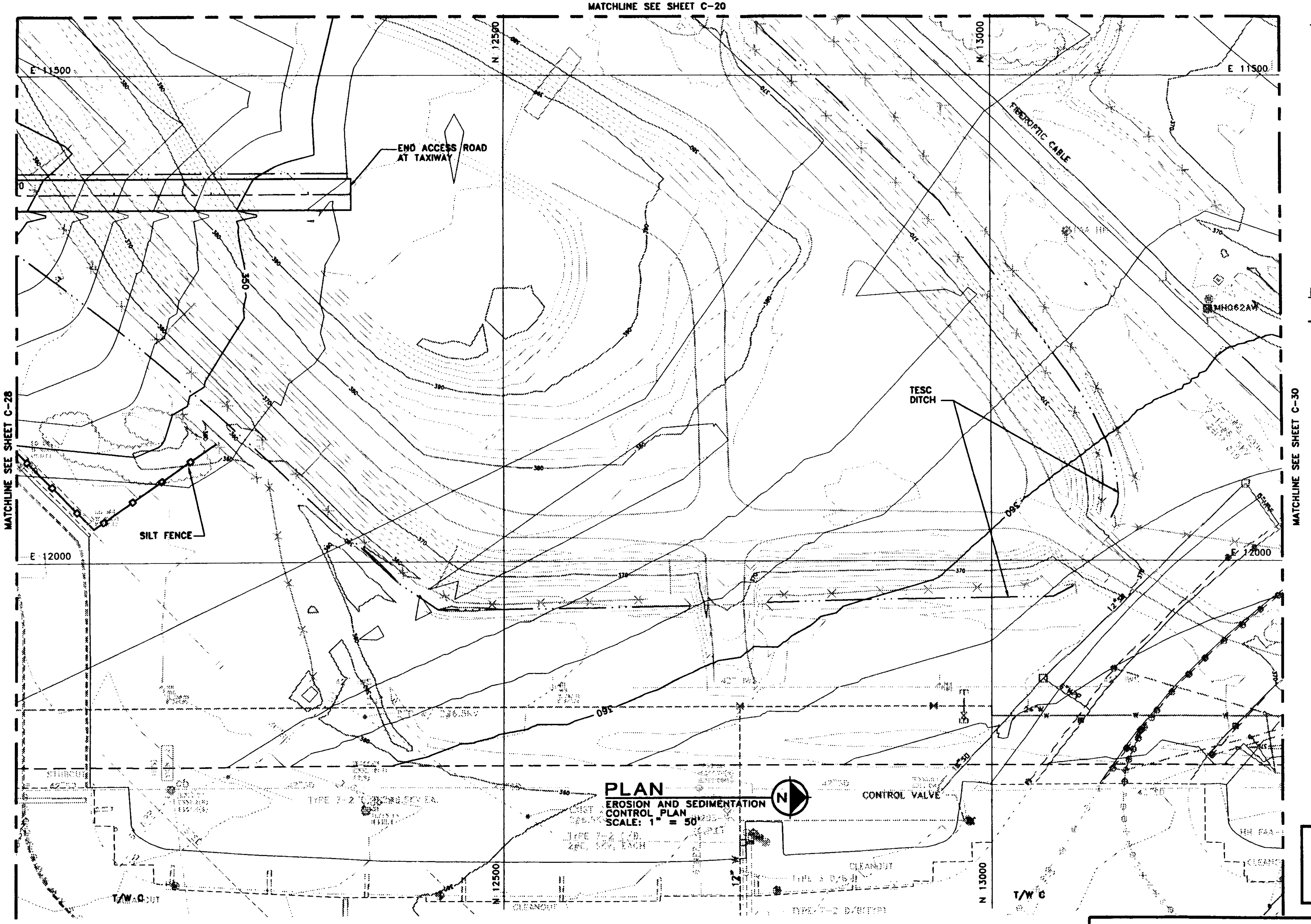
50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C28



PLAN
EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

—□——□— SILT FENCE

▨ WETLANDS

AR 030306

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

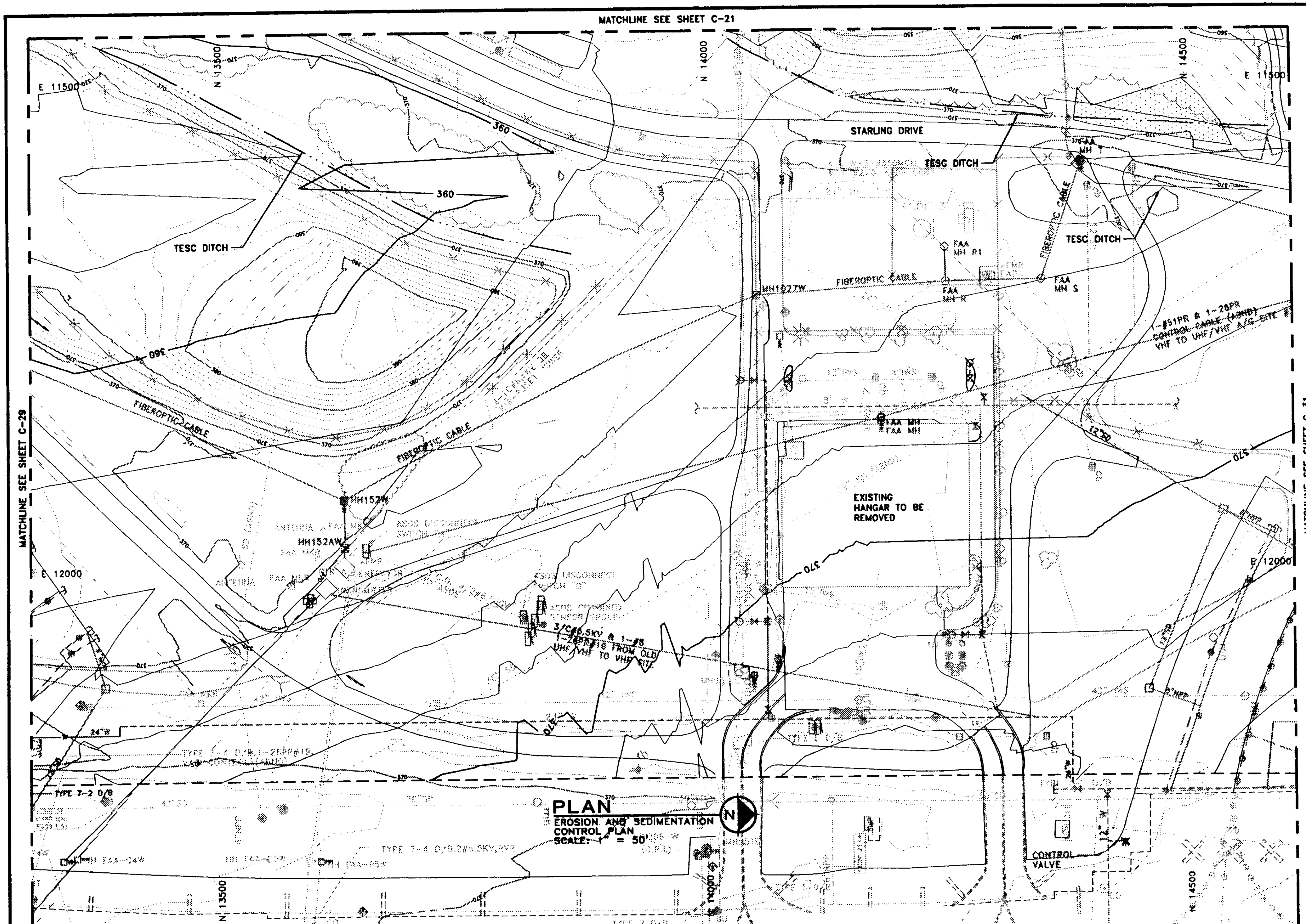
SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE: DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.

EXHIBIT_ C29



PLAN
EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

—□—□— SILT FENCE

▨ WETLANDS

AR 030307

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

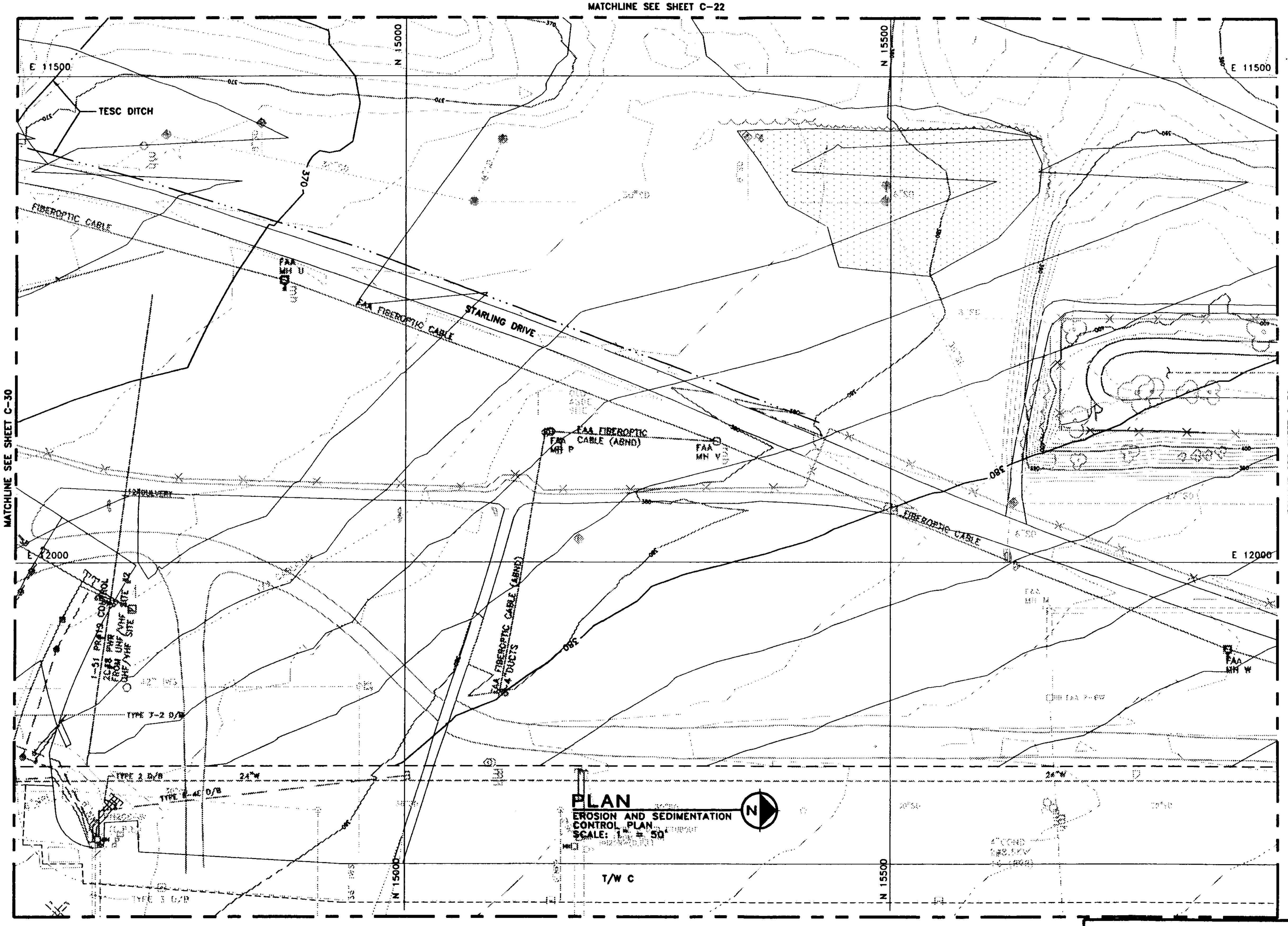
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C30



NOTES:

LEGEND:

—□——□— SILT FENCE

▨ WETLANDS

AR 030308

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

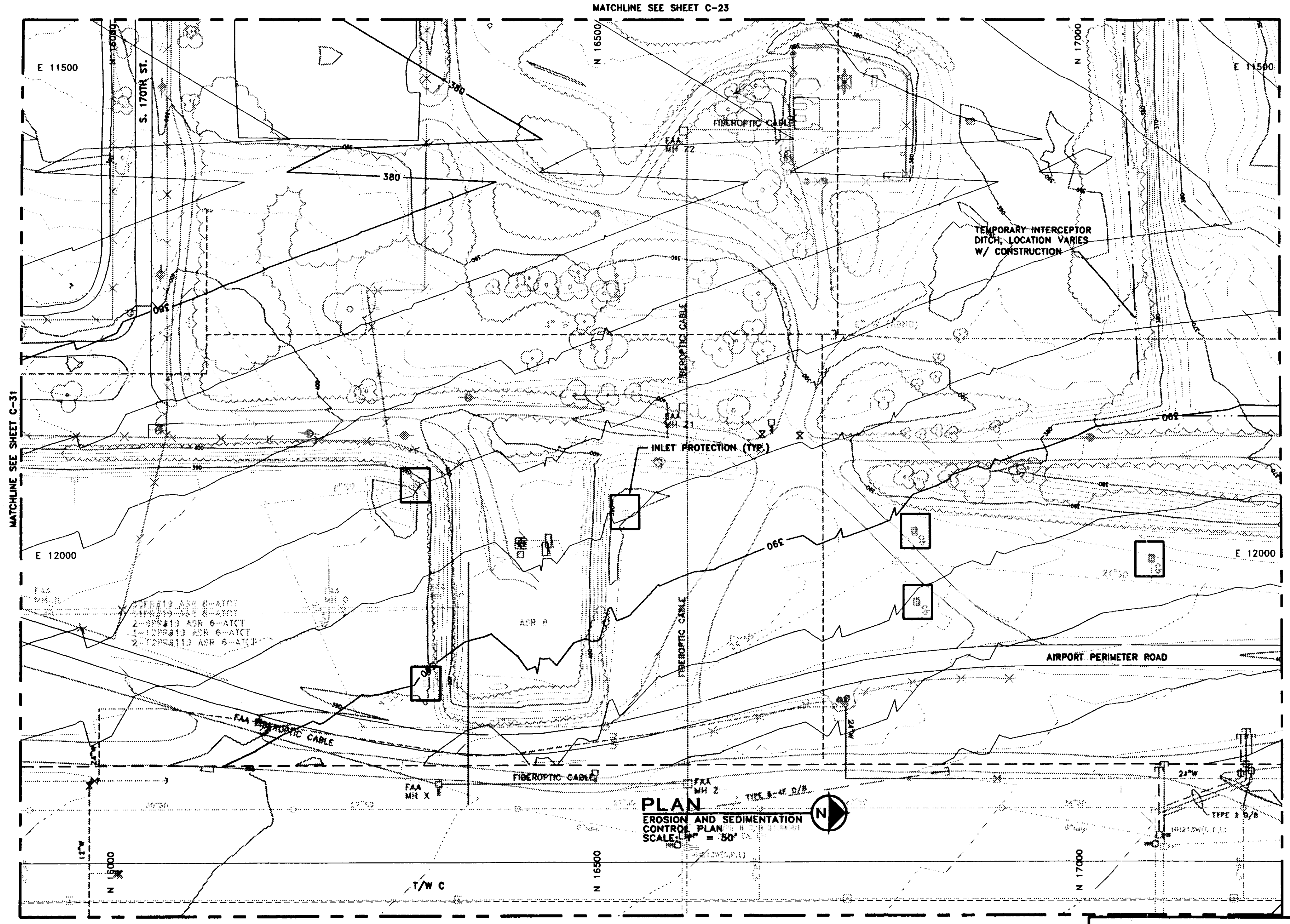
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C31



PLAN

EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

—□—□— SILT FENCE

▨ WETLANDS

AR 030309

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

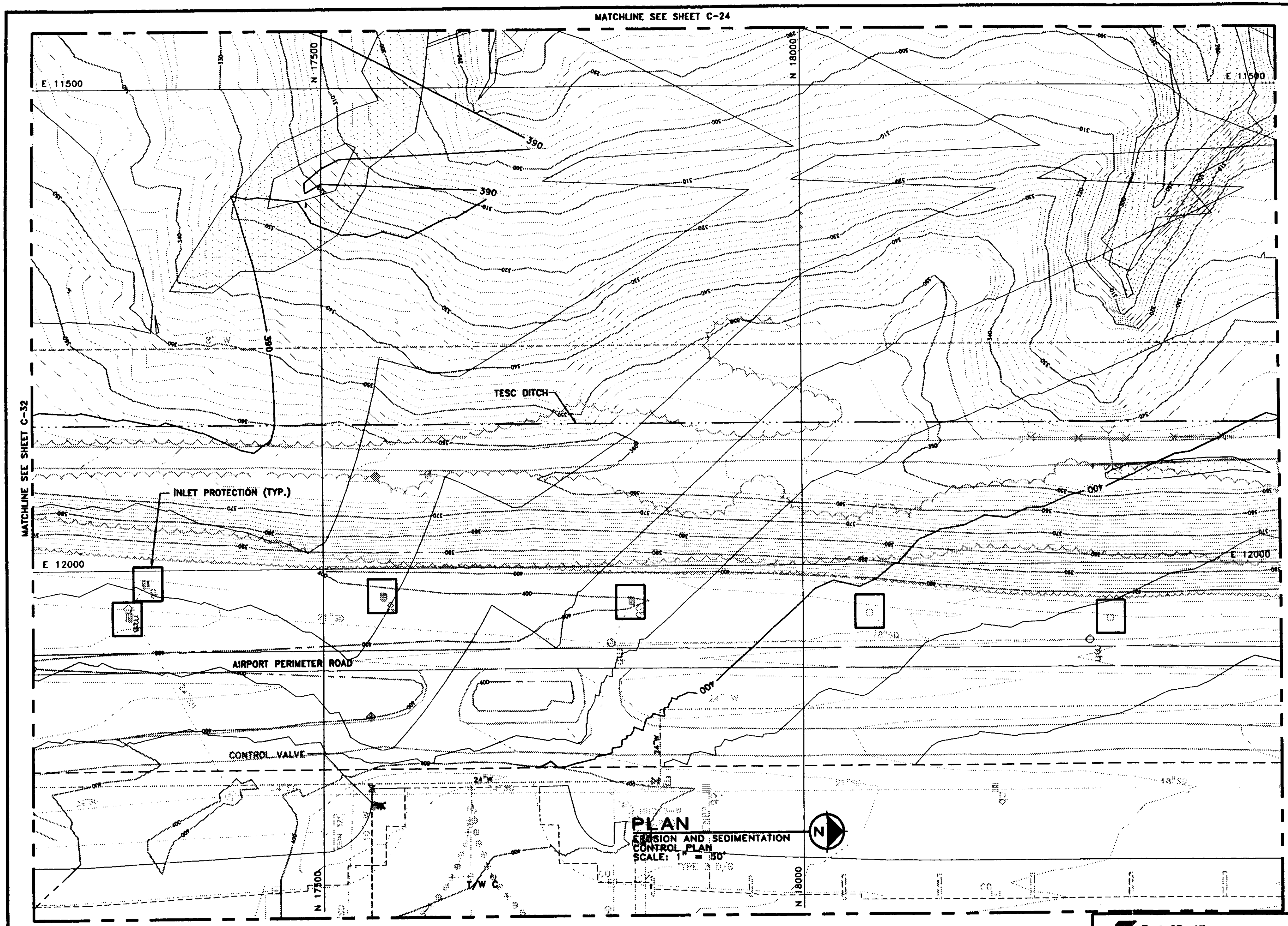
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C32



PLAN

EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

—□——□— SILT FENCE

▨ WETLANDS

AR 030310

SCALE: 1"=50'
50' 0 50' 100'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

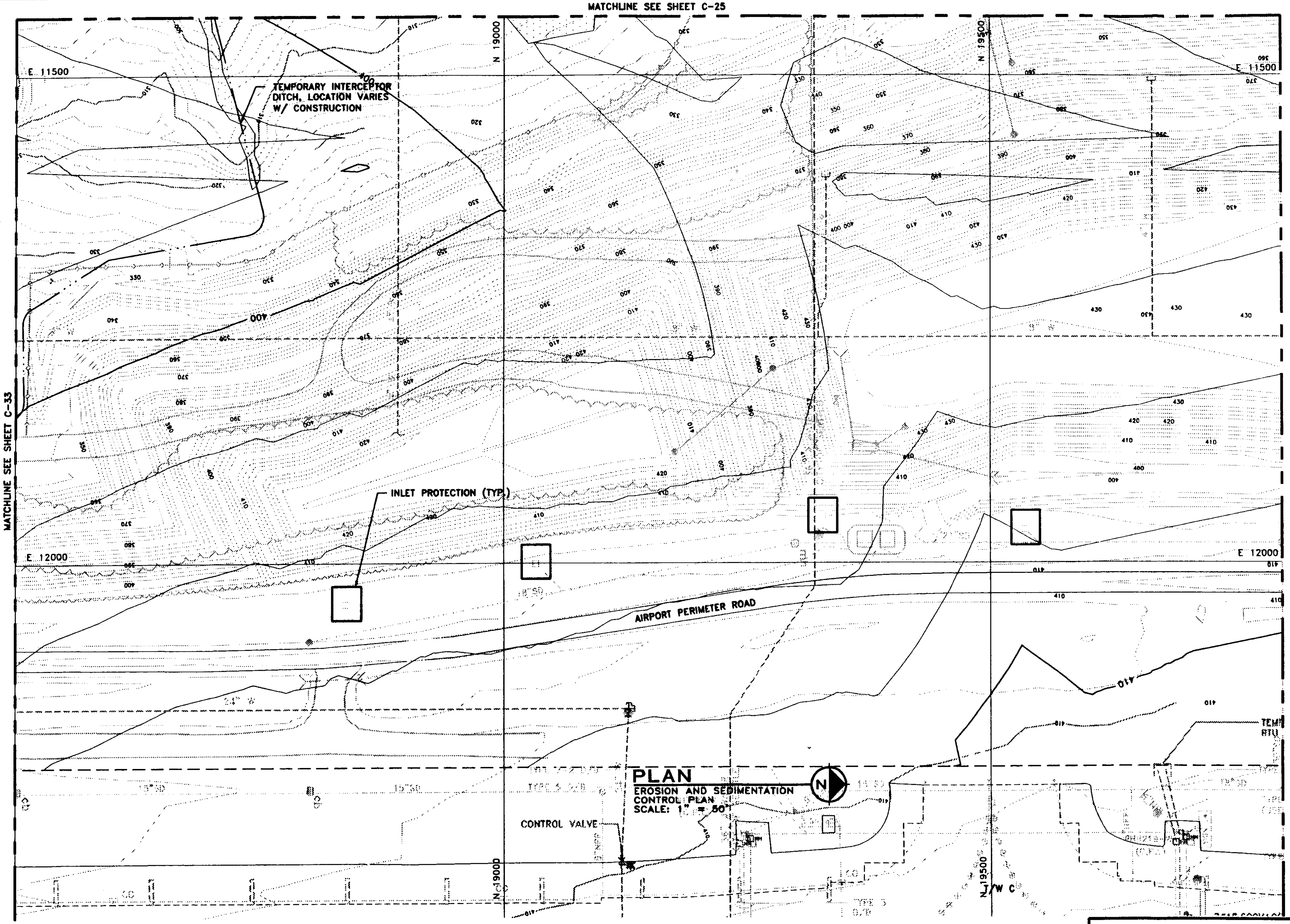
SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.

EXHIBIT_ C33



NOTES:

LEGEND:

—□——□— SILT FENCE

▨ WETLANDS

AR 030311

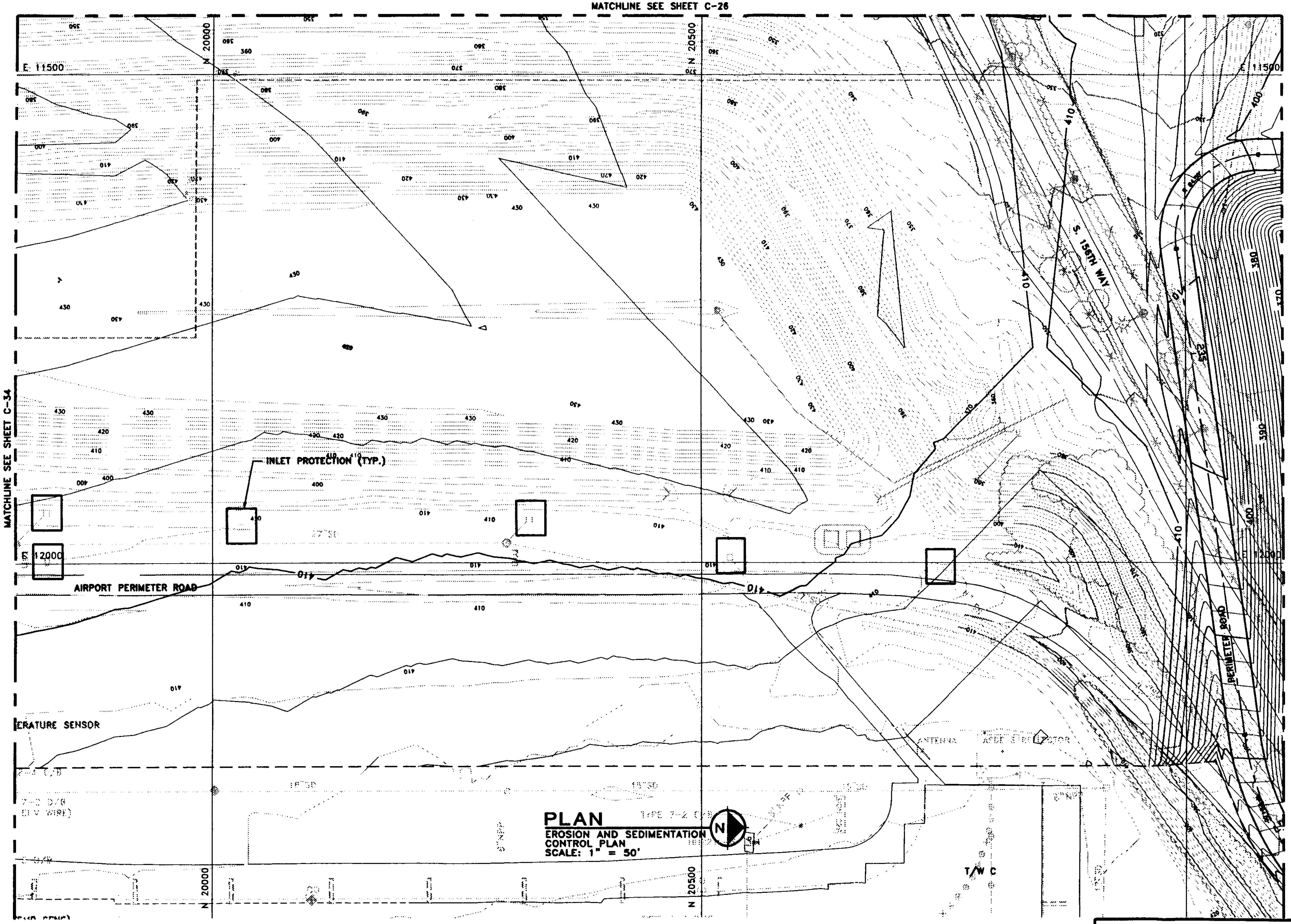
50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6
SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C34



PLAN

EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

—□—□— SILT FENCE

▨ WETLANDS

AR 030312

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6

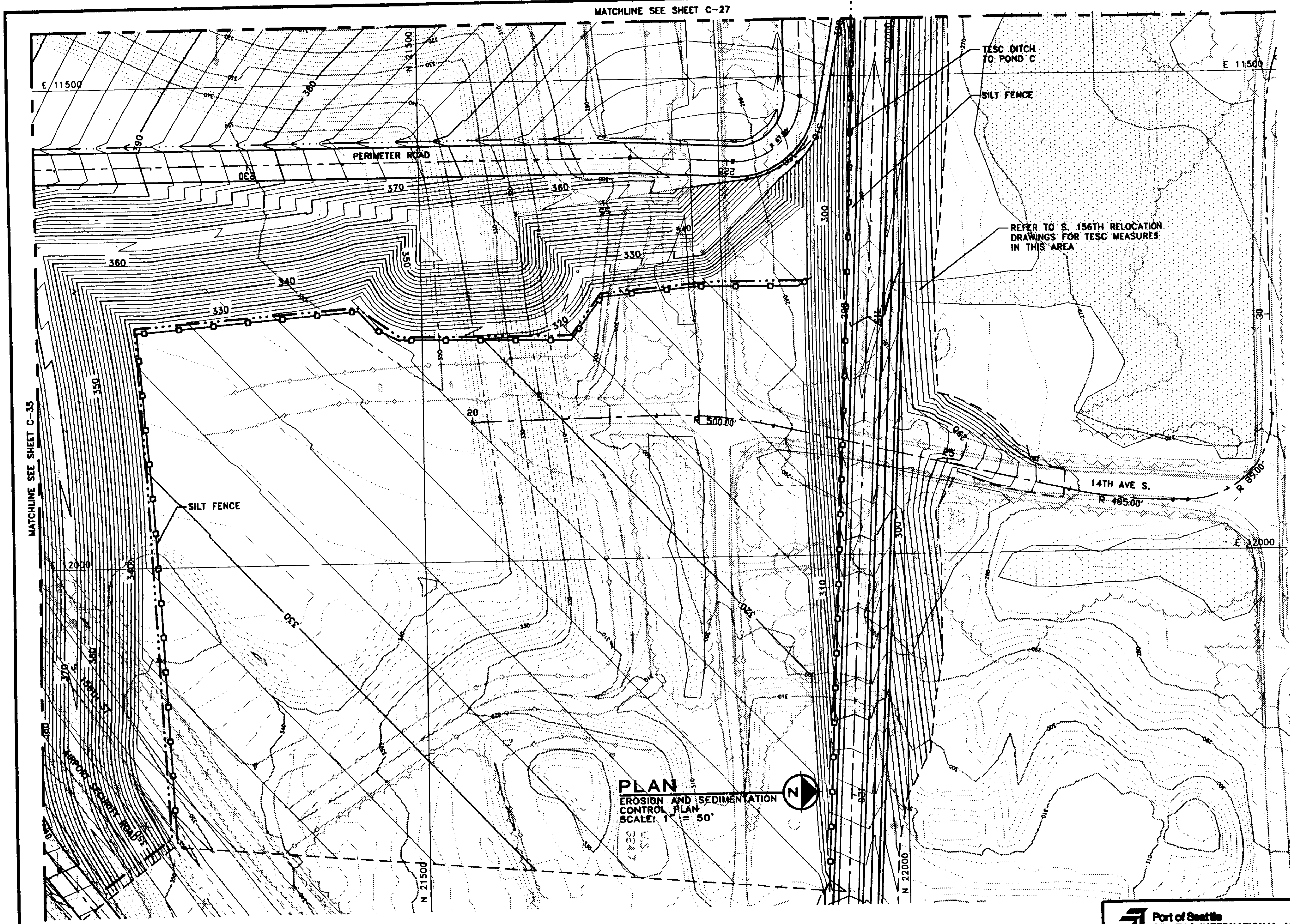
SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.

EXHIBIT_ C35



PLAN

EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

- STORM DRAIN PIPE
- ▨ WETLANDS

AR 030313

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

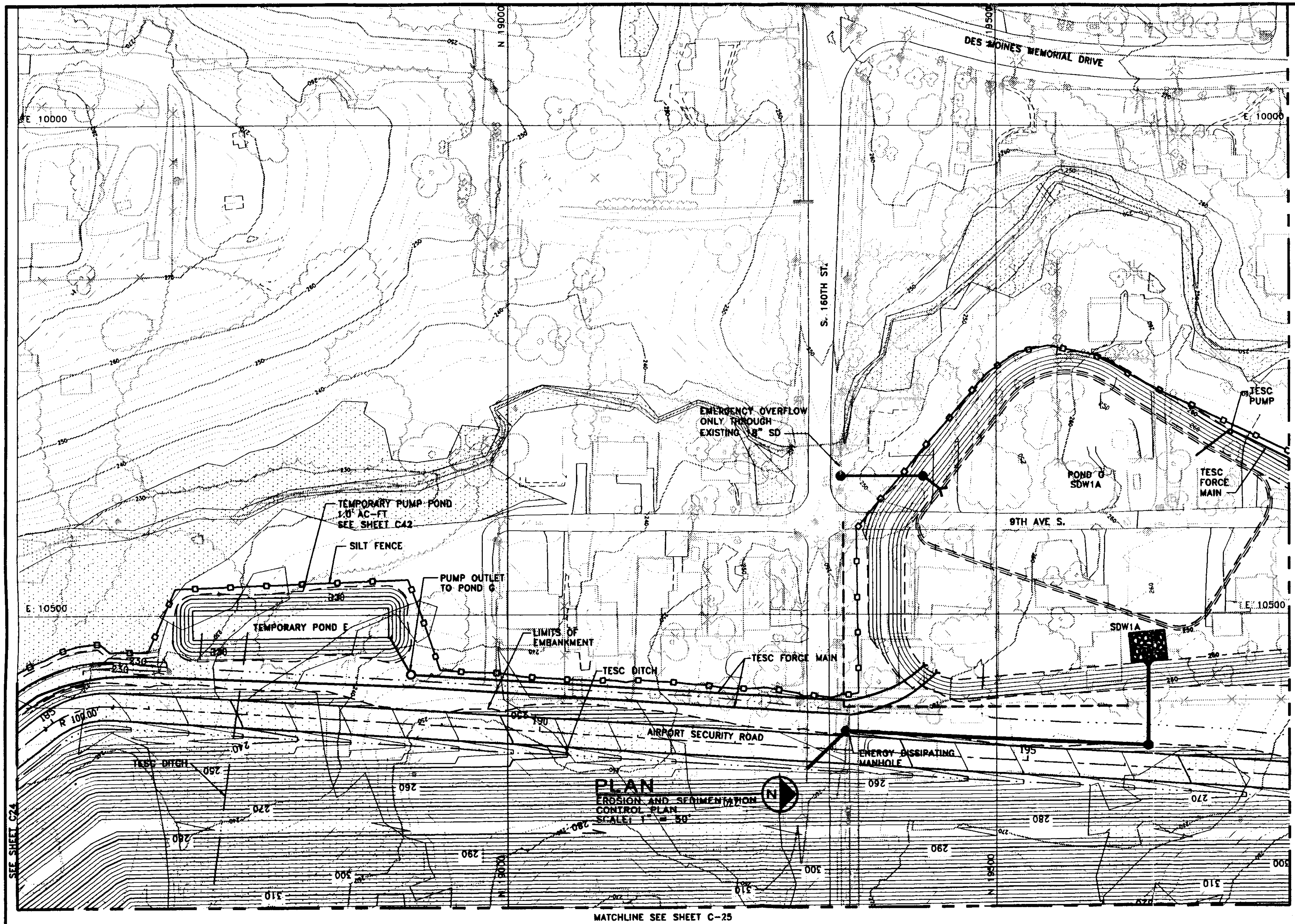
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C36



NOTES:

LEGEND:

—□—□—	SILT FENCE
▨	WETLANDS

AR 030314

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

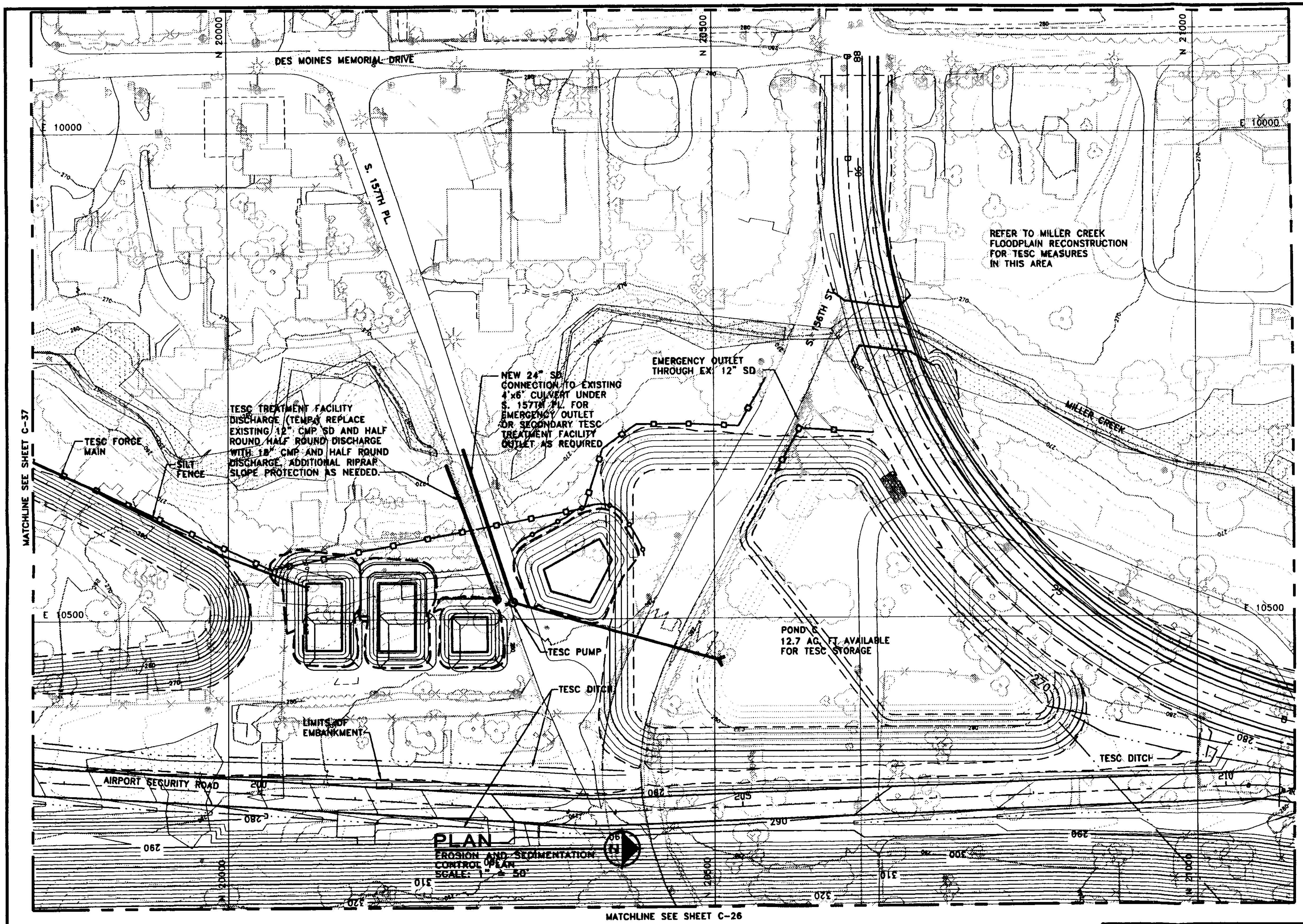
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C37



NOTES:

LEGEND:

—□—□— SILT FENCE

▨ WETLANDS

AR 030315

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: EROSION AND SEDIMENTATION CONTROL PLAN

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
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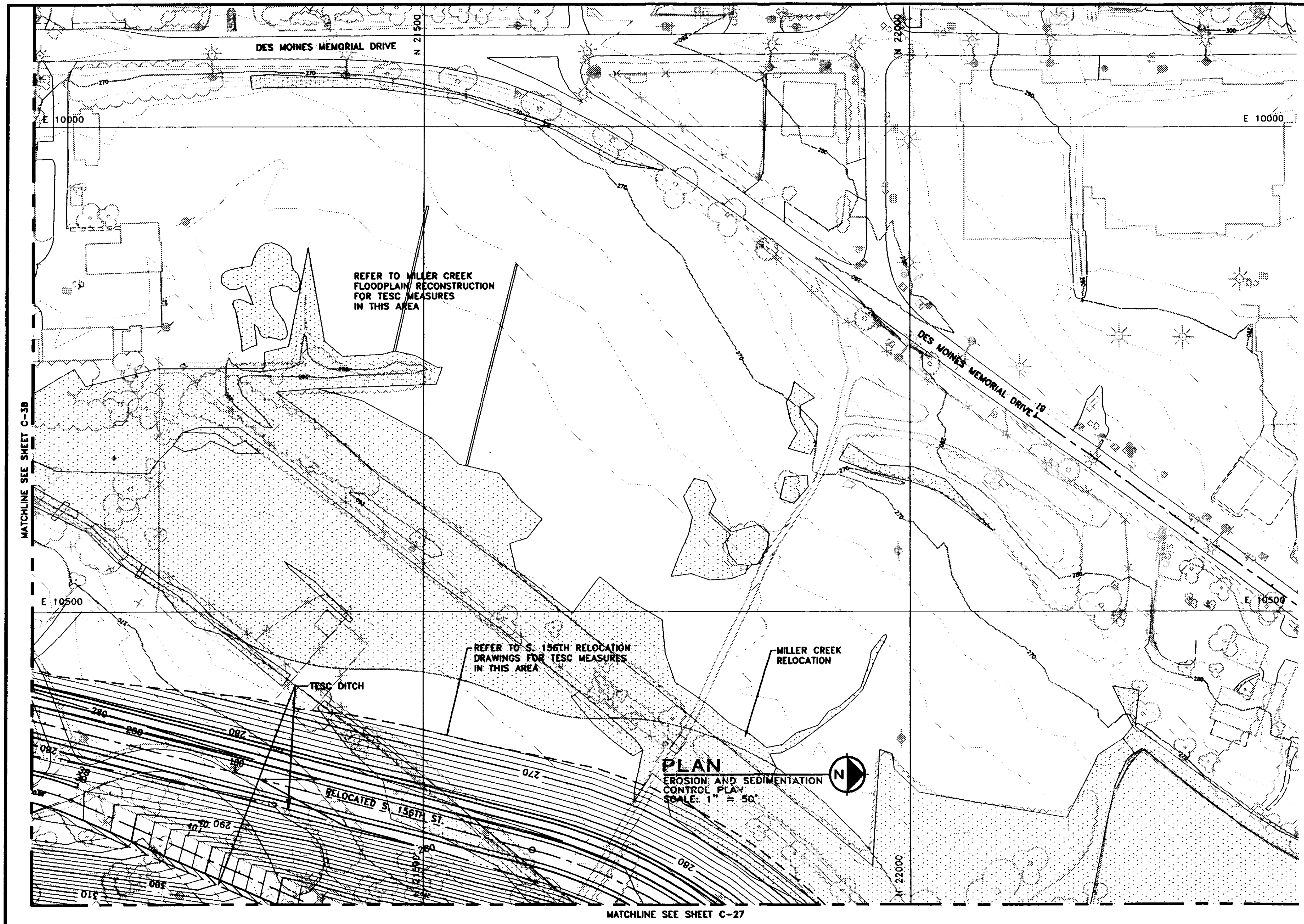


PLAN

EROSION AND SEDIMENTATION CONTROL PLAN
SCALE: 1" = 50'

NOTES:

LEGEND:

STORM DRAIN PIPE

▨ WETLANDS

AR 030316

50' 0 50' 100'
SCALE: 1"=50'

						C37	C38	C39
C19	C20	C21	C22	C23	C24	C25	C26	C27
C28	C29	C30	C31	C32	C33	C34	C35	C36

KEY PLAN

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

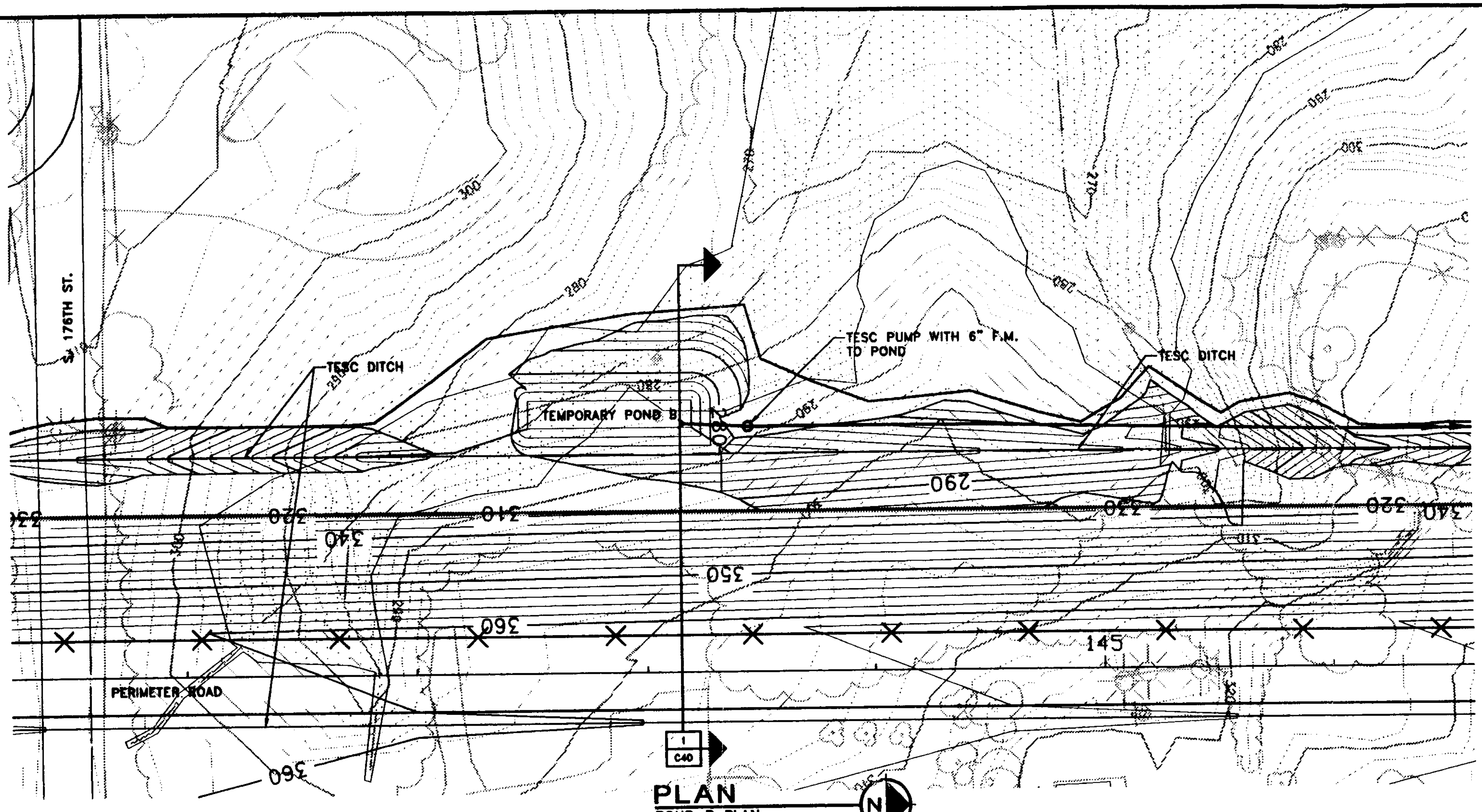
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **EROSION AND SEDIMENTATION CONTROL PLAN**

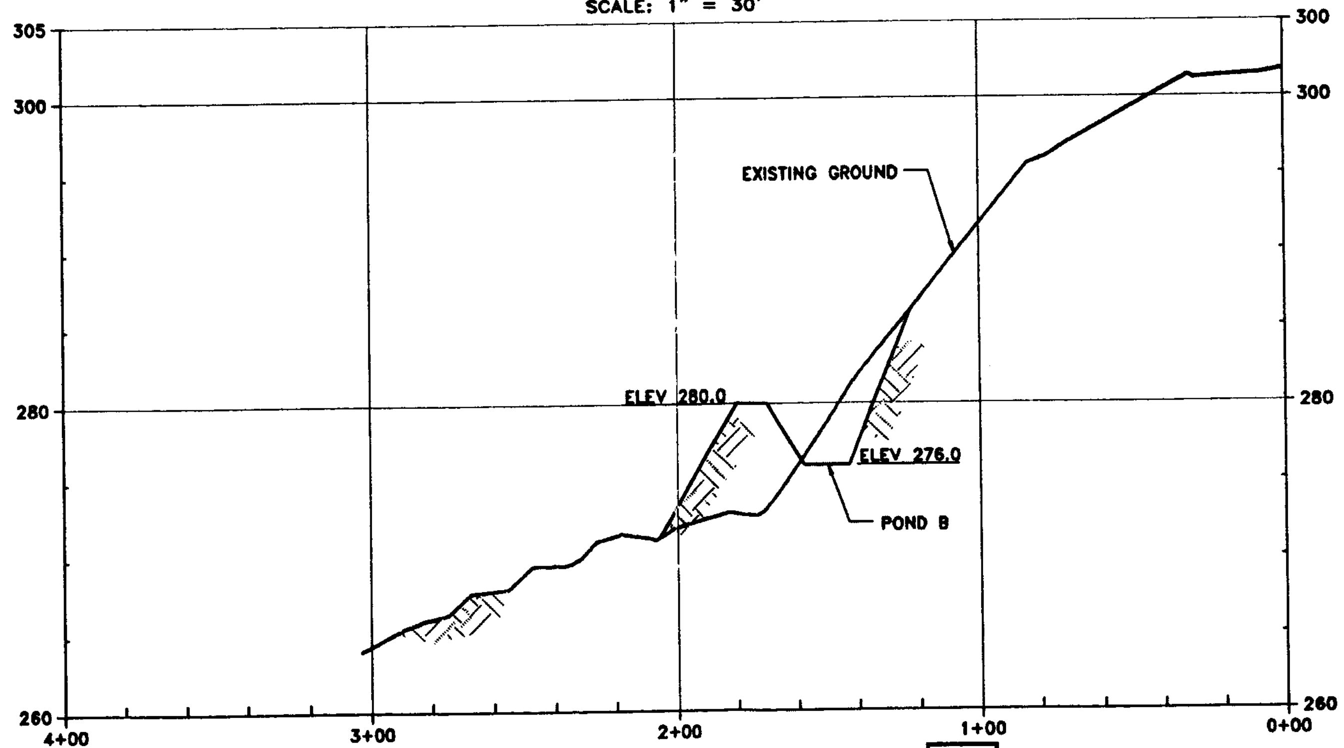
DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C39



PLAN
POND B PLAN
SDWA BASIN POND
SCALE: 1" = 30'



SECTION
POND B PROFILE
SCALE = 1"=30'

1
C40

LEGEND:

—	SILT FENCE
▨	WETLANDS

AR 030317

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

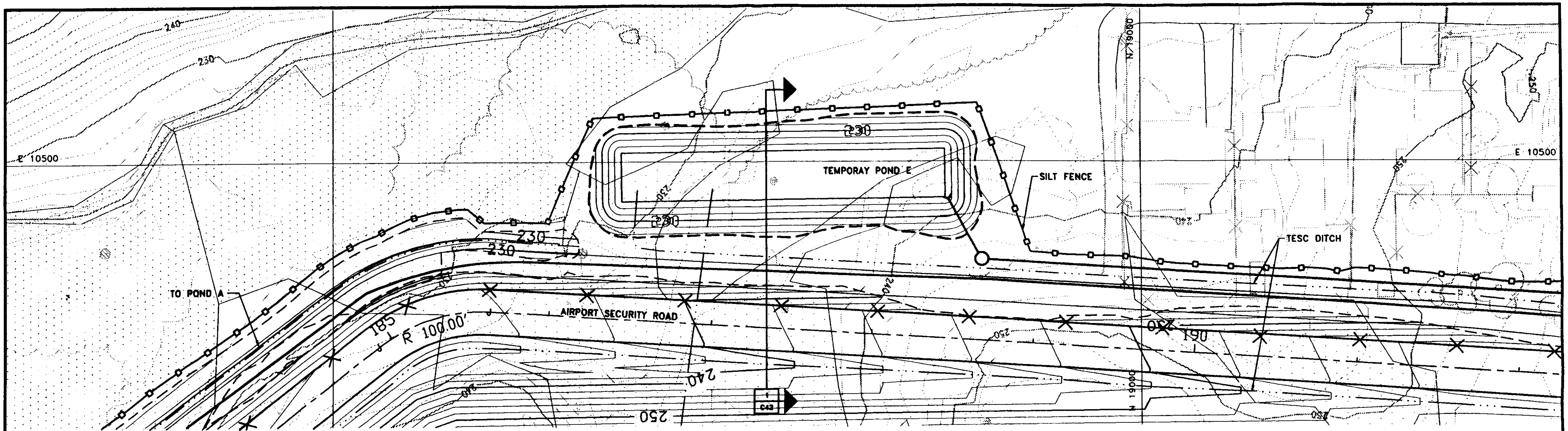
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: POND B PLAN AND PROFILE
SDW2 BASIN TEMPORARY POND

DATE
DEC. 15, 2000

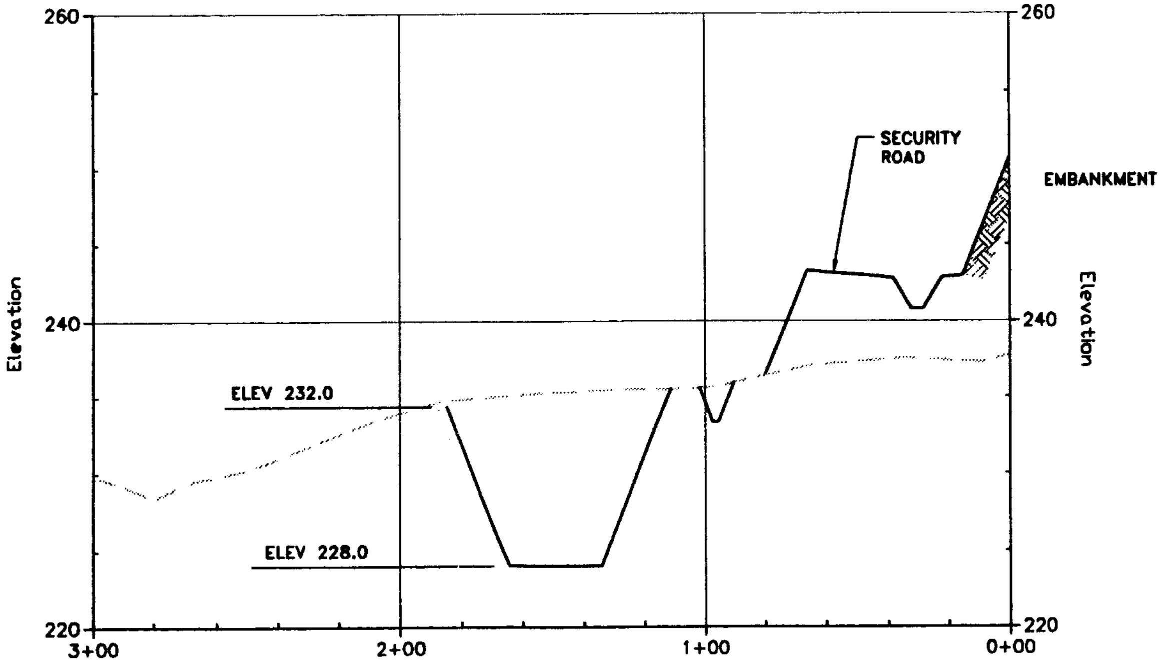
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C40



PLAN

POND E
TESC SDW1A BASIN TEMPORARY POND 2
SCALE: 1" = 30'



SECTION

1
C42

POND E
TESC SDW1A BASIN TEMPORARY POND 2
SCALE: 1' = 30'

LEGEND:

⛆	WETLANDS

AR 030318

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

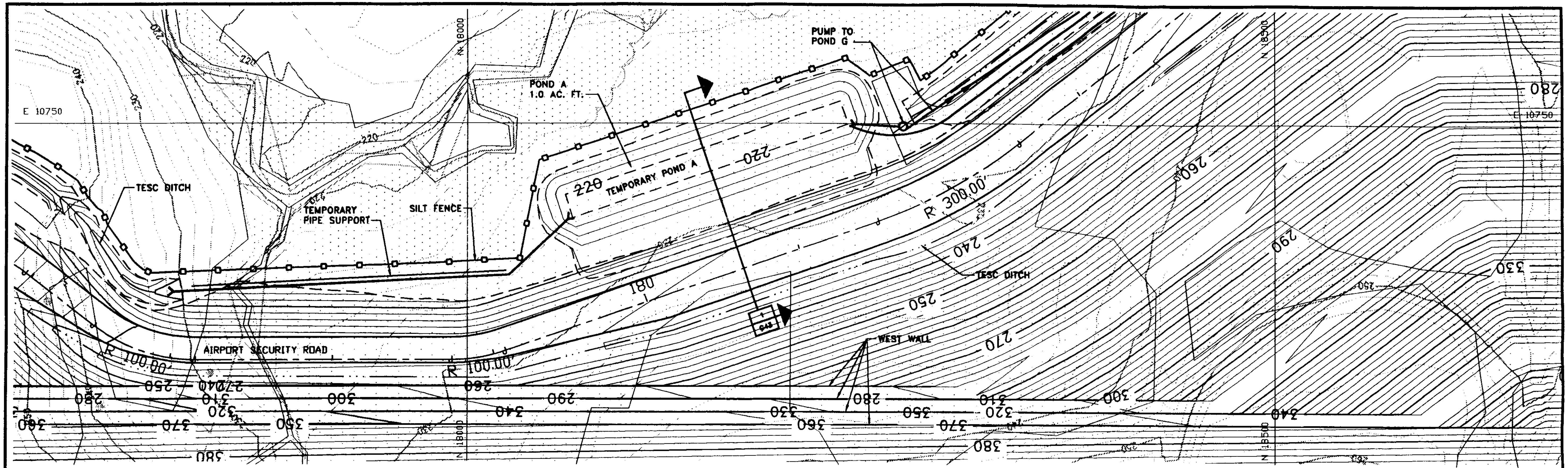
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: POND E/ TESC SDW1A
BASIN TEMPORARY POND 2

DATE
DEC. 15, 2000

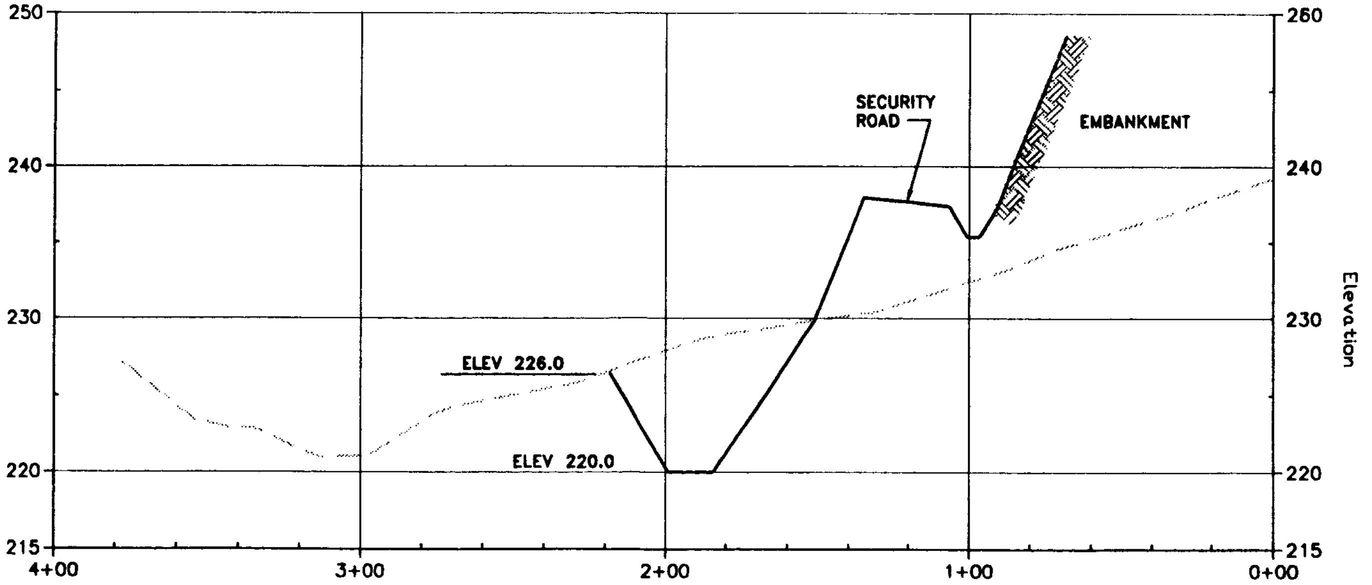
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C42



PLAN

POND A
TESC SDW-1a BASIN TEMPORARY POND 1
SCALE: 1" = 30'



SECTION

1
C43

POND A
TESC SDW-1a BASIN TEMPORARY POND 1
SCALE: 1" = 30'

LEGEND:

▨	WETLANDS

AR 030319

30' 0 30' 60'
SCALE: 1"=30'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6

SHEET TITLE: POND A PLAN & PROFILE SDW1A BASIN TEMPORARY POND 1

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C43

A-4

Avoidance of Wetland Impacts-Temporary Stormwater Pond A

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Avoidance of Wetland Impacts
Temporary Stormwater Pond A
Sea-Tac Third Runway

Prepared for
HNTB and the Port of Seattle

June 18, 2001
4978-06

Prepared by
Hart Crowser, Inc.

Michael A.P. Kenrick 6/18/01
EXPIRES [illegible] 01

MICHAEL J. BAILEY
22484
EXPIRES 12/13/01

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CONTENTS

TABLE

FIGURES

APPENDIX A
SUBSURFACE EXPLORATIONS

FIGURES

CONTENTS (Continued)

Page

FIGURES

TABLE

AVOIDANCE OF WETLAND IMPACTS
TEMPORARY STORMWATER POND A
SEA-TAC THIRD RUNWAY

SUMMARY

The design and construction of Temporary Stormwater Pond A at the Sea-Tac Third Runway project has been analyzed to avoid potential effects on groundwater flow and wetland hydrology. This report examines the hydrogeologic and geotechnical issues related to design, construction, and operation of Pond A. Potential impacts to the hydrology of riparian wetlands between Pond A and Miller Creek can be mitigated through appropriate engineering design.

Pond A will be excavated about 6 to 10 feet in wetland soils, and would have an operating water level roughly 0 to 10 feet below the current water table in the wetlands. A sheet pile wall has been included in the design that isolates the pond from the surrounding water table and wetland hydrology. This wall will prevent Pond A from acting as a hydraulic sink and potentially altering the hydrology of adjacent wetlands.

To prevent the proposed sheet pile wall from disrupting the natural groundwater flow to the wetlands, a gravel-filled trench is planned to convey groundwater flow around the sheet pile wall and allow it to re-infiltrate on the downgradient side of Pond A. This will help to maintain groundwater levels on the western side of the sheet pile wall and thus avoid temporary impacts to the wetlands.

INTRODUCTION

This report addresses engineering and hydrogeologic issues related to the design and construction of temporary Stormwater Pond A at the Sea-Tac Third Runway project. Figure 1 shows a site plan including location of existing subsurface explorations and elevation contours for the shallow groundwater.

Construction of Pond A is planned to occur at the toe of the Third Runway embankment, near the West MSE Wall. The location is within riparian wetlands adjacent to Miller Creek. This report explains the engineering design for the pond and how this design is to avoid impacts to the hydrology of the adjacent wetland.

The purpose of Pond A is temporary collection of stormwater during part of the embankment construction, and is anticipated to be in service for one to two years. During wet weather, a low water level would be maintained near the bottom of Pond A by pumping to provide storage of runoff from storm events. During the summer months, the pond would fill with groundwater seepage, to avoid cost of pumping.

If the pond were constructed without the sheet pile wall, calculations suggest that the rate of seepage into the pond would be low (less than 5 gpm). Since this could be enough to lower the water table locally and potentially alter the hydrology of the wetland, the Port has developed plans to avoid impacting the wetland hydrology as described herein. The proposed pond design and mitigation includes the following elements:

- Stockpiling native wetland soil for use in restoring temporary wetland impacts.

- Installation of a continuous ring of sheet piles to form a cutoff wall around the pond to limit seepage into the pond. The sheet pile wall would be driven into the top of very dense silty sand soils below the surficial soils, effectively cutting off seepage of groundwater into the pond.

- Installation of a gravel-filled trench (similar to a "French drain") around the outside of the sheet pile wall to maintain existing groundwater flow and avoid potential lowering of water levels on the immediate downgradient side of the pond.

- Monitoring wetland vegetation adjacent to the pond during construction and pond operation to verify no loss of wetland functions and/or to enable supplemental mitigation, if needed.

- Removal of the temporary sheet pile wall and French drain after construction in the area is complete, backfilling with native soil, and revegetation to restore pre-construction conditions (see Section 5.2.4 of the Natural Resources Mitigation Plan; Parametrix 2000). Backfill would consist of soil types similar to those excavated; compaction would be avoided to enhance revegetation and to restore pre-construction seepage conditions.

The following sections of this report provide a summary of subsurface conditions, followed by a detailed description of the proposed design and mitigation. Figure 1 shows a site plan and existing shallow groundwater contours. Figure 2 shows a general geologic cross section through the pond. Figure 3 shows a detailed layout of temporary Pond A including a sheet pile wall and French drain around the perimeter. Figure 4 shows a cross section through the sheet pile wall and French drain.

Appendix A presents logs of soil borings at Pond A; Appendix B discusses hydrogeologic modeling used to verify effectiveness of the proposed French drain in maintaining shallow groundwater movement to the downslope wetland; and Appendix C describes geotechnical analysis of the sheet pile.

SUMMARY OF SUBSURFACE CONDITIONS

Subsurface conditions in the vicinity of Pond A generally consist of 5 to 15 feet of soft or loose soils overlying very dense glacial till. The soft surficial soils consist of interbedded silty to very silty sand, peat and slightly sandy silt. Below these soils, the borings encountered silty, slightly gravelly to gravelly sand (glacial till). Logs of borings in the area of Pond A are presented in Appendix A. Figure 2 presents a generalized cross section through the long axis of the proposed Pond A.

The proposed bottom of pond elevation is 220 feet (existing ground surface elevations between about 226 to 230 feet). Groundwater levels vary seasonally between about 224 to 230 feet (Table 1).

Groundwater in the area of Pond A is within a few feet of the ground surface throughout the year. The groundwater level varies seasonally up to about 2-1/2 feet, as indicated by measurements in observation wells HC99-B38 and HC99-B39 from March of 1999 through January 2001 (Table 1).

PROTECTION OF WETLANDS

Given the potential for Pond A to alter wetland hydrology, alternative methods for protecting the wetland were considered. These included modifications to the operating regime for Pond A with operation restricted during the summer to prevent any potential for wetland impacts at this time. A design that hydraulically isolates Pond A was also developed and the effect of this isolation on the hydrology of the neighboring wetlands was analyzed using a simplified groundwater flow model (Appendix B).

The sheet pile wall will completely encircle Pond A, forming a hydraulic barrier from groundwater in the surficial soils surrounding the pond (Figure 3). Seepage below the sheet piles is anticipated to be negligible, due to the low hydraulic conductivity of the very dense silty sand (glacial till) and limited differential head between the bottom of the pond and groundwater level outside the pond. Details of the sheet pile wall design are presented in Appendix C.

Although the sheet pile wall will provide hydraulic isolation of Pond A from the surrounding wetland, a potential effect of the wall could be a disruption of the natural pattern of shallow groundwater movement in the subsoils downslope of the wall. To prevent disruption of groundwater flow, the design also includes a gravel-filled trench, constructed as a French drain encircling the sheet pile wall. This French drain will convey groundwater flow around the "obstruction" created by the pond.

A numerical groundwater flow model was used to assess the potential for changes in groundwater levels and flows as a result of the sheet pile wall, and to test alternatives measures for mitigating these effects (Appendix B). Worst case simulations suggested that without the French drain system, groundwater levels could potentially be reduced by 1 to 2 feet on the downgradient side of the sheet pile wall in the zone between Pond A and Miller Creek. The French drain is designed to avoid this potential impact.

Groundwater flow would be maintained around the sheet pile wall by conventional French drain consisting of a gravel-filled trench with a perforated drain pipe located within the gravel. The gravel-filled trench provides for relatively uniform seepage into the French drain and from the French drain into the adjacent undisturbed soil. The pipe enables effective transmission of water around the sheet piled area with relatively little loss of head. A geotextile filter fabric around the gravel will prevent migration of fine soil particles and potential clogging that might otherwise diminish effectiveness over the one to two year operating life of the system. Dimensions and details of the system are shown on Figure 4.

The trench will collect shallow groundwater on the upstream (eastern) side of Pond A, and convey it to the soils on the downstream (western) side of the pond. Flow can occur around both the southern and northern ends of the pond. Groundwater that seeps into the upgradient side of the drain will be available to re-infiltrate back into the shallow soils on the western side of Pond A, thus maintaining groundwater levels in the wetland.

The rate of flow into and out of the trench will be limited by the hydraulic conductivity of the native soils. Accordingly the drain would not lower water tables in upgradient soils.

USE OF THIS REPORT

This report was prepared for the Port of Seattle for the site and facility described herein. We completed this work in accordance with conventionally accepted geotechnical engineering practices for the nature and conditions of work conducted in the same or similar localities at the time the work was performed.

Hart Crowser would be pleased to address any questions on this report.

REFERENCES

Parametrix 2000. "Final Natural Resource Mitigation Plan, Master Plan Update Improvements, Seattle-Tacoma International Airport."

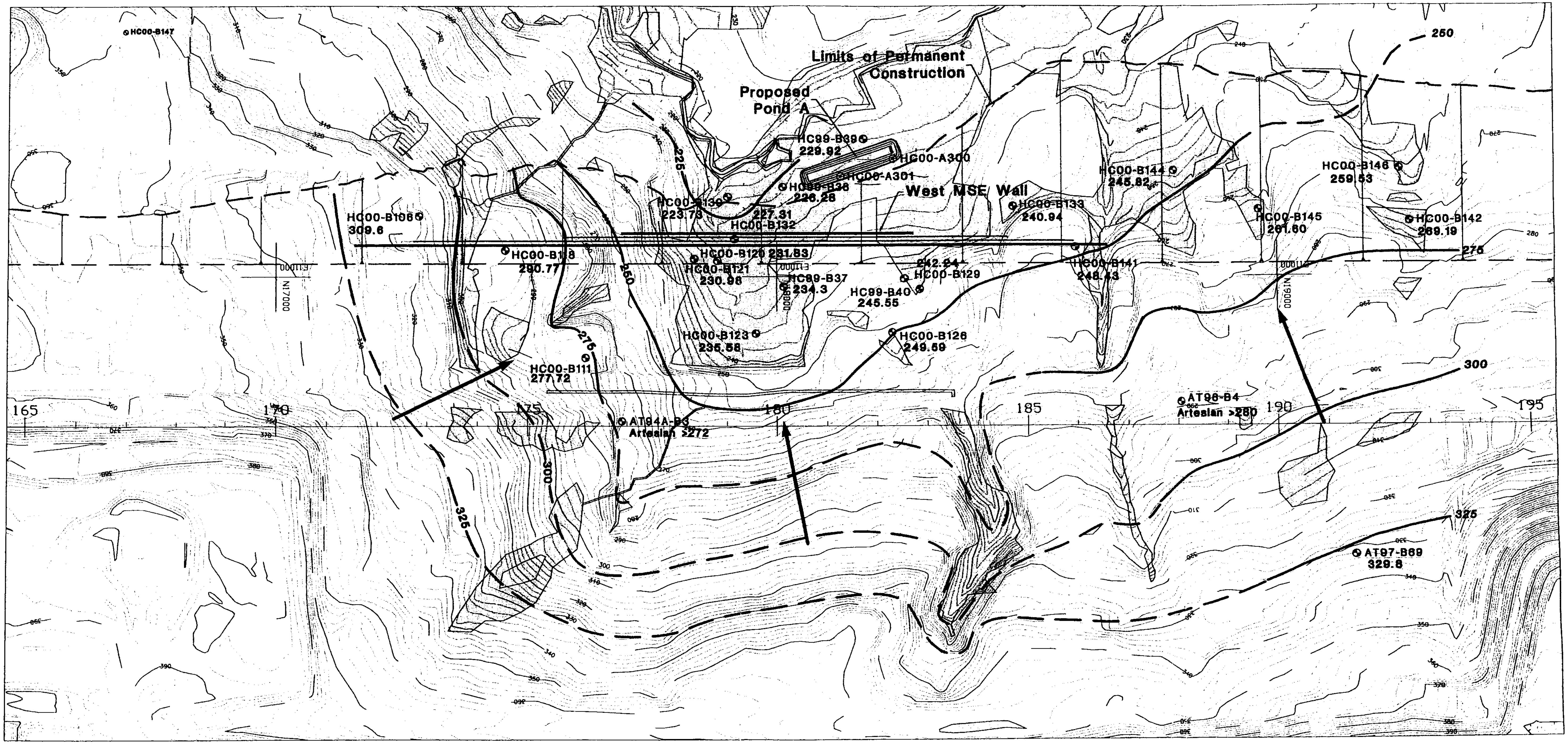
F:\Docs\Jobs\497806\PondAReportRev2.doc

Table 1 - Observed Groundwater Levels in Monitoring Wells near Pond A

Monitoring Well:	HC99-B38		HC99-B39	
	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Measuring Point	0.00	230.88	0.00	230.80
Ground Level*	3.3	227.6	-0.3	231.1
Top of Screen*	12.3	218.6	4.7	226.1
Bottom of Screen*	22.3	208.6	14.7	216.1
Date: 3/8/1999	4.40	226.48	0.69	230.11
3/10/1999				
4/5/1999	4.41	226.47	0.74	230.06
5/4/1999	4.60	226.28	0.86	229.94
5/15/1999				
6/14/1999	5.90	224.98	1.68	229.12
7/13/1999	5.93	224.95	2.05	228.75
8/13/1999	6.08	224.80	2.18	228.62
9/14/1999	6.48	224.40	2.51	228.29
10/13/1999	5.98	224.90	2.09	228.71
11/11/1999	4.25	226.63	2.90	227.90
12/9/1999	4.38	226.50	0.27	230.53
1/13/2000	4.35	226.53	0.54	230.26
2/14/2000	4.33	226.55	0.59	230.21
3/9/2000	4.43	226.45	0.61	230.19
4/11/2000	4.60	226.28	0.88	229.92
5/10/2000	4.32	226.56	0.88	229.92
6/19/2000	4.91	225.97	1.15	229.65
7/10/2000	5.72	225.16	1.61	229.19
10/10/2000	5.99	224.89	2.17	228.63
1/22/2001	4.42	226.46	0.79	230.01
5/4/2001	4.58	226.30	1.05	229.75

Depth* All depths are below measuring point (NOT below the ground surface)
Blank indicates data not available.

Site and Exploration Plan
Groundwater Elevation Contour Map
Pond A



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg," dated October 4, 1999. Wetland delineation prepared from drawing provided by Parametrix entitled "W_020800.dwg," dated February 8, 2000.

⊛HC00-B118	Monitoring Well Location and Number
⊙HC00-A300	Hand Auger Boring Location and Number
290.77	Groundwater Elevation in Feet (April 11, 2000)
Artesian >272	Confirmed Groundwater Estimated Piezometric Level in Feet
⬭	Wetland Location
— —250—	Groundwater Elevation Contour in Feet (Dashed where Inferred)
←	Inferred Groundwater Flow Direction
185	Proposed Runway Centerline Stationing

N

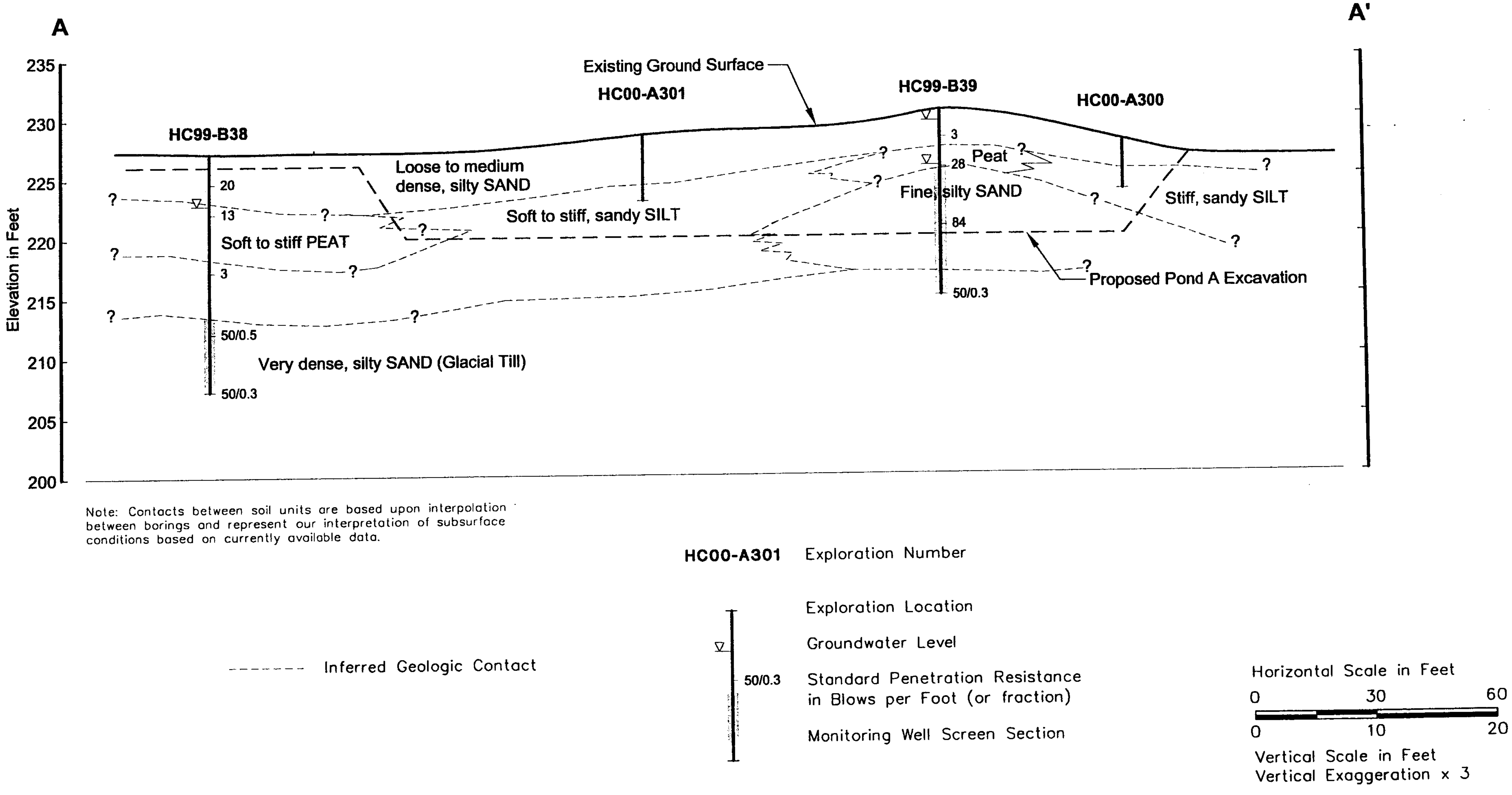
0 200 400
Scale in Feet

AR 030330

HARTCROWSER
J-4978-06 06/01
Figure 1

RC 6/18/00 1=200 (xref)see drawing file/charlie.pc2
4978068₄

Cross Section A-A'

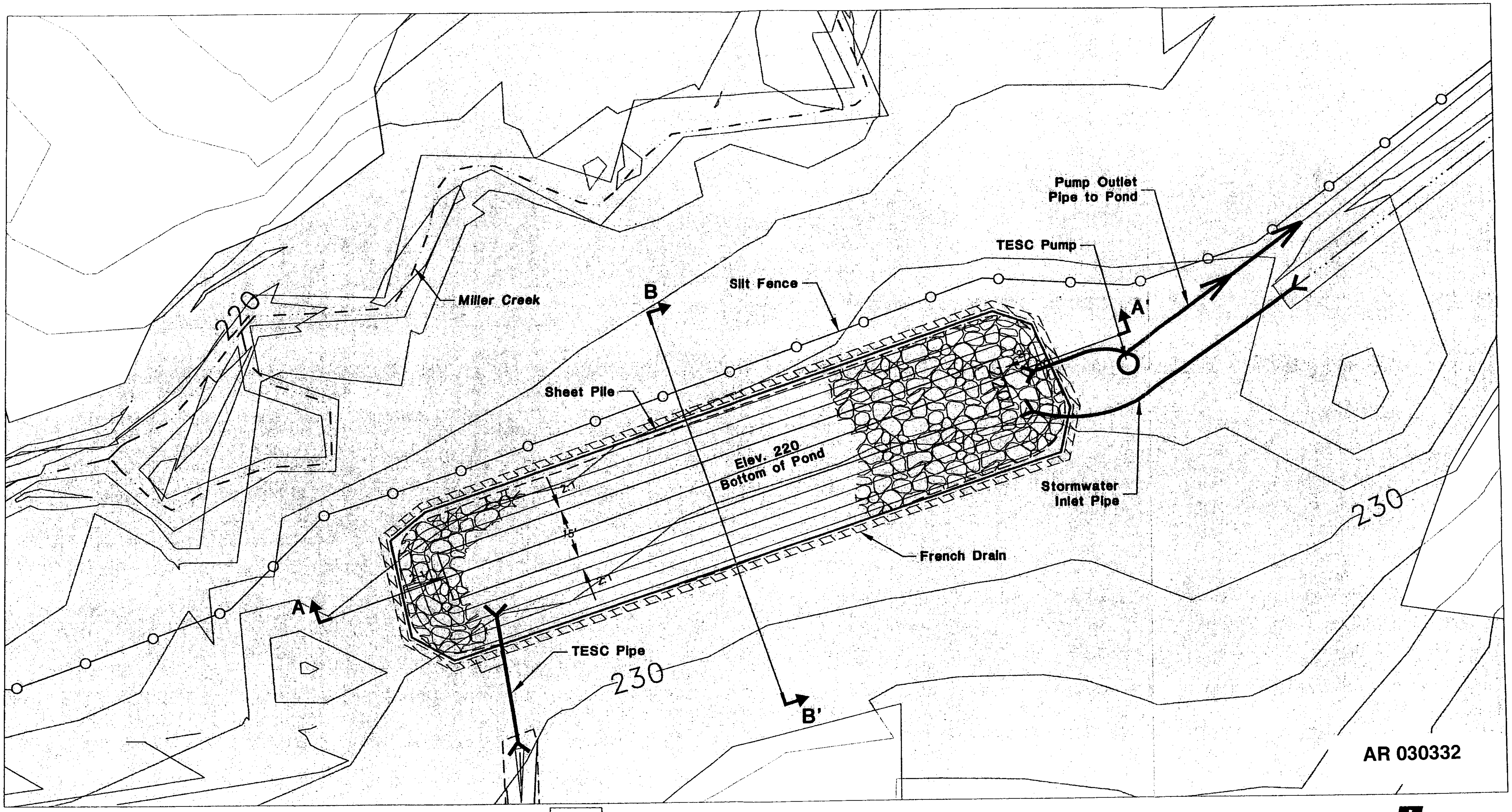


Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

DTN 6/18/01 1=1 charlie-8.pc2
4978081

HARTCROWSER
J-4978-06 6/01
Figure 2

Pond A Detail



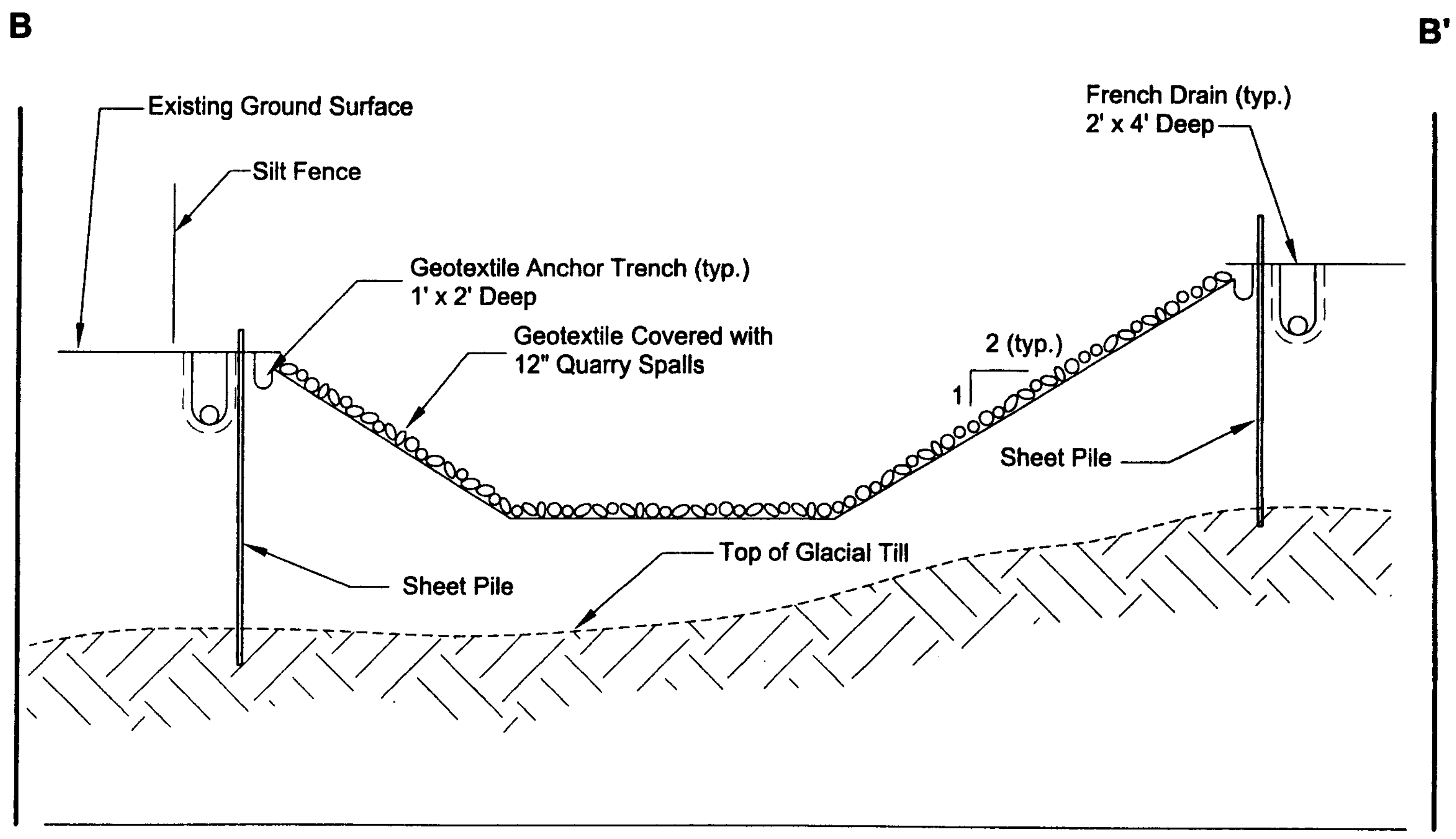
Note: Base map prepared from drawing provided by HNTB entitled "X_topo.dwg," dated April 4, 2001. Wetland delineation prepared from drawing provided by Parametrix entitled "W_022201.dwg," dated February 22, 2001.

HARTCROWSER
J-4978-06 6/01
Figure 3

RC 6/18/01 1=30 (xref)see drawing file/charlie.pc2
49780687

DTN 6/18/01 charlie-8.pc2 49780679

Cross Section B-B'



Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Not to Scale

HARTCROWSER
J-4978-06 6/01
Figure 4

APPENDIX A
SUBSURFACE EXPLORATIONS

Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling Test Symbols

BORING SAMPLES

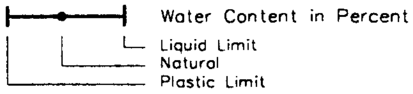
☒	Split Spoon
⧅	Shelby Tube
▥	Cuttings
◫	Core Run
*	No Sample Recovery
P	Tube Pushed, Not Driven

TEST PIT SAMPLES

☒	Grab (Jar)
⧄	Bag
⧅	Shelby Tube

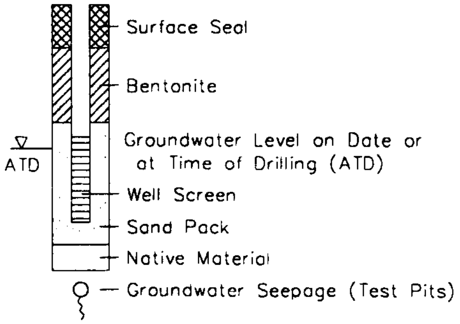
Test Symbols

GS	Grain Size Classification
CN	Consolidation
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits



PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	*In Situ* Density Test

Groundwater Observations



1=1 A-1 STANDARD

HARTCROWSER

J-4978-06 6/01

Figure A-1

Boring Log HC99-B38

N 18,011.99, E 10,819.39

Soil Descriptions

Ground Surface Elevation in Feet: 227.58

(Loose), moist, brown, silty SAND.

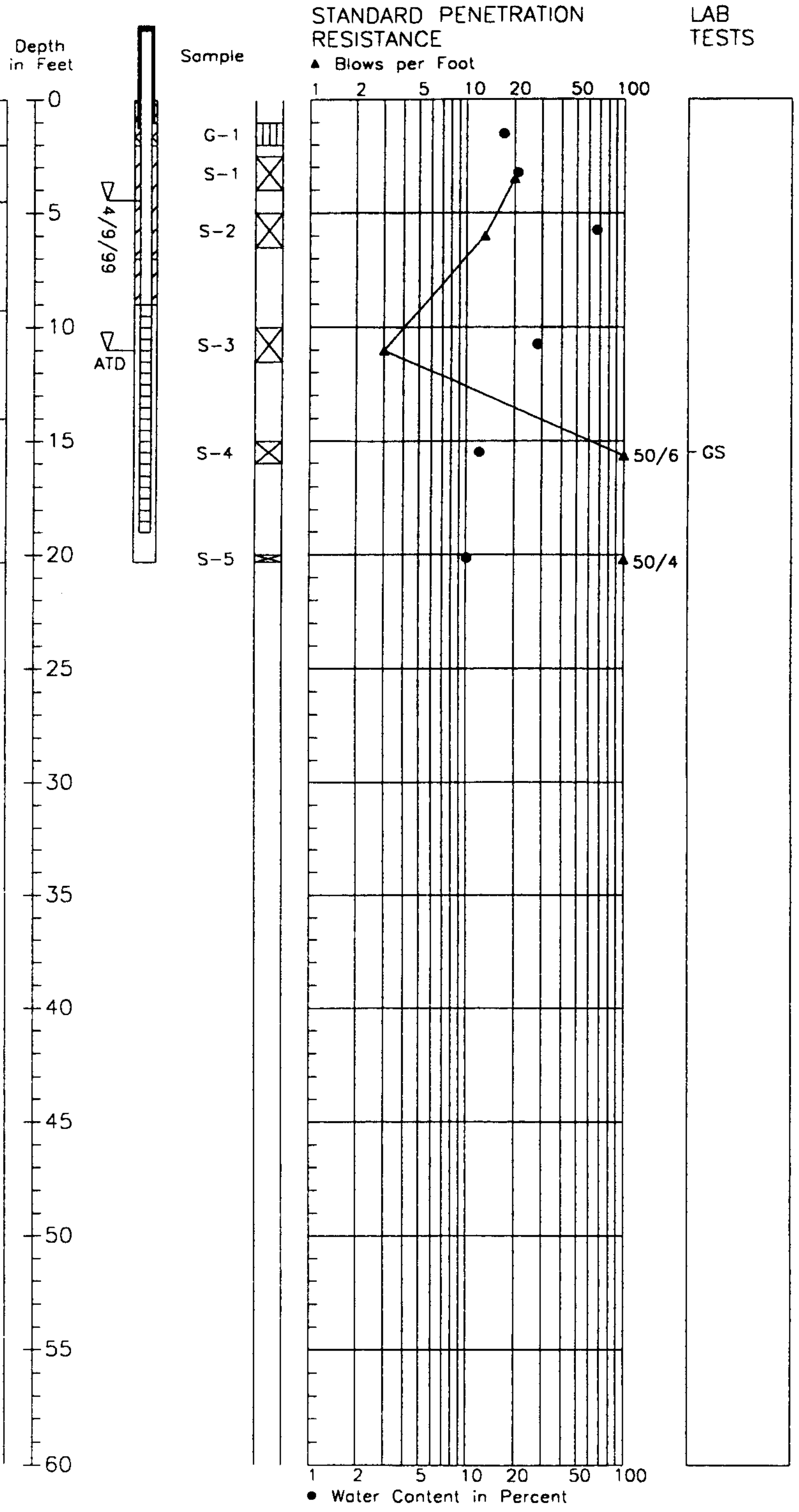
Medium dense, moist, gray, very silty SAND.

Stiff, moist, dark brown, sandy PEAT with occasional wood debris.

Soft, moist, gray, slightly sandy SILT with occasional wood debris.

Very dense, moist to wet, gray, slightly gravelly, silty SAND.

Bottom of Boring at 20.3 Feet.
Completed 2/22/99.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DTN 6/18/01 1=1 charlie.pc2
4978\LOGS\99 BORINGS

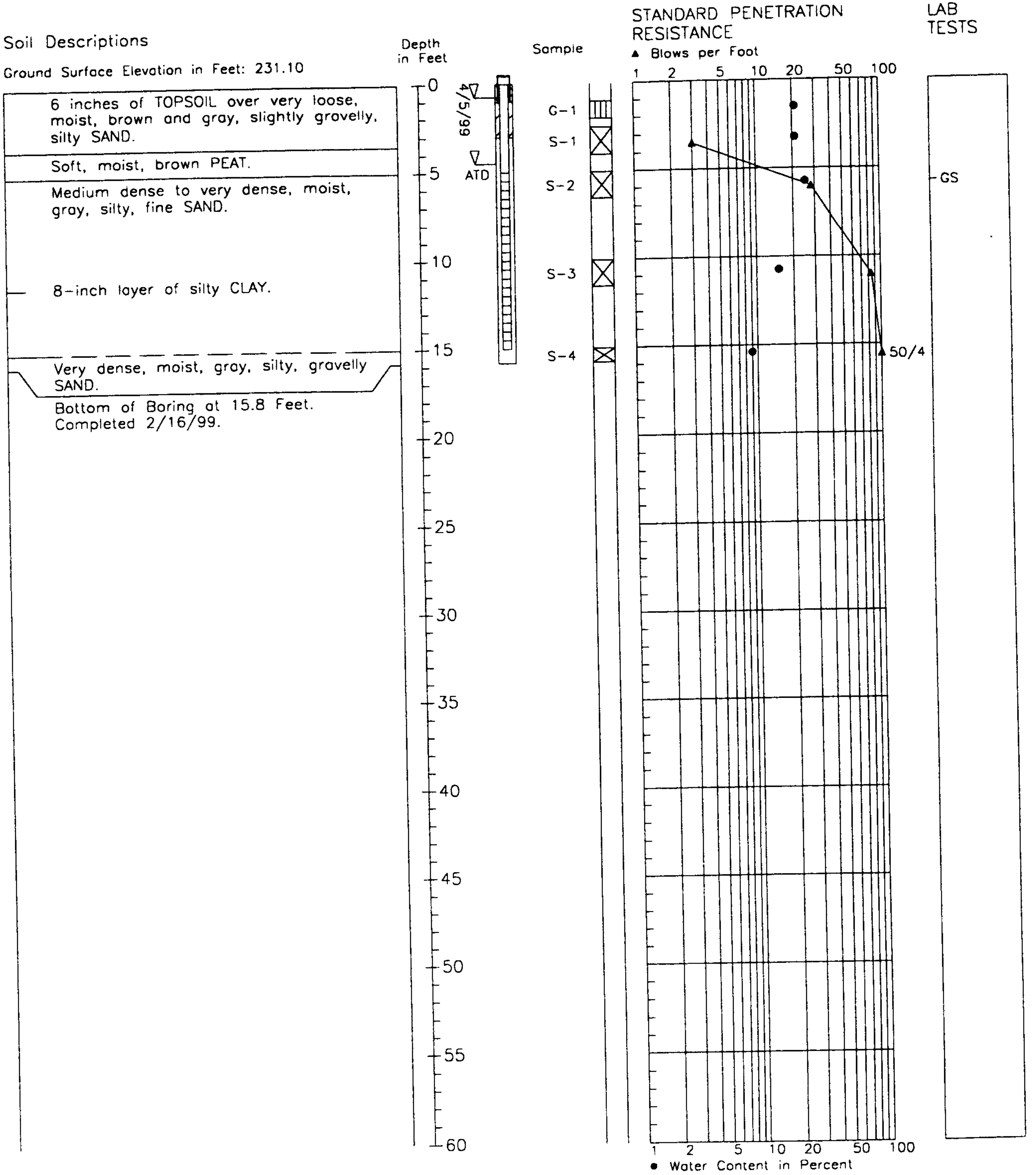
HARTCROWSER

J-4978-06 **6/01**

Figure A-2

Boring Log HC99-B39

N 18,174.14, E 10,722.31



6 inches of TOPSOIL over very loose, moist, brown and gray, slightly gravelly, silty SAND.

Soft, moist, brown PEAT.

Medium dense to very dense, moist, gray, silty, fine SAND.

8-inch layer of silty CLAY.

Very dense, moist, gray, silty, gravelly SAND.

Bottom of Boring at 15.8 Feet.
Completed 2/16/99.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DTN 6/18/01 1=1 charlie.pc2
4978\LOGS\99 BORINGS

Hand-Auger Log HC00-A300

N 18235
E 10762

Sample	Water Content
S-1 ☒	33
S-2 ☒	27
S-3 ☒	33

Depth in Feet — SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 228

(Loose to medium dense), wet, dark brown, silty SAND with organic material.

(Medium dense), wet, gray, silty SAND with trace organic material.

(Medium stiff to stiff), wet, gray, clayey, sandy SILT with trace organic material.

Bottom of Hand-Auger at 4.0 Feet
Completed 5/12/00.

Seepage noted @ 1.0'

Hand-Auger Log HC00-A301

N 18127
E 10798

Sample	Water Content
S-1 ☒	47
S-2 ☒	21
S-3 ☒	19
S-4 ☒	28
S-5 ☒	28

Depth in Feet — SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 229

(Loose to medium dense), moist to wet, dark brown, very gravelly, silty SAND with abundant organic material.

(Loose to medium dense), wet, brown to gray, silty SAND with trace organic material.

(Medium stiff to stiff), wet, gray, slightly clayey, sandy SILT with trace organic material

Bottom of Hand-Auger at 5.5 Feet
Completed 5/12/00.

Seepage noted @ 1.5'

DTN 8/30/00 1=1 CHARLIE-8.PC2
497806 HANDAUGERS.dwg

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

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Figure A-4

APPENDIX B
GROUNDWATER SEEPAGE ANALYSIS

APPENDIX B
GROUNDWATER SEEPAGE ANALYSIS

This appendix describes the groundwater seepage analysis that was performed to examine the potential hydrologic effect of Pond A on groundwater. The analysis was also used to design sheet pile wall and a gravel-filled trench (French drain) that mitigates the potential hydrologic effect of the pond.

Approach

The approach taken to assess the effect of the sheet pile wall and the French drain on the groundwater flow regime was to prepare a simplified groundwater flow model, using a MODFLOW computer model based on observations of groundwater levels in nearby monitoring wells. The model showed the generalized effect of the sheet pile wall as a blockage to the pre-construction groundwater flow pattern in the area.

The model simulates changes in groundwater flowpaths, as well as the mounding effect on the upstream side of the sheet piles, and the corresponding reduction in groundwater levels on the downstream side of the sheet piles. Simulation of the French drain with the same model shows how it will collect water that mounds on the upstream side, and conduct it around to the downstream side of the sheet piles. On the downstream side, seepage re-infiltrates into the shallow soils so as to maintain groundwater levels in the wetland. The re-infiltration of groundwater is considered important to sustain the hydrologic regime of the riparian wetland adjacent to Miller Creek.

Model Setup

A numerical groundwater flow model was used to assess the likelihood for changes in groundwater levels and flows due to the proposed sheet pile wall around Pond A, and to test alternatives measures for mitigating these effects. The model was created using the USGS MODFLOW code (McDonald and Harbaugh 1988) with the Visual MODFLOW pre- and post-processor (Waterloo Hydrogeologic 2000). MODFLOW is a block-centered finite difference code capable of simulating steady-state and transient groundwater flow in a range of aquifer types and configurations.

The model was set up to provide a simplified representation of the shallow groundwater flow system in the vicinity of Pond A. The model represents a numerical approximation to the general pattern of groundwater flow, for the purpose of demonstrating cause and effect of the proposed sheet piling and French drain relative to an assumed base condition. This approach is valid for the mitigation design since, using a consistent set of groundwater and soil parameters in the model, it focuses on the changes to groundwater flow caused by the proposed construction and shows how these impacts are avoided by the proposed mitigation.

The model domain is shown on Figure B-1 and encompasses an area extending from north of South 166th Street, to Detention Pond G in the south, with Detention Pond A located approximately in the center. The lateral extent covered by the model is the area west of the existing airfield, bounded on the west side by Miller Creek.

The model was configured with its top surface defined by the existing topography, and its base defined as the top of the glacial till (very dense silty sand) underlying the site, as determined from geotechnical borings conducted in the area. Shallow groundwater flow occurs in the surficial soils based on observation of seepage in test pits and inferred from water level measurements in monitoring wells nearby. Groundwater flow conditions in the area are well documented because of various exploratory borings and monitoring wells observations for the Third Runway. Data sources are listed at the end of this appendix.

The MODFLOW model was constructed with two layers to represent the construction of a gravel-filled trench surrounding the sheet piles. The upper layer of the model consisted of a 3-foot-thick layer that mimics the surface topography. The lower layer represents the remainder of the shallow surficial soils (above the glacial till) that varies in thickness from about 3 to 10 feet across the area of the model. The horizontal area of the aquifer to be modeled was discretized into a rectangular grid with a cell size of 10 feet by 13 feet covering the area of interest (Figure B-1).

Aquifer Material

The aquifer parameters listed below were assigned to both layers with the exception of the ring of cells representing the drainage layer in the upper layer. The silty sands and other deposits above the glacial till were represented as general aquifer material with the following uniform properties:

- Hydraulic conductivity: 8.2×10^{-5} fps

No attempt was made to represent the likely spatial variation in aquifer properties within the surficial soils around Pond A.

Drainage Layer Material

The French drain used to maintain groundwater levels around the outside of the sheet piles was represented in the model with a more permeable material typical of a non-silty free-draining gravel:

- Hydraulic conductivity: 6.6×10^{-3} fps

Boundary Conditions

Constant-head boundaries were established along the eastern edge of the model to represent existing groundwater flow derived from the east. The elevation of the applied head was adjusted along the boundary to simulate the approximate variation in groundwater levels observed at the site. The west side of the modeled domain was represented by a series of river nodes to simulate the course of Miller Creek.

The northern and southern sides of the model were simulated as no-flow boundaries representative of groundwater streamlines in the aquifer, with groundwater flow in the body of the model occurring parallel to these sides. The lateral boundaries of the model were established a sufficient distance from Pond A (with the exception of Miller Creek) such that small changes in the boundaries would not strongly affect the groundwater flow pattern in the area of Pond A. The dense glacial till soils underlying the modeled area are assumed to be relatively low in permeability such that flow through the till is small in comparison to flow in the shallow soils, and can be ignored.

Recharge was applied uniformly over the entire area of the model to help simulate the general shape of the observed water table at the site.

Calibration

The model was calibrated in a general sense to two sets of water levels representative of the range observed in site monitoring wells (Table 1): an average winter high-water level and an average late-summer low-water level were used to define conditions for two separate model scenarios. Different water levels were achieved by varying the areal groundwater recharge value applied in the model from 16 to 10 in/yr.

Monitoring Points

Two virtual observation wells were assigned within the model to track simulated water levels at specific locations: one upgradient and one downgradient of Pond A.

Assumptions

Listed below are the assumptions associated with the construction and use of this groundwater model:

- Groundwater flow in the shallow aquifer is unconfined and modeled as steady-state;
- The underlying till/dense silty sands have lower permeability such that groundwater flow through these layers can be neglected;
- Aquifer materials are homogeneous and isotropic;
- Recharge to the groundwater is uniform over the model domain;
- Miller Creek is treated as a fixed-head river boundary defined by streambed elevation interpolated from topographic map coverage;
- Groundwater discharges to Miller Creek as baseflow;
- The area west of Miller Creek is ignored (inactive) in the model;
- Wetland function is not modeled explicitly but represented by groundwater levels at or close to ground surface; and
- Evapotranspiration from shallow groundwater table and/or wet surface soils is not modeled.

Results

The following results were obtained from steady-state solutions of the groundwater model described above for two different water level regimes.

Simulated Winter Water Levels

Three steady-state solutions were analyzed for determining the effect of the sheet pile wall on the shallow groundwater flow system in winter conditions. The resulting groundwater head distributions and streamflow lines are shown in the following figures:

- Figure B-2 - Existing Winter Conditions
- Figure B-3 - Pond A with Sheet Piles
- Figure B-4 - Pond A with Sheet Piles and Diversion Drain

Comparison of predicted water levels for the above scenarios show a rise in groundwater levels upgradient of Pond A and decreased groundwater levels downgradient of Pond A when only the sheet piles surround Pond A. Upon adding a groundwater diversion drain around the perimeter of Pond A, the groundwater levels return to pre-construction elevations, thus demonstrating no effect to the method.

Simulated Later Summer Water Levels

Two steady-state solutions were analyzed for determining the effect of the sheet pile wall on the shallow groundwater flow system in late summer conditions. The resulting groundwater head distributions and streamflow lines are shown in the following figures:

- Figure B-5 - Existing Conditions
- Figure B-6 - Pond A with Sheet Piles and Diversion Drain

Comparison of predicted water levels for the above scenarios show the groundwater levels at pre-construction elevations, thus demonstrating no effect to the Wetland.

Data Sources for Appendix B

FAA 1995. DRAFT Environmental Impact Statement for Proposed Master Plan Update Development Actions at Seattle-Tacoma International Airport. US Department of Transportation, Federal Aviation Administration, April 1995.

Hart Crowser 1999, Subsurface Conditions Data Report, 404 Permit Support, Third Runway Embankment, Sea-Tac International Airport, SeaTac, Washington, July 1999.

Hart Crowser 2000. DRAFT Subsurface Conditions Data Report, West MSE Wall, Third Runway Embankment, Sea-Tac International Airport, SeaTac, Washington, June 2000.

Hart Crowser 2000. DRAFT Subsurface Conditions Data Report, Additional Field Explorations and Advanced Testing, Third Runway Embankment, Sea-Tac International Airport, August 2000.

Hart Crowser 2001. Appendix C, DRAFT Geotechnical Engineering Analyses and Recommendations, Third Runway Embankment, Seattle-Tacoma International Airport, SeaTac, WA

Pacific Groundwater Group 2000. "Sea-Tac Runway Fill Hydrologic Studies Report", June 19, 2000.

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Groundwater Modeling Area

Pond A

Note: Base map prepared from drawing provided by HNTB entitled "X_TOP00401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

Extent of Model Area (Groundwater Flow Simulated in Unshaded Portion)

0 300 600
Scale in Feet

N

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Figure B-1

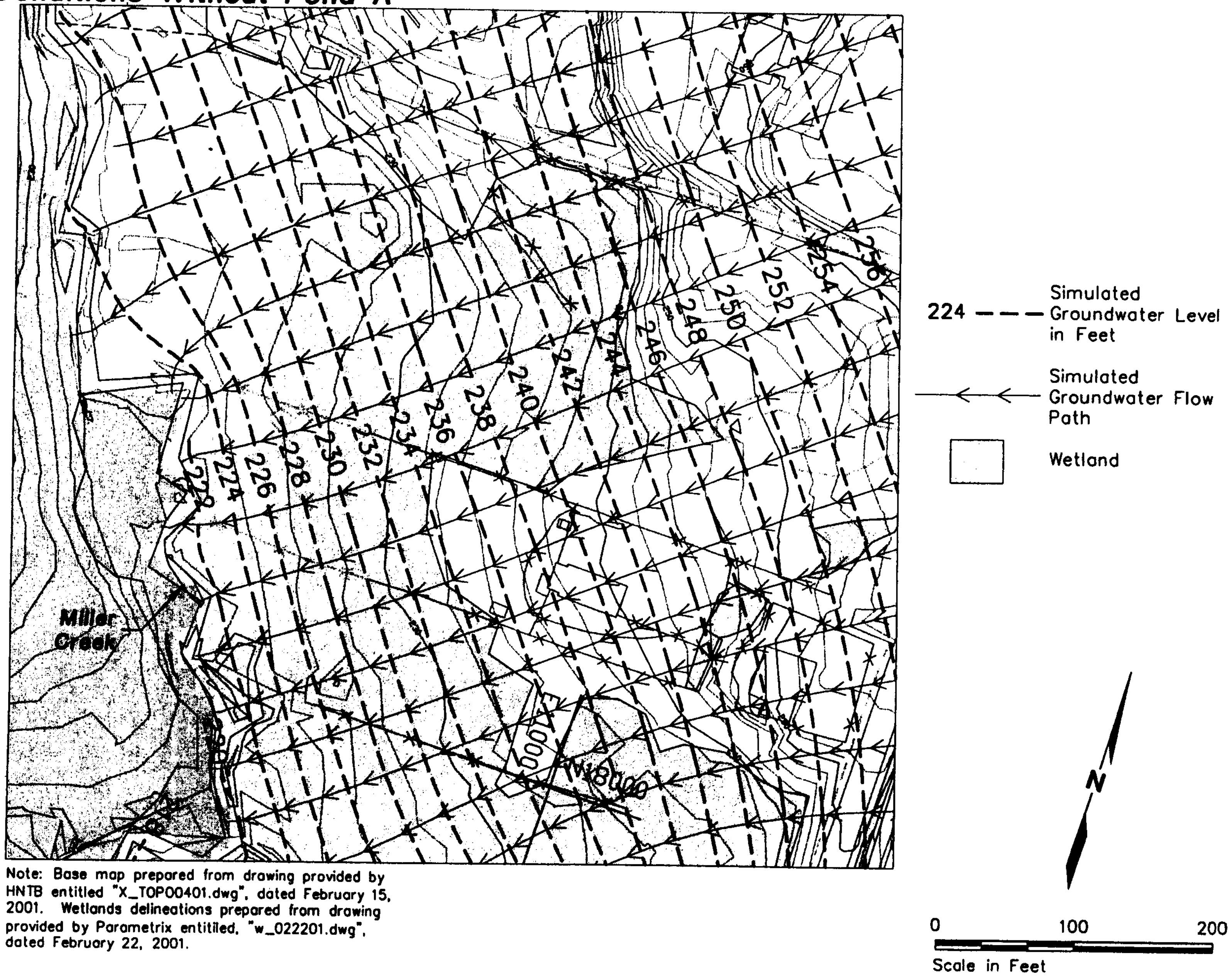
AR 030346

RC 6/18/01 1=300 (xref)see drawing file/charlie.pc2
49780673

RC 6/18/01 (xref)see drawing file/charlie-8.pc2 49780682

Simulated Average Water Table

Existing Conditions Without Pond A



Note: Base map prepared from drawing provided by HNTB entitled "X_TOP00401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitled, "w_022201.dwg", dated February 22, 2001.

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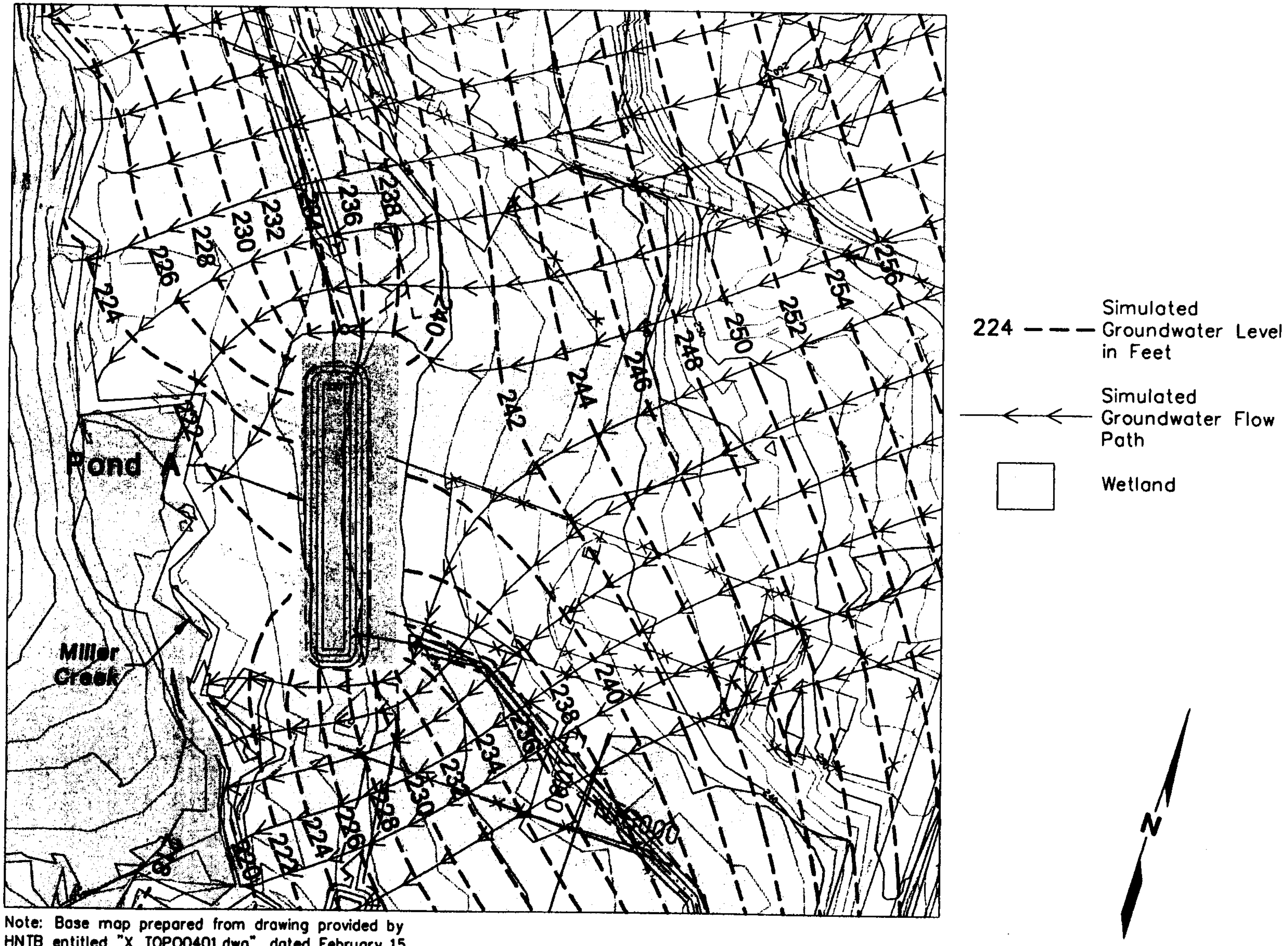
J-4978-06 6/01

Figure B-2

RC 6/18/01 1=100 (xref)see drawing file/charlie-8.pc2 49780680

Simulated Average Water Table

Pond A with Sheet Piles



Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

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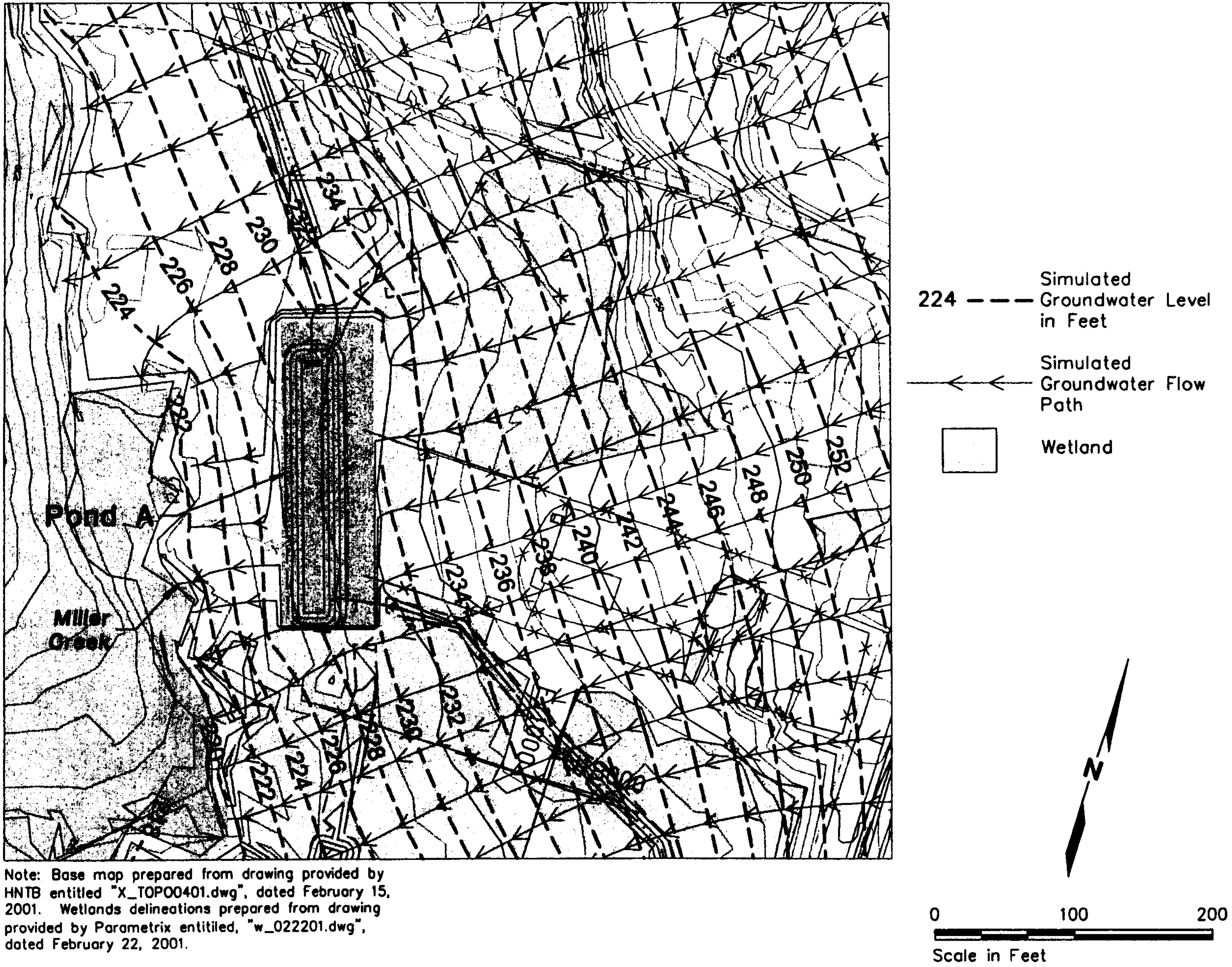
J-4978-06 6/01

Figure B-3

RC 6/18/01 1 ;xref)see drawing file/charlie-8.pc2 49780683

Simulated Average Water Table

Pond A With Sheet Piles and Diversion Drain



Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

HARTCROWSER

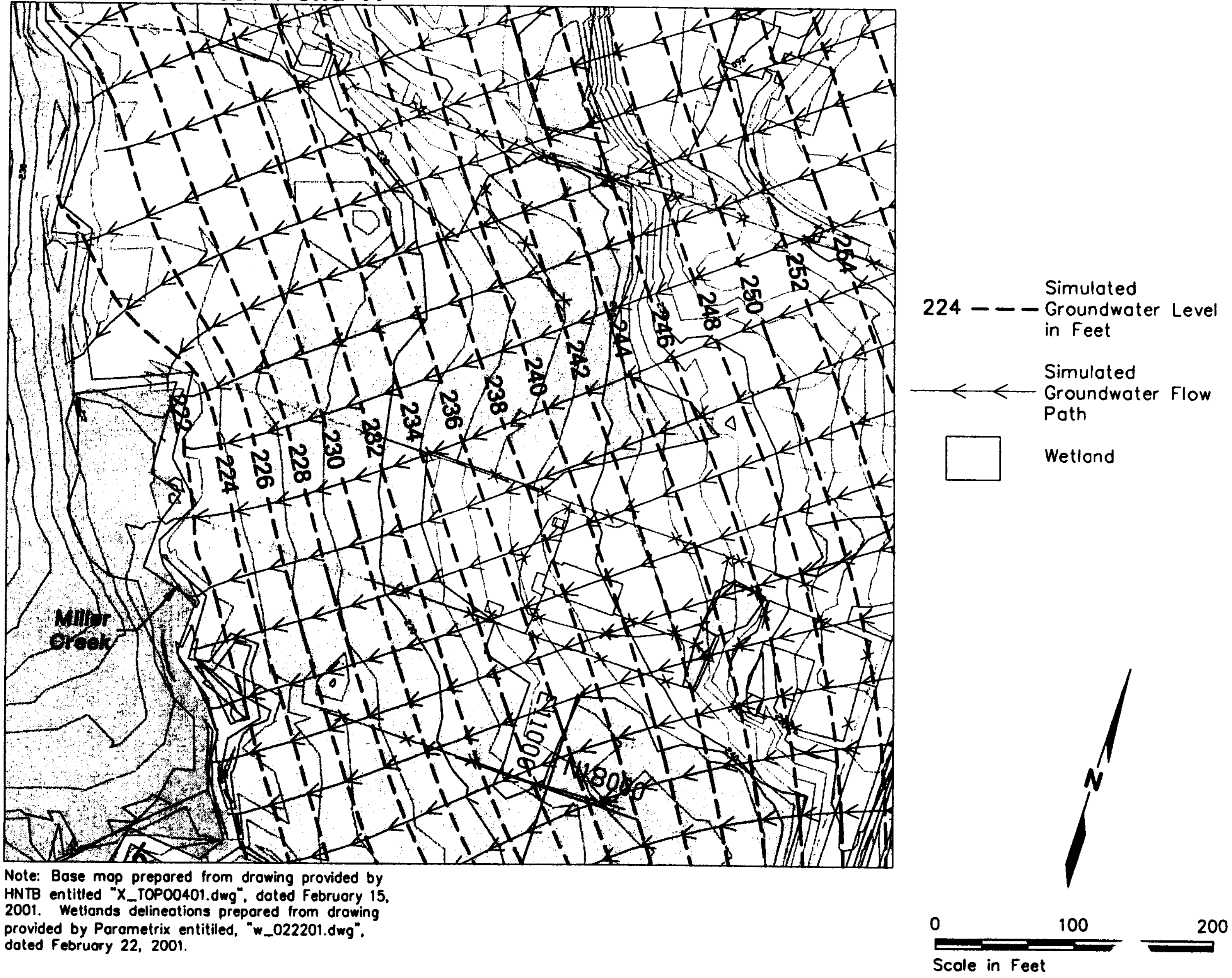
J-4978-06 6/01

Figure B-4

RC 6/18/01 1=100 (xref)see drawing file/charlie-8.pc2 49780685

Simulated Late Summer Water Table

Existing Conditions Without Pond A



Note: Base map prepared from drawing provided by HNTB entitled "X_TOP00401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

HARTCROWSER

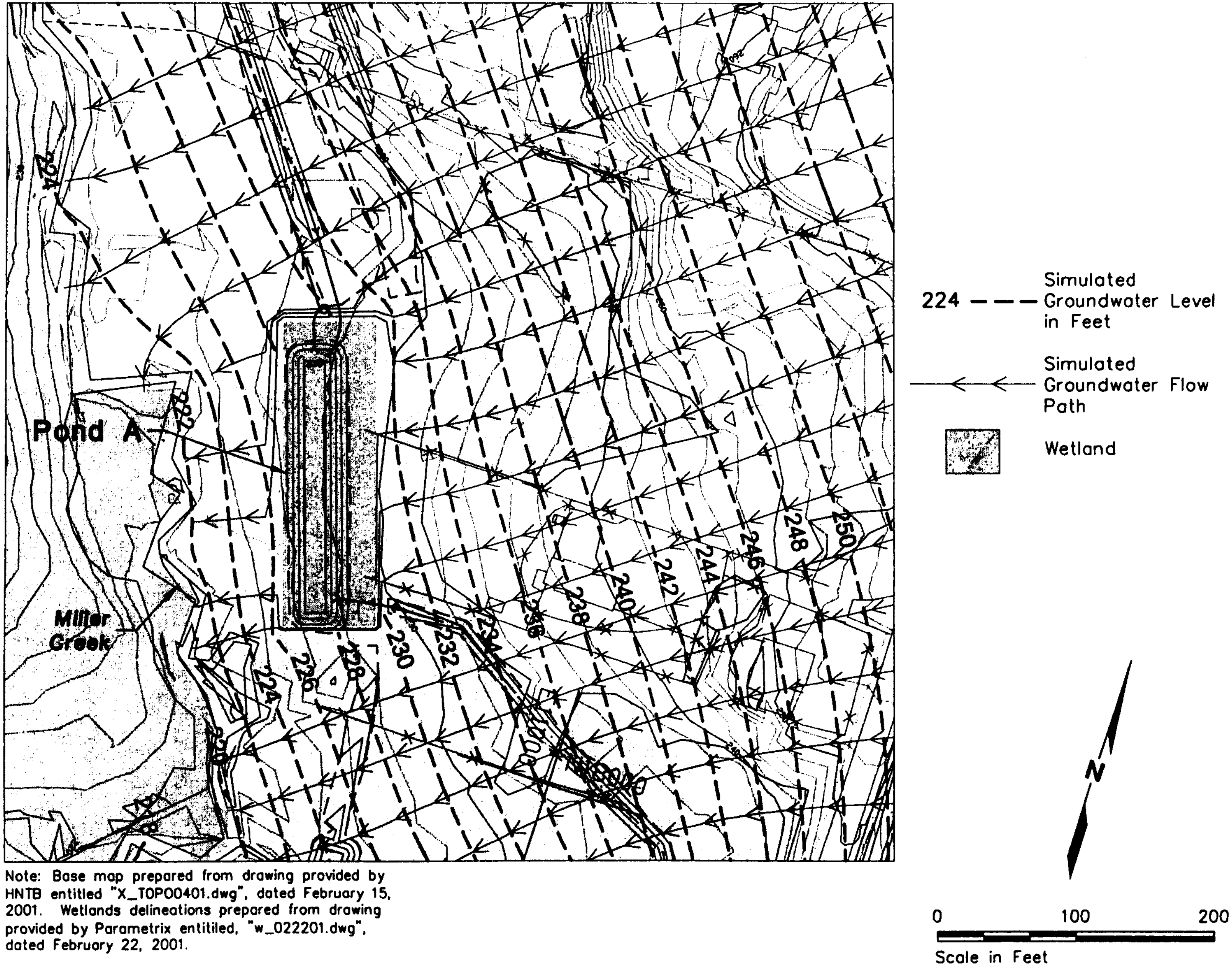
J-4978-06 6/01

Figure B-5

RC 6/18/01 \ ,xref)see drawing file/charlie-8.pc2 49780686

Simulated Late Summer Water Table

Pond A With Sheet Piles and Diversion Drain



Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

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J-4978-06 6/01

Figure B-6

APPENDIX C
SHEET PILE DESIGN AND CONSTRUCTION

APPENDIX C
SHEET PILE DESIGN AND CONSTRUCTION

The proposed sheet piles around Pond A were designed to fulfill three functions:

a. Cut-off shallow groundwater so that seepage into the pond does not remove shallow groundwater from the adjacent wetland;

b. Protect adjacent wetlands from potential excavation-induced impacts such as slope failure and sloughing of loose/soft soil during excavation of the pond); and

c. Provide long-term static stability for pond constructed within a soil profile of loose and soft soils above glacial till.

Design

Sheet pile design to address the functional requirements noted above was based on soil and groundwater conditions encountered in local borings (see Appendix A). For design, we assumed water level in the pond varied from completely full to completely empty, or about 226 to 220 feet in elevation. We assumed groundwater coincides with ground surface on the upslope side of the sheet pile walls due to the anticipated effects of the perimeter drainage trench.

Table C-1 provides the soil parameters used in our slope stability and force/moment calculation. These analyses are discussed further below.

Earth Pressure Diagrams

Soil strength parameters were used to develop earth pressure diagrams for the embedded portion of the sheet pile. The diagrams enable a structural engineer to calculate the required sheet pile section modulus.

We assumed the sheet pile "cell" around the pond should be designed as a cantilever wall without anchorage. Active earth pressures acting on the piles located east of Pond A typically should include a surcharge pressure equal to the weight of an additional 2 feet of soil, to account for increased loads where the access road is located adjacent to the sheet pile wall. Passive earth pressures were factored to account for the loss of support due to the pond excavation.

Our analysis of sliding and overturning discussed below indicates the passive resistance sufficient to achieve target factors of safety depends on embedment, therefore design may need to be reviewed and/or modified in the event minimum embedment is not obtained due to variations in elevation of the glacial till. However, since the till is relatively impermeable and much stronger than the surficial soils, reduced penetration of piles due to shallow glacial till is not anticipated to result in any reduction in slope factors of safety.

Our analysis of the stability of the sheet pile wall and pond slopes consisted of two separate analyses: limit equilibrium analysis using the program Slope/W to analyze global slope stability (i.e., potential for failure below sheet piles) and b) force/moment equilibrium calculations to check factors of safety against sliding and rotation.

Slope Stability Analysis

We used Slope/W with Spencer's method for limit equilibrium analysis to calculate factors of safety for circular and wedge-type failure surfaces passing below the sheet pile wall. We analyzed the following conditions:

- Steady state (pond full) including the effect of soil buoyancy;
- Steady state (pond empty) without the effect of buoyancy; and
- Rapid drawdown (pond empty) including the effect of pore pressures.

Minimum target factors of safety were 1.5 for steady state conditions and 1.1 for rapid drawdown, consistent with normal geotechnical engineering practice for this area.

Factors of safety met target criteria provided sheet pile can be embedded at least 8 feet (to the top of the very dense glacial till) on the north side of the pond, with the case of rapid drawdown of the pond level being most critical. Embedment was critical for stability.

Force and Moment Equilibrium

Analyses were completed to verify that adequate factors of safety were achieved for both force and moment equilibrium, for resistance to sliding (or translation) and rotation. Target factors of safety were achieved for both steady state (pond full, buoyant conditions) and rapid drawdown conditions. By inspection we concluded that the steady state (pond empty) condition was less critical than the other two cases.

Erosion and Sloughing

Hart Crowser used the weighted creep method of analysis to assess potential for piping below the bottom of the sheet piles through fine to medium sand and silt soils. Results indicate mitigation is needed. Also, considering the soft and loose to medium dense soils that will be exposed in the 2H:1V pond side slopes, we expect that the slopes of the pond may undergo sloughing related to water level fluctuations during normal pond operations.

Recommended mitigation consists of driving the sheet piles to refusal in the underlying glacial till and lining the pond with a geotextile separation fabric and minimum 1 foot thickness of quarry spalls.

Construction

Hart Crowser makes the following recommendations for construction:

- Install the perimeter French drain entirely around the proposed pond prior to any sheet pile installation. This will assure adequate access for construction on the west side of the pond without any wetland encroachment and avoid any interruption of groundwater seepage as the sheet piles are installed.
- Install sheet piles on the west, north, and south sides of the pond (i.e., the sides closest to Miller Creek) prior to excavation. This will enable the piles to protect the creek in the event there is any excavation sloughing during pond construction.
- Drive piles to refusal in the top of the glacial till soils. The Port's contract documents should state that "jetting" shall not be used to aid driving.
- Prior to construction, the Contractor should provide the Port with a submittal that describes pile driving equipment and sequence of construction. During construction, the Port should verify that minimum embedment criteria are met.

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Table C-1 - Soil Parameters Used in Design

Soil Type	Moist Unit Weight in pcf	Drained Strength		Undrained Strength	
		c′ in psf	ϕ′ in deg.	c in psf	ϕ in deg.
Loose to Medium Dense Sand	125	0	32	-	-
Medium Dense to Dense Sand	130	0	35	-	-
Dense to Very Dense Silty Sand (Glacial Till)	135	250	40	-	-
Soft Peat or Organic Silt	90	0	15	300	0
Soft to Stiff Silt/Clay	115	0	30	1000	0

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Appendix B

APPENDIX B

GEOTECHNICAL ENGINEERING REPORTS FOR THE THIRD RUNWAY EMBANKMENT CONSTRUCTION

B-1 **Geotechnical Engineering Report**

B-2 **Proposed MSE Wall Subgrade Improvements**

B-3 **Geotechnical Summary Report-Third Runway Embankment and MSE Retaining Walls**

APPENDIX B

GEOTECHNICAL ENGINEERING REPORTS FOR THE THIRD RUNWAY EMBANKMENT CONSTRUCTION

This appendix contains several geotechnical engineering reports assessing geologic conditions beneath the proposed third runway embankment. Construction and design approaches that minimize or prevent direct or indirect impacts to wetlands located downslope of the project are also discussed.

B-1

Geotechnical Engineering Report

Geotechnical Engineering Report
404 Permit Support
Third Runway Embankment
Sea-Tac International Airport

Prepared for
HNTB Corporation and
The Port of Seattle

July 9, 1999
J-4978-06

CONTENTS

CONTENTS (Continued)

GEOTECHNICAL ENGINEERING REPORT
404 PERMIT SUPPORT
THIRD RUNWAY EMBANKMENT
SEA-TAC INTERNATIONAL AIRPORT

INTRODUCTION

This report evaluates subsurface conditions and geotechnical engineering aspects of the proposed Third Runway embankment construction in the Miller Creek drainage basin. This evaluation includes determining potential indirect impacts to wetlands downgradient of the Third Runway embankment, resulting from project construction. Design and construction measures to avoid indirect adverse impacts to wetlands during and after construction are also identified.

Avoidance of potential indirect impacts includes:

- Providing engineered measures to maintain or enhance existing infiltration on non-paved portions of the airfield and groundwater recharge to support wetlands and baseflow to Miller Creek downgradient of the embankment;
- Verifying construction of the embankment will not impair existing subsurface groundwater movement; and
- Designing the embankment to be stable during anticipated seismic events.

Figure 1 shows the project vicinity. The main areas of focus in this report are the north end and mid-west side of the proposed embankment, where retaining walls will be used to reduce the amount of wetlands filled by construction. Figures 2 and 3 provide additional detail for these areas, including the wetlands of potential concern, Miller Creek, and limits of the proposed embankment and related construction. Related construction includes relocation of South 154th Street around the north end of the embankment, and a new airport security road around the embankment perimeter.

SUMMARY

Information in this report is based in part on exploratory borings in representative wetland areas, accomplished under a Nationwide 6 Permit from the Corps of Engineers (Hart Crowser, 1999, see reference list following the main text of this report). Additional information was obtained from test pits excavated in representative areas outside the wetlands, as well as previous explorations by others for a variety of purposes.

General findings of this report are:

- Soil conditions in the embankment footprint area will generally provide good (better than required) foundation support, assuring long-term stability.
- Construction will locally include subgrade improvements (removal and replacement or *in situ* improvement of soils, as needed) to improve foundation support.
- Satisfactory embankment and retaining wall seismic stability will result from conventional construction practices (including the subgrade improvements).
- Existing shallow groundwater seepage rates will be relatively unchanged because construction will include engineering measures to maintain flow from existing seeps, and transmit this flow downgradient to recharge wetlands west of the embankment.
- Infiltration through the embankment will reach Miller Creek later due to a longer seepage path compared to existing infiltration, producing a beneficial impact on late summer stream flow.
- Overall, recharge to shallow groundwater will continue during and after construction, much as it does at the present time.

This report identifies geotechnical design and construction measures to avoid or mitigate temporary (construction-related) impacts to wetlands, such as re-infiltration and/or re-injection of groundwater from dewatering, limiting the extent of soil disturbance, and subgrade improvements. Information on the wetlands, extent of impacts, and other mitigation are discussed in separate reports (Parametrix Inc., 1999a and 1999b).

This report also discusses geotechnical design and construction measures to avoid or mitigate indirect permanent impacts to wetlands. Mitigation measures that minimize direct impacts include engineering design to:

- Limit disturbance of groundwater discharge zones;
- Maintain groundwater seepage to Miller Creek, and adjacent wetlands; and
- Permanently protect undisturbed wetlands with approved buffers.

GEOTECHNICAL OVERVIEW RELATED TO WETLANDS

Construction of the Third Runway will require filling topographic low areas west of the existing airfield to an elevation of about 400 feet MSL. Construction will require filling some existing wetlands and temporary construction impacts to additional wetlands as discussed by Parametrix (1999b). Geotechnical design and construction planning to protect wetlands focused on the following main areas:

- Use of retaining walls (referred to as MSE walls) to avoid relocating a portion of Miller Creek and to avoid filling adjacent wetlands;
- Use of appropriate embankment construction techniques and materials to minimize indirect wetland impacts during and after construction;
- Design for embankment and retaining wall stability to avoid indirect post-construction impacts to wetlands; and
- Design of subsurface embankment drainage to preserve flow to wetlands and augment groundwater recharge that becomes baseflow to wetlands and Miller Creek.

Storm water management during construction and temporary erosion and sediment control (TESC) to avoid construction impacts to wetlands are discussed by HNTB (1999) and Parametrix (1999a and 1999c).

SUMMARY OF EXISTING SUBSURFACE CONDITIONS

Subsurface conditions at the site have been explored by drilling and sampling test pits, various types of infiltration tests, and use of cone penetrometer soundings, as discussed in several reports (Hart Crowser, 1999; AGI 1998; CivilTech, 1997). These reports document information on subsurface conditions that has been primarily developed subsequent to completion of the 1996 Final Environmental Impact Statement (FEIS) and the 1997 Final Supplemental EIS (FSEIS). This new geotechnical information provides more detail, at specific locations, to provide the basis for detailed project design. The findings from this work are consistent with geotechnical information used for evaluation of the project design and impacts in the FEIS and FSEIS.

Soil Conditions

Most of the proposed embankment is anticipated to be built on recessional outwash soils, typically consisting of 5 to 10 feet of medium dense, moist, silty, slightly gravelly to gravelly sand, overlying dense to very dense glacial till (typically silty, gravelly sand) and advance outwash soils of similar gradation. Where the surficial soils have been locally disturbed by previous site development, they are referred to as "fill" on the exploration logs (Hart Crowser, 1999).

Within the wetland areas, generally similar soils are encountered at relatively shallow depths, with additional surficial soil layers of soft to medium stiff, low plasticity, sandy clay and silt, which varies to loose to medium dense, non-silty to clayey sand, and may contain organic material (peat). Borings completed under the Nationwide 6 Permit indicate these soils range up to about 20 feet in thickness (Hart Crowser, 1999).

Available information on soils within wetlands in the north safety area (Wetlands 9, FW6, and FW3) as well as on the west side of the Third Runway (Wetlands 18, 37, and 44) are discussed in Appendix A to this report. This information is based on detailed geotechnical explorations accomplished by subsurface borings under a Corps of Engineers Nationwide 6 Permit. Other wetlands not explored are anticipated to include similar limited thicknesses of soft to medium stiff , wet and organic soils, based on comparison to conditions encountered in explorations to date in the north end and west wall areas.

Soil conditions observed in the specific project areas addressed in this report are summarized in Appendix A, based on boring and test results presented in the Subsurface Conditions Data Report (Hart Crowser, 1999).

Surface Water Conditions

In the project area, pre-construction baseflow to Miller Creek is comprised primarily of groundwater discharge from the Shallow Regional Aquifer, from both the airport (east) side of Miller Creek, and from the area on the western side of the creek basin. Additional discharges to Miller Creek are in the form of surface runoff and near-surface interflow (Parametrix, 1999c).

Precipitation onto the airfield becomes runoff, is intercepted by the storm water management system, is lost to evapotranspiration, or is available for infiltration (see Parametrix 1999c). The amount of infiltration available as recharge depends on soil characteristics, slope, and engineered measures.

Groundwater Conditions

Hydrologic assessments completed by Parametrix (1999c) and AGI Technologies (1996) show completion of the Third Runway will increase total area of impervious surface and storm water runoff within the embankment footprint. This will result in a slight decrease in baseflow to Miller Creek due to the net reduction in infiltration in this part of the Miller Creek basin. Mitigation for this effect is provided by the hydraulic lag of seepage from the infiltration which does occur, resulting in a net increase in recharge and baseflow in the late summer, as discussed in this report.

Existing shallow groundwater in the project area includes:

- Infiltration from the ground surface;
- The surficial interflow zone;
- Discontinuous perched water zones; and
- The Shallow Regional Aquifer.

This report discusses potential local impacts and mitigation for these near-surface groundwater components, shown diagrammatically on Figure 4. The shallow groundwater components are discussed in more detail below.

Infiltration. Hydrologic measurements conducted for the study on which the airport's Stormwater Management Plan is based (Parametrix, 1999c) were used to calculate infiltration characteristics for existing airfield fill soils, to provide information on effects of constructing the Third Runway embankment. Infiltration to the underlying groundwater system is able to occur over the existing large areas of the airport and adjacent land areas which are not paved. Similarly, infiltration is anticipated over the unpaved areas (~80 acres) on top of the new embankment.

Surficial Interflow. The surficial interflow zone exists in the upper few feet of the soil profile. Flow in this zone is essentially subsurface stormflow that is usually associated with periods of substantial rainfall. The near-surface soils become saturated and allow flow to move laterally from the upper to lower parts of the watershed catchment area. Interflow tends to last for at most a few days after major storms, but may persist through the winter months when storms occur frequently. Interflow could be a factor in sustaining some of the wetland areas that are not fed by perched groundwater or by the Shallow Regional Aquifer.

Discontinuous Perched Water. Zones of perched groundwater appear to exist in the sloping hillside that forms portions of the western flank of the existing airfield, east of 12th Avenue. The forested slope is formed of a mixture of glacial till and outwash soils, which allow differing amounts of runoff, infiltration, and evaporation to occur.

- The glacial till and hard silt soils (where present) are typically at a depth of 5 to 10 feet below ground level, overlain by outwash soils.
- The outwash soils facilitate more infiltration, allowing perched zones to develop in places on the glacial till, or on other silty (i.e., less-permeable) layers above the Shallow Regional Aquifer (see Figure 4).

The lateral continuity of such perched zones depends on extent and stratigraphic position of the perching layers. Test pit observations (Hart Crowser, 1999) indicate limited continuity and frequent gradational transitions in the silt content of on-site soils. These variations affect shallow seepage in two ways:

- Along the margins of silty soil zones, perched groundwater tends to percolate downward to the Shallow Regional Aquifer; and
- Surface seeps can form where the perching layers crop out at the ground surface. Locally these seeps may be important sources of water to wetlands.

Shallow Regional Aquifer. Figure 5 shows groundwater elevation contours for the Shallow Regional Aquifer. These contours generally mimic the surface topography, with higher groundwater levels occurring beneath the airfield. The elevated groundwater levels reflect groundwater recharge that occurs beneath the existing airfield and discharges as baseflow to Miller Creek. Recharge is derived from part of the infiltration through the extensive areas of flat grassland that flank the paved runways and taxiways.

The potential area for groundwater recharge to the Shallow Regional Aquifer that discharges to Miller Creek extends from Miller Creek to the eastern side of the existing airfield based on the location of the groundwater divide in this aquifer (Hart Crowser, 1985). Much of this area is underlain by glacial till, a dense relatively less-permeable soil unit (an aquitard) that ranges up to 50 feet in thickness below the airfield. A portion of the infiltration likely recharges shallow perched water zones above the glacial till aquitard, rather than directly recharging the Shallow Regional Aquifer, see Figure 4.

Recharge to the Shallow Regional Aquifer creates elevated groundwater levels beneath and east of the airport, and generates lateral groundwater flow toward the adjacent drainages (Miller Creek, Des Moines Creek, and their tributaries).

A portion of the groundwater recharge that enters the Shallow Regional Aquifer passes through that groundwater body and percolates deeper. Eventually this seepage becomes part of the regional recharge to the Intermediate and Deep Regional Aquifers that are located at depth. The Intermediate Regional Aquifer and Deep Regional Aquifer, are not anticipated to be impacted by development at Sea-Tac. Regional groundwater movement including relationship of the Third Runway project to the Seattle Public Utility wells in the Intermediate Aquifer and the Highline Water District Wells in the Deep Aquifer, is well-documented in the Third Runway FEIS/FSEIS and studies by others (Federal Aviation Administration, 1997; AGI Technologies, 1996; Hart Crowser, 1985).

GEOTECHNICAL DESIGN CONSIDERATIONS

Geotechnical design to avoid and/or mitigate construction impacts to wetlands has been refined from the initial analysis presented in the FEIS, to include several specific elements. These include the following:

- Use of retaining walls to reduce filling some wetlands and limit creek relocation;
- Use of soil zones to provide a stable embankment that can be constructed cost-effectively with the least impact possible to local groundwater recharge;
- Exploration and analysis of the local soils to design a stable foundation for the embankment and retaining walls; and
- Design of the embankment to avoid or mitigate long-term, indirect impacts to groundwater, adjacent wetlands, and Miller Creek.

Embankment Design Refinements Accomplished since the FSEIS

Subsequent to completion of the FSEIS (Federal Aviation Administration, 1997) and in response to requests for information to support the Corps of Engineers' 404 Permit, the Port completed an extensive analysis of alternatives for construction to avoid impacts to wetlands. A major component of this was selection of embankment slope and retaining wall configurations to minimize the extent of wetland impacts.

Geotechnical engineering aspects of the analysis of wall and slope alternatives were subjected to peer review, conducted by the firm Shannon & Wilson, Inc. Shannon & Wilson found the analysis to be both appropriate and consistent with conventional engineering practices. Details of the analysis are presented in a

1999 report by HNTB, Hart Crowser, and Parametrix, which includes the peer review report as an attachment.

As part of evaluating alternatives to filling wetlands, Port operations staff (security, fire and rescue, and maintenance) identified alternatives to reduce the area of impact related to roads on and around the runway embankment. This included elimination of an intermediate access road along much of the embankment, and revising the security road alignment and profile, to reduce the extent of construction impacts to wetlands.

Another design refinement has focused on surface water and groundwater drainage from the embankment. After completion of construction, runoff from the new embankment will be detained and otherwise managed to reduce storm water impacts to Miller Creek (see Parametrix, 1999b). Designs to promote storm water infiltration and maintenance of groundwater recharge are discussed in this report.

Use of MSE Walls to Avoid Filling Key Wetlands and Creek Relocation

During the past two years, Port staff and consultants have completed geotechnical, hydrologic and wetland studies, to identify alternatives and verify that existing MSE (mechanically stabilized earth) technology can provide safe and relatively cost-effective construction of retaining walls for soil conditions at the site.

The Port of Seattle reviewed a large number of embankment slope and retaining wall alternatives to avoid or reduce impacts to Miller Creek and adjacent wetlands. MSE retaining walls were selected as the recommended alternative, (HNTB, Hart Crowser, and Parametrix, 1999).

Where retaining wall height exceeds about 60 feet, MSE retaining walls will typically be used in combination with narrow, relatively horizontal terraces and conventional or reinforced 2H:1V embankment sections, to limit the area of filled wetlands.

- At the north end of the embankment, MSE walls will be used to limit the impact to Miller Creek and the extent of filling Wetlands A-1 and 9;

- Near the middle of the west side of the embankment (approximately runway stations 174+00 to 186+00), an MSE wall will be used to avoid filling a significant part of Wetland 37a, and to avoid relocating part of Miller Creek; and

- Near the south end of the new runway, an MSE wall will be built to limit the extent of filling Wetland 44a.

Specific design and construction considerations for the embankment and MSE walls in these areas are discussed later in this report.

What are MSE Walls?

MSE is a method of constructing earth embankments using a combination of compacted soil and reinforcing elements. MSE technology includes a range of steel and polymer (plastic) products (mesh, strips, and grids) used to retain and reinforce soil, and provides a number of advantages over other types of retaining walls. The MSE technology improves soil strength through incorporation of reinforcing strips or sheets (geogrids or geotextiles) within the soil embankment during construction. There are a number of proprietary products used for this purpose.

Some, but not all, MSE products include a means to secure a retaining wall facing to the reinforced soil mass, permitting a range of embankment slopes up to and including vertical walls. MSE walls may be faced with wire mesh, geotextile, or concrete facing elements. Concrete facings are typically used for permanent installations of the type contemplated for the Third Runway, and may consist of pre-fabricated concrete wall facing components installed during or after construction, or cast-in-place/shotcrete facings applied after construction.

MSE walls can be designed to accommodate a considerable range in site drainage conditions. Typically the reinforced zone includes relatively non-silty, free-draining soil, which would enhance infiltration near the face of the wall. The reinforced zone would be hydraulically connected to the embankment underdrain, to enable infiltration from above the wall to seep beyond the toe of the wall. Also, MSE walls do not require a structural concrete key below ground for stability; thus unlike some other types of wall, MSE walls do not impede subsurface seepage.

MSE walls are relatively economical to construct compared to other types of retaining structures, particularly at heights in excess of about 25 feet. MSE walls have been successfully used to retain embankment fills well over 100 feet in height, including both tiered walls and single "flat faced" wall configurations. MSE embankments and retaining walls can be designed to be highly stable under both static and seismic loads.

Figure 6 shows a schematic cross section of an MSE retaining wall.

Geotechnical Design to Accommodate Site Conditions

Foundation Soil Conditions in Wetlands and Upland Slopes

Native soils capable of providing a suitable foundation to support the embankment have been observed at depths ranging from zero to around 20 feet below the existing ground surface across the site. Available information indicates very little subgrade preparation will be needed across most of the site. Wetland soils and soils in some other specific areas will need to be improved or replaced to support parts of the fill and MSE walls. This subgrade improvement will be accomplished without reducing subsurface groundwater movement as discussed below.

Existing subgrade soils which are unsuitable to provide structural support for the embankment (because they are soft, wet, or contain organic materials), will be removed and replaced with compacted structural fill, or improved *in situ* (i.e., in-place or without removal), as discussed below. The unsuitable subgrade material that is removed will be reused where possible in non-structural areas of the embankment.

Following excavation of unsuitable soils, stable subgrade will be prepared by either:

- Placing structural fill that is free-draining and non-silty. The relatively high permeability of this fill will not decrease the soil capacity to transmit groundwater flow through these areas; or

- Making *in situ* improvements to existing subgrade soils, including "stone columns," soil mixing, or similar technologies, as described later in this report. These techniques increase subgrade strength with some corresponding reduction in permeability in the immediate vicinity of application.

Designs will address mitigation for the potential change in permeability where *in situ* soil improvement is used. Mitigation would typically include thickening the embankment underdrain layer (discussed below) or installation of "french drains" through areas of soil improvement, to compensate for any reductions in soil permeability within the zone of improvement.

Embankment Drainage Layer

At the base of the proposed embankment, a drainage layer will be constructed that extends over the existing soil surface (after clearing and grubbing). The drainage layer will be constructed of select non-silty material that is significantly more permeable than the typical fill soils used in the body of the embankment. A minimum thickness of the drainage layer will be maintained throughout the area covered, which may be locally increased within areas of subgrade improvement, and filled wetlands, seeps, or springs. The embankment drainage layer, referred to as an underdrain, is commonly used for earth dams and other embankments.

The underdrain enables beneficial discharge of water that infiltrates into the embankment from above or below, to be conveyed downgradient to discharge into wetlands between the embankment and Miller Creek. The underdrain will:

- Prevent excess pore pressures and associated stability problems;
- Prevent erosion where seepage is discharged near the toe of the embankment; and
- Provide perennial seepage to recharge groundwater and wetlands beyond the toe of the embankment.

The primary purpose of the underdrain is as a stability-enhancement measure to prevent the build-up of pore water pressures within the soils at the base of the embankment, and to prevent subsurface erosion, a condition known as "piping." Piping can have serious consequences in constructed embankments if inadequate consideration is given to the movement and discharge of seepage or other groundwater within the embankment.

The underdrain provides a controlled seepage path below the embankment. Gradation of the drain layer is designed to prevent piping and clogging or sedimentation within the drain. The hydraulic lag resulting from seepage through the embankment and underdrain increases the relative amount of late-summer recharge downgradient of the embankment, to mitigate indirect impacts on wetlands and Miller Creek.

The underdrain will collect seepage, intercepting water that percolates down from the surface of the new embankment, as well as collecting subsurface seeps and springs that currently occur on the existing ground surface. Collecting this water in the underdrain will allow it to be beneficially managed for the long-term protection of downslope wetlands, and to maintain groundwater baseflows to Miller Creek.

The completed underdrain will be separated from the surface of the airfield by the full thickness of the embankment. In the event of a contaminant release (such as an airfield fuel spill), the long flow path through the new fill would provide substantial opportunity to accomplish source control and remediation before any contaminants could reach wetlands, Miller Creek, or the underlying aquifers.

Characteristics of Proposed Embankment Fill Soils

The proposed embankment will be constructed with varying fill materials as needed to satisfy specific design requirements in specific zones.

1. **Type 1 Fill.** About 40 percent (roughly 6.5 million cubic yards) of the embankment would be constructed of relatively silt-free sand and gravel soils, referred to as "Type 1" fill.

2. **Type 2 Fill.** About 60 percent (roughly 10 million cubic yards) of the embankment would be constructed of more or less silty sand (glacial till and outwash soils). These "Type 2" fill soils are similar in particle size gradation but will be less densely compacted than the existing glacially overridden soils below the embankment (resulting in the fill having corresponding higher soil porosity compared to the native soils).

Relative proportions of these predominant soil types may vary depending on final design and availability at the time of construction. The descriptions above refer to general soil characteristics; construction contract documents will utilize fill specifications that are more precise and may add variations to the types shown to accommodate construction.

Within each of the two general fill types, there will be variations for specific construction requirements.

- Typically the relatively silt-free Type 1 fill would be used below pavements, the embankment underdrain, MSE wall reinforcement zones as wet weather fill, and elsewhere as needed to accommodate construction.

- Generally the more silty Type 2 fill will be used to the maximum extent possible, balancing relatively high availability (low cost) with limitations of trying to compact such material in wet weather. (Typically as the silt content of a soil increases, it becomes increasingly difficult to compact it to a uniformly dense condition in wet weather.)

Comparison of Native Soils to Embankment Fill Soils

Typical near-surface soils in the area to be filled are more or less silty (Hart Crowser, 1999; AGI, 1999), and are generally similar in gradation to the Type 2 fill that will be predominantly used as embankment fill. While the Type 1 fill is anticipated to have significantly better infiltration and seepage characteristics compared to existing site soils, they will not have much influence on overall infiltration into the embankment because of location (i.e., predominantly under pavement, within the underdrain, and within specific zones. Where infiltration seeps through both Type 1 and Type 2 soils, it will seep relatively faster through Type 1 and relatively slower through the Type 2 soils.

Type 2 fill compacted in the embankment will be less dense than existing glacially overridden on site soils, but will probably be more dense than the relatively looser near-surface soils (upper 5 to 10 feet). The embankment fill is anticipated to store and transmit groundwater in a manner intermediate between the existing loose to medium dense near-surface soils (upper 5 to 10 feet), and the deeper glacially overridden soils which dominate the site. Generally the new embankment is expected to have infiltration characteristics similar to the existing airfield.

Because of the similarity in gradation and contrast in density noted above, Type 2 fill will typically retain surface infiltration longer than existing native soils. The embankment will therefore release water to Miller Creek and wetlands later into the summer compared to native soils in the area to be filled.

Changes in the relative proportions of these two predominant soil types in the embankment are unlikely to have a significant impact on drainage characteristics of the embankment as a whole, because the arrangement of the fill zones within the embankment will allow for interconnection and free drainage of the relatively more permeable soils.

Fill Zones within the Embankment

The Third Runway embankment will be designed as a zoned embankment, with different fill types and/or different compaction requirements used in specific areas to accommodate strength, compressibility and drainage requirements, see Figure 6. These zones include:

A-1. Pavement Subgrade. High-strength, low-compressibility granular soil used in the upper few feet immediately below airfield pavements (Type 1).

A-2. **Drainage Material.** Free-draining soil used in the underdrain and in areas of overexcavation to improve foundation support (Type 1).

B-1. **Pavement Support Fill.** Low-compressibility soil used below the pavement subgrade zone A-1 (may be Type 1 or Type 2 fill).

B-2. **MSE Reinforced Backfill.** High strength granular soil used in the reinforced zone behind retaining walls (Type 1).

C-1. **Common Embankment Fill.** Moderate strength compacted soil (may be Type 1 or Type 2 fill).

C-2. **Common Embankment Fill.** Compacted soil used adjacent to slope faces. This fill (which may be Type 1 or Type 2) may be more select and/or have somewhat higher compaction requirements compared to C-1, depending on where it is used.

D. **Non-structural Fill.** Soil removed from foundation areas because it is unsuitable for foundation support (Type 2).

Construction of a zoned embankment in this manner provides significant environmental benefits, including:

- Seasonal limitations on use of relatively silty soils in wet weather will reduce erosion and sediment control problems;
- Use of relatively silty soils as "fair-weather fill" for common embankment construction will increase the hydraulic log (late summer recharge volume) compared to non-silty soils;
- Reduction in truck haulage for the embankment by enabling use of local borrow materials and elimination of "export" haulage to dispose of unsuitable subgrade soils; and
- Ability to construct an embankment underdrain which collects infiltration and seepage, for controlled discharge to promote infiltration, and preserve groundwater recharge to downgradient wetlands and Miller Creek.

Embankment and MSE Wall Stability Analyses

Engineering analyses of embankment slope stability were completed for a typical embankment fill cross section (nominal 2H:1V), as well as for representative

MSE wall cross sections in or adjacent to wetlands for both the north and west areas. These analyses were conducted to:

- Verify suitability of the proposed geometry of embankment slopes and retaining walls;
- Assess base preparation required to avoid instability; and
- Assess sensitivity of embankment fill parameters.

The analyses incorporated specific subsurface information developed through explorations accomplished under a Nationwide 6 Permit for drilling in wetlands at the site. Soil conditions in these area are summarized in Appendix A based on data presented in Hart Crowser (1999). The stability analyses considered various combinations of wall/slope geometry and subsurface soil and groundwater conditions. Cross sections were analyzed for the Wetland 37 Wall (the retaining wall which will be used to reduce filling wetlands and to avoid relocating a portion of Miller Creek), and wall-slope combinations for the north end of the embankment (in and adjacent to Wetlands 9, FW6, and FW3) that will be used to limit wetland fill.

Embankment stability was evaluated using computer analyses that employ the conventional limit equilibrium methods developed by Janbu, and more rigorous procedures developed by Spencer (Wright, 1991; Sharma, 1994). Search routines were conducted using the Janbu method of analysis to identify the most plausible potential failure surfaces for the given combination of slope/wall geometry and subsurface conditions. The potentially critical failure surfaces selected by the computer program were then reanalyzed using Spencer's method to more accurately determine the factor of safety.

Stability Analysis Parameters

Soils. Table 1 provides a summary of the engineering and strength parameters used in the analyses for the soils in the project area. Strength parameters for on-site soils were developed using laboratory test results developed for the Third Runway project (Hart Crowser, 1999; AGI, 1998) and through published correlation of field and laboratory test results (Hart Crowser, 1998b and 1998c).

For these analyses, MSE walls were assumed to include reinforcing elements with lengths equal to 80 percent of the wall height. Base stability was analyzed for potential failure surfaces below the reinforced zone.

Groundwater. Groundwater levels were modeled using an assumed piezometric surface concurrent with the present ground surface and/or partial saturation of the underdrain below the embankment soils and retaining wall backfill. Sensitivity analyses were performed to measure the effect of raising the water level within the underdrain. This is a conservative approach because it assumes that all the soils below the underdrain will be saturated and subject to buoyant forces.

Seismic Input. Two types of seismic analysis were completed to verify both overall stability of the embankment and to estimate anticipated deformation under seismic loads.

The combined result of the two types of stability analysis show the embankment including the MSE retained wall sections, in and adjacent to the wetlands, can be constructed to have comparable stability as for other parts of the embankment, and with the same low risk of catastrophic failure, accepted for other major transportation facilities.

Stability analyses used standard geotechnical methods that are widely accepted for embankment design. Seismic (pseudostatic) stability analyses were performed on the most critical failure surfaces that were found during searches for minimum *static* factors of safety. The seismic analysis incorporated a horizontal acceleration component into the computer model to account for the effects of an earthquake. The acceleration term used in the preliminary analysis is based on the peak ground acceleration (PGA) that would be expected in the SeaTac area during an earthquake with a 475-year return interval (10 percent probability of exceedence in 50 years). This corresponds to a somewhat larger seismic event than both the 1965 SeaTac earthquake (Richter magnitude 6.5) and the 1949 Olympia earthquake (Richter magnitude 7.1).

Additional seismic analysis of the Wetland 37 Wall was accomplished to estimate the magnitude of potential embankment movements, using the Newmark procedure (Kramer, 1996). This analysis used a much larger seismic event, corresponding to the maximum probable earthquake with a nominal return period of 3,000 years, a so-called "great earthquake." The Newmark analysis calculates deformation of the reinforced soil mass as a sliding block.

Sensitivity. The sensitivity of the stability analyses was checked by varying the following:

- Shape of failure surface;
- Depth of failure surface;
- Length of reinforcement in vertical walls;

- Soil strength;
- Groundwater level;
- Backfill and base preparation strengths;
- Backfill unit weight;
- Limit equilibrium analysis method; and
- Analysis tools (i.e., different software programs and analytical methods).

Results of Stability Analyses

Static factors of safety ranged from 1.2 to 2.0, and pseudostatic seismic factors of safety ranged from 0.8 to 1.2 for critical sections. A target factor of safety of 1.3 (static) and 1.05 (seismic) was selected for these analyses, based on conventional geotechnical design for comparable embankments.

The target factors of safety were obtained for the Wetland 37 Wall, but not for some areas of existing soils under some of the wall/slope combinations analyzed for the north end of the embankment. These results demonstrate the need to, and provide some of the basis for, designing subgrade improvements to the native soils in these areas.

Failure to obtain the target factors of safety in the north area resulted from insufficient existing strength in the medium stiff silt and clay below part of the proposed embankment, particularly under seismic loading. Subsequent analyses to show improved stability can result from improving subgrade strength during construction after overexcavating the unsuitable soils and replacement with compacted soil fill (possibly MSE reinforced) or *in situ* soil improvement.

The results are referred to as "proof of concept" because they demonstrate satisfactory stability will result from conventional construction procedures. Final design of the subgrade improvements will be based on further analyses accomplished following additional subsurface explorations. *In situ* measurements accomplished by cone penetrometer, test pits, and test trenches in the wetlands (which are not covered under the existing Nationwide 6 Permit program) will provide the specific input for design of subgrade improvements in the wetlands.

Results of the initial Newmark deformation analysis indicated that movement of the maximum height MSE retained fill, the Wetland 37 Wall, will be less than about 10 feet during a maximum probable earthquake. This analysis indicates that MSE reinforced fills designed for the site would have acceptable deformations during the maximum credible seismic event. Much smaller deformations would result from more likely earthquakes (i.e., an earthquake with a 475-year return interval (10 percent probability of exceedence in 50 years) compared to this "great earthquake." More detailed strain analyses to complete design of the MSE reinforced zone will be accomplished using finite difference methods.

Post-Construction Infiltration and Baseflow to Miller Creek

Hart Crowser analyzed post-construction effects of the Third Runway embankment on the Miller Creek drainage. These include the effect of infiltration into the new embankment that becomes groundwater recharge, and the effect of the new embankment on groundwater that infiltrates below the existing airfield and discharges to wetlands and Miller Creek west of the airfield. While the relative amount of runoff will increase in new paved areas and embankment slopes, infiltration is anticipated to increase over about 80 acres of relatively flat grassed areas that will be created between the new and existing runways and taxiway pavements.

In the area of construction, specific groundwater recharge contributions to Miller Creek will include:

- Infiltration into the top surface of the new embankment;
- Infiltration into the side slopes of the new embankment;
- Management of runoff from the side slopes;
- Maintenance of existing shallow interflow below the embankment; and
- Flow from the Shallow Regional Aquifer into Miller Creek.

These are discussed below individually. Appendix B provides additional detail on water balance calculations before and after construction.

Infiltration into the Top Surface of the New Embankment. Infiltration into the unpaved portion of the new embankment top surface exceeds existing on-site infiltration in the same area for the following reasons:

- Large area (about 80 acres) of relatively flat grassed land between runway and taxiway pavements permits greater infiltration compared to pre-construction sloping ground in the same areas;

- Post-construction grassed area between pavements will have less evapotranspiration (ET) compared to forest vegetation on the pre-construction slopes; and

- Soil conditions within the embankment will promote infiltration in some areas and overall have better average groundwater transmission rates compared with the underlying native soils (glacial till, glacially overridden silty advance sand, and hard silt units).

The large embankment thickness (up to 165 feet) provides significant buffering of storm water infiltration, increasing the available groundwater recharge and short-term storage before seepage eventually reaches Miller Creek or downslope wetlands.

Seasonal infiltration into the embankment soil mass will fill near-surface soil pore space until the soil reaches a condition referred to by soil scientists as "field capacity." Field capacity is the threshold moisture content above which a soil will drain freely. Additional infiltration will then percolate downward into the embankment. This percolating water will eventually intercept the embankment underdrain at the base of the fill, and most of this seepage will then flow to the west to Miller Creek or adjacent wetlands. The amount of deep percolation into soils directly underlying the new embankment will therefore be reduced relative to existing conditions. Recharge of seepage from the underdrain downgradient of the embankment is designed to mitigate this reduced deep percolation (adjacent to, rather than below, the embankment).

Infiltration into the Side Slopes of the New Embankment. Infiltration into the new embankment side slopes (nominal 2 horizontal to 1 vertical) is anticipated to be slightly less than existing infiltration over the "foot print" area of the side slopes (38 percent of rainfall post-construction, versus 50 percent for pre-construction infiltration). The reduction is mainly the result of the increased slope causing increased runoff. The potential for increased runoff is mitigated by improved infiltration capacity of the embankment fill relative to the existing glacially overridden soils, reduced evapotranspiration, and increased storage of water within the fill.

Infiltration into the new embankment side slopes will percolate downward until it is also intercepted by the underdrain discussed above. Benches on the slope face also mitigate the runoff and provide more opportunity for infiltration. This seepage will be increased slightly by additional infiltration along storm water swales which collect runoff from the embankment slopes.

Maintenance of Existing Shallow Interflow below the Embankment. In addition to intercepting seepage infiltration from the top of the embankment, the embankment underdrain also provides a means for existing seepage in the filled area to continue to flow downgradient to the west.

The existing ground surface below the embankment will largely be left undisturbed prior to fill placement, as discussed later in this report. Shallow interflow seeps, expressed where perching layers outcrop on the slope, will continue to discharge into the underdrain, or will continue to flow downslope below the underdrain.

Areas of soft soils that need to be removed to provide embankment foundation support will be backfilled with free-draining sand and gravel hydraulically connected to the underdrain. In this way existing seepage into wetlands that are filled will continue to be available as seepage through the underdrain. This water will flow downgradient to the west, and eventually reach downslope wetlands and Miller Creek.

Flow from the Shallow Regional Aquifer into Miller Creek. A geotechnical analysis was used to assess whether the weight of the embankment would significantly reduce the amount of existing baseflow from the Shallow Regional Aquifer to Miller Creek (Hart Crowser, 1998a).

Experience with earth dams shows seepage under an embankment is typically not reduced by the weight of the fill, and grout curtains or sheet pile cutoffs are typically constructed where control of seepage is necessary below embankments (Terzaghi & Peck, 1967). None the less, Hart Crowser calculated the effect of the embankment on seepage below the new fill.

These calculations indicate that volume of soil pore space, expressed as the void ratio (volume of voids relative to volume of solids) within the Shallow, Intermediate, and Deep Aquifers within the area immediately underlying and adjacent to the embankment would be reduced by roughly 1 to 3 percent due to the maximum weight of the embankment. For perspective, this corresponds to about a 4-inch maximum change in thickness for the 50-foot-thick Shallow Aquifer. The magnitude of the change in void ratio would diminish rapidly both laterally and as a function of depth. There would be no effect in the Shallow Aquifer more than 50 feet from the edge of the embankment, and no effect in the Deep Aquifer more than about 500 feet from the edge of the embankment.

Reductions in permeability on the order of 2 to 5 percent corresponding to the change in void ratio are estimated immediately below the embankment, with the effects decreasing with depth. The estimated 2 to 5 percent change is insignificant, given that differences in permeability are usually evaluated in terms of orders of magnitude (powers of 10).

Effects of the magnitude estimated could conceivably produce a slight groundwater mounding in the Shallow Regional Aquifer on the upgradient side of the embankment (i.e., below the existing airport), but this would probably not be measurable. Baseflow to Miller Creek located west of the embankment is not likely to be impacted, since the effect of the mounding would be to locally increase the groundwater flow gradient resulting in no net loss of baseflow.

No impacts are anticipated to drinking water resources in the Intermediate and Deep Aquifers. The effect of the embankment weight diminishes with increasing depth and distance from the fill. There are no wells within the affected area (maximum about 500 feet from the edge of the embankment).

GEOTECHNICAL OVERVIEW OF PROPOSED CONSTRUCTION

This section of the report discusses the general sequence of construction from a geotechnical perspective, focused on avoidance or mitigation of sediment-loading impacts to Miller Creek and wetlands. Each of the areas outlined below should be addressed in the construction plans and specifications, but may need to be modified as additional information is obtained.

Installation of TESC

Temporary erosion and sediment controls (TESCs) will be installed prior to any other land disturbance for construction. TESC will be installed upgradient of Miller Creek and the undisturbed portions of wetlands.

All construction and related activities such as access and staging, will be accomplished in specific areas with appropriate TESC measures.

TESC measures will be designed prior to construction. Installation and maintenance will be specified as part of construction contract documents. TESC measures will conform to the Port's NPDES permit, including best management practices (BMPs), (Parametrix, 1999a).

Temporary Construction Access Road to Maintain TESC

Temporary construction access roads will be installed along the perimeter of disturbed areas to enable regular inspection and maintenance of TESC facilities. Wood chip mulch (tub grindings) from other site clearing can be used seasonally to limit generation of dust and improve roadbed trafficability along such roads in wet conditions.

After completion of construction and permanent erosion controls, temporary construction roads not needed for permanent airport operations would be removed from wetland and stream buffer areas. Restoration of temporary road areas would include:

- Removing any rock fill or quarry spalls;

- Grading to permanent slopes designed for erosion control;

- Ripping or plowing to loosen surficial soils compacted by traffic; and

- Revegetating with appropriate plant materials (identified in the Natural Resource Mitigation Plan; Parametrix, 1999b).

Clearing—Topsoil Removal Limited to Specific Areas

Prior to placement of any embankment fill, the site will be cleared, including close-cutting all vegetation to within a few inches of the ground surface and removal of existing structures.

Specified site clearing shall be limited within the construction area to reduce potential erosion and sedimentation.

Topsoils will not be stripped within most of the construction area.

- Based on experience with fill construction in 1998, the Port does not plan to strip topsoil or grub (remove) root masses within most of the area to be filled; and

- Stability analyses and the 1998 fill experience indicate the effect of surficial topsoil on stability of the fill is limited to the toe of the embankment. The extent of topsoil stripping was found to have little influence on stability as embankment height increases. Topsoil removal and grubbing will typically be limited to a zone about 50 feet wide along the toe of the embankment.

Limiting the extent of grubbing and topsoil stripping in this manner will significantly reduce potential for erosion to occur in the period between clearing and fill placement.

Existing structures will be removed down to the foundation level, along with removal of any existing underground fuel (home heating oil) tanks.

Subgrade Preparation

Following site clearing, heavy compaction equipment will be used to "proof roll" the subgrade, to aid in identifying local areas of soft, loose, or otherwise unsuitable foundation soils. These areas will be compacted in place, or otherwise improved as discussed later.

During subgrade preparation, visible seepage may be collected in gravel and perforated pipe "french drains" for conveyance and reinfiltration outside the immediate construction area. This may be done for instance to avoid mixing clean groundwater with potentially more turbid storm water, or to improve drainage/reduce mud in work areas.

Limited Construction Dewatering

Temporary construction dewatering may be accomplished in limited areas so that structural fill can be compacted below grade in areas where existing soils need to be replaced, or to enable construction of subgrade drainage.

Shallow excavations in stable soils would typically be excavated with internal sumps to remove any accumulated seepage or precipitation. Construction dewatering to depths of around 10 to 15 feet would typically be accomplished with well points around the perimeter of the area to be dewatered. Dewatering to the maximum anticipated depth of soil removal or improvement, on the order of up to about 20 feet, would probably be accomplished with staged well point systems.

Discharge from individual well points or sump pumps would be discharged in a controlled manner.

- Pumping from open sumps and initial discharge of well development water, which may be somewhat silty, would be pumped to the TESC sediment ponds for treatment as needed prior to discharge to Miller Creek; and

- During operation, clean water from the wells would be discharged through land application adjacent to Miller Creek. Typically this involves low velocity discharge through perforated pipe laid along the ground surface in grassed or forested uplands adjacent to the creek buffer.

Well points rather than pumped well systems are anticipated to be used. Pumped well systems, which cause groundwater drawdown over extensive areas, are <u>not</u> anticipated to be used because:

- Dewatering is needed only in limited areas and depths;

- The soils that need to be dewatered are relatively silty or include stratified zones of relatively silty and non-silty soils; and

- Dewatering will be of short duration (a few weeks in each location)

Temporary construction dewatering systems would be designed to avoid adverse impacts to Miller Creek and Walker Creek. Lateral extent of drawdown adjacent to dewatered areas likely will be very limited (on the order of tens of feet) due to the typically silty nature of soils to be dewatered. Where more extensive impacts may occur (i.e., based on possible findings of future explorations), construction can incorporate reinjection wells and/or temporary use of sheet pile cutoffs to control the area of drawdown.

Rates of dewatering will depend on the sequence of construction, excavation geometry, and specific local soil conditions. Relatively low flow rates for dewatering are anticipated based on results of slug tests and an attempted pumping test (Hart Crowser, 1999). Total magnitude of discharge in any area will depend on the size of the dewatered zone (to be determined during final design of subgrade improvements).

Local Overexcavation and Removal of Unsuitable Soils

Existing soils in the area below the Wetland 37 Wall, below portions of the embankment, and below portions of walls in the North Safety Area, are unsuitable to support load of the new fill and/or retaining walls. Engineering measures to improve subgrade support during construction, will typically consist of local overexcavation and removal of unsuitable soils.

Typically, soils are unsuitable foundation material because they have one or more of the following characteristics:

- Excessive amounts of organic material (peat);
- Relatively compressible or low strength (medium stiff) silt or clay; and/or
- Loose to medium dense relatively non-silty sands which may be subject to liquefaction.

Typically depth of such overexcavation is anticipated to be on the order of about 15 feet or less, based on wetland exploratory borings accomplished under the Nationwide 6 Permit. Specification of the final extent and depth of overexcavation to remove unsuitable soils will require additional explorations, which will need to include test trenches and test pits, to be completed after construction access is permitted in the wetland areas to be filled.

Overexcavation would typically be accomplished with open cut slopes averaging 2H:1V or flatter. Temporary sheet pile would be used as needed to limit the extent of disturbance in wetlands along the edge of the embankment fill, such as Wetlands 44a, 41a, 11, 37a, A6, and A1 (see Figure 8).

Where unsuitable soils are removed, they will be replaced with compacted free-draining granular fill (Type 1). This structural fill may be MSE reinforced as needed for stability. The MSE reinforcement will not impede infiltration, thus new subgrade fill in wetland areas will typically have better infiltration characteristics relative to existing (relatively silty) wetland soils.

The free-draining structural fill in overexcavated areas would be hydraulically connected to the embankment underdrain to promote infiltration and permit dissipation of accumulated seepage (see Figures 8 and 9).

- For filled areas below the main embankment, the hydraulic connection with the underdrain enables any natural seepage into the overexcavated area to be conveyed to the edge of the embankment with no adverse impact on stability. Beyond the edge of the embankment, this seepage is available as recharge to downgradient wetlands

- For wetlands along the edge of the embankment, the hydraulic connection with the underdrain enables infiltration (recharge) of seepage from below the embankment to the remaining wetland.

Local in situ Improvement of Unsuitable Soils

In situ soil improvement may be used where depth of unsuitable soils or other circumstances makes overexcavation and replacement infeasible. Alternative approaches, such as stone columns, soil mixing, jet grouting, etc. may be used along with appropriate seepage mitigation to improve shear strength and reduce compressibility of existing soils below the MSE reinforced zones behind retaining walls.

Earthwork details will be developed as needed for subgrade improvement areas to preserve transmission of seepage beyond the embankment. There are a number of proprietary techniques to accomplish foundation improvement. As an example, stone columns are created by placement of compacted gravel zones in the existing soil through vibratory densification, see Figure 10.

Selection of specific construction method(s) for soil improvement will be completed prior to construction, when subsurface explorations and test trenches are completed in wetland areas to be filled.

Embankment Drainage Layer

The first layer of embankment fill will consist of free-draining sand and gravel to form the embankment underdrain. The underdrain will range from 2 to 4 feet thick depending on the overlying fill, and locally the thickness would be increased to include fill in overexcavated areas.

In addition to assuring good subsurface drainage for the embankment fill that is subsequently placed, the underdrain will provide an initial working surface that can be sloped to reduce subsequent runoff and erosion.

The underdrain material would be placed in lifts and densely compacted. Typically it would be constructed working up from the lowest part of a given fill area and in from the edges of the fill. Graded granular filters, a combination of filter fabric and soil, and/or rock riprap would be used to prevent erosion in areas of active seepage, such as along the drainage swale at the downgradient edge of the underdrain, see Figure 8.

MSE Retaining Wall Construction

Construction of the MSE retaining walls would be accomplished by constructing an initial strip footing along the alignment of the wall facing, and then placing the reinforced backfill behind the wall in lifts, working upward. In some areas, the wall(s) would be constructed on top of densely compacted fill rather than directly on the subgrade.

Typically the foundation for the wall elements consists of a strip of below-grade MSE reinforced soil, and a compacted gravel pad or concrete strip footing. Placement of the reinforcing and backfill soil is accomplished from behind the wall. Temporary road access along the face of the wall may be provided to install a final wall facing, such as pre-cast concrete panels. Other than this temporary road and required TESC facilities, construction of the walls would not need to intrude into the wetlands in front of the wall.

During construction, the top of the fill would be sloped gently downward behind and away from the face of the wall (about 2 percent) to facilitate storm water runoff away from the wetlands, and to help control alignment of the wall facing. Runoff would be collected in temporary swales on the back of the fill (away from the wetlands) and conveyed to sediment ponds in the same manner as was successfully used during the 1998 embankment construction.

Placement and Compaction of Embankment Fill

Earth fill for the Third Runway embankment would be placed in layers and compacted. Soil would be moisture-conditioned as needed to improve compaction. Typically the conditioning could include:

- Spreading and aeration by disking to reduce soil moisture;
- Light sprinkling to increase soil moisture; or
- Use of soil blending or use of a more select soil, in wet weather.

During construction, the top of the fill would be sloped gently (about 2 percent) to the east, away from the face of the wall to direct storm water runoff away from the wetlands. Runoff would be collected in temporary swales on the back of the fill (away from the wetlands) and conveyed to sediment ponds such as were used successfully for the 1998 embankment construction.

Construction specifications would include provisions for maintaining runoff and erosion protection during any construction shut-downs.

Embankment Slope Protection

As embankment construction phases are completed, permanent erosion protection would be installed. Typically this would include planting vegetation on the embankment slopes and monitoring to assure it becomes well-established and self-sustaining (Parametrix, 1999a).

The Port has had good success with hydroseeding to provide temporary erosion protection on the 1998 fill. This experience demonstrates:

- Hydroseeding is a viable means of controlling erosion in the winter immediately following fill placement; and
- The resultant cover can be relied on until permanent vegetation is established and/or completion of other construction phases.

MITIGATION OF POST-CONSTRUCTION HYDROGEOLOGIC IMPACTS

Management of Storm Water Runoff

Storm water runoff from the embankment will be collected and handled as discussed by Parametrix (1999a and 1999c).

Storm water runoff from the sloping face of the embankment will be collected in a permanent swale alongside the security road (see Figure 9) and conducted to detention facilities below the toe of the slope.

The swales provide some opportunity for infiltration. These swales will be rock-lined where necessary or otherwise protected against erosion along the toe of MSE walls, see Figure 8. Infiltration in this area will recharge to the Shallow Regional Aquifer and contribute to groundwater discharge to wetlands and Miller Creek.

Discharge of Seepage from the Embankment Underdrain

Most seepage collected from the embankment via the underdrain will discharge to a collection swale at the toe of the slope or below the toe of the MSE wall, the remainder will infiltrate directly into the Shallow Regional Aquifer under the embankment footprint. Seepage into the swale is likely to occur discontinuously along the length of the embankment, with flow concentrating at topographic low spots or in areas where there are pre-existing seeps.

The purpose of the swale is to collect seepage from the underdrain and conduct it laterally along the toe of the embankment for surface discharge to wetlands. Additional infiltration to recharge shallow interflow and the Shallow Regional Aquifer, will occur along the swale.

Facilities to enhance infiltration can be constructed at specific locations to augment water supplies for existing wetlands that are left undisturbed beyond the area of impact for the project. Facilities will be designed to infiltrate water from the drainage layer into the shallow subsurface soils that form the delineated wetlands. These can include:

- Locally increasing the swale width to reduce velocity and provide increased infiltration area;
- Overexcavating the side of the swale and replacing the existing soil with a sandy gravel berm to promote side wall seepage;
- Overexcavating the bottom of the swale to provide small check dams to hold water for continued infiltration in low flow times; and/or
- Construction of lateral gravel-filled finger-trenches

Post-Construction Baseflow to Miller Creek and Riparian Wetlands

The embankment underdrain plays a key role in collecting percolating water that has infiltrated into the surface and facing slopes of the embankment. The underdrain intercepts percolation and enables some control of groundwater recharge for the Shallow Regional Aquifer beneath the embankment:

- All of the water in the underdrain is available as direct recharge, by vertical seepage into the underlying soil; and
- Water which infiltrates through the embankment at a rate faster than it can infiltrate into the native soil will seep laterally downgradient within the underdrain, to swales which convey it to wetlands beyond the embankment.

By collecting and re-infiltrating seepage from the underdrain as described above, the impact of runway construction on baseflow to Miller Creek will be substantially mitigated.

Typical MSE Wall Section

Impacts to recharge in the vicinity of the Wetland 37 Wall between Station 175+00 and 185+00 are summarized in Appendix B. The water-balance model is based on average conditions and 40 inches of annual rainfall. The variation of pre-project and mitigated post-construction recharge to groundwater during an average year is depicted on Figure 11.

In this analysis, the impact of infiltration to baseflow is proportional to monthly rainfall, with the major impacts occurring in the winter months. The embankment will provide increased storage and a corresponding delay in discharge of infiltration, caused by groundwater travel time through the embankment subsurface. The effect of these factors is to delay the groundwater recharge by one or two months, providing higher flow than at present in the early summer months.

Typical 2:1 Embankment Section

Impacts to recharge along the main embankment between Station 185+00 and 215+00 are summarized in Appendix B. The variation of pre-project, impacted, and mitigated baseflows through an average year is depicted on Figure 12.

PREPARATION OF THIS REPORT

This report has been prepared for the exclusive use of HNTB Corporation and the Port of Seattle for specific application to the site and project discussed herein. Hart Crowser, Inc., accomplished this work in general accordance with our proposal dated January 28, 1999. We completed this work in accordance with conventionally accepted geotechnical engineering practices for the nature and conditions of work completed in the same or similar localities at the time the work was accomplished. We make no other warranties, express or implied.

We appreciate the opportunity to assist you on this project. Please call if you have any questions.

Sincerely,

HART CROWSER, INC.

22484

7/9/99

EXPIRES 12/13/99

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Principal Engineer

7/9/99

EXPIRES 9/17/99

MICHAEL A.P. KENRICK, P.E.
Sr. Assoc. Hydrogeologist

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Table 1 - Soil Parameters Used for Stability Analysis

Soil Description	Moist Unit Weight in pcf	Cohesion in psf	Friction Angle in Degrees
Fill - Select Runway Fill	125	0	35
Fill - Wall Backfill	109 to 120	0	32 to 36
Glacial Till	130	250	40
Peat	90	0	19
Sand - Advance Outwash	125	0	35
Sand - Base Preparation	130	0	32 to 40
Sand - Dense to Very Dense	125	0	39
Sand - Drainage Layer	140	0	40
Sand - Medium Dense to Dense	120	0	35 to 37
Sand - Recessional Outwash	120	0	35
Silt - Hard, Sandy	120	4000	0
Silt - Medium Stiff	120	400	20 to 24
Topsoil	90	0	23

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Vicinity Map

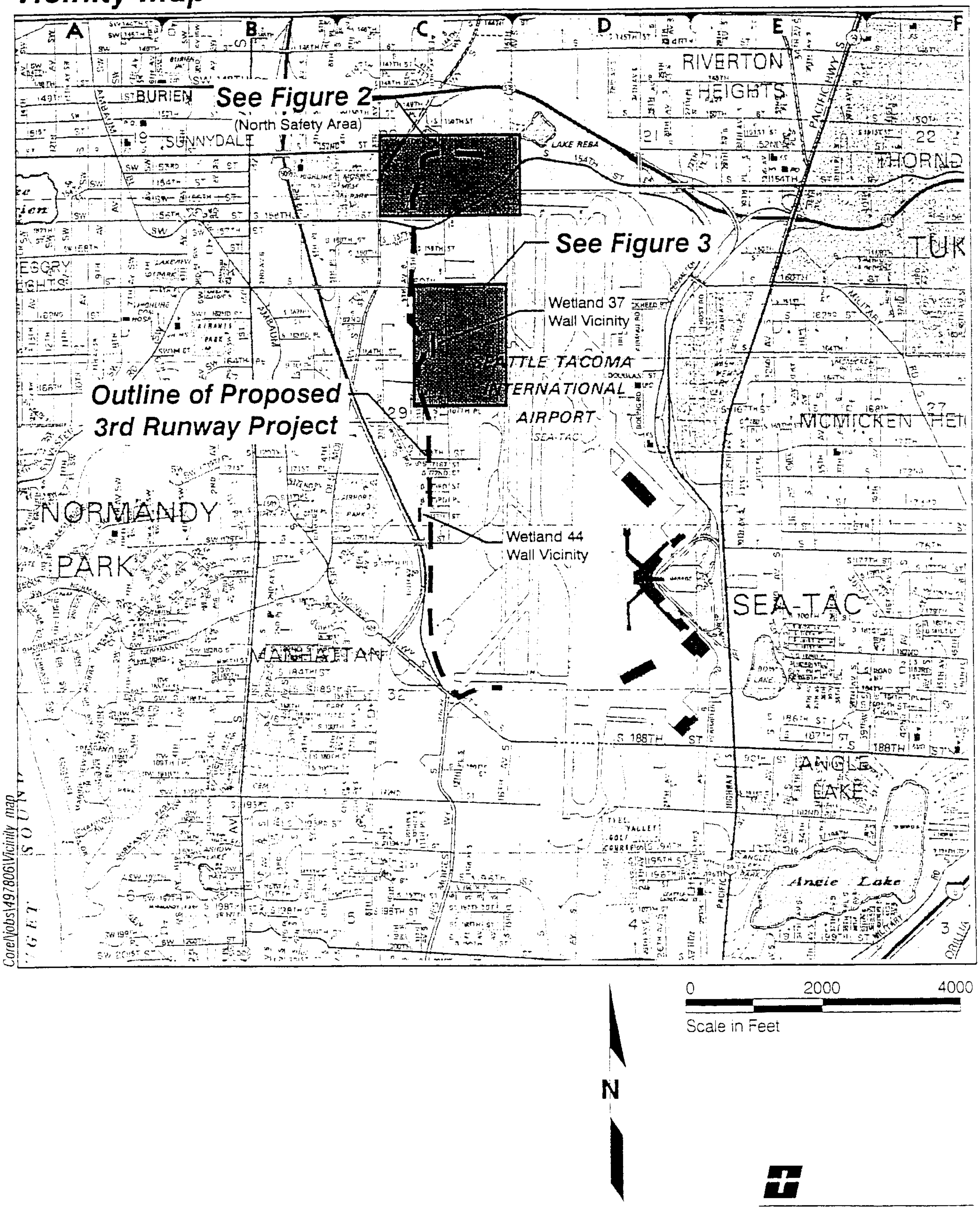

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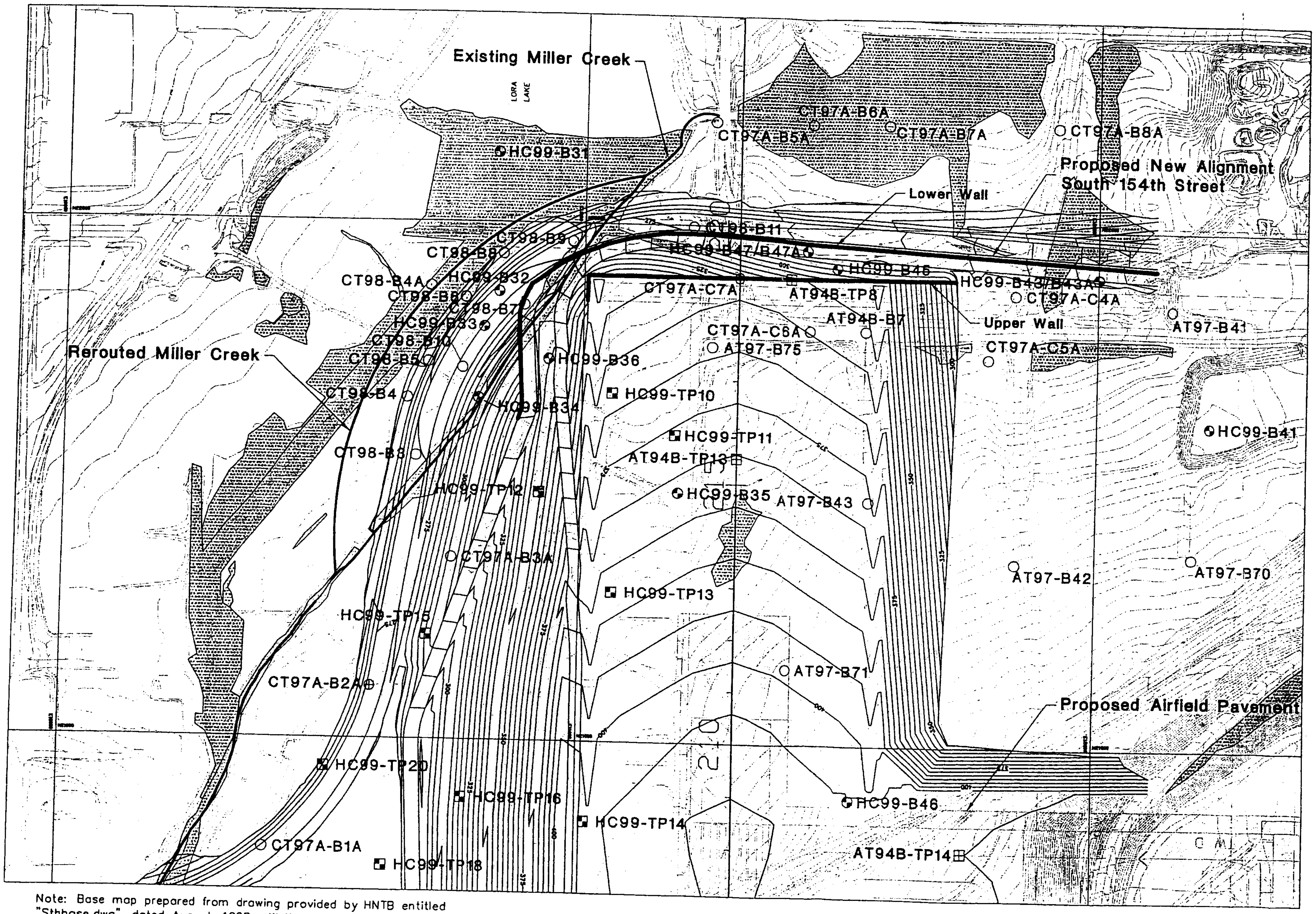
Figure 1

Site and Exploration Plan - 1 of 2

North Study Area



HC99-B31	Monitoring Well Location and Number (Current Study)
HC99-TP11	Test Pit Location and Number (Current Study)
○ CT98-B9	Exploration Location and Number, by others
	Wetland
360	Existing Elevation Contour in Feet
400	Proposed Elevation Contour in Feet
175	Runway Stationing

0 200 400
Scale in Feet

Note: Base map prepared from drawing provided by HNTB entitled "Sthbase.dwg", dated August, 1998. Wetland locations based on drawing provided by Parametrix entitled "w_050799.dwg", dated May 7, 1999.

(xref)see drawing file/woodstock.pcp

HC 6/10/99
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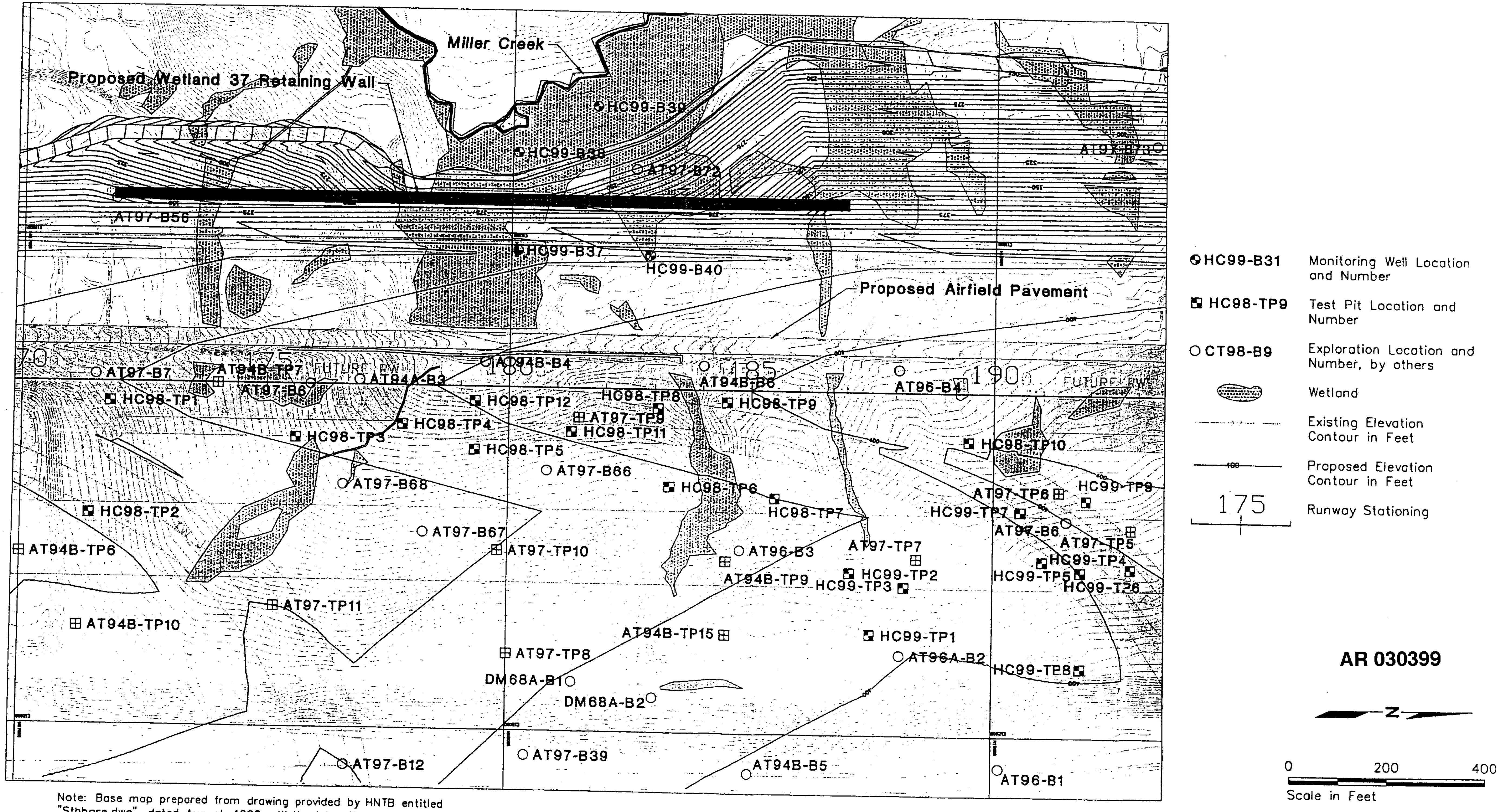
Figure 2

Site and Exploration Plan - 2 of 2

West Study Area



Note: Base map prepared from drawing provided by HNTB entitled "Sthbase.dwg", dated August, 1998. Wetland locations based on drawing provided by Parametrix entitled "w_050799.dwg", dated May 7, 1999.

RC 6/10/99 1-200 (xref)see drawing file/woodstock.pcp
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Figure 3

Elements of Shallow Groundwater Movement

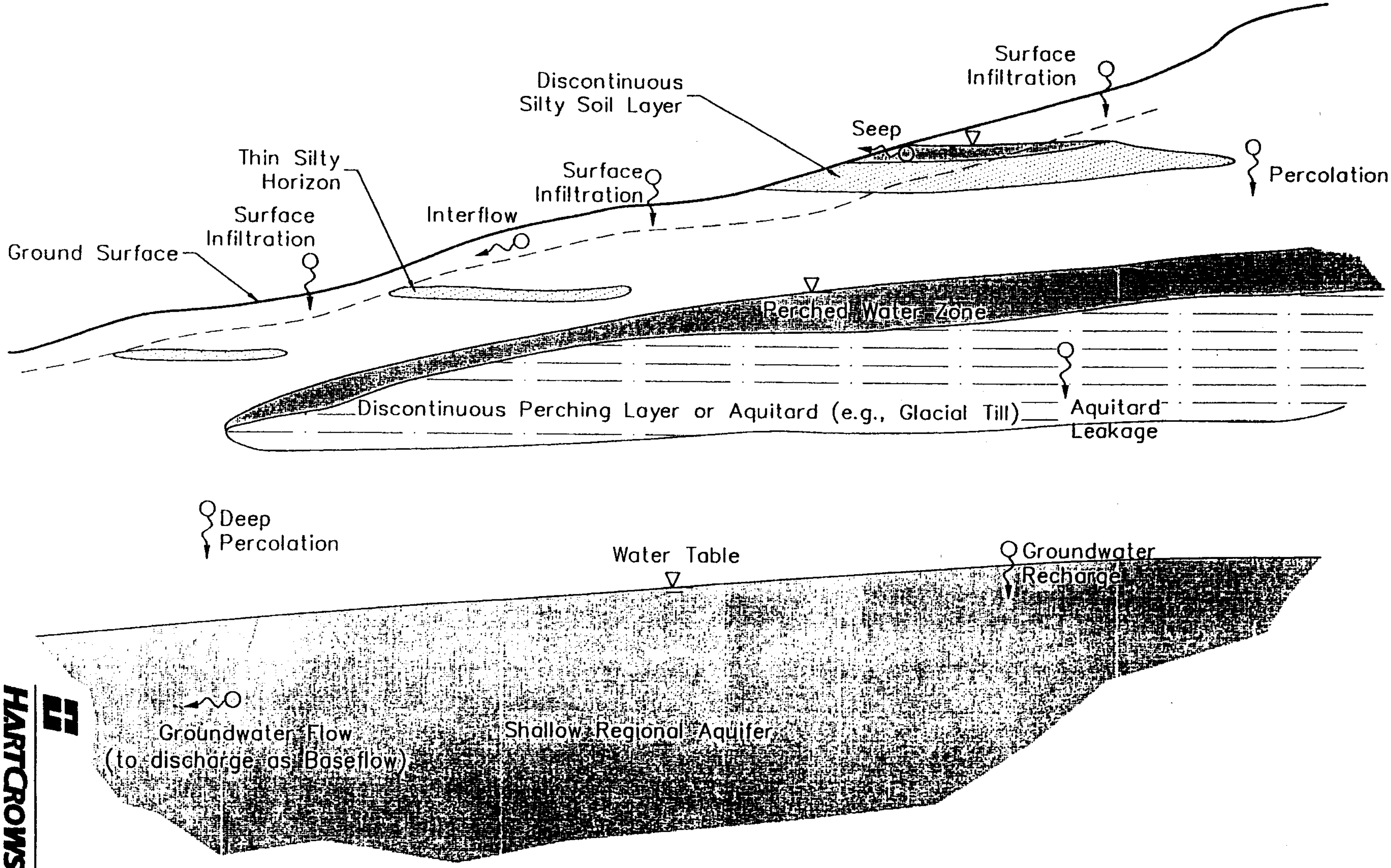

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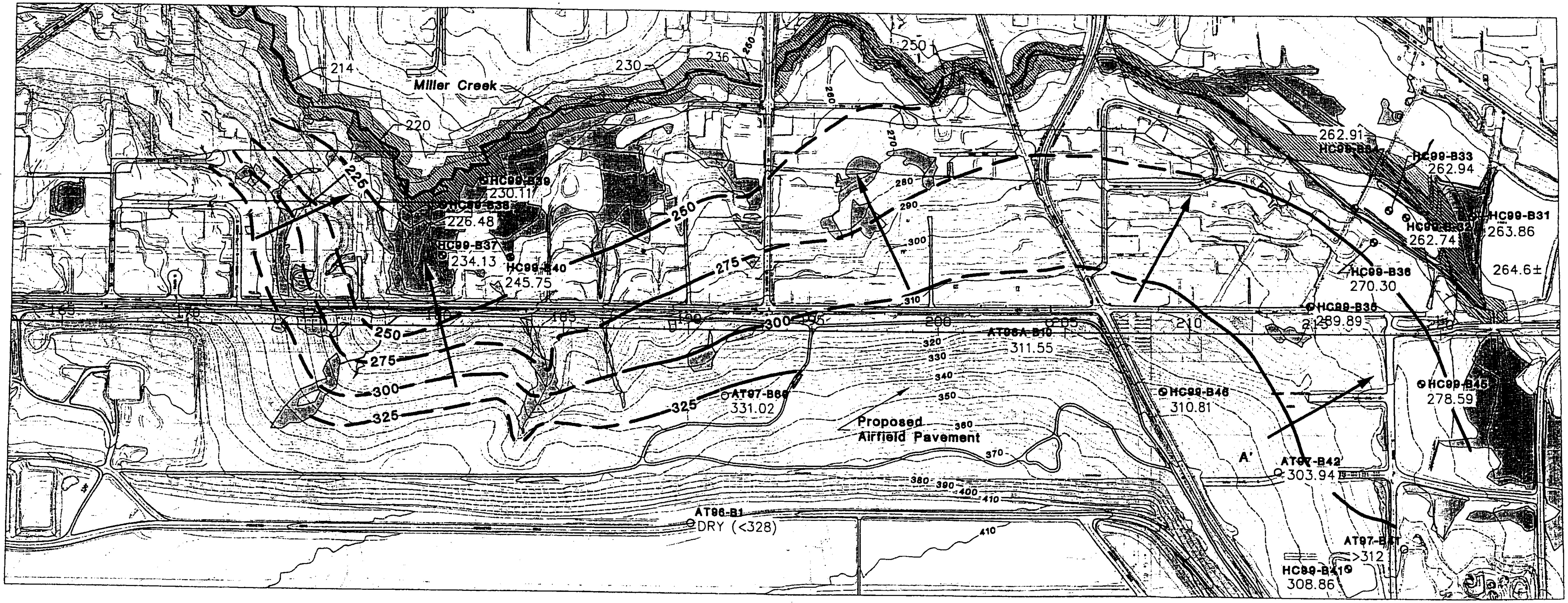
Figure 4

Shallow Regional Aquifer Groundwater Elevation Contour Map



Note: Base map prepared from drawing provided by HNTB entitled, "SthBase.dwg", dated August, 1998. Wetland locations based on drawing provided by Parametrix entitled, "w_050799.dwg," dated May 7, 1999.

— —300—— Groundwater Elevation Contour in Feet

----410---- Existing Elevation Contour in Feet

⊕HC99-B35 Monitoring Well Location and Number

278.59 Groundwater Elevation in Feet

←—— Inferred Groundwater Flow Direction

175 Runway Stationing

Wetland

N

0 400 800
Scale in Feet

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MSE Wall Schematic

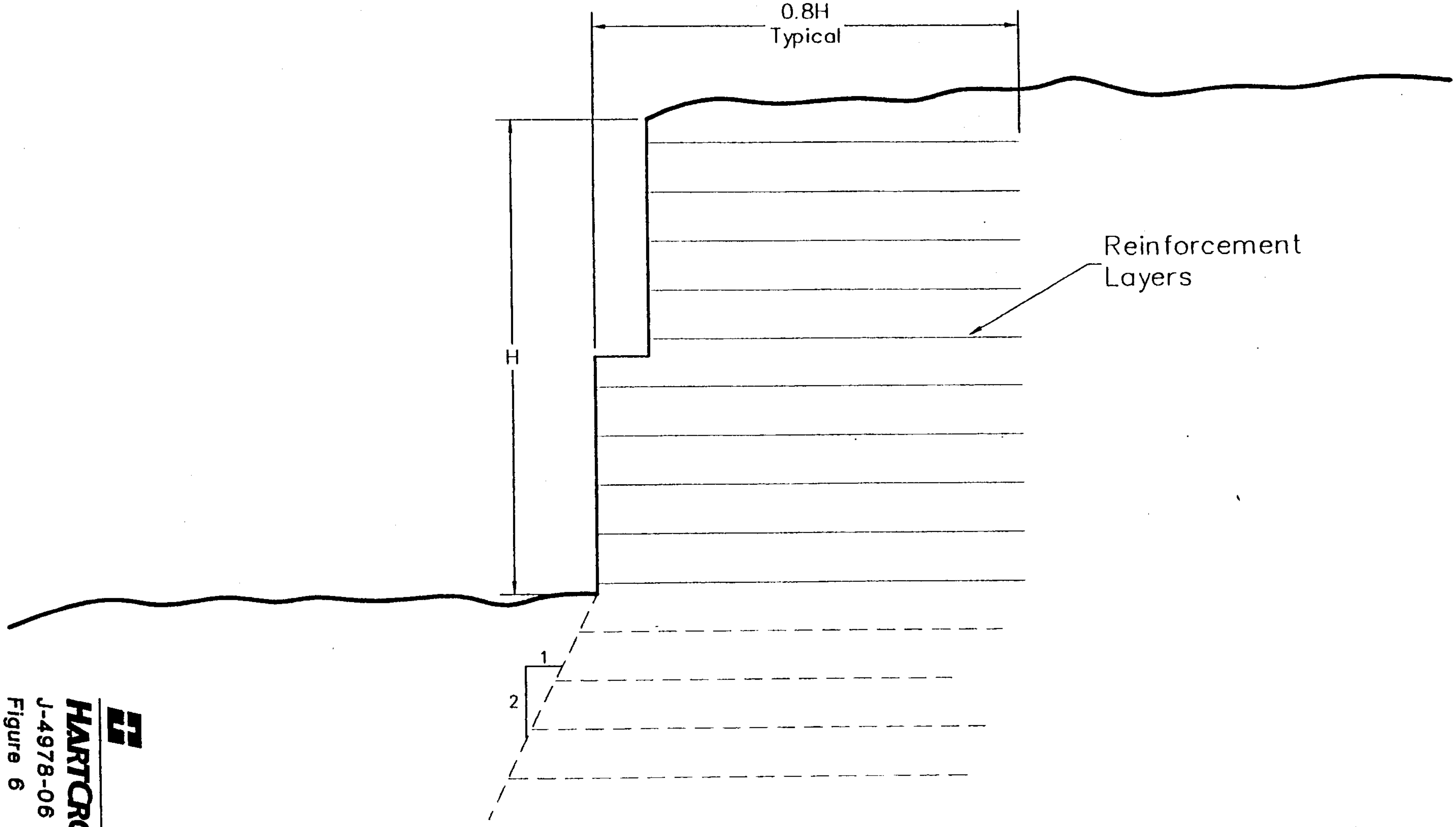

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Figure 6

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Conceptual Zoned Embankment Cross Sections

EMBANKMENT ZONES

A_1 PAVEMENT SUBGRADE

A_2 DRAINAGE

B_1 PAVEMENT SUPPORT

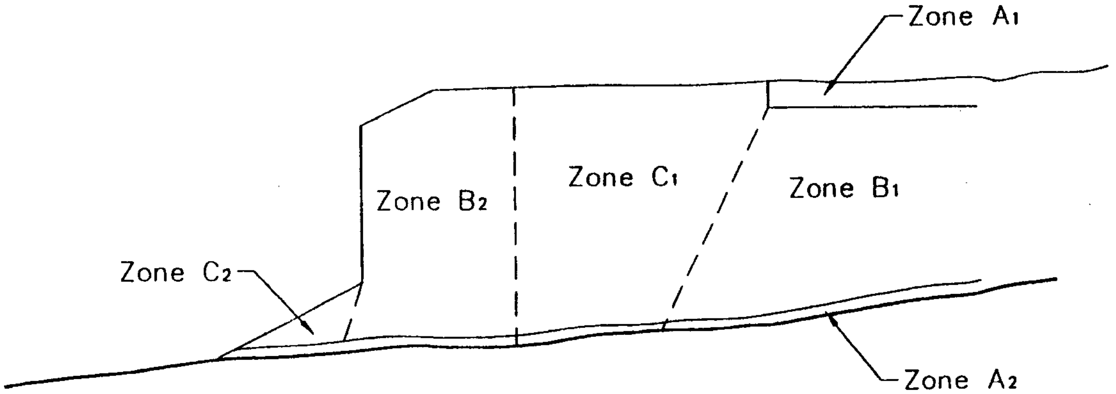
B_2 MSE REINFORCING

C_1 COMMON EMBANKMENT

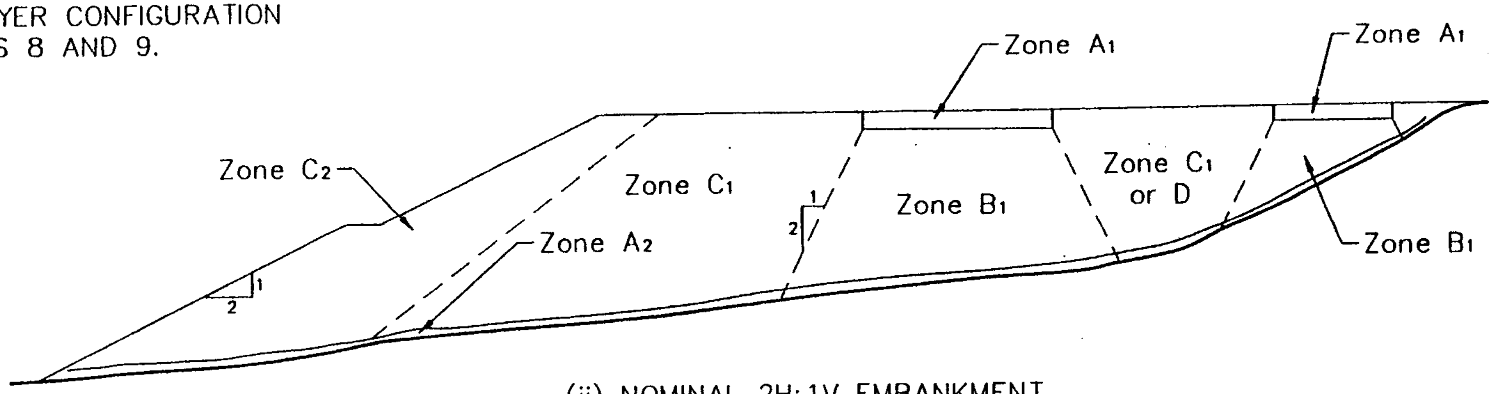
C_2 COMMON EMBANKMENT, SLOPE FACE

D NON-STRUCTURAL FILL

NOTE: DRAINAGE LAYER CONFIGURATION VARIES, SEE FIGURES 8 AND 9.



(i) MSE RETAINED EMBANKMENT



(ii) NOMINAL 2H:1V EMBANKMENT

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Figure 7

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Extent of Overexcavation for Replacement of Foundation Soils

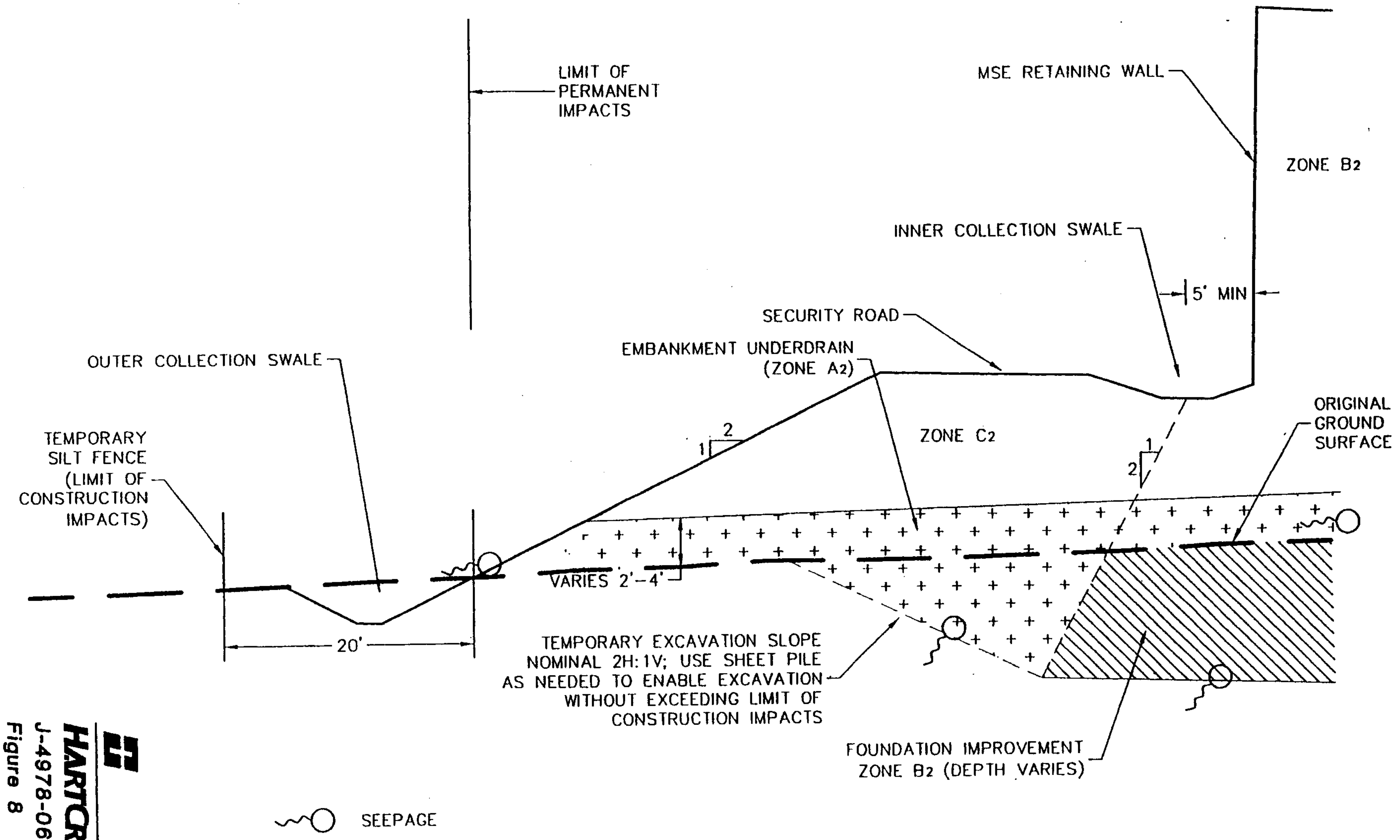

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Figure 8

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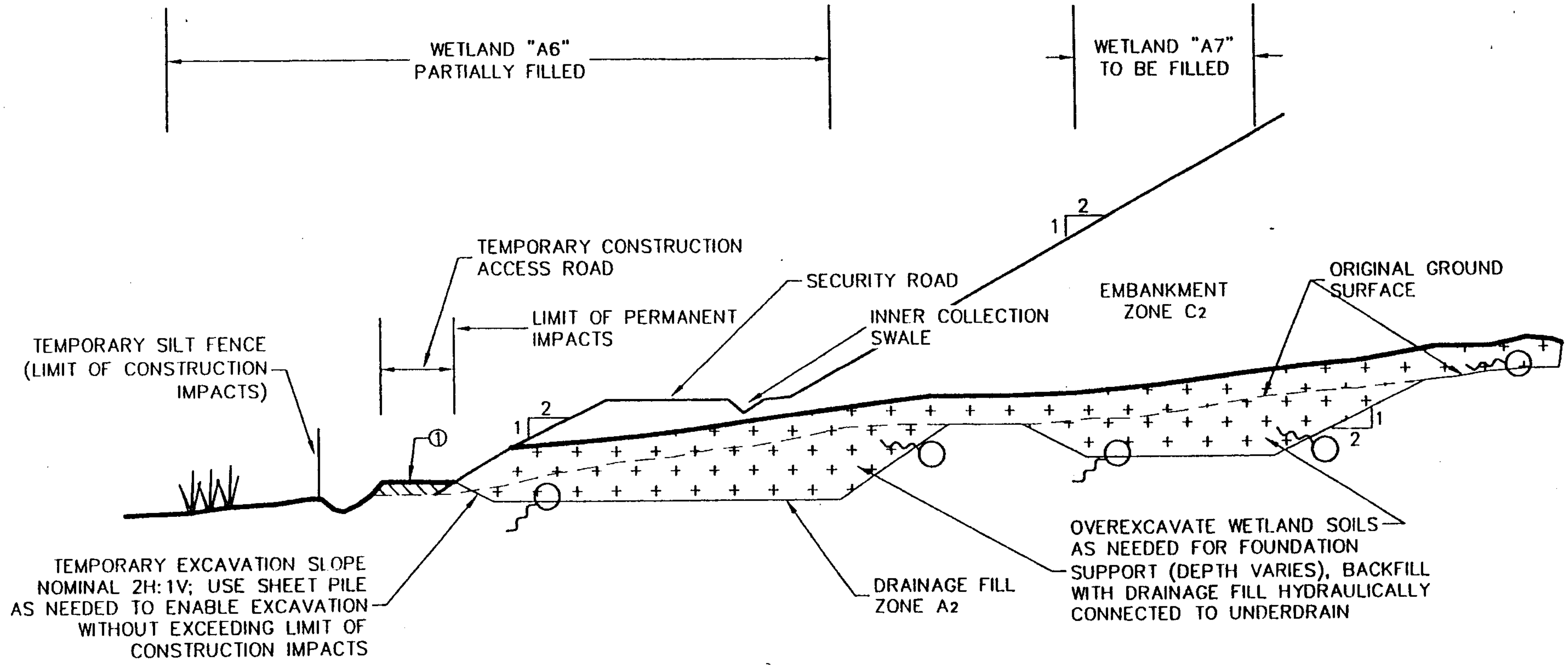
Hydraulic Connection between Wetland Fill and Embankment Underdrain



① TEMPORARY ROAD FILL TO BE REMOVED AFTER CONSTRUCTION

~○ SEEPAGE

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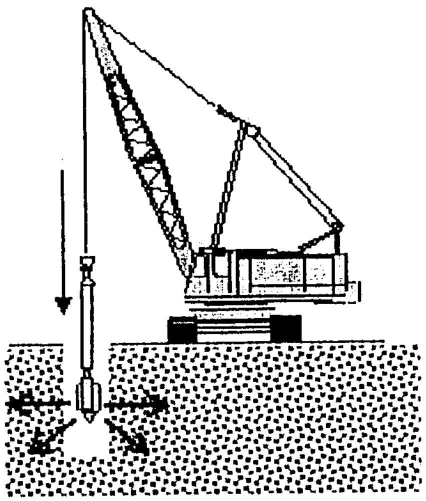
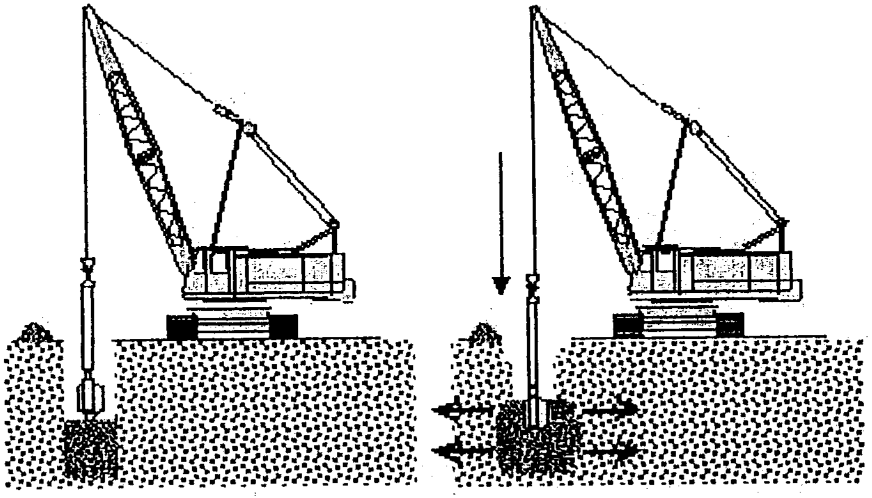
Figure 9

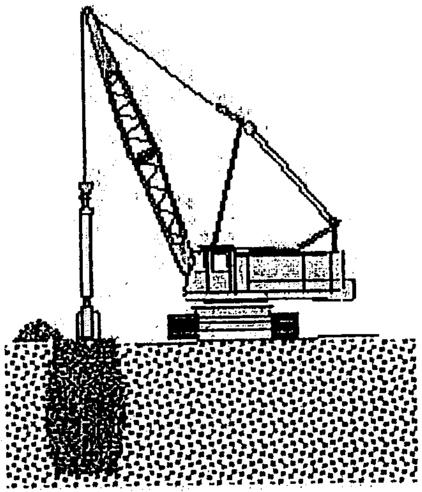
Stone Column Installation for Subgrade Improvement



Borehole is formed by sinking vibrator into the ground



Backfill material is placed into the borehole in stages and compacted



Alternating backfilling and compacting form continuous stone column

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Figure 10

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Comparison of Pre- and Post-Construction Groundwater Recharge

Runway Stations 175+00 to 185+00 (Typical MSE Wall)

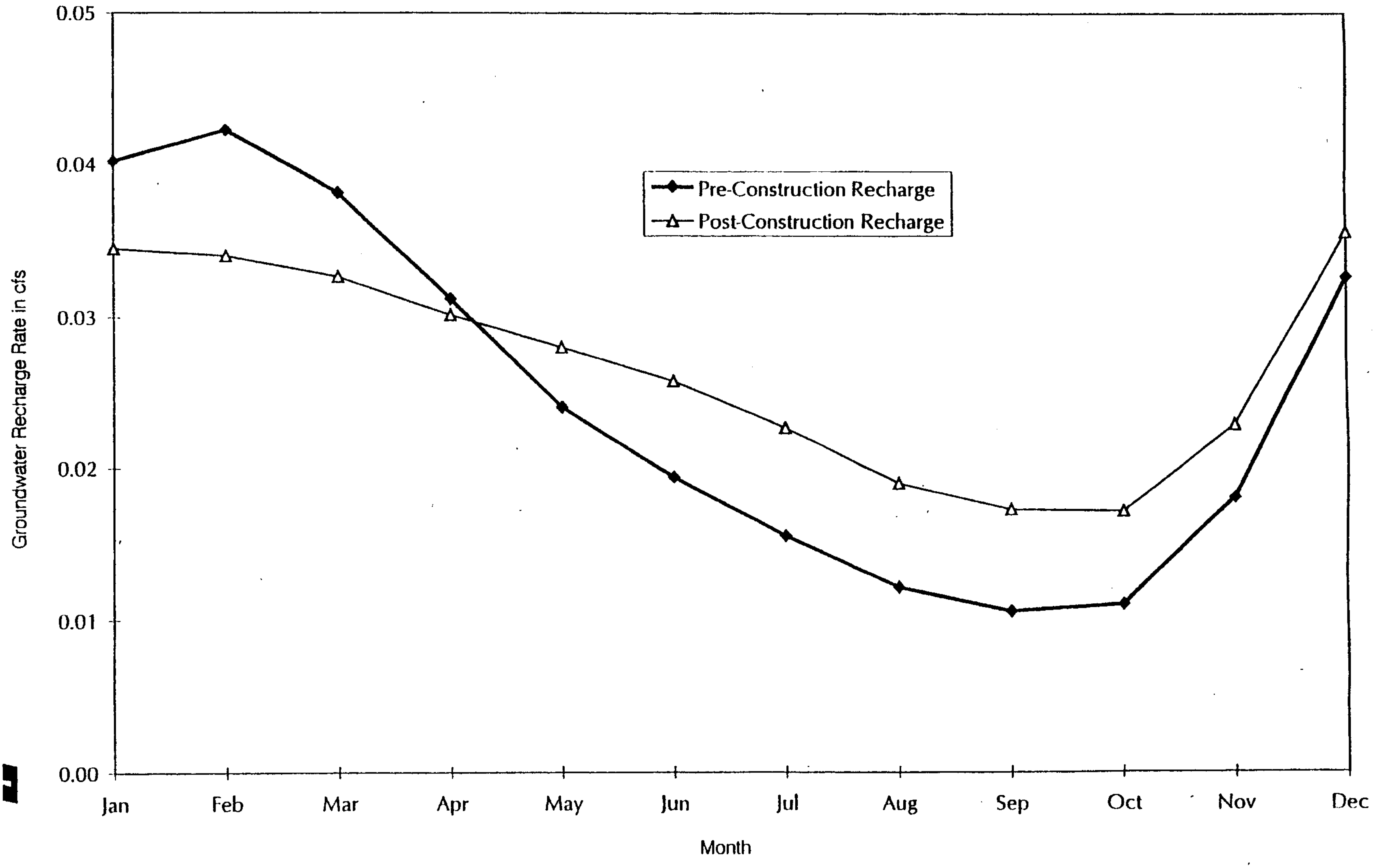

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Figure 11

Comparison of Pre- and Post-Construction Groundwater Recharge Runway Stations 185+00 to 215+00 (Typical 2H:1V Embankment)

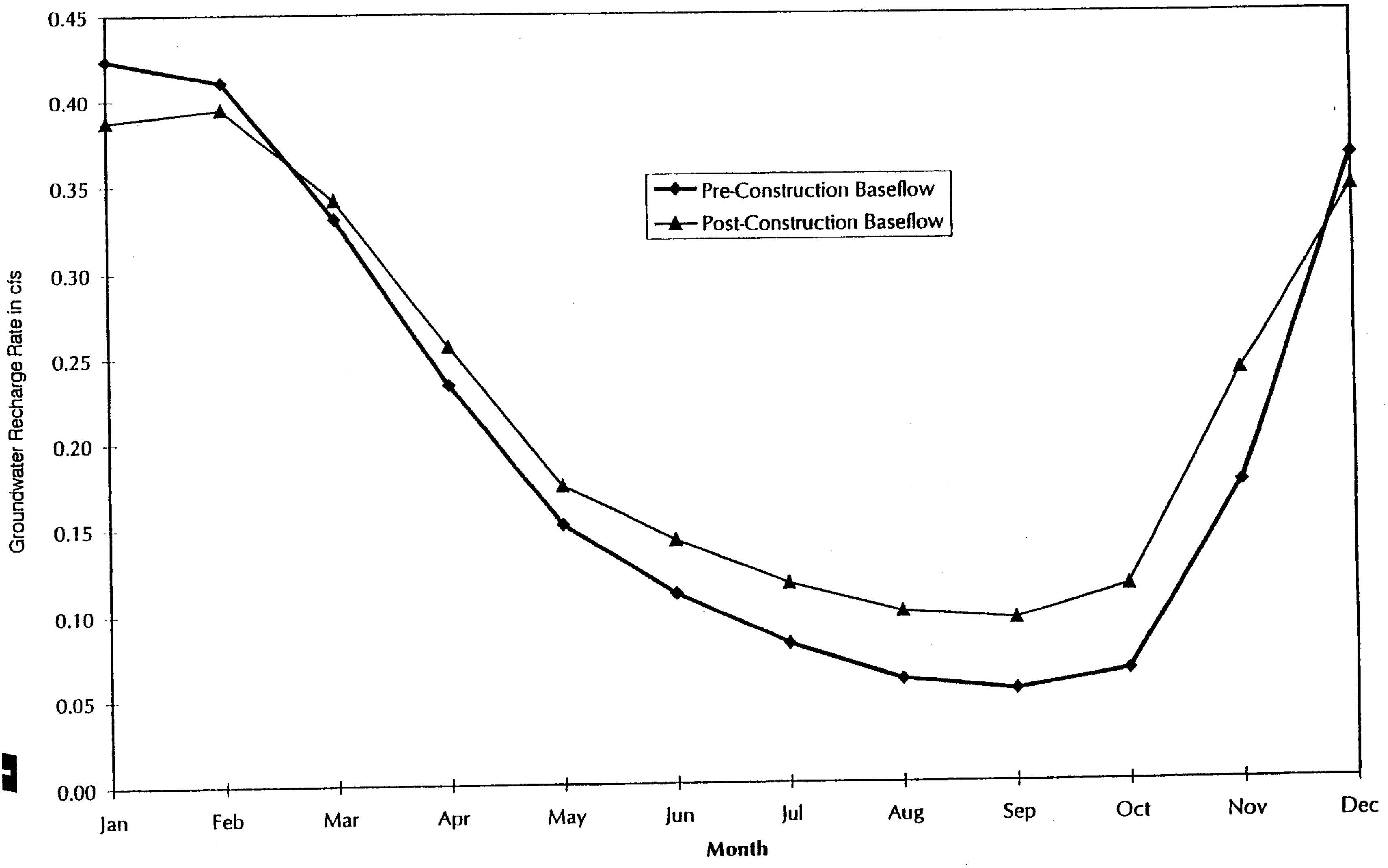

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Figure 12

APPENDIX A
SUBSURFACE CONDITIONS IN SELECTED REPRESENTATIVE WETLAND AREAS

APPENDIX A
SUBSURFACE CONDITIONS IN SELECTED REPRESENTATIVE WETLAND AREAS

This appendix summarizes geotechnical soil conditions encountered in exploratory borings accomplished within representative wetland areas. Boring logs and test results, along with additional information are presented in Hart Crowser (1999). The selected wetlands were identified as being representative based on review of existing information, or as significant based on anticipated location of MSE walls to retain the fill. Available information indicates other wetlands to be filled are likely to have similar geotechnical characteristics.

North Safety Area (Combination of Slopes and Walls)

Near-surface soils in the vicinity of the north end of the embankment including Wetlands 9, FW6 and FW3, generally consist of:

- Loose to medium dense, moist, silty, gravelly sand;
- Sand with occasional gravel and occasional thin layers of silt;
- Occasional peat and soft, organic silt; and
- Medium stiff to hard, sandy silt.

These soils are predominantly recessional outwash deposits which comprise the majority of surficial materials in the embankment footprint (AGI, 1996). Some recent alluvium is also present. The recessional outwash soils and alluvium combined are typically less than about 10 to 20 feet in thickness, and overlie dense to very dense glacial till and advance outwash deposits.

Soils at the north end of the embankment are relatively variable in gradation compared to soil conditions under most of the embankment footprint. Soil conditions affecting embankment design include the following significant units:

- In the area upslope of Wetland 9, the near-surface soils consist of medium stiff to very stiff, sandy silt, underlain by a laterally consistent layer of medium stiff to hard, moist to wet, fine sandy silt. Laboratory testing indicates this soil has low plasticity, low cohesion, and potential to consolidate (gain strength) under the embankment load. This fine sandy silt is anticipated to be relatively well-drained due to the presence of thin layers of silty fine sand which are wet and relatively more permeable than the fine sandy silt.

- An area of very soft to soft peat and organic silt was encountered in Wetland FW6, in the northwest area of the embankment, during explorations for the 154th Avenue relocation alignment study (CivilTech, 1997). HC99-B36, which is slightly upslope of the soft peat soils, encountered 8 feet of loose, very silty sand over stiff to hard silt. The soft, moist to wet, peat and silt soils vary from a single layer generally less than 15 to 20 feet in thickness, to peat interbedded with loose to medium dense silty sand or stiff silt.

West Side of Embankment

Wetland 37 Wall

Surficial soils were evaluated on the west side of the embankment within and adjacent to Wetland 37a as part of evaluating retaining wall and slope alternatives (to avoid relocating Miller Creek and reduce the filling of wetlands) in this area.

Near-surface soils within the topographically low-lying areas generally consist of interlayered:

- Loose to medium dense, moist to wet, silty to very silty, fine sand, which is occasionally slightly gravelly;
- Soft to stiff, moist peat and organic silt; and
- Soft to stiff, moist, sandy silt.

Dense to very dense glacial till soils are generally encountered at 5 to 17 feet in depth (i.e., below the loose or soft soils identified above). Typically the thicker deposits of soft and loose materials appear to be in the topographic lower portions of the wetland. As the ground surface topography rises, the surficial soils transition from the recently deposited peat, silt, and fine sand into medium dense, moist, silty, slightly gravelly to gravelly sand, identified as recessional outwash soils. The depth to glacial till in the upland areas typically appears to be 5 to 10 feet, somewhat less than in the low lying areas.

Wetland 44a Wall

A third area where construction impacts to wetlands can be significantly reduced by retaining wall construction is Wetland 44a. Subsurface explorations have not been completed to date within Wetland 44a, because of property access constraints and because drill-rig access is likely to require cutting and filling within the ravine which would disturb wetland and buffer habitat. Review of available soil and groundwater information adjacent to Wetland 44a suggests subsurface conditions will likely be similar to those discussed above for Wetland 37a.

Upslope of the ravine, exploration borings AT97-B53, AT97-B59, and AT97-B60 have been accomplished on South 176th and South 174th Streets. These explorations indicate that very dense, glacially overridden soils are close to the surface around the upslope perimeter of Wetland 44a. Surficial soils generally consist of about 5 to 10 feet of medium dense, silty sand with occasional gravel over very dense, silty sand to slightly gravelly, silty sand.

Boring AT97-B60, which is located further south and west of the anticipated wall area, encountered 9 feet of very dense, silty sand with cobbles, over very dense sand with occasional gravel.

Visual reconnaissance suggests that the topographically lower portions of the ravine likely include loose to medium dense silty sand (colluvium) and possibly soft to medium stiff silt and/or peat.

Test pit and trench explorations, along with fill construction to enable access for cone penetrometer explorations, will be completed for final design, after completion of 404 Permit process.

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APPENDIX B
WATER BALANCE MODEL

APPENDIX B
WATER BALANCE MODEL

Model Objective

The objective of the water balance modeling conducted to support the geotechnical re-evaluation of wetland impacts is to examine changes in hydrologic flows (runoff, interflow, groundwater flow, and baseflow) that will occur as a result of embankment construction. The analysis is designed to include the effects of internal drainage facilities constructed within the proposed embankment, and to evaluate the ways for redistribution of flows generated from this drainage layer, to mitigate potential impacts to wetlands and baseflow.

Previous Work

Previous analyses of baseflow changes resulting from construction of the Third Runway and associated project components have considered overall changes in land use occurring within individual surface catchments or sub-basins that contribute flow to Miller Creek or Des Moines Creek, and their tributaries. The latest approach (Parametrix, 1999c) includes both HSP-F modeling of the catchments, and a water-budget analysis based on the rainfall-runoff-evapotranspiration-recharge characteristics of different soil types involved.

The results of the HSP-F catchment modeling by Parametrix show relatively small changes in groundwater recharge and consequently in baseflow, predicated on the observation that airport fill behaves hydrologically in a manner similar to outwash soils, rather than glacial till soils. Outwash soils are typically more permeable, allowing more infiltration and less runoff than glacial till soils. In this way, it is shown that Masterplan Project construction will in general allow some increase in potential groundwater recharge in areas that are not covered by impervious surfaces. However, the overall increase in impervious surfaces as a result of project development more than compensates for the increased groundwater recharge, resulting in the predicted small reductions to baseflow overall (see Parametrix 1999c, page 4-16).

Re-Evaluation Issues

One embankment design factor not considered in the previous baseflow analyses is the hydrologic effect of the internal drainage layer that is required to ensure embankment stability. The drainage layer will typically be placed as a blanket over the existing ground surface at the base of the fill soils. The primary function of the drainage layer is to control the build-up of pore water pressures within the embankment by providing a preferential drainage path for any pore water draining downward through the embankment.

The primary source of pore water in the embankment will be percolation of excess moisture from the upper soil layers following the infiltration of rainfall. In the earlier analyses of baseflow, it is assumed that such deep percolation will recharge the shallow groundwater beneath the embankment, and then discharge to the neighboring creeks as baseflow.

A portion of the groundwater recharge that enters the Shallow Regional Aquifer passes through that groundwater body and percolates deeper through the underlying aquitards. Most of this deep groundwater flow is removed from the shallow groundwater system that provides baseflow to local drainages including Miller Creek and Des Moines Creek.

- A portion of this deeper groundwater recharge returns to the Shallow Aquifer along valley areas where there is an upward groundwater gradient from depth.

- The remainder recharges the intermediate and deep regional aquifers that are located at depth within the Puget Sound sediments.

In the current design concept for the embankment, a substantial proportion of the infiltration will be intercepted by the drainage layer, and conducted laterally to recharge wetlands beyond the toe of the new embankment.

The analysis presented here is intended to compliment the work of Parametrix. It uses the same parameters as their water-budget analysis (Parametrix, 1999c; Appendix D) to quantify groundwater recharge before and after embankment construction, and to predict drainage-layer outflow. The management and reapplication of the drainage-layer outflow is then examined to maintain groundwater recharge and provide additional water to supplement water sources for off-site wetlands.

Model Concept

The concept used to examine the effect of the drainage layer is a water-balance model that considers inflows and outflows occurring within a representative vertical-slice through the proposed embankment. For this analysis, two representative embankment profiles are considered:

1) The Wetland 37 Wall (between Sta. 175+00 and 185+00)
2) The typical 2H:1V embankment (between Sta. 185+00 and 215+00).

Each embankment profile is divided into a series of blocks that allows the components of the water balance to be traced through the profile (see Figures B-1 and B-2).

Pre-Construction Conditions

The water balance model is initially set up to represent existing hydrologic conditions at the location of the typical embankment profiles. Existing land surface profiles and soil types are assigned to each block, and values are ascribed for evapotranspiration, runoff, interflow, and deep percolation that becomes groundwater recharge, using the runoff responses developed by Parametrix (Table 3-1 in Appendix D of Parametrix 1999c). Resulting hydrologic flows are accumulated for each block, and passed to the adjacent downgradient block as appropriate. Groundwater flow within and between each block is modeled using analytical equations for one-dimensional groundwater flow.

Notes and Assumptions:

1. Surface runoff from the existing airport area (Block 1) and from new embankment construction is diverted away to separate storm water management facilities;

2. Interflow in Block 1 likely contributes to groundwater flow toward the west. The model preserves interflow as a separate component that ultimately enters Miller Creek, or is intercepted by the drainage layer.

3. The apportionment of precipitation into its component parts focuses on shallow "active" groundwater that discharges to local streams; the analysis takes account of deep basin recharge, which replenishes lower aquifers and ultimately discharges to Puget Sound.

4. Some of the groundwater recharge will be retained as storage during winter months when the water table is rising; this water is released from storage during the summer when water levels are falling.

5. Wetlands represented in Block 4 may be sustained by one or a combination of precipitation, runoff, interflow, and groundwater discharge.

The existing water balance is calculated as an average for the year, and on a month-by-month basis, using average annual and monthly precipitation data.

Post-Construction Conditions

The water balance model is adjusted to represent post-construction conditions in which the embankment has been constructed on part of the original profile (see Figure B-1 (b)). In the model, the embankment is represented as an additional sub-block consisting of airport fill, placed above the existing land surface. Precipitation on the airport fill is split into evapotranspiration, runoff, interflow, and percolation. Approximately 90 percent of the percolation enters the drainage layer and is removed as drainage outflow. Approximately 10 percent of the deep percolation through the new embankment fill is assumed to pass through the drainage layer and into the underlying groundwater system, based on the contrast in hydraulic conductivity between the drainage layer and the underlying soil.

Pre-construction interflow in the soil layers beneath the embankment fill will be replaced, as a result of construction of the embankment. The MSE wall will include a wide zone of permeable material near the wall face, allowing all interflow in the new fill to enter the drainage layer (see Figure B-1). Interflow in the 2H:1V embankment is also assumed to enter the drainage layer (see Figure B-2).

Outflow from the drainage layer is applied as recharge to Block 4 in each of the embankment profiles. This may be achieved in practice by installing a variety of different infiltration facilities near the embankment toe, as outlined in the main text of this report.

Model Results

Water balance models were prepared for two representative cross sections through the proposed embankment: the Wetland 37 MSE Wall (between Stations 175+00 and 185+00) and the typical 2H:1V embankment (between Stations 185+00 and 215+00).

Overall Water Balance

At the MSE wall location, the water balance model shows that the overall precipitation on the cross section is divided up as follows:

Flow Component	Pre-Construction	Post-Construction
Evapotranspiration:	42.0%	38.2%
Surface Runoff:	15.5%	26.7%
Interflow:	8.0%	1.5%
Shallow Groundwater Flow:	10.1%	12.6%
Deep Groundwater Recharge:	24.3%	21.0%

Evapotranspiration is reduced, the main increase is in the form of runoff. Interflow and deep percolation captured by the drainage layer is re-infiltrated to increase groundwater flow. The drainage-layer outflow represents 11.3 percent of the overall water balance for the cross section. Comparable results are obtained at the 2H:1V embankment location, where the precipitation is divided up as follows:

Flow Component	Pre-Construction	Post-Construction
Evapotranspiration:	42.1%	38.7%
Surface Runoff:	14.9%	27.0%
Interflow:	10.9%	1.2%
Shallow Groundwater Flow:	9.6%	11.7%
Deep Groundwater Recharge:	22.4%	21.3%

The increase in groundwater recharge is achieved by re-infiltration of water flowing from the drainage layer. Drainage-layer flow represents 12.8 percent of the overall water balance.

Seasonal Changes in Groundwater Recharge

Figures 11 and 12 in the main report depict the variation in groundwater recharge on a monthly basis through an average year, for the two cross sections described above. The pre-construction recharge curves reflect the seasonal changes in precipitation from winter to summer.

The best conditions for re-infiltration of drainage-layer flow to create additional groundwater recharge occur during the summer months, when groundwater levels are low. However, drain flow rates are at their lowest during this period, allowing all the drain flow to be recharged. During the winter months, when groundwater levels are higher, recharge will be less effective, but excess water will be available for recharge, due to higher rates of seepage into the underdrain. Any water that cannot be recharged will overflow the recharge system, and flow through constructed swales into the wetlands as overland flow. Depending on the levels of soil saturation in the wetland, some of the excess flow may infiltrate; some will be lost by evapotranspiration, and some will run off as overland flow to Miller Creek.

Implications for Wetlands

Wetlands located beyond the toe of the embankment (off-site wetlands) are sustained by one or a combination of water sources including:

- Precipitation;
- Runoff;
- Interflow or discharge of perched groundwater; and
- Groundwater discharge from the Shallow Regional Aquifer.

In qualitative terms, the findings of the water balance model indicate the following:

- The amount of **precipitation** falling on off-site wetlands will not be affected by embankment construction.

- The amount of **runoff** supplied to off-site wetlands will change if embankment construction occurs in the catchment area above the wetland. Existing runoff from upslope areas will be eliminated as the embankment and new storm water facilities are constructed. For the off-site wetlands, this source of water will be replaced by flow from the underdrain system during the winter months.

- Off-site wetlands supplied by **interflow** or seepage of perched groundwater may see a change due to embankment construction above the wetland. Off-site wetlands will still be recharged by this mechanism although the volume of interflow may change. Interflow to wetlands which are partially filled and interflow to off-site wetlands will be replaced by seepage through the underdrain and overflow from the swale constructed at the edge of the underdrain. During the winter months, seepage from the perimeter swale will infiltrate to create interflow to off-site wetlands.

- Off-site wetlands supplied by **groundwater discharge from the Shallow Regional Aquifer** will see an overall increase in flow as a result of increased recharge of water from the drainage layer.

The analysis is based on long-term average annual and monthly precipitation rates. Natural variation in precipitation form month to month and year to year will produce differing results.

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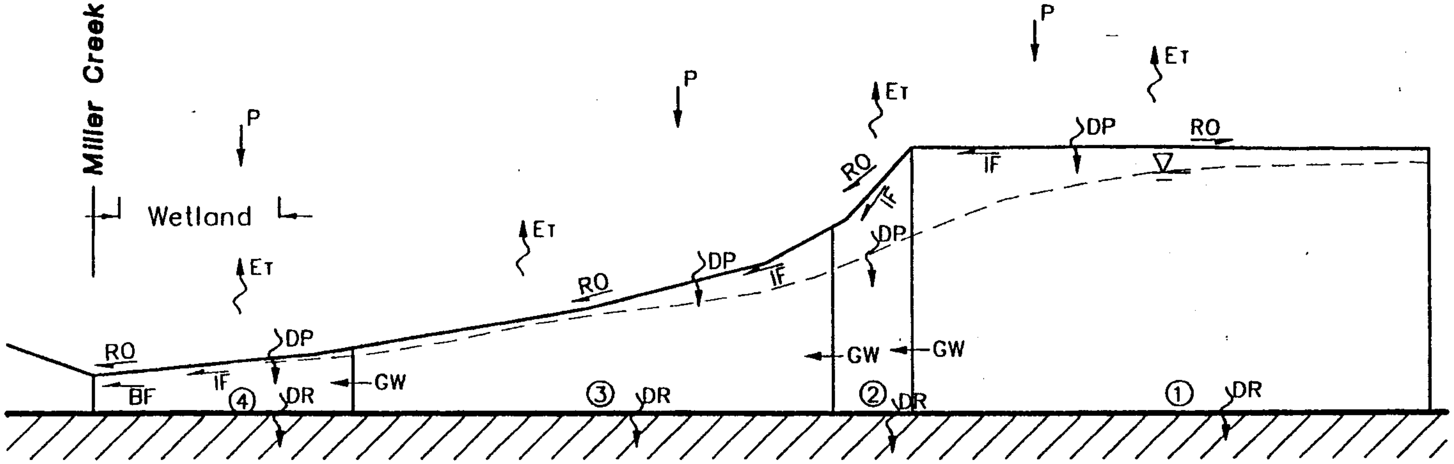
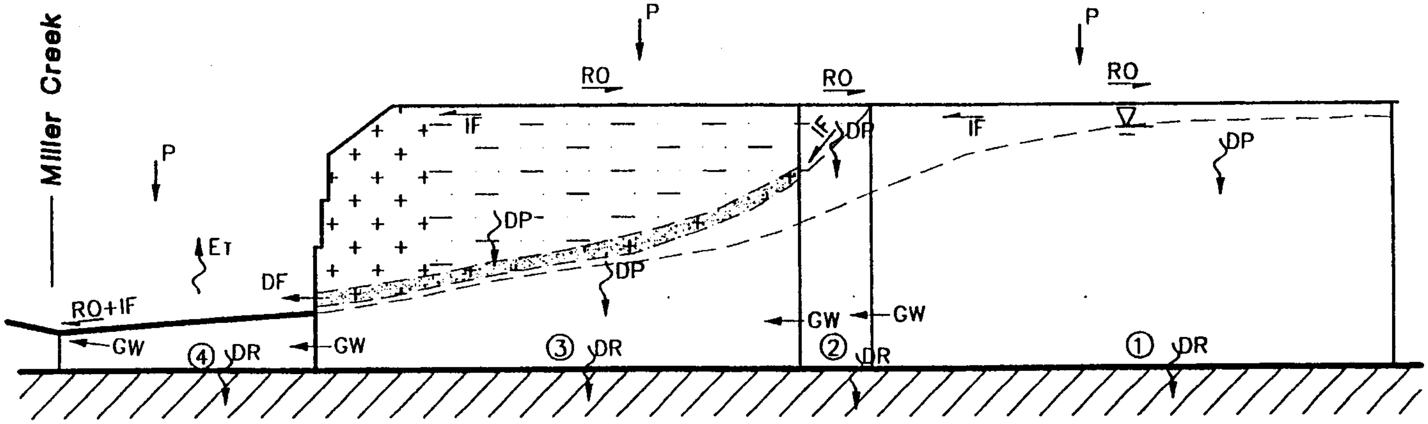
Water Balance Schematic between Stations 175+00 and 185+00 (Typical MSE Wall)

④	Block Number
P	Precipitation
ET	Evapotranspiration
RO	Runoff
IF	Interflow
DP	Deep Percolation
GW	Groundwater Flow
DF	Drainage Flow
∇	Water Table
DR	Deep Recharge
▨	Drainage Layer
— —	New Embankment
+ +	Free-draining Backfill



a) Pre-Construction



b) Post-Construction (with MSE Wall and Internal Drainage Layer)

Not to Scale

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Figure B-1

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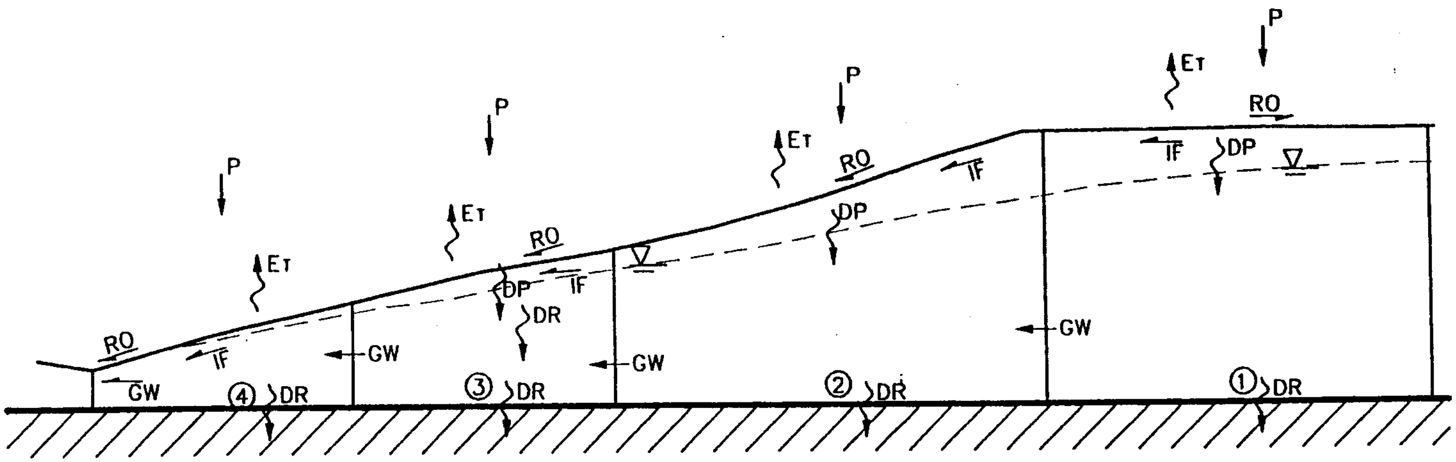
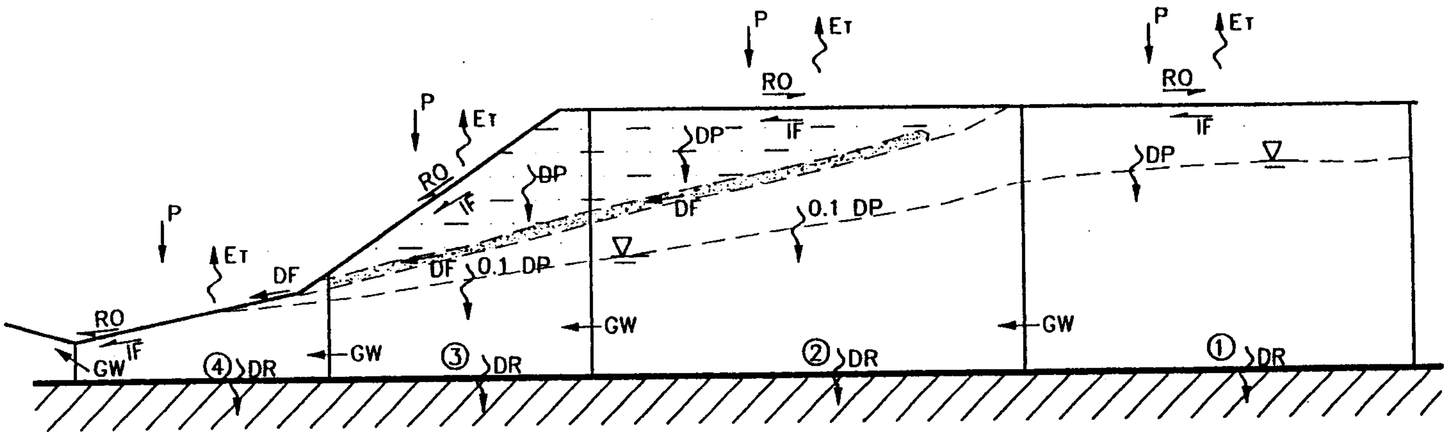
Water Balance Schematic Between Stations 185+00 and 215+00 (Typical 2H:1V Embankment)

④	Block Number
P	Precipitation
ET	Evapotranspiration
RO	Runoff
IF	Interflow
DP	Deep Percolation
GW	Groundwater Flow
DF	Drainage Flow
∇	Water Table
DR	Deep Recharge
▨	Drainage Layer
— —	New Embankment



a) Pre-Construction



b) Post-Construction

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Figure B-2

B-2

Proposed MSE Wall Subgrade Improvements

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MEMORANDUM

MICHAEL J. BAILEY
22484
EXPIRES 12/13/01

DATE: December 8, 2000

TO: Ms. Elizabeth Leavitt, Port of Seattle

FROM: Michael Bailey, P.E., Hart Crowser, Inc.

RE: **Proposed MSE Wall Subgrade Improvements**
Seattle-Tacoma International Airport
J-4978-06

CC: Jim Thomson, P.E., HNTB

In response to your request, this memo provides an update on design of the subgrade improvements to support the mechanically stabilized earth (MSE) retaining walls for the Third Runway embankment at Sea-Tac.

This memo describes why the proposed construction below existing ground level will have no adverse impact to groundwater flow below the proposed MSE walls.

The basic design concept, construction approach, and subsurface conditions below the proposed MSE walls are generally discussed in Appendix B in the Wetland Functional Assessment and Impact Analysis document for the project, which includes Hart Crowser's July 9, 1999, report entitled "Geotechnical Engineering Report, 404 Permit Support, Third Runway Embankment." This memo provides additional detail based on subsurface explorations and design work completed since July 1999. This memo provides a description of the components used in the MSE wall foundation and the proposed subgrade soil improvements, and why these constructed features will not impede shallow groundwater flow that recharges Miller Creek and adjacent wetlands.

MSE Wall and Foundation Components

Figure 1 shows a schematic cross section of the proposed MSE wall that will be constructed to avoid relocating Miller Creek. The cross section, located at runway Station 178+60, is a good section to use for illustration because it includes wetland soils and is near the

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maximum height of the proposed wall. Figure 2 shows location of the cross section as well as the extent of the proposed subgrade improvements in plan view for the west wall.

Figure 1 shows elements of the reinforced wall backfill zone and subgrade improvement zone that are discussed in this memo. Construction elements that are related to groundwater flow include the following:

Native Surficial Soils. This soft or loose to medium dense surficial soil unit consists of silty sand with organics, interbedded silty sand, gravelly sand, and sandy silt, and occasional sandy clay. The surficial soils contain the shallow aquifer that recharges Miller Creek and the adjacent wetlands. The seasonal groundwater level is near to, and locally slightly above the ground surface in this area, as indicated by Hart Crowser's monitoring wells and observations of shallow puddles in the wetland and overland flow from the east during the late spring. The surficial soils vary from about 10 to 20 feet in depth in this area. These surficial soils are not suitable to provide structural support of the proposed MSE wall.

Glacial Till. Underlying the surficial soils is glacial till or other hard glacially overridden soils that consist of very dense silty sand and hard sandy silt, with varying amounts of gravel. This soil unit will provide very good foundation support for the proposed MSE walls.

Reinforced Fill Zone. The proposed MSE wall is constructed of concrete facing panels connected to strips of steel reinforcing that extend back into the wall backfill behind the wall. Both the panels and the reinforced backfill are embedded below the surface of the new fill in front of the wall, to provide support for the wall. Depth of embedment is depends on the wall height and ground slope; in this area, it will be about 8 feet.

Subgrade Improvement Zone. The reinforced fill and MSE wall facing will be supported on soils which are adequately strong and non-compressible, to transfer the weight of the wall to the underlying glacial till. There are two types of subgrade improvement that may be used where the existing surficial soils need to be "improved" to provide this support;

- In areas where the depth of subgrade improvement is relatively shallow, existing soils in the subgrade improvement zone can be removed and replaced with compacted structural fill.
- In areas where the soils that need improvement are more than a few feet thick, subgrade improvement may be accomplished by installing stone columns to reinforce the existing native soils.

Both types of subgrade improvement are discussed later in this memo.

As shown on Figure 1, the eastern part of the reinforced fill extends a few feet below the existing ground surface at the cross section (Station 178+60). The depth of this embedment for the reinforced zone varies~~,~~ for instance at Station 177+75, the reinforced zone will extend below the ground surface about 9 feet.

The remainder of the memo describes the construction sequence and why shallow groundwater recharge to Miller Creek and the wetlands west of the MSE wall will not be impeded by either the reinforced fill extending below the ground surface, or either type of subgrade improvement.

Shallow Groundwater Seepage through Subgrade Improvements

Subgrade improvements will be constructed by either 1) overexcavation and replacement with compacted fill, or 2) use of stone columns. In some areas, the reinforced fill may also extend below the groundwater level.

Removal and Replacement for Subgrade Improvement

Where unsuitable soils are excavated as part of subgrade improvement, backfill will consist of relatively free-draining structural fill of the type used for wet weather construction or for the embankment underdrain. This fill will be well-graded and have a maximum fines content (percentage of silt and clay), limited by the construction specifications to not more than 8 percent. Figures 3 and 4 show gradation of the fill materials that may be used for this purpose. Permeability of this fill will be greater than the existing surficial soils it replaces, because of its overall gradation and the limited percent fines.

Stone Columns

Where stone columns will be used for subgrade improvement, design calls for them to have a nominal diameter of 42 inches and be spaced in a triangular pattern 8 feet apart. Figure 5 shows the method of constructing stone columns, and Figure 6 shows the spacing. The design calls for the stone columns to be constructed of coarse gravel with a maximum of 10 percent passing the no. 4 size sieve with little or no fines (silt and clay sized particles). The coarse gravel columns will occupy about 17 percent of the native soil volume based on the design spacing and diameter. Figure 7 shows gradation of the gravel specified for use in the stone columns.

Some densification of the native surficial soils will occur during stone column construction. However, the degree of densification is less in silty or clayey soils of the type that exist at the

Third Runway site, compared to non-silty soils. There are no reports in the engineering literature of stone columns impeding groundwater flow. In fact there are many case studies that show that stone columns actually improve site drainage by enhancing vertical seepage between granular soils that are separated by more silty interbeds.

Reinforced Zone

The MSE wall consists of concrete facing panels that are separated vertically by elastomeric bearing pads that maintain a ¾-inch gap completely around the perimeter of each concrete panel. The gap in the joint between MSE panels enables the face of the wall to be free-draining, including the portion embedded below the ground surface. Where the wall extends above the ground surface, this joint is so free-draining that it is typically protected with filter fabric to prevent soil erosion. Figure 8 shows the joint between MSE panels.

The bottom of the wall bears on a 6-inch-high concrete pad. This concrete pad will not impede shallow groundwater flow through the area where the wall is embedded because of its small height relative to the thickness of the aquifer.

The reinforced zone behind the wall facing has steel strips laid horizontally in the soil, to provide the MSE soil reinforcing. These strips are typically about a quarter-inch thick by four inches wide, and they are spaced a minimum of 9 inches on center both horizontally and vertically. The reinforcing will not impede shallow groundwater flow, for the same reason noted above, because of the small area occupied by the reinforcing strips relative to the overall height of the aquifer.

Please call if you have any questions.

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Attachments:
Figure 1 - West MSE Wall Cross Section Station 178 + 60
Figure 2 - West MSE Wall Subgrade Improvement Plan
Figure 3 - Grain Size Envelope for Group 1A Fill Material
Figure 4 - Grain Size Envelope for Group 1B Fill Material
Figure 5 - Stone Column Installation for Subgrade Improvement
Figure 6 - Stone Column Layout Plan
Figure 7 - Grain Size Envelope for Gravel Used in Stone Columns
Figure 8 - Joint Details between MSE Wall Panels

West MSE Wall Cross Section

Station 178+60

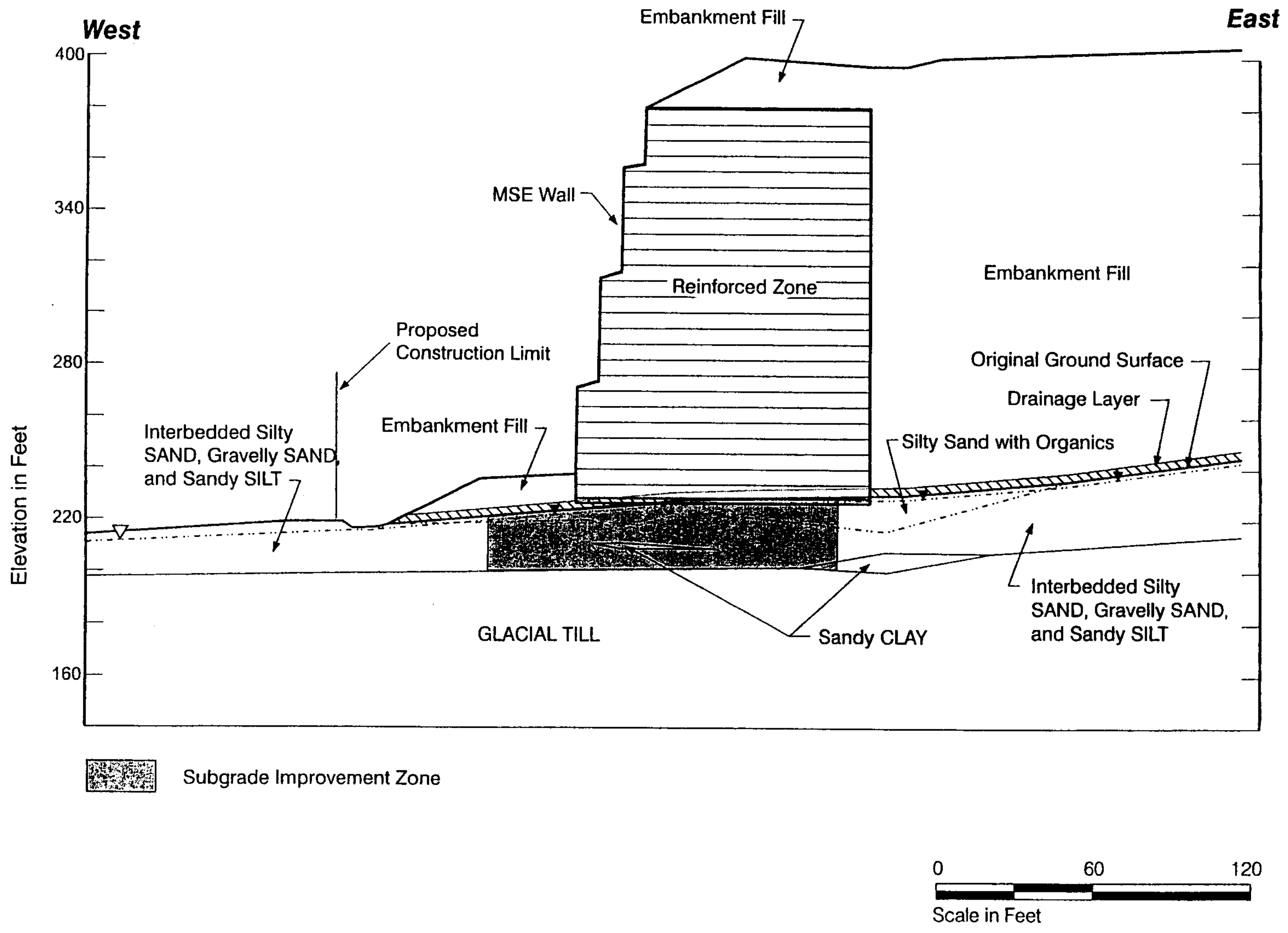

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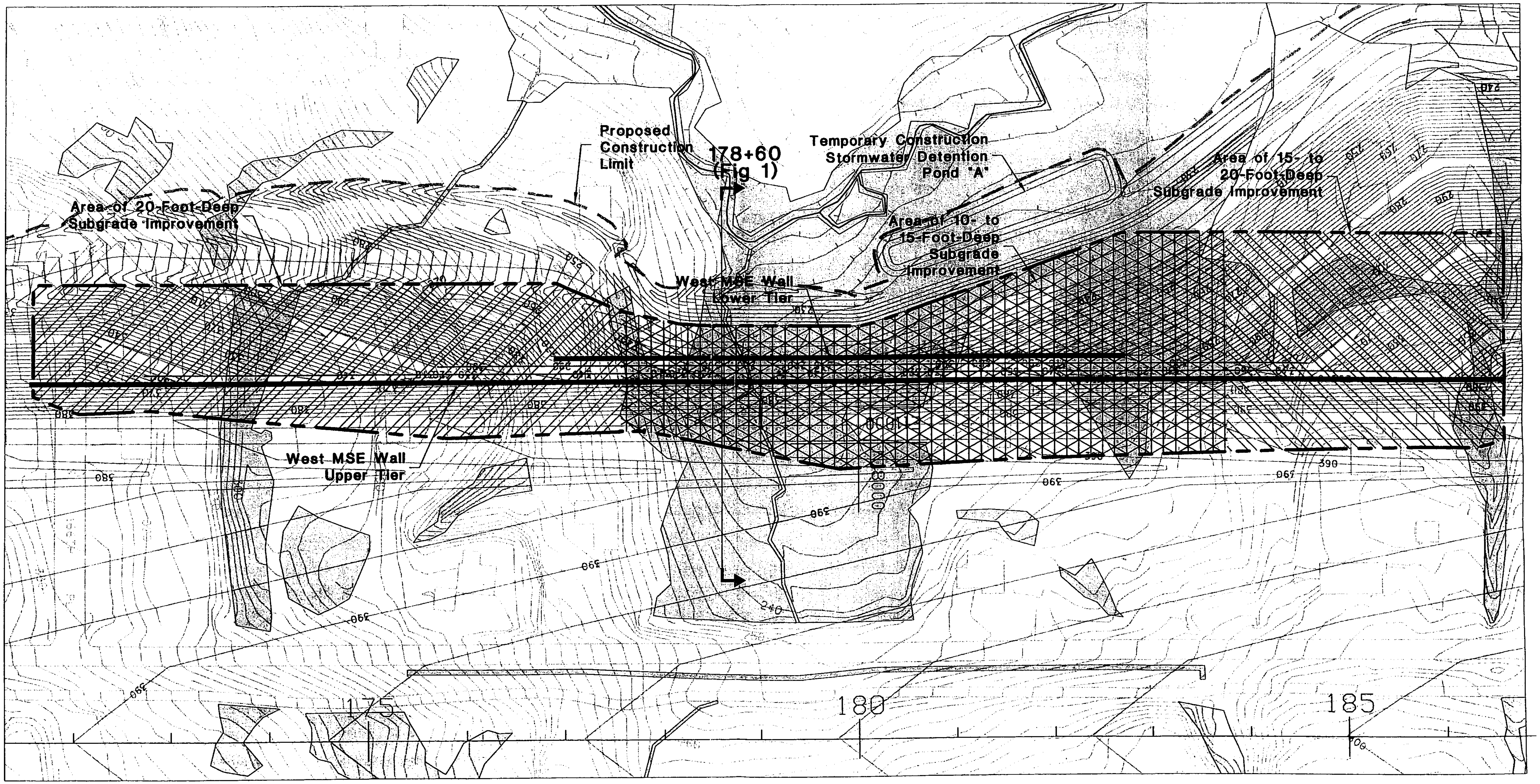
Figure 1

West MSE Wall Subgrade Improvement Plan



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetland delineation prepared from drawing provided by Parametrix entitled, "W_110800.dwg", dated November 8, 2000.

178+60 ↑⎯↑ Cross Section Location and Designation

N

0 100 200

Scale in Feet

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Figure 2

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Grain Size Envelope for Group 1A Fill Material

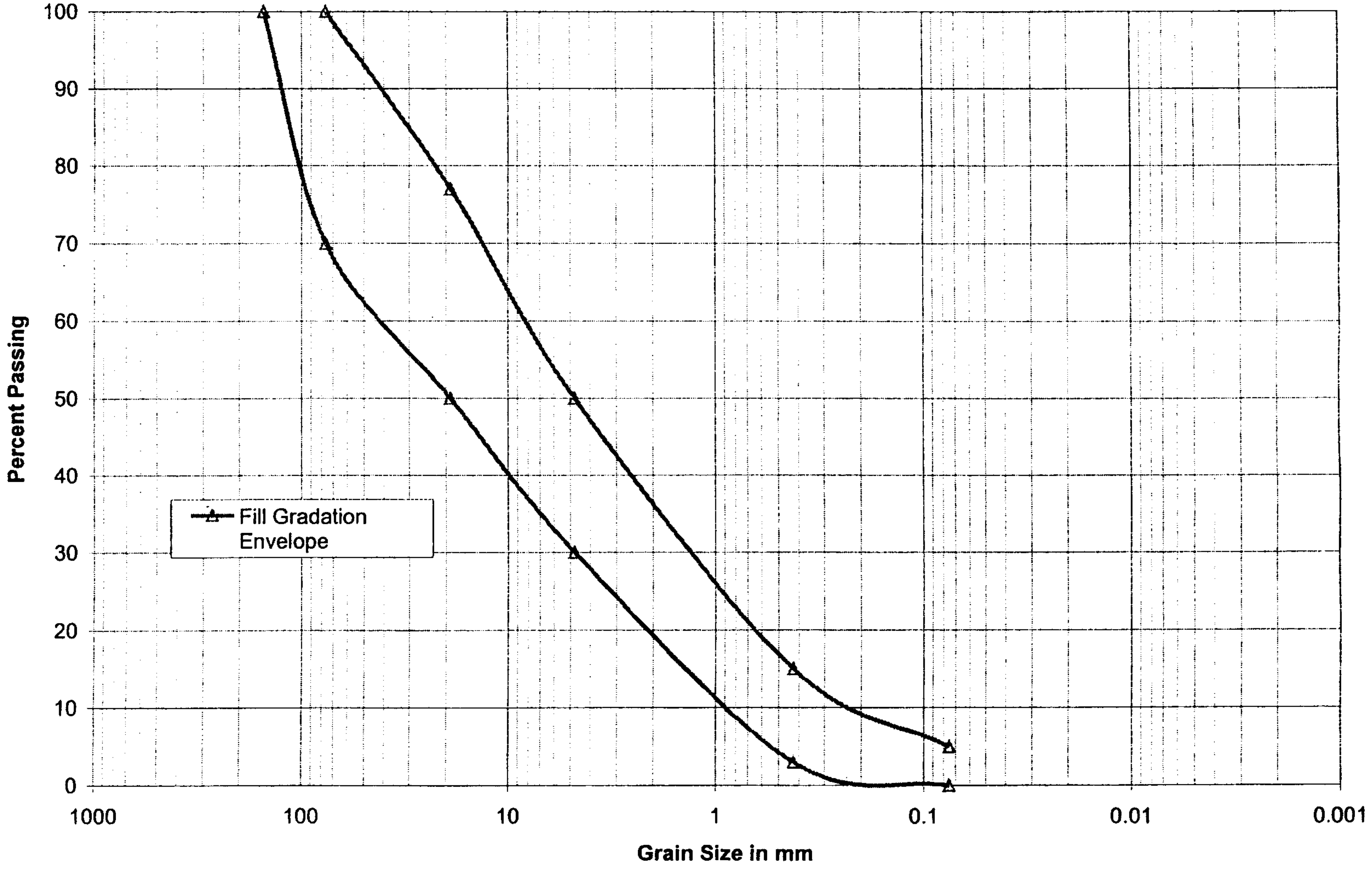

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Figure 3

Grain Size Envelope for Group 1B Fill Material

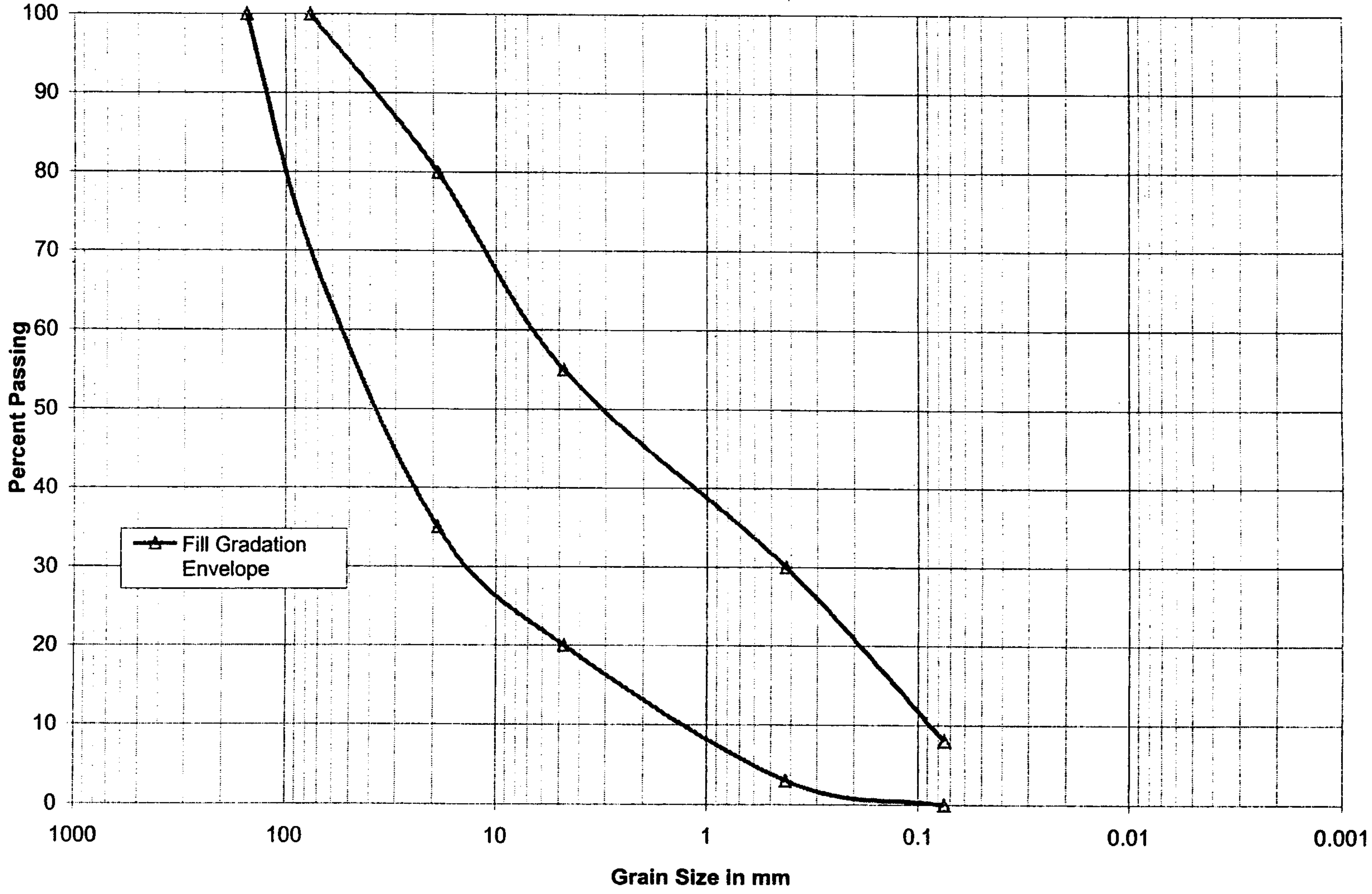

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Figure 4

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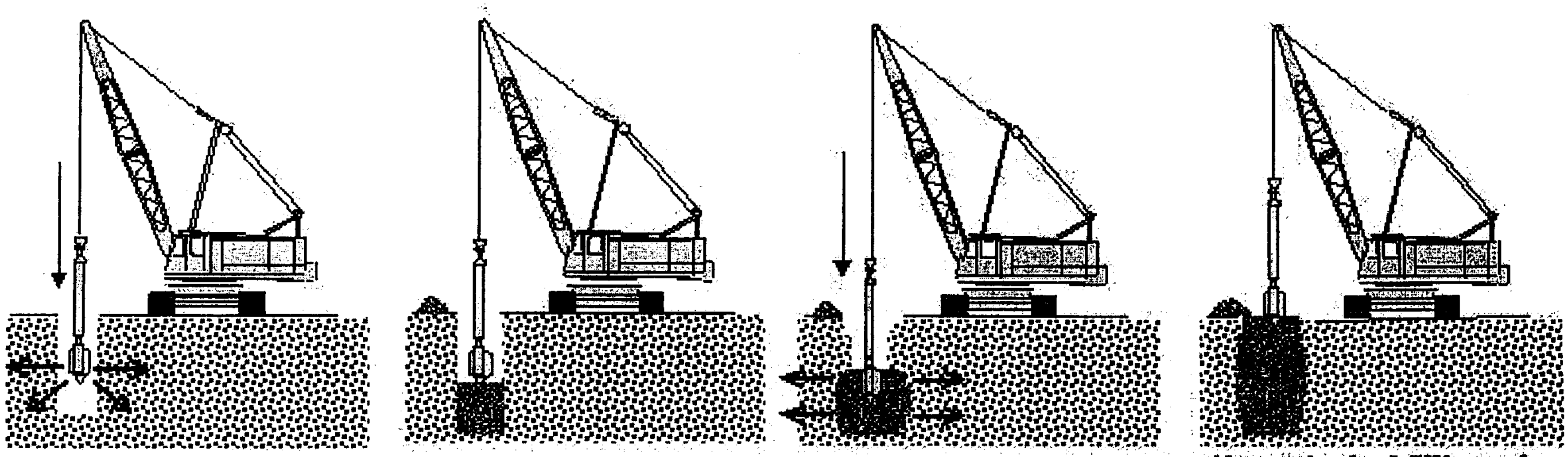
Stone Column Installation for Subgrade Improvement



Borehole is formed by sinking vibrator into the ground

Backfill material is placed into the borehole in stages and compacted

Alternating backfilling and compacting form continuous stone column

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Figure 5

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Stone Column Layout Plan

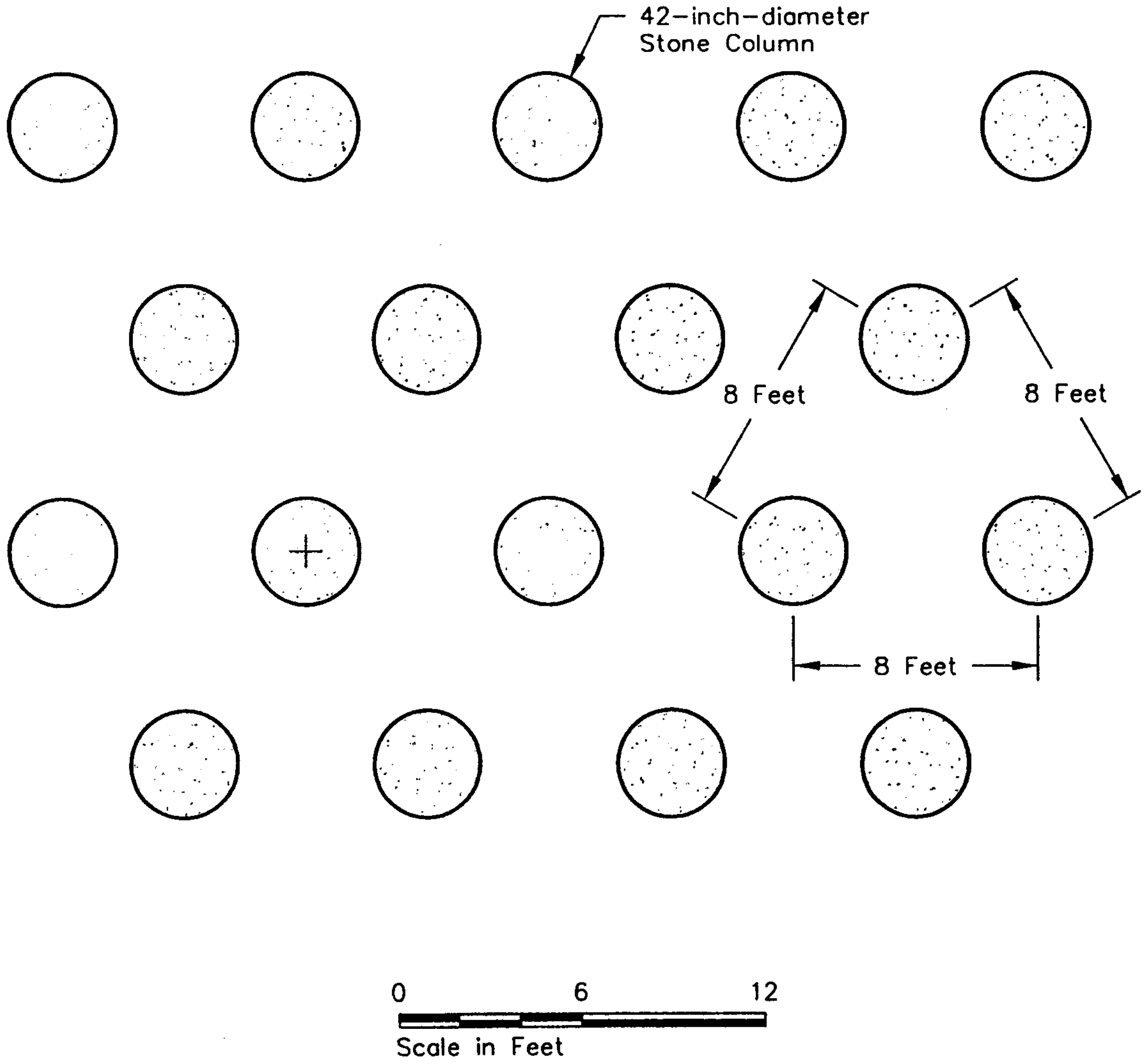

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Figure 6

Grain Size Envelope for Gravel Used in Stone Columns

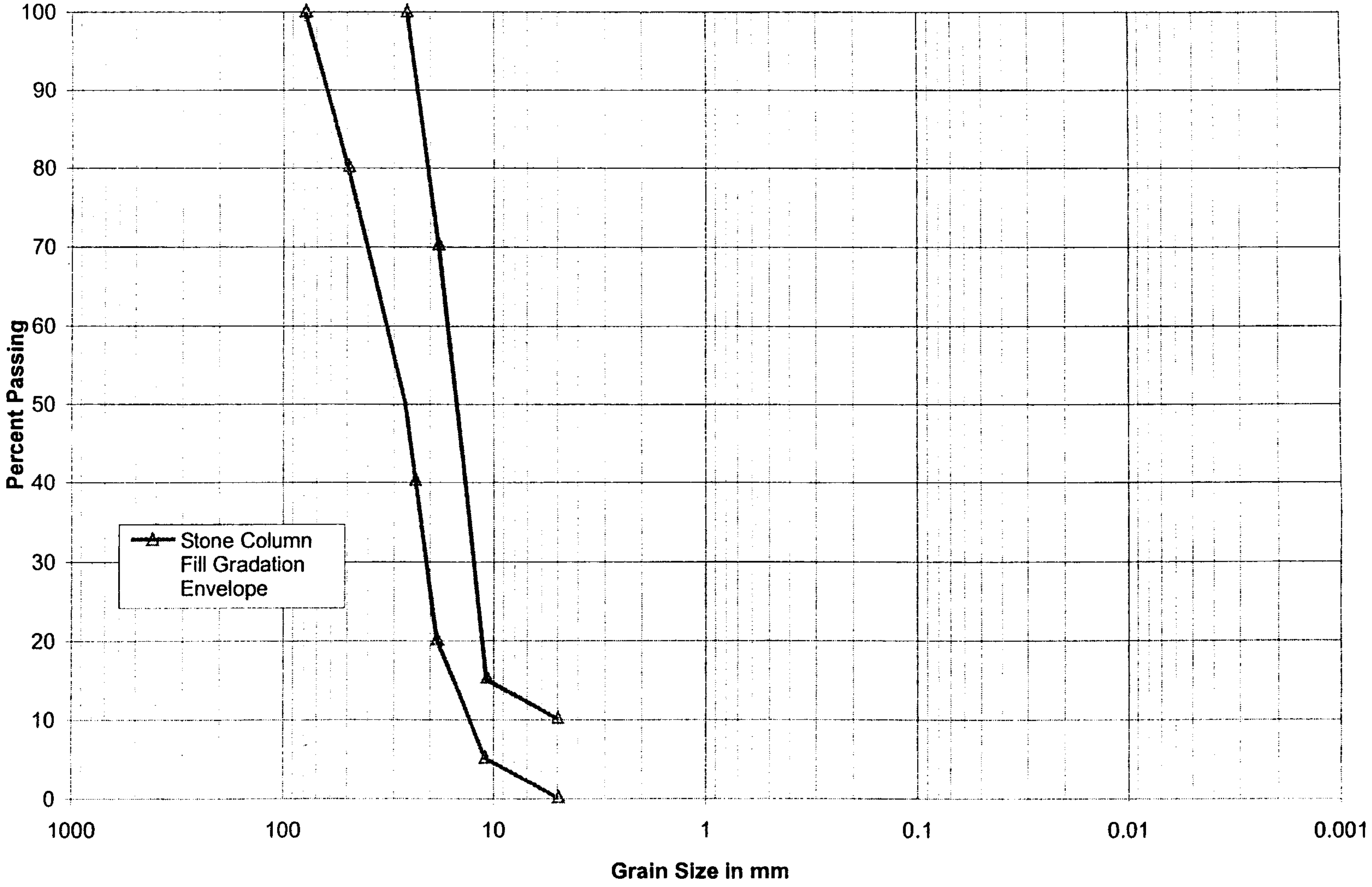

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Figure 7

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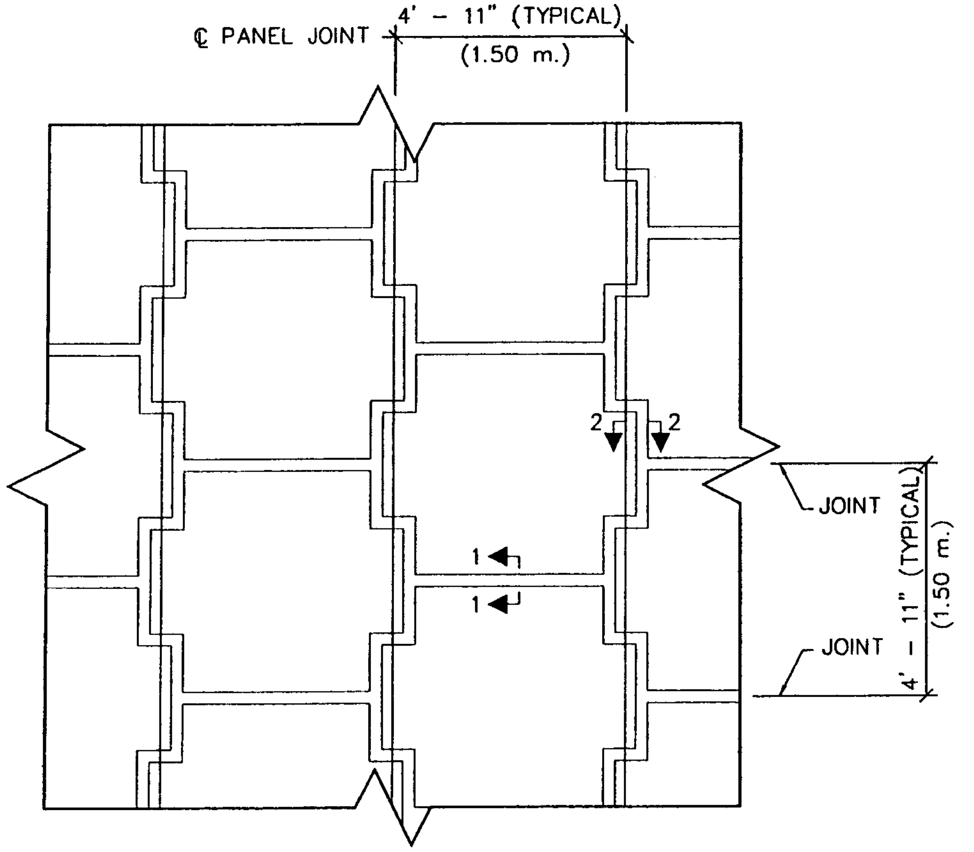
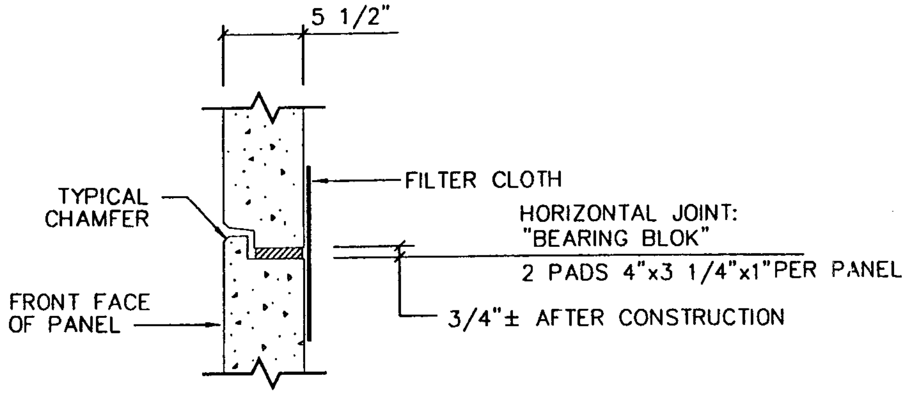
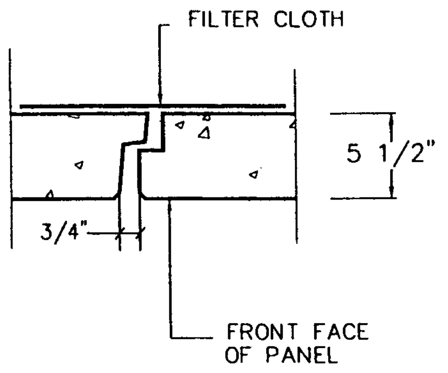
Joint Details Between MSE Wall Panels



TYPICAL MSE PANEL LAYOUT
PARTIAL ELEVATION - FRONT FACE
SCALE: 1/4" = 1'-0"



SECTION 1-1
SCALE : 1" = 1'-0"



SECTION 2-2
SCALE : 1" = 1'-0"

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Figure 8

B-3

Geotechnical Summary Report-Third Runway Embankment and MSE Retaining Walls

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Geotechnical Summary Report
Third Runway Embankment and MSE Retaining Walls
Seattle-Tacoma International Airport

Prepared for
The Port of Seattle
for Presentation to
The U.S. Army Corps of Engineers

November 2, 2001
4978-06

Prepared by
Hart Crowser, Inc.

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GEOTECHNICAL SUMMARY REPORT
THIRD RUNWAY EMBANKMENT AND MSE RETAINING WALLS
SEATTLE-TACOMA INTERNATIONAL AIRPORT

EXECUTIVE SUMMARY

This report describes the engineering process used to address design issues related to soil conditions, groundwater, and potential earthquakes for the proposed Third Runway at Seattle-Tacoma International Airport (STIA). Overall, the runway project will include placement of 17,000,000 cubic yards of compacted fill, 3,000,000 cubic yards of excavation, and construction of three "mechanically stabilized earth" (MSE) retaining walls that range from 50 to 135 feet in maximum height.

The executive summary of this report describes its purpose, general contents of the report, and results of the engineering analysis. A key part of the work described herein has been the involvement of an independent technical review board composed of distinguished experts to provide input into the geotechnical design process.

The main part of this report summarizes the geotechnical data collection and engineering analyses accomplished over a multi-year period by the Port of Seattle. The Seattle District, US Army Corps of Engineers (Corps) requested this executive summary as part of its review of the Third Runway Project.

Scope and Purpose of This Report

The scope of this report is to address the following:

- Introduce the reader to the design team and explain what each firm's role has been, including the involvement of outside reviewers;
- Describe the main features of the embankment and MSE retaining walls that are addressed in this report;
- Summarize information that has been collected on soil and groundwater conditions at the Third Runway site;
- Generally describe how the Port has studied the risk posed by earthquakes, and how seismic hazards are being addressed in the design process;
- Discuss the methods of engineering analyses used for design of the embankment slopes and retaining walls; and
- Describe how construction will include specific measures to mitigate problematic soil conditions, assure stability and meet seismic performance criteria.

The purpose of this report is to provide the Corps with a summary of the geotechnical work that has been accomplished for the Third Runway project, including references to other reports prepared by the Port's design team that provide more comprehensive discussion and details.

"Road Map" for Readers

A detailed table of contents, with lists of figures and tables, follows this executive summary. Thereafter:

- Section 1 is a general introduction to the Third Runway project and the engineering design team.
- Section 2 describes the geotechnical design process.
- Section 3 explains how soil and groundwater information was obtained and provides a geologic description of the project site.
- Section 4 discusses the methods of geotechnical engineering analyses used.
- Section 5 describes how the MSE wall design has incorporated geotechnical input and the results of independent checks and review.
- Section 6 discusses how construction will include "subgrade improvements" to mitigate problem soil conditions, and assure stability.

A bibliography of other reports that present geotechnical information for the Third Runway project follows the main text, along with a list of other technical references. Tables, figures, and the oversize plates cited in the text are included at the end of the report.

Engineering Quality Assurance

The Port of Seattle has assembled a team of notable engineering firms (HNTB, Hart Crowser, and RECo) to the design the Third Runway embankment and retaining walls. Qualifications of these firms to fill their specific roles, along with other experts who are providing support to the design team are discussed as part of the introduction to the design process, later in this report.

MSE retaining walls for the Third Runway are being designed in accordance with, and exceeding criteria established by the American Association of State Highway and Transportation Officials (AASHTO). Design of the project features is being accomplished with methods that are well-established and widely accepted by the engineering community. In addition, the Port has utilized advanced engineering analysis to check the design and evaluate performance of the Third Runway embankment and retaining walls. The Port's design meets or exceeds comparable "factor of safety" criteria used by the Corps for design of earth embankments (levees) and retaining walls.

To support the design team, the Port has used outside technical reviewers to provide independent assessment of various parts of the design process. The Embankment Technical Review Board (ETRB) members include Dr. James K. Mitchell, P.E., an expert in soil behavior, ground improvement, and earth reinforcement; Dr. I.M. Idriss, P.E., a recognized authority on earthquake engineering; and Dr. Barry Christopher, P.E., an internationally recognized expert in MSE wall design, construction, and performance.

The ETRB has worked closely with the Port's design team to develop an understanding of the Third Runway project and subsurface conditions at the site. The Board has provided detailed recommendations for improving design analyses and implementation of additional test and sophisticated analyses to improve the design. The Port's design team has addressed the Board's recommendations, and thereby enhanced the design. In addition to the ETRB, the Port has utilized other experts to provide independent technical input to the Third Runway design team, in several other specific instances since 1998.

This report describes specific input from the ETRB and others at different parts of the design process, which provides assurance that the work accomplished meets the highest technical standards.

Seismic Performance Goals for the Embankment and Walls

The Port has adopted seismic performance goals for the Third Runway embankment and MSE walls. The purpose of these goals is to clearly state the result of the geotechnical design process in terms that are easier to understand compared to the numeric factors of safety specified by the AASHTO code.

The Port of Seattle's design team gave considerable attention to selecting the level of earthquake shaking that would be used as the basis for design. This process considered statistical extrapolation of seismic data for our region, and explicitly considered the effect of variations in size, location and attenuation of future earthquakes. The methods used were subjected to scrutiny by the design team and the ETRB experts, and analyses by well-established methods were checked by independent methods to verify appropriateness of the design.

The Third Runway project is being designed as a "structure of ordinary importance" similar to large public buildings and other transportation infrastructure such as bridges and highways. In technical terms, the project is being designed to perform well for seismic ground motions that have a 10 percent probability of being exceeded in 50 years - or in other words, the level of shaking that has an average return period of 475 years.

Specific performance goals for the Third Runway project are to meet the following conditions for this design level of shaking:

- The MSE walls and embankment fill will remain stable. Some deformation is acceptable (up to a few feet) provided stress in the retaining wall materials are typically below the value allowed by the AASHTO code;
- There will be no wetland or creek impacts due to seismic shaking of the embankment or MSE walls; and
- There will be no operational impacts to the new runway related to movement of the embankment slopes and walls during an earthquake.

The engineering analyses described in this report have been accomplished iteratively with design modifications to assure the completed embankment slopes and MSE retaining walls will meet the performance objectives. As needed, the design has been modified by increasing the extent of "improvement" of subgrade soils and/or by increasing length or embedment of the MSE reinforcing. In addition to using the conventional engineering analyses specified by AASHTO, the Port has utilized advanced methods of analysis that are more typically used for design of dams impounding reservoirs.

The remainder of this report provides additional technical detail to expand on information provided in this executive summary.

CONTENTS

CONTENTS (Continued)

TABLES

FIGURES

PLATES

GEOTECHNICAL SUMMARY REPORT
THIRD RUNWAY EMBANKMENT AND MSE RETAINING WALLS
SEATTLE-TACOMA INTERNATIONAL AIRPORT

1.0 INTRODUCTION

This report provides a summary of the process used for geotechnical site investigations, laboratory testing, and analyses used for design and construction of the Third Runway embankment and MSE walls at Seattle-Tacoma International Airport (STIA).

Since 1998, the Port of Seattle has obtained detailed information on soil and groundwater conditions at the site of the proposed Third Runway. This information has been incorporated into the design so that construction will be appropriate for site conditions and conform to applicable building codes and engineering standards. A significant part of this process is to identify seismic hazards and assure that the completed facility meets the seismic performance goals set by the Port.

Geotechnical explorations and tests to identify and measure subsurface soil and groundwater conditions have been accomplished in phases, with intermediate analyses used to evaluate potential stability of the embankment and MSE walls and to identify areas where additional data collection was needed. Methods and results have been extensively reviewed and modified as needed to assure the completed project is safe and will perform as designed.

In several instances, the design approach utilized by the Port significantly exceeds the normal standard of care for transportation infrastructure, and incorporates techniques that are more commonly used for earthen dams. Clearly, performance of the Third Runway project is not as critical as a dam would be from the perspective of safeguarding human life. However, the Port of Seattle recognizes the project is a significant engineering structure, and the Port has utilized sophisticated engineering methods in recognition of the project location adjacent to sensitive and valued surface water resources, and the local community.

The purpose of this geotechnical summary report is to provide the US Army Corps of Engineers (Corps) with documentation of the geotechnical design process that has occurred, and the work in progress, which will lead to completion of design for the embankment and MSE walls.

1.1 Project Overview

The proposed Third Runway will be constructed in part on an embankment of compacted earth fill, so that the new runway elevation matches the existing airfield. Part of the runway will also be located on native soils near the south end of the existing airfield.

To accommodate the slope of the existing terrain, the new embankment will vary up to a maximum fill thickness of about 165 feet. The new embankment is being constructed as a zoned earth fill, with specific types of soil materials and compaction requirements used in different areas to provide necessary stability, drainage and settlement characteristics. Overall, the new embankment will include about 17,000,000 cubic yards of compacted earth fill. Approximately 3,000,000 cubic yards will be excavated onsite, leaving 14,000,000 cubic yards of fill to be imported.

The new embankment will be constructed on the west side of the existing airfield, see Figure 1. New embankment side slopes will have an average inclination of 2H:1V. Three retaining walls will be used to limit the extent of embankment slope from impacting sensitive portions of Miller Creek and adjacent tributary wetlands. These walls will have exposed faces that range up to maximum heights of 50 to 135 feet above ground.

The proposed retaining walls will be constructed of "mechanically stabilized earth" using engineering techniques more than 30 years old that use steel or other material to reinforce soil (FHWA 2001). The Port of Seattle evaluated eight types of retaining wall, and more than 60 wall and slope geometric arrangements before selecting the proposed MSE walls for the project. The methods and results of that evaluation are presented in the report entitled: *Draft Evaluation of Retaining Wall/Slope Alternatives to Reduce Impacts to Miller Creek Embankment Station 174+00 to 186+00, Third Dependent Runway,* that was prepared for the Port by HNTB Corporation, Hart Crowser, Inc., and Parametrix in April 1999. Note that the documents cited herein are listed in the bibliography at the end of this report (e.g., see HNTB, Hart Crowser, and Parametrix 1999).

The specific type of MSE walls being designed for the Third Runway utilize strips of steel layered in the compacted soil fill, and a relatively thin reinforced concrete facing to form a near vertical retaining wall face. MSE walls have been used around the world, with exposed face heights of up to 140 feet. This type of wall provides the advantages of very good seismic performance along with being very cost-effective. The completed walls will not impede groundwater seepage, or reduce base flow to the wetlands and Miller Creek, as discussed later in this report. (Note that a companion summary prepared for the Corps, provides additional detail on the hydrogeologic analyses of the Third Runway and adjacent wetlands and creeks; see Hart Crowser 2001l).

1.2 Embankment and MSE Wall Design Team

The Port of Seattle design team for the Third Runway embankment and MSE walls includes internationally recognized engineering firms and a distinguished independent review board. Figure 2 presents an organization chart for the project.

HNTB Corporation is the engineering project manager and civil engineer for the Third Runway project. In business since 1914, HNTB provides engineering and architectural design, planning and construction management for major transportation infrastructure projects. Recent airport experience includes major airport expansion and renovation projects at George Bush Intercontinental Airport in Houston, Midway Airport in Chicago, and Dulles international Airport near Washington DC.

HNTB has selected the Reinforced Earth Company (RECo) to design the MSE walls for the Third Runway project, and Hart Crowser Inc. to provide geotechnical engineering services.

- RECo was chosen as MSE wall designer for the Port of Seattle since they have more extensive experience with design and construction of high MSE walls than anyone else in the world. RECo has designed and successfully constructed more than twenty thousand MSE walls (FHWA 2001), including 12 that are more than 90 feet high, and have been successfully constructed. RECo designed two MSE walls that were built to about the same height as the maximum proposed wall height at SeaTac: a 137-foot-high wall built in 1979 in South Africa and a 133-foot-high wall built in Hong Kong in 1993. These walls were successfully constructed and have preformed well for some time.

- Hart Crowser Inc. is a local geotechnical engineering firm with more than 25 years experience in the Seattle area. Hart Crowser has been lead geotechnical engineer on major infrastructure projects such as the US Navy Home Port in Everett, WA and high-rise buildings in downtown Seattle, such as the Millennium Tower. Hart Crowser has been responsible for stability analyses for the right abutment at Mud Mountain Dam for the Corps of Engineers, Cedar Embankment at Chester Morse Lake for the Seattle Water Department, as well as major tailings embankments for the mining industry.

Hart Crowser has been responsible for design of MSE reinforced slopes that have been successfully constructed up to 150 feet in height.

Hart Crowser has retained expert subconsultants from the University of Washington and elsewhere to provide special geotechnical assistance on the Third Runway design team. These experts include Professor Robert Holtz, PhD, P.E., an internationally recognized MSE expert; and Professor Steve Kramer, PhD, P.E., an expert in earthquake engineering. Other expert subconsultants utilized for the Third Runway Project including Professor Pedro Arduino, University of Washington, for assistance in computer modeling; and Dr. John Hughes who is a specialist in *in situ* testing using the soil pressure meter. Specialty testing firms were also used to assist in geophysics (GeoRecon International); cone penetrometer testing (Northwest Cone); and drilling for soil sampling and installation of monitoring wells (Holt Drilling).

1.3 Embankment Technical Review Board (ETRB)

HNTB has retained the services of an internationally recognized group of eminent engineers to form a special technical review board, to provide independent technical review for the Third Runway project. Detailed resumes for the board members have been submitted to the Corps as part of the record for the 404 permit process. The board members include:

Dr. James K. Mitchell, P.E., is a University Distinguished Professor Emeritus at the Virginia Polytechnic Institute and State University and former Chairman of the Civil Engineering Department at the University of California, Berkeley. Professor Mitchell is an expert in soil behavior, ground improvement, and earth reinforcement.

Dr. I.M. Idriss, P.E., is Professor of Civil Engineering at the University of California at Davis. Professor Idriss is a recognized authority on earthquake engineering and on seismic performance of embankments and other soil structures.

Dr. Barry Christopher, P.E., is an independent geotechnical engineering consultant and internationally recognized expert in MSE wall design, construction, and performance.

The Port's Technical Review Board is coordinated by **Mr. Peter Douglass, P.E.** Mr. Douglass is an independent geotechnical consultant who has earned advanced degrees in civil engineering and geology. Mr. Douglass has more than 30 years of geotechnical engineering experience in the Seattle area as well as around the world.

The ETRB has been given the engineering data, design reports, results of calculations, and MSE design plans to date, for review and comment. Some or all of the members of the Board met with the Port's design team six times in the period November 2000 to October 2001, and have participated in several conference calls to provide expert input to the ongoing site explorations, analyses and design.

Working closely with the Port's design team, the ETRB has developed a good understanding of geotechnical issues pertinent to design and construction of the Third Runway. Drawing on their extensive expertise with analysis of earthquakes, soil reinforcement, and soil behavior, the Board has provided recommendations for improving the accuracy of analyses by the design team and use of sophisticated engineering methods to confirm results. Equally important is the practical knowledge and understanding the ETRB has from their extensive experience in construction and performance evaluations of large embankments and MSE walls around the world.

1.4 Other Independent Review Consultants

During preliminary stages of design, the Port of Seattle reviewed eight different types of retaining wall and more than 60 wall/slope combinations before selecting the proposed MSE wall configuration (HNTB, Hart Crowser, and Parametrix 1999). The evaluation of alternatives by the Port's design team was independently reviewed by qualified geotechnical engineers at Shannon & Wilson Inc. Shannon & Wilson is a highly regarded local engineering firm that is **not** part of the Port's Third Runway design team.

Shannon & Wilson concluded that the proposed MSE retaining walls are "most appropriate" for this site. Their findings were documented by letter and submitted to the Corps of Engineers as part of the public record for the Section 404 permit process.

The Port also obtained technical assistance in developing the scope for MSE wall design from Mr. Tony Allen, P.E. Mr. Allen is the State Geotechnical Engineer for the Washington State Department of Transportation (WSDOT). He has participated extensively in developing national standards for MSE design through his work with the American Association of State highway and Transportation Engineers (AASHTO).

AASHTO has developed a rigorous code for design of MSE walls based on the experience of numerous state transportation agencies, other engineering organizations, and research by the Federal Highway Administration (FHWA). This code is part of AASHTO's "Standard Specifications for Highway Bridges" and is the standard of the industry for design of MSE walls. The current version of is presented in the 16th edition, 1996, which has been updated with interim addenda through 2000 (AASHTO 1996-2000). Reference to the AASHTO code in this report indicates the provisions of the 1996 edition with inclusion of the interim addenda through 2000 (which is the most current addendum).

Based in part on recommendations from Tony Allen, the Port is designing the Third Runway MSE walls in accordance with the AASHTO code. Mr. Allen also recommended the Port utilize another industry standard, the HiTec Protocol, another industry standard as part of checking the MSE wall designs for the Third Runway project, and this is being done by HNTB.

2.0 GEOTECHNICAL SUMMARY

This section of the report provides a discussion of the geotechnical work completed and current progress of design of the Third Runway embankment and MSE walls that is discussed later in this report. Engineering aspects of the project that were described in a previous report to the Corps (Hart Crowser 1999c) are substantially unchanged.

This report summarizes the performance standards, and codes and standards that guide the geotechnical design process for the Third Runway project. This summary also describes the extensive soil explorations, tests and analyses that have been completed and/or are ongoing as part of final design. This report notes where additional geotechnical information is documented in the reports and technical memoranda that are listed at the end of this report, along with other references.

2.1 Performance Standards for Geotechnical Design

The geotechnical design for the Third Runway project conforms to several types of design performance standards. These include satisfaction of numerical requirements in the AASHTO code for design of MSE walls, as well as the readily understood seismic performance goals that were outlined in the executive summary to this report.

The Port has used a great deal of care to identify applicable design requirements and to verify that its design satisfies all the requirements of the AASHTO code. The Port has also addressed other engineering methods and criteria as a check on its design. In particular, the Port has accomplished deformation modeling with sophisticated computer modeling tools (programs referred to as QUAD4 and FLAC, that are described later in this report). Deformation models are important because they provide "real world" estimates of performance (such as "how far will a wall move during an earthquake?"). The deformation models used by the Port also provide a detailed picture of how stresses in the embankment and the MSE walls will change during earthquake shaking.

The approach used by the Port enables verification that not only does the design satisfy the code requirements, but also that estimated movements of the embankment and MSE walls are acceptable.

The Port has designed the Third Runway embankment and MSE walls to meet the following seismic performance requirements:

- MSE walls and fill will remain stable during and following the design level of earthquake shaking (average return interval of 475 years). Some deformations and/or cosmetic damage to the walls are acceptable provided the stresses are not large enough to cause failure.

- There will be no wetland or creek impacts from the embankment or MSE walls due to design level earthquake shaking. Movement will be limited to prevent soil sloughing or release of water that would impact surface water resources adjacent to the airfield.

- There will be no runway operational impacts due to the movement of the embankment slopes or MSE walls subject to the design level of earthquake shaking.

Note that the third performance criterion is specific to the embankment slopes and walls nearest to Miller Creek and adjacent wetlands. Potential effects of liquefaction on pavement within the interior part of the airfield have not been completed as part of the present study.

The design team is able to modify design of the subgrade improvements, MSE reinforcing, and/or the embankment materials and compare the estimated amounts of deformation for representative areas of the project, by the analyses detailed in this report. Seismic deformations analyzed to date for the final design configuration are typically well under a foot, and in some cases up to several feet, based on two independent types of analysis (FLAC and Newmark analyses, see Section 4.2 of this report). Rather than specify a single value for maximum allowable deformation, the design team is reviewing the results of the analyses to assess whether estimated deformations for different areas meet the performance criteria above. For comparison, allowable deformation of up to about three feet is commonly considered acceptable for slopes and earth embankments (ASCE 1983 and Seed 1979).

Finally, it is notable that the Port's design team considered embankment and wall performance over a wide range of circumstances. For instance, the Port checked and verified that the MSE reinforcing stress and deformation levels would still be acceptable if the design level earthquake happened after the reinforcing strength was reduced by the calculated corrosion loss corresponding to a 100-year service life. This combination of the assumed long-term corrosion loss prior to occurrence of the design earthquake is an example of the Port's conservative approach to design.

2.2 Codes and Standards

Design of the Third Runway is covered by the Washington State regulations covering the practice of Professional Engineering (Chapter 18.43 RCW). The senior engineers supervising the work described in this report are Professional Engineers, licensed by the State of Washington, employed by experienced engineering firms such as Hart Crowser, HNTB, and RECo.

The Port's design team reviewed applicable engineering codes and standards, and decided to design and construct the Third Runway MSE walls in accordance with the current edition of the AASHTO code and its interim updates. (AASHTO 1996-2000) and by reference the FHWA standards on MSE walls (FHWA 1997). This decision was based on research contacts with other organizations and companies designing and/or involved with construction of MSE walls, including Professor Robert Holtz, University of Washington; Mr. Tony Allen, WSDOT; and Mr. James (Mickey) McGee, Georgia DOT).

In accomplishing our work, the Port's design team has also referred to other standards of practice for engineering works, such as the engineering manuals developed by the U.S. Army Corps of Engineers (EM 1110-2-2502, EM 1110-2-1913, and ER 1110-2-1806). Geotechnical design work for the Third Runway is similar to what the Corps would require for design of MSE walls and earth embankments (levees), as is also discussed later in this report.

Historically, safety of earth structures such as embankment slopes and retaining walls has been evaluated by stability analyses, using "factors of safety" to assess adequacy of the design relative to the loads expected during the lifetime of the structure. In its simplest form, a "factor of safety" is the ratio of the forces tending to maintain stability divided by the forces tending to cause instability. The AASHTO code (and other standards such as Corps documents EM 1110-2-2502, EM 1110-2-1913, and ER 1110-2-1806) specifies target factors of safety that the design must achieve for specific methods of analysis, and/or goals of analysis where alternative methods of analysis are determined by site-specific conditions.

The Port's geotechnical design procedures and resultant Factor of Safety for each specific analysis meet all AASHTO criteria, and are consistent with procedures used by the Corps (EM 1110-2-2502; EM 1110-2-1913; and ER 1110-2-1806) for design of retaining walls and earth embankments for levees, (Corps 1989, 1995, and 2000). The Port's design significantly exceeds AASHTO requirements by including sophisticated deformation analyses and independent peer review input from the ETRB and others.

HNTB is using the "HiTec Protocol" as a guide for their independent check on RECo's design. The HiTec Protocol (CERF 1998) was developed by the Civil Engineering Research Foundation, an affiliate of the American Society of Civil Engineers, working in conjunction with FHWA and various state departments of transportation. Use of this protocol to check the design documents provides verification that the design includes all the elements found necessary for MSE walls to meet criteria developed by FHWA and the states.

2.3 Subsurface Explorations and Tests

Subsurface exploration and testing to determine soil and groundwater conditions affecting Third Runway design have been underway since the environmental review process for the project in the mid-1990s. The Port has used a phased approach to collect information for different parts of the site, with additional explorations accomplished as needed to better define conditions in particular areas. This report describes how 218 soil borings, 156 test pits, and other explorations have been used to identify and document soil and groundwater conditions; as the basis to assess environmental impacts and for design of the Third Runway.

Initially the subsurface exploration and test program accomplished by the Port of Seattle was based on local geotechnical experience and the results of initial observations. Existing mapped soils information was supplemented with soil borings and test pits to define baseline conditions for environmental review (FAA 1996 and 1997 and AGI 1996).

Additional explorations and tests were accomplished in specific areas to provide detailed information for related projects, conceptual design of the runway, and on-site borrow areas (CivilTech 1997, HWA Geosciences 1998, AGI 1998, and Hart Crowser 1998 and 1999a). A detailed description of the project was prepared for the Corps (Hart Crowser 1999c) with an accompanying subsurface conditions data report (Hart Crowser 1999b).

Subsurface information was subsequently obtained as part of a phased investigation that first addressed the locations for the three proposed MSE walls

(Hart Crowser 2000b (North or NSA Wall), 2000d (South Wall), and 2000f (West Wall)).

The type and frequency of subsequent explorations and testing were determined from assessment of the project's geologic environment; the extent of variation observed in initial test results; and additional data needs for specific parts of project design (Hart Crowser 2000j and 2001b and Appendix C of Hart Crowser 2001j). The design team had input from the ETRB in identifying the need for the final explorations and tests.

Field and laboratory work was accomplished in general accordance with standards developed by the American Society for Testing and Materials (see ASTM 2001 for current details). Table 1 summarizes the subsurface explorations that were accomplished; Table 2 lists the laboratory analyses that were used.

2.4 Seismic Basis of Design

The Port's design team made a considerable effort to select a reasonable basis of design to evaluate seismic effects on the Third Runway embankment and MSE walls. After review of procedures used for seismic design of other major structures and facilities, the Port of Seattle design team selected a probability-based approach that utilizes measurements from previous earthquakes throughout the Pacific-Northwest region, to predict the level of future seismic shaking at Sea-Tac (Hart Crowser 2000e and 2001a).

The design team completed a site-specific probabilistic seismic hazard assessment (PSHA) that utilizes current attenuation relationships and earthquake data, which have been peer-reviewed and are extensively used in Seattle and elsewhere for design of bridges and major buildings. The PSHA produced a relationship between the peak seismic acceleration and average recurrence period specific to the project site.

The Port of Seattle is basing design on the level of seismic shaking that has a 10 percent probability of exceedence in 50 years and an average return period of 475 years. Design using the 475-year seismic level of shaking is reasonable for the Third Runway facility. This level of event is commonly used for transportation facilities of normal importance, such as highway bridges and public buildings. While the Third Runway embankment and retaining walls are significant structures; they are not essential to airport operations. Potential damage to the Third Runway that might occur from an earthquake larger than the basis of design event would be similar to what might occur for other transportation facilities that use similar design standards. There is no risk of catastrophic loss of life due to seismic effects on the Third Runway, such as might result from failure of a dam or nuclear power plant.

Design for the level of shaking selected for the Third Runway is consistent with the approach that has been used for other major construction at STIA (e.g., the current South Terminal Expansion Project—a building that has thousands of people in it every day). The Third Runway design specifically addresses both the amount of movement that will occur as well as the stresses that will develop within the embankment and MSE walls as a result of earthquake shaking.

The design included development of several ground motions that were used in progressively more sophisticated analysis as design has proceeded. This aspect of design includes expert input from the University of Washington and has been closely scrutinized by the ETRB. Final design includes evaluation of stability and deformation for three ground motions (acceleration time history records) that were selected to represent the range of shaking obtained from the PSHA, as well as a ground motion from a deterministic source (the Seattle Fault) corresponding to a 475-year return period.

2.5 Stability and Deformation Analyses

The basic design approach for the Third Runway embankment and retaining walls is to use limit equilibrium stability analyses to determine the extent of subgrade improvement needed to meet minimum target factors of safety for different load conditions. For the MSE walls, the analyses included both global stability (to evaluate potential failure surfaces that extend behind and below the MSE reinforcing) as well as compound stability (to evaluate potential failure surfaces that pass through the reinforced soil zone). Reinforcement thickness, length, and/or embedment were increased as needed to meet target factors of safety. As a final check, deformation analyses are being used to verify the design will meet the Port's performance standards.

Limit equilibrium stability analyses were used to assess stability of the embankment including its MSE reinforced wall sections. Representative cross sections of the Third Runway embankment and retaining walls were analyzed for stability under the following load conditions:

- End of construction;
- Steady state;
- Seismic; and
- Post-liquefaction.

Cross sections were selected for analysis to represent the fill height, shape or geometry of the embankment/wall cross section, and the range in observed subsurface conditions. In most cases, our analyses showed that stability was more influenced by the strength of the existing subgrade soils, than the strength of the embankment or MSE fills, and "subgrade improvement" was needed to meet target factors of safety in specific areas (as described in Hart Crowser 2000 g). In some cases, increased length or depth of embedment of the MSE reinforcement was needed to meet target factor of safety (Hart Crowser 2000m, 2001g, and 2001k).

Two types of deformation analysis are being used to independently check performance of the Third Runway embankment and MSE walls.

- One method uses a finite difference program (FLAC) to calculate changes in stress and strain to simulate construction, and effects of the acceleration time history for seismic shaking. This analysis also considers the effect of reduced soil strength and stiffness due to liquefaction and cyclic loading.
- The other method uses a finite element program (QUAD4) to calculate accelerations throughout the embankment and MSE walls, and calculates displacements that occur when acceleration exceeds the yield acceleration for different parts of the embankment, using the Newmark method.

2.6 MSE Wall Design

MSE walls for the Third Runway are being designed to satisfy the following criteria:

1) Design requirements in the AASHTO code for MSE walls (AASHTO 1996-2000);

2) RECo in-house criteria, which include results of both theoretical and empirical methods of analysis, and performance criteria based on construction of similar walls;

3) Verification that RECo's design meets the target factor of safety criteria for both global and compound stability (as described above);

4) Verification that the proposed design will result in acceptable deformations for the design level of seismic shaking; and

5) Other functional and aesthetic requirements established by the Port.

All the analyses of the MSE sections were based on the calculated reinforcing section at the end of a 100-year performance period (i.e., including allowance for corrosion).

Design of the MSE walls is well along, including submittal of 30 percent draft plans, calculations, and quality assurance documents by RECo, and review by the rest of the design team (HNTB 2001).

2.7 Geotechnical Aspects of Construction

The culmination of the tests and analyses described in this report is the production of construction contract documents that show how the embankment and MSE walls must be constructed to achieve the design expectations. The limits of subgrade improvement, which were selected by design to meet target factor of safety in the stability analyses, will be shown on construction plans with accompanying Specifications that include detailed information on the quality of construction required.

Within the areas where subgrade improvements are needed, the Port plans to excavate the problematic soils (generally loose saturated sands, soft to stiff silt and clay soils, and peat) and replace them with densely compacted select fill. The Port evaluated nine alternative methods of subgrade improvement (Hart Crowser 2000g) and selected removal and replacement of problem soils (sometimes referred to as overexcavation and replacement) as the most desirable alternative because it will provide the highest level of ground improvement and the best quality control among the available alternatives.

The construction contract documents for the Third Runway project also specify the length, thickness, spacing, and arrangement of steel reinforcing strips that support the MSE walls, and the allowable soil types and compaction requirements needed to assure the constructed embankment meets the criteria used to achieve the target factors of safety and anticipated deformations.

The remainder of this report presents information on the soil and groundwater data used for design, the methods of geotechnical analyses that were used, and input of geotechnical input to the MSE design. Section 6.0 provides additional detail on geotechnical aspects of the proposed construction process.

3.0 SOIL AND GROUNDWATER DATA USED FOR DESIGN

This section of the report provides a summary of the methods of investigation used to assess subsurface conditions at the project site and an overview of geologic conditions that influence design. The final part of this section discusses selection of representative soil properties for use in the stability analyses.

3.1 Subsurface Explorations and Soil Tests

A large number of both conventional and special subsurface explorations have been accomplished to obtain geotechnical engineering parameters for the Third Runway project. These explorations are summarized in Table 1, and shown on a Site and Exploration Plan, Plates 1, 2 and 3, included at the back of this report.

Preliminary Explorations

As part of the environmental impact assessment and initial planning for the Third Runway project, the Port of Seattle accomplished 91 soil borings and a number of test pits and hand auger explorations (AGI 1996 and 1998). The borings were typically accomplished with hollow-stem auger or mud rotary drilling techniques, using the Standard Penetration Test (SPT, per ASTM D 1586) to collect soil samples and information on soil density or consistency. (Note throughout this report, applicable procedures developed by the American Society for Testing and Materials, are referred to simply by their test method designation. See ASTM 2001 for complete details). Nineteen of the initial borings were completed as groundwater observation wells.

Geotechnical Design Phase Explorations

During the geotechnical design phase, Hart Crowser completed an additional 127 hollow-stem auger borings, again using SPT to collect soil samples. At some of these boring locations, parallel borings were also drilled to obtain thin wall (Shelby) tube samples for laboratory testing. (These additional borings were not counted or numbered separately because they were merely to collect additional undisturbed soils samples at specific locations where the primary borings had been used to identify the soil strata).

Hart Crowser completed 65 of the design phase explorations as groundwater monitoring wells. All monitoring well locations were surveyed and groundwater level observations were recorded over a period of 1 to 3 years.

In addition to the borings, the main geotechnical design phase included 122 test pits excavated with a track-hoe, and numerous shallow hand auger explorations. Cone penetrometer test (CPT) soundings were completed at 48 locations to obtain information on stratigraphy, strength and stiffness of fine-grained soils (primarily silt and clay), as well as soil pore pressure parameters.

Additional Special Field Tests

During the design phase, a number of other special field tests were accomplished to better define subsurface conditions. These tests included:

- Two types of infiltration tests were used to evaluate effects of construction on groundwater, and stormwater infiltration. The tests included ring infiltrometer tests accomplished with a double-ring apparatus in test pits, and falling head infiltration tests accomplished in well casings;
- Vane shear tests were accomplished to obtain *in situ* measurements of undrained and remolded strength of clay and peat soils;
- Pressuremeter tests were used to obtain *in situ* stress-strain data, to enable calculation of soil shear modulus; and
- Down-hole compressional and shear wave velocity measurements were completed in a 100-foot-deep boring at each MSE wall location.

The last two of these special tests were accomplished specifically to obtain soil parameters for accurate modeling of MSE wall performance as discussed later in this report.

Soil samples were typically obtained in each boring at 2.5- to 5-foot-depth intervals. Each visible soil strata was individually sampled in the test pits and hand auger explorations.

Soil samples were visually classified in the field, in general accordance with the Standard Practice for Description and Identification of Soils (ASTM D 2488; see Figure 3). The classification is based on describing the density or consistency of the soil, moisture content, color, and gradation. Where present, organic material or debris was also noted.

Results of the explorations and field tests are presented in data reports, which are listed in the bibliography at the end of this report. (See for instance: AGI 1996 and 1998, CivilTech 1997 and 1998, HWA Geosciences 1998, and Hart Crowser 1999a, 1999b, 2000b, 2000d, 2000f, 2000j, 2000n, 2001b, and 2001j).

Laboratory Testing

Soil samples were delivered to Hart Crowser's laboratory in Seattle and logged into the sample tracking system. Hart Crowser's laboratory is currently certified by the Army Corps of Engineers to accomplish geotechnical testing on Corps' projects.

Upon receipt in the laboratory, the visual classification prepared in the field was checked under more controlled conditions, and samples were selected for testing. Moisture content was determined for most of the samples, and representative samples were selected for tests such as plasticity, gradation, strength, or compressibility.

Testing was accomplished in general accordance with the ASTM methods that are listed in Table 2.

All laboratory test results were reviewed by a Hart Crowser engineer, who prepared the data reports, summarized information for specific soil units, and compared results with properties estimated or reported by others for similar soils. In-house technical memoranda were prepared in some cases to summarize and document specific test results, (e.g., Hart Crowser 2001i and Appendix D in Hart Crowser 2000k).

3.2 Geologic Overview

For purposes of designing the Third Runway embankment and retaining walls, site geologic conditions can be divided into three areas of interest: a) relatively soft or loose surficial soils; b) dense or hard glacially overridden soils; and c) location and flow of shallow groundwater. Bedrock is quite deep and is not an explicit part of design except as it relates to potential earthquakes (discussed later).

Surficial Soils

Soils underlying the proposed Third Runway embankment typically consist of up to about 20 feet of loose to medium dense sandy soil with varying amounts of silt or clay, interbedded (or overlain) with soft to stiff sandy silt, clay, peat, and fill. Figure 3 summarizes the system we used to classify these soils and serves as a key to the exploration logs presented in other Third Runway project reports (Hart Crowser 1999a, 1999b, 2000b, 2000d, 2000f, 2000j, 2000n, 2001b, and 2001j). The surficial soils generally present at the Third Runway site included the following components, although not all these types are present at all locations.

Topsoil. Topsoil, consisting of a loose mixture of silt and sand with roots and other organic material, was intermittently encountered in our explorations, ranging from about 1/2 to 1 foot thick, where it was encountered.

Pre-Construction Fill. Existing fill, consisting of a loose to medium dense, variable mixture of silty or clayey sand and gravel, was encountered in some locations, typically associated with prior site use, including paved streets and residential housing. Fill is generally absent in the low-lying portions of the site adjacent to the creeks and wetlands. Most of the fill is less than 1 foot thick but occasionally varies up to 10 or more feet in thickness. The density and granular nature of the fill materials resembles the recessional outwash deposits described below, and the fill is sometimes difficult to distinguish from the outwash.

Alluvial Deposits Consisting of Interlayered Silt, Clay, Sand, and Peat. Alluvial deposits are sediments associated with Miller Creek or Walker Creek. These soils occur mainly in the low-lying areas to depths of up to about 15 feet.

The consistencies of the clay and silt deposits vary widely from soft to stiff or hard, and these soils generally contain sand fractions ranging up to about 30 percent by weight. Typically these clays and silts are low in plasticity, see Figure 4.

The alluvial sands are generally loose to medium dense, and range from non-silty to very silty or clayey (i.e., up to about 50 percent fines [particle sizes less than 0.074 mm]).

Peat was encountered in portions of some wetlands located near the west central part of the embankment, and in the north part of the embankment, both areas near to Miller Creek. Both surficial and shallow buried peat deposits were encountered. Buried deposits tend to be medium stiff to stiff, whereas the surficial peat exhibited consistencies in the very soft to soft range. Buried peat deposits were encountered at depths ranging from about 3 to 10 feet and varied in thickness between about 1 to 6 feet. Peat deposits near the ground surface varied in thickness between a few inches and about 2 feet.

Colluvium and Recessional Outwash. These soils generally consist of medium dense to dense, slightly silty to silty, slightly gravelly to gravelly sand.

Colluvium refers to soils that have been displaced by erosion or other natural processes on slopes subsequent to their original deposition. Recessional outwash overlies the glacial till, and overlies the advance outwash where the glacial till has been eroded. Thickness of the colluvium and recessional deposits varies over the site, but is generally less than 20 feet. These deposits vary in gradation over relatively short distances, and are intermittent or absent where alluvial materials are located.

Glacially Overridden Soils

Glacial Till. Glacial till soils observed at the site consist of dense to very dense, slightly gravelly to gravelly, silty to very silty sand. In general, glacial till differs from the overlying recessional soils by having a higher silt content and much higher density.

Glacial till is generally encountered within 10 to 20 feet of the ground surface, on the upper (eastern) part of west-facing slope on the west side of the existing airfield. The glacial till was not encountered in the explorations in downslope areas to the west, where the explorations terminated in advance soils. Springs and seeps occur along the western edge of the glacial till due to both perched water and interflow above the glacial till horizon as well as groundwater seepage from the aquifer in the underlying advance sands.

Advance Deposits. Underlying the glacial till are soils that were deposited in advance of glaciation and subsequently overridden. These advance soil deposits consist of dense to very dense, slightly silty, slightly gravelly to gravelly sand, with local interbeds of very stiff to hard silty or clayey soils. In general, but not always, the advance deposits can be distinguished from the glacial till by lower silt or clay content.

Groundwater

Shallow groundwater flows through the fill, colluvium, and alluvial soils, including seepage perched on the glacial till and on silty or clayey zones of the soils noted above. Seepage varies seasonally.

Shallow groundwater within the advance outwash soils and perched water in the overlying soil units combines to produce the "Shallow Regional Aquifer" in low lying areas adjacent to Miller Creek and Walker Creek. The Port has been monitoring water levels in this area for several years (1994 to date for some of the wells installed for the Third Runway), to assess the potential effect of embankment construction on base flow to these creeks and their tributary wetlands.

Shallow groundwater elevation contour maps have been developed and presented in several reports dealing with different parts of the project (Hart Crowser 1999c, 2000b, 2000f, and 2001j).

STIA also overlies two other aquifers that are considerably deeper and are used for water supply (AGI 1996).

An accompanying memorandum prepared for the Corps (Hart Crowser 2001l) discusses hydrogeology of the region and modeling to evaluate the effect of the Third Runway embankment on groundwater recharge and surface water hydrology.

3.3 Selection of Soil Parameters for Use in Analyses

The field and laboratory test results were reviewed to determine appropriate values for input to the geotechnical engineering analyses. Conservative test values were typically selected for use in the stability analyses, based on inspection of the range of data collected. Table 3 shows values of soil parameters used for different soil units in the stability analyses. Additional information on parameters used in the deformation analyses is presented in Hart Crowser (2000i).

Parameter values used in the geotechnical analyses were conservatively selected based on the range of results measured. Examples of this are illustrated on the figures described below.

- Figure 5 shows the range of drained friction angles measured over the range of embankment confining pressures (up to about 12 tons per square foot). Values were typically well above the 32 degree value used in analyses (see Table 3) especially at lower confining pressures.
- Figure 6 shows the undrained strength ratio (undrained shear strength normalized with respect to effective overburden pressure) used in our analyses, compared to undrained strength test results for the Third Runway project, and values reported by others for various soil types (Ladd 1986).
- Figure 7 shows the range in values for coefficient of consolidation, c_v, measured for silt and clay soils encountered in our borings. The design value used for analysis of pore pressures at the end of construction (EOC) is below most of the measured values, which results in conservative estimates of the rate of consolidation.
- Where possible, laboratory test measurements for parameters such as undrained strength, fines content, and consolidation coefficient were compared to field test measurements with the CPT, and field exploration data were used to define the areas where specific soils parameters were applicable.

Results of the laboratory tests are presented in data reports and memoranda, (See for instance: AGI 1996 and 1998, CivilTech 1997 and 1998, HWA

Geosciences 1998, and Hart Crowser 1999a, 1999b, 2000b, 2000d, 2000f, 2000j, 2000n, 2001b, and 2001j).

4.0 METHODS OF GEOTECHNICAL ANALYSIS

A number of geotechnical analyses have been completed for design of the Third Runway embankment and retaining walls, specifically including 1) stability of the embankment slopes and MSE walls; and 2) deformation, or movement, of the slopes and MSE walls, for both steady state and seismic conditions. These two types of analyses are discussed in this report because they pertain directly to the question of potential off-site impacts that is of interest to the Corps. (Other types of analyses such as settlement of the embankment, or infiltration and groundwater effects of the embankment, are discussed in Hart Crowser 2000g, Appendix C in Hart Crowser 2000o, and Hart Crowser 2001l).

4.1 Stability Analyses

Limit equilibrium stability analyses were used to evaluate design of the embankment fill, to design the extent of subgrade improvements, and to check the MSE wall reinforced zones. The AASHTO code specifies that both static and seismic analyses should be accomplished, and specifies target factors of safety that should be achieved. (Note, the Port used the same approach for "end of construction" analyses, which is not specified by AASHTO, but was appropriate to include for some soil conditions at the site.)

Table 4 lists the target factors of safety for limit equilibrium analyses used for the Third Runway. For comparison, Table 4 also shows the target factor of safety criteria used by the Corps of Engineers for comparable analyses of levees, as presented in EM 1110-2-1913 (Corps 2000).

Hart Crowser primarily used the program SLOPE/W (Geo-Slope 1998) for limit equilibrium analyses. We checked its performance by comparing analyses on specific MSE embankment sections to analyses using another well-documented program: UTEXAS3 (Hart Crowser 2001b).

To date 30 representative cross sections of the Third Runway embankment and retaining walls were analyzed using limit equilibrium analyses. Additional sections may be selected for further analysis depending on work in progress. Hart Crowser analyzed five to eight sections for each of the three MSE walls, and eight other sections to represent different areas of the 2H:1V embankment slopes. The sections used for analyses were selected to evaluate the range in subgrade conditions and embankment/wall geometries for the Third Runway project as a whole.

Figure 8 shows how soil strata are depicted for stability analysis of a typical embankment slope that is being checked for a potential failure surface; dozens of potential failure surfaces were analyzed for each cross section. In each case where the result did not meet or exceed the target factor of safety, the design was modified and the analysis was repeated until the target was met.

The analysis cases used for the Third Runway are described below:

- End of Construction (EOC) refers to the analysis of stability related to build-up of excess pore pressures in fine-grained soils in the embankment fill or subgrade, as construction proceeds. In cases where analyses using "worst case" unconsolidated, undrained (UU) strength parameters for foundation soils produced factor of safety values below the target level, stability was reanalyzed using more realistic partially consolidated strength properties. Our partially consolidated analysis used a spreadsheet model to calculate changes in subgrade strength due to pore pressure development and dissipation. Pore pressures were calculated as a function of the construction fill placement rate and measured thickness of silt and clay subgrade soils in different parts of the site. Target factor of safety for the EOC condition for MSE walls is 1.3.

- EOC analyses also included analysis of the range of excess pore pressures observed in previous construction with fine-grained embankment fill. Analysis of the Third Runway embankment for the pending Phase 5 construction with the maximum pore pressure values reported in the literature for embankments more than 200 feet high produced factors of safety of 1.3 or greater (Clough and Snyder 1966). We anticipate similar results would be achieved for future stages of embankment design. Hart Crowser is also using EOC analyses to check temporary cut slopes for the subgrade improvement excavations.

- Steady-state refers to the stability of the embankment under long-term conditions (i.e., with gravity loading but not seismic). Soil strength values used in these limit equilibrium analyses included the effect of strength gain due to consolidation from embankment construction, so a higher factor of safety is expected for some soils compared to the EOC condition. AASHTO allows the factor of safety for this condition to be either 1.3 or 1.5 depending on importance of the wall. Target factor of safety for MSE walls subject to steady state conditions for the Third Runway project is 1.5.

- Seismic stability analyses consisted of pseudo-static limit equilibrium type analyses, to conform to AASHTO criteria (AASHTO 1996-2000). AASHTO requires the target factor of safety for seismic conditions to be at least 1.1, which is the value used by the Port. The seismic hazard analysis used to obtain representative ground motions is described below in Section 4.2, (see also Hart Crowser 1999d, 2000e, and 2001a).

- For preliminary analyses, Hart Crowser used a value of 0.16 for the pseudo-static horizontal load vector in the limit equilibrium analyses. The initial value of 0.16 used for the pseudo-static load was half the peak horizontal acceleration (PHA) obtained from the averaged results of one-dimensional ground motion analysis (PROSHAKE) for embankment heights of 40 and 160 feet. Final design used half the PHA from the two-dimensional QUAD4 analyses discussed below, where this value was greater than 0.16.

  Hart Crowser used the consolidated undrained soil strength for cohesive soils (silts/clays) for the pseudo-static stability analysis (and the FLAC analysis discussed below) to account for the combined effect of both strength increase due to higher strain rate and potential strength reduction due to cyclic shaking.

  Minimum target factor of safety for the seismic (pseudo-static) stability specified by AASHTO is 1.1. For some areas, the analyses produced factors of safety between 1.0 and 1.1 for small potential failure surfaces near the toe of the fill or shallow raveling type zones on the upper surface of embankment slopes. In these instances, Hart Crowser verified the target factor of safety was met for deeper potential failure surfaces and relied on deformation analyses discussed below to verify there was no potential for progressive failure (i.e., potential for shallow raveling to lead to more extensive instability).

- Post-liquefaction stability analyses utilize reduced soil strength to represent the strength loss that occurs in some soils when excess pore pressures develop due to seismic shaking. Details of the liquefaction trigger analysis and estimation of post-liquefaction residual strength are discussed below in Section 4.3 (also see Hart Crowser 2001d). The target factor of safety for the post-liquefaction residual strength analyses was 1.1.

The limit equilibrium analyses were accomplished for both global stability and compound stability for the MSE walls. "Global stability" refers to analysis of potential instability due to failures below and behind the reinforced zone of the MSE walls, as shown on Figure 9. "Compound stability" refers to analysis of potential stability that extends through the reinforced zone as well as behind or below it (see Figure 10). In each analysis, a wide range of potential failure surfaces was examined, including circular surfaces, wedge-shaped surfaces, and irregular surfaces.

Limit equilibrium analyses were initially accomplished to estimate the spatial limits of subgrade improvement that might be needed using an assumed geometry for the reinforced zone behind the MSE walls (Hart Crowser 2000g). Additional analyses were accomplished for the 2H:1V embankment (Hart Crowser 2000o) and for the MSE walls using the reinforced zone geometry presented in RECo's 30 percent plans (Hart Crowser 2000m and 2001i). Limit equilibrium analyses for final design are currently in progress. For some of these analyses we are also considering the effect of using different backfill materials with higher strength values to potentially reduce the extent of subgrade improvements for particular sections, while still meeting performance standards.

MSE Wall Design Analyses

Section 5 of this report provides a summary of the MSE design process for the Third Runway; this subsection summarizes conventional limit equilibrium slope stability analyses that were utilized to check and/or modify the MSE design. Other forms of limit equilibrium analyses were also used by RECo for internal design of the reinforced zone for each of the Third Runway MSE walls in accordance with AASHTO code.

Design of MSE walls for the Third Runway is required to satisfy all of the following criteria:

1. Design requirements in the AASHTO code for MSE walls (AASHTO 1996-2000);

2. RECo in-house criteria, which include results of both theoretical and empirical methods of analysis, and performance criteria based on construction of similar walls; and

3. Verification that RECo's design meets the target factor of safety criteria for both global and compound stability (as described above); and

4. Verification that the proposed design will meet acceptable deformation criteria.

Table 5 summarizes geotechnical design requirements for the Third Runway MSE walls (for more detail see Hart Crowser 2000h). As noted above, the final design satisfies the strictest criteria from both RECo and AASHTO.

There is considerable similarity between the Third Runway design based on the AASHTO code requirements and the design criteria used by the Corps of Engineers for design of retaining walls, as presented in the engineering manual EM 1110-2-2502 (Corps 1989). Table 6 shows the Corps design criteria for retaining walls. The Corps criteria are very nearly the same as the Third Runway criteria presented in Table 5, with two minor exceptions:

- AASHTO allows the factor of safety for bearing capacity to be 2.0 on the basis of a detailed geotechnical analysis, while the Corps requires a value of 3.0. Analysis by Hart Crowser indicated the bearing capacity factor of safety for the Third Runway MSE walls exceeds the minimum value specified by the Corps.

- In addition, the sliding analysis specifically for walls on bedrock required by the Corps (see Note 3 in Table 6) is not applicable for the Third Runway, because the Third Runway walls are not founded on bedrock.

Except for the bedrock criterion that is not relevant, the design used for the Third Runway MSE walls meet or exceed comparable criteria used by the Corps (1989).

4.2 Deformation Analyses

Dynamic deformation analyses were used to assess performance of the Third Runway embankment and MSE walls by calculating how much movement would be produced by the design level shaking. The deformation analyses provide an independent check of the adequacy of the subgrade improvements, which were designed using the limit equilibrium analyses.

Two types of deformation model were used: a Newmark analysis and the finite difference model FLAC.

Newmark Analysis

Review by the ETRB identified reliance on pseudo-static analyses as one area where the Port could improve its design over the AASHTO requirements and recommended that a Newmark deformation analysis also be used.

The Newmark analysis method calculates displacements that will occur when the acceleration due to seismic shaking exceeds the level referred to as the yield acceleration (which is the acceleration that would produce a factor of safety of 1.0 in a pseudo-static analysis) (Newmark 1965). For this analysis, Hart Crowser used successive pseudo-static limit equilibrium analyses (accomplished with

Slope/W) to determine the yield accelerations for potential failure surfaces. In all cases we checked 10 or more potential failure surfaces for each of several cross sections. A two-dimensional site response program, QUAD4, was used to calculate seismic acceleration for each of these potential failure masses, using one or more acceleration time histories. Displacements were calculated by double integration of the motion during the times when acceleration produced by the time history exceeds the yield acceleration value.

Figure 11 illustrates a typical distribution of potential failure surfaces for the Newmark analysis of a MSE wall section, and the corresponding tabulated values of the yield acceleration k_y and maximum seismic acceleration k_{max}. We used both direct integration of the time history to estimate deformation, as well as the simplified approach using a k_y/k_{max} ratio as described by Makdisi and Seed (1978), since different magnitudes of deformation were produced by these methods for some of the sections. In most cases evaluated to date, the analysis showed negligible displacements (<0.1 foot). Subgrade improvements are being re-evaluated for two sections that had horizontal displacements of 1 to 2 feet.

Where the Newmark analysis displacements exceeded negligible values, Hart Crowser is accomplishing more detailed deformation analysis using the FLAC program. The Newmark analysis is also being used to check on some embankment sections to assess whether potential shallow surficial sloughing or small zones of potential instability (indicated by the pseudo-static limit equilibrium analysis) could lead to progressive raveling.

FLAC Analysis

The computer modeling program FLAC is being used to evaluate the seismic response and deformation of the Third Runway embankment and MSE walls. FLAC is an advanced tool for seismic analysis that is being used to confirm and supplement the conclusions from the more conventional analyses.

FLAC provides a good means to display results of stress-strain analysis using the finite difference method. The FLAC model helps illustrate the mechanisms of deformation, which generally verify the limit equilibrium analyses. (Lack of consistency between results of the two methods would be an indication of the need for further analysis of a particular section, if this were to occur.)

FLAC has been extensively used by others for dynamic analysis of earth structures, including some comparison of FLAC results with centrifuge models and in some cases with the effects of real earthquakes. Examples in engineering literature include: Inel, Roth, and C. de Rubertis 1993, Lee 1997, Makdisi, Wang, and Edwards 2000, Bathurst and Hatami 1998 and 1999, and Roth et al. 1993.

The Third Runway design team is using FLAC analysis techniques that have been demonstrated effective by research completed at the University of Washington that includes use of FLAC for both static and seismic analyses of MSE wall performance. The University of Washington research demonstrates the reasonableness of FLAC analyses for seismic analysis of MSE walls based on comparison with shaking table and centrifuge test results.

The finite difference mesh used in the FLAC model is "built" incrementally to provide a realistic estimate of stresses and deformations due to the weight of the fill. A "time history" of earthquake motion provides the basis for calculating additional stresses and deformations to assess the effect of design level earthquake shaking on the proposed embankment and MSE walls. The FLAC program provides both graphic and tabulated output, which can be used for further analysis, (for example see Hart Crowser 2000m and 2001g).

Figure 12 shows an example of the maximum horizontal displacement calculated for preliminary analysis of a representative section of the west MSE wall. The displacement contours indicate that the top of the wall would have a permanent displacement of about 10 inches resulting from the earthquake design motion (discussed below). The calculated vertical deformations are much less than the horizontal displacement. Another part of this same analysis provides designers with a tabulation of the maximum stress in the MSE reinforcing strips used in this section (see for example Hart Crowser 2001g).

FLAC model results are used to check predicted deformation vs. performance goals for the MSE walls. As needed, the reinforced zone or the subgrade improvements can be modified and the analysis repeated to see how performance (displacement or stress) is affected. An acceptable design for each section is obtained by comparing the results of both limit equilibrium and deformation models. Use of FLAC enables the Port to estimate wall movement and stresses in the reinforcing for a wide range of conditions from construction through performance in various size earthquake events, a capability that is not equally available from alternative computer models.

The FLAC analyses used for the Third Runway are above and beyond conventional design practice for MSE walls, i.e., the AASHTO code, which only requires pseudo-static analyses, used by the Port. However, the use of deformation-based analyses is gaining wide acceptance because of limitations in other types of analyses. Use of FLAC by the Port's design team provides an increased level of understanding regarding the MSE walls performance both during construction and in service.

4.3 Seismic Basis of Design

Input for both QUAD4 and FLAC is in the form of a record of motion, which is developed from an earthquake acceleration record selected to represent a "design level earthquake." This section discusses the basis for selecting the design level earthquake.

The Third Runway embankment and MSE walls are being designed to perform well during and after earthquake shaking that has a 10 percent probability of exceedence in 50 years, or an average return period interval of once in 475 years. Seismic events of this frequency are commonly used for design of many structures such as commercial buildings and highway bridges. This is the same basis of design return period that the Port of Seattle has used for other significant structures at STIA, such as the South Terminal Expansion Project currently under construction.

The process used to determine the magnitude of the seismic basis of design event began with a Probabilistic Seismic Hazard Assessment (PSHA). The PSHA utilizes thousands of analyses (for different source-site distances, magnitudes, and earthquake characteristics [such as the effects of fault type], and attenuation relationships) to produce a probability based uniform hazard spectra that represents potential earthquake effects on the site (Hart Crowser 1999d, 2000e, and 2001a).

Several ground motions have been utilized for the Third Runway analysis to cover the range of earthquake shaking characteristic of the design level event. These motions, designated A, B, C and D, include one motion that is deterministically based, to specifically assess motion on the most significant local fault, the Seattle Fault.

Initial design analyses used the model PROSHAKE to complete a one-dimensional site response analysis. The average peak horizontal acceleration (PHA) from this analysis was used to provide input to a) the pseudo-static analyses used to evaluate global and compound stability; and b) the MSE design analyses accomplished by RECo. The AASHTO design method includes PHA in a Mononabe Okabe-type analysis for determination of lateral earth pressures.

Subsequent Third Runway design analyses used the program QUAD4 to complete two-dimensional site response analysis for representative embankment and MSE wall sections. The QUAD4 analysis was used to obtain the following:

- Seismic cyclic shear stresses at different locations, to assess potential for liquefaction below or adjacent to the embankment;

- Maximum acceleration (K_{max}) to be used in the Newmark analysis; and

- Verification that the preliminary PROSHAKE-derived PHA values used in the pseudo static analyses are conservative, or to provide PHA (K_{max}) values for re-analysis.

Finally, QUAD4 was used to compare the effects of the different ground motions and to produce the input ground motion for the FLAC analyses.

Although not a formal part of selecting the seismic basis of design for the Third Runway, the design team made a careful assessment of conditions at the project site (and performance of local MSE walls) following the February 28, 2001, Nisqually earthquake (see Hart Crowser 2001c, 2001e, and 2001f). No adverse effects of that earthquake were observed in the native soils on the Third Runway fill placed prior to that time.

4.4 Liquefaction Analysis

"Liquefaction" refers to the temporary reduction in shear strength that occurs in some soils as a result of development of excess pore pressures that develop in an earthquake. Identification of the conditions that will trigger liquefaction and calculation of the post-liquefaction soil strength are important parts of the geotechnical analysis affecting stability and deformation of the Third Runway embankment and MSE walls.

Potential liquefaction is a consideration for some areas of the native soils that underlie the proposed embankment, including portions of the MSE walls. The effected soils are saturated, predominantly granular, and typically loose to medium dense. Some areas of silty or clayey soils were also found to be susceptible to liquefaction, based on screening using the "Chinese Criteria" as modified by the Corps (Kramer 1996).

Trigger Liquefaction

Determining the susceptibility of soils to loss of strength due to liquefaction is referred to as the "trigger liquefaction" analysis. Trigger liquefaction analysis is based on a recent update to the state of the art method (Youd et al. 2001). The trigger liquefaction analysis compares *in situ* soil characteristics at the Third Runway site with soil parameters that have been found to indicate liquefaction, (Seed and Harder 1990 and Idriss 1998).

The Third Runway embankment incorporates an underdrain over much of its base area, including the areas below the three MSE walls. The main purpose of the underdrain is to prevent development of any excess pore pressures within the embankment such as might develop from saturation due to infiltration or filling over existing surface seeps. Drainage provided by the underdrain and the dense compaction of the embankment fill protect the embankment itself from liquefaction. The potential occurrence of liquefaction is limited to some areas of existing native soils. The purpose of the liquefaction analysis is to identify the areas where subgrade improvement is needed to mitigate potential instability, or excessive deformation, due to liquefaction.

Details of the liquefaction analysis for the Third Runway are presented in Hart Crowser (2000k and 2001d). More recent analyses have incorporated cyclic shear stresses calculated with QUAD4.

The trigger liquefaction analysis uses a factor of safety of 1.25 to account for small increases in pore pressures that may have some effect on strength. This safety factor is separate from, and in addition to, achieving the target factor of safety in the previously discussed limit equilibrium analyses. The trigger liquefaction analysis provides the values of SPT required to trigger liquefaction which are then compared with SPT values measured at the site (Hart Crowser 2000k and 2001h). The adjustment in N-values is based on well-documented procedures (Youd et al. 2001). We also evaluated CPT data for prediction of liquefaction at the Third Runway site.

Soil conditions were evaluated for more than 25 cross sections that were selected to represent the range in subgrade and embankment/MSE wall configuration. For each cross section, the adjusted N-values required to trigger liquefaction were compared to the SPT and CPT data. Potentially liquefiable zones were delineated, and the residual strength was estimated using SPT data. The post-liquefaction stability was analyzed with limit equilibrium methods to determine the extent of subgrade improvement needed to meet the target factor of safety, as previously discussed.

Residual Strength Calculation

Large ground failures and deformations resulting from liquefaction have only been documented to occur when adjusted SPT N-values are 15 or less (Seed and Harder 1990 and Idriss 1998). However, our analysis suggested that liquefaction could potentially occur for some soil conditions at the site corresponding to N-values up to around 30. To address the potential effect of this on stability, the Third Runway design team used a soil behavior-based extrapolation of the documented residual strength of soils that have liquefied. We calculated the residual strength using corrected SPT blow counts $(N_1)_{60\text{-}CS}$ by extrapolating the residual strength curve (Idriss 1998). While there is no theoretical basis for limiting residual strength increases based on extrapolation of these curves, we limited and capped the extrapolated residual strength to 1,200 psf, corresponding to $(N_1)_{60\text{-}CS} = 24$.

For each MSE wall or embankment cross section, the N-values which fell below the threshold value of $(N_1)_{60\text{-}CS}$ were tabulated and residual strength calculated for each soil unit. Each cross section evaluation included consideration of changes in soil parameters observed in explorations on each side of the cross section, along with the maximum groundwater level at each well (see Hart Crowser 2001j). The range of interpolation for each cross section varied, depending on how closely spaced the sections are to one another. We looked for consistent soil units that extended from one cross section to the next, as well as for local variations that distinguished one section from another.

Residual strength values were selected for liquefiable soil units. The residual strength values used for analysis were selected to provide a reasonable lower bound, looking at the range and variation of specific SPT values in each unit, where a soil unit was identified on the basis of continuous soils of similar gradation, density, and saturation. We used the lower third value of the range for residual strength in each unit if the data showed much scatter; where there was no significant scatter, we used the mean value of residual strength for the analysis.

Finally, estimated residual undrained strength values were checked to make sure they do not exceed the drained shear strength for the same type soil. The stability analyses used the lower value of either the estimated residual strength or the drained shear strength.

5.0 MSE WALLS

This section discusses why MSE walls were selected for the Third Runway, and specific design steps used for the Third Runway MSE walls.

5.1 Background

During preliminary stages of design, the Port of Seattle reviewed eight different types of retaining walls and more than 60 wall/slope combinations to identify the best means of limiting the embankment impact to Miller Creek, Walker Creek, and adjoining wetlands. The Port of Seattle selected MSE walls as the best alternative for the project based on seismic performance, constructability, historical performance, and cost-effectiveness (HNTB et al. 1999). The selection of MSE technology was confirmed via a peer review by Shannon & Wilson (1999).

After selection of MSE walls as the best alternative to limit embankment impacts to creeks and wetlands, the Port of Seattle consulted with in-house staff and experts at the University of Washington and the Washington State Department of Transportation to determine appropriate criteria for selection of an MSE wall design engineer for the Third Runway MSE walls. A formal request for qualifications was published through the mailing lists from two MSE trade associations, the Geosynthetics Materials Association and the Association for Metallically Stabilized Earth.

The Port's design team received and reviewed nine submittals from prospective designers of the Third Runway MSE walls. The Port selected RECo USA, the North American subsidiary of Terre Armee International (TAI), based on their recent experience with MSE walls of similar height and layout as those planned for the Third Runway. RECo/TAI has been responsible for design and construction of more than a dozen walls more than 90 feet in height, including two that are about the same height as the maximum wall height proposed for the Third Runway. Upon selection of RECo as the MSE wall designer, they were assimilated into the design team with HNTB and Hart Crowser. Construction of the MSE walls will be accomplished by a general contractor with components specified by the design team, and manufactured from any supplier.

5.2 Design of MSE Walls

The following steps were utilized in the progressive design and analysis of MSE walls for the Third Runway.

- An initial layout of MSE walls was developed to fit within the embankment geometry and minimize or avoid impacts to wetlands as much as possible.

- The design team met to review and discuss the design parameters, loads and details (geotechnical recommendations for design are presented in Hart Crowser 2000h). Over a period of several weeks, the design team worked through regular teleconferences to review proposed design criteria and reached consensus on the basis for design, including structural, mechanical, and aesthetic details.

- Using initially assumed reinforcement geometry, limit equilibrium analyses were used to verify that design could satisfy the AASHTO code (AASHTO 1996-2000) and other design requirements for conditions at the Third Runway site.

- Analysis of preliminary sections was used to assess the need for subgrade improvement in order to satisfy stability and allowable settlement criteria.

- Initial wall design, including length, depth, and density of MSE reinforcing was developed by RECo, based on the design criteria and RECo design computations. RECo evaluated internal stability needs for a 100-year performance period addressing reinforcement durability, pullout and tensile capacity. External stability was evaluated for sliding and overturning.

- RECo submitted design plans showing type, size, and location of MSE wall and reinforcing components, for review by HNTB and Hart Crowser. RECo developed hand calculations to check and document the results of computer-based analyses. These calculations along with RECo's project Quality Assurance Plan were reviewed by Hart Crowser and HNTB. Written comments were submitted to document recommendations (HNTB 2001).

- Hart Crowser checked global and compound stability of the initial RECo design sections, and accomplished initial deformation analyses (Hart Crowser 2000m, 2001g, and 2001i).

- Hart Crowser is now checking deformation of the MSE sections with the Newmark analysis. Sections with a) the lowest factor of safety; or b) largest deformation from the Newmark analysis have been selected for further deformation analysis with FLAC.

- Architectural and structural issues continue to be addressed in light of geotechnical needs. These include arrangement of wall facing details to accommodate vertical settlement joints; wall panel thickness; reinforcing strip lengths; number of reinforcing strips per panel; tier elevation; top treatments, etc.

At various stages of the analyses outlined above, modifications were made as necessary to change the extent of subgrade improvement and/or the length or depth of the MSE reinforcing zone. After review by the design team, recommended subgrade and/or MSE modifications were incorporated into the design in an iterative manner (Hart Crowser 2001g and 2001i).

6.0 CONSTRUCTION CONTROL

As previously mentioned, the Port plans to use "subgrade improvement" to mitigate areas of soft or loose soils that affect stability or deformation. This includes areas of compressible soils, soils with low shear strength, and soils that are subject to liquefaction. The anticipated subgrade improvements range from about 15 to 20 feet below the existing ground surface, based on information from the existing borings.

The Port reviewed nine different methods for subgrade improvement (Hart Crowser 2000g) and selected two preferred alternatives: 1) removal and replacement with compacted structural fill, or 2) stone columns. Relative feasibility, including the degree of ground improvement, constructability, quality assurance, and cost were considered for the Third Runway project., as well as potential post-construction effects on base flow to Miller Creek and adjacent wetlands (Hart Crowser 2000p).

Final selection of the removal and replacement method was made by the Port after stone column field tests were accomplished as part of the Phase 4 construction in 2001. These tests included collection of SPT and CPT data, accomplished before and after installation of more than 100 stone columns in four test patterns. The tests indicated that it would be difficult to obtain the same degree of construction quality assurance with the stone column method as with the remove and replace method. The remove and replace method was selected because it would achieve better construction reliability.

The Port has successfully monitored embankment construction to date, using the same type of soils and methods of construction that are planned for the remainder of the embankment. Construction specifications allow different types of soil materials to be used in different parts of the embankment, with appropriate moisture content limits, lift thickness, and compacted density specified to achieve a consistent quality earth fill. Compaction control and other fill quality tests are based on Federal Aviation Administration specifications (P-152) that have been modified to reflect local soil conditions.

Backfill for the subgrade improvement areas will utilize very densely compacted granular fill, compacted to 95 percent of the modified Proctor maximum density per ASTM method D 1557. The Port utilizes full-time construction inspection and services of a testing lab, field results are reviewed by both HNTB and Hart Crowser to verify conformance to the specifications.

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Table 1 - Summary of Explorations

Preliminary Evaluation & Environmental Assessment Phase

91 Borings (12 Monitoring Wells)

34 Test Pits

7 Vane Shear Tests

Final Design Phase

127 Borings (65 Monitoring Wells)

122 Test Pits

48 Cone Penetrometer Soundings

10 Vane Shear Tests

Notes:

1. Table includes explorations related to main embankment as well as for partial relocation of Miller Creek for the North Safety Area embankment construction, but does not include geotechnical studies for relocation of South 154th Street, borrow sites, or other parts of the Port of Seattle Capital Improvement Program. Hand auger explorations for wetlands delineation and shallow soil sampling not shown.

2. See Plates 1, 2, and 3 for location of explorations.

Table 2 - Laboratory Test Methods

Soil Classification	ASTM D 2488 (for visual identification only) and ASTM D 2487 (precise classification based on measured indices)
Classification of Peat	ASTM D 4427
Soil Moisture Content	ASTM D 2216
Grain Size Analysis	ASTM D 422
Atterberg Limits (Liquid Limit, Plastic Limit and Plasticity Index)	ASTM D 4318
One-dimensional Consolidation Test	ASTM D 2435
Consolidated Undrained Triaxial Test	ASTM D 4767
Unconsolidated Undrained Triaxial Test	ASTM D 2850
Direct Shear Tests	ASTM D 3080

Table 3 - Soil Parameters Used in Stability Analyses

Soil Type	Unit Weight in pcf	Drained Strength		Undrained Strength Parameters
		c′ in psf	ϕ' in Degrees	S_u/σ_v' (a)
Existing Subgrade Soils				
Loose to medium dense Sand	125	0	32	-
Medium dense to dense Sand	130	0	35	-
Dense to very dense Sand	135	0	37	-
Glacial Till	130	250	40	-
Soft Peat or Organic Silt (c)	110	0	7 to 15	0.23
Medium stiff Silt/Clay (b)	115	0	30	0.23
Stiff to hard Silt/Clay (b)	115	0	30	0.23
Post Construction Soils				
Embankment Fill	135	0	35	-
Drainage Blanket	140	0	37	-
Improved Subgrade	135	0	35	-

(a) Undrained strength ratios were used for fine-grained soils based on CU triaxial results and are a function of confining pressure (σ_v'). For pseudo-static analyses, this value is assumed to reflect the combined effect of strength increase due to high rate of seismic loading and potential strength reduction due to cyclic loading.

(b) Undrained strength parameters were used for the end-of-construction cases, otherwise, drained strength properties were used.

(c) Drained friction angle for the peat was 15 degrees except at low confining pressure where a value of 7 degrees was used, see Hart Crowser (2001k).

Table 4 - Target Factors of Safety for Limit Equilibrium Analyses

Type of Analysis (1)	Target Factor of Safety Used for Third Runway MSE Wall Design	Target Factor of Safety Used by Army Corps of Engineers for Levees (EM 1110-2-1913, Corps 2000)
End of Construction	1.3	1.3
Steady State	1.5	1.4
Seismic	1.1	See note 2
Post-liquefaction	1.1	See note 2

Notes:

1. The Rapid Drawdown case used by the Corps is not applicable to the Third Runway because the Third Runway embankment does not retain water.
2. The Corps of Engineers does not specify a target factor of safety for seismic analysis. Reference to ER 1110-2-1806 (Corps 1995) indicates the Corps relies on procedures that include assessment of project hazard potential, potential earthquake motion and project features to determine design requirements for specific projects. This is essentially the same as the procedure used for the Third Runway as described in Section 4.3 and applied in the analyses described in Sections 4.1, 4.2, and 4.4.

Table 5 - Summary of Design Requirements for Third Runway MSE Walls Sheet 1 of 2

5-1 - Static Stability Analysis [a]

	AASHTO 1996 - 2000 (Target F.S. or Other)	RECo Design Manual 1999 (Target F.S. or Other)
External Stability		
Sliding	≥1.5	≥1.5
Overturning	≥2.0	≥2.0
Eccentricity at Base	Not specifically stated	Not specifically stated
Bearing Capacity (for sliding and overturning)	≥2.0 (if justified by geotech analysis); ≥2.5 otherwise	≥2.0 (if detailed geotech info.); ≥2.5 (if general geotech info.)
Deep-Seated Stability (i.e., Global and Compound Stability)	≥1.3 (if soil param. based on lab tests); ≥1.5 otherwise	Not specifically stated
Internal Stability		
Pullout Resistance	≥1.5, where maximum friction angle of 34 deg. is used to calculate the horizontal force (if without the benefit of triaxial or direct shear testing to provide soil shear strength data)	Defaults to AASHTO, Interim 1998
Pullout Resistance[b]	$T_{max} \leq 0.55\ F_y$	$T_{max} \leq 0.55\ F_y$

5-2 - Seismic Stability Analysis [a]

	AASHTO 1996 - 2000 (Target F.S. or Other)	RECo Design Manual 1999 (Target F.S. or Other)
External Stability		
Sliding	≥1.1; include 100% of inertial force and 50% of dynamic thrust[c]	≥1.1
Overturning	≥1.5; include 100% of inertial force and 50% of dynamic thrust	≥1.5
Eccentricity at Base	Not specifically stated	Not specifically stated
Bearing Capacity (for sliding and overturning)	75% static (i.e., ≥1.5; include 100% inertial force and 50% of dynamic thrust [c]	Not specifically stated
Deep-Seated Stability (i.e., Global and Compound Stability)	≥1.1	Not specifically stated
Internal Stability		
Pullout Resistance	75% static; reduce F* to 80% static value; include internal inertial force[d]	Not specifically stated
Pullout Resistance	$T_{max} \leq 0.55\ F_y$	$T_{max} \leq 0.55\ F_y$

Table 5 - Summary of Design Requirements for Third Runway MSE Walls (cont'd) Sheet 2 of 2

5-3 - Comparison of Other Aspects of MSE Wall and Reinforced Slope Design Standards (a)

	AASHTO 1996 - 2000	RECo Design Manual 1999
MSE Embedment(e)	H/7 for 2H:1V slope in front of wall, where H is from top of wall at wall face to top of leveling pad	Same as AASHTO 1996
Horizontal Bench in Front of Walls Founded on Slopes	4 feet minimum width	3 feet minimum width
Calculation of Sliding for External Stability	Neglect passive resistance; include width and weight of wall facing in calculation of sliding/overturning	Not specifically stated
Leveling Pad Width	Designed to meet local bearing capacity needs and differential settlement between wall facing and backfill	Not specifically stated
Maximum particle size for reinforced backfill (see text for detailed discussion)	4 inches	6 inches
Friction Factor for Internal Reinforcement Design (backfill on ribbed steel strips)	$F^*_{max}<2.0$; $F^*_{max}<1.2 + \log C_u$, where C_u equals backfill uniformity coefficient. $C_u = 4$ for ribbed steel strips if tests are not available	Based on extensive pullout tests, but no values are specifically stated

5-4 - Comparison of Recommended Backfill Electrochemical Properties (a)

	AASHTO 1996 - 2000	RECo Design Manual 1999
Soil pH	5 to 10	5 to 10
Soil resistivity (at 100% saturation)	>3000 ohm-cm(f)	>3000 ohm-cm
Water soluble chloride content	<100 ppm	<100 ppm
Water soluble sulfate content	<200 ppm	<200 ppm
Organic content	1% max. (for material finer than No. 10 sieve)	Free of organics and other deleterious materials

a Note Third Runway MSE design is controlled by the "more strict" requirement when AASHTO and RECo are not the same. See also FHWA 1997 for criteria not specified by either AASHTO or RECo, such as base eccentricity (Hart Crowser 2000h).

b T equals "tension" and F_y equals "yield strength."

c Dynamic thrust determined by the pseudo-static Mononobe-Okabe analysis.

d F* is the friction factor variable, which is part of the reinforcement pullout analysis.

e MSE embedment is not a specific requirement of AASHTO or FHWA, but is provided as guidance for MSE constructed on fill.

f If soil resistivity is greater than or equal to 5,000 ohm-cm, the chlorides and sulfates requirement may be waived.

Table 6 - (from Corps 1989)

Retaining Wall Stability Criteria

Case No.	Loading Condition	Sliding Factor of Safety, FS	Shear Strength Test Required		Overturning Criteria Minimum Base Area in Compression		Minimum Bearing Capacity Safety Factor
			Soil Foundation	Rock Foundation[3]	Soil Foundation	Rock Foundation	
R1	Usual	1.5	(Q &/or S)[2,1]	Direct shear	100%[4]	75%[4]	3.0
R2	Unusual	1.33	(Q &/or S)[2,1]	Direct shear	75%[4]	50%[4]	2.0
R3	Earthquake	1.1	(Q)	Direct shear	Resultant within base	Resultant within base	>1.0

Notes

1. For soil foundations which are not free draining (permeability < 10 × 10^{-4} cm/sec), analyze for both Q and S strengths and design for the worst condition. For free-draining soil foundations (permeability > 10 × 10^{-4} cm/sec), analyze for S strengths only.

2. For construction loadings in Cases R1 and R2, use Q strengths when excess pore water pressure in the soil foundation is anticipated and S strengths when it is not anticipated.

3. The sliding analysis of a wall on rock should be based on the frictional resistance (tan ϕ) of concrete on rock or rock on rock. The values should be obtained from direct shear tests of pre-cut samples of concrete on rock and rock on rock, or direct shear tests of natural rock joints or bedding planes.

4. Less base area in compression than the minimum shown may be acceptable provided adequate safety against unacceptable differential settlement and bearing failure is obtained.

Project Vicinity Map

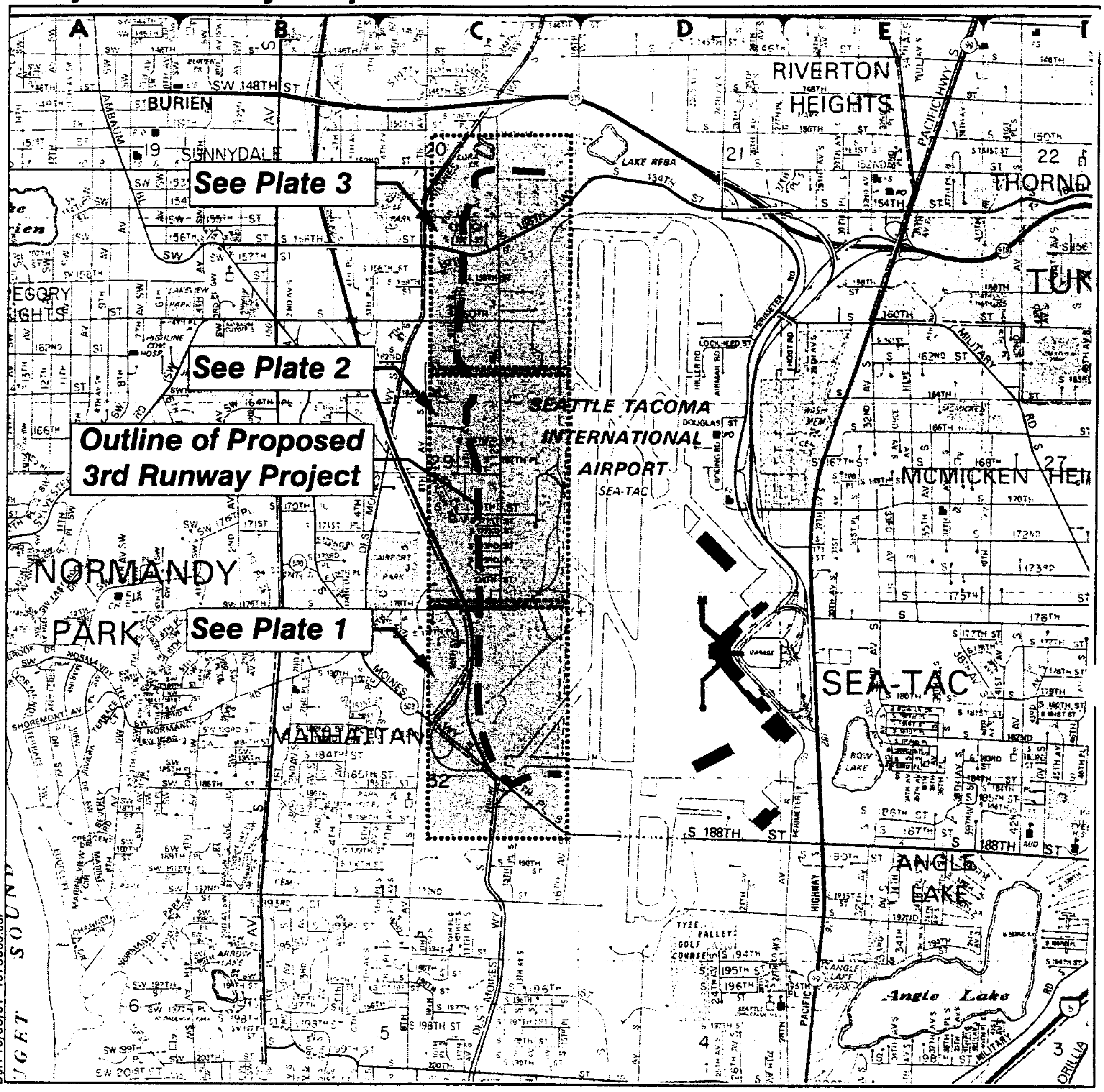

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Figure 1

Organization Chart for Third Runway Embankment Design Team and Independent Review Board

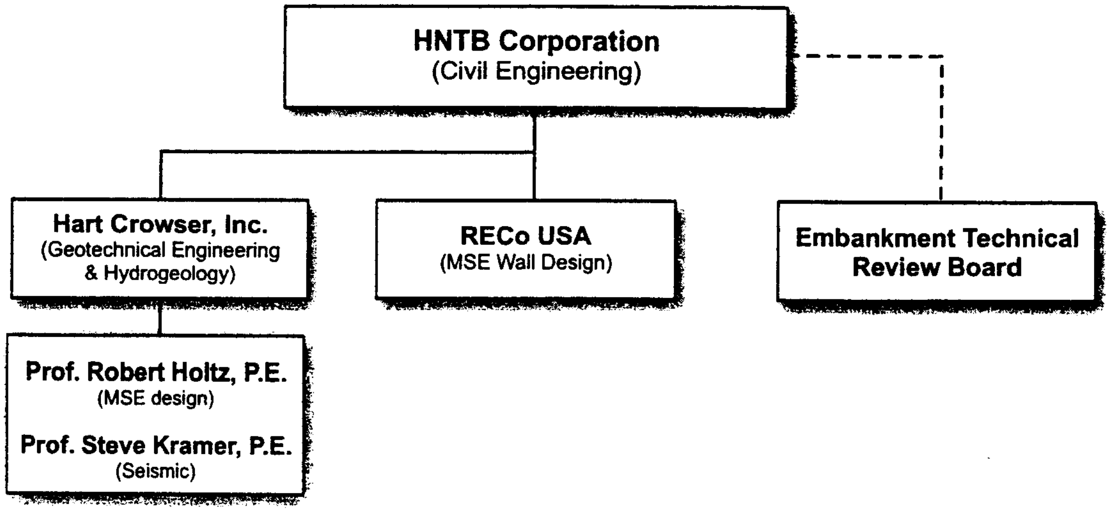

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Figure 2

Soil Classification System and Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

Minor Constituents	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling Test Symbols

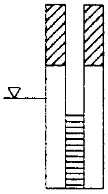
BORING SAMPLES

☒	Split Spoon
⧅	Shelby Tube
▥	Cuttings
◫	Core Run
*	No Sample Recovery
P	Tube Pushed, Not Driven

TEST PIT SAMPLES

☒	Grab (Jar)
⧄	Bag
⧅	Shelby Tube

Groundwater Observations



Surface Seal

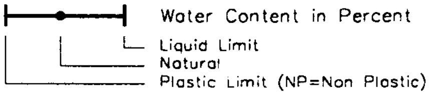
Groundwater Level on Date (ATD) At Time of Drilling

Observation Well Tip or Slotted Section

Groundwater Seepage (Test Pits)

Test Symbols

GS	Grain Size Classification
CN	Consolidation
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits



PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	*In Situ* Density Test

DJH 1=1 497806 A-1 Boring key.DWG

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Figure 3

Soil Plasticity Summary Plot

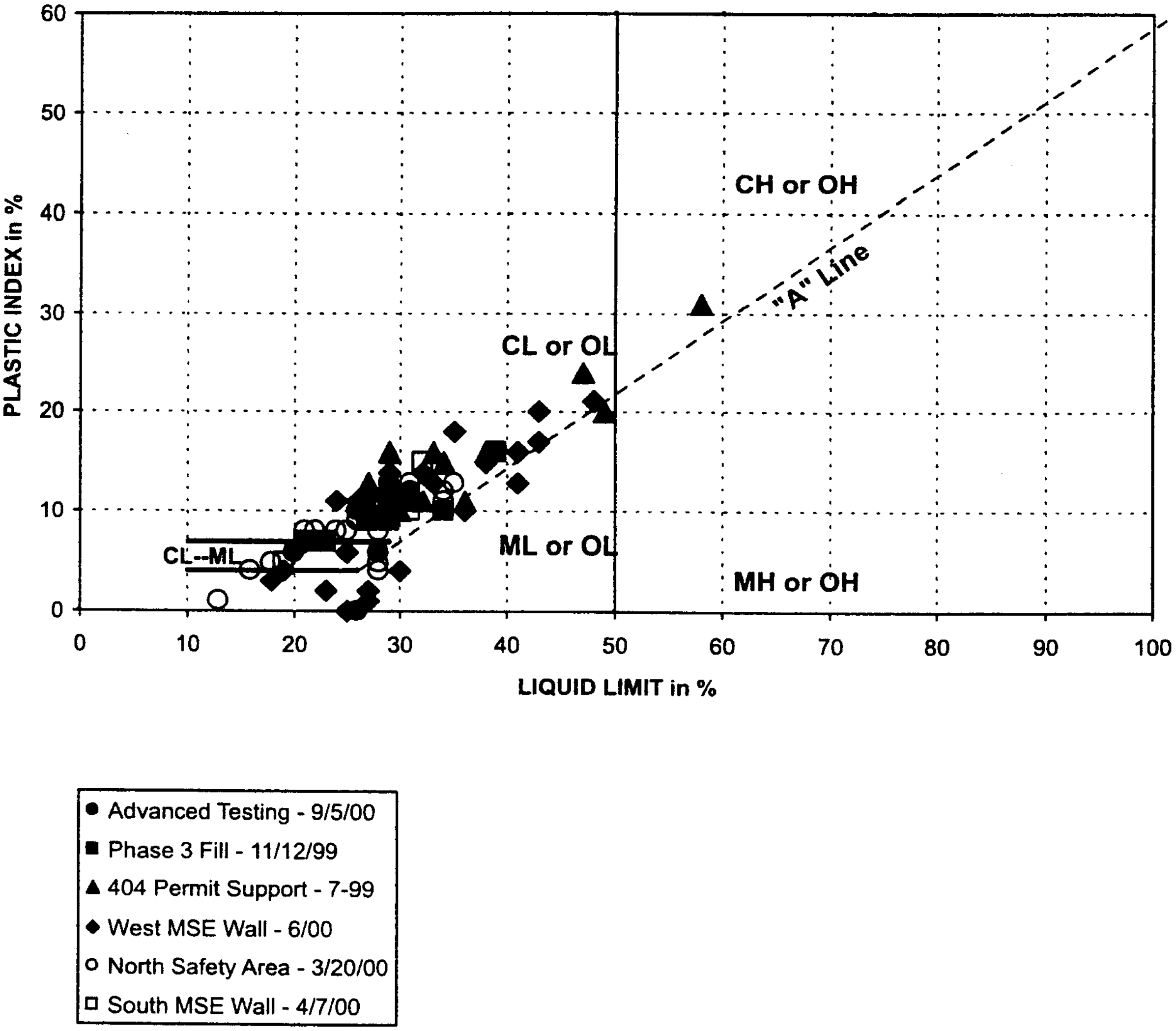

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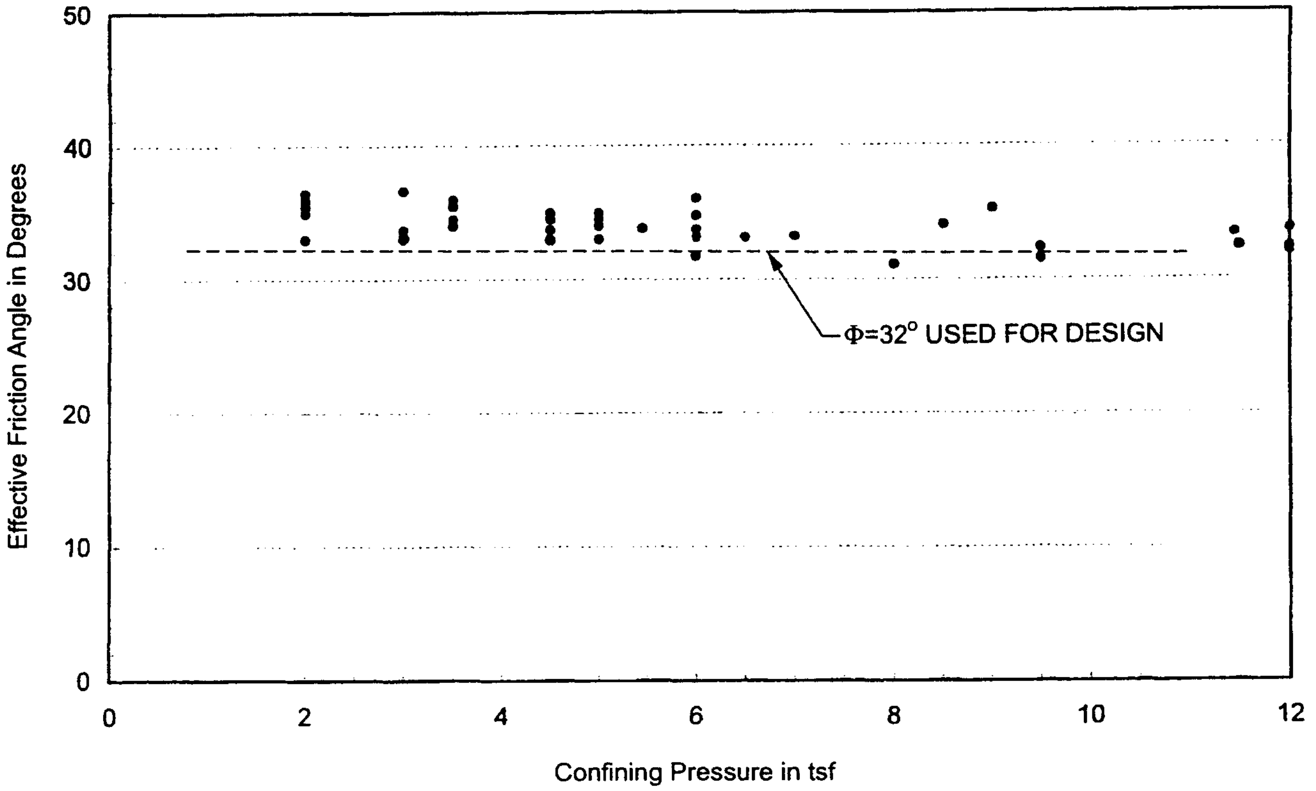
Figure 4

Effective Friction Angle vs. Confining Pressure for Clays and Silts



● Soil Sample Test Result

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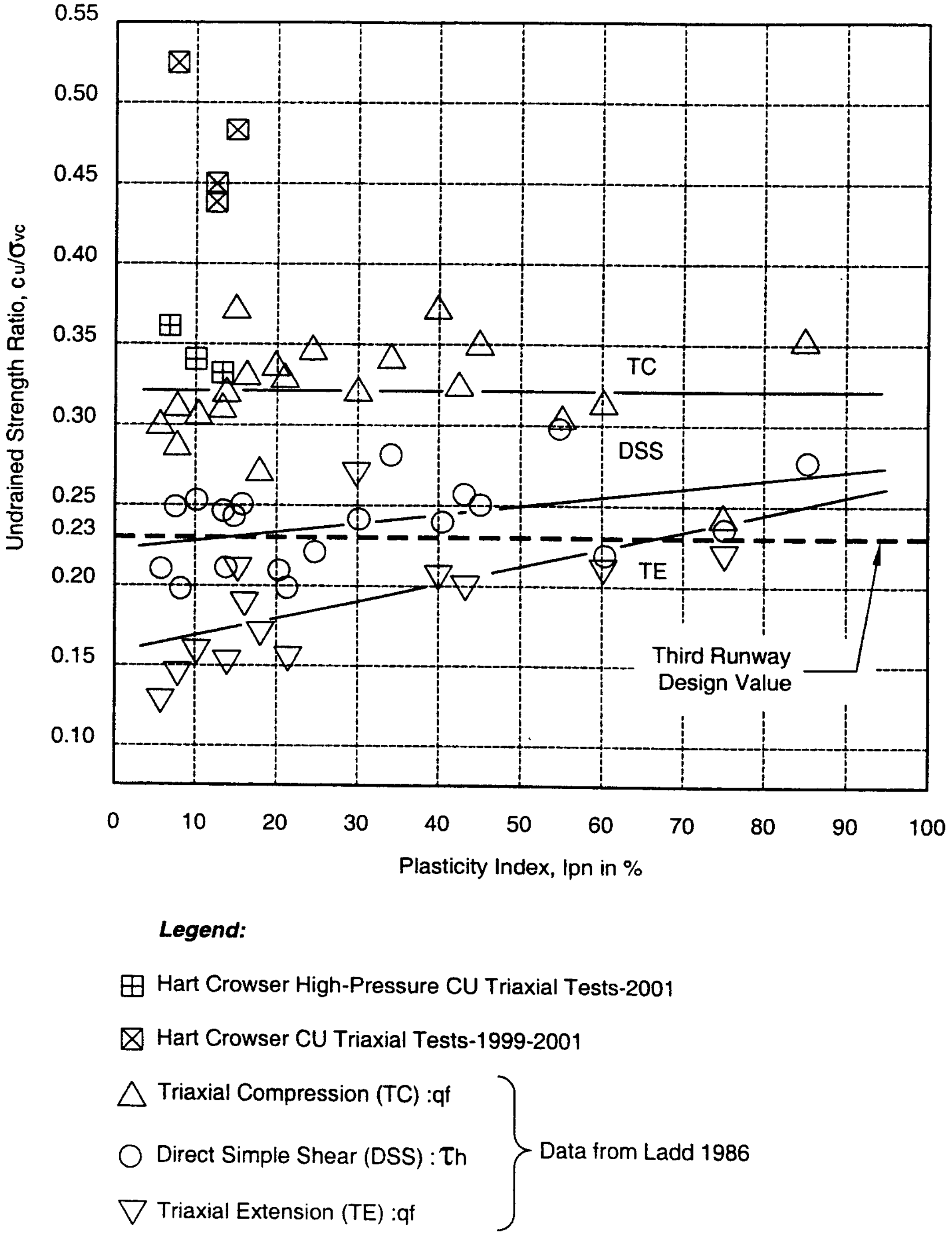
Figure 5

Undrained Strength Ratio for Normally Consolidated Clays and Silts Compared to Design Value and Published Data



49786098.DWG CAS NOT TO SCALE

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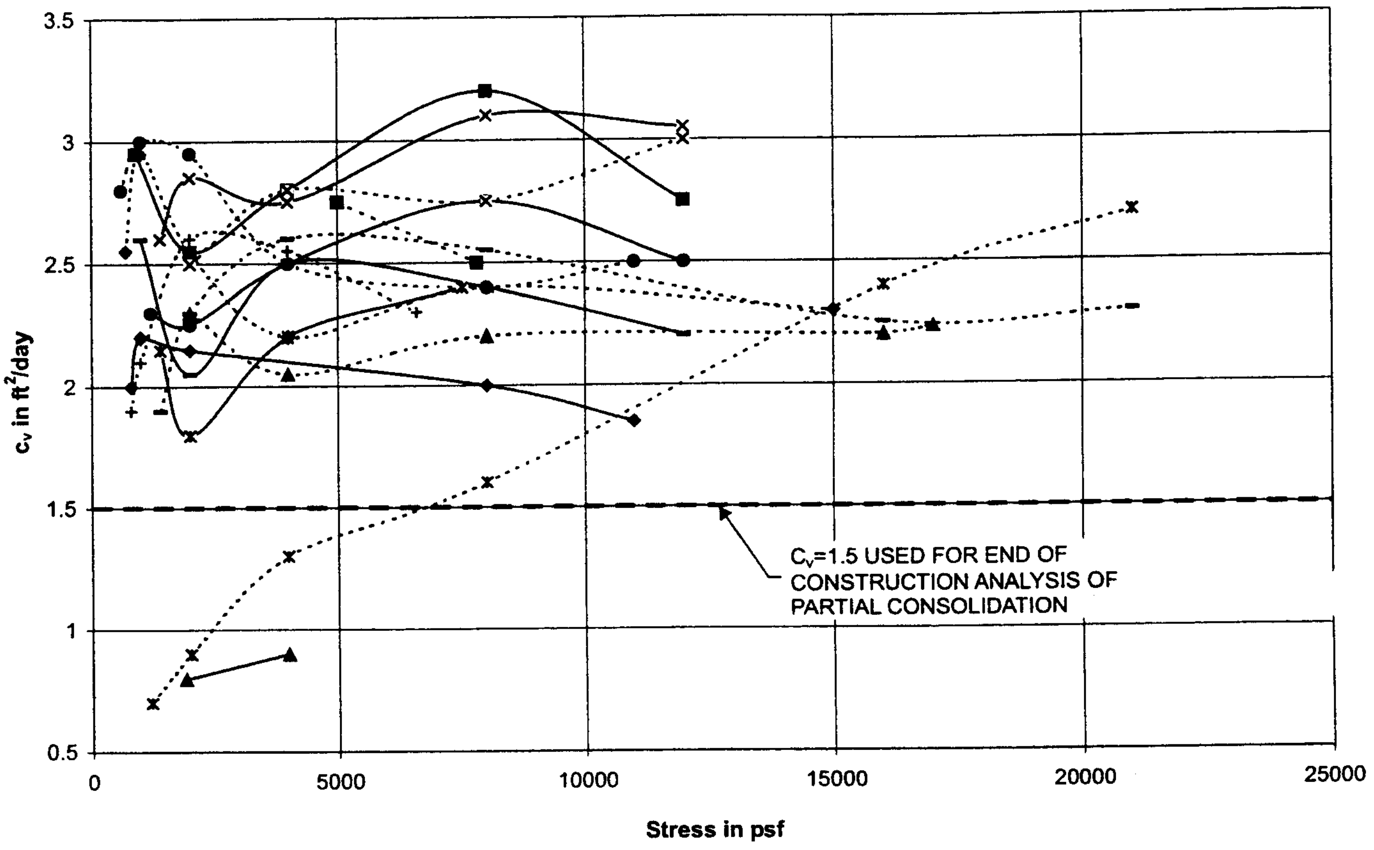
Figure 6

Coefficient of Consolidation vs. Embankment Load Range



Note:
The lower and upper stresses for each sample represent *in situ* and *in situ* + embankment load respectively, such that the results are applicable for the stress range during construction.

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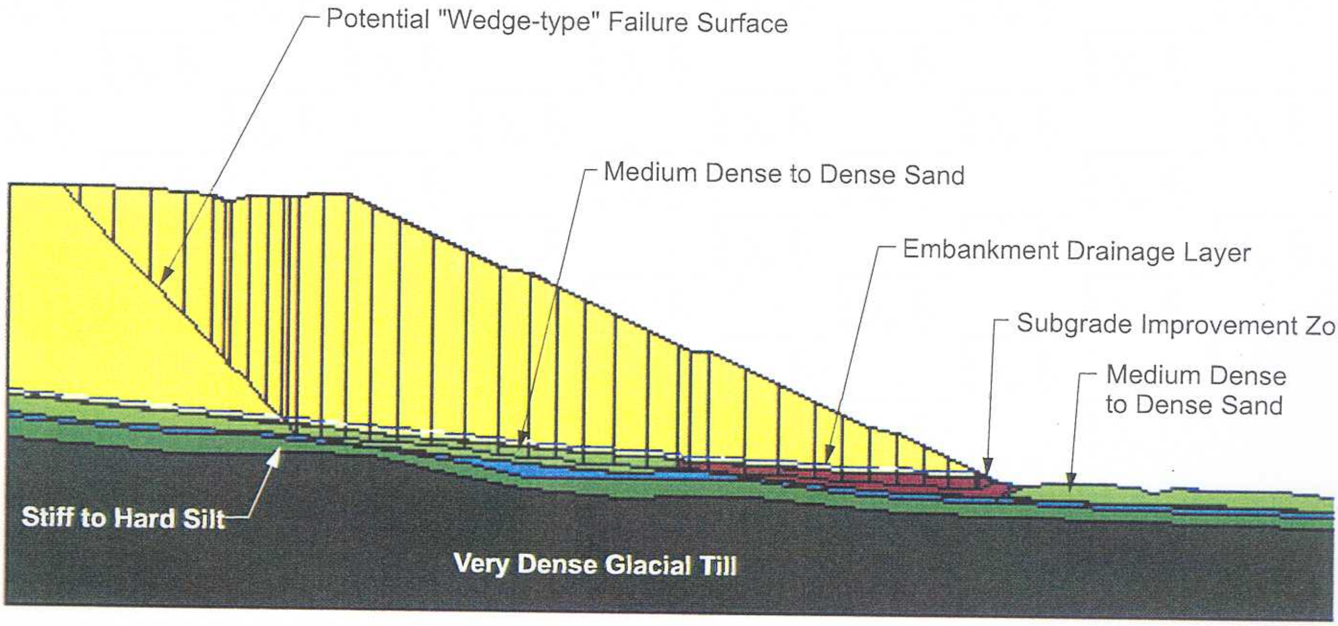
Figure 7

Equilibrium Stability Analysis for a 2H:1V Embankment Section



Note:
This figure illustrates a typical limit equilibrium analysis using Spencer's method with the program SLOPE/W. Each stability analysis includes calculating factor of safety for dozens of such surfaces. The limits (width and depth) of the subgrade improvement zone are adjusted so the analysis proceeds until all potential failure surfaces meet the target factor of safety. Subgrade improvements are constructed to mitigate weak or compressible soil or to assure stability.

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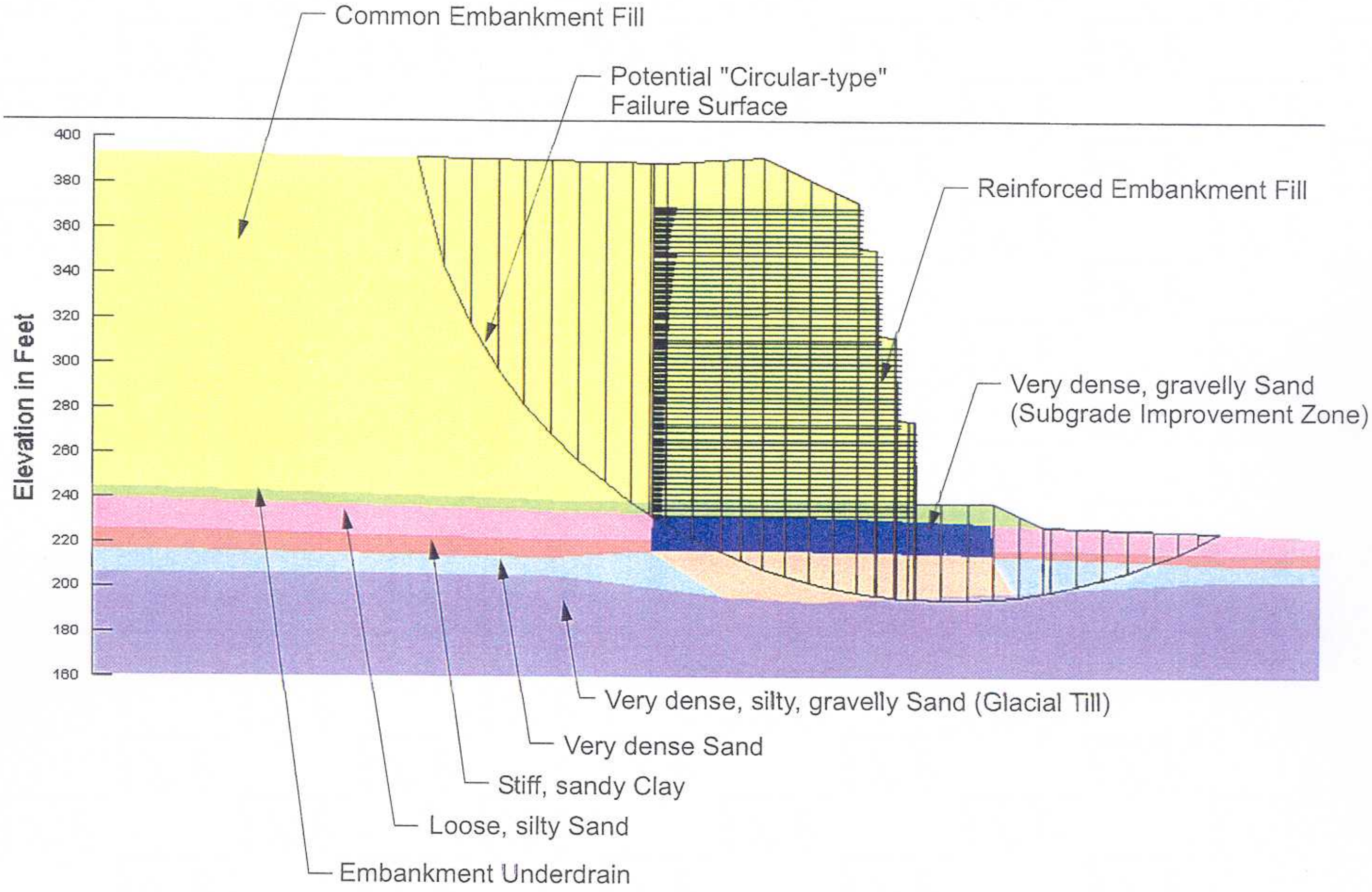
Figure 8

Global Stability Analysis for a West MSE Wall Section



Note:
Global stability analysis is a type of limit equilibrium analysis that looks for potential failure surfaces that extend below and outside the MSE reinforcing.

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Figure 9

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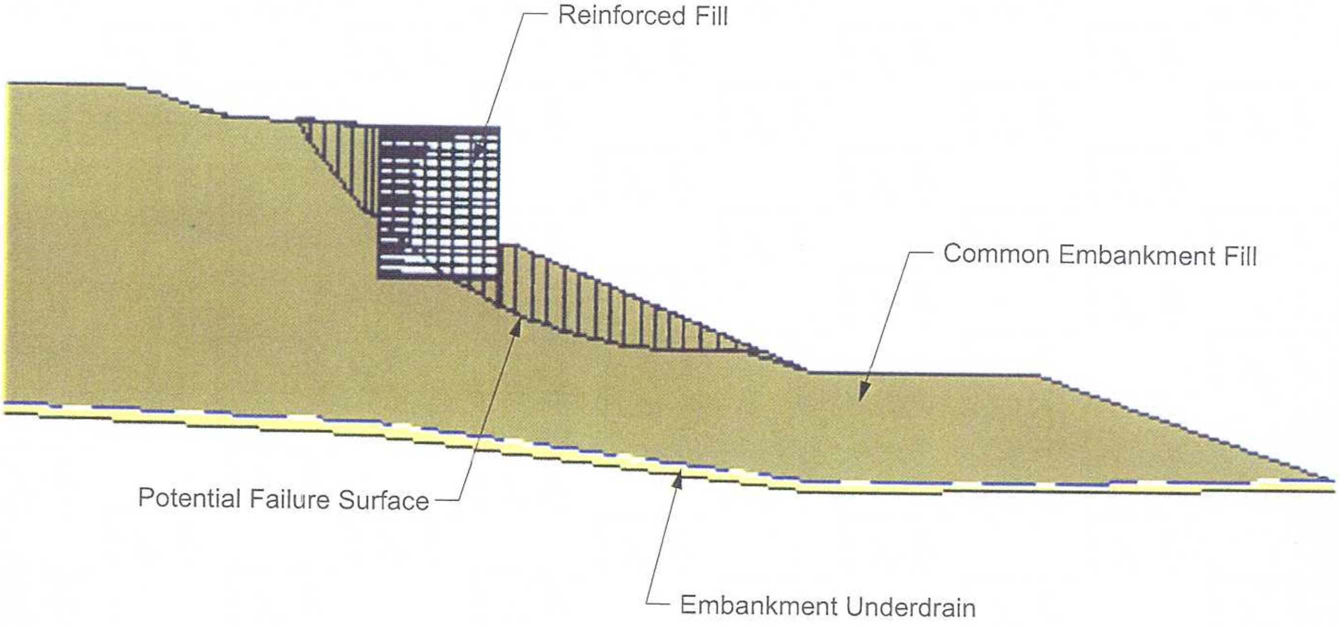
Compound Stability Analysis for a South MSE Wall Section



Note:
Compound stability analysis is a type of limit equilibrium analysis that looks for potential failure surfaces that extend through the soil reinforcing. As needed, the length, thickness, and/or depth of embedment of the MSE reinforcing can be adjusted for iterative analyses until all potential failure surfaces meet target factors of safety.

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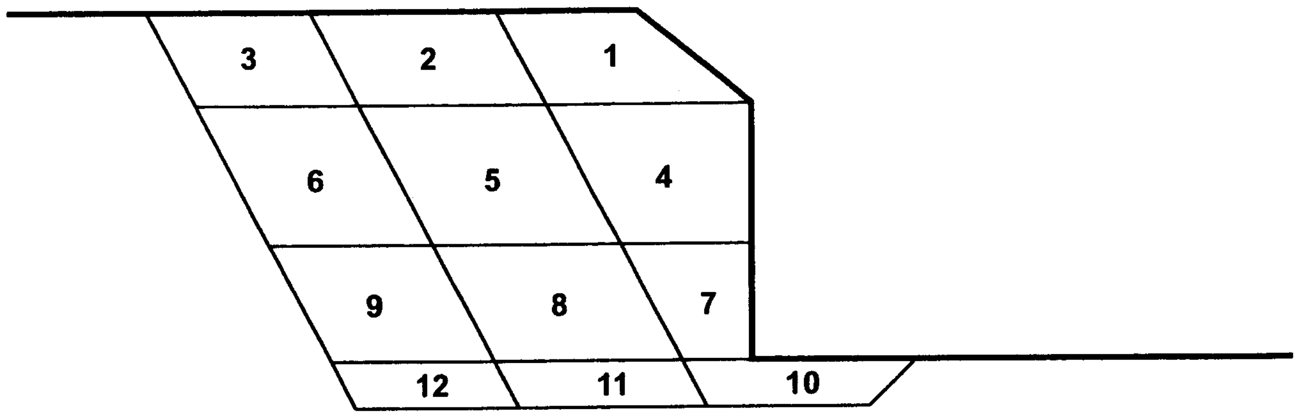
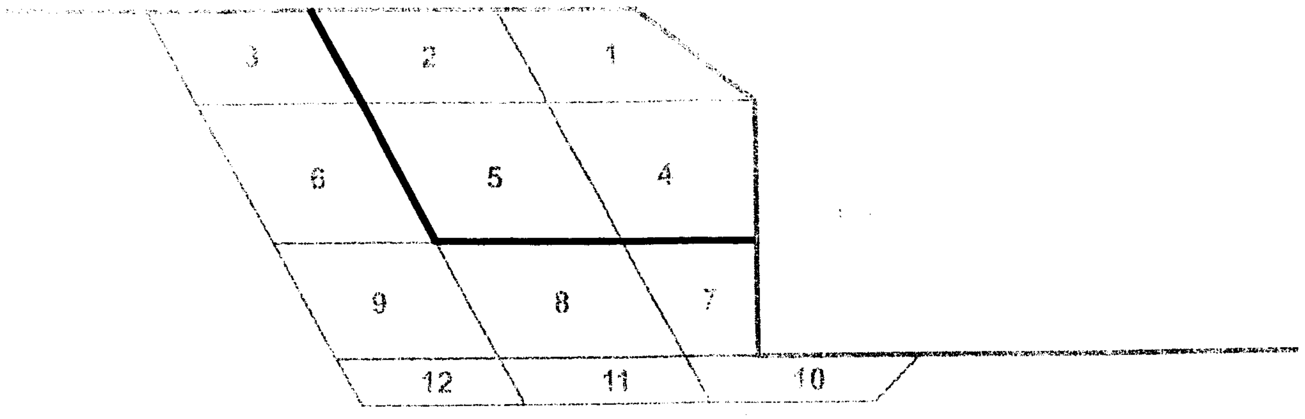
Figure 10

Illustration of Newmark Deformation Analysis



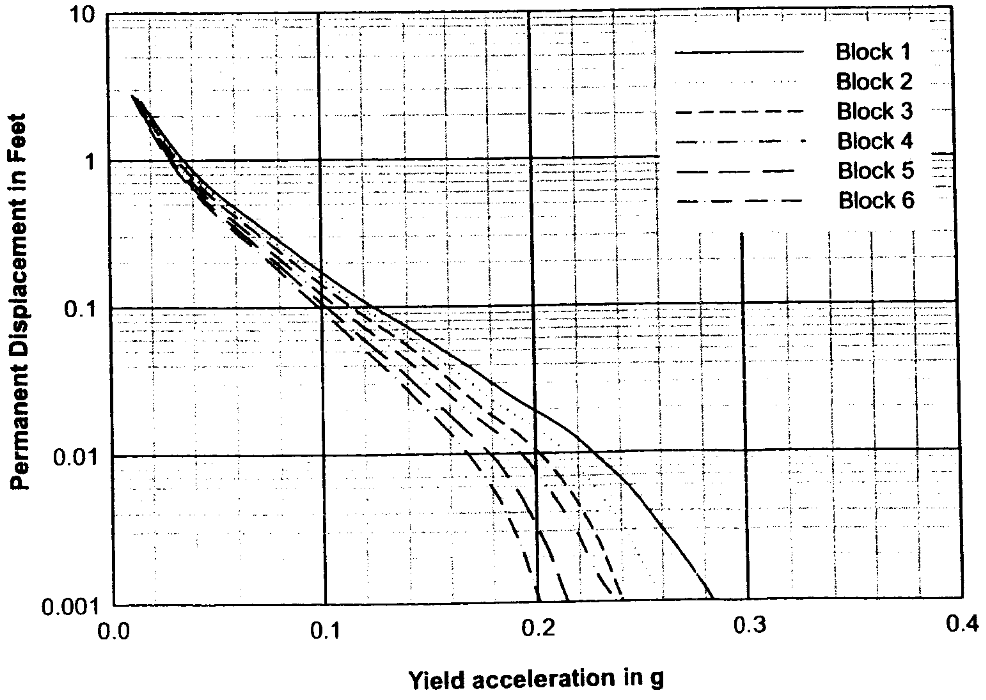
Note:
Illustration of numbering system used for identifying wedges. (For clarity, soil and wall details not shown)



Note:
Illustration of potential failure surface for Wedge 5 includes volume of potential failure wedges 1, 2, and 4.

Block ID	k_y	k_{max}
1	0.43	0.45
2	0.59	0.44
3	0.64	0.42
4	0.56	0.36
5	0.53	0.34
6	0.61	0.33
7	0.61	0.33
8	0.48	0.28
9	0.53	0.27
10	0.52	0.28
11	0.10	0.24
12	0.44	0.24

Note:
Seismic shaking produces displacement of a wedge when k_{max} exceeds k_y.



Note:
Permanent displacement varies depending on yield acceleration and k_{max} for each potential failure wedge.

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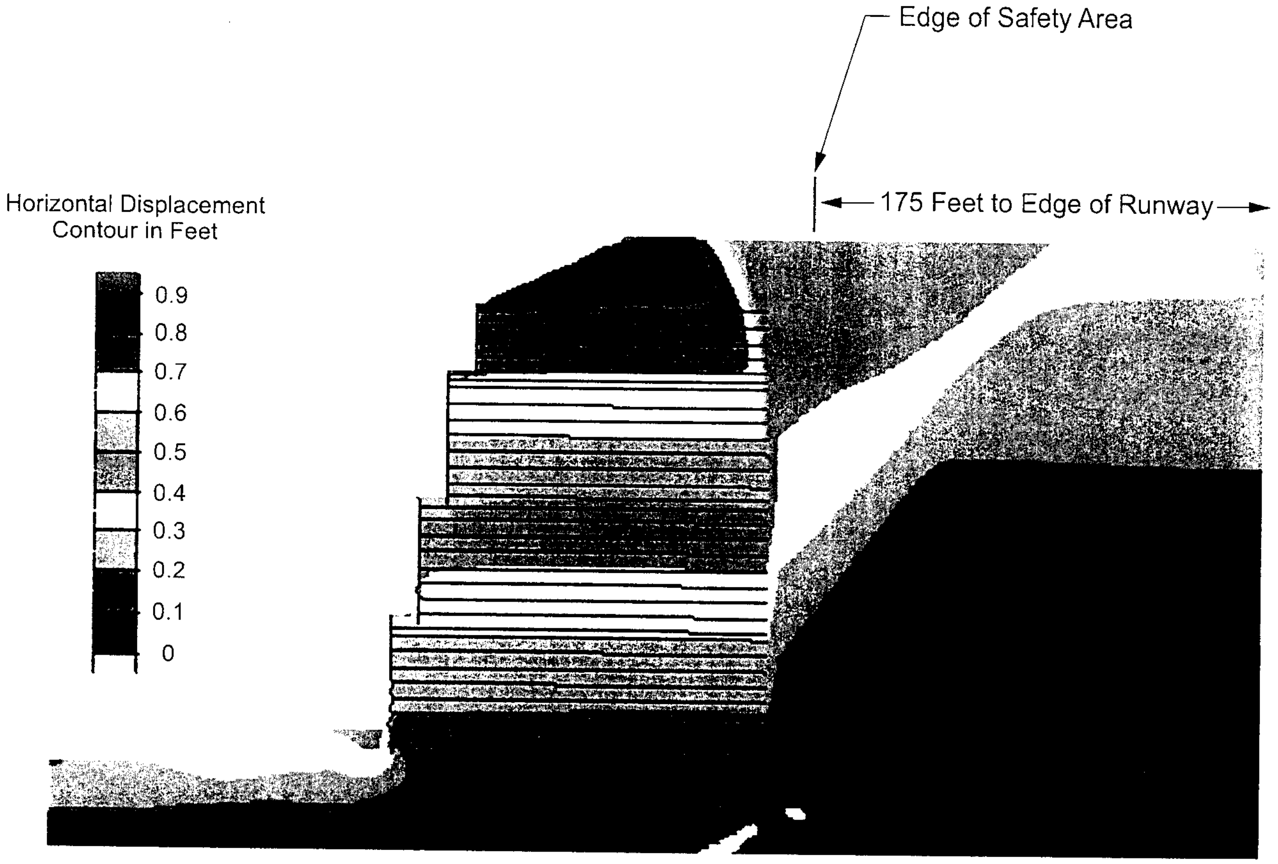
J-4978-06 *10/01*

Figure 11

hel 10/31/01 497806f.cdr

FLAC Model Deformation Analysis for a West MSE Wall Section



Note:
Illustration of horizontal ground displacement from FLAC model after design level earthquake shaking. Colors indicate approximate zones of uniform displacement. Details of soil horizons and subgrade improvement omitted from this figure for clarity.

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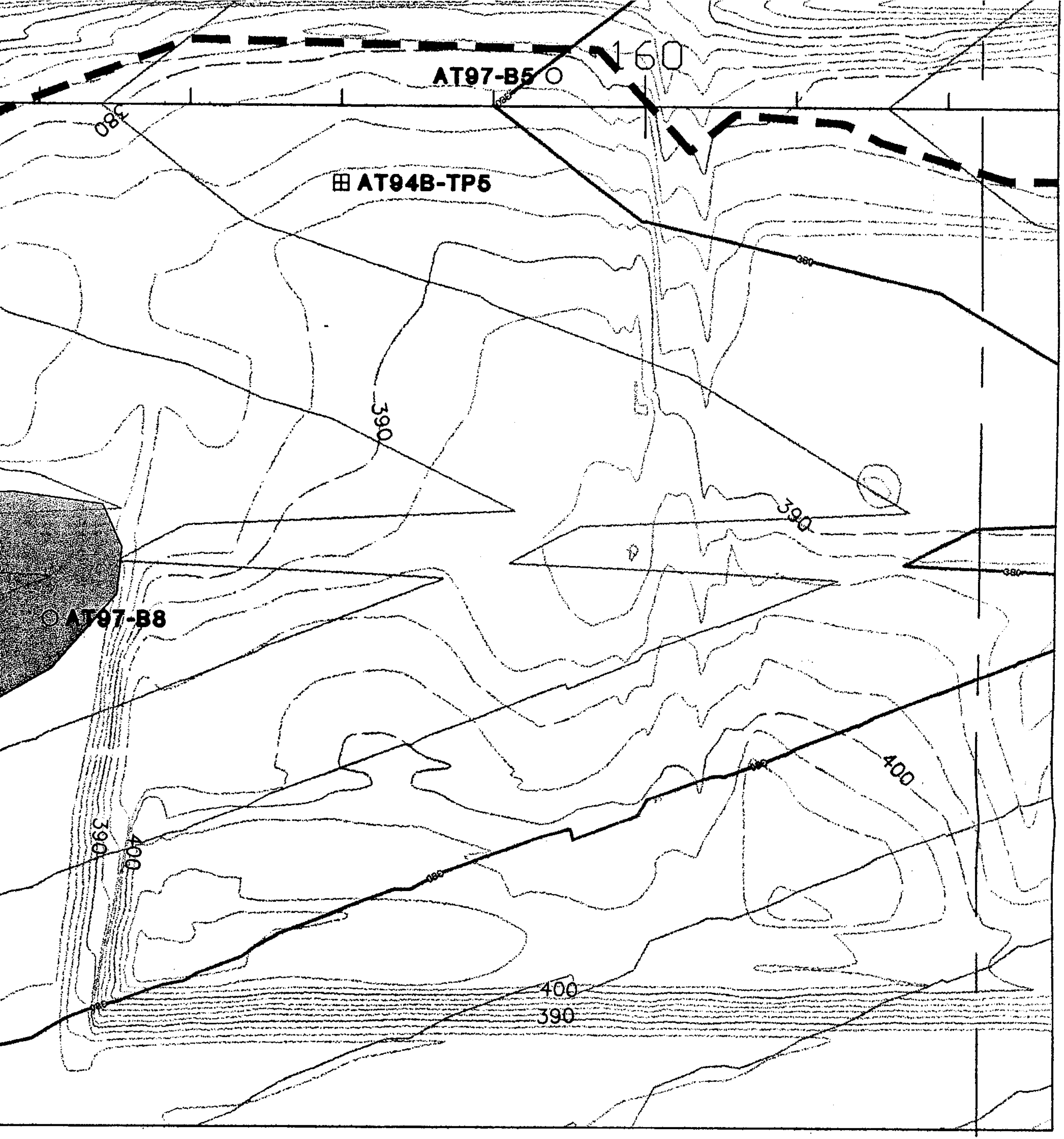
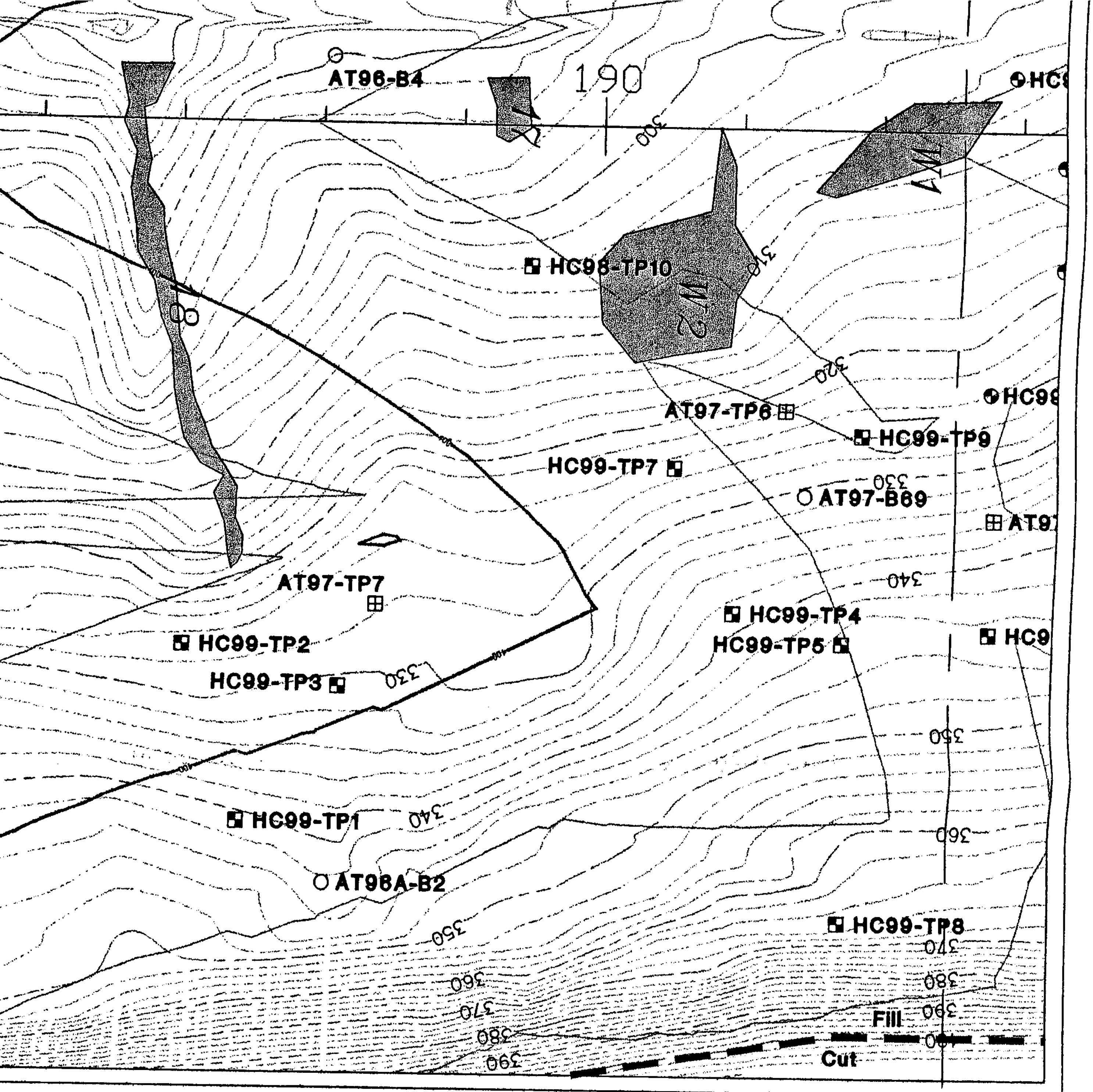
Figure 12



SEA-TAC THIRD RUNWAY

SITE AND EXPLORATION PLAN
SOUTH WALL AREA

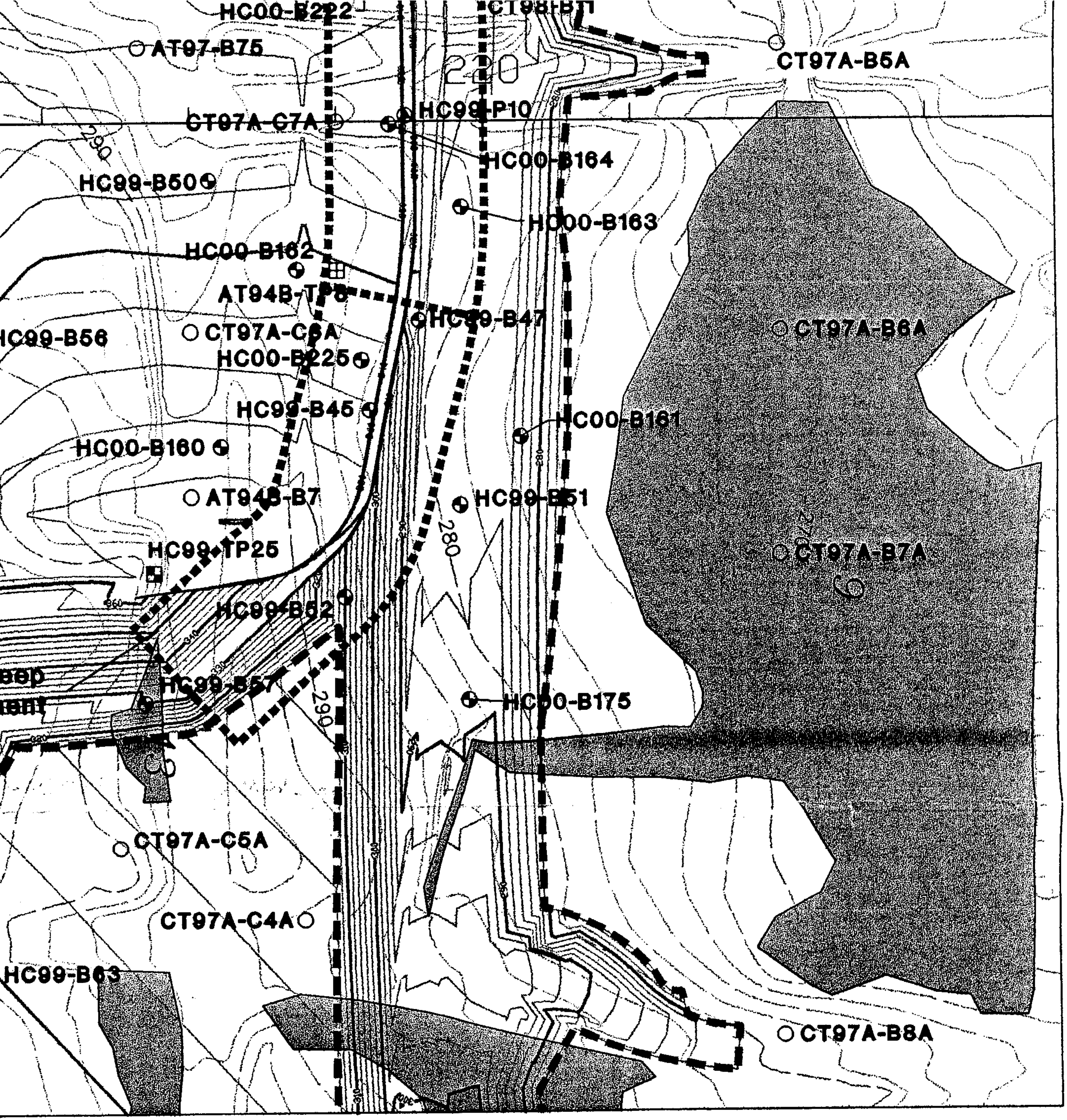
: SHOWN	Date Issued: 10/08/01	Drawing Type: DRAFT	Job No.: 4978	SHEET: 1 of 3	PLATE: 1



SEA-TAC THIRD RUNWAY

SITE AND EXPLORATION PLAN
WEST WALL AREA

Scale: AS SHOWN	Date Issued: 11/1/01	Drawing Type: DRAFT	Job No.: 4978	SHEET: 2 of 3	PLATE: 2



SEA-TAC THIRD RUNWAY

SITE AND EXPLORATION PLAN
NORTH SAFETY AREA

Scale: AS SHOWN	Date Issued: 11/1/01	Drawing Type: DRAFT	Job No.: 4978	SHEET: 3 of 3	PLATE: 3

Appendix C

APPENDIX C

BORROW AREA IMPACTS TO WETLANDS

APPENDIX C

BORROW AREA IMPACTS TO WETLANDS

Appendix C contains geotechnical-engineering reports that address potential impacts to wetlands as a result of the development of the 3 proposed on-site borrow areas. The reports form, in part, that basis for the analyses of direct and indirect wetland impacts from borrow area development.

C-1

Borrow Areas 1, 3, and 4 – Projected Impacts to Wetlands

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Seattle

MEMORANDUM

DATE: December 8, 2000

TO: Ralph Wessels, Port of Seattle

FROM: Reese P. Hastings and Michael J. Bailey, P.E., Hart Crowser, Inc.

RE: **Third Runway Project, Borrow Areas 1, 3, and 4**
Projected Impacts to Wetlands
J-4978-06

CC: Marti Louther and James C. Kelley, Ph. D., Parametrix, Inc.
J. Thomson, P.E., HNTB

On-Site Borrow Activities

This memorandum quantifies the potential impacts to wetland resources resulting from development of Borrow Areas 1, 3, and 4, and an on-site haul route for use in the construction of the Third Runway embankment. Completion of the Third Runway embankment will require about 17 million cubic yards of compacted earth fill. Use of borrow sites owned by the Port of Seattle (Port) to provide this material will significantly reduce air quality and local traffic impacts associated with haulage from off-site sources.

The Final Environmental Impact Statement (FEIS) (prepared for Sea-Tac International Airport's Proposed Master Plan update development actions) discussed development of construction fill material borrow areas from eight identified sources within property controlled by the Port. Based on several factors (wetlands impacts, material types, operational costs) the Final Supplemental Environmental Impact Statement (FSEIS) indicated that four of these eight on-site resource areas could likely be used to extract a maximum quantity of 15.45 million cubic yards of fill material. Further study by the Port has focused on the Borrow Areas designated 1, 3, and 4, which are proposed to provide a combined total of 6.7 million cubic yards. Figure 1 - Site Location Map shows the location of Borrow Areas 1, 3, and 4.

Original resource estimates for two of these borrow areas have been revised in an effort to minimize the potential impacts on wetland resources delineated therein. The decrease in

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the potential impacts to wetland resources and the decline in the resource estimates are described below.

Borrow Area 1

Borrow Area 1 is located less than a mile south of the Airport's 34 R runway. It consists of approximately 121 acres situated northwest of South 216th Street and 24th Avenue South. The area is bounded by these streets to the south and east, respectively, and on the north and west sides by the Des Moines Creek Park and the proposed Washington State Department of Transportation (WSDOT) SR-509 extension right of way. Borrow Area 1 is located in the City of Des Moines and City of SeaTac.

Engineering estimates conducted in 1994 supporting the FEIS and FSEIS indicated that the borrow material resource consists of glacially deposited, slightly silty to silty sands and gravels. Volumetric estimates presented in the FSEIS indicated that 6.6 million bank cubic yards (BCY - volume unit of soil in place, prior to excavation) of material were available from Borrow Area 1. Changes in site development conditions and the adoption of wider buffers (perimeter, stream) have resulted in this figure being adjusted. Estimates were revised in 1998 and indicate that this area still has the potential to generate substantial quantities of fill, and if fully utilized, it would produce approximately 4.8 million BCY of borrow material. Figure 2 shows the conceptual end of mining topography for the area based on full utilization.

There are 1.83 acres of wetlands within Borrow Area 1, some of which can be avoided without significantly diminishing the available borrow resource (as discussed below). Examination of Figure 2 shows how the current full utilization development plan will avoid several perimeter wetlands, and how it will utilize a 200-foot setback to avoid the Des Moines Creek drainage system. Post-extraction topography would drain toward the creek through approved erosion, infiltration, and sediment control structures constructed along the western margins of the excavation.

Under the Port's currently proposed development alternative to avoid impacts to wetlands and enhance site infiltration and off-site drainage to Des Moines Creek within or adjacent to the western margins of Borrow Area 1, approximately 4.2 million BCY of borrow material would be available. The resource reduction from 4.8 million BCY to 4.2 million BCY was done specifically to avoid impacts to off-site wetlands. Figure 3 shows how this alternative would be contoured to infiltrate or drain precipitation naturally through existing wetlands, draws, or ravines into Des Moines Creek and adjacent wetlands.

Borrow Area 3

Borrow Area 3 is located south of the Airport's 34 L runway, in the City of SeaTac. It consists of approximately 60 acres, bounded on the north by South 200th Street, and to the east by 18th Avenue South and the WSDOT right of way. The resource consists of glacially deposited, slightly silty to silty sands and gravels. Borrow Area 3 contains 2.35 acres of wetlands. Full utilization of the available resource would produce approximately 1.5 million BCY of borrow material for use in the construction of the Third Runway embankment (see Figure 4). Under the Port's currently proposed development alternative to avoid impacts to all the wetlands in Area 3, approximately 1.0 million BCY of the borrow resource would be available (see Figure 5). The resource reduction from 1.5 million BCY to 1.0 million BCY was done specifically to avoid impacts to on-site wetlands. Material extraction would be conducted in a manner that would preserve local hydrologic seepage thought to support Borrow Area 3 wetlands (see Hart Crowser, 2000).

Borrow Area 4

Immediately north of Borrow Area 3 and approximately 1,100 feet south-southwest of the runway is Borrow Area 4 (see Figure 4). The site comprises an area of approximately 36 acres and is located west of the Tyee Golf Course. It is bounded to the south by South 200th Street, to the east by 18th Avenue South, and to the north by South 196th Street. The resource geology has been identified as being generally similar to that of Borrow Area 3. No wetlands exist in Borrow Area 4. Full utilization of the available resource will produce approximately 1.5 million BCY of borrow material for use as embankment fill.

Conceptual Truck and Conveyor Haul Routes

Transfer of borrow materials from the above-named sources will be accomplished by truck or conveyor haulage. Conceptual haul route alternatives have been laid out to avoid wetlands impacts and to avoid conflicts with future construction of the proposed regional detention facility (RDF) to be located within the existing Port-owned Tyee Golf Course.

Figure 6 shows conceptual haul routes across Port property consisting of the Tyee Golf Course and the southern airport roadway system, to transport materials from Borrow Areas 1, 3, and 4 as presented in the FSEIS.

Three conceptual haulage mechanisms were evaluated: conventional or heavy mining truck haulage using a dedicated haul road on Port property; and a material conveyor system aligned along a similar route with a dedicated service road. The truck and conveyor routes are aligned primarily to avoid wetlands and accommodate industry-standard turning radii and roadbed grades (trucks set at <8%, conveyor set at <15°) suitable for the selected haul method (see Figure 6).

Haul routes would cross existing City of SeaTac streets (18th Avenue South and South 200th Street) at grade or via grade-separated crossings depending on selection of a preferred haul method and outcome of future studies. Haulage within the City of Des Moines would utilize existing streets or dedicated routes again depending on selection of a preferred haul method. Haulage across South 188th Street is anticipated to utilize a grade separation (special purpose bridge) regardless of which haulage method is selected.

The conceptual haul routes utilize similar terrain traversing along the eastern edge of Borrow Area 3 north toward South 200th Street, crossing onto the southeastern corner of Borrow Area 4 before heading northeast across the Tyee Golf Course toward the airport. Conceptual haul route alignments across the Golf Course have been laid out to avoid wetland impacts. Once the routes reach the central portion of the golf course, they extend along the southeastern berm of the proposed Des Moines Creek RDF, cross Des Moines Creek, and then turn north in a parallel course next to the runway approach light towers. At the southern toe of the runway embankment, the routes ascend the grade to connect into the existing airport roadway system situated on the west flank of the 34 R runway embankments. The routes then follow the southern edge of South 188th Street westward to a point where a proposed new bridge crossing structure will connect the haul route to the existing airport roadway system on the north side of the street. The haul route will then follow existing roadways along the western edge of the airport to the embankment construction site.

Borrow Development - Potential Impacts to Wetland

Wetland delineation efforts conducted throughout 1998 and 1999 identified the wetland resources indicated on Figures 2 and 4 within Borrow Areas 1 and 3. Delineation efforts have not identified any wetland resources within Borrow Area 4. Of the wetlands delineated within the Tyee Golf Course, only those adjacent to the conceptual haul route are shown on Figure 6. The areal extent of wetlands in each borrow area and the golf course that could be potentially impacted by borrow material development and hauling activities are summarized in Table 1.

Borrow Area 1

Full development of construction materials from Borrow Area 1 would likely impact approximately 1.40 acres of the 1.83 acres of wetland delineated for this site. However, the proposed approach to developing Area 1 as depicted on Figure 3 would minimize these impacts to 1.03 acres or less, and facilitate on-site infiltration and free drainage of direct precipitation and surface runoff into Des Moines Creek and the adjoining wetlands located on the parcel adjacent to and west of Wetlands 15a and 48. Excavation in these five wetlands (B-1, B-4, B-15a/b, 32, and 48) will be avoided by configuring the borrow site boundary and mined slopes a minimum of 50 feet away from wetland edges.

Potential impacts to Wetland B-15a/b and 48 would be completely avoided by not having any material extraction activities from the area west of 20th Avenue South. The portion of land west of 20th Avenue South would be managed to preserve the overland flow, which contributes, in a limited manner, to the perched wetland hydrology supporting these two flat-lying wetlands. Potential impacts to Wetlands B-1, B-4, B-15a/b, 32, and 48 will also be avoided through the use of 50-foot buffers. No borrow material extraction would occur within the wetland buffer.

It will not be practicable to avoid the remaining wetlands in Borrow Area 1 because:

- The preservation of the wetlands would render the resource impracticable to mine; or
- Mining the resource would completely remove the upgradient source of water sustaining the wetland.

Borrow Area 3

Full development of Borrow Area 3 would impact the wetlands delineated within the area boundary. However, the proposed approach to developing Borrow Area 3 as depicted on Figure 5 would avoid these impacts. As explained Hart Crowser October 20, 2000, memo, hydrogeologic studies indicate the source of water feeding the Borrow Area 3 wetlands will remain intact given that surface drainage and perched seepage systems immediately upgradient will remain undisturbed and seepage adjacent to Wetland 29 will remain unimpaired. As noted above, avoiding the wetlands would still allow development of a substantial volume of construction material from Borrow Area 3. Where mining intercepts surface seepage in areas immediately to the north of these wetlands, a collection and conveyance system in the form of a drainage swale will help ensure that an adequate amount of water from these areas will supply of water to nearby wetlands Figure 5 (Hart Crowser, 2000).

The haul route has been aligned through Borrow Areas 3 and 4, and the Tyee Golf Course with the goal of avoiding or minimizing the potential for impacts to wetlands:

- Wetlands delineated in Borrow Area 3 would not be impacted by the construction and operation of the conceptual means of haulage; and
- Wetlands delineated within the confines of the Tyee Golf Course have been avoided.

Mitigation

In addition to avoidance of wetland fill or excavation, other mitigation activities that will minimize indirect wetland impacts arising from borrow development or haulage will include:

- Conduct material extraction during the summer season and maintain site drainage through use of TESC measures throughout the winter rainy season;
- Use of 50-foot-wide undisturbed buffers around delineated wetlands;
- Preservation of water recharge source areas upgradient of wetlands;
- Construction of a drainage swale to maintain seepage flows to wetlands in Borrow Area 3;
- Use of berms or other erosion protection to prevent overland flow away from wetlands into excavated areas;
- Implementation of TESC measures (berms, silt, fencing, hay bales, drainage control swales, ponds, recontouring, etc.) within the borrow and haul areas to protect wetlands from storm water impacts; and
- Modification of mining methods (borrow area bench layout, slope stability, recontouring), and re-alignment of preferred construction material haul routes (side-cast materials, road maintenance).

Borrow Area 1

Mitigation of potential impacts in Area 1 will include modification to the conceptual post-mining contours along portions of the southern, western, and eastern perimeter. Use of a 50-foot-wide undisturbed buffer around five wetlands (B-1, B-4, B-15a/b, 32, and 48) would insulate the wetlands from activity related to borrow material development, (see Figure 3). Borrow Area 1 operations can be completed without disrupting the upgradient source of water needed to sustain these wetlands, for example, near Wetlands B-15a/b and 48, borrow material extraction activities have been shifted over 200 feet to the east.

Mitigation will also include the use of a stream setback averaging 200 feet to protect Des Moines Creek from the potential impacts of borrow development activities. Excavation along the stream buffer areas would allow borrow area bench layout and recontouring measures to provide for adequate positive drainage or infiltration from the extraction areas to the east. This combined approach to on-site infiltration and off-site drainage is required to prevent water from accumulating in the borrow area for significant periods of time.

Borrow Area 3

Mitigation of potential impacts to wetlands in Borrow Area 3 will rely upon the combined effect of avoidance and mitigation incorporated into the alternate development scenario portrayed on Figure 5.

The preferred plan for excavating borrow materials from Borrow Area 3 (identified as Alternative 2) would preserve the wetlands by maintaining 50-foot-wide undisturbed buffer zones around the wetlands, and by not mining in any areas that directly contribute surface water or groundwater flow to the wetlands. Borrow development would include construction of a drainage swale to convey seepage and precipitation into Wetland 29 that might reach this wetland by lateral flow mechanisms from the perched seepage zone to the north. Proposed mining would not impact up gradient flows into this wetland. The water conveyed by this drainage swale into Wetland 29 would mitigate potential indirect effects of mining north of this wetland (Hart Crowser, 2000). Mining would not affect seepage draining from Wetlands B-10 and 29 south and east through Wetlands B-5, B-6, B-7, and B-9 and Wetland 30, by virtue of their locations on the slopes above the mined areas.

Mining will occur to elevations that are no more than 1 to 2 feet below the base elevations of the nearest adjacent wetlands as shown by the proposed end of mining topography on Figure 5. Given that these wetland experience significant losses by percolation through permeable soils beneath the wetlands, and that seepage from upgradient sources will remain uninterrupted, mining will not materially affect the hydrology of the wetlands. Mining will be confined to a zone north and east of the wetlands, leaving the primary wetland water source areas in the southwestern portion of the site generally undisturbed.

Haul Routes

The haul route alignment was developed to avoid wetland impacts, to the maximum extent practical. Mitigation of potential impacts arising from hauling activities would consist of TESC measures near wetlands or buffers. The routes laid out for both the truck or conveyor options will have some minor temporary impact on riparian Wetland E, where the haul route must cross Des Moines Creek (see Table 1 and Figures 6 and 7). The proposed conceptual haul route alignments go around Wetlands G-1, G-2, and G-3, entirely avoiding any impacts by utilizing existing roads. Aside from the steam crossing, the routes maintain a minimum buffer distance of 50 feet, except in the vicinity of Wetland G-3 (on the west side of the 34 R runway embankment), the routes maintain a minimum buffer distance of 50 feet, see Figure 8.

In that single location, the haul route would come within 20 to 30 feet of the northeastern tip of this wetland (see Figure 8). The potential for sedimentation or water quality impacts to this wetland from hauling activity in this area would be avoided by the installation of silt fencing, berm and a drainage ditch along the outside shoulder of the road, and other appropriate TESC measures (storm water management ponds, etc.).

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Attachments:
Table 1 - Summary of Potential Wetland Impacts for Borrow Areas 1, 3, and 4 and
Conceptual Haul Routes
Figure 1 - Site Location Map
Figure 2 - Conceptual End of Mining Topographic Map for Borrow Area 1
Alternative 1 - Full Utilization
Figure 3 - Conceptual End of Mining Topographic Map for Borrow Area 1
Alternative 2 - Avoidance of Wetland Impacts
Figure 4 - Conceptual End of Mining Topographic Map for Borrow Areas 3 and 4
Alternative 1 - Full Utilization of Borrow Area 3
Figure 5 - Conceptual End of Mining Topographic Map for Borrow Areas 3 and 4
Alternative 2 - Avoidance of Wetland Impacts
Figure 6 - Proposed Haulage Routes Map
Figure 7 – Details of Proposed Haulage Routes
Figure 8 - Borrow Area Haul Route Representative Cross Section
At Closest Encroachment Wetland (Sta H+59.5)

References:
Hart Crowser, 2000. Memo, Sea-Tac Third Runaway – Borrow Area 3, Preservation of Wetlands.
J-4978-06, October 20, 2000.

Table 1 - Summary of Potential Wetland Impacts for Borrow Areas 1, 3, and 4 and Conceptual Haul Routes

BORROW AREA 1

Wetland	Area in Acres	Impacted Area in Acres	Comments
B-1	0.27	0	Impacts avoided
B-4	0.07	0	
32	0.09	0	
B-15a	0.19	0.19	Mining will temporarily alter buffers, wetland, and surface water sources
48	0.14	0.14	
B-11	0.18	0.18	Impacts unavoidable, mining will eliminate upgradient sources of water
B-12	0.07	0	
B-14	0.78	0.78	
B-15b	0.02	0.02	

TOTAL	**1.81**	**1.31**

BORROW AREA 3

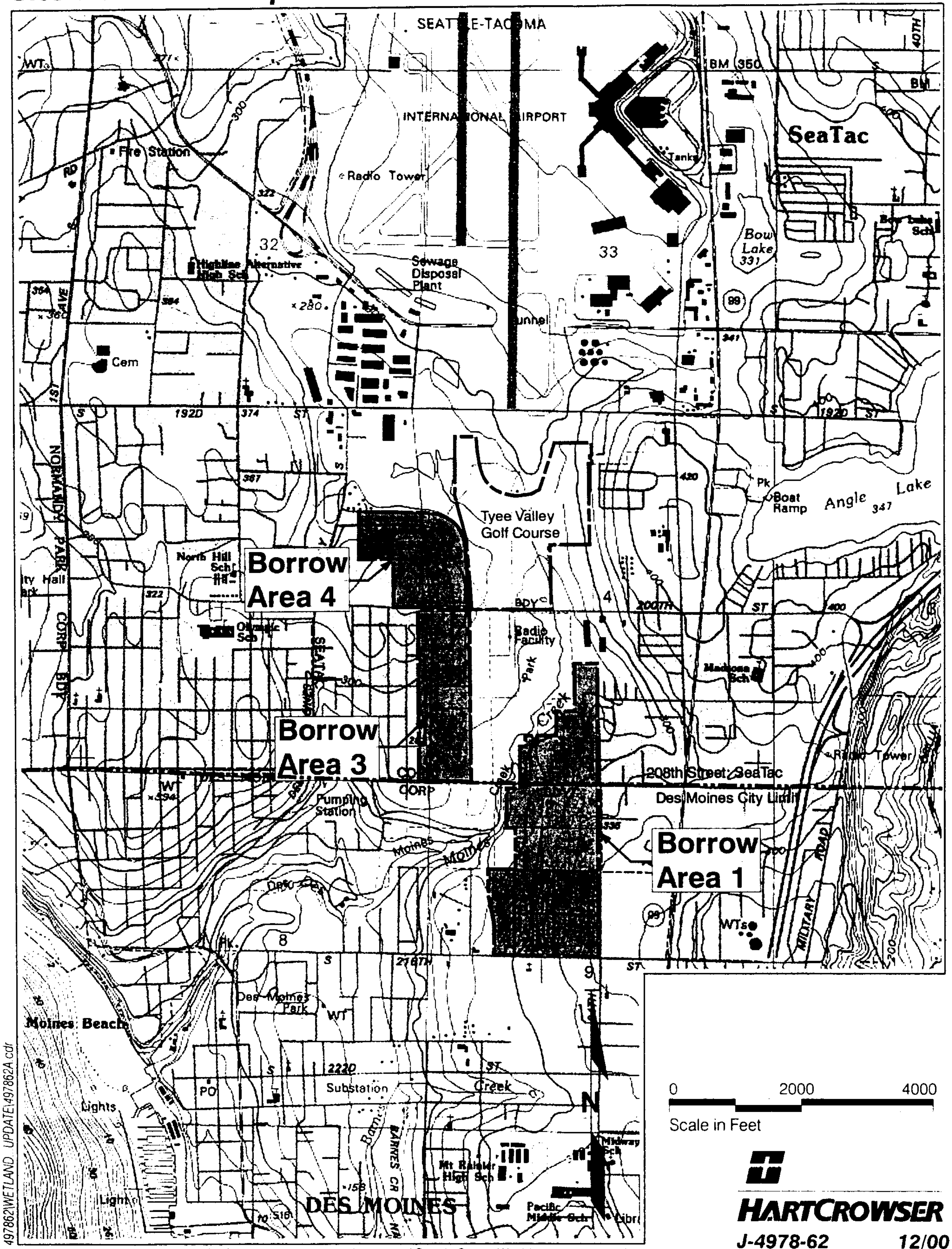
Wetland	Area in Acres	Impacted Area in Acres	Comments
B-1	0.02	0	Impacts completely avoided with Mining Alternative 2
B-5	0.08	0	
B-6	0.55	0	
B-7	0.03	0	
B-9	0.05	0	
29	0.74	0	
30	0.88	0	
TOTAL	**2.35**	**0**	

CONCEPTUAL HAUL ROUTES (DES MOINES CREEK CROSSING)

Wetland	Area in Acres	Impacted Area in Acres	Comments
		Truck/Conveyor	
E	0.07	0.03/0.01	Impact depends on selected haulage method
TOTAL	**0.07**	**0.03/0.01**	

497806/impactwetlands-finrph.xls

Site Location Map



Note: Base map prepared from USGS 7.5 minute quadrangle maps of Seattle South, Washington, revised 1995

497862\WETLAND_UPDATE\497862A.cdr

HARTCROWSER

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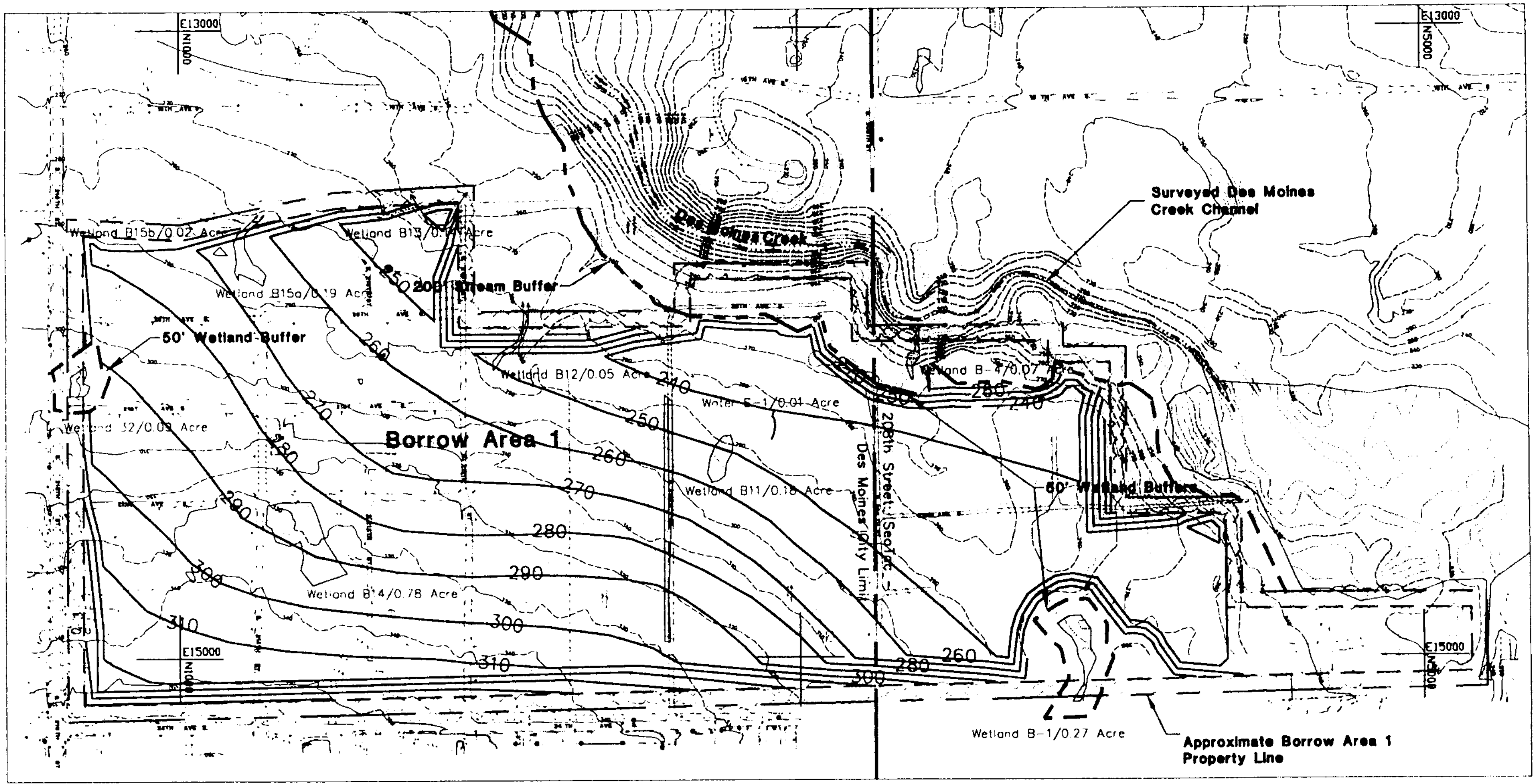
Figure 1

RC 12/4/00 1=500 (xref)see drawing file/woodstck.pcp
Wetland..Update\49786237

Conceptual End of Mining Topographic Map for Borrow Area 1

Alternative 1 - Full Utilization



Notes: Base map prepared from drawing provided by HNTB entitled "Base03", dated October 6, 1998. Wetland and stream channel survey data provided by Parametrix drawing entitled "w052899," dated May 28, 1999.

—300— Conceptual End of Mining Elevation Contour in Feet

Existing Elevation Contour in Feet

— — — — Reclamation Setback

Wetlands Delineated by Parametrix (11/00)

— — — — 50-Foot Wetland Buffer

— - - — 200-Foot Stream Buffer

N

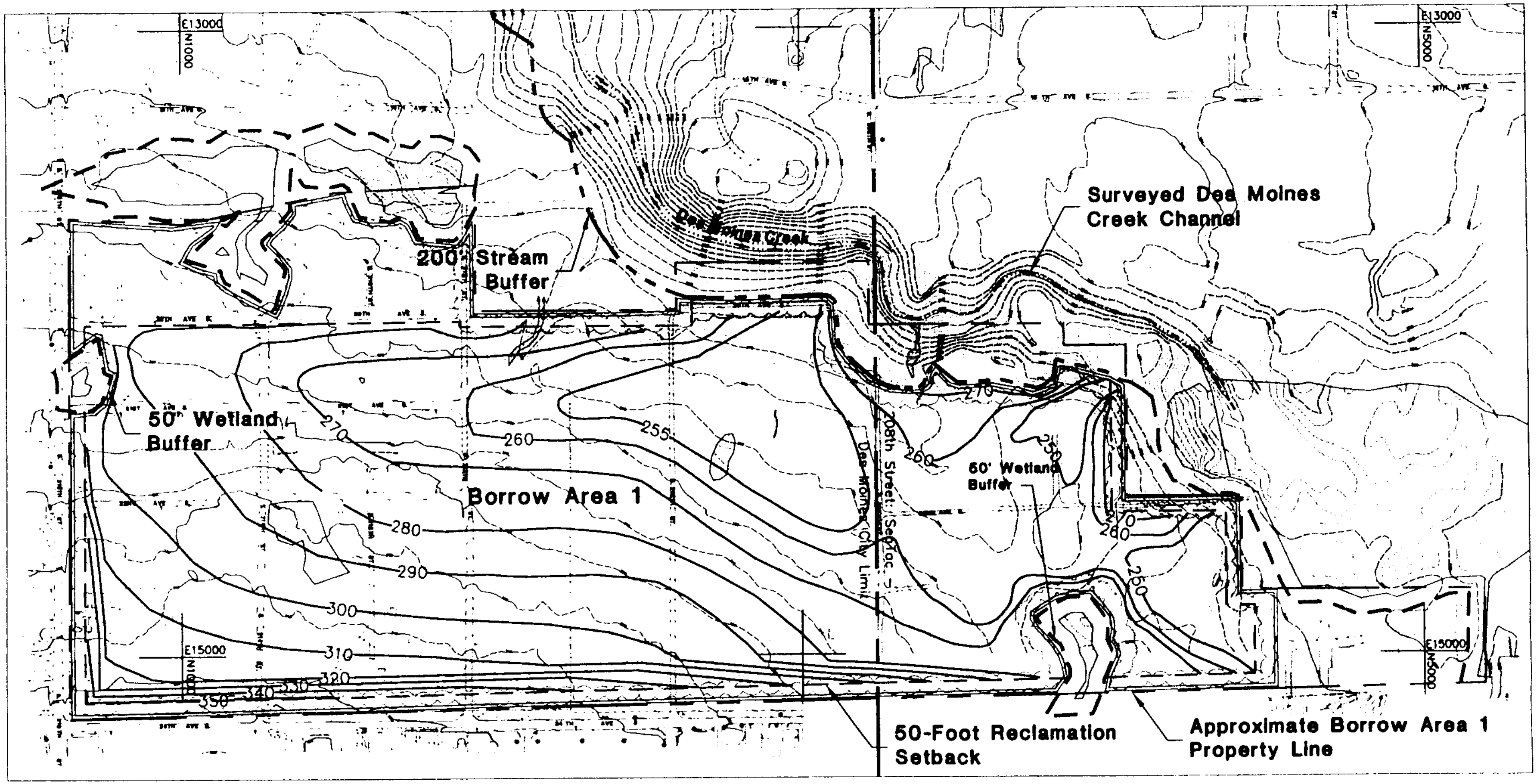
0 500 1000
Scale in Feet

HARTCROWSER
J-4978-62 12/00
Figure 2

RC 12/4/00 1=500 charlie-8.pc2Wetland...Update\49786234

Conceptual End of Mining Topographic Map - Borrow Area 1

Alternative 2 - Avoidance of Wetland Impacts



Note: Base map prepared from drawing provided by HNTB entitled "Base03", dated October 6, 1998. Wetland and stream channel survey data provided by Parametrix drawing entitled "W_110800," dated November 8, 2000.

HARTCROWSER

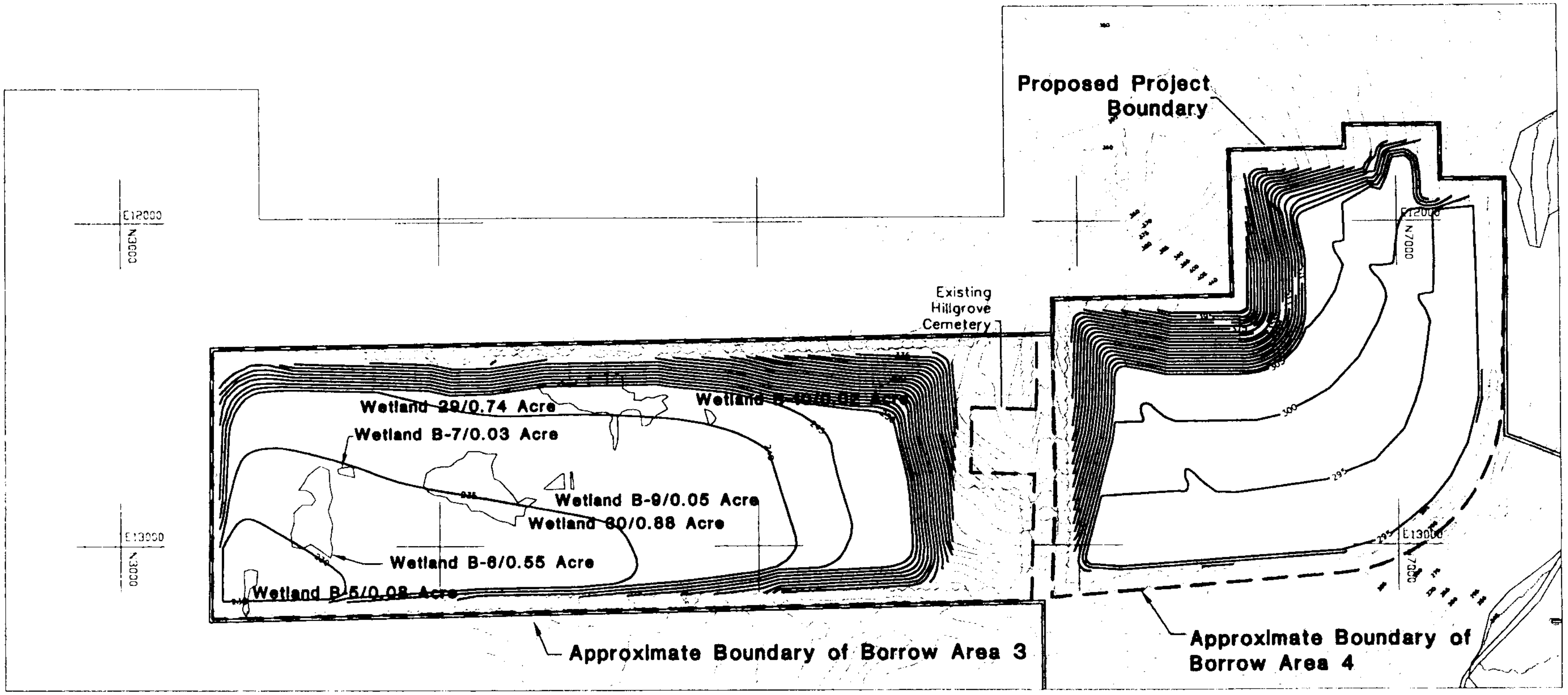
J-4978-62 12/00

Figure 3

RC 12/4/00 1=500 (xref) w052899.dwg/woodstck.pcp 8.5x11
Wetland Update\49786235

Conceptual End of Mining Topographic Map for Borrow Areas 3 and 4

Alternative 1 - Full Utilization of Borrow Area 3



Note: Base map prepared from drawing provided by HNTB entitled "Borrow Site Areas 3 & 4 Grading Plan," dated April 13, 1998.

250 Proposed End of Mining Elevation Contour in Feet

Existing Elevation Contour in Feet

Wetlands Delineated by Parametrix (8/98)

Proposed Borrow Development Project Boundary

N

0 500 1000

Scale in Feet

HARTCROWSER

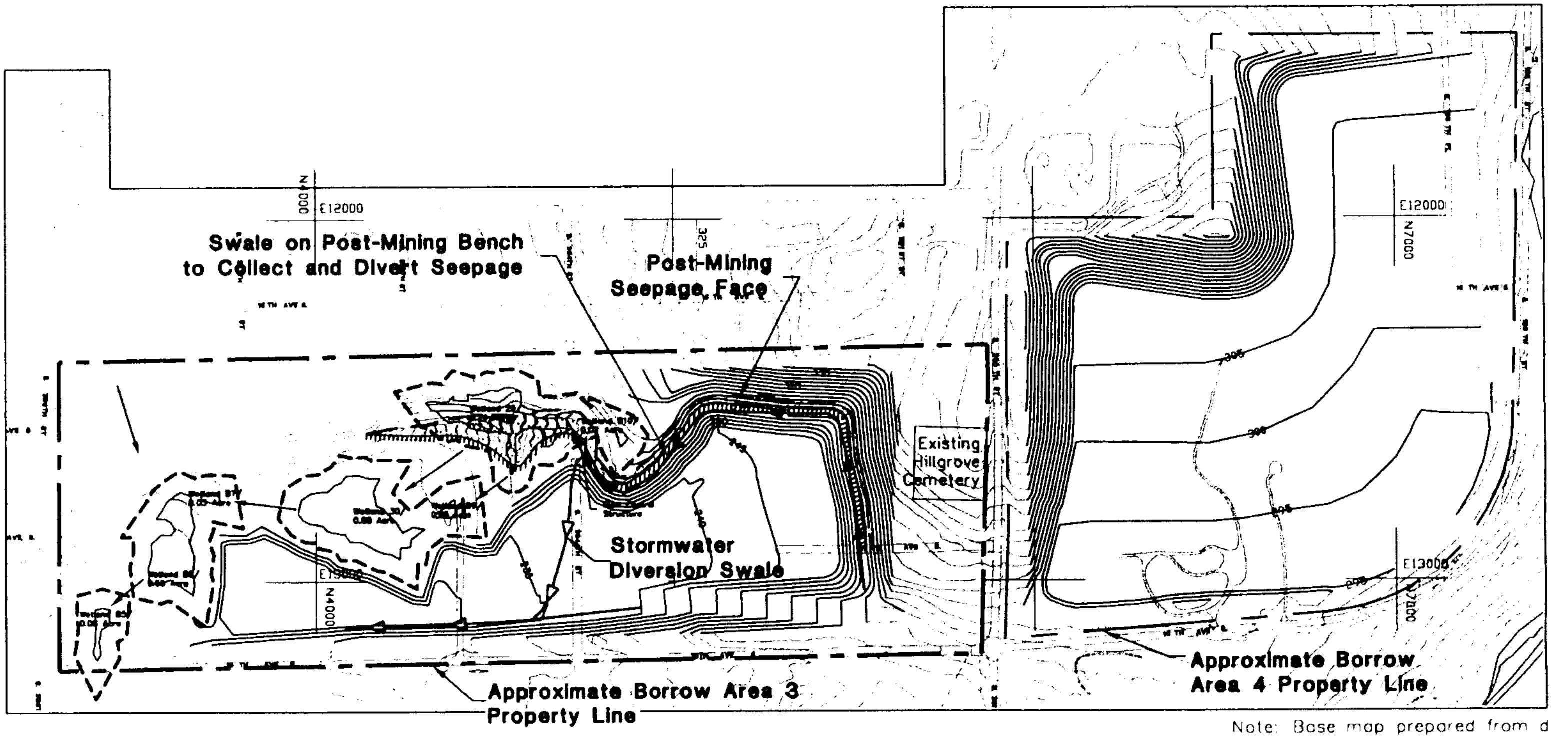
J-4978-62 12/00

Figure 4

RC 12/4/00 1=500 (xref)grid.dwg, wet040799.dwg, seepage.dwg, base-newA4.dwg/woodstock.pcp 8.5x11
Wetland...Update\49786236

Conceptual End of Mining Topographic Map for Borrow Areas 3 and 4

Alternative 2 - Avoidance of Wetlands Impacts & Drainage Swale



Note: Base map prepared from drawing provided by HNTB entitled "Borrow Site Areas 3 & 4 Grading Plan", dated April 13, 1998.

250 Proposed End of Mining Contour

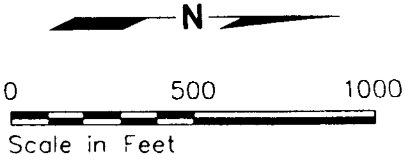
300 Existing Contour

Wetlands Delineated by Parametrix (8/98)

Wetland and Stream Buffer

Inferred Seepage Face above Outcrop of Perching Layer

Direction of Surface/Shallow Subsurface Drainage



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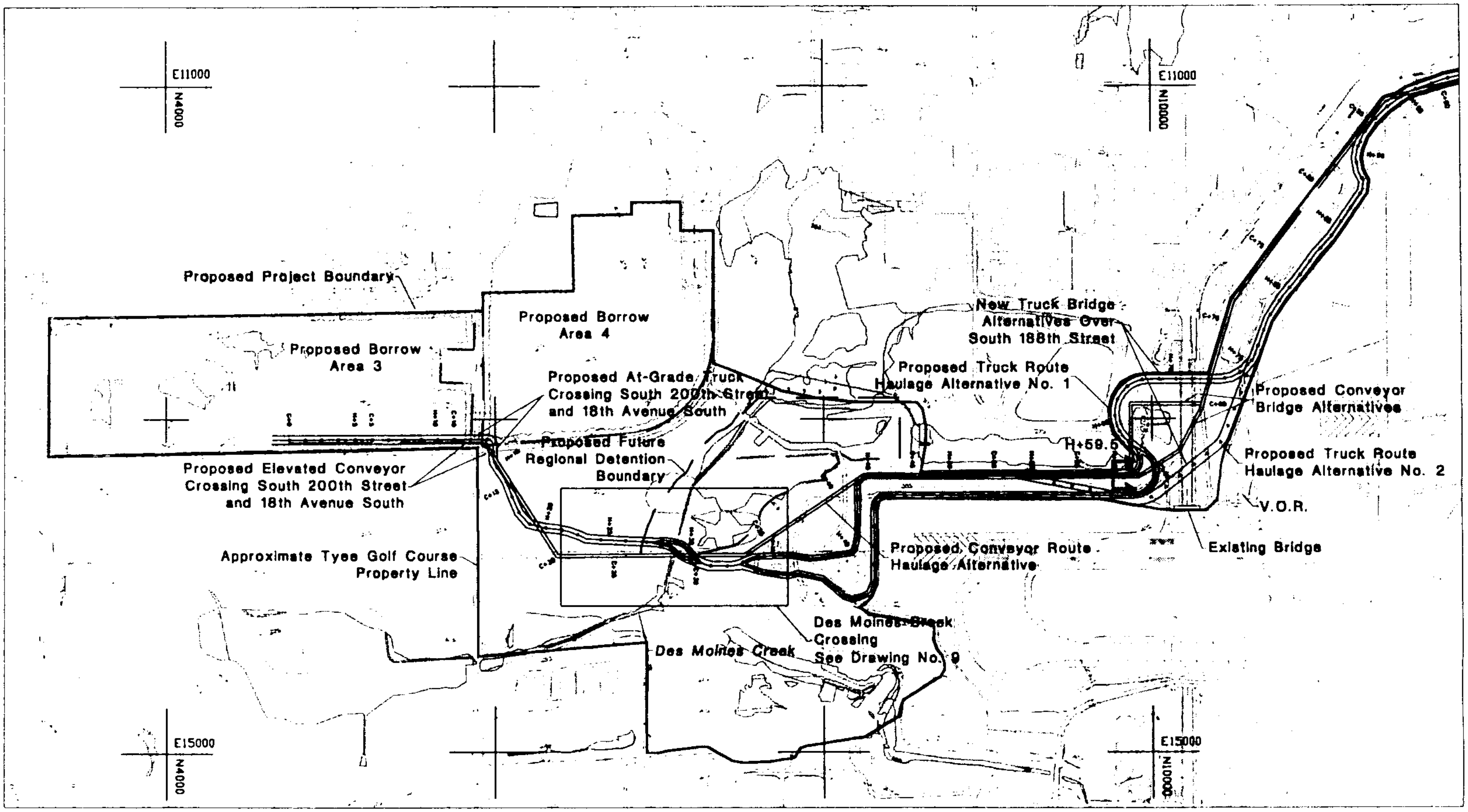
J-4978-62 12/00
Figure 5

RC 12/5/00 1=1 (xref)see drawing file/charlie-8.pc2
49786239

Proposed Haulage Routes Map



Note:
1) 25-foot elevation contours generated from drawing provided by HNTB entitled "Borrow Areas 3 & 4 Grading Plan", dated April 13, 1998.
2) Wetland delineation prepared from drawing provided by Parametrix entitled, "W_062700.dwg", dated June 27, 2000.

○	Wetland Delineated by Parametrix and King County
— —	RDF Boundary (Flooding extends beyond boundary shown)
H+59.5	Cross Section Location (See Figure 7)

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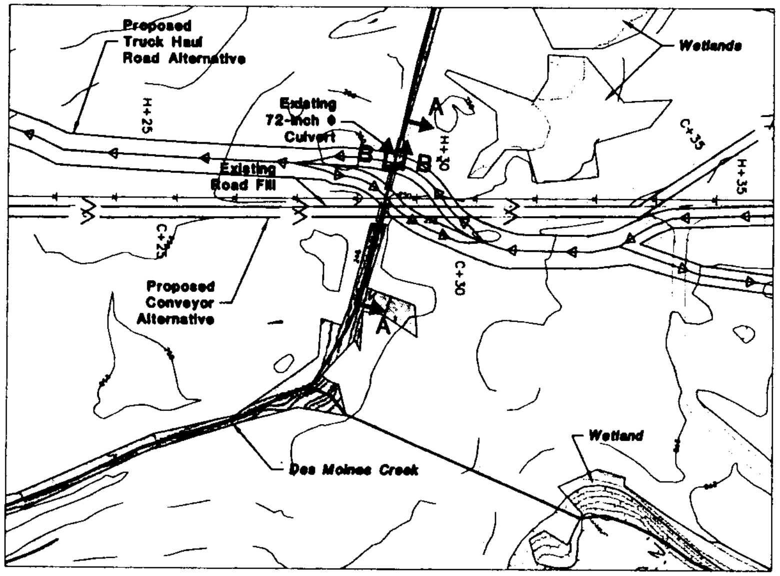
Figure 6

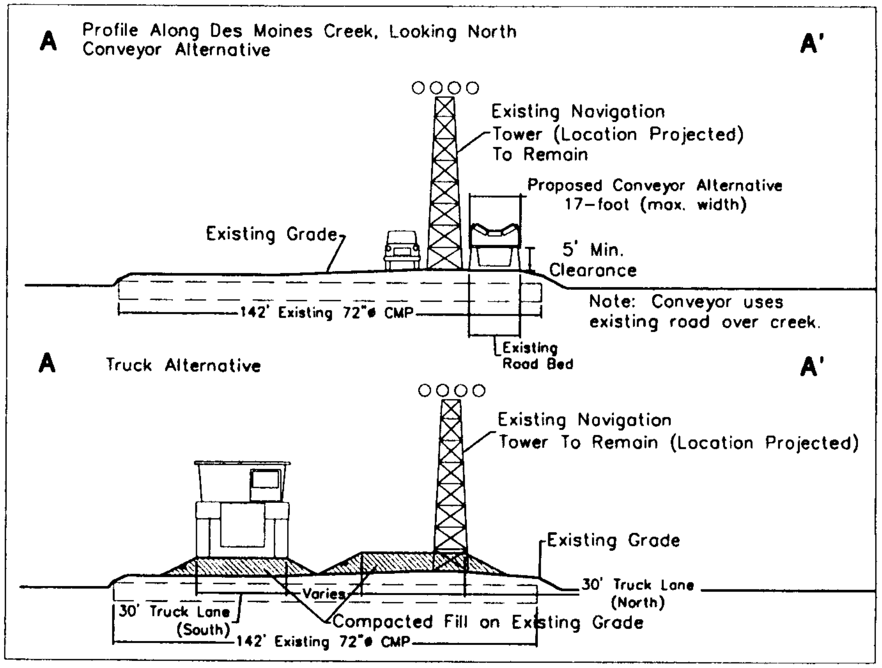
RC 12/5/00 1=1 (xref)see drawing file/charlie.pc2
49786240

Representative Conceptual Des Moines Creek - Borrow Area Haul Road Crossing Map and Cross Sections

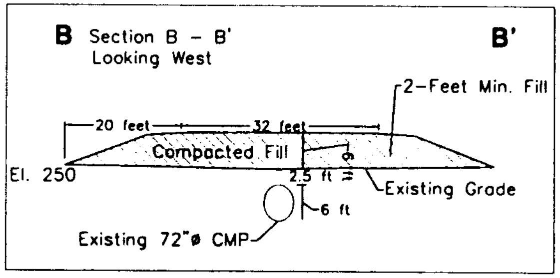


Conceptual Des Moines Creek - Haul Road Crossing Map

Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetland delineation prepared from drawing provided by Parametrix entitled, "W_062700.dwg", dated June 27, 2000.



Conceptual Haul Road Crossing of Des Moines Creek



Conceptual Fill Section at Haul Road Crossing Des Moines Creek

Note: Culvert will be replaced in accordance with "Fish Passage Design at Road Culverts," published March 3, 1999, by Washington Department of Fish and Wildlife.

RC 12/4/00 1=100 8.5x11 woodstock.pc2 49786241

Borrow Area Haul Route Representative Cross Section

At Closest Encroachment to Wetland (Sta H+59.5)

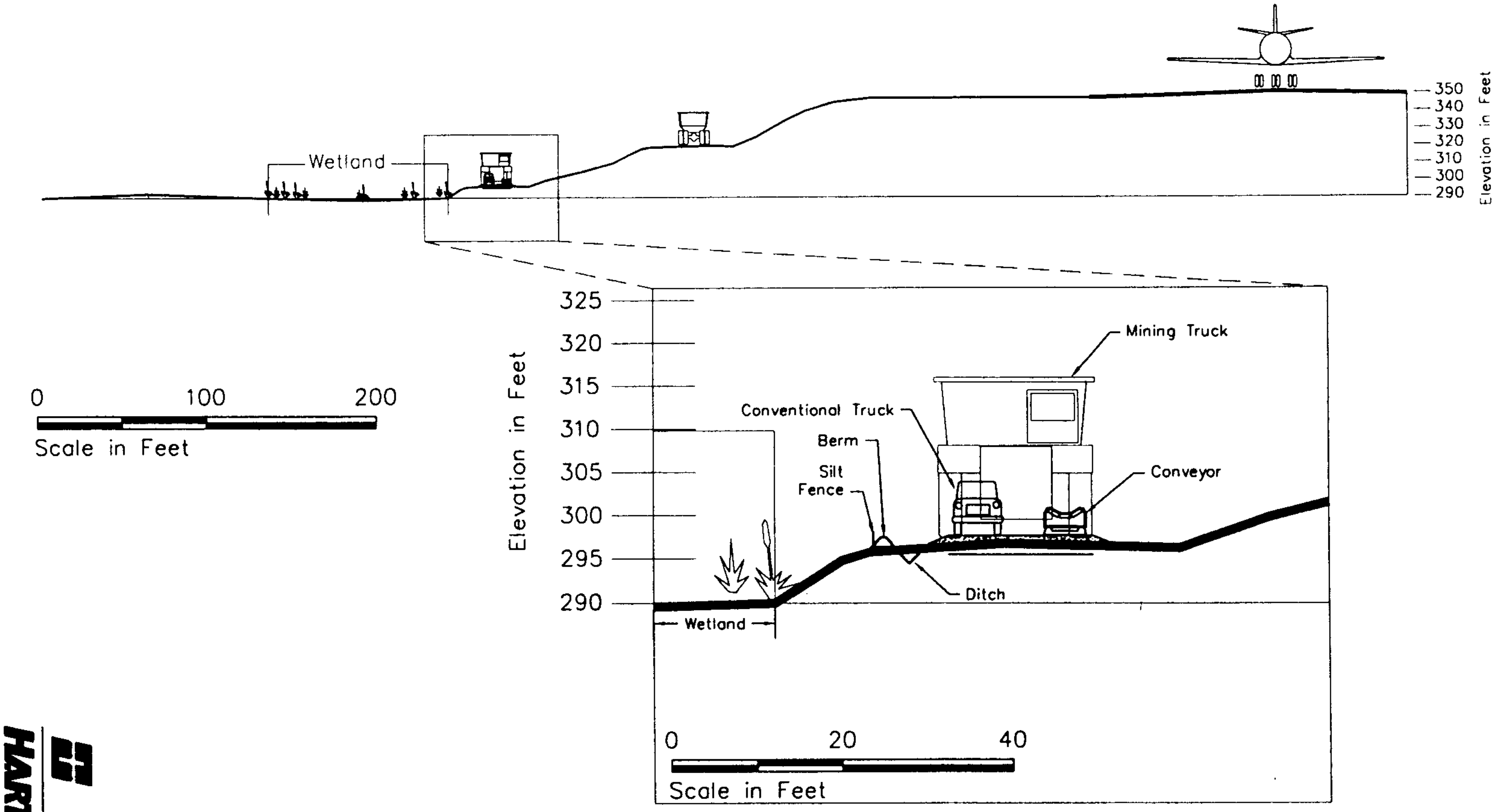


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Figure 8

C-2

Hydrologic Conditions and Wetland Hydrology-Borrow Area 1

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MEMORANDUM

DATE: December 12, 2001

TO: Jim Thomson, HNTB

FROM: Michael Kenrick & Reese Hastings, Hart Crowser Inc.

RE: **Hydrologic Conditions and Wetland Hydrology**
Borrow Area 1
4978-62

INTRODUCTION

This memorandum provides an analysis of pre-construction and post-construction surface water and groundwater conditions at Borrow Area 1, which is one of the three proposed on-site borrow areas that are part of the Port of Seattle's Master Plan Update for Sea-Tac International Airport (STIA). The analysis includes evaluations of changes to local surface water and groundwater conditions, and measures planned by the Port to avoid potential hydrologic impacts to Des Moines Creek and wetland resources.

The Final Environmental Impact Statement (FEIS) prepared for STIA's Proposed Master Plan Update development actions (FAA 1996) discussed development of construction fill material borrow areas from eight identified sources within property controlled by the Port. Further study by the Port has focused on the Borrow Areas designated 1, 3, and 4, which are proposed to provide a combined total of 6.7 million cubic yards of fill material for embankment construction. Drawing 1 – Site and Exploration Plan shows the layout of Borrow Area 1. Development of materials from Borrow Areas 3 and 4 and the mitigation of potential hydrologic impacts to wetlands has been addressed in separate memoranda, including Sea-Tac Third Runway Borrow Area 3 Preservation of Wetlands (Hart Crowser 2000) and the conceptual development and reclamation plan (Hart Crowser 2001).

SUMMARY

Development of Borrow Area 1 has been planned to avoid disturbing wetlands to the maximum practical extent, and to avoid negative impacts to site hydrology associated with

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runoff and infiltration. The analysis of hydrologic impacts to wetlands discussed herein is consistent with results of the previous hydrologic study commissioned by the Washington State Department of Ecology (PGG 2000).

The proposed excavation plan for Borrow Area 1 preserves the upgradient surface drainage features that currently provide water to off-site wetlands, and promotes additional surface drainage that will continue to sustain these wetlands. Wetlands internal to the site (1.08 acres) will be unavoidably impacted by the borrow excavation. However, the excavation will remove mostly glacial till soils, which currently promote runoff and interflow that follow a relatively direct path to Des Moines Creek.

The completed excavation will expose an area of advance outwash soil below the glacial till. Since the outwash soils have greater permeability compared to the glacial till, precipitation and runoff from the post-mining topography will infiltrate into the exposed outwash and increase recharge to the underlying water table. This process will increase overall flow path duration, groundwater storage, and result in increased base flow to Des Moines Creek.

EXISTING CONDITIONS

Borrow Area 1 is located less than a mile south of the STIA's 34R runway. It consists of approximately 116 acres situated northwest of South 216th Street and 24th Avenue South. The area is bounded by these streets to the south and east, respectively, and on the north and west sides by the Des Moines Creek Park and the proposed Washington State Department of Transportation (WSDOT) SR-509 extension right of way. Borrow Area 1 straddles the boundary between the City of Des Moines and City of SeaTac.

Site Geology

Investigations of site geology at Borrow Area 1 have consisted of a review of prior field work in the area and six exploratory borings drilled by Hart Crowser in 1999, as shown on Drawing 1. The surficial geology in Borrow Area 1 previously identified as consisting of glacial till, preglacial, and recessional outwash materials (AGI 1995 and 1996) has been modified somewhat by more recent boring information. Hart Crowser's work determined that the glacial till forms a moderately thick continuous layer, with surface expression in the southern, central, and eastern portions of the site, while recessional outwash covers the lower elevations in the northern part of the site.

Drawings 2 and 3 show the principal soil units (recessional outwash, glacial till, and advance outwash), which are relatively continuous across the site. For clarity, several minor soil units that are not continuously present at the site are discussed below, but are not shown on the drawings.

Shallow Soils

Topsoil. Typically, this soil consists of a loose mixture of silt and sand with roots and other organic material. Topsoil is generally 1/2 to 1 foot thick where encountered. Many of the surficial soils at the site appear to be glacial soils at different stages of weathering.

Fill Soils. Fill soils were encountered in both the north and west of the site, typically associated with access roads, paved streets, or other grading activities associated with prior site use. Fill soils are generally loose to medium dense, comprising a variable mixture of silt, clay, sand, and gravel, and appear to be derived from the local glacial soils. The density and granular nature of the fill materials resemble the recessional outwash deposits, and the fill is sometimes difficult to distinguish from the outwash.

Alluvial Deposits. These soils occur in the low-lying areas and generally consist of soft or loose, moist to wet, interlayered silt, sand, and peat. While limited occurrences of these soils have been observed in the field, none were noted in our exploration borings.

Recessional Outwash. This material is generally slightly silty to silty, slightly gravelly to gravelly sand. Recessional outwash overlies the glacial till, and overlies the advance outwash where the glacial till has been eroded. Localized areas in the northern portions of Borrow Area 1 have deposits of recessional outwash measuring 20 feet or more in thickness.

Deeper Soils

Glacial Till. The till forms the predominant glacially overridden unit underlying the surficial materials described above. This material is generally comprised of a dense, slightly gravelly to gravelly, silty to very silty sand with local areas of gravelly clay. The particle size gradation of the till varies both vertically and laterally, as is common in the Puget Lowland.

In general, glacial till differs from the overlying recessional layers by having a higher silt content and much higher density. The top of the glacial till soils is generally within 5 feet of the ground surface except in the northern portions of Borrow Area 1. Some weathering has been noted near the surface of the glacial till in explorations of the borrow area.

Advance Outwash. This material is generally dense to very dense, slightly silty, slightly gravelly to gravelly sand. Most fines were washed away as this material was laid down by melt water from advancing glaciers, so the advance outwash can generally be distinguished from the glacial till by lower silt content. However, some areas of advance outwash may be silty or contain lenses of lacustrine silt and clay. The advance outwash occurs beneath the glacial till in the borrow area.

Surface Topography and Runoff

The site of Borrow Area 1 forms part of an elevated bluff rising above the southeast bank of Des Moines Creek where it crosses the boundary between the City of SeaTac and the City of Des Moines. Surface soils within Borrow Area 1 have been disturbed by prior site use, as noted by Parametrix (2001a). This area was a well-established residential development prior to acquisition by the Port of Seattle in the 1970s. The dominant topography and surface conditions at the site therefore include remnant features of site development prior to the Noise Abatement buyout and subsequent demolition of housing in the area.

Site development and abandonment has left a network of paved streets and old housing plots, which still carry features such as surface and roadside drains, buried pipes, and abandoned culverts. Previous grading has modified the land surface in the form of site leveling, driveways, landscaping, etc. Depressions filled with impermeable soils contribute to local ponding of water. These features tend to control drainage from the eastern and mid-sections of Borrow Area 1, affecting the concentration of runoff in a number of instances which have a direct bearing on the occurrence of wetlands, as described below.

Generally, the presence of the underlying glacial till layer promotes surface runoff and interflow, with less infiltration and deep percolation compared to outwash soils. Consequently, the overall hydrology of the existing site currently provides significant quantities of runoff, either directly or as short-term interflow, which has a relatively rapid flowpath to Des Moines Creek.

Groundwater Conditions

Hart Crowser has monitored the groundwater levels in eight monitoring wells within Borrow Area 1 from the spring of 1999 to the spring of 2001. The water level monitoring data for the two-year period are presented in Table 1 and displayed on Drawing 4. The highest recorded groundwater levels (Spring 1999) are shown on Drawing 4, along with interpolated water level contours for groundwater in the advance outwash beneath Borrow Area 1. Seasonal variation in groundwater levels has ranged from 2.9 to 5.0 feet.

Groundwater elevations shown on Drawing 4 indicate flow is generally toward the northwest, consistent with recharge entering the Shallow Regional Aquifer beneath a broad area of higher ground southeast of Borrow Area 1. The water table in the advance outwash generally mimics the local topography manifesting a hydraulic gradient from Borrow Area 1 down to Des Moines Creek. The water table slopes consistently toward Des Moines Creek, implying that groundwater discharge from the shallow aquifer contributes to Des Moines Creek baseflow (Hart Crowser 1999a). The Shallow Regional Aquifer also recharges deeper aquifers beneath the Des Moines upland and discharges via underflow into Puget Sound and the Green River valley (AGI 1996).

On an average annual basis, precipitation on the glacial till (and surficial soils underlain by shallow glacial till) can be divided as shown below, based on hydrologic modeling performed for the Port (Parametrix 2000b) that simulates basin-wide conditions for Des Moines Creek:

Hydrologic Component	Forested Till	Grassed Till
Evapotranspiration	40.5%	33.8%
Direct Surface Runoff	0.2%	1.1%
Interflow (Basin Runoff)	8.5%	26.8%
Shallow Recharge (Baseflow)	19.2%	15.3%
Deep Recharge	31.6%	23.0%

The glacial till has low to moderate permeability, allowing on average between 38 and 51 percent of precipitation to percolate down to the underlying advance outwash (i.e., the combination of shallow recharge and deep recharge). The advance outwash is typically more permeable than the glacial till. By contrast, deep percolation through outwash that becomes groundwater recharge is therefore somewhat greater (between 60 and 68 percent of annual precipitation), where the till is not present, as the following figures show:

Hydrologic Component	Forested Outwash	Grassed Outwash
Evapotranspiration	40.1%	32.2%
Direct Surface Runoff	0.1%	0.3%
Interflow (Basin Runoff)	0.0%	0.0%
Shallow Recharge (Baseflow)	22.2%	26.3%
Deep Recharge	37.6%	41.2%

The glacial till forms a semi-perching layer with winter precipitation typically saturating the near-surface soils and generating significant quantities of interflow. A local perched water-bearing zone is commonly observed in the topsoil and upper portion of the till, especially where shallow porosity and permeability of the glacial till have been increased by weathering processes. These perched or interflow zones occur principally above the unweathered glacial till layer (which is mostly unsaturated), and well above the much deeper groundwater level in the advance outwash.

Deep percolation through the till occurs as unsaturated flow that is controlled primarily by the moisture and permeability characteristics of the till. The maximum percolation rate occurs under conditions that are likely close to saturation during the winter months. This rate is around 10 inches per month, based on the above HSPF data, and corresponds to a saturated permeability for the till of 1×10^{-5} cm/sec (0.028 ft/day).

Since the till exhibits low to moderate permeability, it does store and transmit some water; however, it is not normally considered to be an "aquifer" because the rates and amounts of water transmitted are small in comparison to more permeable deposits such as the outwash materials, which are largely composed of sands and gravels. Horizontal flow within the till is therefore not generally considered to be significant; however, vertical flow, especially over large areas, can form a small to moderate portion of the overall water balance for some groundwater systems.

Although the potential deep percolation rate through the outwash is significantly higher than that for the till due to its much higher permeability, actual rates are controlled by the amount of water available from the surficial soil zone due to precipitation, after evapotranspiration demands have been met. In the Des Moines Creek basin, maximum monthly percolation rates through the outwash are therefore limited to approximately 25percent higher than those for the till, based on the HSPF data cited above.

Wetland Hydrology

Development of Borrow Area 1 will eliminate all or portions of three wetlands (designated B11, B14, and part of B12) totaling 1.03 acres as shown by comparison of Drawing 1 and Drawing 5. However, the remaining acres of wetlands within or adjacent to the proposed excavation will be protected by designing the borrow site to avoid impacting their surface catchment areas, and this will help to avoid or mitigate temporary impacts to off-site wetlands along with the imposition of protective buffers to limit adjacent disturbance (Parametrix 2000a and 2001b).

Wetland hydrology for those wetlands designated for avoidance of permanent impacts is addressed below.

Wetland B-1 (on the east side of Borrow Area 1) is connected to the neighborhood storm drain system to the east via a ditch and is surrounded by upland forest. It occupies a shallow depression located on till soils. Precipitation and stormwater runoff conveyed to the wetland from the ditch to the east appears to maintain seasonally wet soils in the wetland.

Wetland B-4 (on the west side of the site) is located at the base of a steep ravine where surface water, interflow, and shallow groundwater seep into a seasonal drainage. The base of the ravine contains a failed stormwater discharge system, and the ravine is littered with disconnected sections of a 12-inch culvert. The culvert originally conveyed stormwater from 208th Street to Des Moines Creek, but over time stormwater runoff has eroded the pipeline foundation, sections have separated, and flows have eroded the ravine. Ongoing erosion has prevented the establishment of dense natural vegetation. Groundwater also seeps onto the ravine slopes, and stormwater runoff enters the area from the east.

Wetland B12 (on the west side of the site) is located along a ravine that drains runoff from the west of the perimeter of Borrow Area 1 to Des Moines Creek. The water entering the ravine from upslope areas supports wetland conditions. Much of the water appears to originate from the existing stormwater drainage system still in place along 20th Avenue South.

Wetland B15 (a/b) and Wetland 48 are located along the southwest boundary of Area 1 and occur on a gentle slope (Wetland 15) or a shallow depression (Wetland 48). Portions of both wetlands pond 1 to 2 inches of surface water during rainy periods. Portions of the wetlands contain disturbed soils and fill material, and they were recently (pre-1970s) pastureland. Wetland hydrology appears to be sustained by direct precipitation falling on relatively flat terrain underlain by low-permeability soils.

The wetlands are located above a relatively thick (>20 feet) layer of dense low-permeability glacial till soils that likely encourages the shallow ponding and storage of water within the wetland. Field observations indicate the wetlands' source of water appears to be supplemented by overland flow and possibly shallow interflow from the gentle slopes that form a small catchment area to the southeast. The eastern extent of the potential catchment area is limited by 20th Avenue South, which is elevated relative to the surrounding land and contains a stormwater drainage system. The street crown is sloped to the east, and directs runoff toward a series of drainage ditches, storm drains, and catch basins along its eastern margin. There appears to be little if any existing surface flow or runoff from areas located on east side of 20th Avenue South to land west of the street, because the drainage system intercepts this water and directs it to Wetland B12.

Wetland B13 occurs downslope and west of the excavation area, and is in a ravine where stormwater drainage pipes outfall. The hydrology of the wetland is similar to Wetlands B12 and B1, in that it is largely maintained by stormwater runoff generated from the paved surfaces of abandoned streets (South 210th Street and 20th Avenue South).

Wetland 32 (located on the south side of the borrow area) is located on the northwest corner of South 216th Street and 20th Avenue South. The wetland is situated in a small depression that receives runoff from the stormwater ditch servicing the northern side of South 216th Street. The wetland's catchment includes a small depression, which is slightly larger than the wetland.

Wetland 51 (located to the northwest of the northern part of Borrow Area 1) occupies a broad low-lying riparian area adjacent to Des Moines Creek. The area appears to be underlain by outwash materials, with till that forms the next downstream reach of Des Moines Creek to the south, possibly forming a buried shelf or dam that helps to impound surface waters. The main portion of this wetland is situated generally at an elevation of around 230 feet, which is similar to or lower than water levels measured in monitoring wells at the northernmost end of Borrow Area 1 (see Drawing 4). These observations indicate that this wetland is likely maintained by the water table present in the advance outwash aquifer that extends beneath the site. A small portion of Wetland 51 occurs upslope of the riparian area and is in a roadside drainage ditch north of Borrow Area 1. This area is outside the Borrow Area Development Boundary and the runoff areas that contribute to the wetland will not be affected by borrow area excavations.

SITE DEVELOPMENT

This section describes the basic approach of the Port plans to use to obtain borrow materials from Borrow Area 1. Mine planning activities to date have focused on confirming initial observations about site geology, hydrogeology, and revising the resource estimate by applying a set of project limitations to a basic material extraction scenario. The site will be developed to avoid or mitigate potential impacts to wetland resources delineated within and adjacent to Borrow Area 1. As soil excavation occurs, appropriate measures will be taken to ensure that erosion, sedimentation, and stormwater runoff are managed in accordance with the Port's standards and state and local permit requirements. The effects of site development activities on post-excavation surface water and groundwater features are also presented below.

Mine Plan

Planning for the excavation of Borrow Area 1 has focused on avoidance of wetland impacts to develop a conceptual mine plan. Sequence of excavation and other details are not yet as complete as those for Borrow Areas 3 and 4, which will be developed prior to Borrow Area 1. Mine planning activities for Borrow Area 1 are based on a resource estimate derived from field explorations that supports basic mine planning assumptions and material haul options. The resource estimate, development concepts, and haul options are described in the following paragraphs.

Resource Estimate

Engineering estimates conducted in 1994 (AGI 1995, HNTB 1995) to support the FEIS indicated that 6.6 million bank cubic yards (BCY - volume unit of soil in place, prior to excavation) of material were available from Borrow Area 1. Changes in site development conditions and the adoption of wider buffers around the site perimeter and adjacent to Des Moines Creek resulted in this figure being adjusted in 1998 to approximately 4.8 million BCY of borrow material.

Additional exploration borings (Hart Crowser 1999b) generally confirmed earlier engineering estimates. While bedding thickness varies between sites, the slightly silty to silty sands and gravels in Borrow Area 1 materials closely resemble those observed in Borrow Areas 3 and 4. After adjusting the conceptual mine plan to avoid all unnecessary wetland impacts, recent estimates indicate that Borrow Area 1 could produce approximately 4.2 million BCY of borrow material. The post-excavation contours and geologic composition of the remaining pre-reclamation materials are depicted on Drawings 5 and 6.

Conceptual Mine Plan, Assumptions and Constraints

Mine planning for Borrow Area 1 is intended to follow an approach similar to that taken in developing Borrow Areas 3 and 4, described in the Conceptual Development and Reclamation Plan for Borrow Areas 3 and 4 (Hart Crowser 2001). Equipment utilization, site pre-development, seasonal operations, and reclamation would likely follow the similar steps taken to develop the other borrow areas.

Drawing 5 illustrates how the current development plan will avoid several perimeter wetlands, and how it will typically maintain a 200-foot setback to protect the Des Moines Creek riparian area. The Borrow Area 1 development plan is based on the following constraints and assumptions:

- The perimeter of the proposed excavation limits is inside a 50-foot reclamation setback from the Area 1 property boundary;
- Wetland buffers of 50 feet separate mining-related surface disturbances from protected wetlands, and a 200-foot setback to avoid impacts to the Des Moines Creek drainage system;
- Temporary excavation and sediment controls (TESC) will be implemented prior to any site disturbance. The TESC will include provision to infiltrate detained stormwater to the maximum practical extent;
- A 10-foot minimum separation will be maintained between excavation floor and underlying water table;
- Final reclaimed slopes within the site will be 2H:1V or flatter, with the central part of the site regraded to a minimum 2 percent drainage slope toward Des Moines Creek;
- Reclamation, including replacement of stockpiled topsoil, revegetation, and permanent erosion and sediment controls, will be accomplished annually to protect the areas already mined; and
- The Port will monitor the hydrologic, soil, and vegetation conditions in wetlands located near the borrow areas according to conditions D5, D6, and D7 of the *Water Quality Certification #1996-4-02325 (Amended-1)* issued by the Washington State Department of Ecology on September 21, 2001.

Further refinements to this conceptual plan and the extraction schedule may be made as the decisions to utilize these borrow materials progress.

Site Preparation, Stormwater Management, and Reclamation Activities

The Port would use a similar approach to site development, stormwater management, and site reclamation as it has put forward for developing materials from Borrow Areas 3 and 4 (Hart Crowser 2001, Parametrix 2001a). All Temporary Erosion and Sedimentation Control (TESC) and permanent, post-reclamation stormwater measures will be consistent with the NPDES Sand and Gravel General Permit, applicable portions of the King County Surface Water Design Manual (King County 1998), and other applicable permits and approvals.

Stormwater management and TESC facilities would be installed prior to site development. Site clearing preparations would consist of vegetation stripping and topsoil removal. Prior to vegetation stripping and topsoil removal, merchantable timber will be harvested and removed from the site in accordance with a Forest Practices Permit. All remaining vegetation would be removed and managed by composting or land filling as needed.

During the site clearing and pre-production stage, native topsoils would be stockpiled adjacent to areas utilized for excavation and outside of wetland protection areas. The stockpiled soils would then be utilized in reclaiming each area.

Collection ditches would be used to direct site runoff to infiltration ponds, drainage swales, or other diversion systems appropriate for site-specific stormwater drainage. These facilities would be sized to accommodate a 100-year storm event while providing filtration for lesser flows. Drawing 7 depicts general site drainage features of the post-excavation topography.

Depending on other Third Runway project constraints, utilization of Borrow Area 1 may extend over 1, 2, or 3 years. Near the end of each work season, disturbed areas will be stabilized, and reclamation efforts will be implemented to control wet season-related surface erosion, slope stability, and stormwater runoff. As each portion of the borrow site is permanently reclaimed, additional temporary or permanent erosion, slope stability, and stormwater management measures will be implemented as necessary. As shown on Drawing 7, post-extraction topography would be contoured to drain naturally toward the creek, with increased infiltration occurring where outwash soils are exposed in the floor of the excavated borrow area.

Post-extraction topography would drain toward the creek through approved erosion, infiltration, and sediment control structures constructed along the western margins of the excavation. During excavation and site development, these would include drainage ditches and swales, stormwater detention ponds, and any stormwater BMPs required for treatment of surface water runoff.

Impacts on Site Hydrology

Excavation of fill materials from Borrow Area 1 will change surface contours and exposed surface soils, which will affect hydrologic process such as runoff, infiltration, interflow, deep percolation, and groundwater recharge. Drawing 6 illustrates the post-excavation limits and resulting surficial geology.

Runoff

Approximately 71 percent of the existing ground surface at Area 1 consists of glacial till, residual soils (topsoil, fill) derived from the glacial till, and/or other shallow soils underlain by glacial till. This condition generates moderate to high rates of direct surface runoff and interflow that currently flows overland or through the surficial soils to enter Des Moines Creek with little or no time delay. In addition, the site includes approximately 4.2 percent impervious area composed of abandoned streets, old driveways, and concrete building foundations. The remaining area (23 percent) is underlain by recessional outwash that is relatively permeable and generates very little runoff. Approximately 1.9 percent of the site is occupied by wetlands.

After excavation, the amount of exposed till surfaces is estimated to be reduced to 53 percent, with much of the surficial recessional outwash being removed along with a substantial portion of the till. Exposed till slopes around the perimeter of the excavated area would be expected to produce a temporary increase in runoff (which would be mitigated by constructed stormwater management facilities) until they are reclaimed with topsoil and planted. Lower runoff rates will occur on the relatively flat portion of the glacial till soils (average slope about 2 percent) left in the main excavated area. Impervious surfaces will be reduced to 1.4 percent, reducing the amount of runoff compared to existing conditions.

Infiltration

Infiltration into the till areas will be changed by the removal of vegetation and the excavation that will create new surfaces, which will form the final grade within Borrow Area 1. After reclamation, the infiltration in the exposed till slopes around the excavation will be less than occurs to current till soil areas, due to the increased average surface slope, loss of forest cover, and lack of a surficial weathered till zone.

Existing infiltration into the surficial recessional outwash soils will be replaced by infiltration into the increased area of exposed advance outwash beneath the till, which will occupy approximately 45 percent of the site as shown on Drawing 6. Overall, rates of infiltration to the site will increase due to the compensating effects of these changes in subsoil exposure. Increased infiltration to the water table will have beneficial results of reducing peak flows to Des Moines Creek, increasing groundwater recharge, and extending higher base flows from the aquifer for longer periods into the late summer.

Interflow

Interflow currently provides a relatively rapid pathway for a portion of the stored water perched on the till to flow downslope and into Des Moines Creek. This flowpath (estimated for HSPF simulations for the Third Runway project to be typically 3 to 7 days in duration) will be interrupted by development of the Borrow Area 1. In the developed condition, interflow is expected to occur as runoff from the exposed till slopes around the excavation perimeter, which then will flow across the main, relatively flat area of glacial till soils left after mining, where additional infiltration is anticipated, or will infiltrate as relatively rapid groundwater recharge via the exposed advance outwash (see Drawing 6). Both these flowpaths are expected to be longer than the existing interflow, with the beneficial result of reducing peak flows to Des Moines Creek, increasing groundwater recharge, and extending higher base flows from the aquifer for a longer period into the late summer.

Deep Percolation

Changes in the quantity and timing of deep percolation through the till will be one of the more significant hydrologic effects of developing Borrow Area 1. Based on modeling work for the Third Runway embankment, storage effects and slow percolation through the existing till layer are estimated to delay downward flow by around 1 to 2 months. However, because infiltration into and percolation through the glacial till is limited by the lower permeability of the till compared to the advance outwash soils exposed by mining, the amount of water involved in this process is less than the amount of deep percolation that will occur through the same area of exposed outwash. In the developed site, this small portion of delayed deep percolation through the till will be replaced by a larger quantity of direct infiltration into the increased surface area of the exposed outwash soils. This flow will reach the water table more rapidly, and the greater volume of water will serve to increase groundwater storage and thus extend the baseflow discharge period compared to existing conditions. (Release of this water during low-flow periods has not been evaluated.)

Groundwater Recharge

The amount of groundwater recharge occurring post-excavation is expected to increase slightly over current conditions, because the exposed outwash area is increased and the area of impervious surfaces is reduced. Based on the change in areas of exposed soils as a result of the excavation, an increase in shallow groundwater recharge equivalent to around 0.03 cfs is estimated. This is comparable to the value estimated by Pacific Groundwater Group (2000) in their report *Runway Fill Hydrologic Studies* (p 73). This will provide increased baseflow to Des Moines Creek.

Wetland Protection

Original development plans anticipated impacts to 1.40 of the 1.83 acres of wetlands in Borrow Area 1. Current plans for the extraction of borrow materials from Borrow Area 1 would minimize these impacts to 1.03 acres as depicted by Drawing 7.

- The proposed site development approach would facilitate on-site infiltration and controlled drainage of surface runoff into Des Moines Creek and the adjoining wetlands located on the parcel adjacent to and west of Wetlands 15a and 48.
- Excavation in two wetlands (B-1 and B-4) will be avoided by configuring the borrow site boundary and mined slopes to avoid disturbing land inside a 50-foot buffer around the wetland margins.
- Potential impacts to Wetlands B-15a/b, 32, and 48 would be completely avoided by avoiding any material extraction activities west of 20th Avenue South.

The following text explains how the wetland hydrology will be preserved, as depicted by Drawings 5 and 7.

Wetland B-1. The water source for wetland B-1 is a storm drain system associated with development east of Borrow Area 1. The ditch, and hence the seasonal water supply to Wetland B-1, will not be affected by development of Borrow Area 1. Wetland B-1 will therefore continue to receive current water flows with no impacts to wetland hydrology. The shallow subsoils in the depression sustaining the wetland will not be disturbed, and the 50-foot wetland setback will leave in place the natural low-permeability soils that form the closed depression As a result, excess drainage out of the wetland will be avoided.

Wetland B4. No excavation will occur within this wetland, and the primary impact of borrow area development will be to remove the stormwater drainage that reaches the wetland from the abandoned streets (South 208th Street and 22nd Avenue South). Removal of these stormwater sources would reduce peak flows in the wetland and likely promote increased vegetation cover in the eroded ravine that forms the wetland. Groundwater, precipitation, and interflow sources of water to the wetland will remain following excavation.

Wetland B12. Precipitation, groundwater, and interflow sources of water that support Wetland B12 will remain following excavation. The current source of seasonal runoff generated by 20th Avenue South will also be maintained.

Wetland B13. The current sources of precipitation and groundwater flow that help maintain wetland conditions will remain. Seasonal stormwater runoff generated from South 210th Street and 20th Avenue South drainage systems will be removed. Since the wetland is at elevations lower than much of the floor of the borrow area, a surface drainage path to the wetland will be established to provide runoff as shown on Drawing 7.

Wetland B15 and Wetland 48. The catchment area for these wetlands (located west of 20th Avenue South) will be avoided by preventing surface disturbance within this area. As a result, the existing precipitation and runoff sources of water to the wetlands will remain undisturbed after Borrow Area 1 has been developed.

Wetland 32. Development of Borrow Area 1 will not affect the off-site source of flow to this wetland. The stormwater ditch feeding runoff from South 216th Street to Wetland 32 will not be altered as it is located outside the area disturbed by borrow are a excavation activities. A 50-foot buffer around the wetland will prevent impacts to the margins of the wetland and its slightly larger catchment area.

Wetland 51. The hydrology of this riparian wetland is associated with Des Moines Creek and regional groundwater discharge from the advance outwash aquifer. These hydrologic conditions will not be affected by development of Borrow Area 1, except by a possible increase in groundwater levels. Borrow area excavation is not anticipated to have any significant effect on the rate or amount of seepage from the water table that reaches this wetland.

The Port has considered alternatives to the proposed development plan and determined that it would not be practicable to avoid impacts to the remaining wetlands B14, B11, and part of B12 within Borrow Area 1, because: 1) preservation of the wetlands would render the resource impracticable to mine; and 2) excavation of the resource would completely remove the upgradient source of water flow sustaining these wetlands. Mitigation for these wetlands is described in the Natural Resource Mitigation Plan (Parametrix, Inc. 2001b).

Attachments:
References
Table 1 - Borrow Area 1 Water Level Data
Drawing 1 - Site and Exploration Plan
Drawing 2 - Pre-Excavation Topography and Surficial Geology
Drawing 3 - Geologic Cross Section A-A'
Drawing 4 - Groundwater Elevation Contour Map
Drawing 5 - Conceptual Post-Excavation Elevation Contour Map

Drawing 6 - Post-Excavation Limits and Surficial Geology
Drawing 7 - Post-Excavation Site Drainage

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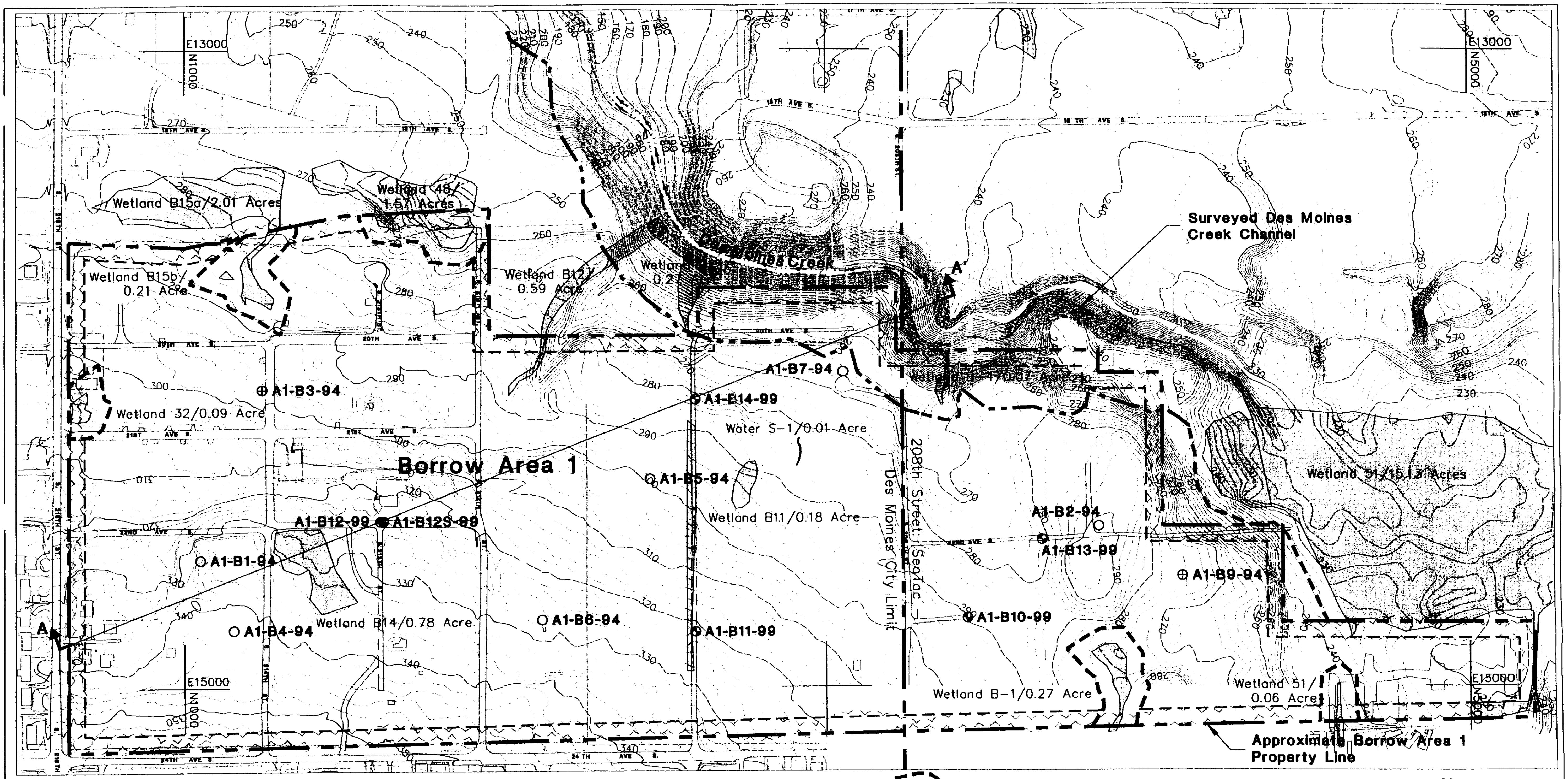
Table 1 - Borrow Area 1 Water Level Data

		AGI Borings				Hart Crowser Borings					
		A1-B3-94		**A1-B9-94**		**A1-B10-99**		**A1-B11-99**		**A1-B12-99**	
		Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Top of Monument	(Monument)	*-0.25*	304.67	*-0.25*	279.29	-0.68	273.30	-0.35	322.41	-0.25	324.78
Measuring Point	(Top of Casing)	0.00	*304.42*	0.00	*279.04*	0.00	272.90	0.00	322.06	0.00	324.53
Ground Level	(Stick-Up)	*1.90*	*302.5*	*1.52*	*277.5*						
Top of Screen	(below GS)	*43.0*	*259.5*	*53.0*	*224.5*	59.0	213.9	55.0	267.1	79.0	245.5
Bottom of Well	(below GS)	*53.5*	*249.0*	*63.0*	*214.5*	69.0	203.9	65.0	257.1	89.0	235.5
Water Levels	12/28/1994	30.5	272.02	49.9	227.62						
	1/26/1995	29.5	273.02	48.7	228.82						
	(ATD)					52.7	220.20	41.0	281.06	62.0	262.53
	2/16/1999					52.8	220.10	41.25	280.81	61.1	263.43
	2/19/1999	28.57	275.85	47.34	231.70	53.10	219.80	41.08	280.98	61.55	262.98
	5/5/1999	28.94	275.48	46.71	232.33	53.87	219.03	40.84	281.22	60.56	263.97
	6/14/1999	29.22	275.20	47.60	231.44	53.65	219.25	40.84	281.22	59.90	264.63
	7/15/1999	29.65	274.77	48.24	230.80	54.20	218.70	41.23	280.83	60.04	264.49
	8/13/1999	30.00	274.42	48.71	230.33	54.70	218.20	41.52	280.54	60.24	264.29
	9/14/1999	30.21	274.21	49.20	229.84	54.99	217.91	41.79	280.27	60.33	264.20
	10/13/1999	30.52	273.90	49.52	229.52	55.50	217.40	42.19	279.87	60.71	263.82
	11/11/1999	30.85	273.57	49.36	229.68	55.62	217.28	42.60	279.46	61.60	262.93
	12/10/1999	30.16	274.26	49.00	230.04	55.16	217.74	41.97	280.09	61.30	263.23
	1/12/2000	29.10	275.32	48.65	230.39	54.31	218.59	41.26	280.80	60.96	263.57
	2/15/2000	28.84	275.58	48.40	230.64	53.85	219.05	41.23	280.83	61.32	263.21
	3/10/2000	28.45	275.97	47.99	231.05	53.34	219.56	40.92	281.14	61.09	263.44
	4/12/2000	28.52	275.90	48.08	230.96	53.40	219.50	40.76	281.30	60.58	263.95
	5/10/2000	28.79	275.63	48.30	230.74	53.83	219.07	40.64	281.42	60.05	264.48
	6/21/2000	29.56	274.86	49.12	229.92	54.71	218.19	41.28	280.78	60.25	264.28
	7/11/2000	29.78	274.64	49.52	229.52	55.09	217.81	41.49	280.57	60.30	264.23
	10/13/2000	30.89	273.53	50.94	228.10	56.79	216.11	42.79	279.27	61.16	263.37
	1/23/2001	30.94	273.48	51.00	228.04	56.95	215.95	42.58	279.48	61.72	262.81
	5/3/2001	32.12	272.30	50.88	228.16	56.22	216.68	43.02	279.04	64.90	259.63

Notes:
1) AGI Borings have stick-up monuments
2) Hart Crowser borings are completed with flush monuments
3) Water levels are measured as depths below the Measuring Point
4) Measuring Point is top of PVC casing
5) - Indicates data not available.

Table 1 - Borrow Area 1 Water Level Data

		Hart Crowser Borings					
		A1-B12S-99		**A1-B13-99**		**A1-B14-99**	
		Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Top of Monument	(Monument)	-0.40	324.64	-0.58	288.57	-0.45	283.25
Measuring Point	(Top of Casing)	0.00	324.24	0.00	287.99	0.00	282.80
Ground Level	(Stick-Up)						
Top of Screen	(below GS)	59.0	265.2	58.9	229.1	55.0	227.8
Bottom of Well	(below GS)	64.0	260.2	69.2	218.8	65.0	217.8
Water Levels	12/28/1994						
	1/26/1995						
	(ATD)	61.5	262.74	62.5	225.49	53.0	229.80
	2/16/1999	-	-	41.9	246.09	52.6	230.20
	2/19/1999	61.26	262.98	40.33	247.66	53.41	229.39
	5/5/1999	60.53	263.71	39.76	248.23	52.44	230.36
	6/14/1999	59.93	264.31	40.33	247.66	53.17	229.63
	7/15/1999	59.97	264.27	40.96	247.03	53.16	229.64
	8/13/1999	60.03	264.21	41.46	246.53	53.80	229.00
	9/14/1999	60.12	264.12	41.75	246.24	54.15	228.65
	10/13/1999	60.41	263.83	42.20	245.79	54.22	228.58
	11/11/1999	60.72	263.52	42.20	245.79	54.27	228.53
	12/10/1999	60.93	263.31	41.92	246.07	53.91	228.89
	1/12/2000	60.85	263.39	41.30	246.69	53.27	229.53
	2/15/2000	61.06	263.18	41.03	246.96	53.28	229.52
	3/10/2000	60.95	263.29	40.48	247.51	52.86	229.94
	4/12/2000	60.55	263.69	40.46	247.53	52.83	229.97
	5/10/2000	60.20	264.04	40.66	247.33	52.93	229.87
	6/21/2000	60.18	264.06	41.52	246.47	53.63	229.17
	7/11/2000	60.17	264.07	42.00	245.99	54.13	228.67
	10/13/2000	60.84	263.40	43.51	244.48	55.38	227.42
	1/23/2001	61.49	262.75	43.36	244.63	55.15	227.65
	5/3/2001	63.71	260.53	43.45	244.54	55.52	227.28



— — —340— — Existing Elevation Contour in Feet

— — — — — — — Reclamation Setback

▬ ▪ ▪ ▬▬ ▪ ▪ ▬ 200-Foot Stream Buffer

▬▬ — — ▬▬ Property Line

⊕ A1-B12S-99 Boring with Observation Well (by Hart Crowser)

⊕ A1-B9-94 Boring with Observation Well (by AGI)

○ A1-B6-94 Boring (by AGI)

Wetland B11/0.18 Acre Wetlands Delineated by Parametrix (06/01) with 50-Foot "No Disturbance" Wetland Buffer and Number/Area

AA' Cross Section Location and Designation

N

0 300 600

Scale in Feet

Notes:
1) Base map prepared from drawing provided by HNTB entitled "Borrow Sites Areas 3 & 4 Grading Plan", dated April 13, 1998.
2) Wetland and stream channel survey data prepared from drawing provided by Parametrix entitled, "w_060601.dwg", dated June 6, 2001.

RC 12/7/01 1=1 (xref)see drawing file/charlie.pc2
49786902.dwg

Bench Mark:					
Proj. Mgr.: M. J. BAILEY		Designed By: R. HASTINGS		Drawn By: R. CHAO	
Checked By: G. T. BOTH		Approved By: MJB		Date: 12/05/01	
No.	Date	By	Revision		

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SEA-TAC THIRD RUNWAY BORROW AREA 1

SITE AND EXPLORATION PLAN

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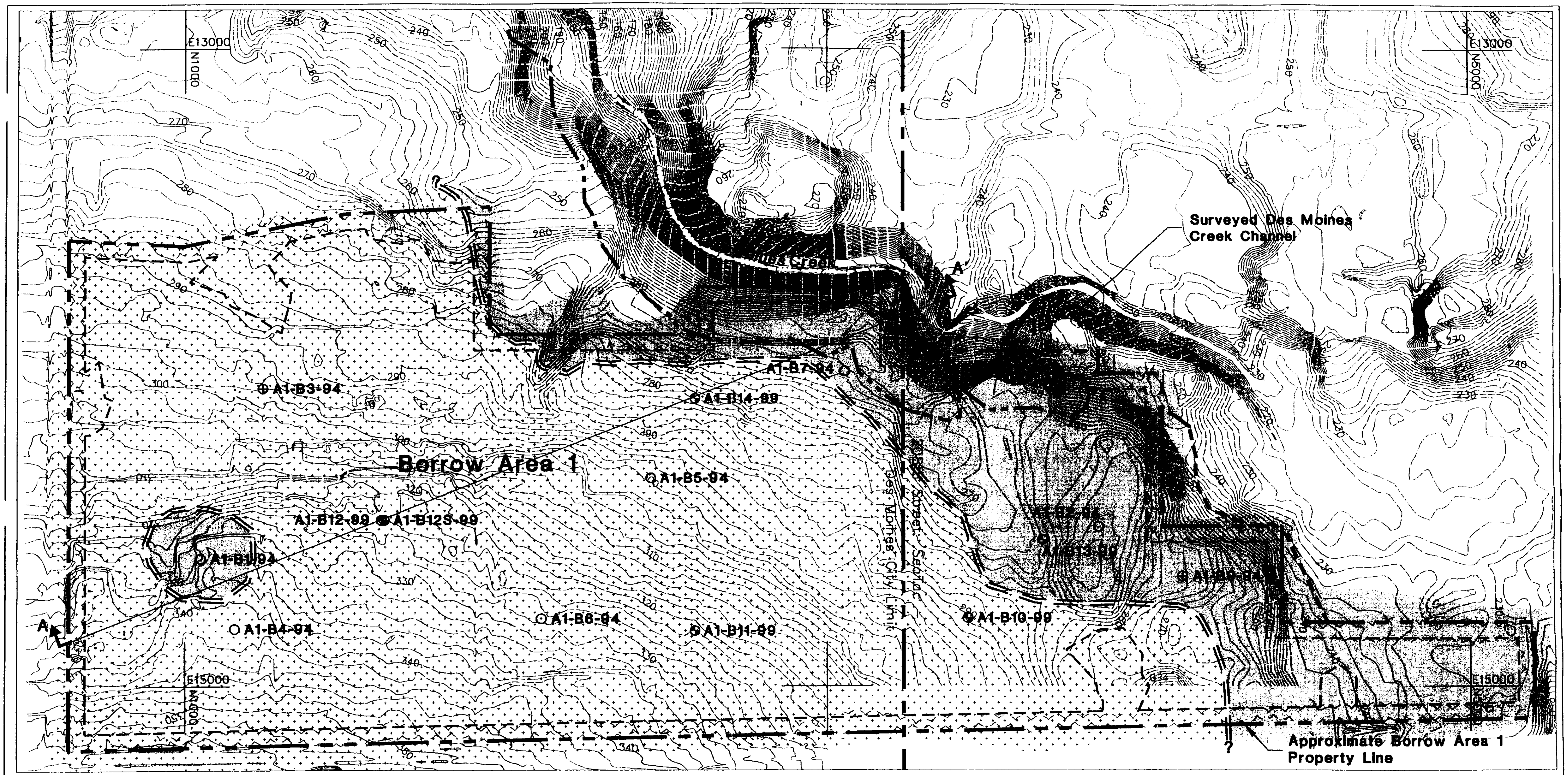

— — — 340 — — Existing Elevation Contour in Feet

— — — — — — — Reclamation Setback

▬ ▪ ▪ ▬ ▪ ▪ ▬ 200-Foot Stream Buffer

▬ — — ▬ Property Line

A1-B12S-99 Boring with Observation Well (by Hart Crowser)

⊕ **A1-B9-94** Boring with Observation Well (by AGI)

○ **A1-B6-94** Boring (by AGI)

Glacial Till

Inferred Contact

Outwash (Recessional/Advanced)

AA' Cross Section Location and Designation

N

0 300 600

Scale in Feet

Notes:
1) Base map prepared from drawing provided by HNTB entitled "Borrow Sites Areas 3 & 4 Grading Plan", dated April 13, 1998.
2) Wetland and stream channel survey data prepared from drawing provided by Parametrix entitled, "w_060601.dwg", dated June 6, 2001.

RC 12/7/01 1=1 (xref)see drawing file/charlie.pc2
49786903.dwg

Bench Mark:					
Proj. Mgr.: M. J. BAILEY	Designed By: R. HASTINGS		Drawn By: R. CHAO		
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No.	Date	By	Revision		
1	12/05/01	RC/RPH	LOCAL GEOLOGY		

AR 030548

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SEA-TAC THIRD RUNWAY BORROW AREA 1

PRE-EXCAVATION TOPOGRAPHY
AND SURFICIAL GEOLOGY

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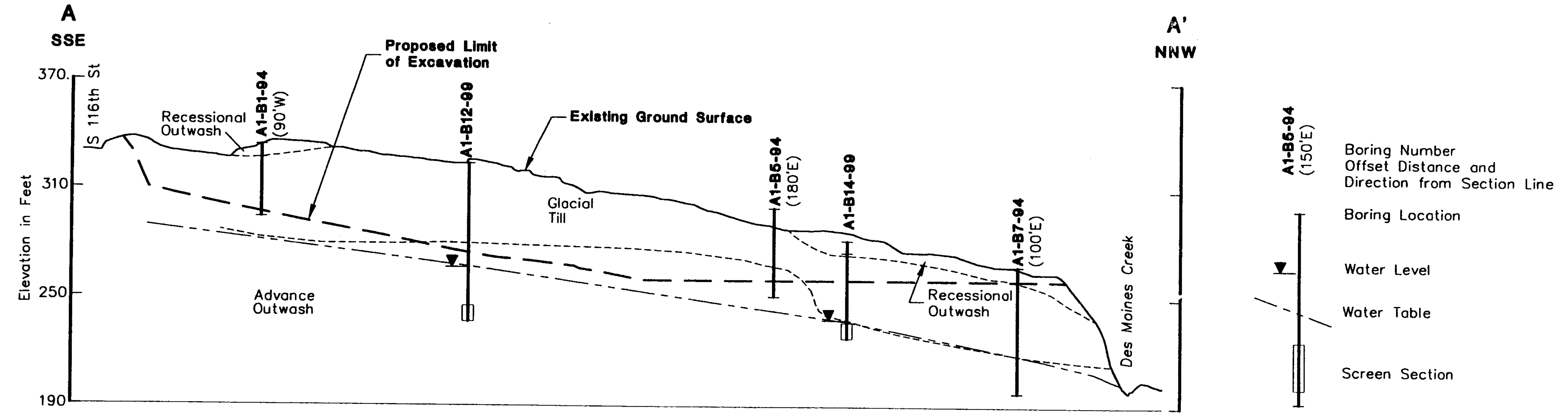
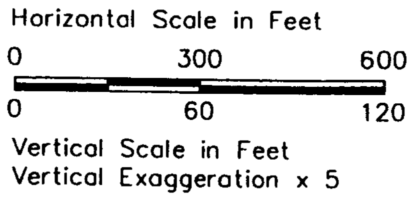


Notes: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.



AR 030549

Bench Mark:					
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Checked By: C. T. BOTH		Approved By:	MJB	Date:	12/05/01
No.	Date	By	Revision		
1	12/05/01	RC/RPH	GEOLOGIC CROSS SECTION		

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SEA-TAC THIRD RUNWAY BORROW AREA 1

GEOLOGIC CROSS SECTION A-A'

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DJH 12/05/01 1=1 (xref)see drawing file/charlie.pc2
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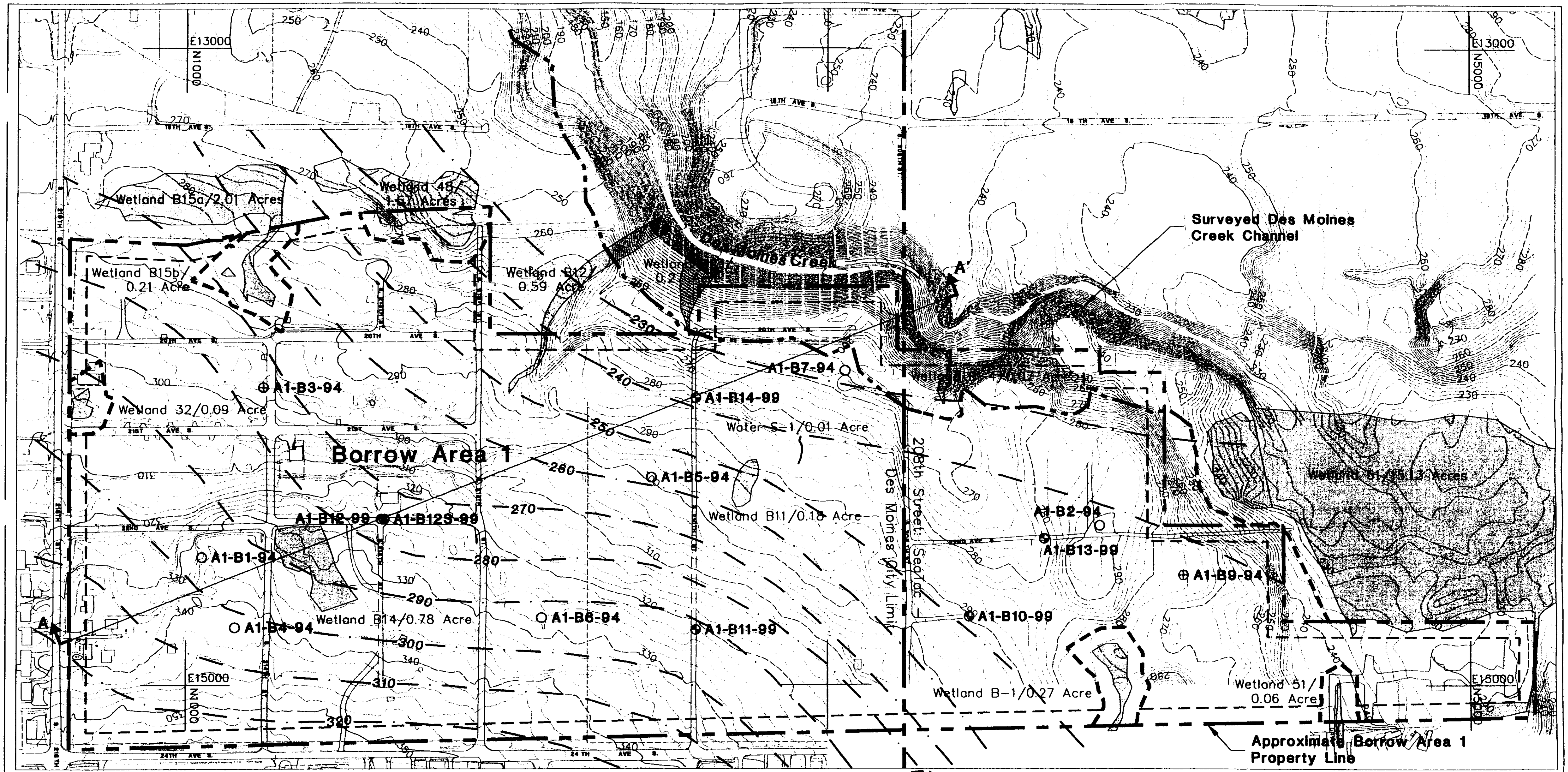

— · —300— · — Groundwater Elevation Contour in Feet

— — —340— — — Existing Elevation Contour in Feet

– – – – – – – – Reclamation Setback

▬ ▪ ▪ ▬ ▪ ▪ ▬ 200-Foot Stream Buffer

▬ — — ▬ Property Line

⊕ A1-B12S-99 Boring with Observation Well (by Hart Crowser)

⊕ A1-B9-94 Boring with Observation Well (by AGI)

○ A1-B6-94 Boring (by AGI)

Wetland B11/0.18 Acre — Wetlands Delineated by Parametrix (06/01) with 50-Foot "No Disturbance" Wetland Buffer and Number/Area

AA' — Cross Section Location and Designation

N

0 300 600

Scale in Feet

Notes:
1) Base map prepared from drawing provided by HNTB entitled "Borrow Sites Areas 3 & 4 Grading Plan", dated April 13, 1998.
2) Wetland and stream channel survey data prepared from drawing provided by Parametrix entitled, "w_060601.dwg", dated June 6, 2001.

RC 12/7/01 1=1 (xref)see drawing file/charlie.pc2 49786908.dwg

Bench Mark:				
Proj. Mgr.: M. J. BAILEY		Designed By: R. HASTINGS	Drawn By: R. CHAO	
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No.	Date	By	Revision	

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Seattle, Washington 98102-3699
FAX 206.328.5581
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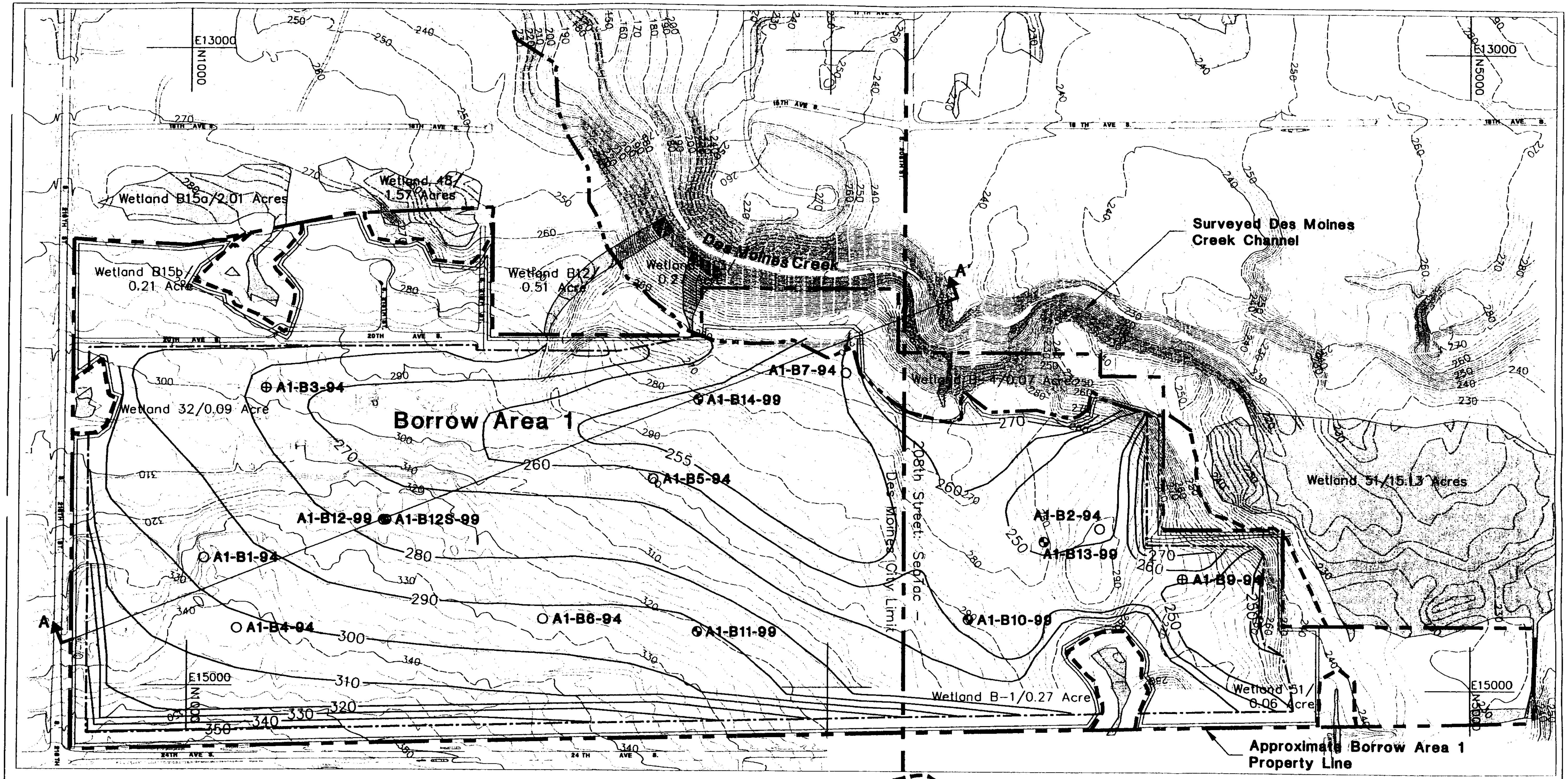
SEA-TAC THIRD RUNWAY BORROW AREA 1

GROUNDWATER ELEVATION CONTOUR MAP

Drawing Size	Scale	Date Issued	Drawing Type	Job No.	SHEET	Drawing No.
11x17	AS SHOWN	12/05/01	DRAFT	4978-69	4 of 7	4



— — 340 — — Existing Elevation Contour in Feet

——320—— Post-Excavation Elevation Contour in Feet

—·—·—·— Limit of Excavation

▬ ▪ ▪ ▬ 200-Foot Stream Buffer

═══ Borrow Area Development Boundary

▬ — — ▬ Property Line

A1-B12S-99 Boring with Observation Well (by Hart Crowser)

⊕ **A1-B9-94** Boring with Observation Well (by AGI)

○ **A1-B6-94** Boring (by AGI)

Wetland B11/0.18 Acre

Wetlands Delineated by Parametrix (06/01) with 50-Foot "No Disturbance" Wetland Buffer and Number/Area

AA' Cross Section Location and Designation

N

0 300 600

Scale in Feet

Notes:
1) Base map prepared from drawing provided by HNTB entitled "Borrow Sites Areas 3 & 4 Grading Plan", dated April 13, 1998.
2) Wetland and stream channel survey data prepared from drawing provided by Parametrix entitled, "w_060601.dwg", dated June 6, 2001.

RC 12/7/01 1=1 (xref)see drawing file/charlie.pc2 49786904.dwg

Bench Mark:			
Proj. Mgr.: M. J. BAILEY	Designed By: R. HASTINGS	Drawn By: R. CHAO	
Checked By: C. T. BOTH	Approved By: M.B	Date: 12/05/01	
No.	Date	By	Revision

AR 030551

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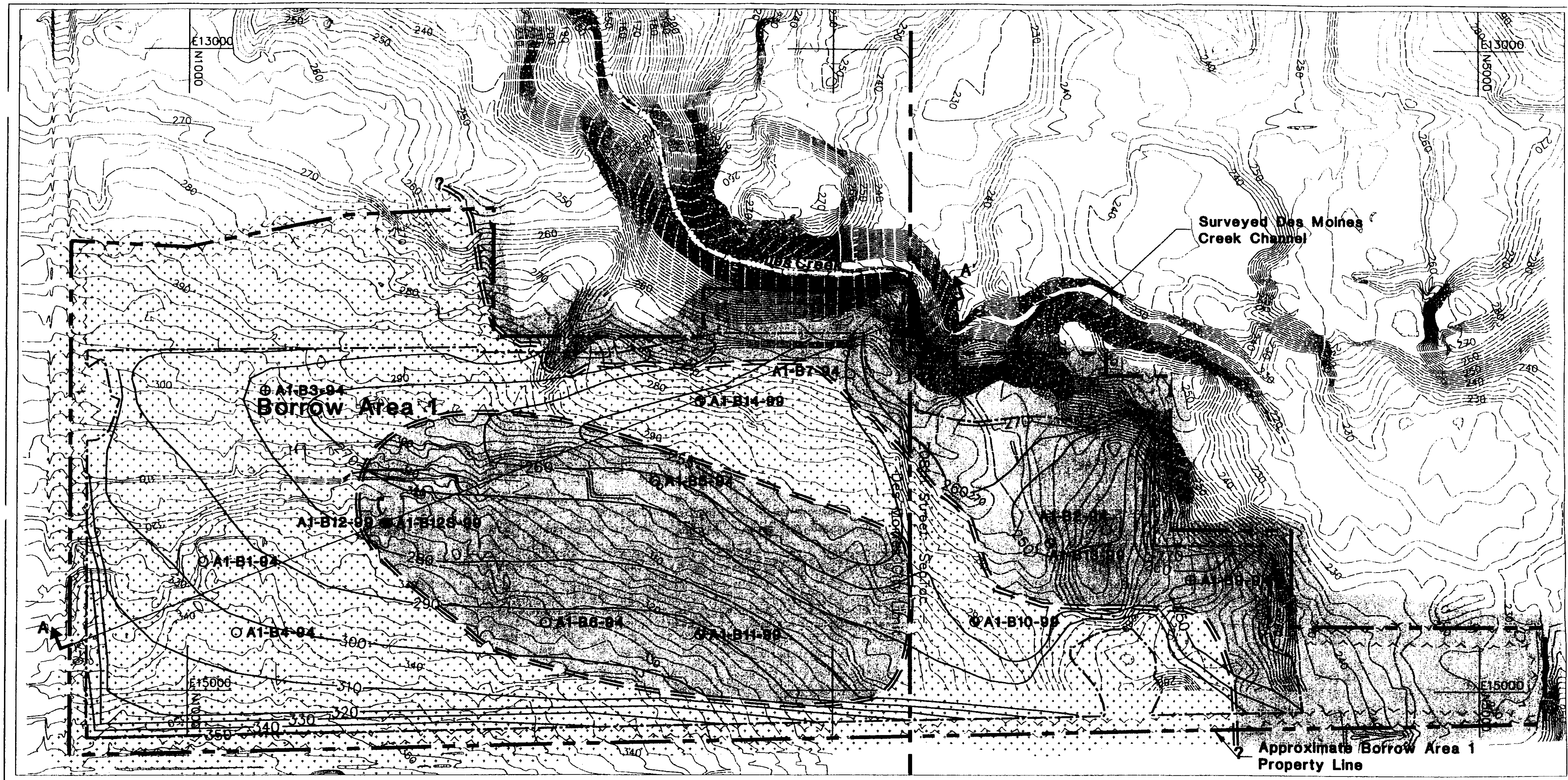
SEA-TAC THIRD RUNWAY BORROW AREA 1

CONCEPTUAL POST-EXCAVATION ELEVATION CONTOUR MAP

Drawing Size:	Scale:	Date Issued:	Drawing Type:	Job No.:	SHEET:	Drawing No.
11x17	AS SHOWN	12/05/01	DRAFT	4978-69	5 of 7	5



— — —340— — Existing Elevation Contour in Feet

———320——— Post-Excavation Elevation Contour in Feet

—·—·—·— Limit of Excavation

▬ ▬ ▬ Property Line

⊕ A1-B12S-99 Boring with Observation Well (by Hart Crowser)

⊕ A1-B9-94 Boring with Observation Well (by AGI)

○ **A1-B6-94** Boring (by AGI)

Glacial Till

Inferred Contact

Outwash (Recessional/Advanced)

AA' Cross Section Location and Designation

Notes:

1) Base map prepared from drawing provided by HNTB entitled "Borrow Sites Areas 3 & 4 Grading Plan", dated April 13, 1998.

2) Wetland and stream channel survey data prepared from drawing provided by Parametrix entitled, "w_060601.dwg", dated June 6, 2001.

DJH 12/05/01 1=1 (xref)see drawing file/charlie.pc2
49786909.dwg

Bench Mark:					
Proj. Mgr.: M. J. BAILEY		Designed By: R. HASTINGS		Drawn By: R. CHAO	
Checked By: G. T. BOTH		Approved By: MJB		Date: 12/05/01	
No.	Date	By	Revision		
1	12/05/01	RC/RPH	POST-EXCAVATION GEOLOGY		

AR 030552

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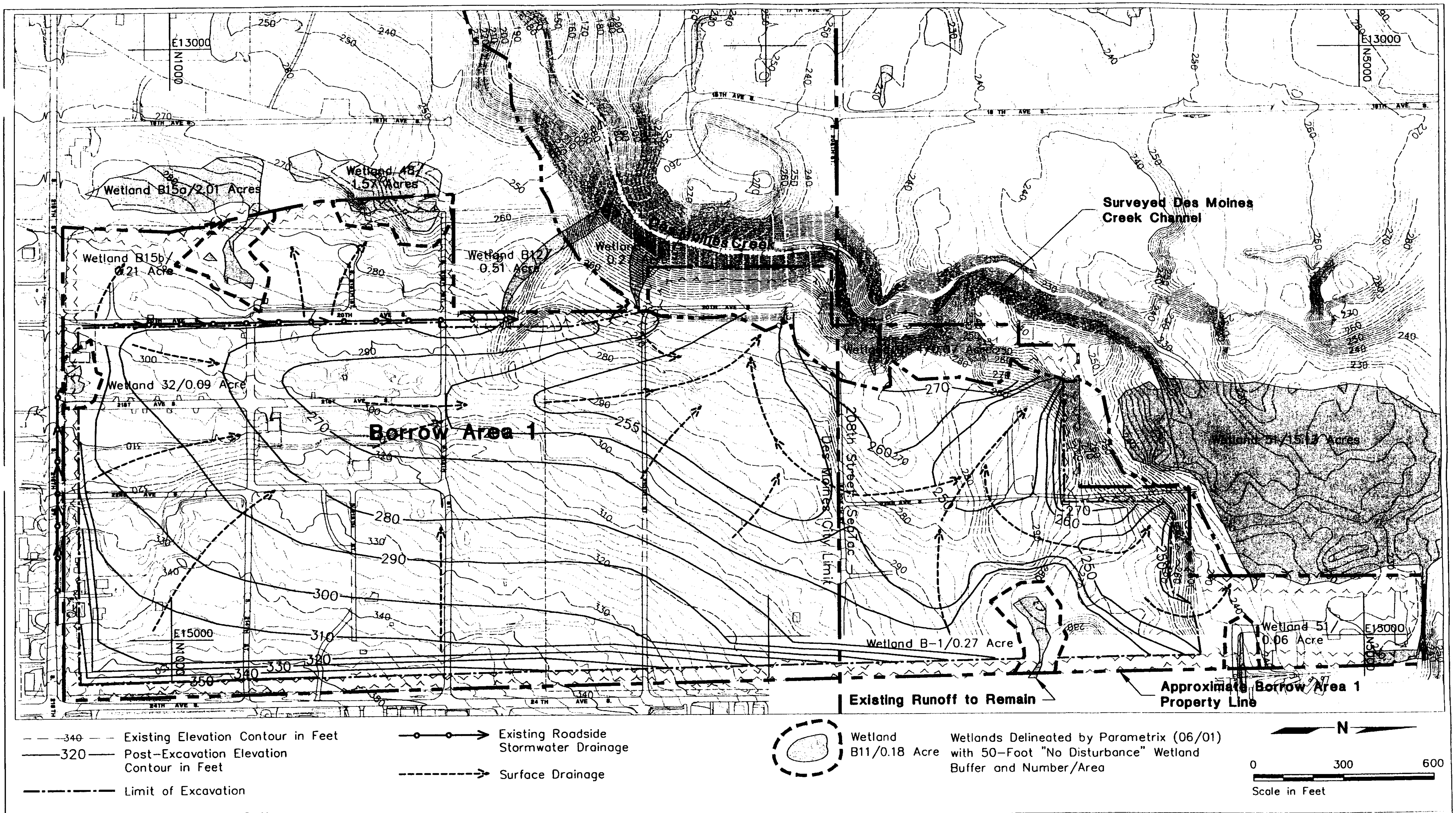
SEA-TAC THIRD RUNWAY BORROW AREA 1

POST-EXCAVATION LIMITS
AND SURFICIAL GEOLOGY

Drawing Size:	Scale:	Date Issued:	Drawing Type:	Job No.:	SHEET:	Drawing No.:
11x17	AS SHOWN	12/05/01	DRAFT	4978-69	6 of 7	6



Notes:

1) Base map prepared from drawing provided by HNTB entitled "Borrow Sites Areas 3 & 4 Grading Plan", dated April 13, 1998.

2) Wetland and stream channel survey data prepared from drawing provided by Parametrix entitled, "w_060601.dwg", dated June 6, 2001.

RC 12/7/01 1=1 (xref)see drawing file/charlie.pc2
49786905.dwg

Bench Mark:			
Proj. Mgr.: M. J. BAILEY	Designed By: R. HASTINGS	Drawn By: R. CHAO	
Checked By: G. T. BOTH	Approved By: MJB	Date: 12/05/01	

No.	Date	By	Revision

HARTCROWSER

Hart Crowser, Inc.
1910 Fairview Avenue East
Seattle, Washington 98102-3699
FAX 206.328.5581
206.324.9530

SEA-TAC THIRD RUNWAY BORROW AREA 1

POST-EXCAVATION SITE DRAINAGE

Drawing Size:	Scale:	Date Issued:	Drawing Type:	Job No.:	SHEET:	Drawing No:
11x17	AS SHOWN	12/05/01	DRAFT	4978-69	7 of 7	7

Appendix D

APPENDIX D

PRESERVATION OF WETLANDS IN BORROW AREA 3

APPENDIX D

PRESERVATION OF WETLANDS IN BORROW AREA 3

This appendix contains information and analysis to show how excavation of the borrow area has been modified to avoid potential hydrologic impacts to the wetlands that occur south and downslope of the excavation footprint. Mitigation explained in the report and illustrated in the revised drawings includes modifications of the excavation footprint, modification of the depth of excavation, and provision of a drainage channel to convey groundwater that will seep into the north and west sides of the embankment to Wetland 29 and other wetlands.

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MEMORANDUM

DATE: October 20, 2000

TO: Jim Thomson, HNTB

FROM: Michael A.P. Kenrick, P.E., and Michael J. Bailey, P.E., Hart Crowser

RE: **Sea-Tac Third Runway – Borrow Area 3**
Preservation of Wetlands
J-4978-06

As requested by the Port of Seattle, this memo and the attached figures provide conceptual design and supporting information for the proposed drainage swale to protect wetlands in Borrow Area 3. We also provide a brief explanation of the hydrology that supports the wetlands, including why excavation of Borrow Area 3 will not drain these wetlands. Figure 1 shows the location of Borrow Area 3 to the south of Sea-Tac Airport.

REVIEW OF BORROW AREA 3 WETLAND HYDROLOGY

The first section of this memo provides a review and explanation of the hydrology that currently supports and sustains wetlands in Borrow Area 3. Understanding these hydrologic factors is important in ensuring the long-term preservation of the wetlands during and after excavation of the fill materials contained in Borrow Area 3.

Factors Promoting Preservation of the Wetlands

Existing wetlands and current topography in Borrow Area 3 are shown on Figure 2; the proposed area of mining and resulting contours for final excavation are shown on Figure 3.

The series of wetlands mapped in Borrow Area 3 follow a line of shallow depressions in the southcentral part of the site, extending to the southeast from Wetland 29 through Wetlands B9, 30, B7, B6, and B5. These wetlands exist in an area of relatively permeable subsoils where the main groundwater table is at a depth of 10 to 15 feet below the wetlands. Depth of the water table indicates the wetlands are supported by other sources of water. The sources of water appear to include surficial runoff and shallow interflow, as well as groundwater seepage occurring from a perched zone above the main water table that discharges in the area of Wetland 29. Observation wells in the area indicate the perched zone does not contribute flow directly to the other wetlands but, by extension, flow from Wetland 29 appears to pass along the line of wetlands, to each wetland in turn.

The key factors for sustaining wetland hydrology in Borrow Area 3 are (1) ensuring the continued supply of water and (2) preventing the undue loss of water from the wetlands. Wetland hydrology is typically sustained by a combination of hydrologic processes, as shown schematically on Figure 4. The processes supporting wetland hydrology include precipitation (P), groundwater flow (GW) and spring seepage (Sp), runoff (RO), and interflow (IF). Other processes such as evapotranspiration (Et) and deep percolation (DP) lead to the potential loss of water from wetlands. Where wetlands exist, it can be assumed that the sources of water exceed the losses, for at least a large part of the year. Maintenance of the water sources, without increasing the losses, should ensure preservation of the wetlands in perpetuity.

One of the main constraints on wetland development in the area is the relatively high permeability of the surficial soils. In agricultural terms, the surficial soils are identified to be part of the Indianola series (USDA, 1973) and are characterized as being "excessively drained" with "rapid permeability." This is consistent with the predominant soil material in Borrow Area 3 being stratified glacial drift, which is primarily sand and gravel outwash with varying amounts of silt in a predominantly granular matrix.

The overall approach for maintaining wetlands in Borrow Area 3 focuses on preserving or enhancing the existing sources of water, and ensuring that no additional loss pathways are created.

Wetland 29

Wetland 29 is unique in that it occurs on a hillside (see Figure 3). Its existence is attributable primarily to a continuous supply of groundwater that seeps from the hillside at this point. Investigation of subsurface conditions at Borrow Area 3 links this area of seepage with a laterally continuous zone of perched groundwater that extends to the north and west, behind Wetland 29 (Hart Crowser, 1999, see reference list following the text of this memo). In hydrologic terms, the wetland occupies part of a surface seepage discharge area for groundwater flowing through the perched zone, as illustrated in the cross section on Figure 4. Part of the seepage from the perched zone flows into Wetland 29, the rest of the seepage from the perched layer does not appear elsewhere on the surface, so is assumed to percolate down into the shallow regional aquifer in the eastern part of the site where the perching layer has been removed by erosion.

The proposed borrow area excavation to the east of Wetland 29 (Figures 3 and 4) will not interfere with the perching layer behind or beneath the wetland and will, therefore, have no direct effect on the continued discharge of groundwater from the west. An analysis of groundwater flow potentially diverted from Wetland 29 (Hart Crowser, 2000) indicates that excavation could change the seepage gradient and result in a decrease in flow to Wetland 29. Mitigation to address this potential change is discussed below.

Although the base of the Borrow Area 3 excavation will be lower in elevation than most of Wetland 29, excavation will occur in predominantly permeable soils that are above the water table. These existing permeable soils already provide a drainage pathway for seepage losses from the wetlands. The persistence of the wetlands despite the presence of permeable soils and a relatively deep water table demonstrates that wetlands will not be drained by the adjacent excavations.

Other Wetlands

Water in Wetland 29 is primarily lost by percolation to the underlying aquifer and evapotranspiration. A portion of the water flowing through Wetland 29 is inferred to move downslope as interflow or shallow subsurface flow to feed successive wetlands that trend southeastward from Wetland 29, occupying a series of shallow depressions (see Figure 3 - note that this flow is out of the plane of the cross section on Figure 4). This inference is based on the topographic position of the adjacent wetlands and the absence of other sources of water. Flow appears to move from one wetland to the next, and some water is likely lost as deep percolation into the permeable subsurface soils that underlie most of the site, including the wetlands. Some additional water probably comes as surface runoff or interflow from the surface catchments feeding each wetland.

According to the Wetland Delineation Report (Parametrix, 1999) and supporting Field Data Sheets, the wetlands in Borrow Area 3 typically feature 10 to 12 inches of "black muck" - a fine-grained richly organic soil that appears to help the ponding of water in the wetland, and likely retains saturation of the root zone rather than allowing much of the water to percolate downward. The concept is illustrated on Figure 5, which is a cross section through Wetland 30.

Note that Wetlands 30, B7, B6, and B5 appear to exist beyond the main perching layer. It is possible that these wetlands formed on locally silty (less permeable) zones in the predominantly granular soil, promoting shallow perched conditions that sustain the wetland hydrology. As evidence of this, Wetland B7 is reported to have a seasonally high water table that would be 10 to 15 feet above the main groundwater table in the underlying relatively permeable shallow regional aquifer. As a result, excavation of the perching layer northeast of Wetland 29 would not have any direct impact on the other wetlands in Borrow Area 3 provided flow into Wetland 29 is maintained as described below.

Proximity of Excavations

The Port proposes that excavations of Borrow Area 3 (see Figure 3) will leave at least a 50-foot buffer around the wetlands. Excavation to the east of the wetlands will proceed to approximate elevation 233 to 235 feet, whereas the wetlands themselves are at approximate elevations 236 feet (Wetland 30) and 235 to 238 feet (Wetlands B6 and B7), see Figures 5 and 6. The hydrology of these wetlands will not be adversely impacted by the excavations because:

- The wetlands already exist over permeable subsoils;
- The buffer will be retained, preventing any lateral "short circuit" flowpath that could divert water from the wetlands and into the borrow site excavation; and
- Base elevations of the proposed excavations are at most only a foot or two lower than the lowest point in these adjacent wetlands.

Wetland B5 is at about elevation 230 feet, well below the proposed excavation. Wetlands B9 and 29 are upslope of the proposed excavation and would be protected against any potential loss of water by the proposed mitigation discussed herein. Wetland B10 is upslope of the perched zone and, therefore, would not be impacted by changes in perched zone flow.

Potential Loss of Surface Flows

In some areas of the buffer zone between the wetlands and the proposed excavation, there may be localized low spots that provide a potential pathway for overland flow to occur from the wetland into the excavation at periods of exceptionally high water levels. If erosion occurs during periods of high water in the wetlands, formation of gullies could divert increased surface flows from the wetlands into the excavations. Erosion will be prevented by preserving existing vegetation in the wetland buffer areas and revegetating the excavated area in accordance with Washington Department of Natural Resources reclamation criteria. However, if erosion threatens the wetland floor, mitigation could easily be accomplished. The Port has proposed a period of wetland monitoring following excavation of the borrow site. If necessary during or after excavations, berms or other erosion protection will be constructed outside the wetland buffer and on the edge of the excavations to prevent overland flow occurring from the wetland depressions into the adjacent excavation. This element of the mine plan will depend on field surveying for elevation control of the land-surface profile along the buffer zone, reclamation of the site to a stable condition, and monitoring after reclamation, which the Port has already committed to.

DRAINAGE SWALE DESIGN

The remainder of this memo addresses the design of a drainage swale that will provide additional water to Wetland 29 to replace the potential loss of seepage from the perched zone.

As described in Hart Crowser (2000), groundwater modeling suggests the possibility that mining will produce a small change in the groundwater flow regime within the perched zone that feeds Wetland 29. Modeling suggests increased drawdown in the perched zone due to excavation in the Borrow Area 3 (see Figure 3) could cause a shift in the seepage gradient. This change in gradient could reduce groundwater flow by a maximum of about 20 percent of the current flow to Wetland 29, or about 400 ft^3/day (roughly 2 gallons per minute). The Port proposes to mitigate this potential indirect impact by collecting groundwater seepage in a swale along the western slope face of the excavation (see Figure 3) and diverting this to Wetland 29.

Overall Concept for Drainage Swale

The proposed drainage swale is designed to collect groundwater seepage from the excavated slope face on the north and west sides of Borrow Area 3, as depicted on Figure 3. The groundwater seepage represents natural flow from the perched zone that is forced to discharge at the cut slope face, as described in detail in Hart Crowser (2000). The flow will be collected and conducted southward in a swale that drains into Wetland 29. Grades along the swale are expected to be between about 1 and 2 percent. A schematic profile along the drainage swale is shown on Figure 7. Modeling shows there is about 2,400 ft^3/day of groundwater flow available compared to projected maximum loss to Wetland 29 of 400 ft^3/day (Hart Crowser, 2000). There is more than enough seepage flow available to make up any loss in the natural perched zone groundwater flow to Wetland 29.

Adaptive Design Approach

The detailed design and construction of the drainage swale will be modified as needed to take account of field conditions revealed during the excavation of Borrow Area 3. For example, the swale could be lined with HDPE (see Figure 6) if needed to prevent loss of flow in the event soils encountered during construction are more permeable than indicated by the borings. Design, construction, operation, and maintenance issues are described under the following headings.

Typical Cross Section

The typical cross section for the proposed drainage swale is shown on Figure 6(a). This cross section presupposes that a sufficient thickness of natural low-permeability soils (the lateral extension of the perching layer) will be present in the upper part of the bench holding the swale.

Prevention of Leakage

To allow for potential variability in the surface elevation or thickness of the perching zone, the design assumes the invert of the swale may extend below the base of the perching horizon in places, in order to maintain the design slope of 1 to 2 percent. If the perching horizon is thin or even be eroded away in places, this will be revealed as excavation of Borrow Area 3 occurs and the intersection of the perching layer with the final cut slope becomes visible. In the event that field mapping during excavation shows insufficient low-permeability soil is present to form the required subgrade for the unlined drainage swale, the swale grade or alignment could be modified, and/or an impermeable lining (protected by gravel) would be used in the base of the swale to prevent seepage loss, as shown on Figure 6(b).

Control of Excess Flows

The position of the drainage swale at mid-slope around the northern and western sides of Borrow Area 3 will cause the swale to collect surface water runoff during high precipitation. Some precipitation upslope of the swale is likely to infiltrate but may appear as shallow interflow or perched water and contribute to seepage in the swale. Also, if constructed to its full length as shown on Figure 3, the swale is expected to collect more than enough groundwater seepage to make up for the projected maximum loss in flow from Wetland 29.

Two measures are available to deal with these anticipated excess flows:

1) A flow-control structure will be constructed in the course of the swale before it enters Wetland 29 (see Figure 9); and
2) The length of the swale can also be modified (at time of construction, or after some period of post-construction monitoring) to control the amount of seepage (and runoff) that is collected and diverted to Wetland 29.

The proposed flow control weir or diversion structure will be designed to provide a consistent low flow of seepage into Wetland 29 and enable diversion of excess flow in the drainage swale away from Wetland 29. The excess flow will be diverted along a channel and into the base of Borrow Area 3, where it will infiltrate and/or be handled by the stormwater facilities for managing runoff from the remainder of the borrow area.

The flow control structure will be constructed of reinforced concrete. As illustrated on Figure 9, it will include a narrow flow slot at the lower elevation to enable a continuous low flow from the drainage swale into Wetland 29. The second part of the flow control structure will include a broad overflow weir that will allow water to spill over into a diversion channel during periods of higher flow in the swale. Flow through both the narrow slot and the broad weir will be controlled with adjustable boards as shown on Figure 9. Flow to Wetland 29 will be fine-tuned during the initial maintenance period (following construction) by adjusting the height of the boards placed in each part of the structure. Final flow levels may then be fixed by replacing the boards with masonry at the end of the monitoring period.

Construction

Construction of the drainage swale will be integrated with the mining and reclamation plan for the excavation of Borrow Area 3. This will prevent over-mining of the perching layer in close proximity to the final slope contours for the excavation. Mining will progress from the highest area of the site in the northwest part of Borrow Area 3, working down the slope and reclaiming the upper part of the final cut slope as excavation proceeds. The perched zone will be encountered as wet areas at the base of the working slope. Mining will then step in approximately 20 feet to allow the bench for the drainage swale to be formed in the perching layer beneath the perched zone.

The next stage will be to excavate within the bench width to cut the swale into the perched zone and underlying perching layer. The bench will be cleaned off and graded to form the swale, which will be constructed per the typical cross section. This will provide the opportunity to determine from field surveying the elevation, profile, and thickness of the perching layer in the area of the final slope. The final design of the swale invert elevations and cross sections will then be adjusted as required to best match subsurface conditions and topography, facilitating final construction the swale at the required elevation on the bench. Mining will then proceed into the lower part of the slope below the drainage swale.

Surface Protection and Reclamation

Reclamation of the borrow area will be accomplished in accordance with Washington Department of Natural Resources criteria and the Port of Seattle landscape plans. Once final grades have been established, the drainage swale and adjacent slopes will be protected from erosion using the same techniques demonstrated to be effective by the embankment construction to date. The excavation slopes will be dressed and hydroseeded with a bonded fiber matrix. The swale will be protected with erosion control matting until grass is established as part of the post-excavation site reclamation.

Operation and Maintenance

Operation of the swale, and particularly the flow control structure, will require monitoring and recordkeeping for an initial period of about two to five years. During this period, the amount of seepage and operation of the flow control weir will be monitored. The weir height may be adjusted to ensure stable and appropriate flows to Wetland 29, which are consistent with plant and ecological requirements of the wetlands.

Long-term operation and maintenance of the swale will be restricted to periodic (annual) inspections of the facility to check the basic integrity of the swale and look for signs of erosion or blockage that could require remedial work by Port grounds maintenance staff.

F:\docs\jobs\497806\DraftWetlandPreservationSwale.doc

Attachments:
References
Figure 1 - Site Location Map
Figure 2 - Pre-Excavation Topography and Wetlands – Borrow Area 3 Perched Zone
Figure 3 - Post-Excavation Topography and Drainage Facilities - Borrow Area 3 Drainage Swale
Figure 4 - Cross Section A - A′ through Wetland 29
Figure 5 - Cross Section B - B′ through Wetland 30
Figure 6 - Cross Section C - C′ through Wetland B6
Figure 7 - Drainage Swale – Profile D-D′
Figure 8 - Typical Cross Sections E-E′ - Borrow Area 3 Drainage Swale
Figure 9 - Flow Control Structure Schematic - Borrow Area 3 Drainage Swale

REFERENCES

Hart Crowser, Inc., 1999. Subsurface Conditions Data Report, Borrow Areas 1, 3, and 4, Sea-Tac Airport Third Runway. Prepared for HNTB and the Port of Seattle, September 24, 1999 (J-4978-02).

Hart Crowser, Inc., 2000. Evaluation of Perched Zone Interception and Possible Impacts to Wetland Hydrology, Borrow Areas 3, Sea-Tac Airport Third Runway. Prepared for HNTB and the Port of Seattle, September 12, 2000 (J-4978-13).

Parametrix, Inc., 1999. Wetland Delineation Report, Seattle-Tacoma International Airport, Master Plan Update Improvements. Prepared for Port of Seattle, August 1999.

USDA, 1973. Soil Survey, King County Area, Washington. United States Department of Agriculture, Soil Conservation Service, 100 pp. November 1973.

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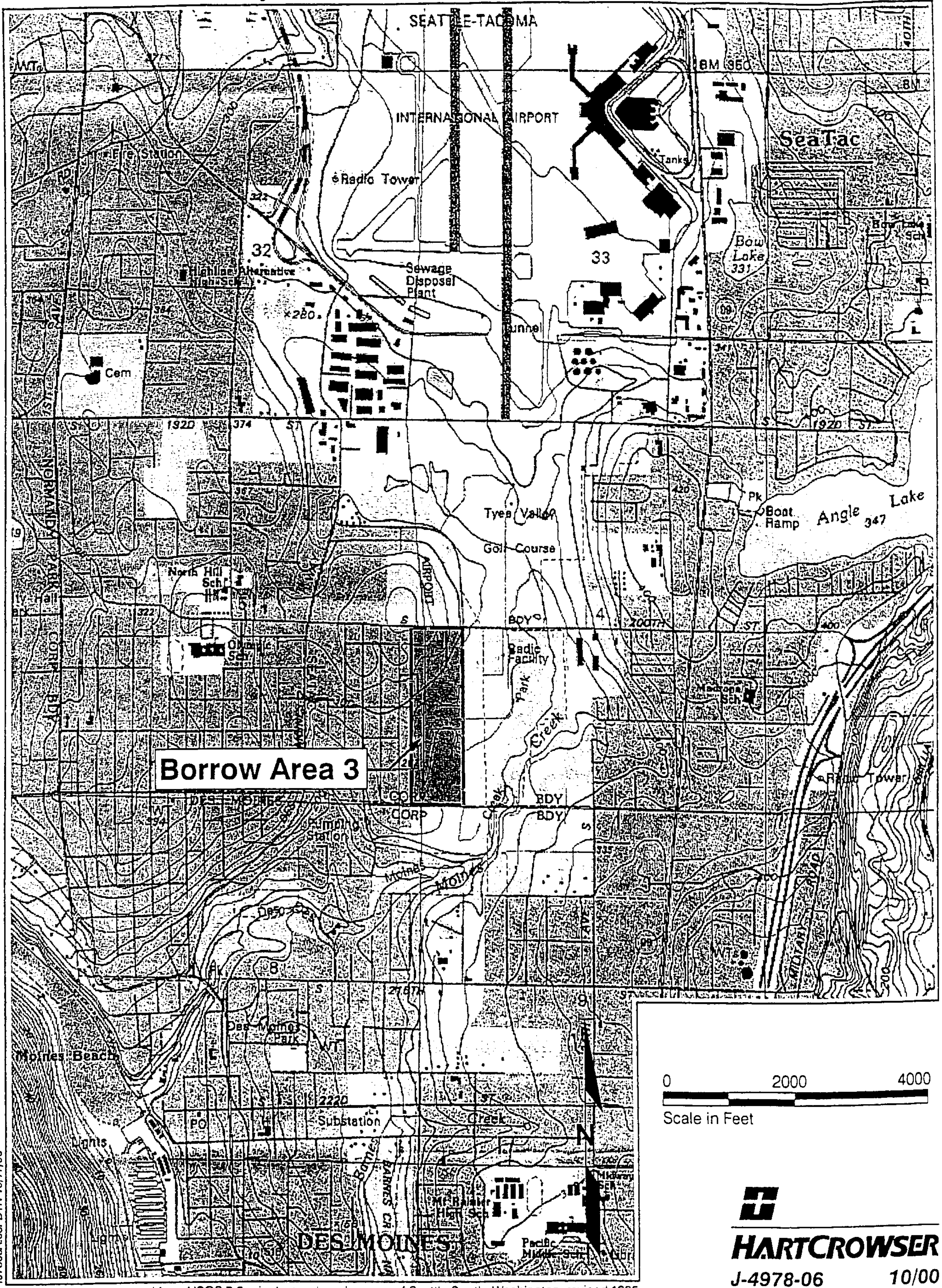
Site Location Map



Note: Base map prepared from USGS 7.5 minute quadrangle maps of Seattle South, Washington, revised 1995.

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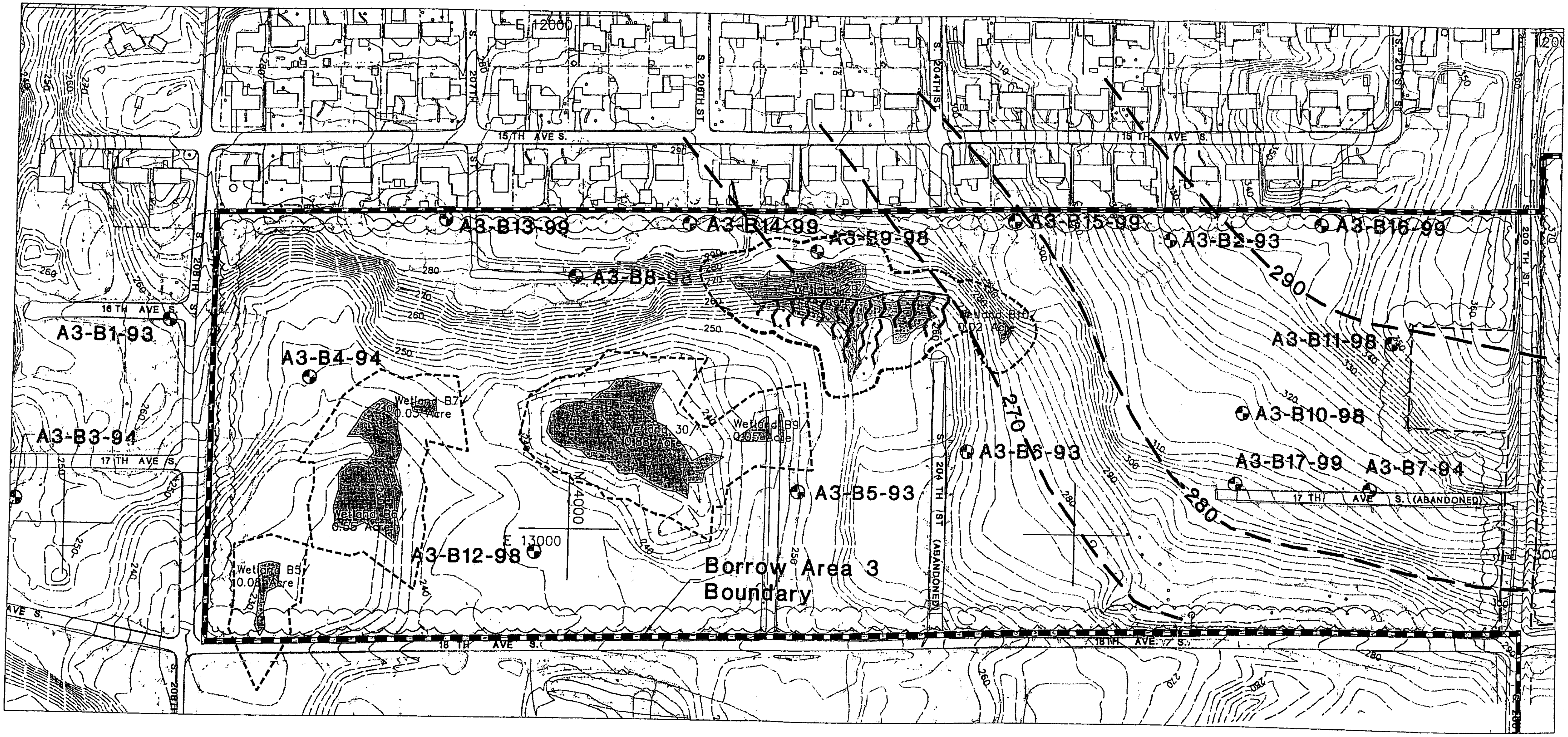
J-4978-06 *10/00*

Figure 1

Pre-Excavation Topography and Wetlands

Borrow Area 3 Perched Zone



- A3-B4-94 — Exploration Boring with Monitoring Well
- 280 — Perched Zone Groundwater Elevation Contour in Feet
- Wetland Location, Designation, Acreage, and 50-foot Wetland Buffer (Based on Parametrix, 1999)
- Inferred Seepage Face

N

0 200 400

Scale in Feet

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J-4978-06 10/00

Figure 2

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Post-Excavation Topography and Drainage Facilities

Borrow Area 3 Drainage Swale

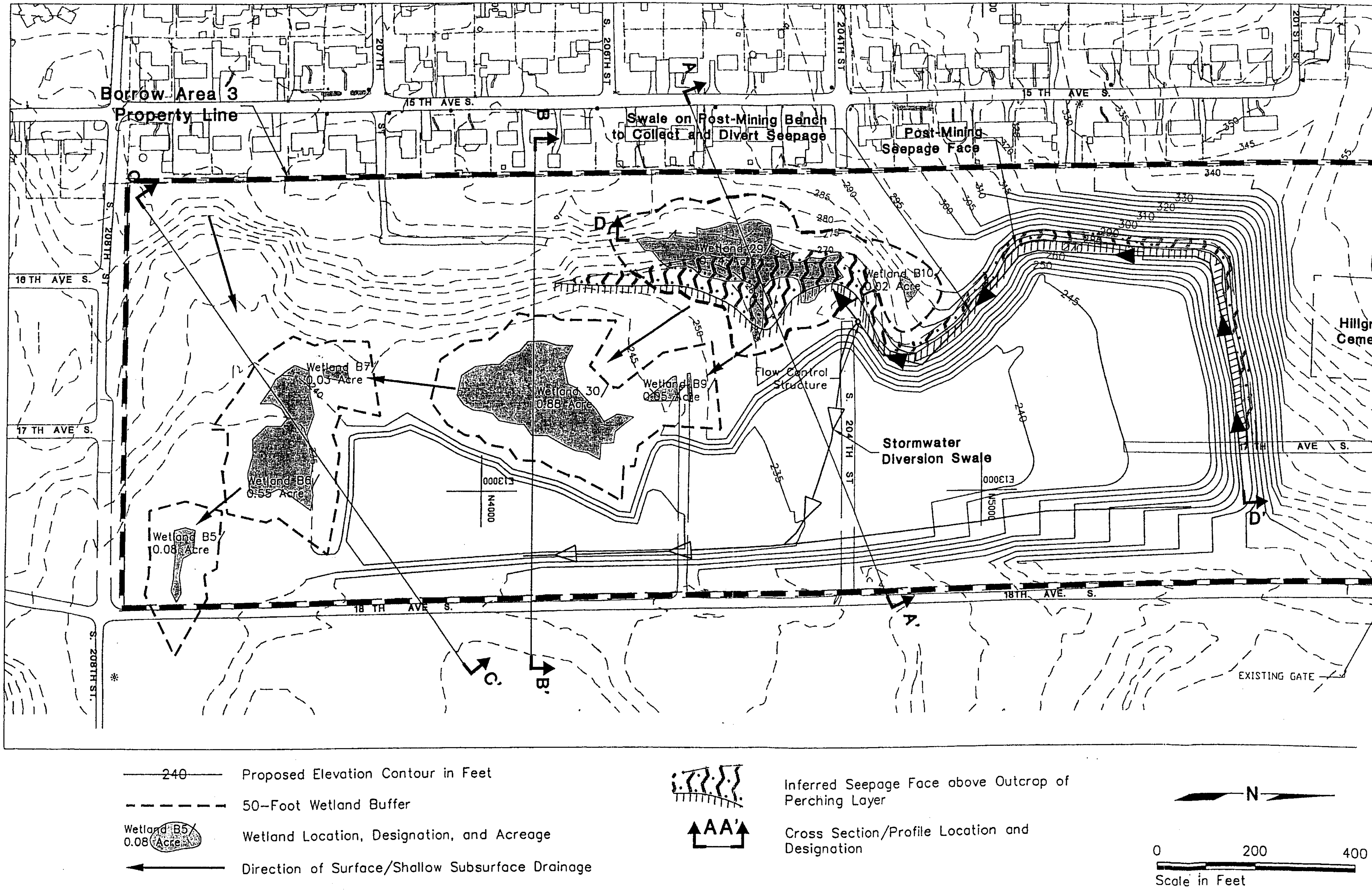

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Figure 3

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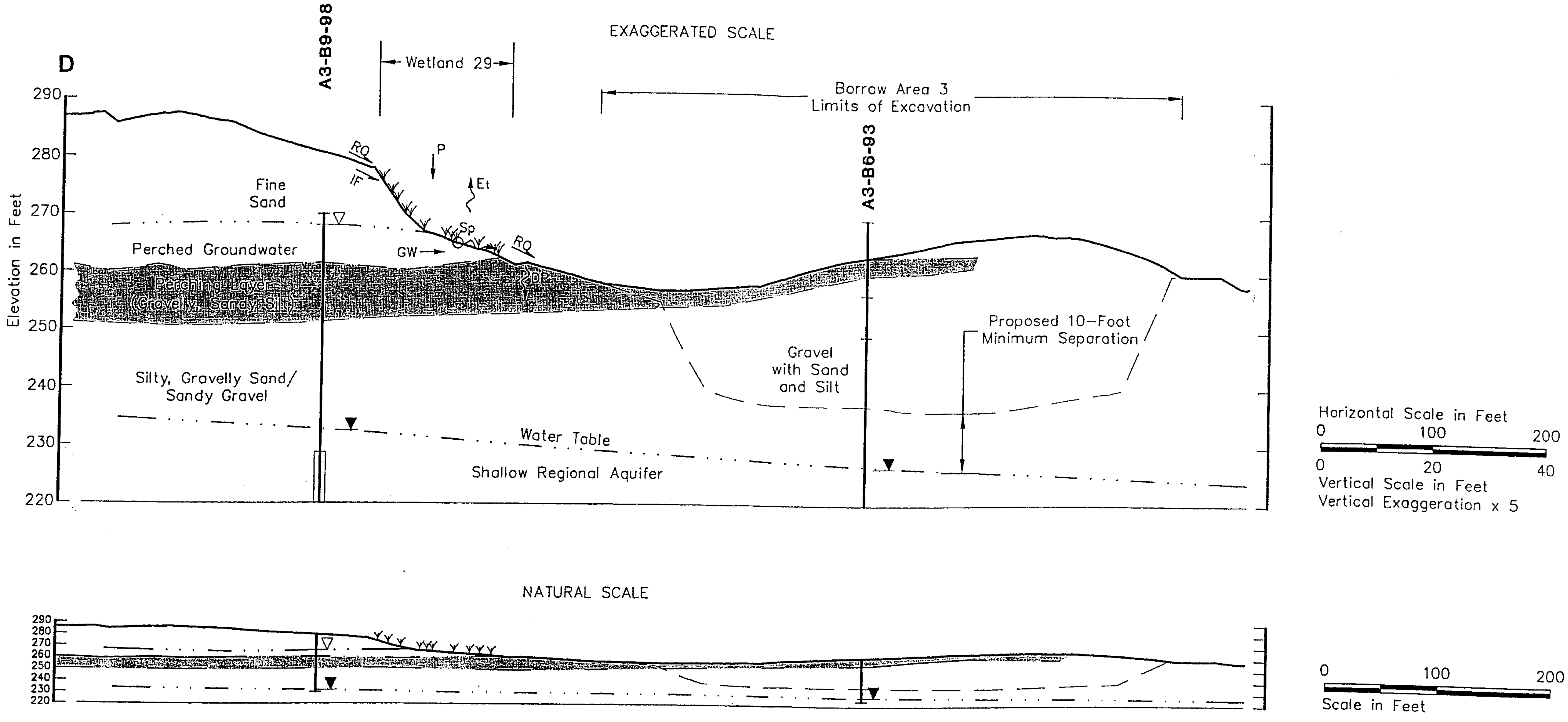
Cross Section A-A' through Wetland 29

Looking North



Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Wetland Hydrology

Inflows:
- P Precipitation
- RO Runoff
- IF Interflow
- Sp Springs or Seeps
- GW Groundwater

Outflows:
- Et Evapotranspiration
- DP Deep Percolation

A3-B8-98 Exploration Number

┬ Exploration Location

▽ Perched Water Level

▼ Shallow Aquifer Water Level

▯ Screened Interval

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49780635

AR 030570

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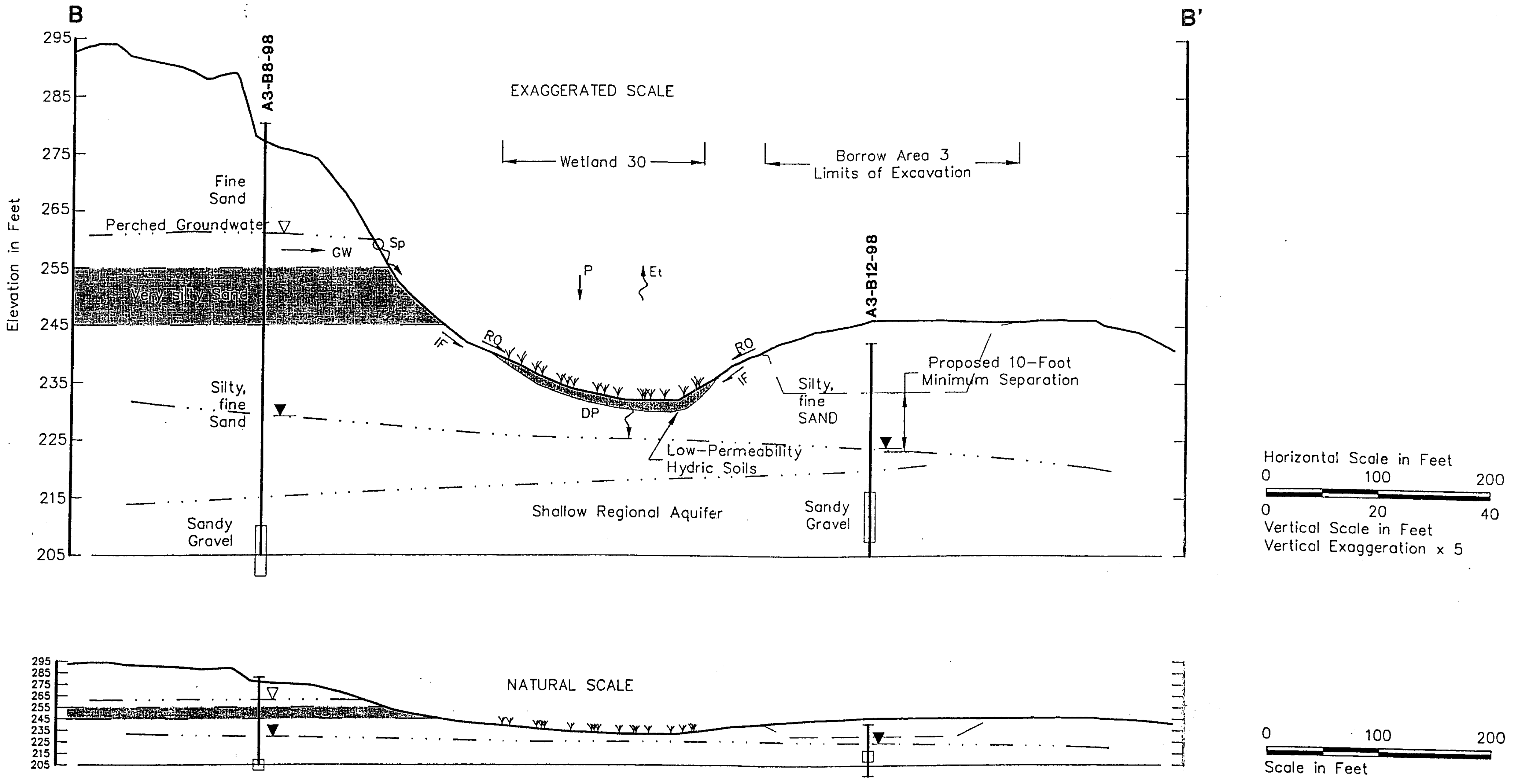
J-4978-06 10/00

Figure 4

Cross Section B-B' through Wetland 30

Looking North



Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Wetland Hydrology

Inflows:
- P Precipitation
- RO Runoff
- IF Interflow
- Sp Springs or Seeps
- GW Groundwater

Outflows:
- Et Evapotranspiration
- DP Deep Percolation

A3-B8-98 Exploration Number

Exploration Location

▽ Perched Water Level

▼ Shallow Aquifer Water Level

Screened Interval

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49780638

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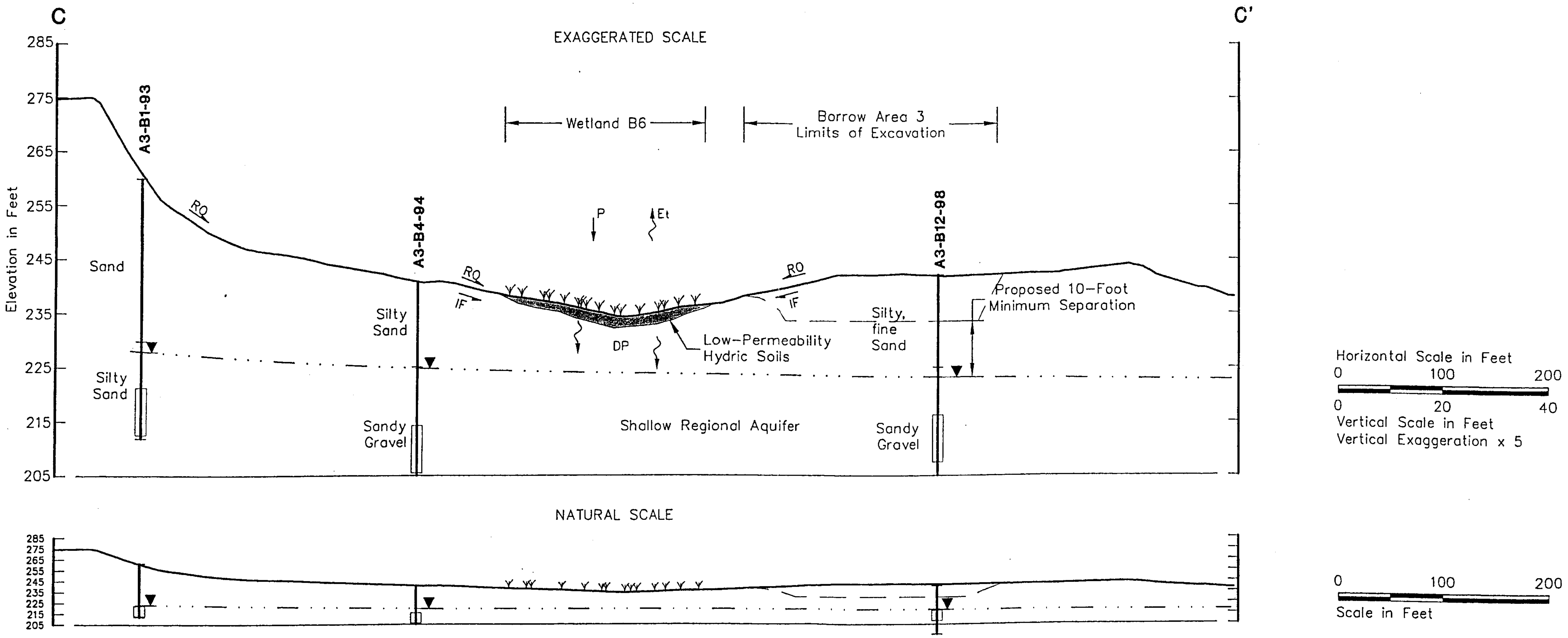
J-4978-06 10/00
Figure 5

Cross Section C-C' through Wetland B6

Looking North



Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Wetland Hydrology

Inflows: P Precipitation
RO Runoff
IF Interflow
Sp Springs or Seeps
GW Groundwater

Outflows: Et Evapotranspiration
DP Deep Percolation

A3-B8-98 Exploration Number
Exploration Location
▽ Perched Water Level
▼ Shallow Aquifer Water Level
Screened Interval

DTN 10/17/00 1=100 charlie.pc2
49780639

AR 030572

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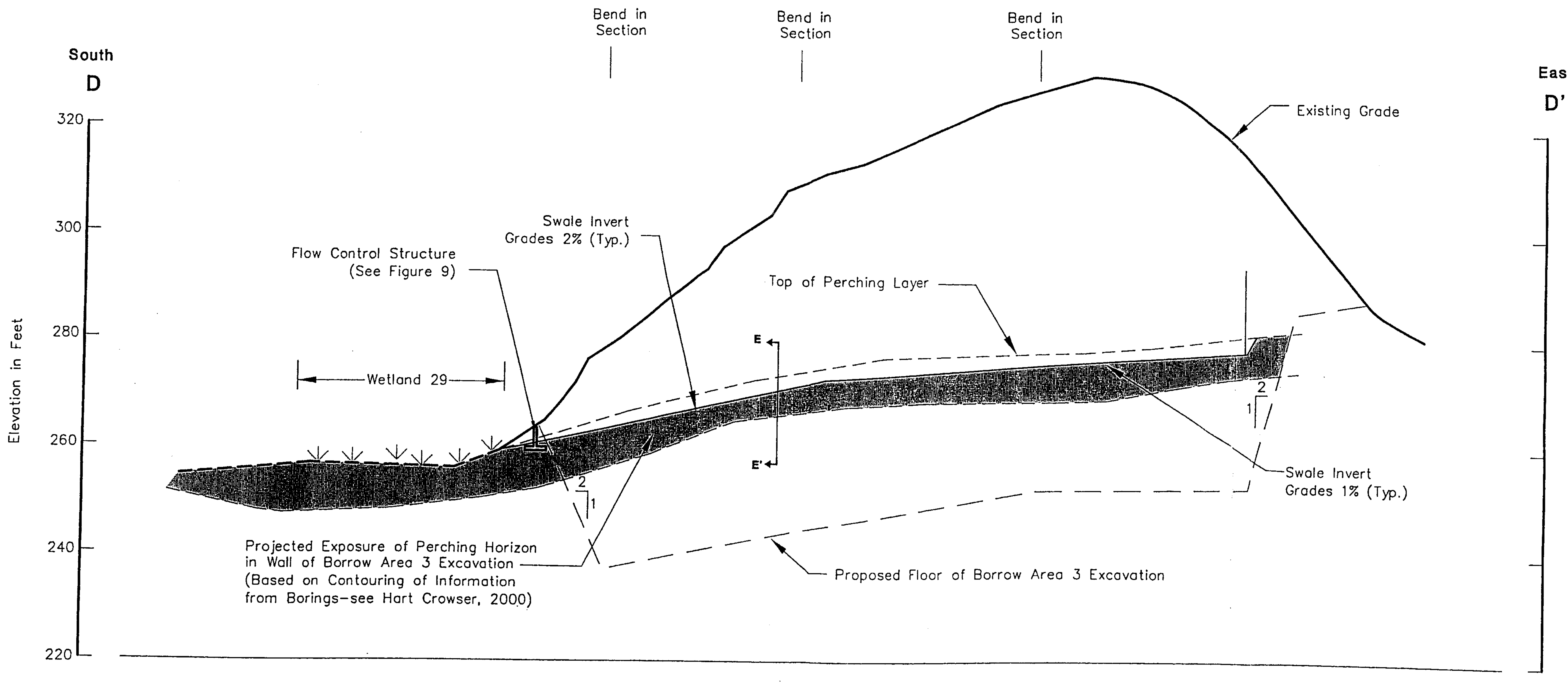
J-4978-06 10/00
Figure 6

Drainage Swale - Profile D-D'

Borrow Area 3



Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Horizontal Scale in Feet
0 200 400
0 20 40
Vertical Scale in Feet
Vertical Exaggeration x 10

DTN 10/18/00 1=200 chorlie.pc2
4978064O

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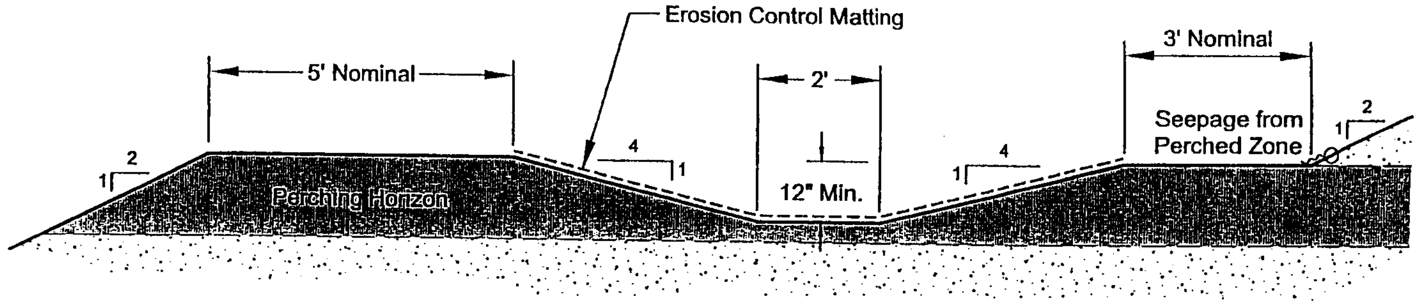
J-4978-06 10/00
Figure 7

DTN 10/18/00 charlie-8.pc2 49780641.dwg

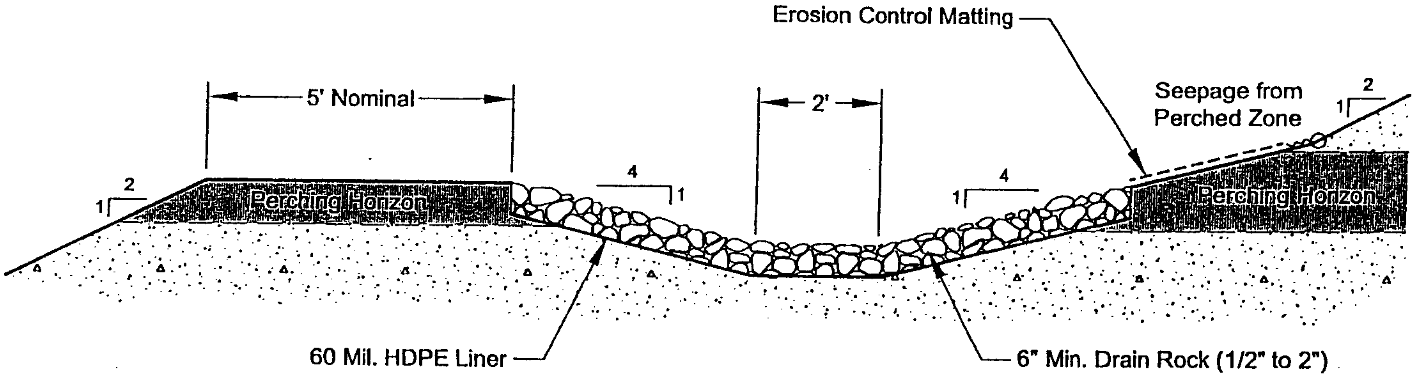
Typical Cross Sections E-E'

Borrow Area 3 Drainage Swale



(a) DRAINAGE SWALE (TYPICAL)

Not to Scale



(b) LINED DRAINAGE SWALE (AS NEEDED)

Not to Scale

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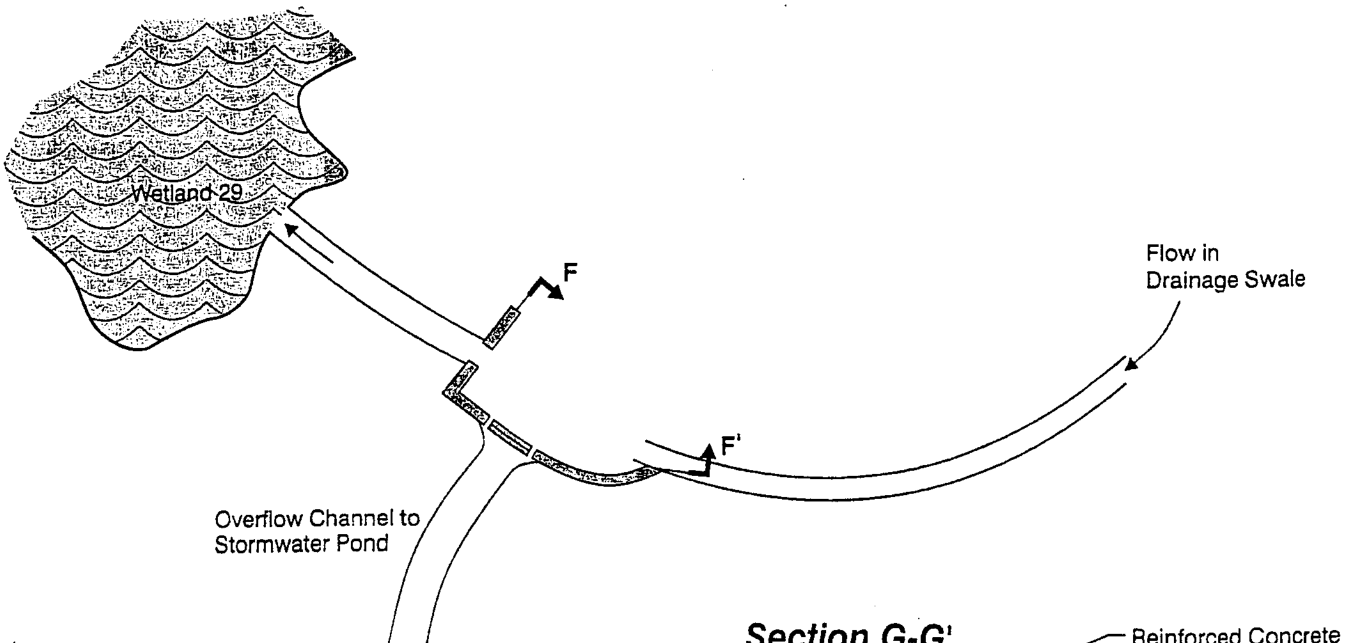
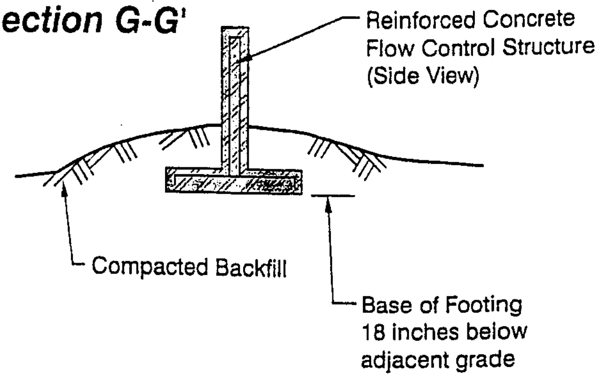
Figure 8

Flow Control Structure Schematic

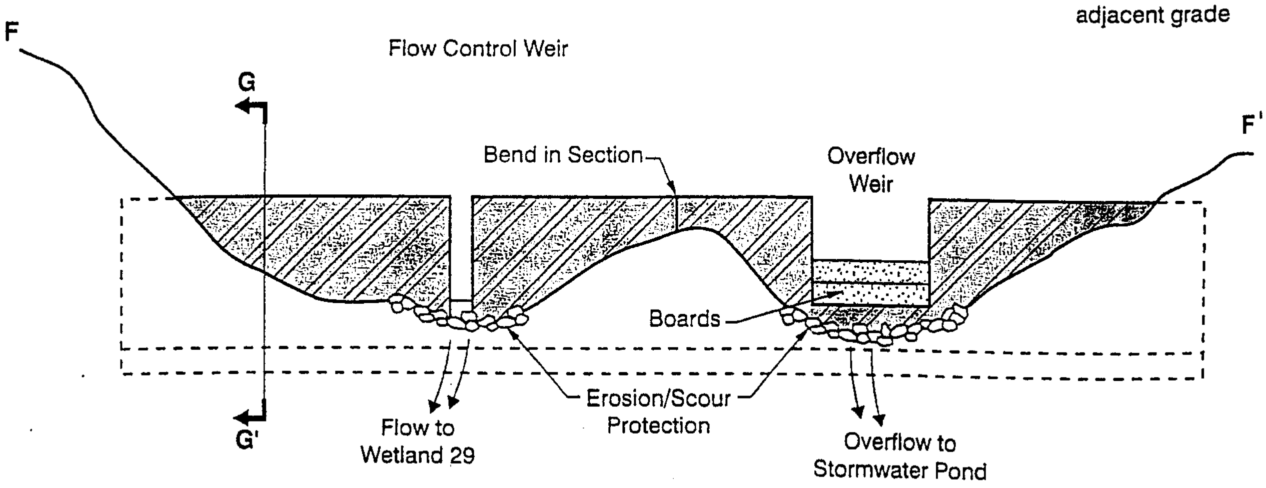
Borrow Area 3 Drainage Swale



Section G-G'



Elevation F-F'



hel 10/18/00 4978068.cdr

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Figure 9

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Letter of Transmittal

To: Parametrix
5808 Lake Washington Blvd. NE
Suite 200
Kirkland, WA 98033-7350

Date: June 18, 2001

Job No.: 4978-06

Attn: Jim Kelley

Re: Third Runway Project, Borrow Area 3 Wetland Protection Swale

We are sending the following items:

Date	Copies	Description
6/01	3	Figure 1 Draft Post-Reclamation Topography and Drainage Facilities
6/01	3	Figure 2 - Draft Typical Cross Sections
6/01	3	Figure 3 - Draft Post-Reclamation Topographical Detail
6/01	3	Figure 4 - Draft Proposed Wetland Protection Swale Profile and Cross Section

These are transmitted:

☐ *For your information* ☐ *For action specified below* ☐ *For review and comment* ☒ *For your use* ☐ *As requested*

Remarks

Enclosed please find the revised plan and sections for the Borrow Area 3 Wetland protection Swale that provides mitigation of potential seepage changes. Per your request, copies are being sent directly to Ann Kenny at Ecology and Katie Walter at Shannon and Wilson. Pending any comments from the agencies, these draft plans and sections will be incorporated into the Borrow Area 3 excavation plans.

Please call if you have any questions.

By: Michael Bailey
Michael Bailey, P.E.

Title: Senior Principal

Copies to:
Ann Kenny, Ecology (4)
Katie Walter, Shannon & Wilson (1)
Elizabeth Leavitt, Port of Seattle (1)
Alan Black, HNTB (2)
Jim Thomson, HNTB (1)
Paul Fendt, Parametrix (1)
Ralph Wessels, Port of Seattle (1)

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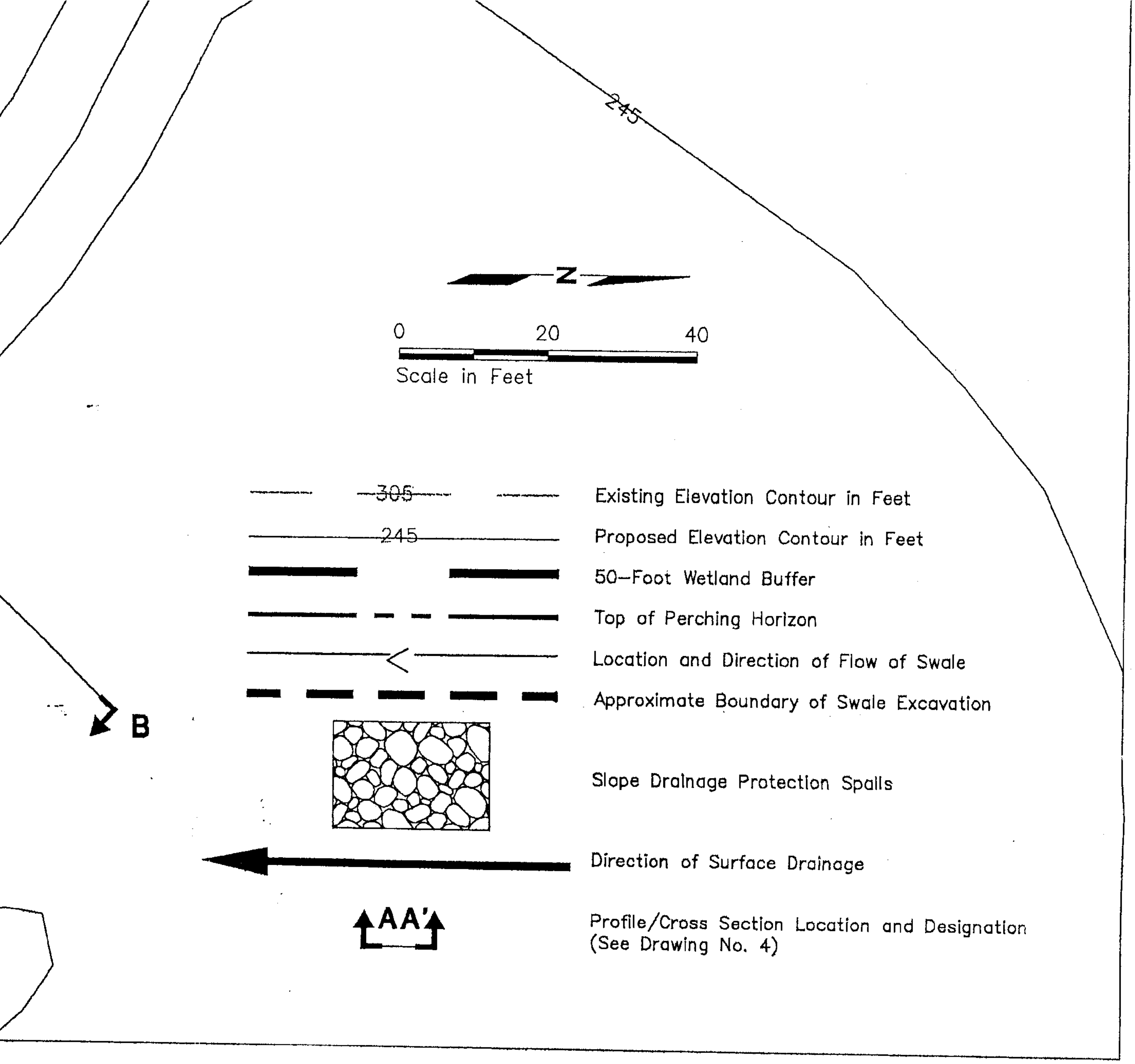
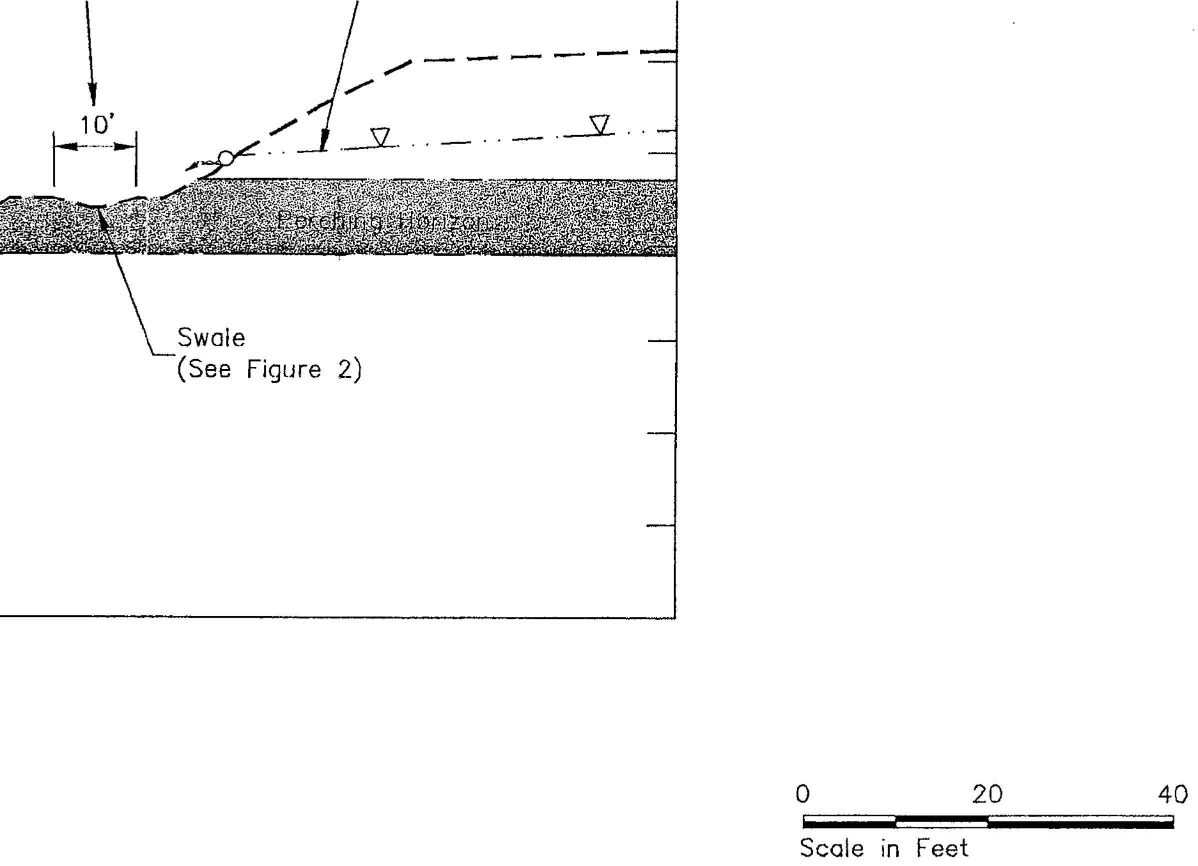


SEA-TAC THIRD RUNWAY

POST-RECLAMATION TOPOGRAPHIC DETAIL BORROW AREA 3 WETLAND PROTECTION SWALE HNTB REVISION

ng 24x36	Scale: AS SHOWN	Date Issued: 6/15/01	Drawing Type: DRAFT	Job No.: 4978-06	SHEET: of	Drawing No.: 3



SEA-TAC THIRD RUNWAY

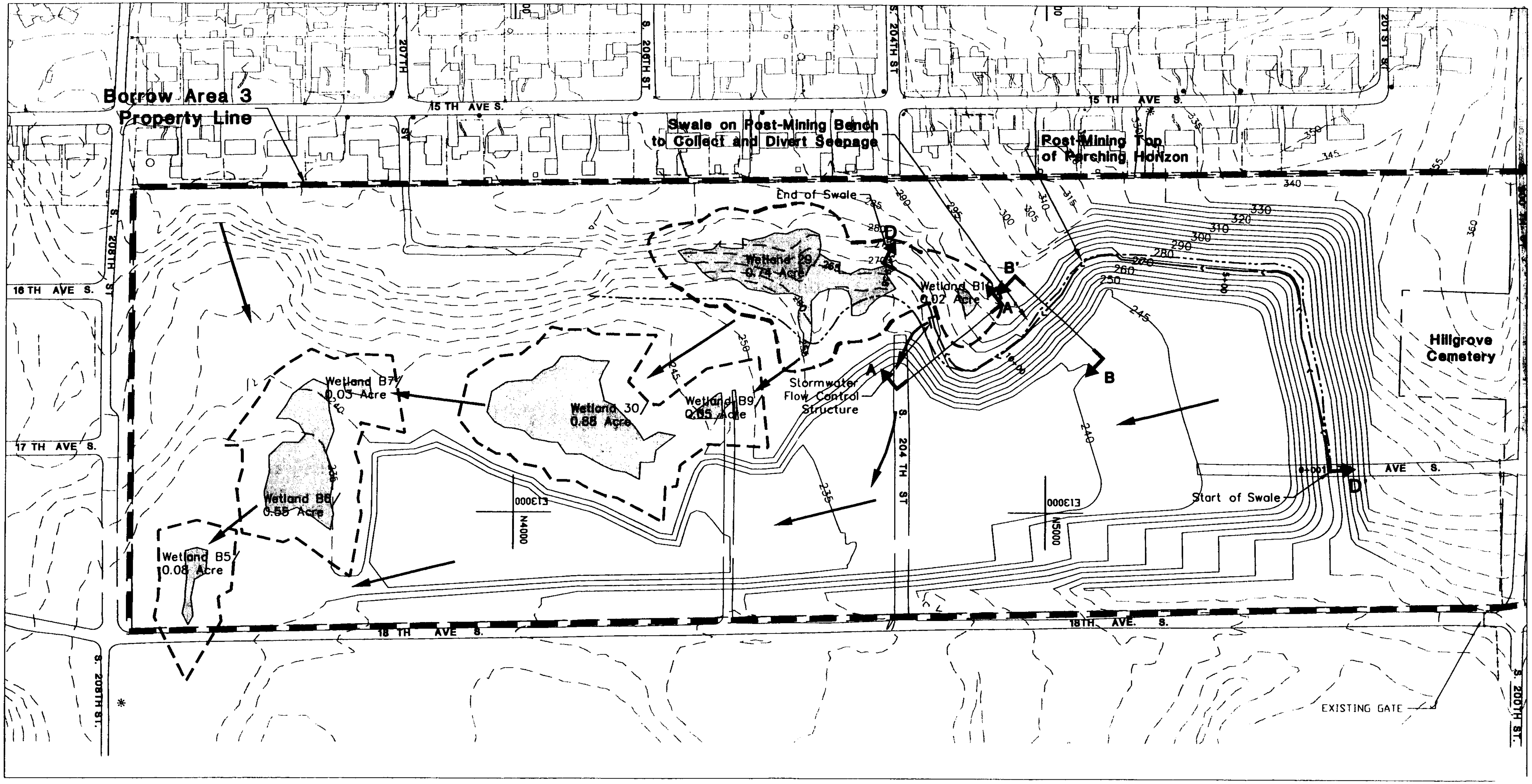
ROPOSED WETLAND PROTECTION SWALE PROFILE AND CROSS SECTIONS BORROW AREA 3

Scale: AS SHOWN	Date Issued: 6/7/01	Drawing Type: DRAFT	Job No.: 4978-06	SHEET: of	Drawing No.: 4

Post-Reclamation Topography and Drainage Facilities

Borrow Area 3 Wetland Protection Swale

DRAFT



300 Existing Elevation Contour in Feet

240 Proposed Elevation Contour in Feet

50-Foot Wetland Buffer

Wetland B5 0.08 Acre Wetland Location, Designation, and Acreage

Direction of Surface/Shallow Subsurface Drainage

Proposed Drainage Swale

Inferred Seepage Face above Outcrop of Perching Layer

AA' Cross Section/Profile Location and Designation

N

0 200 400

Scale in Feet

AR 030579

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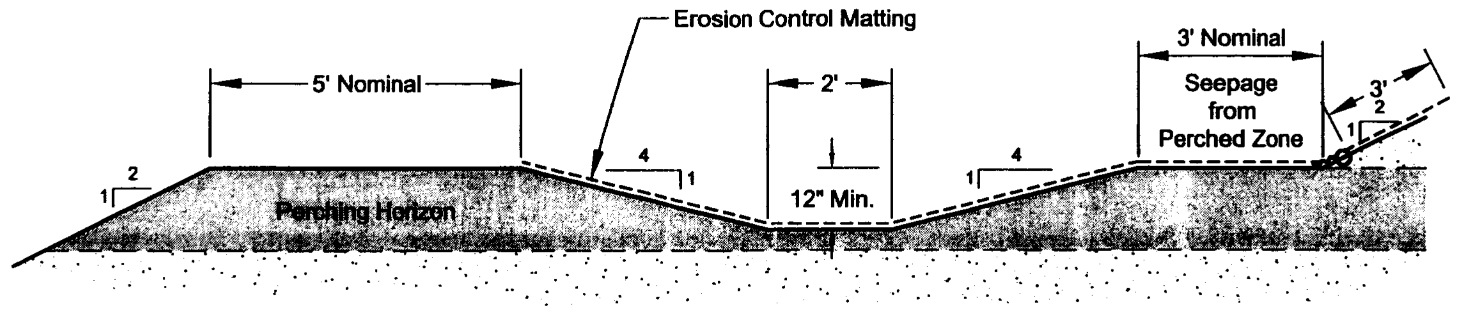
Figure 1

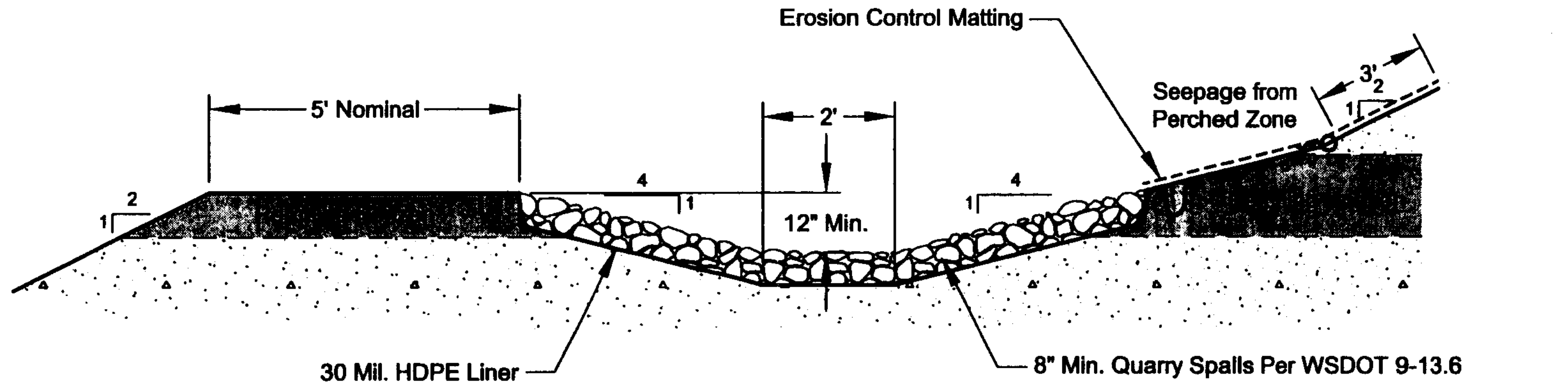
RC 6/11/01 1=200 (xref)see drawing file/charlie.pc2
49780670

Typical Cross Section
Borrow Area 3 Wetland Protection Swale

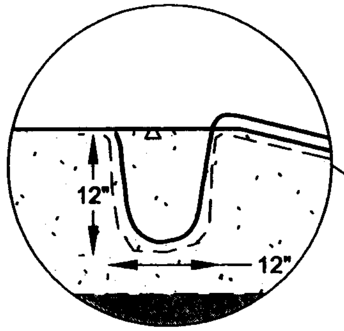
DRAFT



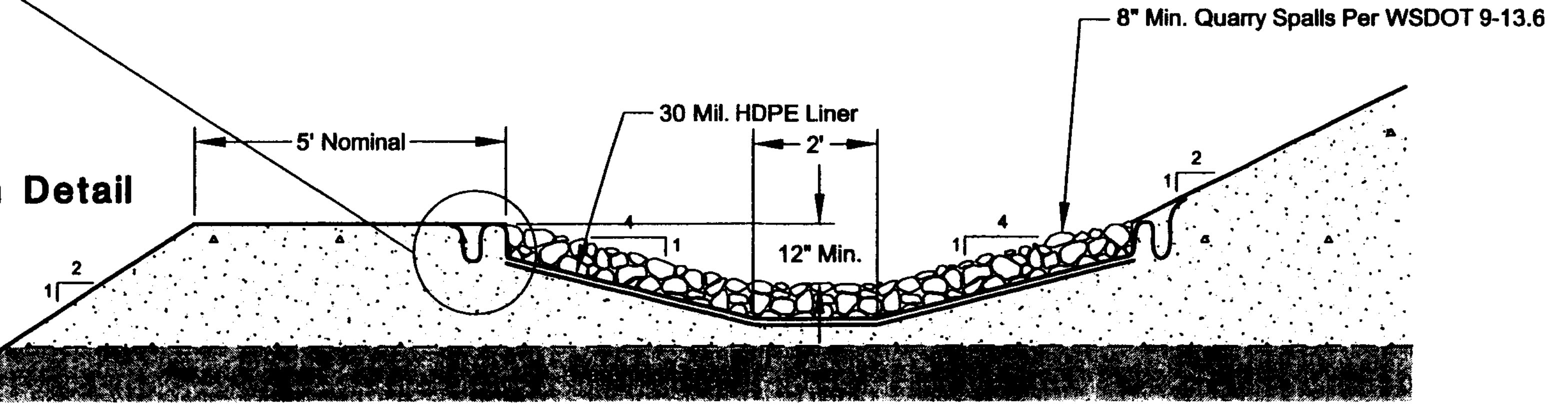
(a) DRAINAGE SWALE (TYPICAL)
Not to Scale



(b) LINED DRAINAGE SWALE (AS NEEDED)
Not to Scale



Typical Anchor Trench Detail



(c) LINED DRAINAGE SWALE (AS NEEDED)
Not to Scale

↝○ Seepage Zone
------ Erosion Control Matting
——— 30 Mil. HDPE Liner
▨ Perching Horizon

Note:
Elevation and thickness of perching horizon and groundwater levels are shown schematically based on existing information. Design grades will be established following field survey during excavation of Borrow Area 3 and exposure of the perching horizon.

AR 030580

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J-4978-06 6/01
Figure 2

Appendix E

APPENDIX E

HYDROLOGIC CHARACTERISTICS OF THE THIRD RUNWAY EMBANKMENT

APPENDIX E

HYDROLOGIC CHARACTERISTICS OF THE THIRD RUNWAY EMBANKMENT

The reports contained in this appendix address the hydrologic properties of the third runway embankment. The analyses evaluate the runoff and infiltration characteristics of the embankment fill, the downward movement of infiltrated water through the fill, and the behavior of water at the interface of the drain layer and existing ground surface. The reports form the basis, in part, to the analysis of indirect impacts to wetlands located downslope of the embankment.

E-1

Effects of Infiltration on Baseflow

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DRAFT

MEMORANDUM

DATE: October 13, 2000

TO: Jim Thomson P.E., HNTB

FROM: Michael Bailey, P.E., and Michael Kenrick, P.E., Hart Crowser

RE: **Effects on Infiltration and Base Flow**
Proposed Third Runway Embankment
J-4978-06

CC: Paul Fendt and Jim Kelley, Parametrix

In response to your request, this memo presents Hart Crowser's most recent analysis of infiltration into the proposed Third Runway embankment and related effect on the shallow water-bearing zone in native soils that provide base flow to Miller Creek and adjacent wetlands. The analysis presented in the attachment to this memo is Appendix C from Hart Crowser's pending geotechnical report on the proposed embankment (Hart Crowser, 2000).

The analysis presented in the attachment is the third and most sophisticated analysis we have accomplished on potential impacts of embankment construction to base flow (see Hart Crowser, 1999 and 1998). The three Hart Crowser analyses are consistent and confirm the independent analysis accomplished by Ecology's consultant Pacific Groundwater Group (PGG, 2000). These analyses indicate that construction of the embankment is expected to reduce overall annual base flow only slightly, and the net effect is a benefit to the environment since percolation through the embankment will experience a hydraulic lag, resulting in increased base flow in the summer months when it is most needed.

The analysis described in the enclosed attachment used a sequence of three models to represent the process of unsaturated flow through the embankment.

- The first part of this approach is a model called Rosetta that uses moisture-conductivity-suction relationships based on gradation of the actual fill materials, to develop parameter sets that control infiltration and unsaturated percolation in the embankment.

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Tel 206.324.9530

- The second part is the EPA developed HELP model that models infiltration and allows the direct simulation of the lateral drainage layer at the base of the embankment.
- The third component is SoilCover, a model that uses real precipitation records and links the subsurface saturated/unsaturated groundwater system and the atmosphere above the soil in a rigorous mathematical algorithm.

These analyses were accomplished with parameters for the type of embankment soils actually being used (Groups 1A through Group 4, using the gradations in the construction specifications). The analyses were also run for the existing native soil conditions to represent the pre-construction condition. The results indicate that groundwater flow rates beneath the proposed embankment will generally be similar to existing conditions but that slight differences are predicted depending on whether annual precipitation is more or less on average, as discussed below.

1. Groundwater flow rates beneath the proposed embankment will generally be similar to or slightly lower than for existing conditions during wet years.
2. Groundwater flow rates beneath the embankment would show a relative increase over existing conditions during dry years.
3. The overall long-term average flows are generally very similar in all years, except for the seasonal lag which produces a net increase in base flow to Miller Creek and adjacent wetlands in the summer and early fall.

The simple layman's explanation for these findings is that although the runway project will produce slightly more runoff (especially in wet years) compared to existing conditions, the longer seepage path through the embankment means more water as base flow in dry years and in the dry part of all years.

As mentioned, the results of the current modeling are consistent with results of PGG's recharge model and Hydrus-2D model results. PGG concluded: "Flows would be lower in the winter than under the current condition, and greater in summer compared to the current condition." PGG also noted that "dependent flows to local wetlands and the creeks will be reduced only in winter when abundant water is typically present anyway."

These results are also consistent with Hart Crowser's previous water balance model (Hart Crowser, 1999) and a previous analysis of potential aquifer compaction (Hart Crowser, 1998), both of which were made available to PGG and the agencies. What these results are not consistent with is the HSPF model that was used to size stormwater management ponds for the Third Runway project. We infer this difference is because 1) the HSPF model is intended to address conditions in the entire drainage basin and is not well-suited to the analysis of unsaturated flow through the embankment; and 2) the HSPF calibration data are from the 1998 fill after the top surface had been smooth rolled to resist erosion, and thus did not represent the condition of the final grassed surface of the permanent embankment adjacent to the airfield pavement.

Please call if you have any questions.

References:

Hart Crowser, 1998. Letter to Ms. Barbara Hinkle, Port of Seattle, re. Sea-Tac Third Runway - Aquifer Compaction, December 9, 1998.

Hart Crowser, 1999. Geotechnical Engineering Report, 404 Permit Support, Third Runway Embankment, Sea-Tac International Airport. July 9. 1999.

Hart Crowser, 2000. Embankment Slope Stability Analyses and Subgrade Improvement Recommendations, Third Runway Project. (DRAFT report in progress, October 2000).

Pacific Groundwater Group, 2000. SeaTac Runway Fill Hydrologic Studies Report, June 19, 2000.

F:\docs\jobs\497806\infiltrationmemo.doc

Attachment:

Appendix C
Embankment Infiltration and Seepage Studies
(From Hart Crowser, 2000)

APPENDIX C
EMBANKMENT INFILTRATION AND SEEPAGE STUDIES

CONTENTS

TABLES

FIGURES

CONTENTS (Continued)

Page

FIGURES

APPENDIX C
EMBANKMENT INFILTRATION AND SEEPAGE STUDIES

Introduction

This appendix presents the results of seepage analyses designed to track changes in the infiltration and deep percolation of moisture occurring as a result of constructing the proposed Third Runway embankment. Understanding of these changes is important for a number of reasons:

- Different soil types proposed for the embankment fill will result in different amounts of infiltration and runoff. The surface soil type will also affect rates of evapotranspiration.

- The percolation of moisture through the embankment could potentially create zones of saturation were pore pressures could build up, with consequent risk to the stability of slope faces.

- The rate and timing of recharge to groundwater beneath the embankment could change, affecting the groundwater level beneath the fill. This could affect the extent of areas susceptible to liquefaction during earthquake events, and/or affect base flow to wetlands and Miller Creek.

The analyses presented in this appendix are designed to address:

- The relative quantities of moisture percolating downward through the embankment and into the underlying drainage layer;
- The proportion of moisture that flows along the drainage layer and discharges at the embankment toe;
- The proportion and timing of groundwater recharge occurring as downward seepage from the drainage layer into the native soils beneath the embankment; and
- The water table elevation maintained in the existing subgrade soils after embankment construction.

Approach

The movement of moisture into and through the Third Runway embankment represents a complex interplay of hydrologic processes occurring at and beneath the soil surface, which are listed and defined below. Figure C-1 shows a representative cross section through the embankment and illustrates the water balance components used in the model.

- **Precipitation (P).** The occurrence of rainfall is the main driver for the infiltration process.
- **Evaporation (E).** A portion of the precipitation evaporates without infiltrating or running off, this includes interception storage on leaves and in shallow surface ponds.
- **Runoff (R_o).** The occurrence of runoff from the surface of the embankment (excluding the effect of impervious surfaces) depends on a number of factors, including:
  - The intensity and duration of each precipitation event;
  - The prevailing moisture content of the surface soil, as influenced by antecedent conditions;
  - The type and density of vegetation;
  - Surface slope; and
  - The hydraulic conductivity of the surface soil, as influenced by grain size, soil fabric, macro-porosity, and degree of compaction.
- **Infiltration (I).** The amount of water infiltrating into the soil surface is complimentary to the runoff, and is largely dependent on the same factors.
- **Transpiration (T).** A portion of the moisture in the upper soil layer(s) is taken up by the vegetation and lost back into the atmosphere.
- **Percolation (P).** Excess moisture in the upper soil zone(s) is available to move downward under the influence of gravity and the pressure gradient created by soil moisture tension in the unsaturated vadose zone within the body of the embankment. The moisture content in the vadose zone continually adjusts to the rate of percolation to achieve a dynamic balance with the unsaturated hydraulic conductivity.
- **Seepage (S).** Locally saturated conditions can occur within or beneath the embankment where deep percolation encounters lower-permeability layers (e.g., silty or clayey soils or very dense soils such as glacial till), potentially creating zones of saturation in which water can perch and move laterally.
- **Drain Flow (DF).** Seepage within the underdrain is identified as drain flow. There is both a horizontal and vertical component of drain flow.
- **Groundwater Flow (GW).** Seepage into the native soils below the underdrain becomes groundwater flow (horizontal or base flow component).
- **Deep Percolation (DP).** Deep percolation is the vertical component of groundwater flow that goes down into the ground below the surficial water-bearing zone to recharge deeper regional aquifers.

The approach taken to analyzing embankment infiltration and seepage uses a sequence of three models to represent these processes, recognizing that unsaturated flow conditions likely predominate within the embankment.

Rosetta. The USDA has developed a "neural network" database model to generate soil moisture and hydraulic conductivity characteristic curves from grain size and soil density information (Schaap and Bouten, 1996). These curves define the fundamental moisture-conductivity-suction relationships that control infiltration and unsaturated percolation in the embankment, and are needed as input to simulation models, such as SoilCover and SEEP/W.

HELP. The EPA has developed a program for studying runoff, infiltration, and evapotranspiration as an aid to the design of landfill covers (Schroeder et al., 1994). The program, called HELP (Hydrologic Evaluation of Landfill Performance) has since been widely used to calculate groundwater recharge. It is applicable to the Third Runway embankment design in that it allows the direct simulation of lateral drainage layers within the embankment.

SoilCover. SoilCover is a soil-atmosphere flux model that links the subsurface saturated/unsaturated groundwater system and the atmosphere above the soil in a rigorous mathematical algorithm that represents the physical processes that occur between the soil and the atmosphere. These include: precipitation, infiltration, runoff, transpiration, and evaporation. The model calculates moisture fluxes within an unsaturated soil profile, as driven by day-to-day variations in atmospheric conditions, including precipitation, temperature, humidity, and solar radiation.

Soil Properties

Infiltration and seepage of moisture into the proposed embankment are controlled primarily by atmospheric conditions and soil properties. The soil properties of interest are those that govern the physical processes occurring at the soil surface, namely runoff, infiltration, and evapotranspiration. These processes are controlled primarily by the relative hydraulic conductivity of the soil layer, where the hydraulic conductivity of the unsaturated soil varies with the moisture content of the soil. The relative hydraulic conductivity is some fraction of the saturated hydraulic conductivity of the soil.

In recent years, numerous attempts have been made to define the unsaturated characteristics of soils using mathematical relationships among the three key parameters: moisture content, matric suction, and hydraulic conductivity. The computer program Rosetta was used to determine unsaturated hydraulic parameters from the grain-size distributions of the proposed fill materials (van Genuchten, 1980). Once the parameters were obtained, relationships (also known as soil characteristic curves) between matric potential (also known as soil suction or tension) and volumetric water content were constructed using the van Genuchten method, and between matric potential and unsaturated hydraulic conductivity using the Mualem (1976) method. Rosetta input requires percentages of sand, silt, and clay along with the bulk density for the soil(s) of interest. The program uses a limiting maximum bulk density value of 2.0 g/cm^3 (128 pcf).

Existing Soils

Hart Crowser reviewed the results of more than 50 test pits and borings in the proposed embankment foot print area, and identified two soil types that are representative of the overall embankment subgrade. The existing embankment subgrade soils of interest for the infiltration and seepage study are as follows:

- **Outwash Sand and Silty Sand.** Outwash sand and silty sand are the predominant surficial soil type within the embankment footprint. A representative sample of this soil type was chosen for use as input to the analyses based on a review of grain-size analyses. Sample S-2 from a depth of 8 feet in boring HC00-B115 was chosen. Gradation for this sample was comprised of 74 percent sand and 26 percent silt, with an estimated bulk density of 106 pcf (1.7 g/cm^3). These parameters were run through the Rosetta model to develop the characteristic unsaturated moisture content/matric potential/hydraulic conductivity curves shown on Figure C-2.

- **Dense Glacial Till.** Surficial soils at the embankment site are underlain at relatively shallow depth (5 to 20 feet) by glacially overridden advance outwash and glacial till soils, generally consisting of silty sand and sandy silt. For the HELP runs, the "glacial till" was represented using a default soil type available within the HELP program (Material 24 - a sand-silt-clay loam mixture with a saturated hydraulic conductivity of 2.7×10^{-6} cm/sec.). This material is considered representative of the conductivity expected for glacial tills and silty advance deposits of the type observed at the embankment site. The moisture/conductivity characteristic curves for this soil generated within SoilCover, using field capacity and wilting point data from HELP, are shown on Figure C-3.

Fill Materials

Four generalized soil groups are proposed for the Third Runway embankment construction, with Group 1 soils split into two subgroups (see Hart Crowser, 2000):

- **Group 1A.** This is a free-draining sand and gravel with less than 5 percent fines (i.e., passing the US No. 200 sieve) conforming to the grain size envelope presented on Figure C-4. Group 1A soils are required to be used for the embankment drainage layer.

- **Group 1B.** This is a sand and gravel with less than 8 percent fines conforming to the grain size envelope presented on Figure C-5.

  Soils from Groups 1A and 1B will be used as select fill in the reinforced zone for the West MSE wall, may be used in the reinforced zone for the South MSE and NSA walls, and as wet weather fill for the embankment.

- **Group 2.** This is a sand and gravel with up to 12 percent fines conforming to the grain size envelope presented on Figure C-6. Group 2 soils may be used in the reinforced zones for the NSA and South MSE walls, and will be used as common embankment fill except during wet weather.

- **Group 3.** This is a silt, sand, and gravel with up to 35 percent fines conforming to the grain size envelope presented on Figure C-7. Group 3 soils are intended for use as common embankment fill, except during wet weather.

- **Group 4.** This is a clay, silt, sand, and gravel with up to 50 percent fines conforming to the grain size envelope presented on Figure C-8. Group 4 soils may be used as common embankment fill, except during wet weather.

For each of these soil groups, a median grain size distribution was selected to be representative of the respective group (as shown on the figures listed above). This median grain size distribution was extrapolated into the fines region and used to define the proportions of gravel, sand, silt, and clay for each soil group. These proportions are listed in Table C-1. The Rosetta model was then used to generate the unsaturated moisture content/matric potential/hydraulic conductivity characteristic curves for each representative median soil type. Curves for soil Groups 1B, 3, and 4 are shown on Figures C-9 through C-11.

The soils proposed as fill material for the Third Runway embankment have significant percentages of gravel (up to 80 percent in Group 1A), which is ignored in the inputs to the Rosetta program. Rosetta deals only with the sand-silt-clay fractions, so the percentages listed in Table 1 were normalized to discount the presence of gravel before being input to Rosetta. As a result, the Rosetta model tends to slightly underpredict the unsaturated hydraulic parameters to a degree that is proportional to the gravel content.

A method was devised to account for the effect of gravel content on the hydraulic properties calculated by the Rosetta model. The parameter that can be manipulated in Rosetta without affecting the grain size distribution of the soil is the bulk density. A correction factor for the percentage of gravel contained in the soil was therefore applied to the saturated hydraulic conductivity value calculated initially by Rosetta, after the method of Brakensiek et al. (1974). This correction factor was determined by:

Correction Factor = 1 + (% gravel) / 100

As needed, the bulk density value for each soil group was then reduced to below limiting value of 2.0 g/cm³ and Rosetta was rerun to produce a new parameter set with a saturated hydraulic conductivity equal to the corrected value. The reduction in bulk density represents in part the reduced degree of compaction achieved among the sand-silt-clay fraction in soils with increasing gravel content.

Note that hydraulic conductivity of the glacial till was not analyzed with the Rosetta model because we used a default conductivity value from the HELP model for the till. This is acceptable because the unsaturated hydraulic properties of the glacial till would not be affected by the presence of the embankment. The Rosetta model was used for the embankment fill materials and the native surficial soil (outwash) so that the HELP model output would accurately represent conditions following embankment construction.

Weather Data

Precipitation, temperature, humidity, and solar radiation are the main atmospheric drivers controlling the surficial soil moisture. Data collected at SeaTac for the most recent 11 years (1987 through 1997) and published by NCDC (1998 and 1999) were used to the extent possible. Data are incomplete for the years 1998 and 1999; however, the total precipitation in those years was similar to 1995 and 1991, respectively. We therefore reused data from 1995 and 1991 to extend the data record to the end of 1999.

Simulations

The HELP model was used to simulate infiltration and seepage under existing conditions at the site of the proposed embankment, and to study changes in infiltration and seepage that will occur following construction of the embankment. HELP works by routing the products of precipitation, apportioning them between runoff, evapotranspiration, and percolation. In the model, precipitation is applied as inches of rainfall and is thus independent of the surface area under consideration. To maintain consistency in the model, all other fluxes are measured in inches of water per unit time.

Existing Conditions (Baseline)

The infiltration and seepage analysis was applied to existing subgrade soils in the embankment area to establish a baseline for post-construction comparisons. Natural vegetation conditions at the embankment site were approximated in HELP with a leaf area index (of 4.5 for Western Washington forested lands) and an evaporative zone depth of 20 inches. Net infiltration from the surface water balance currently sustains the shallow groundwater table typically found in the outwash sands and silts, perched on the underlying till layer, as noted in observation wells.

Existing hydrogeologic conditions in the proposed embankment area are characterized as follows:

- Moderately sloping ground surface, dropping down from the airfield elevation (~400 feet) to the toe of the west slope of the proposed embankment (between 280 and 320 feet elevation).
- Vegetation cover is generally deciduous forest with a moderate understory
- Shallow soils are typically outwash sands and silts, 5 to 20 feet thick, overlying dense glacial till that is 5 to 15 feet thick

The following soil profile was simulated in HELP:

- **Layer 1.** 5 feet of outwash sand and silt - vertical percolation layer;
- **Layer 2.** 10 feet of outwash sand and silt - lateral drainage layer that transmits base flow in the existing condition; and
- **Layer 3.** 5 feet of glacial till - generally an aquitard or barrier soil layer with only limited ability to transmit deeper percolation vertically.

The model was configured to allow ponding and lateral flow of water in Layer 2, as representative of the perched groundwater conditions observed overlying the glacial till. In calibration runs, the hydraulic conductivity of the glacial till had to be reduced to 5×10^{-7} cm/sec to develop the typical range in saturated thickness (listed in Table C-2 as Head on top of Layer 3) that was comparable to field observations in monitoring wells (i.e., 1 to 10 feet).

Constructed Conditions

The infiltration and seepage analysis was also applied to anticipated soil conditions to assess changes that would occur as a result of embankment construction. The following generalized soil profile was simulated in HELP:

- **Layer 1.** 100 feet of embankment fill - vertical percolation layer;

- **Layer 2.** 3 feet of sand and gravel - lateral drainage layer;
- **Layer 3.** 5 feet of outwash sand and silt - native surficial soil layer that might act as a nominal barrier layer, depending on its conductivity relative to the overlying embankment soils;
- **Layer 4.** 10 feet of outwash sand and silt - existing soils that act as a lateral drainage layer (transmitting base flow to Miller Creek); and
- **Layer 5.** 5 feet of glacial till - existing barrier soil layer.

Three different types of embankment fill material were simulated, representing median conditions and probable extremes in terms of grain size distribution for the bulk of the fill material:

- Group 1B represents the coarsest material likely to be used within the main body of the embankment;
- Group 3 represents the median soil type that may be expected to predominate in embankment construction (based on 1998 (Phase I) and 1999 (Phase II) construction records); and
- Group 4 represents the finest gradation material likely to be used within the embankment.

A long-term vegetated surface condition was modeled for each soil group with a leaf area index of 2.0 (representing a fair stand of grass) with an evaporative zone depth of 20 inches.

Layer 2 immediately beneath the fill represents the drainage layer, comprised of Group 1A material.

The lower layers (3, 4, and 5) in the post-construction model represent the same soils as in the existing conditions (see previous section). A limitation of the HELP model requires that a barrier soil layer must underlie any lateral drainage layer. This does not affect the soil properties, except that HELP considers a barrier soil to be permanently at 100 percent saturation.

We elected not to model the Group 2 soil material because it is very similar in grain size distribution to the Group 1B material, and because quantities used in embankment construction to date have been relatively minor.

Model Results

The models were used to simulate hydrologic conditions as they affect the existing water table beneath the embankment. Predicted model flux rates calculated in HELP are markedly affected by the initially assumed moisture content distribution in the unsaturated soil profile at the start of the simulations;

this effect lasted for between 1 and 3 years into the simulation period, depending on soil type. Our comparison of results, therefore, focuses on the last 10 years of the simulation period (1990 through 1999).

Existing Conditions

The lateral drainage rate from Layer 2 of the HELP model for the existing conditions is equated to groundwater base flow or discharge in the shallow water table aquifer. The predicted rate ranges between 3.8 and 20.0 inches per year as shown highlighted in Table C-2. This forms the baseline we used for comparison with possible changes that are predicted due to the placement of various embankment fill configurations in the constructed condition.

Embankment Conditions

The lateral drainage rate from Layer 4 of the HELP model for the constructed conditions is equated to groundwater base flow or discharge in the shallow water table aquifer beneath the embankment. The abbreviated annual output from HELP for each year of the simulation period is listed in Tables C-3, C-4, and C-5 for the respective embankment soil groups. The predicted discharge rates are highlighted in each table, ranging between 5.1 to 21.3 inches per year, and groundwater of 5.4 to 18.3 inches per year, for the different fill soils modeled.

Group 1B

The embankment profile composed of Group 1B material exhibits minimal runoff and slightly lower evapotranspiration than the other fill materials. The lower evapotranspiration is attributed to higher porosity and steeper soil moisture characteristic curves (see Figure C-9), which limit soil moisture utilization in the active near-surface soil zone. As a result, the amount of deep percolation remaining that can move downward through the embankment is higher than for the finer-grained Group 3 material.

Group 3

The embankment profile composed of Group 3 material exhibits a minor amount of runoff and slightly more evapotranspiration than for the Group 1B soil. As a result, the amount of deep percolation remaining that can move downward through the embankment is lower than for the coarser-grained Group 1B material.

Group 4

The embankment profile composed of Group 4 material exhibits substantial runoff and moderate to low evapotranspiration. Plant growth in Group 4 material is least able to extract moisture from the active surface layer because unit changes in matric suction yield the smallest volume of moisture, due to the relative flatness of the soil moisture characteristic curve (See Figure C-11). Taking into account the water lost as runoff, the amount of deep percolation remaining that can then move downward into the passive mass of the embankment is less than for the Group 3 material, but more than the Group 1B material.

For all fill soils, the seasonality of the groundwater recharge/flow component from the embankment (also called the hydroperiod) is strongly impacted, with reduced peaks and troughs that are shifted by 3 to 6 months relative to the existing conditions (see Figures C-12, C-13, and C-14). These changes reflect the delay and buffering effect created by time for percolation through and storage within the full thickness of the embankment.

Conclusions

The results of the model show groundwater base flow rates for existing and post-construction conditions, indicating substantial differences on a month-by-month basis, but the overall long-term average amounts are generally very similar. The differences are the seasonal lag which produces a net benefit of more base flow to Miller Creek in the summer and early fall. The overall long-term similarity is best illustrated by cumulative plots of groundwater discharge for each fill type for a 10-year simulation period, as plotted on Figure C-15.

Implications for Underlying Water Table Conditions

Close examination of the cumulative plots (Figure C-15) indicates the groundwater flowrates beneath the proposed embankment will generally be similar to existing conditions but that slight differences are predicted depending on whether annual precipitation is more or less on average, as discussed below.

Years with More than Average Precipitation (Wet Years)

Groundwater flowrates beneath the proposed embankment will generally be similar to or slightly lower than for existing conditions during wet years (1990; 1995-99). This implies that groundwater water levels beneath the toe of the embankment would be similar to or slightly lower than those observed in monitored wells over the past 12+ months (a relatively wet period in the precipitation record).

Years with Less than Average Precipitation (Dry Years)

The cumulative plots indicate that groundwater flowrates beneath the embankment would show a relative increase over existing conditions during dry years (1991-94). While this would result in higher water levels compared to existing conditions (i.e., a wet year), it should be noted that the absolute water levels during dry years would be lower than the levels recently observed in monitored wells over the past 12+ months.

It is, therefore, concluded that groundwater levels beneath the constructed embankment should become no higher than the peak levels observed over the last 12 moths or so, which means no increase in the area(s) susceptible to liquefaction is anticipated. Similarly, the effect of the embankment on hydraulic lag in precipitation becoming base flow will be most pronounced in dry years, when the increased water is most beneficial to the environment.

Effect of Different Fill Materials

Although the grain size and consequently the saturated hydraulic conductivity of the fill materials vary widely, there is a much narrower envelope of variation bounding their respective hydrologic behaviors under constructed conditions in the embankment.

Group 1B materials allow more recharge than would occur under existing conditions, but it is unlikely that a large portion of the embankment would be constructed of Group 1B materials.

Group 3 materials allow approximately the same recharge than would occur under existing conditions, and this is likely the most representative of the bulk materials that will be used in the embankment.

Group 4 materials result in less recharge than would occur under existing conditions, but use of Group 4 fill will not be allowed in wet weather conditions (i.e., when the less silty Group 1A or 1B materials must be used), which will limit the overall quantities of Group 4 soils that will be placed.

The reasons for the broad similarity in recharge response (compare Figures C-12 through C-14) relates to the mechanisms of unsaturated flow by which infiltrated water percolates through the embankment.

Deep percolation in the embankment is driven by the net flux leaving the surficial soil layer once the processes of runoff, evaporation, infiltration, and transpiration have been satisfied. This net flux is relatively insensitive to soil type, as long as the infiltration capacity is not too low. The net surface flux that moves downward into the body of the embankment causes the moisture content of the fill material to adjust under the physical constraints of unsaturated flow. This requires that the unsaturated hydraulic conductivity of the soil mass be approximately equal to the net surface flux. The moisture content and matric potential of the soil mass thus adjust in concert with the hydraulic conductivity, as governed by the soil characteristic functions (Figures C-9 through C-11). The result is differing soil moisture and matric suction distributions for the three soil types studied, but very similar unsaturated hydraulic conductivities, because the net flux rates are essentially similar.

This balance should not be significantly affected by layering of different fill materials as the embankment is constructed, as long as each layer is capable of passing the net flux entering from above. The limiting value for the saturated hydraulic conductivity of any discrete layer within the embankment should be no less than the net flux rate for deep percolation in the embankment. This rate is estimated using Soil Cover to be around 4.6×10^{-6} cm/sec, which is well below the value expected for any of the proposed embankment soils. In the event less permeable soils do become part of the fill (for instance, due to variability within an approved fill material source), the result would be creation of a local perched zone of limited extent within the embankment, with no loss in overall infiltration capacity. The frequent gradation checks accomplished as part of the embankment construction process prevent such an effect from extending over any significant area.

Effect of Different Fill Thicknesses

The simulation results presented above were for a nominal 100-foot-thick embankment fill. In reality, the embankment thickness will vary from zero to 160 feet. We made some additional runs of the HELP model using rainfall records for the year 1997, with Group 3 material in fill thickness of 150, 100, 60, 30, and 15 feet to see if there was a trend in seepage behavior, or a point at which the seepage behavior changed significantly.

Flux rates in the simulations of different fill thickness showed little variation (on the order of 2 to 5 percent) from the nominal 100-foot base case (see Table C-6). The results show a trend of increasing groundwater recharge rates with decreasing fill thickness, down to thicknesses of about 30 feet. Reduced thicknesses of fill in general, have less moisture storage capacity and so yield less water during a period of declining precipitation.

References for Appendix C

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Table C-1 - Soil Properties Used for Developing Input to Rosetta Model

	Size Fractions in %					
Material	Gravel	Sand	Silt	Clay	Bulk Density in gm/cm^3	Gravel Correction Factor
Group 1A	74	22	3	1	1.77	1.74
Group 1B	69	26	4	1	1.81	1.69
Group 2	62	31	5	2	1.85	1.62
Group 3	35	57	6	2	1.9	1.35
Group 4	37	38	20	5	1.91	1.37
Outwash	8	68	24	0	1.7	1.08

Notes: Bulk density value is based on the relative compaction of the sand - silt - clay fraction, adjusted by using the Gravel Correction Factor after Brakensiek et al. (1974), (see text).

497806/infiltrationtables - Table 1

Table C-2 - HELP Output Summary for Existing Conditions (Baseline)

	1987 INCHES	1988 INCHES	1989 INCHES	1990 INCHES	1991 INCHES	1992 INCHES	1993 INCHES	1994 INCHES	1995 INCHES	1996 INCHES	1997 INCHES	1998 INCHES	1999 INCHES
PRECIPITATION	29.9	33.0	34.7	44.8	35.4	32.8	28.8	34.8	42.6	50.3	43.3	44.8	42.6
RUNOFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EVAPOTRANSPIRATION	14.3	18.4	16.5	17.8	16.2	17.1	19.5	15.8	18.1	16.8	21.1	17.9	17.8
DRAINAGE COLLECTED FROM LAYER 2	34.0	7.6	9.7	13.3	16.0	8.0	5.6	3.8	13.1	19.8	20.0	13.7	14.1
PERC./LEAKAGE THROUGH LAYER 3	13.6	7.9	8.3	9.1	9.7	8.0	6.8	6.6	9.1	10.5	10.5	9.2	9.3
AVG. HEAD ON TOP OF LAYER 3	71.6	16.0	20.4	28.0	33.5	16.9	11.8	8.0	27.6	41.5	42.0	28.9	29.6
CHANGE IN WATER STORAGE	-31.9	-1.0	0.2	4.6	-6.4	-0.3	-3.1	8.6	2.3	3.2	-8.4	4.0	1.4
SOIL WATER AT START OF YEAR	86.7	54.8	53.8	54.0	58.6	52.2	51.9	48.9	57.5	59.8	63.0	54.7	58.6
SOIL WATER AT END OF YEAR	54.8	53.8	54.0	58.6	52.2	51.9	48.9	57.5	59.8	63.0	54.7	58.6	60.0
SNOW WATER AT START OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SNOW WATER AT END OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL WATER BUDGET BALANCE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Highlight = Contribution of precipitation that becomes groundwater base flow. Note first 3 years of model results reflect "initial saturation" and are not representative of long-term conditions.

497806/infiltrationtables.xls - Table 2

Table C-3 - HELP Output Summary for Group 1B Embankment Fill

	1987 INCHES	1988 INCHES	1989 INCHES	1990 INCHES	1991 INCHES	1992 INCHES	1993 INCHES	1994 INCHES	1995 INCHES	1996 INCHES	1997 INCHES	1998 INCHES	1999 INCHES
PRECIPITATION	29.9	33.0	34.7	44.8	35.4	32.8	28.8	34.8	42.6	50.3	43.3	44.8	42.6
RUNOFF	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0
EVAPOTRANSPIRATION	12.7	16.4	14.5	15.7	14.5	14.5	18.0	13.0	16.5	14.4	18.5	16.4	16.1
DRAINAGE COLLECTED FROM LAYER 2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PERC./LEAKAGE THROUGH LAYER 3	124.3	16.6	18.3	23.7	28.2	18.3	16.7	11.6	22.1	32.3	32.2	25.4	24.6
AVG. HEAD ON TOP OF LAYER 3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE COLLECTED FROM LAYER 4	57.3	54.6	20.4	14.5	17.4	12.4	8.7	5.1	11.2	19.0	21.3	17.1	15.6
PERC./LEAKAGE THROUGH LAYER 5	18.6	18.0	10.6	9.4	10.0	8.9	8.1	7.3	8.6	10.3	10.8	9.9	9.6
AVG. HEAD ON TOP OF LAYER 5	119.9	114.0	42.9	30.4	36.4	25.9	18.3	10.7	23.4	39.6	44.5	35.8	32.7
CHANGE IN WATER STORAGE	-58.8	-56.1	-10.8	4.9	-6.7	-3.1	-6.0	9.4	6.3	6.4	-7.3	1.1	1.3
SOIL WATER AT START OF YEAR	416.7	357.9	301.8	290.9	295.9	289.2	286.1	280.1	289.5	295.8	302.2	294.9	296.0
SOIL WATER AT END OF YEAR	357.9	301.8	290.9	295.9	289.2	286.1	280.1	289.5	295.8	302.2	294.9	296.0	297.3
SNOW WATER AT START OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SNOW WATER AT END OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL WATER BUDGET BALANCE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Fill Height = 98 ft
Runoff Curve Number = 49

Highlight = Contribution of precipitation that becomes groundwater base flow. Note first 3 years of model results reflect "initial saturation" and are not representative of long-term conditions.

Table C-4 - HELP Output Summary for Group 3 Embankment Fill

	1987 INCHES	1988 INCHES	1989 INCHES	1990 INCHES	1991 INCHES	1992 INCHES	1993 INCHES	1994 INCHES	1995 INCHES	1996 INCHES	1997 INCHES	1998 INCHES	1999 INCHES
PRECIPITATION	29.9	33.0	34.7	44.8	35.4	32.8	28.8	34.8	42.6	50.3	43.3	44.8	42.6
RUNOFF	0.1	0.0	0.0	1.0	0.5	0.0	0.0	0.0	0.1	0.6	0.1	1.0	0.1
EVAPOTRANSPIRATION	13.3	17.2	15.8	16.8	15.5	16.1	18.8	14.8	17.4	15.5	20.0	17.1	17.2
DRAINAGE COLLECTED FROM LAYER 2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PERC./LEAKAGE THROUGH LAYER 3	137.1	19.6	17.7	21.0	26.7	19.1	15.8	11.5	17.9	28.7	30.2	24.6	23.8
AVG. HEAD ON TOP OF LAYER 3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE COLLECTED FROM LAYER 4	57.3	57.5	29.2	14.2	15.0	12.7	8.4	5.4	8.5	15.7	19.4	16.6	14.8
PERC./LEAKAGE THROUGH LAYER 5	18.6	18.7	12.5	9.3	9.4	9.0	8.0	7.4	8.1	9.6	10.4	9.8	9.4
AVG. HEAD ON TOP OF LAYER 5	119.9	120.0	61.2	29.7	31.2	26.6	17.5	11.3	17.8	32.7	40.6	34.7	30.9
CHANGE IN WATER STORAGE	-59.4	-60.4	-22.9	3.5	-5.0	-5.1	-6.4	7.2	8.5	8.9	-6.7	0.3	1.1
SOIL WATER AT START OF YEAR	393.3	333.9	273.4	250.6	254.1	249.1	244.1	237.7	244.9	253.3	262.2	255.6	255.8
SOIL WATER AT END OF YEAR	333.9	273.4	250.6	254.1	249.1	244.1	237.7	244.9	253.3	262.2	255.6	255.8	257.0
SNOW WATER AT START OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SNOW WATER AT END OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL WATER BUDGET BALANCE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Fill Height = 98 ft
Runoff Curve Number = 69

Highlight = Contribution of precipitation that becomes groundwater base flow. Note first 3 years of model results reflect "initial saturation" and are not representative of long-term conditions.

Table C-5 - HELP Output Summary for Group 4 Embankment Fill

	1987 INCHES	1988 INCHES	1989 INCHES	1990 INCHES	1991 INCHES	1992 INCHES	1993 INCHES	1994 INCHES	1995 INCHES	1996 INCHES	1997 INCHES	1998 INCHES	1999 INCHES
PRECIPITATION	29.9	33.0	34.7	44.8	35.4	32.8	28.8	34.8	42.6	50.3	43.3	44.8	42.6
RUNOFF	0.6	0.2	0.3	2.6	1.2	0.2	0.1	0.5	1.0	2.2	0.8	2.6	1.0
EVAPOTRANSPIRATION	13.4	17.5	15.8	17.2	15.6	15.9	18.5	14.6	17.4	15.9	20.5	17.4	17.3
DRAINAGE COLLECTED FROM LAYER 2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PERC./LEAKAGE THROUGH LAYER 3	87.4	18.2	17.3	20.7	24.6	18.2	15.9	11.5	17.5	27.9	28.9	23.5	21.9
AVG. HEAD ON TOP OF LAYER 3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE COLLECTED FROM LAYER 4	57.3	35.1	11.7	11.8	13.6	11.8	8.1	5.4	8.4	15.2	18.3	15.6	13.4
PERC./LEAKAGE THROUGH LAYER 5	18.6	13.8	8.8	8.8	9.2	8.8	8.0	7.4	8.0	9.5	10.2	9.6	9.1
AVG. HEAD ON TOP OF LAYER 5	119.9	73.4	24.6	24.7	28.4	24.7	17.0	11.3	17.5	31.6	38.3	32.6	28.1
CHANGE IN WATER STORAGE	-60.0	-33.6	-1.9	4.4	-4.1	-3.9	-5.9	7.0	7.8	7.6	-6.5	-0.4	1.7
SOIL WATER AT START OF YEAR	381.5	321.5	287.9	286.0	290.4	286.2	282.3	276.5	283.5	291.3	298.9	292.4	292.0
SOIL WATER AT END OF YEAR	321.5	287.9	286.0	290.4	286.2	282.3	276.5	283.5	291.3	298.9	292.4	292.0	293.8
SNOW WATER AT START OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SNOW WATER AT END OF YEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL WATER BUDGET BALANCE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Fill Height = 98 ft
Runoff Curve Number = 79

Highlight = Contribution of precipitation that becomes groundwater base flow. Note first 3 years of model results reflect "initial saturation" and are not representative of long-term conditions.

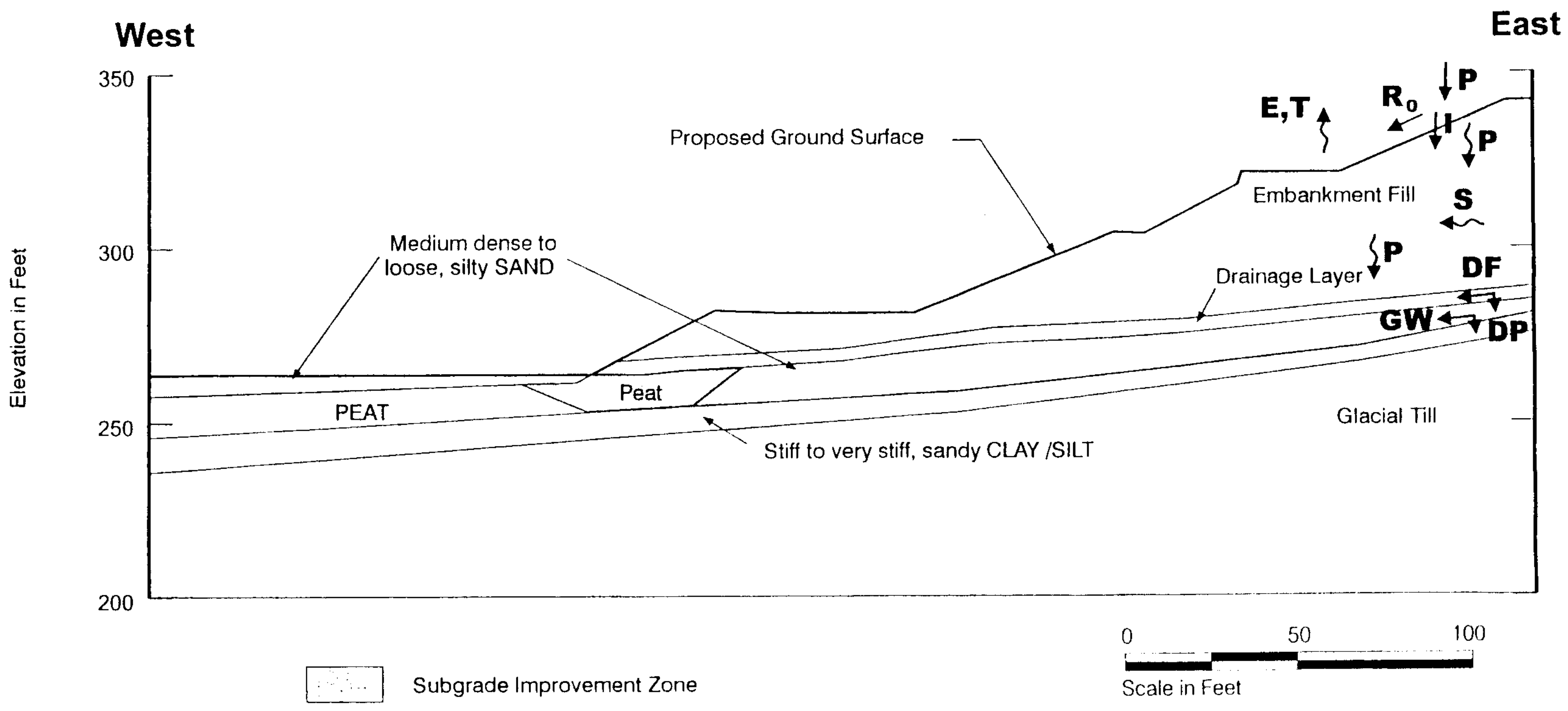
Table C-6 - HELP Output Summary for Various Embankment Heights

	Embankment Height in Feet				
	150	100	60	30	15
	Inches of H_2O				
PRECIPITATION	43.3	43.3	43.3	43.3	43.3
RUNOFF	0.0	0.0	0.0	0.0	0.0
EVAPOTRANSPIRATION	20.0	20.0	20.0	20.0	20.0
DRAINAGE COLLECTED FROM LAYER 2	0.0	0.0	0.0	0.0	0.0
PERC./LEAKAGE THROUGH LAYER 3	28.9	30.5	31.0	30.4	28.0
AVG. HEAD ON TOP OF LAYER 3	0.0	0.0	0.0	0.0	0.0
DRAINAGE COLLECTED FROM LAYER 4	17.9	19.6	20.6	21.0	20.9
PERC./LEAKAGE THROUGH LAYER 5	10.1	10.5	10.7	10.8	10.7
AVG. HEAD ON TOP OF LAYER 5	37.3	41.1	43.1	44.0	43.9
CHANGE IN WATER STORAGE	-4.7	-6.9	-8.1	-8.5	-8.4
SOIL WATER AT START OF YEAR	358.8	267.0	192.3	136.4	109.3
SOIL WATER AT END OF YEAR	354.1	260.1	184.2	127.9	100.9
SNOW WATER AT START OF YEAR	0.0	0.0	0.0	0.0	0.0
SNOW WATER AT END OF YEAR	0.0	0.0	0.0	0.0	0.0
ANNUAL WATER BUDGET BALANCE	0.0	0.0	0.0	0.0	0.0

Comparison is based on data for 1997.

497806/infiltrationtables.xls - Table 6

Embankment Slope Showing Water Balance Components
Shown for Section 101+20 (NSA Wall Stationing)



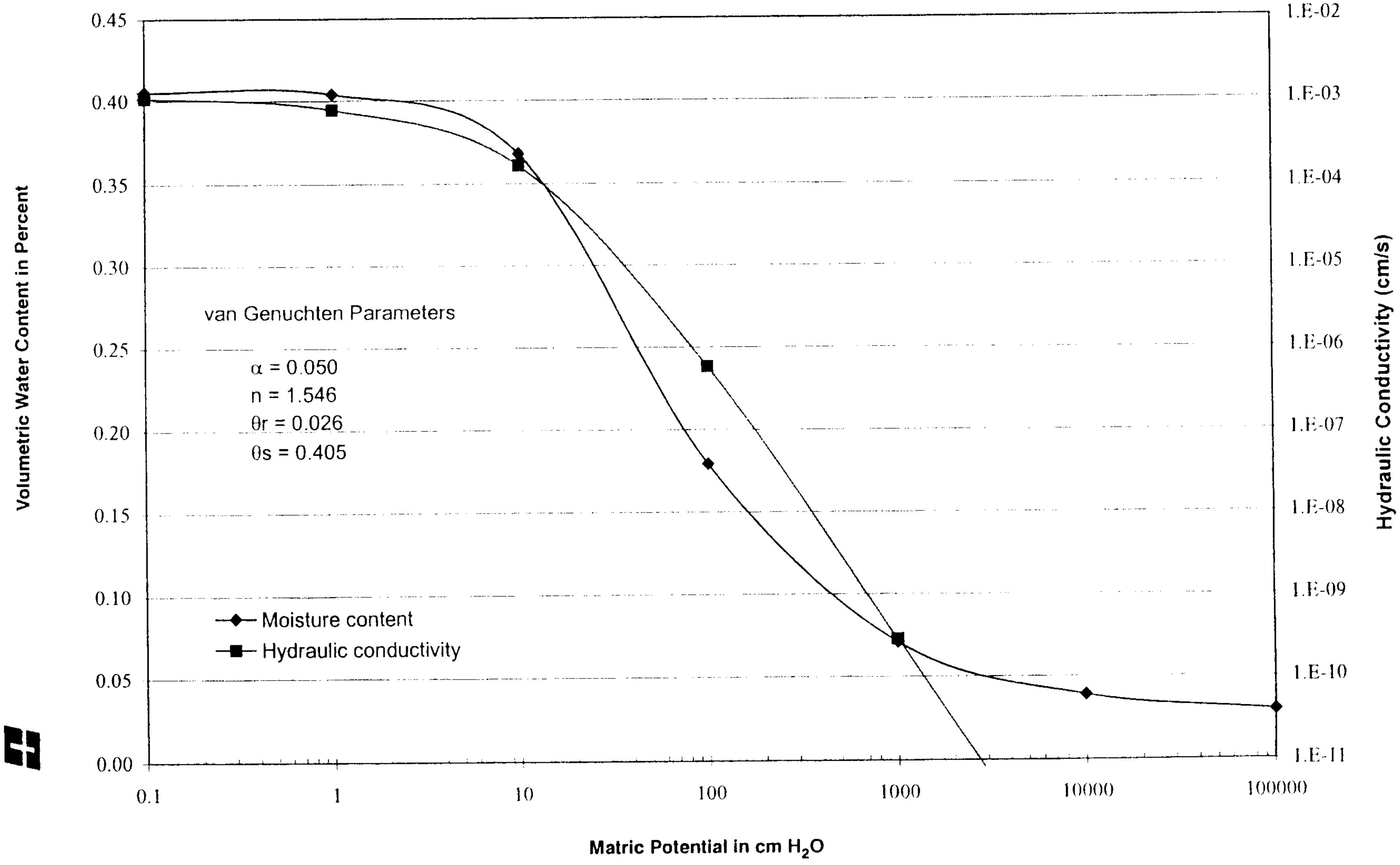
DJH 10/12/00 4978260.cdr

HARTCROWSER

J-4978-28 10/00

Figure C-1

Soil Moisture/Conductivity Characteristic Curves of Outwash Silty Sand



van Genuchten Parameters

$\alpha = 0.050$
$n = 1.546$
$\theta r = 0.026$
$\theta s = 0.405$

DJH 10/12/00 497828P.cdr

HARTCROWSER

J-4978-28 10/00
Figure C-2

Soil Moisture / Conductivity Characteristic Curves for Glacial Till

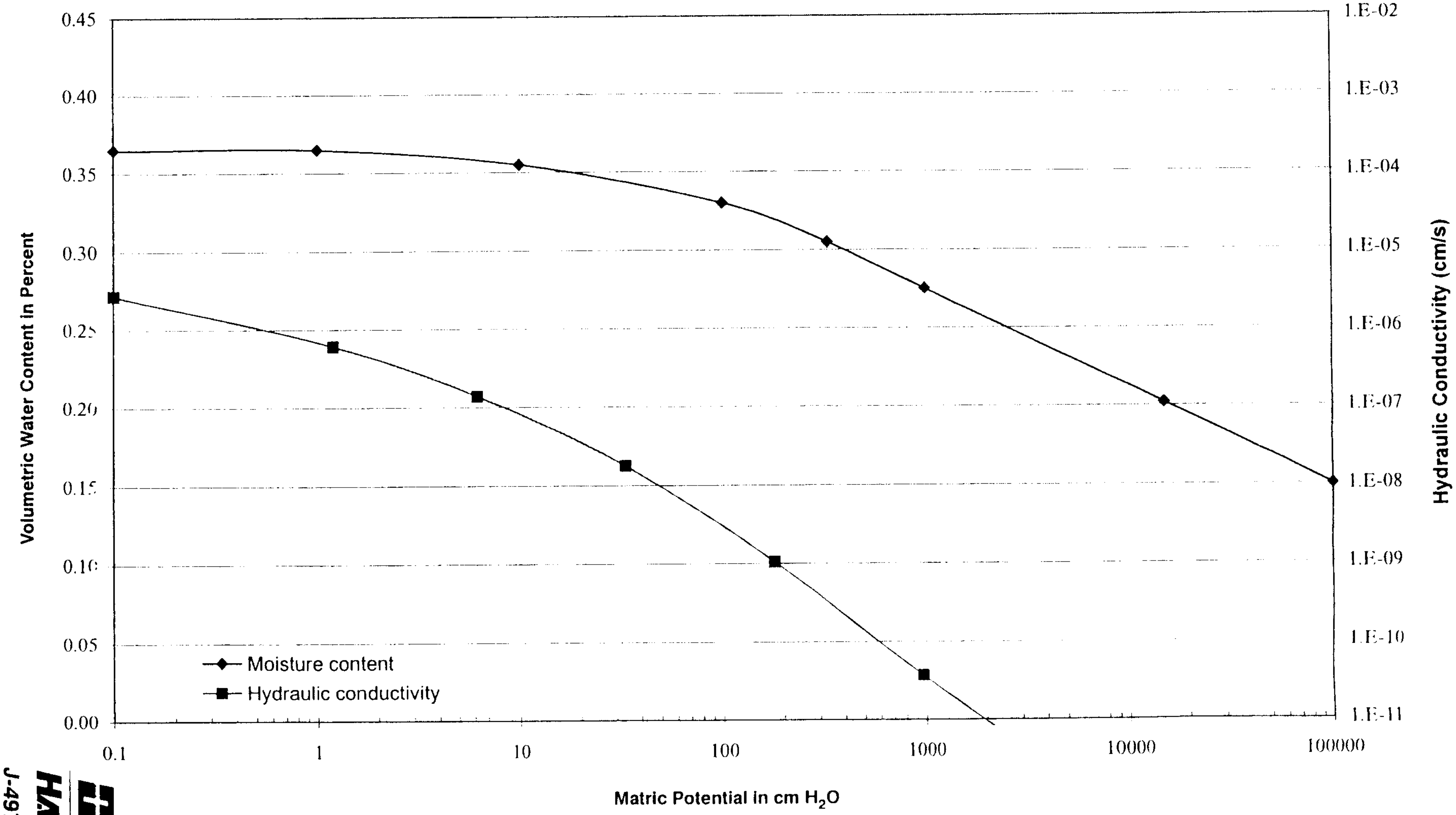


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Figure C-3

DJH 10/12/00 4978285.cdr

Grain Size Envelope for Group 1A Fill Material

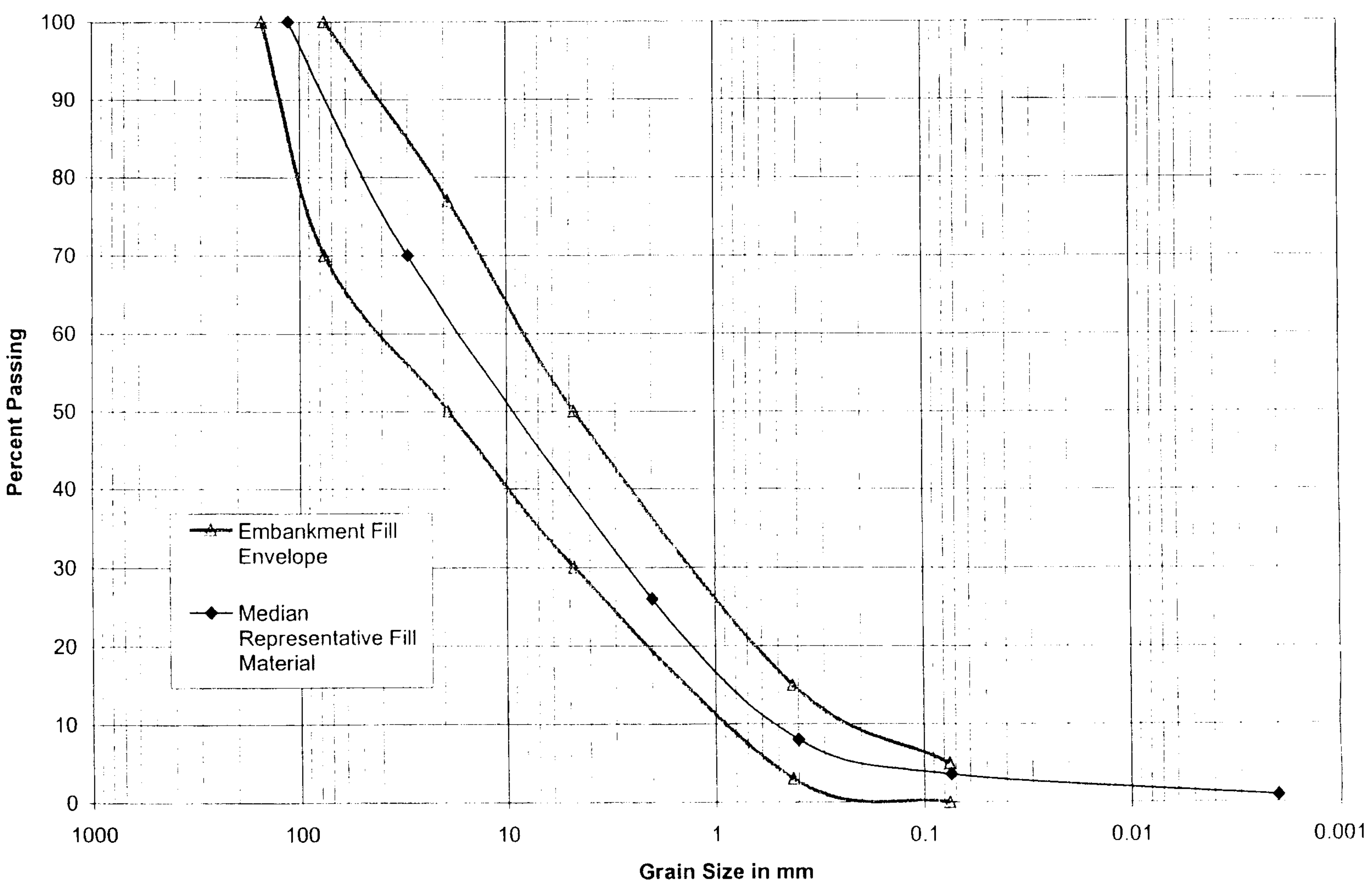

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Figure C-4

Grain Size Envelope for Group 1B Fill Material

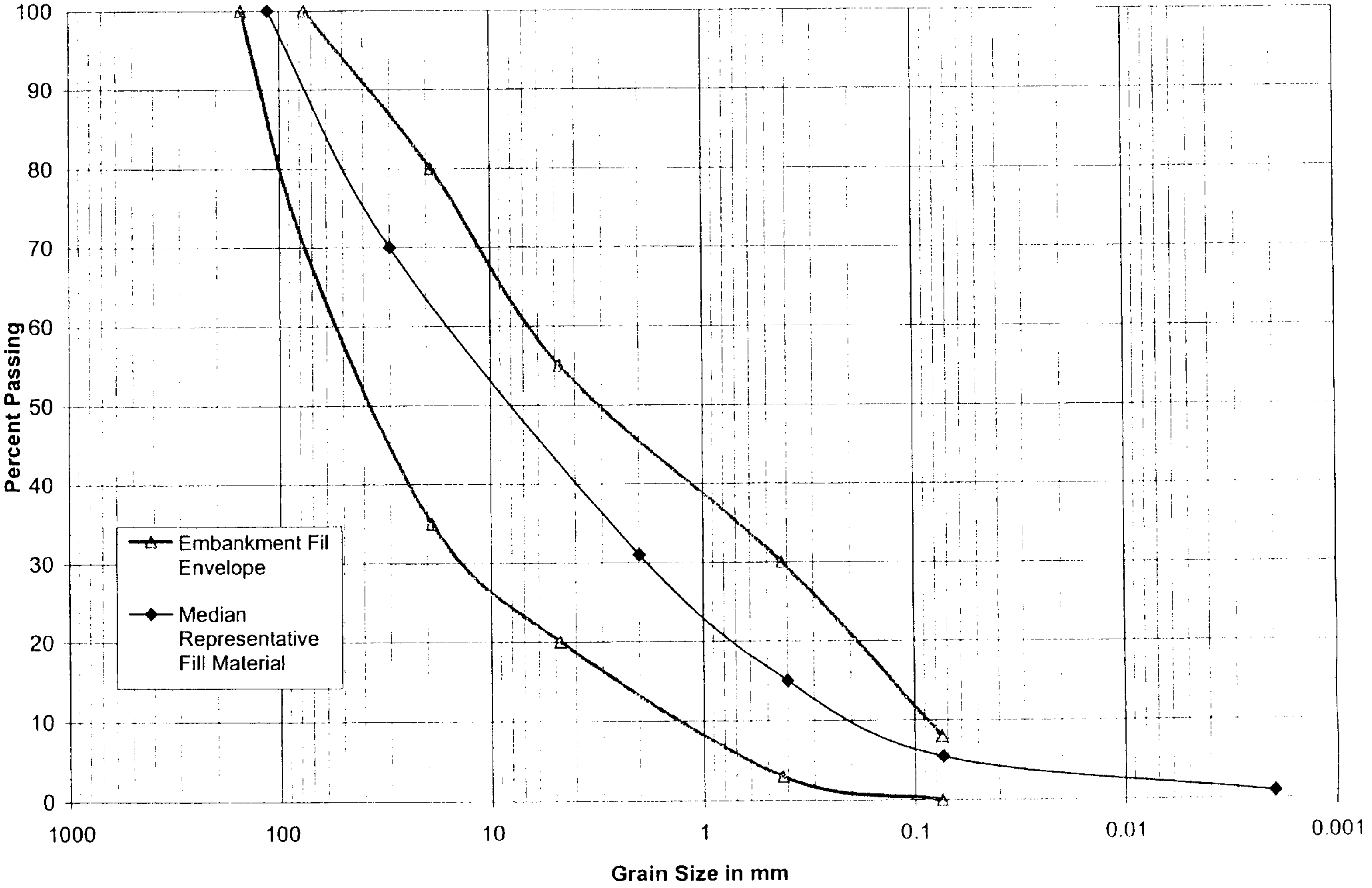

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Figure C-5

Grain Size Envelope for Group 2 Fill Material

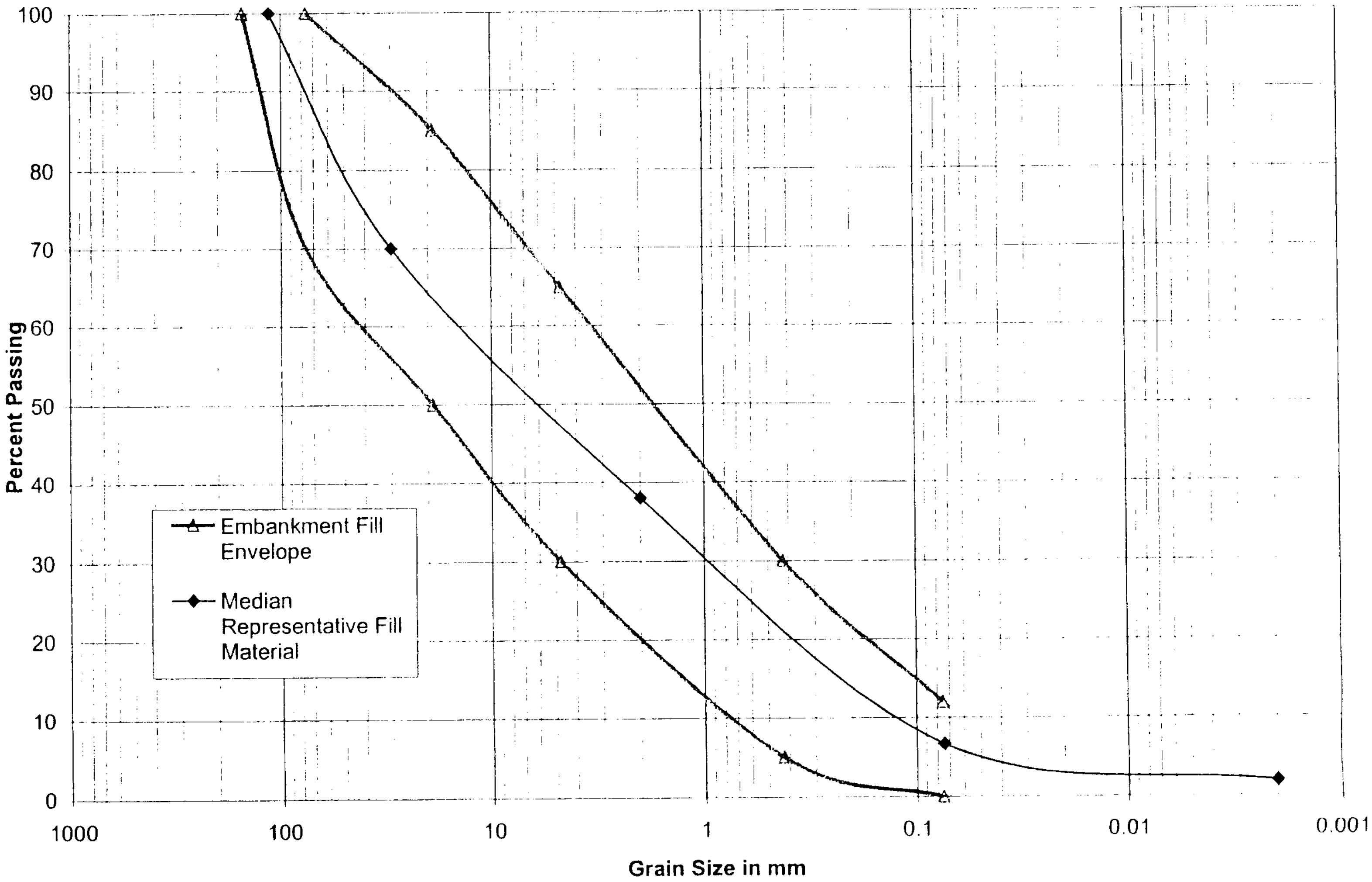

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Figure C-6

Grain Size Envelope for Group 3 Fill Material

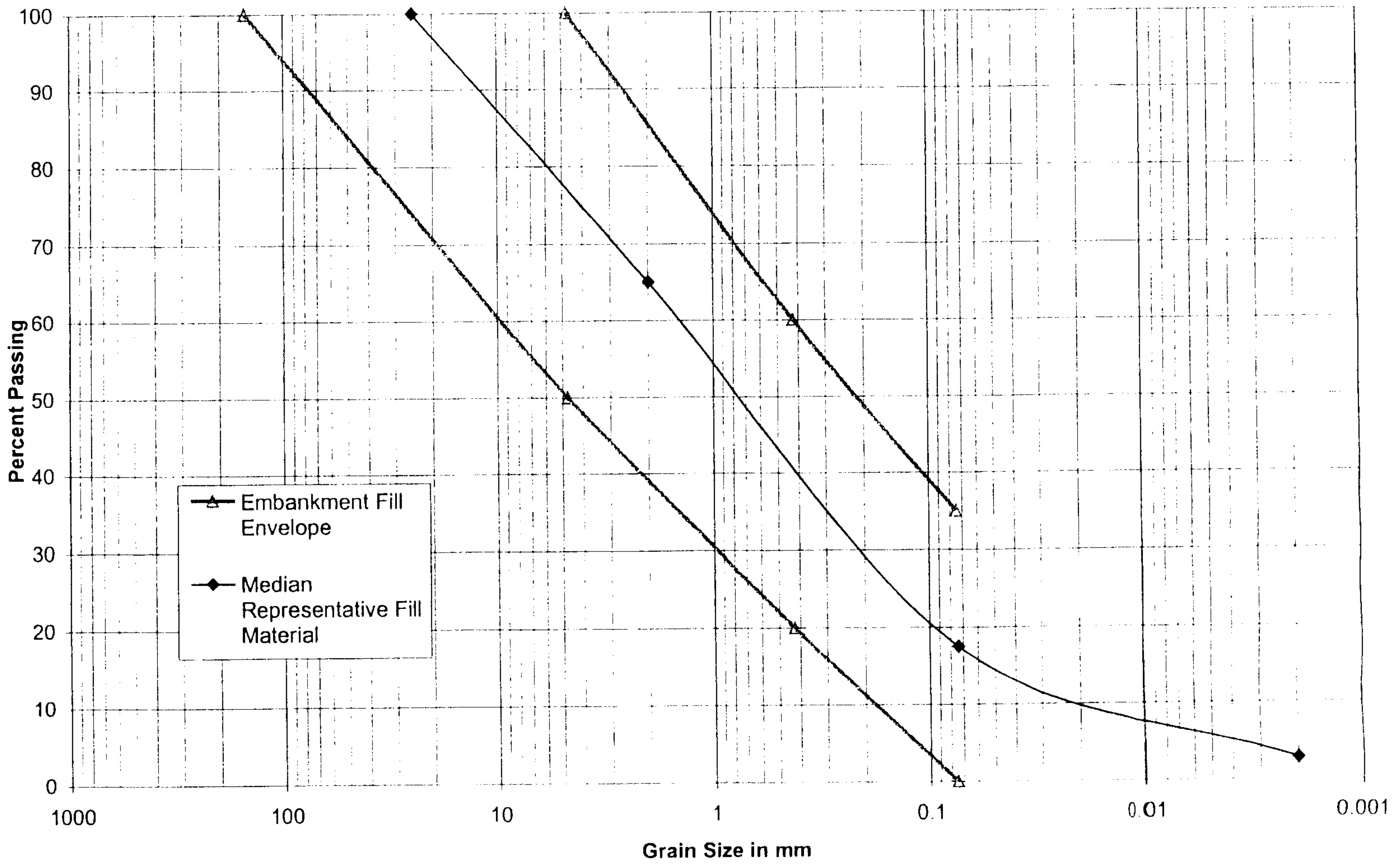

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Figure C-7

Grain Size Envelope for Group 4 Fill Material

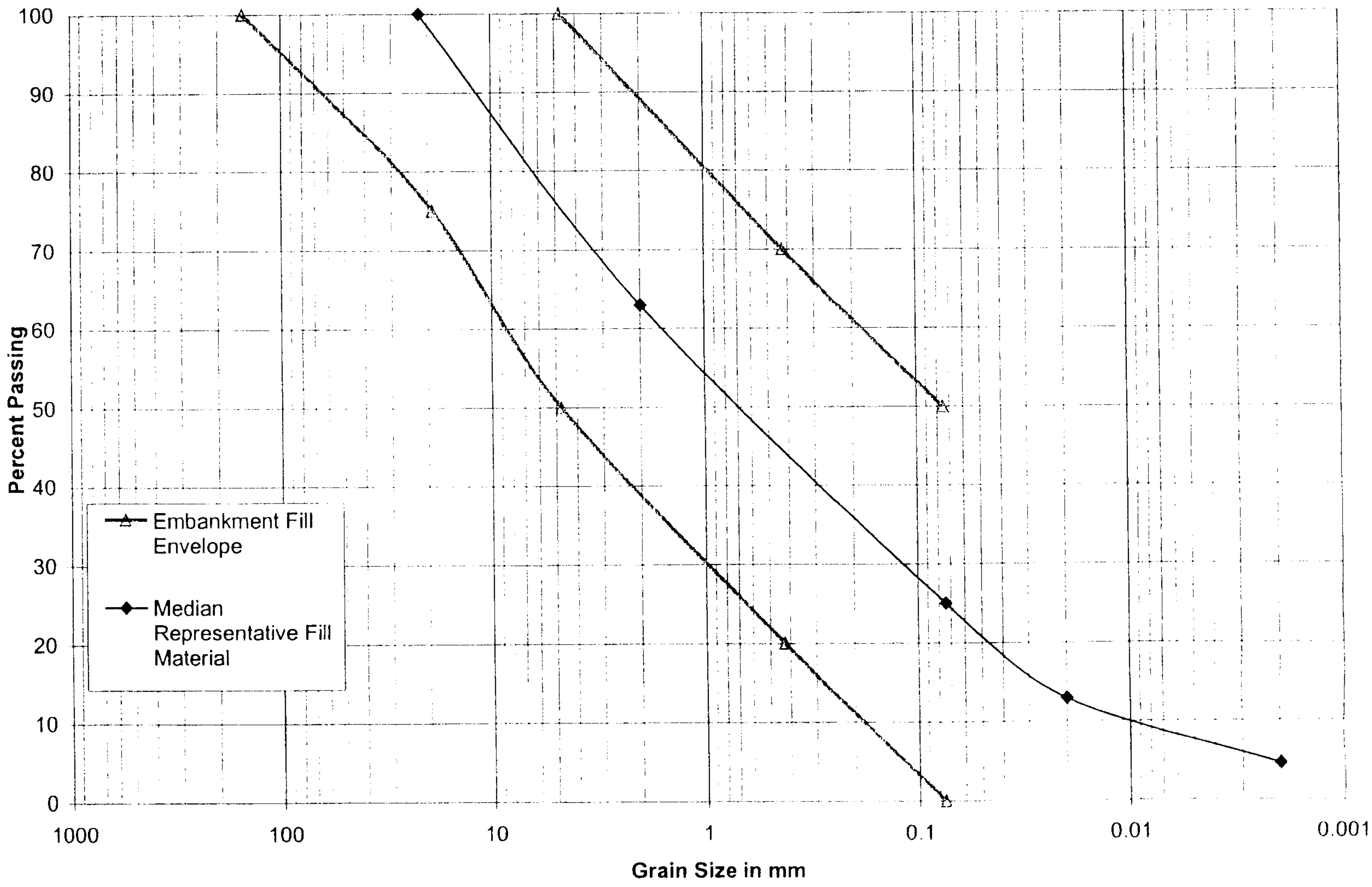

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Figure C-8

Soil Moisture/Conductivity Characteristic Curves for Group 1B Fill Material

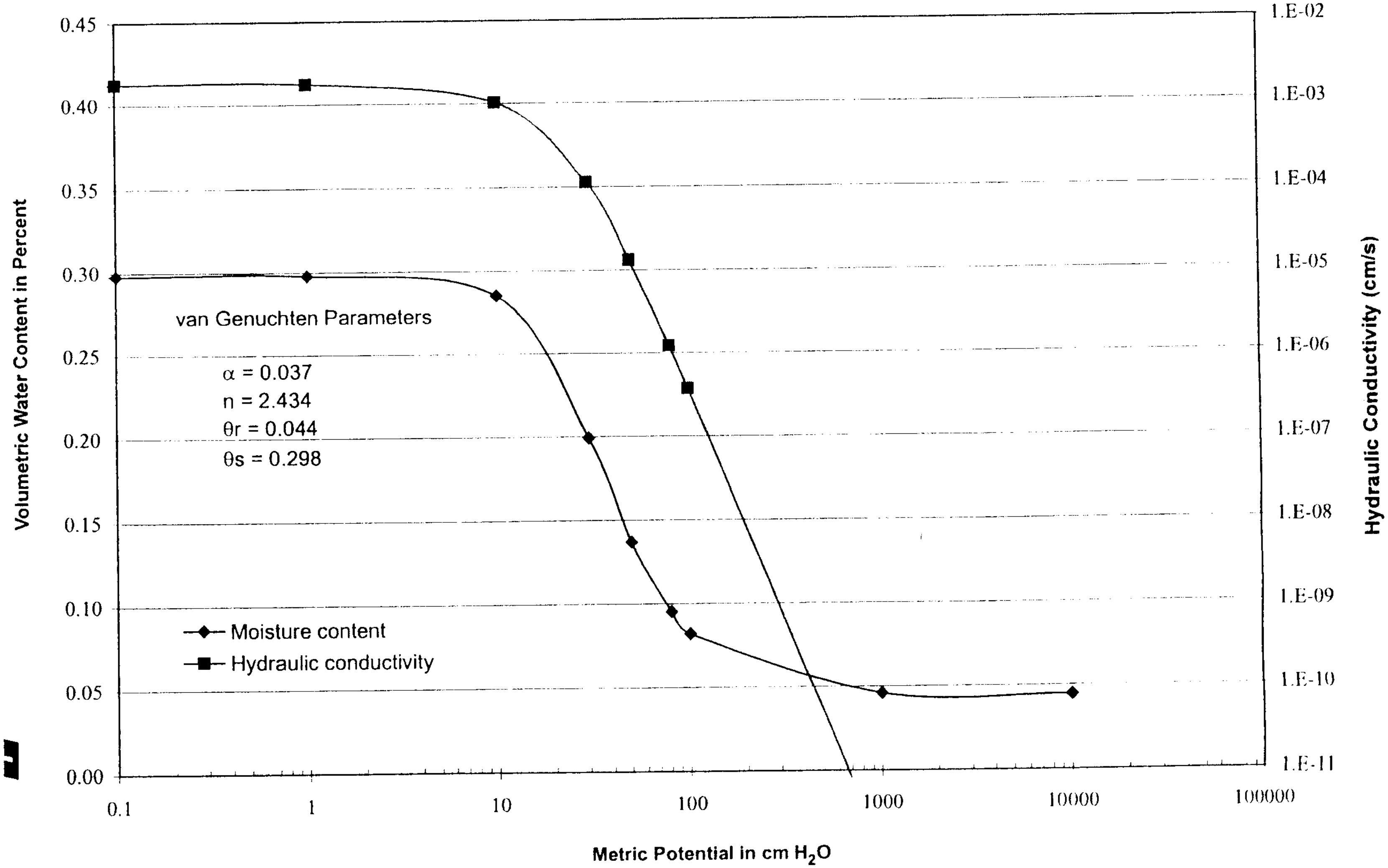

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Figure C-9

Soil Moisture/Conductivity Characteristic Curves for Group 3 Fill Material

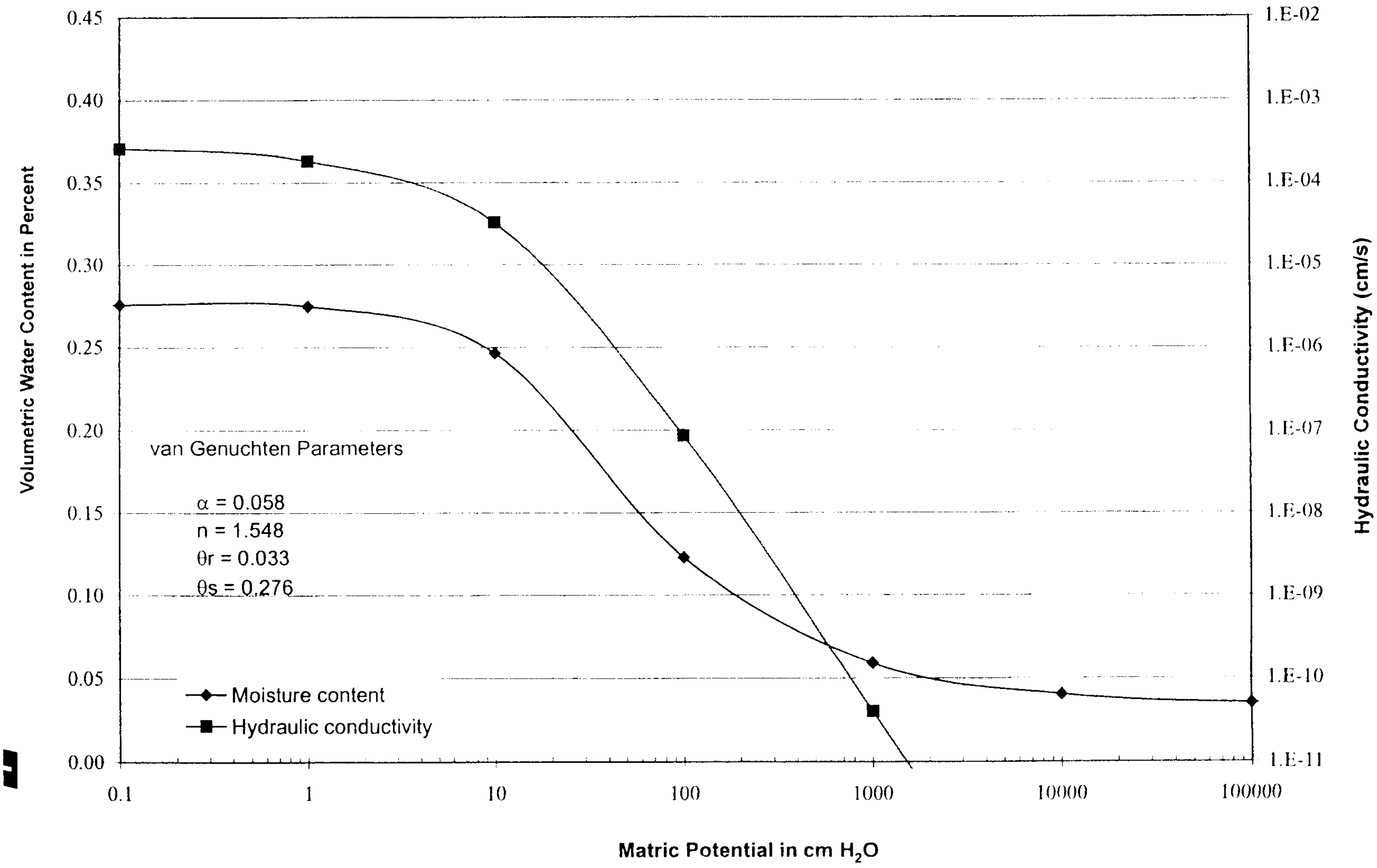

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Figure C-10

Soil Moisture/Conductivity Characteristic Curves for Group 4 Fill Material

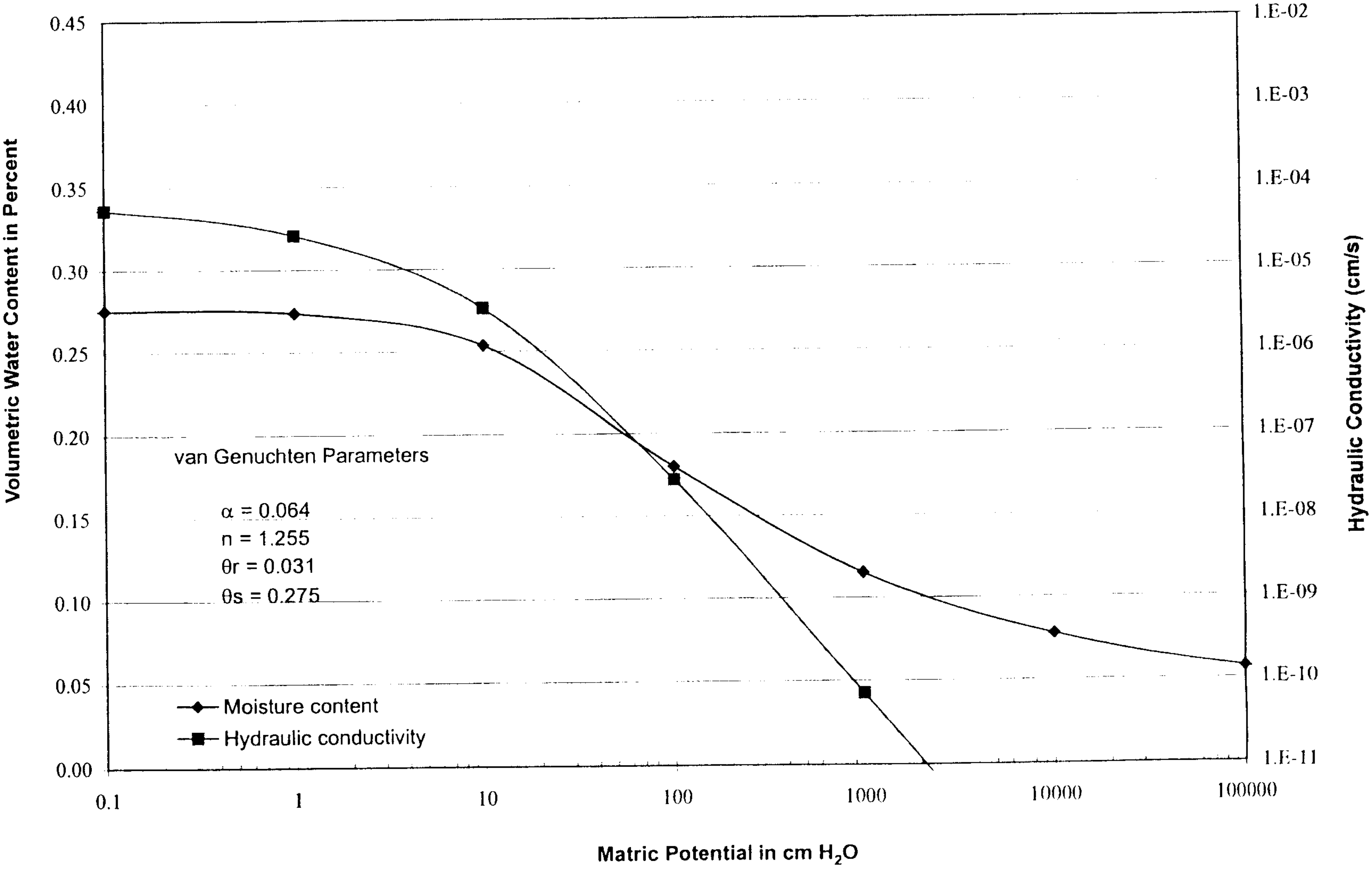

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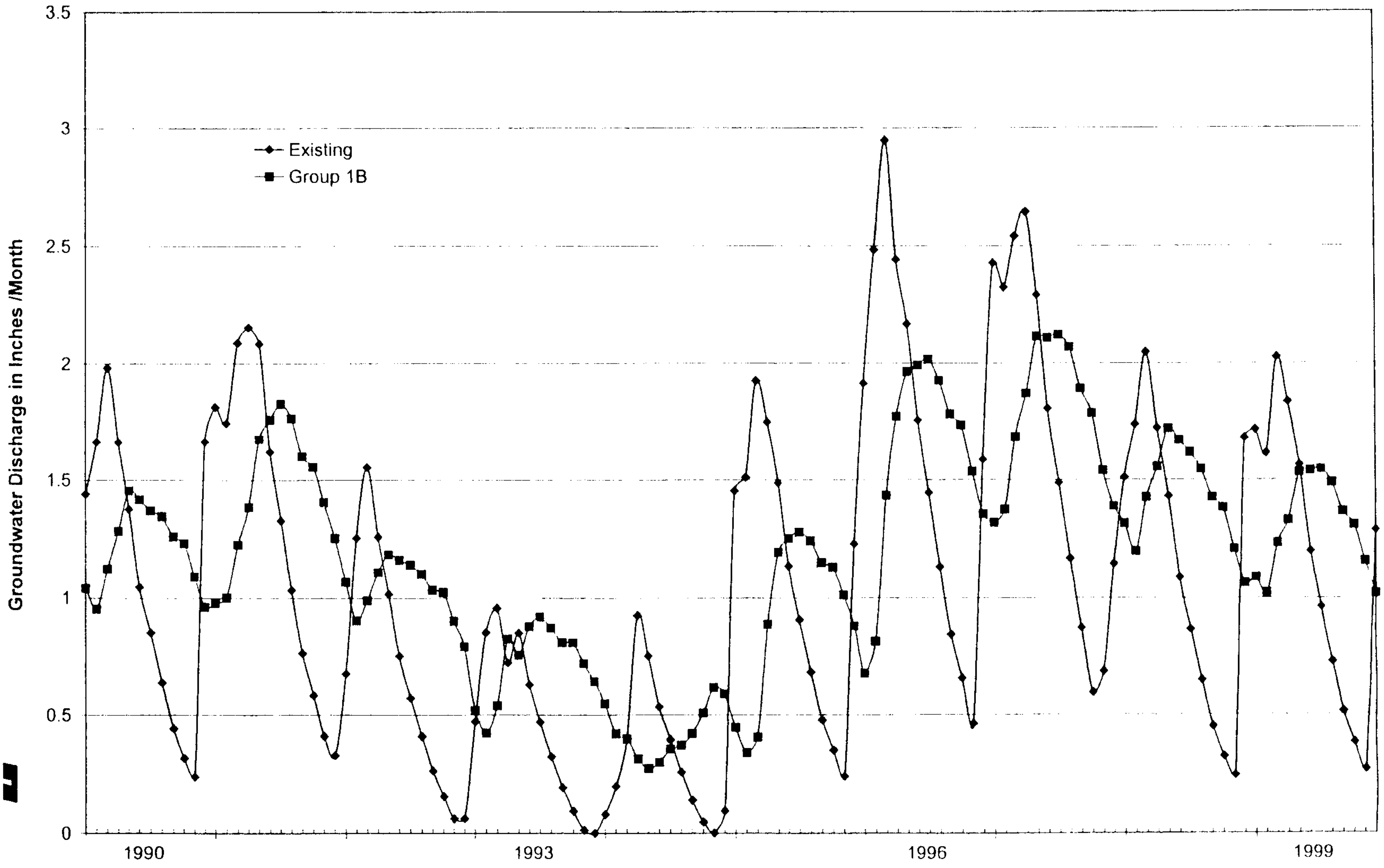
Figure C-11

Simulated Groundwater Discharge Rates for Existing Conditions and Group 1B Fill



DJH 10/12/00 497828AA.cdr Sheet 1 of 4

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J-4978-28 10/00

Figure C-12

Simulated Groundwater Discharge Rates for Existing Conditions and Group 3 Fill

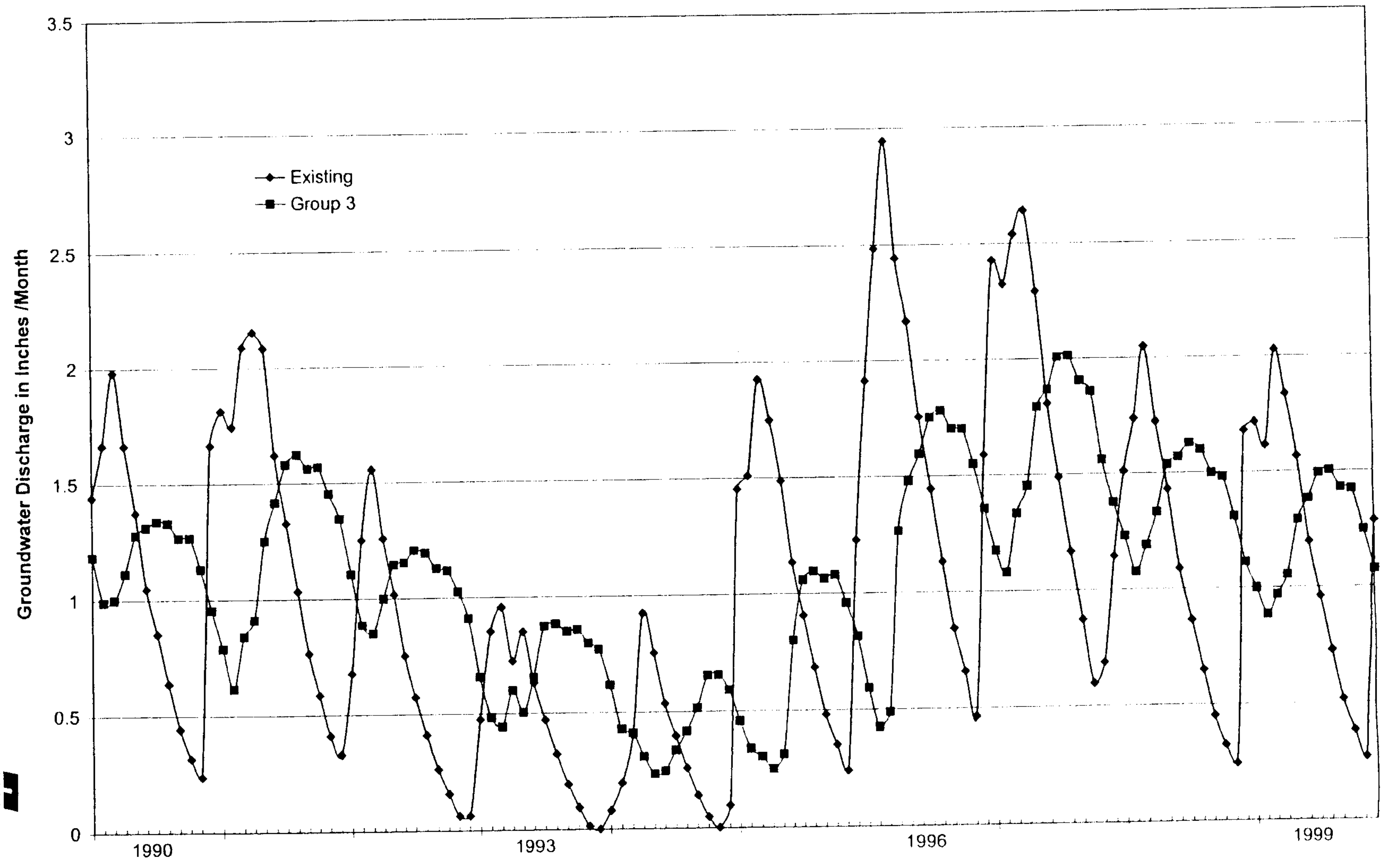

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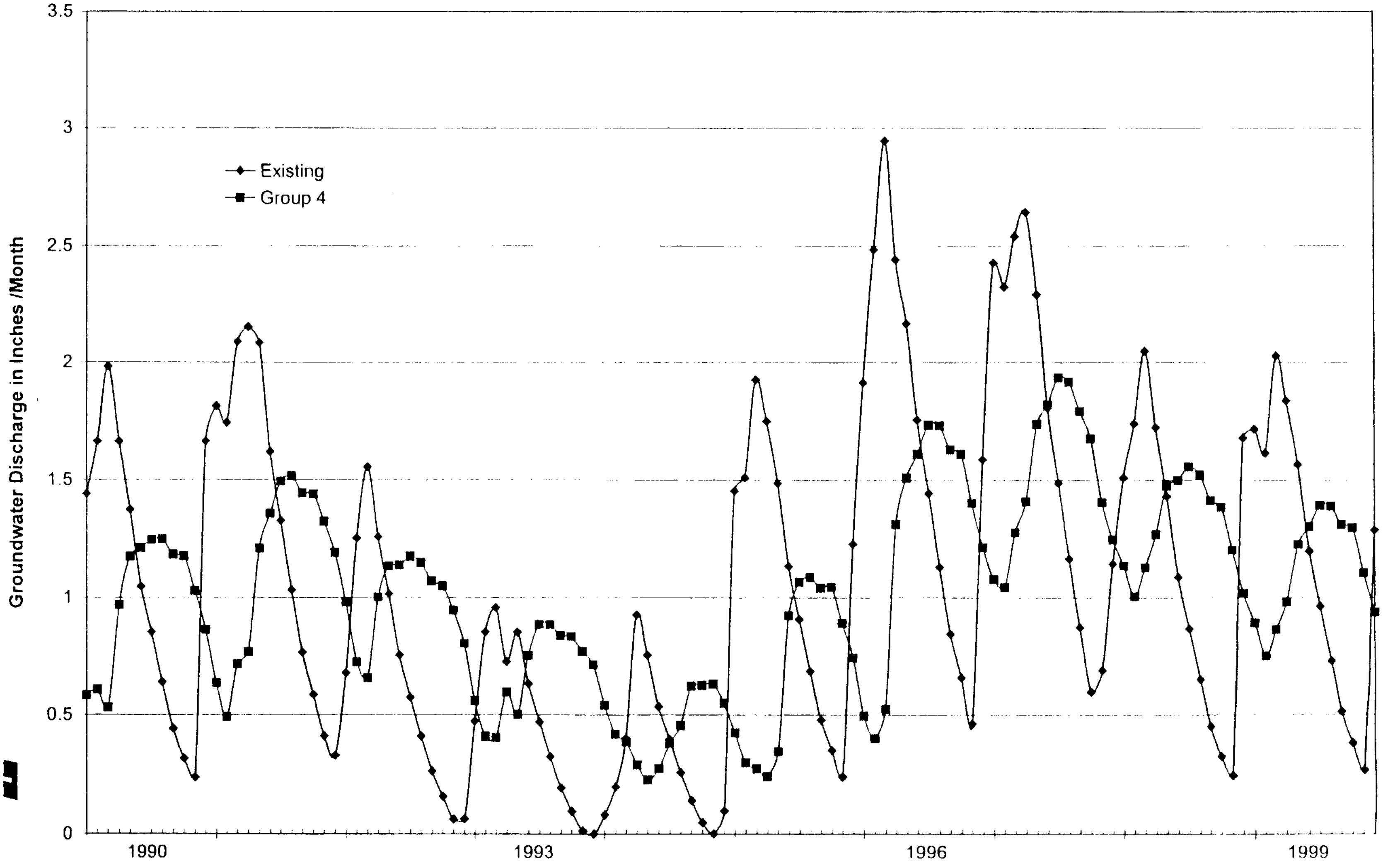
Figure C-13

DJH 10/12/00 497828AA.cdr Sheet 2 of 4

Simulated Groundwater Discharge Rates for Existing Conditions and Group 4 Fill



DJH 10/12/00 497828AA.cdr Sheet 3 of 4

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J-4978-28 10/00
Figure C-14

Cumulative Plot of Simulated Groundwater Discharge Rates

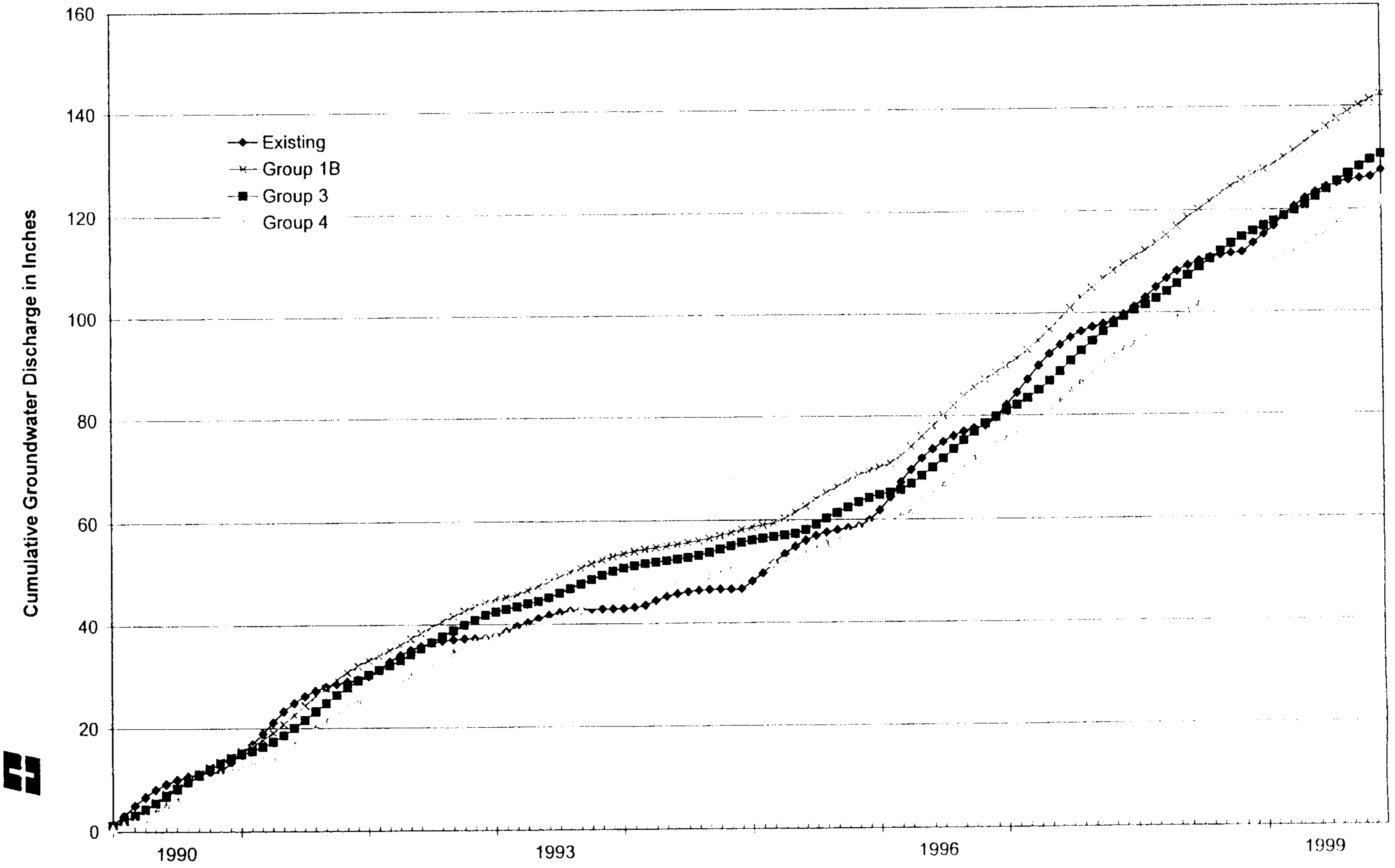

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Figure C-15

E-2

Wetland Hydrology and the Third Runway Embankment

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MEMORANDUM

DATE: October 30, 2001

TO: Jim Thomson, HNTB

FROM: Michael Kenrick, Hart Crowser, Inc.

RE: **Wetland Hydrology and the Third Runway Embankment Fill**
4978-06

CC: Elizabeth Leavitt, Port of Seattle

During the course of the Third Runway project, the Port of Seattle and its consultants have evaluated a number of issues that relate to impacts to and preservation of the wetlands and maintaining baseflow to the creeks resulting from construction of the Third Runway Embankment. This memorandum presents the US Army Corps of Engineers (Corps) a summary and guide regarding these studies and how the analyses address key issues of concern regarding long-term protection of wetlands hydrology.

We outline the understanding of current conditions at the Third Runway site, as they relate to the main hydrologic processes that maintain the wetlands and baseflow to Miller and Walker Creeks. We then describe the work done to assess the potential for the Third Runway to affect these hydrologic processes, and how construction of the project is designed to avoid or mitigate adverse effects.

UNDERSTANDING OF EXISTING CONDITIONS

In this section, we answer the question: What are the soil and hydrologic features and characteristics at or near the Third Runway site that maintain wetland hydrology?

Hydrologic and Geologic Setting

The existing conditions at Third Runway site have been documented for both wetlands and hydrology/hydrogeology as part of the *Final Environmental Impact Statement* (FEIS) for the proposed Master Plan Update (FAA/Port of Seattle 1996), of which the Third Runway is a part:

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- Hydrologic conditions in the basins are summarized as part of the *Hydrologic Modeling Study* (Montgomery Water Group 1995) presented in Appendix G (in Volume 3) of the FEIS.

- The original *Wetland Delineation* and *Wetland Function and Values Assessment* for the project were presented in Appendix H-A and H-B (Volume 3) of the FEIS.

- Hydrogeologic conditions at the project site were summarized in the *Baseline Groundwater Study* (AGI 1996), included as Appendix Q-A in Volume 4 of the FEIS.

A schematic cross section showing typical groundwater conditions at the Third Runway project site is shown on Figure 1.

As the project has developed, more detailed studies have been performed. Geotechnical issues related to the filling of wetlands were analyzed by Hart Crowser in its *Geotechnical Engineering Report - 404 Permit Support* (Hart Crowser 1999a). This report contains a summary of existing subsurface conditions (page 3) including soil and groundwater.

The body of work completed through December 1999 has been reviewed and summarized in the *Sea-Tac Runway Fill Hydrologic Studies Report* by the Pacific Groundwater Group (PGG 2000). This work was commissioned by the Washington State Department of Ecology (Ecology) independent of the Port's consultants, under an order of the State Legislature specifically to assess potential hydrologic impacts of the Third Runway project.

Wetland Hydrology

A range of studies performed for the project have provided understanding of the factors which contribute to and sustain the hydrology of hillslope, depression, and riparian wetlands in and adjacent to the Third Runway embankment construction project.

Depression Wetlands. These wetlands generally occur on relatively flat topography and are mostly fed by runoff or interflow draining in from a surface catchment surrounding the depression as a result of recent precipitation events. The depression facilitates ponding of water (if closed) and usually contains fine-grained subsoils. These soils tend to be of low permeability, which helps to sustain shallow saturation for the periods required to qualify as a wetland. During the summer, such wetlands may loose substantial amounts of moisture with soils becoming relatively dry for long periods. Most depression wetlands in the Third Runway project area will be filled as a result of embankment construction.

Slope Wetlands. These wetlands generally occur on sloping land and are mostly fed by surface runoff or interflow draining in from a surrounding catchment as a result of recent precipitation events. Surface topography that is typically concave, or gullied, and/or fine-grained subsoils tend to combine to create the wetland conditions, which provide shallow saturation for the minimal periods required to qualify as a wetland. In dry periods, such wetlands may loose substantial amounts of moisture and suffer long dormant periods in the summer. In some cases, these wetlands may also be fed by the occasional discharge of groundwater from shallow perched water-bearing zones. These are some of the key wetlands that will remain in the Third Runway project area following construction.

Riparian Wetlands. These wetlands generally occur on flat or gently sloping land adjacent to stream channels or bodies of open water, and tend to be fed by a shallow water table that is connected with the surface water body. The water table may be an expression of seasonal groundwater discharge from an upslope perched water-bearing zone, may include components of interflow, and/or more sustainable discharge from the water table of the shallow regional aquifer, where this discharges in part through the wetlands, as well as more directly to the adjacent surface water in the form of baseflow. During the summer, the water table typically drops, and surficial soils are no longer saturated. The wetlands do not necessarily dry out because water fluxes through the wetland flora may be sustained via capillary rise and evapotranspiration from the deeper water table. These also include key wetlands that will remain adjacent to the Third Runway project area following construction.

In some locations, very flat topography and constricted outflow points from a depression will create sustained saturation, with some areas of open water. These typically occur in an area of sustained groundwater discharge from the regional shallow aquifer, with water present the year round except during but the driest of years.

The following summary presents an assessment of these factors in the context of the main hydrologic processes that control the supply and abundance of water to the wetlands.

Site Investigations and Modeling

Understanding of the wetland hydrology at the Third Runway is predicated on information collected about the local geology, soils, and groundwater since these play critical roles in the occurrence of wetland conditions. The main factor sustaining wetland hydrology is precipitation. Models used to examine the hydrologic effect the embankment construction simulate the routing of precipitation into its derivative parts (i.e., infiltration, runoff, evapotranspiration, etc.), as those shown for the simple water balance model included on Figure 2. A series of such models has been used to examine specific aspects of the project, as described in the following sections. The main hydrologic studies performed for the project use a computer program called HSPF to develop a comprehensive surface water catchment modeling technique (described below) to simulate the destiny of precipitation at the site under both existing conditions and future post-construction conditions.

HSPF Modeling

One of the main tools used on the project to examine the fate of precipitation at the basin and sub-basin level is the water balance and stormwater modeling performed by Parametrix as part of the *Comprehensive Stormwater Management Plan* (CSMP, Parametric 2000c). This work was implemented using the *Hydrologic Simulation Program - Fortran* (HSPF), a widely recognized computer-modeling tool developed for the EPA (Donigian et al. 1984) and applied locally by King County as the basis for hydrologic analyses that underlie its *Surface Water Design Manual* (King County 1998).

Four years of the precipitation record (Water Years 1991 through 1994) was generally used in HSPF and other project hydrologic modeling. This part of the record is considered representative in that it includes a drought period (1991-93), with 1993 having the third lowest annual rainfall total (28.8 inches). Calibration of the HSPF models for Miller Creek (which includes Walker Creek as a tributary) focuses on this part of the precipitation record as being representative of a reasonably wide range of hydrologic conditions occurring at a time when land use in the basin could be accurately estimated (see Appendix B2 in Volume 3 of the CSMP).

Calibration of the HSPF model at the basin/sub-basin level provides the most defensible understanding and simulation of local hydrology, and forms the baseline for evaluations of changes in basin hydrology as a result of the Third Runway project. The division of the local drainage basins into sub-basins for HSPF modeling is shown on Figure 4-1 (page 4-2) of the CSMP.

The HSPF modeling as presented in the CSMP is the product of a phased development process that is documented on page 4-12 of the CSMP (Parametrix 2000c). Part of this process included an intensive and detailed independent review of the modeling work through the end of 1999, which is summarized in Section 3.6.2.1 (page 44) of the *Sea-Tac Runway Fill Hydrologic Studies Report* (PGG 2000). The review highlighted a number of calibration and simulation issues that led to cooperative work between Parametrix and King County to achieve a mutually agreeable calibration of the ultimate HSPF models, which form the basis of the CSMP (Parametrix 2000c).

Pre-Project Hydrologic Conditions

The following sections summarize our understanding of each aspect of the pre-project local hydrologic conditions with reference to their representation in HSPF and other models, and additional comments as they relate to wetland hydrology, wetland hydrologic functions, and baseflow to the creeks.

Precipitation

The main factor sustaining wetland hydrology is precipitation. The primary precipitation data used on the project for the area of Sea-Tac International Airport (STIA) are the hourly records of precipitation at the SeaTac NOAA Weather Service station, from October 1948 to the present. The average annual rainfall through September 1996 was 38.3 inches. Subsets of these data are used for specific aspects of the various analyses performed. For example, Hart Crowser used daily precipitation data from 1987 through 1997 for infiltration modeling and analysis. The main hydrologic study performed for the project uses a surface water catchment modeling technique to simulate the destiny of precipitation at the site under both existing conditions and future post-construction conditions.

The last 10 years of the precipitation record were generally used in HSPF and other project hydrologic modeling. This record is considered representative in that it includes a drought period (1991-93), with 1993 having the third lowest annual rainfall total (28.8 inches), as well as some abnormally wet years, e.g., 1996 had the second-highest annual rainfall total (50.7 inches).

Evapotranspiration

Potential evapotranspiration is provided as an input stream of daily or monthly values for hydrologic simulations, based on local measurements of pan evaporation from the Washington State Research and Extension Center in Puyallup. Actual evaporation is calculated from these potential values within HSPF, depending on land use, soil type, and vegetation cover as described below.

Evapotranspiration rates vary with these different land segments; most occur from saturated soils, with forested soils generating more than grassland soils, with very little coming from impervious areas. Actual evapotranspiration is also restricted by the amount of water available in the shallow soil zone, and declines rapidly in late summer as shallow soils dry out. These natural mechanisms are represented in the HSPF models.

Runoff

Runoff is a function of rainfall frequency, intensity, and duration. These aspects are integrated in the HSPF model by use of continuous hydrologic simulation applied to analyze hourly precipitation data, with the model itself operating on a 15-minute time-step throughout the selected simulation periods. Runoff is also dependent on land use and soil type, especially as these relate to vegetation and slope. These factors are represented in HSPF by specifying parameters for elements in the model called permeable land segments (PERLNDs).

Each sub-basin represented in HSPF is made up of different PERLND specifications for broad categories of existing soil type, slope, and vegetation, including a separate category for wetlands or saturated soils. The PERLND specifications are in the form of a set of parameter values, as listed for example in Table B2-2 (page B2-5) in Appendix B (Volume 3) of the CSMP (Parametrix 2000c). These PERLNDs control the behavior of HSPF to best represent the hydrologic response of each of the following soil/vegetation combinations:

- **TFM.** Glacial **T**ill soils supporting **F**orest vegetation on a **M**oderate slope;
- **TGM.** Glacial **T**ill soils supporting **G**rassland vegetation on a **M**oderate slope;
- **OF.** Glacial **O**utwash soils supporting **F**orest vegetation;
- **OG.** Glacial **O**utwash soils supporting **G**rassland vegetation;
- **SAT.** Wetlands and **SAT**urated soils.

The hydrologic meaning and applicable regional values of various PERLND HSPF parameters are provided in Dinicola (1990).

Another critical factor controlling runoff is the proportion or area of each basin or sub-basin that is composed of impervious surfaces (roads, roofs, parking lots, runways, taxiways). These areas are represented directly in HSPF, as listed in Table 4-1 (page 4-4) of the CSMP (Parametrix 2000c).

Wetlands are represented in HSPF through specified PERLND segments representing the appropriate proportion of each modeled sub-basin that is composed of saturated soils (wetlands). See, for example, Table B2-4 (pages B2-7 through B2-14) in Appendix B (Volume 3) of the CSMP (Parametrix 2000c). This table shows the amounts of each sub-basin represented as effective impervious area (EIA) using impermeable land segments (IMPLND) in the HSPF model.

Runoff is generated in HSPF primarily from the impermeable land segments for each storm event, with some contribution coming from areas of till soil, depending on soil-moisture conditions, and antecedent and current precipitation characteristics. Runoff accumulating as streamflow at key points in the model simulation allows direct comparison with streamflow records for the creeks, which are represented in the model.

The HSPF model is calibrated for known conditions by making careful adjustments to model parameters, as described for example on page B2-28 in Appendix B (Volume 3) of the CSMP (Parametrix 2000c), such that the best match is achieved between simulated and real hydrographs of basin runoff. See, for example Figures B2-4 though B2-21 (pages B2-32 ff) in Appendix B (Volume 3) of the CSMP (Parametrix 2000c).

Infiltration

Infiltration occurs when surficial soils are unsaturated and extra moisture is available from precipitation. The type of soil (e.g., outwash or till) strongly influences the rate and amount of infiltration that can occur; other variable factors also control the rate of infiltration on a daily or hourly basis, including the changing rates of precipitation, evapotranspiration (driven by solar and other radiation), and runoff.

Models such as HSPF simulate the amount of infiltration occurring into different pervious land segments. The models track continually changing variables such as precipitation, evapotranspiration, and runoff through simulations based on months or years of real data. The models also determine the portion of infiltration that becomes available for shallow interflow or becomes deeper percolation that recharges the groundwater system.

Existing rates of infiltration into wetlands and the various soil types/vegetation combinations at the Third Runway site were also studied independently as reported in the *Sea-Tac Runway Fill Hydrologic Studies Report* (PGG 2000). Examples of water balance calculations for monthly average infiltration to estimate groundwater recharge rates are presented in Appendix B (Tables B-5 through B-13) of that report. Specifically, average monthly water balances for wetland soils are presented in Tables B-5 through B-7.

Interflow/Perched Groundwater

Interflow, defined as shallow lateral subsurface flow that occurs on sloping land over a period of hours to days after individual storm events, represents an important component of wetland hydrology for slope and depression wetlands at the Third Runway site, and can also play a role in the supply of water to riparian wetlands. HSPF takes account of interflow and represents its contribution at the sub-basin scale (although not on the level of individual wetlands).

A portion of interflow likely contributes to or derives from shallow perched groundwater beneath sloping land at the Third Runway site, where a veneer of relatively permeable surficial soils commonly overlies less-permeable glacial till at shallow depths (typically 5 to 10 feet). The conditions are described on page 5 of the *Geotechnical Engineering Report - 404 Permit Support* (Hart Crowser 1999a). Shallow flows in these soils contribute significantly to the hydrology of slope wetlands and will be sensitive to changes in vegetation or land use that may occur in the small upslope drainage areas associated with most slope wetlands.

As part of the geotechnical investigations for the Third Runway, Hart Crowser has installed approximately 77 shallow monitoring wells, the majority of which monitor water levels in the shallow perched water-bearing zone beneath the proposed embankment. These data are contained in the following *Subsurface Conditions Data Reports* issued for specific sections of the proposed construction area:

- Subsurface Conditions D*ata Report - 404 Permit Support* (Hart Crowser 1999b);
- Subsurface Conditions Data Report - *Phase 3 Fill* (Hart Crowser 1999c);
- Subsurface Conditions Data Report - *North Safety Area* (Hart Crowser 2000a);
- Subsurface Conditions Data Report - *South MSE Wall and Adjacent Embankment* (Hart Crowser 2000b);
- Subsurface Conditions Data Report - *West MSE Wall* (Hart Crowser 2000c);
- Subsurface Conditions Data Report - *Additional Field Explorations and Advanced Testing* (Hart Crowser 2000d);
- Subsurface Conditions Data Report - *Phase 4 Fill* (Hart Crowser 2000f); and
- Subsurface Conditions Data Report - *Phase 5 Fill and Subgrade Improvement* (Hart Crowser 2001b).

The reports also contain boring logs, test pit logs, and the results of laboratory tests among other geotechnical data collected for the project.

Baseflow/Groundwater Recharge

Underlying the glacial till beneath the Third Runway site is the shallow regional aquifer, which exists primarily within the advance outwash deposits of the Vashon glaciation that occurred during the Quaternary period (Qva). Information on the Qva aquifer has been collected over a broad area surrounding STIA as part of an ongoing groundwater study being performed for the Port of Seattle by Associated Earth Sciences Inc (AESI). Based on these data, groundwater elevations and implied flow directions throughout the airport area have been mapped by AESI; see Figure B1-3 (page B1-6) in Appendix B1 (Volume 3) of the CSMP (Parametrix 2000c).

AESI has also prepared a hydrogeologic cross section through the southcentral portion of the airport that extends westward to include part of the Third Runway site. This is presented in a memorandum entitled *Analysis of Preferential Ground Water Flow Paths Relative to Proposed Third Runway* (AESI 2001).

Groundwater elevations in the portions of the Qva aquifer near the creeks show close association with Miller Creek and Des Moines Creek, indicating that these are generally gaining streams supplied by baseflow contributions from the aquifer. The occurrence of this baseflow contribution is reflected by water table elevations adjacent to the creek that are typically somewhat higher than corresponding creek levels (a necessary requirement for baseflow to occur). Depending on surface topography adjacent to the creek, these conditions help to create and sustain riparian wetlands that are fed in part by the shallow groundwater table.

During periods of flooding, water levels in the creeks may briefly exceed the levels of groundwater in the adjacent aquifer, and may flood the riparian wetlands, temporarily reversing the baseflow and mobilizing bank storage within sediments and geologic deposits alongside the creek.

Post-Construction Conditions

The second part of this memorandum addresses the analysis and evaluation of potential hydrologic effects to wetlands and creeks that may occur as a result of Third Runway embankment construction. Specifically, how will the Third Runway embankment and its MSE Walls affect the long-term hydrology of the wetlands?

Embankment Construction

The proposed Third Runway will be constructed on native soils and an embankment of compacted earth fill, so that the new runway level meets the existing airfield level, as shown schematically on Figure 3. To accommodate the slope of the existing terrain, the new embankment will vary up to a maximum fill height of about 165 feet. The new embankment is being constructed as a zoned fill, with specific types of soil materials and compaction requirements used in different areas to provide necessary stability and settlement characteristics. Overall, the new embankment will include about 17,000,000 cubic yards of compacted earth fill.

The new embankment will be constructed on the west side of the existing airfield. The embankment side slopes will have an average inclination of 2H:1V. Three high retaining walls will be used to limit the extent of embankment slope from impacting sensitive portions of Miller Creek and adjacent wetlands. Mechanically stabilized earth (MSE) technology will be used to construct the retaining walls. The specific type of MSE walls being designed for Sea-Tac utilize strips of steel layered in the compacted soil fill, and a relatively thin reinforced concrete facing to form a near vertical retaining wall face.

The foundation soils for the MSE walls and parts of the main embankment require additional measures to improve their performance and to limit the potential effects of liquefaction during a major earthquake (see also the *Geotechnical Design Summary Report*, Hart Crowser 2001d). This includes the excavation of unsuitable foundation soils (typically peat, soft clay, and loose silty sands) and replacement with compacted sand and gravel fill material.

Post-Construction Hydrologic Conditions

Precipitation

Precipitation inputs to HSPF for the modeling of future (post-construction) conditions use the same period of record as described above for existing conditions. This allows comparisons between pre- and post-construction analyses to focus on potential construction effects manifested under comparable precipitation patterns as have occurred in the recent past.

Predictive modeling of post-construction conditions using HSPF allows the overall impact of land use changes at the sub-basin level (including the filling of impacted wetland acreage) to be assessed. This analysis is presented in Appendix A (Volume 2) of the CSMP (Parametrix

2000c). Summaries of this and other related hydrology work are presented below, with references to the corresponding reports containing the detailed work.

Evapotranspiration

Site clearing required for the construction of the Third Runway includes the removal of forested slopes and the filling of wetlands, both of which represent significant sources of water loss to evapotranspiration in the local basins. These changes are simulated at the sub-basin level by defined inputs to the HSPF model, with most of the embankment fill surface that is not impermeable represented as outwash with grass vegetation. As a result, the amount of water available post-construction for the remaining hydrologic processes (runoff, infiltration, interflow, baseflow) is increased at the Third Runway site.

Runoff

Changes in land use that directly affect soil type, vegetation, wetlands, and impervious areas are predicted using HSPF to increase surface runoff from the project area. This is primarily related to the net increase in effective impervious area as a result of runway and taxiway construction that exceeds the removal of existing impervious surfaces (i.e., roads and roofs).

HSPF was used as a key tool in developing the management strategy for stormwater routing, sizing for stormwater facilities, and discharge of stormwater within the requirements of King County's best management practices (BMPs) for surface water (King County 1998). The post-construction HSPF model includes the generation of **all** runoff from new impervious surfaces (runways and taxiways), ignoring the potential for secondary infiltration of runoff into permeable filter-strip soils adjacent to impervious runway/taxiway areas, which is very conservative (see below).

Some of the runoff generated from the face of the embankment will occur at elevations that are below the level that allows free gravity drainage to stormwater ponds. This limited volume of stormwater will be collected in swales and distributed to downslope wetlands via flow dispersal trenches, as shown in Exhibit C-115 of Appendix Q (Volume 4) of the CSMP (Parametrix 2000c).

Infiltration

The Third Runway embankment will be composed of fill material that is moderately permeable and allows the infiltration of water at its surface. Water that has infiltrated the fill surface and is not consumed by evapotranspiration through surface plants (primarily grass) will be available to percolate downward through the embankment under the influence of gravity.

Deep percolation and seepage through the embankment were initially analyzed using a simple block-flow water balance model for two representative cross sections, as described in Appendix B of *Geotechnical Engineering Report - 404 Permit Support* (Hart Crowser 1999a).

A more rigorous analysis of infiltration and seepage, taking into account unsaturated groundwater flow was developed using the US Army Corps of Engineers *Hydrologic Evaluation of Landfill Performance (HELP) model* (Schroeder et al. 1994), as described in Appendix C of *Geotechnical Engineering Analyses and Recommendations* (Hart Crowser 2000g). This work was independently verified by additional modeling prepared as part of the *Sea-Tac Runway Fill Hydrologic Studies Report* (PGG 2000) for one cross section or slice through the future embankment, located at the western MSE wall. In its *Sea-Tac Runway Fill Hydrologic Studies Report* (PGG 2000), PGG used a three-part modeling approach to evaluate the percolation and seepage of water through the completed embankment:

- Infiltration was calculated using a proprietary water balance model to estimate monthly average values of recharge from the surface of the fill, as described in Appendix B of PGG (2000);
- Percolation through various thicknesses of the fill material was simulated using an unsaturated seepage model called Hydrus-2D, as described in Appendix C of PGG (2000); and
- The accumulation of percolating water with shallow groundwater flow and drainage layer flow at the base of the embankment was modeled using a proprietary one-dimensional finite-difference numerical groundwater flow model, called Slice, as described in Appendix E of PGG (2000).

Additional modeling of embankment infiltration and seepage was performed by PGG in support of the *Low-Flow Analysis (Flow Impact Offset Facility Proposal)* prepared by Parametrix (2001). This work included seepage analysis for two additional slices located north and south of the western MSE wall, as shown in Figure 2-1 of the *Sea-Tac Third Runway - Embankment Fill Modeling* report (PGG 2001). The same modeling approach as above was used except that infiltration rates into the surface of the embankment slices were not calculated using PGG's monthly average water balance/recharge model. Rather, to ensure compatibility with HSPF, a series of daily (rather than monthly) values were derived from HSPF, covering four years of simulation based on the conversion of actual precipitation to infiltration on outwash with grass cover. The seepage analysis also included representation of secondary infiltration where stormwater runoff from the runways infiltrates into the embankment fill via permeable filter strips constructed alongside runways and taxiways. Design details for the filter strips are included in Appendix H (Volume 4) of the CSMP (Parametrix 2000c).

Additionally, the seepage and recharge rates calculated by PGG for the three slices were aggregated over the full area of the Third Runway embankment, based on fill thickness, and the corresponding recharge flows were used in HSPF to provide improved representation of seepage through the new embankment and its effect on baseflow/groundwater recharge.

Interflow

Interflow in the area of the Third Runway embankment will occur within the sloping face of the embankment. As shown on Figure 3, the outer shell of the embankment (a 20-foot-wide zone that runs the full height of the main embankment's 2H:1V slope) will be formed of relatively permeable Group 1B material. The grain size envelope specified for Group 1B material is as shown on Figure C-5 (Appendix C) of *Geotechnical Engineering Analyses and Recommendations* (Hart Crowser 2000g). This material will allow more infiltration than would typically occur with the common embankment fill. Most of this infiltration will become interflow that percolates down the sloping interface between Group 1B and common fill material forming the body of the embankment, to enter the drainage layer.

Flow from the drainage layer will in general replace the pre-project interflow, but will provide a much more consistent source of water to the downslope wetlands because of the buffering effect created by storage of pore water within the body of the embankment. This effect is described on page 51 of PGG (2000). The result will be a significant attenuation in peak flows and improved timing in terms of extended periods of flow and of increased flow during the late summer periods. This is demonstrated on Figures 5-4 through 5-6 of PGG (2001).

The main discharge points for flow from the drainage layer beneath most of the completed embankment are expected to be the topographic low spots along the final toe of the embankment. These are expected in some cases to coincide with current wetland locations. Drainage layer flows will be collected and redistributed to the downslope portions of the wetlands that remain following construction, using flow dispersal trenches as shown, for example, in Exhibit C-115 of Appendix Q (Volume 4) of the CSMP (Parametrix 2000c). If excess flows are deemed to be occurring based on monitoring of the wetlands, some of the flow can then be diverted away from the wetland and directed to stormwater ponds for detention and subsequent discharge to the creeks. Conversely, if there is not enough flow to sustain the wetlands, treated stormwater discharges can be diverted to flow through the wetlands.

At the toe of the embankment in the area beneath the West MSE wall, collection swales will not flow by gravity to the stormwater ponds, due to elevation constraints. In this area, a system of replacement channels has been designed (in part to mitigate the burial of drainage channels beneath the embankment) which will carry drainage layer discharges and redistribute flows to the downslope portions of the riparian wetlands that remain following construction. The replacement channels are shown in Appendix D of the NRMP (Parametrix 2000a).

Baseflow/Groundwater Recharge

Beneath most of the embankment, the existing groundwater flowpaths will largely be maintained and unaffected by construction. This includes:

- The shallow soils directly beneath the embankment that contain groundwater perched above the glacial till;
- The underlying shallow outwash aquifer which discharges as baseflow to the creeks and helps sustain the riparian and slope wetlands; and
- The deeper regional aquifers that play an important role in local water supplies.

In particular, seepage and groundwater flow through surficial soils at and below the toe of the embankment will continue to supply water to riparian wetlands and the associated creeks.

Subgrade Improvement

In limited areas of the embankment associated with MSE wall construction, some of the shallow soils are unsuitable as foundation materials and must be strengthened or replaced, as described on page 24 of the *Geotechnical Engineering Report - 404 Permit Support* (Hart Crowser 1999a) and on pages 2 through 12 of the *Preliminary Stability and Settlement Analyses, Subgrade Improvements, MSE Wall Support* (Hart Crowser 2000e). Other sections of the Third Runway embankment foundation may be subject to liquefaction during certain earthquake conditions; strengthening or replacement of subgrade materials will also be implemented in these area, as described on page 4 of *Geotechnical Engineering Analyses and Recommendations* (Hart Crowser 2000g).

Selection of a method for subgrade improvement was strongly influenced by the need to avoid permanent impacts on baseflow to downgradient wetlands. After considering eight alternative methods, two approaches (stone columns; and removal and replacement of native soils) were selected for final design analysis:

- Subgrade strengthening may be achieved by a method such as the installation of stone columns into the foundation soils. These methods are designed to increase soil strength by displacing weak soils with columns of gravel placed in the ground. Stone column installation densifies adjacent sand and gravel soils but provides little or no compaction of silt and clay soils. There is no evidence of stone columns impeding groundwater flow (see *Proposed MSE Wall Subgrade Improvements*, Hart Crowser 2000h) and permeability may increase where silt and clay soils are disturbed. To the extent that recharge area and rates remain unchanged, the amount of groundwater flowing through the area will not change, although water levels and hydraulic gradients may adjust to convey this water through, around, or over the area where stone columns are installed. Increases in water level will be limited by the presence of the drainage layer (see below), which will act as an overflow conduit, preventing water levels from rising much above the original ground level beneath the embankment.

- Another alternative is the excavation of weak, unsuitable soils (to depths ranging typically from 10 to 20 feet, down to a dense bearing layer, such as glacial till), and replacement with compacted free-draining granular fill material, as described on page 25 of *Geotechnical Engineering Report - 404 Permit Support* (Hart Crowser 1999a) and in Appendix C of *Geotechnical Engineering Analyses and Recommendations* (Hart Crowser 2000g). This backfill material will typically be more permeable than the soils it replaces, and becoming saturated below the water table, will conduct groundwater flow from upslope to downslope soils, with flowrates controlled by the hydraulic conductivity of the adjacent native soils.

The second alternative, the removal and replacement of unsuitable soils, has been selected as the best approach for construction by the Port of Seattle following pilot testing of stone columns.

Drainage Layer

Embankment construction includes the placement of a drainage layer beneath sections of the fill that will be 50 feet or more in height. A drainage layer will also be used beneath less tall sections of the embankment where existing or inferred potential seepage could occur into the new fill. The drainage layer will form a blanket with a minimum thickness of 3 feet, laid mainly over the existing ground surface (see Figure 3) and will consist of sand and gravel (designated Group 1A material). The grain size envelope specified for Group 1A material is as shown on Figure C-5 (Appendix C) of *Geotechnical Engineering Analyses and Recommendations* (Hart Crowser 2000g). The drainage layer will be relatively permeable and will provide a somewhat higher rate of seepage in comparison to the average for common embankment fill and the native subsurface soils.

Drainage layer flow in some locations may include a portion of groundwater entering the layer from below, especially downslope of existing wetland areas that are buried beneath the fill. Provision will be made during construction to locally increase the thickness of the drain layer in such areas, as discussed in *Geotechnical Engineering Analyses and Recommendations* (Hart Crowser 2000g) and *Geotechnical Engineering Analyses and Recommendations, Phase 5* (Hart Crowser 2001c). This will ensure that existing seeps and shallow flows are maintained, and that flows issuing from the drainage layer can be managed in a way that will protect the wetlands adjacent to the new embankment.

There is no danger that groundwater contamination from the eastern side of the airport would be transported to the Third Runway project area or enter the drainage layer. Contamination present in perched groundwater on the eastern side of the site will not migrate to the west due to the absence of any plausible migration pathways. This is because the perched water-bearing zones in the glacial till on the eastern and western flanks of the airport are localized and discontinuous, and the glacial till is absent from the central area. Utility tunnels located within permeable outwash materials of the central area are well above the water table in the shallow aquifer and do not constitute a plausible pathway for contaminated water from the perched areas or in the Qva to be transported to the west side of the airport. See the cross section on Figure 6 of the *Analysis of Preferential Ground Water Flow Paths Relative to Proposed Third Runway* (AESI 2001).

On the scale of the airport, the drainage layer, which will begin over a half-mile away from the contaminated groundwater zone, will typically be placed on the existing ground surface mostly above the elevation of groundwater in the Qva aquifer, and will have only limited interaction with it. The drainage layer will collect water from existing small seeps and springs (where local perched groundwater currently discharges to the surface); the presence of the drainage layer will not change the overall movement of groundwater in the shallow aquifer beneath the airport. Furthermore, observations have shown that the maximum migration distance of impacted groundwater in the Qva beneath the perched zones on the eastern side of the airport is limited to less than 550 feet (AESI 2001).

Baseflow

Estimates of baseflow contribution from the area being filled by the Third Runway embankment generally show a slight increase in shallow groundwater flow that provides baseflow to the adjacent creeks. This was initially analyzed using a simple block-flow water balance model for two representative cross sections through the new embankment, as described in Appendix B of *Geotechnical Engineering Report - 404 Permit Support* (Hart Crowser, 1999a).

A subsequent analysis of baseflow effects developed using the HELP model, as described in Appendix C of *Geotechnical Engineering Analyses and Recommendations* (Hart Crowser 2000g), showed similar results. This work was independently verified by additional modeling prepared as part of the *Sea-Tac Runway Fill Hydrologic Studies Report* (PGG 2000), which gave similar results. Additional work by PGG with the same model for two additional embankment slices, as described in the *Sea-Tac Third Runway - Embankment Fill Modeling* report (PGG 2001), also gives similar results.

Output from the final work listed was incorporated in the HSPF models to estimate baseflow under low-flow conditions in the *Low-Flow Analysis (Flow Impact Offset Facility Proposal)* prepared by Parametrix (2001). This analysis shows a relatively small change in baseflow at the sub-basin level over the areas that include the Third Runway embankment (see page 2 of Parametrix (2001)).

Requirements for a temporary stormwater pond (Pond A) below the West MSE Wall raised concerns about temporary local effects on baseflow and wetland hydrology as a result of pond operations. The issues and a solution to avoid potential effects on groundwater flow and wetland hydrology are described in *Avoidance of Wetland Impacts, Temporary Stormwater Pond A* (Hart Crowser 2001a).

Groundwater Recharge

Rates of recharge to the deeper aquifers are controlled in part by water level elevations in the shallow regional aquifer. Since the water levels in the shallow aquifer will not be substantially affected by the Third Runway embankment construction, flowrates for water leaking through underlying aquitards to reach the deeper aquifers will not be affected.

Finally, rates of groundwater flow in the shallow regional aquifer and in the deeper aquifers will not be adversely affected by the additional weight imposed by the new embankment. In a letter to the Port entitled *Sea-Tac Third Runway - Aquifer Compaction*, Hart Crowser (1998) presented an analysis to demonstrate that the additional weight might result in, at the most, a loss of 4 percent of the thickness of the shallow regional aquifer. The corresponding reduction in aquifer transmissivity (3 percent) would not have a measurable effect on groundwater levels or flow rates beneath the embankment.

SUMMARY

- All relevant components of the watershed hydrology and hydrogeology have been studied.
- The embankment and wall design and construction methods include measures that will preserve, promote, or enhance the hydrology of remaining wetlands that are not filled by the embankment.
- On an annual basis, down-slope wetlands are predicted to receive slightly more water, spread over a longer period, with smaller peak flows, which should be beneficial to wetland hydrology.
- There will be no increase in peak flows through wetlands. Excessive water flows through the wetlands that are substantially greater than existing flows (especially highly erosive peak runoff events during storms) will not occur because storm flows will be diverted to stormwater ponds for detention and slow release directly to streams.
- If wetter conditions occur for longer periods, and post-construction monitoring reveals that there is an adverse effect on wetland flora, this will be rectified by adaptive management of flows.

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Attachments:
Figure 1 - Generalized Groundwater Conditions
Figure 2 - Water Balance Schematic
Figure 3 - Conceptual Site Flow Model, Third Runway Embankment

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Generalized Groundwater Conditions

Third Runway

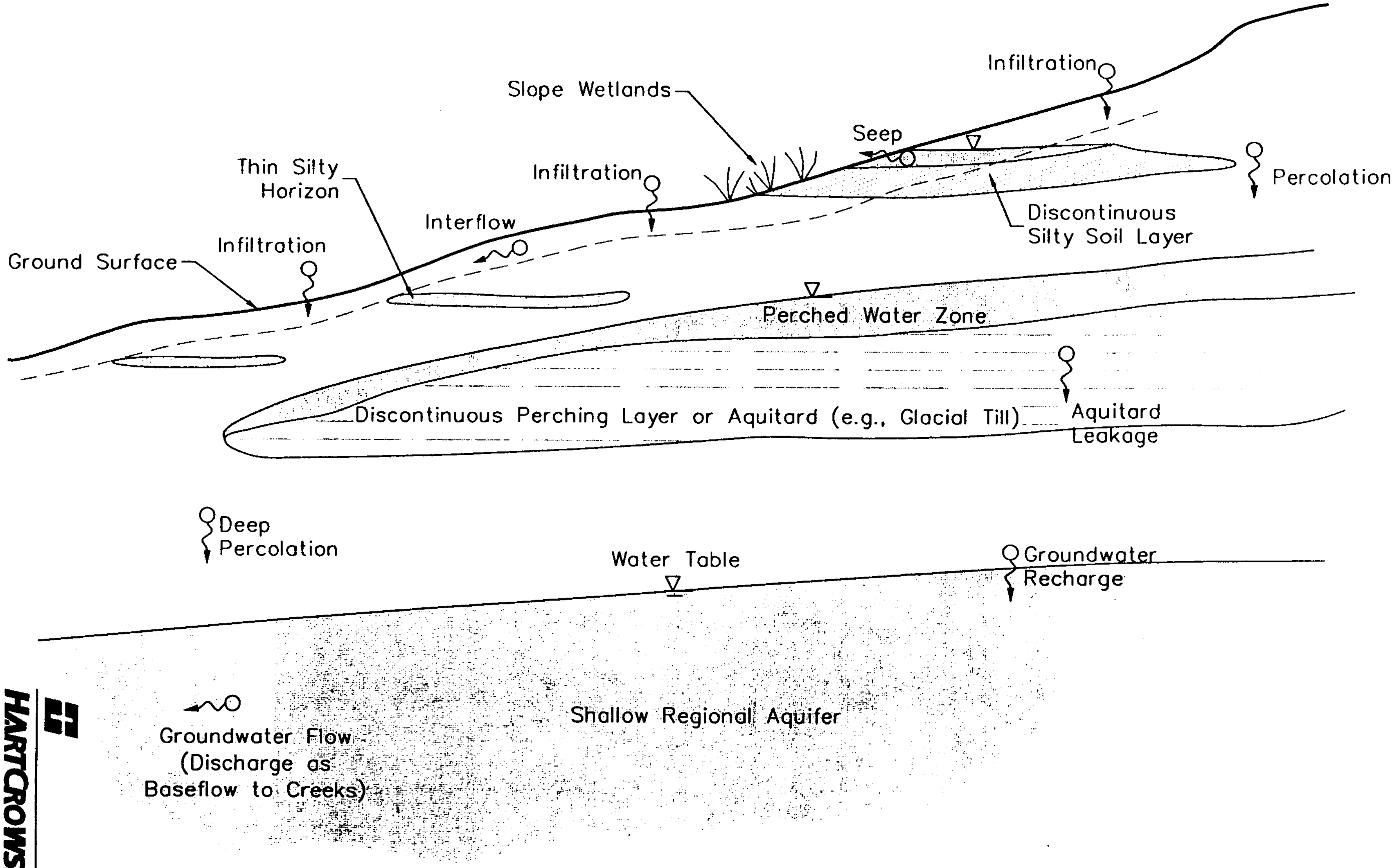

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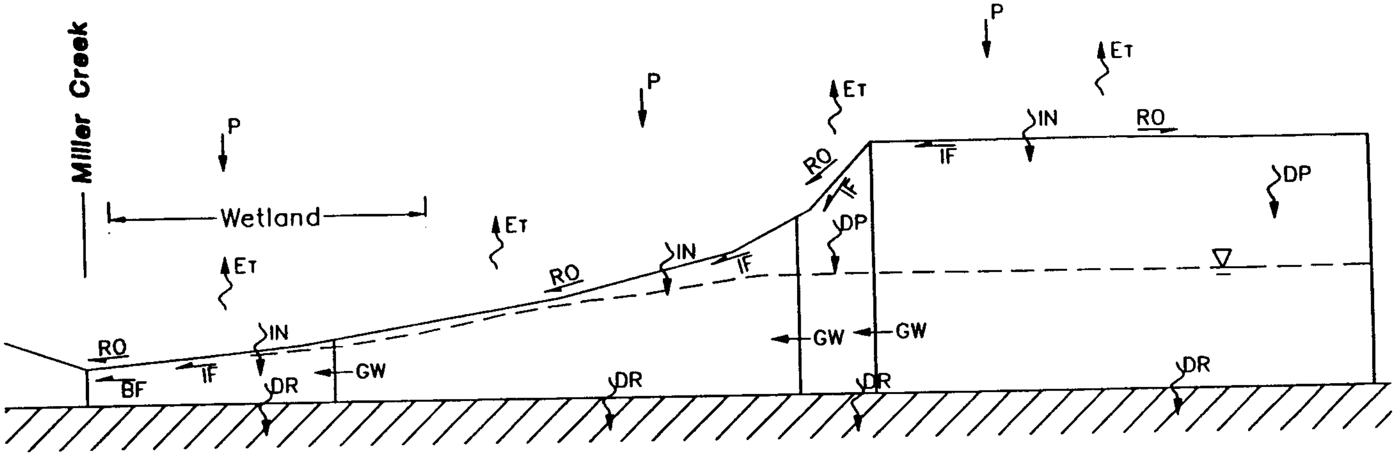
Figure 1

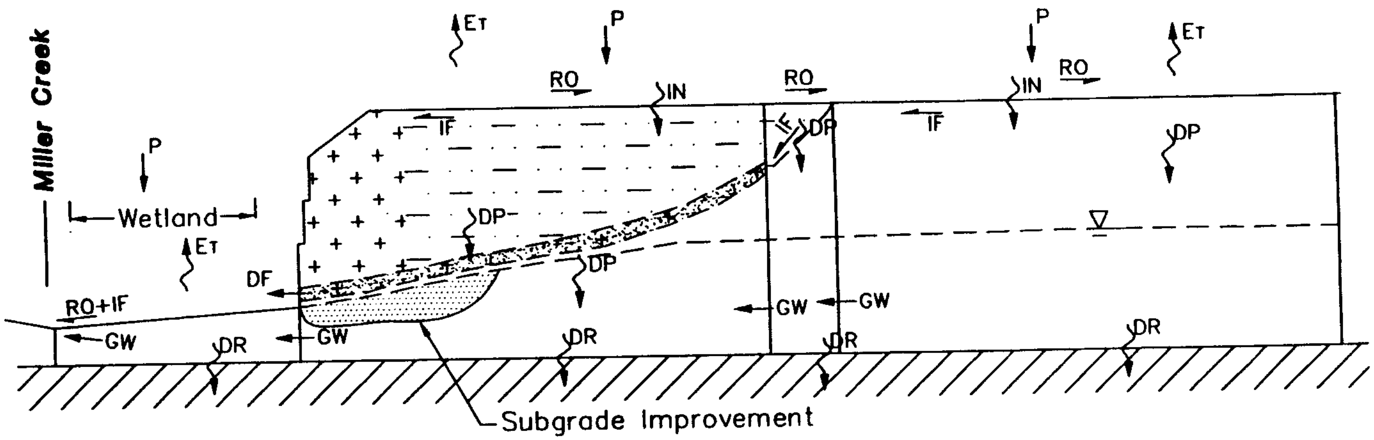
Water Balance Schematic

Third Runway Embankment

P	Precipitation
ET	Evapotranspiration
RO	Runoff
IF	Interflow
IN	Infiltration
DP	Deep Percolation
GW	Groundwater Flow
BF	Base Flow
DF	Drainage Flow
∇	Water Table
DR	Deep Recharge
▨	Drainage Layer
— ·	New Embankment
+ ⊥	Free-draining Backfill



a) Pre-Construction



b) Post-Construction (with MSE Wall and Internal Drainage Layer)

Not to Scale

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Figure 2

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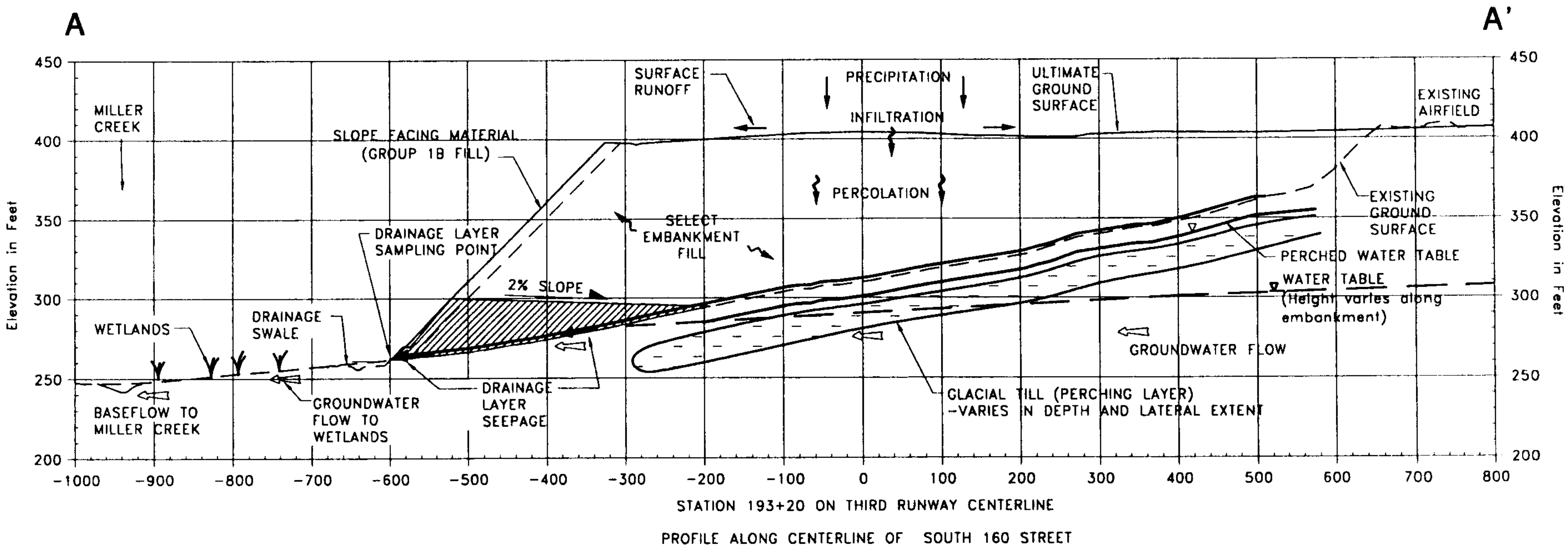
Conceptual Site Flow Model

Third Runway Embankment



Note: The conceptual model is a schematic representaation of flow paths at a typical cross section through the Third Runway embankment. Conditions, dimensions, elevations, and details vary along the length of the embankment.

LEGEND:

▨ Drainage Layer Cover

—— - - —— Drainage Layer

Horizontal Scale in Feet
0 200 400
0 100 200
Vertical Scale in Feet
Vertical Exaggeration x 2

J-4978-06 10/01
Figure 3

Appendix F

APPENDIX F

EMBANKMENT FILL MODELING IN SUPPORT OF LOW-STREAMFLOW ANALYSIS

Pacific Groundwater Group

Port of Seattle
Sea-Tac Third Runway
Embankment Fill Modeling in Support of Low-Streamflow Analysis

November 27, 2001

Pacific Groundwater Group
Seattle, Washington

Port of Seattle
Sea-Tac Third Runway
Embankment Fill Modeling in Support of Low Streamflow Analysis

Prepared for:

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November 27, 2001

JE0105

Table of Contents

Signature Page

This work was performed in part, and reviewed in whole, by the undersigned.

11/27/01

Charles T. Ellingson
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Oregon Registered Geologist G1128
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Certified Groundwater Professional #312 (National Ground Water Association)

List of Tables

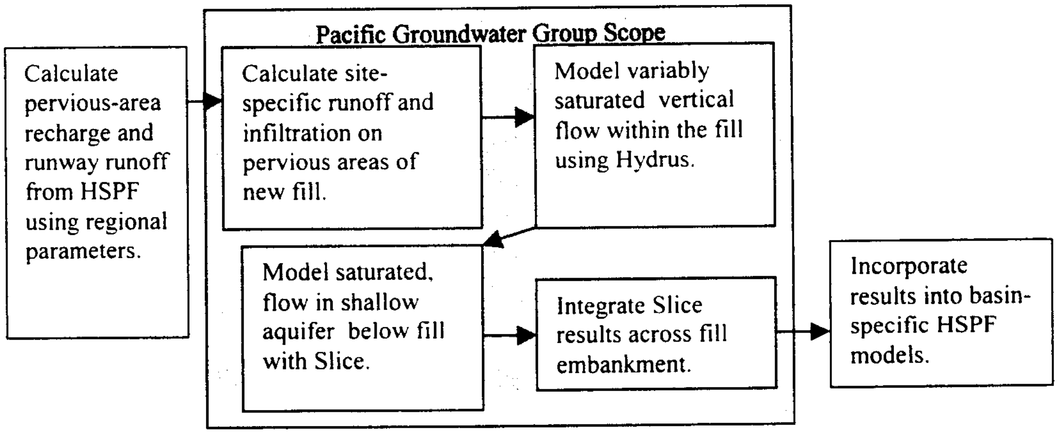
List of Figures

1. Introduction

The Port of Seattle ("the Port") proposes to place a fill embankment in an area west of the existing Sea-Tac Airport complex to build a third runway. Pacific Groundwater work analyzed selected hydrologic impacts for the Department of Ecology in 1999 (Pacific Groundwater Group, 1999). Hydrologic and hydrogeologic studies conducted by Earth Tech, Inc., Parametrix, Inc., Pacific Groundwater Group (PGG) and others then estimated groundwater and low-stream-flow impacts of the proposed fill embankment (Earth Tech, 2000; Pacific Groundwater Group, 2000; and Parametrix, 2001). As part of a more detailed study of low flow impacts to streams near the third runway, the Port contracted Parametrix, Earth Tech and PGG to reevaluate low-stream-flow impacts using a more detailed evaluation of hydrogeologic conditions and fill thickness in the embankment. PGG's role in the more detailed evaluation was to model recharge and redistribution of water within the fill embankment. This is the final report for PGG's portion of that project. The overall project study area includes the Miller Creek and Walker Creek basins, whereas PGG's evaluation was limited to a smaller portion of these basins that are proposed to be underlain by third-runway fill. PGG's evaluation was also limited to post-construction conditions, and did not attempt to simulate existing conditions or use existing conditions for calibration. PGG's study results were used by the HSPF modeling team to evaluate low-stream-flow impacts in the two basins.

1.1 Scope and Approach

PGG's scope of work was authorized by the Port on May 1, 2001. PGG's scope involved reapplication of previously-developed Hydrus and Slice models to post-construction conditions within the proposed embankment as follows:



Input to the modeling process consisted of the following two data sets provided to PGG by Aqua Terra Consultants:

1. direct infiltration from incident precipitation into pervious areas of new fill as calculated by HSPF (model parameter AGWI) for flat outwash

2. runoff from runways and taxiways as calculated by HSPF (model parameter SURO).

Output consisted of the timing and magnitude of runoff from the pervious area, water movement through the shallow aquifer above the till, and downward flow through the till. Output was provided to Aqua Terra and Parametrix Inc. as part of basin-wide simulation of post-construction conditions. The regional HSPF models were modified to allow replacement of regional-scale simulation with local-scale simulation (as described above) in the third runway vicinity. Specifically, Hydrus and Slice models ("Hydrus-Slice") were used instead of the regional HSPF model for the runway fill area, because HSPF was deemed incapable of simulating flow within the embankment. A simulation "test period", consisting of water years 1991 through 1994, was established for Hydrus-Slice modeling in discussions between the Port and the Department of Ecology ("Ecology").

The PGG scope consisted of the following tasks:

- Compile model input using existing information including
    - Fill thickness and extent
    - Hydrogeologic data for the fill area
    - Embankment geometries as represented by three (3) hydrogeologic cross sections
    - Hourly runoff and direct infiltration estimates provided by Aqua Terra Consultants
- Calculate fluxes into the fill based on hourly recharge and runoff estimates
- Calculate daily fluxes through the fill using Hydrus models
- Calculate daily flux through the shallow aquifer at the base of the embankment and the underlying till using Slice models as applied to each basin

Original modeling using the Hydrus-Slice approach was reported on August 8, 2001 (Pacific Groundwater Group, 2001). The modeling reported in this revised report was performed because the original modeling used HSPF parameter AGWO as input instead of the more appropriate parameter AGWI. In addition, the following improvements and changes were made to the revised groundwater modeling:

- PGG adopted the HSPF basin boundary to define the eastern extent of new fill instead of independently-derived boundaries. The independently-derived boundary used in original modeling was similar to the HSPF basin boundary, but not exactly the same. This is a small mathematical change, not a conceptual change.

- PGG included the 1998 fill as third runway fill. Original modeling excluded the 1998 fill because the air-photo-based elevation contours used to calculate fill thickness were flown after placement of the 1998 fill. This change results in a somewhat larger Miller Creek fill area than was originally modeled.

- PGG calculated runoff from pervious areas instead of assuming that all precipitation and runon becomes groundwater recharge. The use of hourly infiltration (AGWI) and runoff (SURO) data from HSPF results in prediction of runoff from filter strips (a portion of the pervious area next to the runways) that simultaneously receive precipitation and runway runoff. This is a more accurate accounting of water performed for the proposed third runway fill area.

- Hydrus 1-D was used to model variably-saturated flow in the fill instead of Hydrus 2-D that was originally used. Hydrus 1-D was required for the revised simulations because it remains stable under the wetter and more variable conditions predicted by the AGWI and SURO model input.

The work was performed, and this report prepared, in accordance with generally accepted hydrogeologic practices, used at this time and in this vicinity, for sole application to the simulation of low-flows under the built condition, and for the sole use of the Port of Seattle. This is in lieu of other warrantees, express or implied.

2. Extent of Fill Modeled by Hydrus-Slice

The modeled fill area (MFA) represents a portion of third runway fill, within the Walker and Miller creek groundwater basins, that would receive precipitation in a post-construction ("built") condition. This area was selected based on discussions with HSPF modelers at the onset of the project. The area was modeled by Hydrus-Slice rather than HSPF for the built condition.

2.1 Geographic Extent of Fill

PGG used existing GIS coverages of pre-fill topography, "built" topography, and third runway pavement distribution to calculate areas for Hydrus-Slice modeling. A graphical approximation of the areas modeled by Hydrus-Slice (and therefore removed from the HSPF model) is shown on **Figure 2-1**. The MFA includes proposed additional runway fill in the Miller and Walker Creek basins minus the steep perimeter slopes along the western and northern edges of the embankment. Steep perimeter slopes were not included in the Hydrus-Slice MFA because surface runoff is assumed to dominate flow in these areas and HSPF is better suited to model these hydrologic conditions. The eastern margin of the MFA is defined by the limit of proposed third runway fill as previously determined by HSPF modelers.

2.2 Thickness of Fill

Fill thickness was calculated by subtracting GIS coverages of pre-fill topography from the "built" topography. A fill thickness of up to 160 feet occurs behind the West Mechanically-Stabilized-Earth (MSE) wall with significantly less fill occurring over most of the third runway area (**Figure 2-1**). For the purpose of Hydrus modeling, fill thickness was descritized into representative values of 10, 20, 30, 50, 70, 90, 110, 130, and 150 feet. Fill thickness in the area of the 1998 fill was approximated and not directly calculated as the difference between two sets of elevations.

2.3 Basin Boundaries and Area Calculations

Groundwater basin boundaries for Miller, Walker and Des Moines Creeks were located for purposes of allocating modeled groundwater flows in the MFA. The groundwater basin boundary of greatest significance in this study is the Miller-Walker divide because these are the receiving basins for groundwater discharge from the fill. A dashed line is drawn on **Figure 2-1** between the Miller and Walker Creek basins. The location of the line is co-incident with the surface water and groundwater basin boundaries used in the HSPF models of 1994 conditions (Parametrix, 2000, Figure B2-2 of Stormwater Management Plan). The Walker-Des Moines groundwater divide is south of the fill area, thus groundwater discharge from the fill will not flow to Des Moines Creek under the current or built condition. The fill areas presented in **Table 2-1** are derived from the basin boundary and model area perimeter shown on **Figure 2-1**. Areas are broken into impervious areas (IA), filter strips (FS), and other pervious areas (OPA). Impervious areas comprised 36 percent and 38 percent of the modeled fill areas in the Miller and Walker Creek basins, respectively.

IA in Walker Creek consists of only the western half of the third runway because runoff from the eastern half will drain to the east and will not flow onto new third runway fill. Runoff from the eastern half of the third runway in Walker Creek was modeled by HSPF.

3. Modeling of Infiltration with Runoff and Evapotranspiration

Precipitation on the MFA was used to calculate hourly runoff (SURO) from impervious surfaces (runway and taxiways) and hourly infiltration (AGWI) into pervious areas with a generic application of HSPF. Pervious areas were modeled as grass on flat outwash. This approach was selected, with agreement from Ecology and King County, to take advantage of HSPF's superior evapotranspiration (ET) and runoff-modeling capabilities. For pervious areas, the generic HSPF model yielded hourly volumes of water that infiltrate beyond the bottom of the root zone (AGWI) and therefore constitute groundwater recharge. That calculation was applied to filter strips and other pervious areas. A separate calculation then estimated the extent to which runoff from impervious surfaces would also infiltrate, or conversely, runoff, from filter strips. The total amount of infiltration into filter strips (a portion of AGWI and SURO) and other pervious areas (AGWI only) was then used as input to the Hydrus models. Calculated runoff was accounted-for but not used in groundwater modeling.

3.1 HSPF Input and Runoff Calculations

Aqua Terra accounted for precipitation, runoff, infiltration, and ET on an hourly basis between 1984 and 1994 using HSPF and regional parameters for grass on outwash soils with land slopes of less than five percent (Joe Brascher, personal communication, May 17, 2001). HSPF model output (AGWI) provided daily estimates of recharge below the root zone considering the effects of runoff and evapotranspiration.

HSPF also calculated hourly volumes of runoff (SURO) from a typical acre of impervious surface. Runoff from impervious surfaces will be routed into "filter strips" that treat the water prior to storage and discharge. The filter strips are part of the pervious surface of the new fill. Therefore, the SURO and AGWI water volumes were added together and compared to the infiltration capacity of the filter strips. Water in excess of the infiltration capacity of the filter strips was considered runoff, and remaining water was considered to infiltrate and become groundwater recharge. For these calculations, areas of impervious surface and filter strips were based on GIS analysis of design data. Flow was assumed uniform over the filter strip, and likely storage of water in surface irregularities was ignored. The infiltration capacity was calculated as the saturated hydraulic conductivity of the fill under a unit hydraulic gradient, over the area of the filter strip. The saturated hydraulic conductivity of the sandy fill matrix was assumed to be $1.35\text{x}10^{-4}$ cm/sec, and no flow was assumed to occur through the portion of the fill occupied by gravel particles, consistent with assumptions throughout PGG's involvement with this project. The total volume of runoff from the filter strips was 28 and 21 percent of the summed AGWI and SURO volumes for Miller and Walker Creek basins, respectively (water years 1991 through 1994 – Table 3-1).

A small amount of runoff was also calculated for "other pervious areas" (pervious areas that are not filter strips and therefore do not receive runoff) because AGWI exceeded the calculated infiltration capacity of other pervious area on occasions. This presumably occurred because of differences between HSPF predictions of runoff from flat outwash, and the runoff-evaluation method applied to the AGWI time series after receipt. The total volume of runoff from the other pervious areas was 6 percent of the AGWI volumes for both basins (water years 1991 through 1994 – Table 3-1).

The Port collected water stage measurements in a sedimentation pond that collected runoff from Phase I (1998) fill of the third runway fill embankment (Parametrix, 2000). The data were collected over about a one-month period in February 1999 and were later used by Parametrix to derive parameters for HSPF modeling of the fill. The interpretation implies a soil infiltration capacity (related to vertical hydraulic conductivity) that is lower than that of regional HSPF parameters for glacial till. The revised runoff calculations summarized above are in much better agreement with observed runoff volumes than the negligible runoff volumes assumed for original modeling reported on August 8, 2001. The observed and predicted runoff volumes are considered to be reasonably consistent although differences in the details may exist for a variety of reasons. As described in Section 4.3, the infiltration volume used in the current modeling could underestimate, and is not likely to over-estimate, actual infiltration. Modeled volumes of groundwater discharge from the fill may therefore be smaller, and are not likely to be larger, than actual discharge. For the purposes of low-flow streamflow assessment, this condition is considered conservative.

3.2 Effective Recharge

Effective recharge (ER) is the average downward groundwater flux over the entire pervious area, just below the root zone. It consists of those portions of AGWI and SURO that infiltrate. As discussed above, the filter strips and other pervious areas receive different amounts of water. In order simplify the analysis, the *average* effective recharge for the entire pervious area was calculated as the summed volume of water infiltrated in those two areas, divided by the total pervious area. Table 3-1 summarizes those water volumes.

4. Modeling of Vertical Flow Through Embankment Fill

Modeling of downward vertical flow through embankment fill describes water movement in the unsaturated or "vadose" zone between the land surface and the proposed drainage layer at the base of the fill. Downward unsaturated flow is the intermediate step between recharge at the land surface and saturated groundwater flow in the shallow aquifer (simulated by the Slice model). An overview of the unsaturated flow modeling completed for this study is presented in the following subsections.

4.1 Summary of Generic Hydrus Model

Vertical flow of effective recharge between the root zone and the water table within the embankment drainage layer was evaluated using the model Hydrus-1D, hereafter called "Hydrus" (Simunek and others, 1999). Hydrus simulates the vertical spreading of recharge fronts as they are predicted to move downward through the proposed embankment fill. Model results describe the lagging and dampening of the recharge pulse for different thicknesses of fill material. Hydrus output was used as recharge input to the Slice models (Section 5).

With the exception of using HSPF-derived recharge input values instead of values derived from average monthly rainfall, the modeling approach used in this study was conceptually identical to the Hydrus simulations completed for the Ecology study (see Appendix C of Pacific Groundwater Group, 2000). Soil characteristics were unchanged. Independent model runs were conducted for the Miller Creek basin using fill thicknesses of 150, 130, 110, 90, 70, 50, 30, and 10 feet. Model runs were conducted for the Walker Creek basin using fill thicknesses of 50, 30, 20, and 10 feet. Hydrus results indicate that substantial lagging and dampening (spreading) of seasonal recharge is likely within the fill, with the amount of lagging and dampening increasing with increased fill thickness. Discharge at the bottom of the fill is predicted to occur throughout the year.

4.2 Characterization of Fill as Soil

The texture of the modeled fill was calculated based on specifications for Phase 1 fill (installed in 1998 and 1999) and proposed embankment composition described by Hart

Crowser (1999). The calculations were also compared to the texture of Phase 1 fill based on soil samples collected by Terra Associates (1998). Details of the characterization of fill texture relative to Hydrus model input is presented in Appendix C of the Ecology study (Pacific Groundwater Group, 2000). Following are summaries of the two types of fill proposed for use in the embankment and designated in this study.

4.2.1 General Fill

Except for Type 1 soils used as fill in limited areas near the MSE walls and runways, the embankment will be comprised of imported material termed "general fill." Average bulk texture for the general fill was estimated to be 55 percent gravel and 45 percent sand-plus-fines matrix. The sand-plus-fines matrix was further estimated to be comprised of an average of 63 percent sand and 37 percent silt; clay was assumed to be absent. Soil-moisture characteristic curves and hydraulic conductivity distributions were developed for the Hydrus runs using Hydrus' version of the U.S. Soil Salinity Laboratory's computer program "Rosetta" based on the grain-size distribution of the matrix.

4.2.2 Type 1 Fill

According to embankment designs presented by Hart Crowser (1999), Type 1 soils are comprised of sand and gravel; they contain virtually no fines. These materials will be used as backfill for the MSE walls and under runways where greater compaction and drainage properties are required. Type 1 soils were assumed to be infinitely permeable and therefore provide immediate delivery of recharge to the underlying drain layer in the Slice models. Type 1 soils were therefore not modeled explicitly using Hydrus although recharge to the drain layer was considered where Type 1 soils existed in modeled areas.

4.3 Representation of Fill in Hydrus

The sand-plus-silt matrix was modeled as an evenly-distributed 45 percent of the general fill and all water flow was assumed to occur within this active matrix. To maintain a water balance while modeling water flow only through the active matrix, effective recharge values were divided by 0.45 and used as the upper boundary condition flux in Hydrus. This matrix-scaled recharge rate used in Hydrus is called the "effective matrix recharge." Logic for using this rate can be understood by considering that any precipitation falling-on, or percolating-into, clusters of gravel particles is likely to be absorbed by the surrounding sand-plus-silt matrix somewhere within the embankment. The gravel fraction of the general fill is therefore treated as inactive. The output at the bottom of the Hydrus model was then multiplied by 0.45 to redistribute flux to the bulk fill body and maintain a long-term water flux equal to the effective recharge rate.

Modeled hydraulic properties for the active fill matrix were generated with Rosetta, based on the percentages of sand and silt summarized in Section 4.2. Rosetta provides estimates of five parameters used to generate the soil moisture characteristic curve; saturated water content, residual water content, "alpha", "N", and "M" (van Genuchten, 1980). Rosetta also provides an estimate of saturated hydraulic conductivity and a factor "L" used to relate the characteristic curve to the unsaturated hydraulic conductivity curve (Mualem, 1976). A default "L" value of 0.5 was assigned by Rosetta in Hydrus, and was used in this analysis. **Table 4-1** presents the hydraulic parameters generated by Rosetta for the general fill matrix. The saturated hydraulic conductivity calculated by Rosetta was 1.35×10^{-4} cm/sec. This value is near the middle of the range presented in Freeze and Cherry (1979) for silty sand. It is near the high end of the reported glacial till range and lower than the clean sand and gravel ranges reported by the same reference.

Although the actual value(s) of hydraulic conductivity are not known for the proposed future embankment, the value calculated by Rosetta is reasonable for the anticipated texture and density of the general fill *matrix*, and is consistent with the active/inactive matrix method of modeling unsaturated flow in the embankment. Experience with testing *saturated* hydraulic conductivity of soils similar in texture to the modeled fill suggests that the Rosetta-calculated value is too low for the bulk (matrix plus gravels) general embankment fill; however, the reason for this discrepancy is the presence of large pores associated with gravels. Large pores associated with gravel deposits dominate saturated flow but can be reasonably assumed inactive under most unsaturated flow conditions because:

- the fill should remain unsaturated except in extreme conditions, and therefore unsaturated flow should predominate,
- large diameter pores associated with gravels will be the first to desaturate as drying occurs,
- over the course of the flow path, water in saturated pores will be absorbed into the finer pores due to matric tension,
- percolation theory (Silliman and Wright, 1988) suggests that continuous paths of finer pores within the matrix will exist throughout the embankment at the modeled texture (it also predicts continuous coarse pore paths which would be predominant in saturated flow),
- it was not feasible for this project to characterize soil moisture retention characteristics of gravels

This representation should be accurate for classical unsaturated flow modeling used by Hydrus and for nearly all other unsaturated flow prediction methods. However, it does not account for the observation that "fingering" of flow can occur in coarse soils under very wet conditions. Fingering occurs when saturation builds-up at one location and then rapidly drains downward through large connected pores in a saturated finger. Such fingering flow will only occur during recharge events when the ground surface, or a subsurface soil zone, becomes saturated. If fingering flow occurs because of a saturated ground surface, this modeling approach will underestimate infiltration. The likelihood of underestimating infiltration has increased relative to the original modeling approach reported on August 8 2001 because of the more variable moisture conditions predicted using hourly precipitation data and the explicit calculation of volumes that will runoff. If fingering flow occurs for substantial distances within the body of the fill, the Hydrus model will overestimate groundwater travel times between ground surface and the water table. The likelihood of overestimating vertical groundwater travel times for the wettest conditions is also somewhat increased relative to the modeling reported on August 8 2001 because of the more variable moisture conditions used in the current assessment.

4.4 Spatial Discretization of Hydrus Models

As described in Section 4.1, Hydrus models were set up to simulate a total of twelve vertical profiles for the proposed fill. Eight different thickness simulations were run for Miller Creek fill and four different thickness simulations were run for Walker Creek fill. Model runs for a given basin differ in fill thickness only. Separate runs were required for the two basins because slightly different IA/PA ratios led to different effective recharge rates.

Nodes representing the land surface were specified flux boundaries. The bottom two nodes were assigned the "water table" boundary condition, which is a constant head boundary equal to elevation head, simulating saturated conditions beneath the embankment fill. Time-series data for flow rates (specific discharge) exiting the bottom of the model domain at the water table boundary nodes were extracted and used as input to the Slice models.

Discretization of the soil profile emphasized detail within the top and bottom six inches of the column to accommodate dramatic changes in recharge and flow. Finer detail within these portions of the soil column improves accuracy in variable flow and water balance calculations as well as improving numerical model performance. Cell size increased in from a minimum of 0.01 cm at the top of the soil profile to about 0.3 inch at a depth of 6 inches. At a depth of 6 inches cells were a constant 6 inches down to 6 inches above the water table, at which point the change in intervals reverted back to 5 percent differences.

4.5 Temporal Discretization

Daily stress periods were used, and daily effective matrix recharge estimates were applied to the top of each model. Model timesteps were automatically optimized by Hydrus, and were typically on the order of 0.10 days. The models were run for water years 1984 through 1994, with only the last four water years comprising the test period. Output from the initial six years was examined visually to assure that residual effects from the initial conditions (uniform moisture) were not present during the 1991-1994 test period.

4.6 Results

Figure 4-1 shows eight daily outflow graphs for the Miller Creek basin fill over the test period. The outflow graphs represent the daily average flow of water to the embankment drain layer (or the water table within the drain) for any one of eight modeled fill thickness intervals. **Figure 4-2** presents comparable results for the Walker Creek fill. Fill thickness intervals correspond with the range of fill geometries occurring in each basin as presented in **Figure 2-1.** Effective recharge into the fill (Hydrus model input) is not shown on these figures because the input is very "spikey" and the lines obscure the model results. Nonetheless, the character of the effective recharge input can be inferred from the 10-foot-thick-fill output, which is only slightly damped and delayed relative to the input.

Figures 4-1 and 4-2 show that the recharge below the root zone is predicted to be lagged and dampened as a function of the thickness of the fill. Lagging causes the arrival of the recharge pulse to be delayed from its introduction at the land surface to its arrival at the bottom of the fill. Dampening causes a reduction in the overall range of flux in the deeper fill. Lagging and dampening both increase with increasing fill thickness and decrease with increasing annual recharge. These effects on the timing of recharge affect the arrival of flow to the top of the slice model (i.e., to the water table in the embankment drainage layer), and ultimately the arrival of baseflow to streams bordering the study area.

The Hydrus models were marginally stable during times of maximum wetness. During some model time steps, saturation was indicated at land surface as would be predicted by the runoff analysis. Hydrus was setup to permanently exclude water that would not enter the land surface at each time step. Water thus excluded was removed from the model and accounted for as a small additional component of runoff (RO3 on Table 3-1). Also, to increase model stability, recharge during one event was artificially lowered, with the removed water accounted as a fourth runoff component (RO4 on Table 3-1). RO3 and RO4 sum to less than 0.3 percent of total water and are insignificant. The runoff time series provided HSPF modelers as a product of this work included all runoff components.

Quality assurance review included comparison of total outflow between runs, and comparison of total inflow to the average total outflow. All model runs had the same total outflow to within 3 percent and 1.6 percent, respectively, for Miller and Walker Creek Hydrus models. For the Miller Creek models, total effective recharge was about 1.4 percent less than the average total outflow, likely as a result of lower storage at the end of the simulation than at the beginning. For the Walker Creek Hydrus models, total effective recharge was about 0.1 percent less than the average total outflow (for the same reason).

Hydrus erroneously predicted zero flux at the bottom boundary in a handfull of time steps. These time steps are apparent on **Figures 4-1 and 4-2.** Review of the time series output and the good mass balance indicates that errors introduced are spurious and not significant.

5. Modeling Saturated Flow Beneath the Embankment Fill

Three simple finite difference slice models were developed to simulate lateral and vertical groundwater flow within the drain layer and existing soils below the embankment. Slice configurations were based on subsurface data described in available geotechnical and hydrogeologic reports and from the pre-fill and "built" topography of the third runway area as supplied by Parametrix and the Port. Slice alignments were located based on the availability of subsurface data and are considered to describe the range of hydrogeologic and fill conditions that exist in the embankment area.

The slice models were used to accumulate recharge in the shallow water table aquifer and move it downgradient to the Miller Creek or Walker Creek wetlands under "built" conditions. Slice 1 was originally developed for the Ecology study (Pacific Groundwater Group, 2000). It was re-applied for this low-flow analysis using daily recharge data for 1984 through 1994 and a more representative runway configuration, but otherwise remained unchanged. Slices 2 and 3 were developed for the low flow analysis using new interpretations of existing hydrogeologic and fill data. The three different versions of the model were constructed to represent a range of conditions that exist within the fill embankment. The slice models are a simplification of subsurface conditions within each hydrogeologic cross section. **Figures 5-1 through 5-3** present simplified cross sections of the slice models used in this study. Slice locations are shown on **Figure 2-1**. Slice 2 was modified slightly from the version reported on August 8 2001 to include the 1998 (Phase 1) fill.

The slice models are based on a quasi-two-dimensional finite-difference formulation of the partial differential equation describing transient groundwater flow through a saturated medium. Model cells were only connected to laterally adjacent neighbors as opposed to overlying or underlying cells – thus the quasi-two-dimensional nature of the model. Each model cell can contain up to three different "soil layers", differing in thickness and hydraulic conductivity. The bottom elevation of each cell is defined by the top of the till layer, and downward flow through the till was simulated. For each cell, the model also specified a uniform specific yield of 30 percent. Recharge for each stress period (day) was derived for each cell from Hydrus output for the appropriate overlying fill thickness. The model assumes unconfined flow (variable transmissivity) under horizontal gradients defined by head differences between adjacent cells. The model was implemented in a Microsoft Excel spreadsheet, using direct (explicit) methods to solve the finite-difference equation. Details of the slice model input and functions are described further in Appendix E of the Ecology study report (Pacific Groundwater Group, 2000).

Downward flow through till was calculated using Darcy's equation, a uniform hydraulic conductivity of $4\text{x}10^{-3}$ ft/day ($1.4\text{x}10^{-6}$ cm/sec), a uniform thickness of 10 feet, and a model-calculated gradient. To calculate the gradient, the head of groundwater above the till was calculated by the model, and head at the bottom of the till was considered to be one of three values. Groundwater head at the bottom of the till was assumed equal to the elevation of that contact where groundwater in the underlying Qva aquifer was expected to be unconfined (see **Figures 5-1 through 5-3**). This condition prevailed in the eastern portions of Slices 1 and 2, and throughout Slice 3. Groundwater head below the till was considered to be equal to groundwater head above the till where the conceptual model predicted highly confined conditions. This "no vertical flow" condition was actually implemented in the model by assigning a zero hydraulic conductivity to the till where highly confined conditions were expected. That condition prevailed in the western lowland portions of Slices 1 and 2. Groundwater head at the bottom of the till, in locations of intermediate confinement of Qva groundwater, was assigned a value equal to the elevation of the mid-point of the till.

5.1 Cross Section 1 and Slice 1

This cross section is located through the thickest portion of the fill embankment with a fill thickness of up to 160 feet (**Figure 2-1**). A simplified cross section showing Slice 1 is presented in **Figure 5-1**. Slice 1 is located at the same location as the original slice model developed by PGG in the Ecology study. Hydrogeologic conditions were defined by eight subsurface explorations located along the 1,320-foot slice alignment. Fill located behind the West MSE wall was modeled using Slice 1.

The geometry and material types represented in the cross section of **Figure 5-1** were used to construct the Slice 1 model. **Tables 5-1 and 5-2** present Slice 1 model cell parameters. Because the removed portion of the HSPF model does not include the steep slopes of the embankment fill, results from Slice 1 were extracted from the portion east of cell 43 ("active model cells").

5.2 Cross Section 2 and Slice 2

Slice 2 is located through the northern portion of the fill embankment near the northern end of the third runway (**Figure 2-1**). A simplified cross section showing Slice 2 is presented in **Figure 5-2**. The slice is located to represent an intermediate fill thickness of up to 100 feet thick and crosses one taxiway in addition to the third runway. Slice 2 was developed from a generalized hydrogeologic cross section originally created by Hart Crowser through the northern toe of the fill embankment (see Section A-A' of Hart Crowser, 1999a) with supplemental information from more recent borings and shallow test pits (Hart Crowser, 2000a). The slice location is based on availability of suitable subsurface data with seven explorations located near the 1,420-foot slice alignment. Slice 2 represents subsurface conditions for the bulk of Miller Creek embankment fill.

The geometry and material types represented in the cross section of **Figure 5-2** were used to construct the Slice 2 model. **Tables 5-3 and 5-4** present Slice 2 model cell parameters. Because the removed portion of the HSPF model does not include the steep slopes of the embankment fill, results from Slice 2 were extracted from the portion east of cell 38 ("active model cells").

5.3 Cross Section 3 and Slice 3

Slice 3 is located immediately north of the South MSE wall (**Figure 2-1**). A simplified cross section showing Slice 3 is presented in **Figure 5-3**. A fill thickness of up to 40 feet occurs in the western end of this slice. The slice location was chosen through fill of intermediate thickness for the Walker Creek fill and minimal thickness for the Miller

Creek fill. Although this slice does not completely describe the variety of fill thicknesses in Walker Creek basin, the thicker portion of the fill is of small areal extent and does not justify an additional slice model. Slice 3 is partially based on a generalized hydrogeologic cross section originally created by Hart Crowser through the northern end of the South MSE wall study area (see Section E-E' of Hart Crowser, 2000b). The hydrogeologic interpretation for this slice has been modified using geotechnical data (Hart Crowser, 2000a), existing and "built" topography, and available till mapping data (AESI, 1999). Eight subsurface explorations occur along the 625-foot slice alignment.

The geometry and material types represented in the cross section of **Figure 5-3** were used to construct the Slice 3 model. **Tables 5-5 and 5-6** present Slice 3 model cell parameters. Because the removed portion of the HSPF model does not include the steep slopes of the embankment fill, results from Slice 3 were extracted from the portion east of cell 25 ("active model cells").

5.4 Individual Slice Model Results

Figures 5-4 through 5-6 present individual Slice model results for Slices 1 through 3 for water years 1991 through 1994. Results are presented as daily time series plots for three Slice model terms: Qvr/drain outflow flow downward through till, and recharge to the drain layer from the fill. The Qvr/drain outflow term is lateral groundwater flow at the western edge of the fill embankment discharging through the shallow (Qvr) aquifer and the constructed drain layer. The Qvr/drain outflow term is extracted from the western-most "active" cell in the slice, and represents subsurface flow towards downgradient receiving waters. Downward flow through till and recharge to the drain layer from the fill are summed for all active cells in the slice. Downward flow through the till represents vertical drainage to the deeper (Qva) aquifer below the till. Recharge to the drain from the fill is obtained by summing Hydrus output as it varies along the slice due to the varying thickness of overlying fill. Model results represent flow for a one-foot-wide slice of the embankment with units reported in cubic feet per day, per foot of width (ft^2/d or $ft^3/d\text{-}ft$).

Results vary substantially between the slices and indicate that a complex set of factors control the relationship between input (recharge to the drain) and output (Qvr/drain outflow and downward flow through till):

- The timing of recharge to the drain layer is controlled by the type and thickness of fill in the slice. More uniform fill thickness in Slice 3 results in more seasonal variability of recharge to the drain layer compared to Slices 1 and 2.
- Differences in the variability of Qvr/drain outflow shows that the presence of Type 1 fill causes output to be nearly as variable as input on Slice 1 where Type 1 fill exists, and to be rather smooth for the other slices where Type 1 fill is assumed to not exist. Transition of flow from wholly within the moderately-transmissive Qvr during dry and moderate periods, to a combination of the Qvr and the highly-transmissive drain layer during wet periods, may also contribute to this effect at Slice 1. The spikiness of modeled Slice 1 Qvr/drain outflow is likely greater than would actually occur.

- Longer flow-length paths and lower gradients within the Qvr and drain layer should contribute to longer horizontal travel time delays. However, longer flow lengths and steeper gradients in Slices 1 and 2 compare to shorter lengths and gentler gradients in Slice 3. This combination of gradient and flow paths for the two sets of slices causes horizontal travel time delays are more similar between the slices than might otherwise occur.
- Downward flow through the till is seasonal due to changes in aquifer saturation. Downward flow through till is also greater on average than Qvr/drain outflow, and is sensitive to till permeability. Qvr/drain outflow exceed downward flow through till during intense recharge events at Slice 1 (through Type 1 fill), and during some seasonal maxima at Slices 1 and 3.
- Seasonal maxima in Qvr/drain outflow are lagged more in dry years than in wet years (this be more a result of vertical flow delays than lateral flow delays).

Quality assurance review of Slice model results included comparison of total inflow, outflow and change in storage between runs. In all cases, the mass balance error in this comparison was less than one percent.

5.5 Method for Integrating Slice Results Over Entire Fill Areas

Groundwater discharge quantities for Miller and Walker Creeks were calculated by multiplying unit-width flow quantities from representative Slice model output by an effective basin width (EBW). This process integrates the slice model results over the entire basin. The EBW represents an idealized length over which groundwater within the embankment will discharge to the respective downgradient receiving waters. EBWs were measured (or calculated) parallel to the long axis of embankment fill, an orientation perpendicular to the slice models and expected groundwater flow lines. EBWs are associated with each Slice model and depend on the width of the basin with characteristics similar to the slice (i.e., thickness and lateral extent). For instance, the entire Walker Creek basin is best represented only by Slice 3 because the embankment fill in this basin is relatively narrow and has limited thickness variation (typically less than 40 feet thick). Walker Creek is therefore modeled by Slice 3 only and the results are integrated over the basin using a single EBW. In contrast, Miller Creek is represented by a combination of Slices 1, 2, and 3 because of variable fill geometries that occur in this basin (fill thickness ranging up to 160 feet over a variety of fill lengths). **Figure 2-1** presents the approximate segments of the Miller and Walker Creek basins that are represented by each of the Slice models. A summary of effective basin widths is presented in **Table 5-7**.

The derivation of EBWs is discussed in the following sections followed by a summary of the integrated flow results for each basin.

5.6 Effective Basin Width for Walker Creek

The EBW for Walker Creek basin was calculated to maintain a water balance for the modeled fill area (MFA) measured for the basin, where MFA=IA+FS+OPA as defined in Section 2.3. To maintain a water balance, the integrated area of the slice models must equal the MFA of the basin. When this condition is met, effective recharge for the basin should equal the effective recharge of the integrated slice model results. In the Walker Creek Basin, an EBW of 2,084 feet was calculated based on a Slice 3 length of 350 feet and an MFA of 729,547 square feet.

5.7 Effective Basin Width for Miller Creek

The total EBW for Miller Creek basin is comprised of four segments that are represented by Slices 1, 2 and 3 (**Figure 2-1**). Multiple slices were used to describe groundwater flow to Miller Creek because of the variable fill width and fill thickness in this basin. Similar to Walker Creek, the EBW for Miller Creek was adjusted to maintain a water balance for the MFA measured previously for the basin. That is, the Miller Creek basin fill area (and therefore basin recharge area) defined by the calculated total EBW was the same as the MFA used for Hydrus and Slice modeling. Because the average fill length (east-west) is considerably less than the Slice 2 modeled fill length (east-west) used to represent the north and south ends of the basin, the Slice 2 EBW was reduced to achieve the desired MFA.

The EBW for the segment represented by Slice 1 adjacent to the West MSE wall was assigned a value of 1,600 feet based on map measurements (**Figure 2-1**). The fill length over this reach is relatively uniform at approximately 1,000 feet and is close to the 1,050-foot Slice 1 model length. The map-measured length was therefore considered representative for this reach of the basin and the map length was adopted as the EBW.

The Miller Creek basin reach located north of the West MSE wall is represented by Slice 2. The northeastern corner of the runway fill has an irregular shape where the actual fill length (east-west) is less than the Slice 2 model length. The basin reach immediately south of the West MSE wall is also represented by Slice 2. The combined map width of the two Miller Creek reaches represented by Slice 2 is approximately 3,700 feet. However, to maintain a water balance for the basin, the combined EBW for Slice 2 segments was reduced relative to map widths shown on **Figure 2-1**. The combined EBW for Slice 2 segments was adjusted to 2,699 feet to maintain the water balance. By adjusting the Slice 2 EBW in this manner, an MFA of 5,001,390 square feet was calculated which is approximately equal to the GIS-measured MFA of 5,001,205 square feet.

The southern reach of the Miller Creek basin is represented by Slice 3 where the fill is relatively thin and narrow (east-west). The EBW for this reach of Miller Creek was assigned as the map-estimated length 930 feet. The actual fill length (east-west) of 340 feet is closely approximated by the modeled slice width of 350 feet. The map-measured EBW is therefore considered representative for this reach of the basin as mass balance is maintained.

5.8 Integrated Flow Estimates for Walker Creek Fill

Integrated estimates of Qvr/drain outflow and downward flow through till for the Walker Creek fill area for water years 1991 through 1994 are presented in **Figure 5-7**. Also shown is the effective recharge input to the Hydrus model. Thus, Figure 5-7 indicates changes in timing of flows resulting from both vertical and lateral groundwater travel. Integrated flows for Walker Creek are the product of the 2,084-ft EBW discussed in Section 5.6 and the model results for Slice 3 discussed in Section 5.4. **Figure 5-7** shows that the timing and magnitude of Qvr/drain outflow varies seasonally, with maximum flows predicted during spring or early summer and minimum flows predicted during winter. Estimated annual maximum Qvr/drain outflows through the fill range between about 3,500 cubic feet per day (cfd) in water year 1991 with a peak flow predicted in late March, and about 1500 cfd in 1994 with a peak flow predicted in late April. Estimated annual minimum Qvr/drain outflows are predicted to occur between October and December, with some years experiencing a period of no flow from the Qvr/drain. High flows lag behind the onset of recharge season because time is required for unsaturated flow to transport recharge through the embankment fill and because time is required for lateral flow from areas of recharge to the downgradient end of the model.

Integrated till seepage rates for the Walker Creek basin fill increase rapidly in November or December when the downward moving recharge within the embankment reaches the water table. This effect is accentuated in the Walker Creek case because of the narrow range of fill thicknesses. After a long period of nearly constant discharge following the sudden rise, a gradual decline occurs in late summer. Seepage through the till is estimated to occur at maximum annual rates of 2200 to 2400 cfd for the four year period shown in **Figure 5-7**. Downward flow through the till is predicted to occur at some rate over the entire year.

Quality assurance review included comparison of total inflow to total outflow. For Walker Creek, integrated outflow was about 4 percent greater than total effective recharge for the 11-year test period, likely as a result of lower groundwater storage at the end of the simulation than at the beginning, and/or the coarseness of slice model cell resolution which prevented exact replication of the GIS-measured IA and PA.

5.9 Integrated Flow Estimates for Miller Creek Fill

Integrated estimates of Qvr/drain outflow and downward flow through till for the Miller Creek Fill area for water years 1991 through 1994 are presented in **Figure 5-8**. Integrated flows are the sum of the products of the effective basin widths discussed in Section 5.7 and the model results for Slices 1, 2, and 3 presented in Section 5.4. **Figure 5-8** shows relatively constant Qvr/drain outflow rates from the Miller Creek fill embankment, punctuated by spikes during rainstorms, and a seasonal maximum in June and July of the relatively wet year of 1991. The spikiness is to some extent a modeling artifact of the infinite permeability assumed for Type 1 fill. Actual flow rates would likely be steadier. Estimated annual maximum Qvr/drain outflows range from about 18,000 cfd in April of 1991 to about 8,000 cfd in late-July of 1994 following a year of low recharge.

Integrated downward flow through the till for the Miller Creek basin fill is relatively constant, but with a smooth seasonal pattern. Model estimates of flow range from about 16,000 to 7,000 cfd. Maxima are in April to June. Minima are in October and November.

Quality assurance review included comparison of total inflow to total outflow. For Miller Creek, integrated outflow was 3 percent greater than total effective recharge for the 11-year test period, likely as a result of lower groundwater storage at the end of the simulation than at the beginning, and/or coarseness of cell size resolution in the slices which prevented exact replication of the GIS-measured IA and PA.

5.10 Use of Integrated Flow Estimates

Integrated flow estimates for Miller and Walker Creek basins were transmitted to Parametrix and Aqua Terra for use in HSPF models of Miller and Walker Creeks. Time series of total daily discharge (volume per day) from above the till (Qvr/drain outflow), and total daily discharge through the till (downward flow through the till) were provided. In addition, total runoff as an hourly time series was provided. All volumes were for the MFAs within the Miller Creek and Walker Creek basins. Parametrix and Aqua Terra used the flow estimates developed in this modeling study as part of a low-stream-flow impact evaluation.

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TABLES

Table 2-1
Summary of Areas Modeled by Hydrus-Slice

	Miller Creek Basin		Walker Creek Basin	
	square feet	acres	square feet	acres
Filter Strip Area (FS)	1,456,854	33.44	353,133	8.11
Other Pervious Fill Area (OPA)	1,746,649	40.10	99,342	2.28
Runway and Taxiway Impervious Area (IA)	1,797,702	41.27	277,072	6.36
Total Modeled Fill Area (MFA) in Basin	5,001,205	114.81	729,547	16.75
IA/total pervious area	0.56		0.61	
FS/PA	0.45		0.78	
IA/total Area	0.36		0.38	

Table 3-1
Summary of Water Volumes

	Water Available to Filer Strip	Water Available to OPA	Runoff from Filter Strip (RO1)	Runoff from Other Pervious Area (RO2)	Water excluded by Hydrus (RO3)	Water artificially removed from Hydrus to promote stability (RO4)	Total Runoff	Total Infiltration
Miller Creek Modeled Fill Area (ft3)	69,006,366	29,689,341	19,625,881	1,652,948	220,585	0	21,499,415	77,196,293
Miller Creek Modeled Fill Area (percent of total water)	70%	30%	20%	2%	0%	0%	22%	78%
Walker Creek Modeled Fill Area (ft3)	12,821,485	1,688,604	2,650,317	94,013	40,091	8,686	2,793,108	11,716,981
Walker Creek Modeled Fill Area (percent of total water)	88%	12%	18%	1%	0%	0%	19%	81%

Table 4-1
Summary of Hydraulic Parameters Used for Fill Matrix in the Hydrus-2D Model

Sand Fraction of matrix	63%
Silt Fraction of matrix	37%
Clay Fraction of matrix	0
Saturated Volumetric Water Content of matrix	0.25
Residual Volumetric Water Content of matrix	0.02
"alpha" (1/cm)	0.088
"N"	1.35
Saturated Hydraulic Conductivity (cm/sec) of matrix	1.35×10^{-4}

Table 5-1
Slice 1 Model Parameters for Different Cell Types

Model Parameters for Cells Types

	Cell Type 1	**Cell Type 2**	**Cell Type 3**
Surficial Soil	removed	removed	removed
Aquifer Materials	fill	outwash stringers	peat & outwash
Land Cover	embankment	embankment	embankment
Wetland/Upland	upland	upland	wetland
Bottom Layer Hydraulic Conductivity (ft/d)	300	6	2.65
Top of Bottom Layer (ft above till)	4	7.5	7.5
Middle Layer Hydraulic Conductivity (ft/d)		300	300
Top of Middle Layer (ft above till)		11.5	11.5
Upper Layer Hydraulic Conductivity (ft/d)			
Top of Upper Layer (ft above till)			
Maximum Saturated Thickness (ft)	4	11.5	11.5
Gradient of Top of Till (ft/ft)	18.75%	18.75%	3.60%
Full Thickness Hydraulic Conductivity (ft/d)	300	108.2608696	106.076087
Maximum Subsurface Flow (cfd)	225	233.4375	43.9155
Maximum Downgradient Flow (cfd)	233.4375	43.9155	124.2
Cell Length (ft)	25	25	25
Specific Yield	0.3	0.3	0.3
Maximum Storage (cubic ft)	30	86.25	86.25
Bottom Layer Storage (cubic ft)	30	56.25	56.25

Model Constants

Till Thickness (ft)	10
Till Permeability Beneath Uplands (ft/d)	0.004
Till Permeability Beneath Wetlands (ft/d)	0
Outwash Permeability (ft/d)	6
Peat Permeability (ft/d)	1
Percent Outwash in Peaty Aquifer	0.33
Peaty Aquifer Permeability (ft/d)	2.65
Drain Material Permeability (ft/d)	300
Till Derived Soil Permeability (ft/d)	4
Outwash Derived Soil Permeability (ft/d)	4
Wetland Surficial Soil Permeability (ft/d)	1
Minimum Saturation Considered for h and T (ft)	0.0001

NOTE: All values are for a vertical slice of 1-foot width.

Time Stepping	
user defined model timestep (d)	0.1

Table 5-2
Slice 1 Model Cell Parameters

Cell ID	Distance from Outlet	Top of Till Elevation	Cell Length (ft)	Cell Type	Till Perme-ability (ft/d)	Head at Bottom of Till	Maximum Subsurface Outflow (cfd)	Specific Yield	Maximum Storage (cf)	Fill Material	Embankment Thickness (ft)	Modeled "Effective" Embankment Thickness (ft)	
1	1137.5	385.0438	25	1	0.004	375.0438	225	0.3	30	Type 2	3	0	
2	1112.5	380.3563	25	1	0.004	370.3563	225	0.3	30	Type 2	7	10	
3	1087.5	375.6688	25	1	0.004	365.6688	225	0.3	30	Type 2	11	10	
4	1062.5	370.9813	25	1	0.004	360.9813	225	0.3	30	Type 2	14	10	
5	1037.5	366.2938	25	1	0.004	356.2938	225	0.3	30	Type 2	19	10	
6	1012.5	361.6063	25	1	0.004	351.6063	225	0.3	30	Type 2	24	-99	taxiway, no recharge
7	987.5	356.9188	25	1	0.004	346.9188	225	0.3	30	Type 2	27	30	
8	962.5	352.2313	25	1	0.004	342.2313	225	0.3	30	Type 2	32	-99	taxiway, no recharge
9	937.5	347.5438	25	1	0.004	337.5438	225	0.3	30	Type 2	35	30	
10	912.5	342.8563	25	1	0.004	332.8563	225	0.3	30	Type 2	40	-99	taxiway, no recharge
11	887.5	338.1688	25	1	0.004	328.1688	225	0.3	30	Type 2	44	50	
12	862.5	333.4813	25	1	0.004	323.4813	225	0.3	30	Type 2	49	-99	taxiway, no recharge
13	837.5	328.7938	25	1	0.004	318.7938	225	0.3	30	Type 2	54	50	
14	812.5	324.1063	25	1	0.004	314.1063	225	0.3	30	Type 2	57	-99	taxiway, no recharge
15	787.5	319.4188	25	1	0.004	309.4188	225	0.3	30	Type 2	60	50	
16	762.5	314.7313	25	2	0.004	304.7313	233.4375	0.3	86.25	Type 2	64	-99	taxiway, no recharge
17	737.5	310.0438	25	2	0.004	300.0438	233.4375	0.3	86.25	Type 2	69	70	
18	712.5	305.3563	25	2	0.004	295.3563	233.4375	0.3	86.25	Type 2	74	70	
19	687.5	300.6688	25	2	0.004	290.6688	233.4375	0.3	86.25	Type 2	78	70	
20	662.5	295.9813	25	2	0.004	285.9813	233.4375	0.3	86.25	Type 2	84	90	
21	637.5	291.2938	25	2	0.004	281.2938	233.4375	0.3	86.25	Type 2	90	90	
22	612.5	286.6063	25	2	0.004	276.6063	233.4375	0.3	86.25	Type 2	96	90	
23	587.5	281.9188	25	2	0.004	271.9188	233.4375	0.3	86.25	Type 2	101	110	
24	562.5	277.2313	25	2	0.004	267.2313	233.4375	0.3	86.25	Type 2	105	110	
25	537.5	272.5438	25	2	0.004	267.5438	233.4375	0.3	86.25	Type 2	111	110	
26	512.5	267.8563	25	2	0.004	262.8563	233.4375	0.3	86.25	Type 2	116	-99	runway, no recharge
27	487.5	263.1688	25	2	0.004	258.1688	233.4375	0.3	86.25	Type 2	120	-99	runway, no recharge
28	462.5	258.4813	25	2	0.004	253.4813	233.4375	0.3	86.25	Type 2	125	-99	runway, no recharge
29	437.5	253.7938	25	2	0.004	248.7938	233.4375	0.3	86.25	Type 2	128	-99	runway, no recharge
30	412.5	249.1063	25	2	0.004	244.1063	233.4375	0.3	86.25	Type 2	132	-99	runway, no recharge
31	387.5	244.4188	25	2	0.004	239.4188	233.4375	0.3	86.25	Type 2	138	-99	runway, no recharge
32	362.5	239.7313	25	2	0.004	234.7313	233.4375	0.3	86.25	Type 2	142	-99	runway, no recharge
33	337.5	235.0438	25	2	0.004	230.0438	43.9155	0.3	86.25	Type 2	147	-99	runway, no recharge
34	312.5	232.25	25	5	0	222.25	43.9155	0.3	86.25	Type 2	148	-99	runway, no recharge
35	287.5	231.35	25	5	0	221.35	43.9155	0.3	86.25	Type 2	148	150	
36	262.5	230.45	25	5	0	220.45	43.9155	0.3	86.25	Type 2	148	150	
37	237.5	229.55	25	5	0	219.55	43.9155	0.3	86.25	Type 2	148	150	
38	212.5	228.65	25	5	0	218.65	43.9155	0.3	86.25	Type 2	148	150	
39	187.5	227.75	25	5	0	217.75	43.9155	0.3	86.25	Type 2	148	150	
40	162.5	226.85	25	5	0	216.85	43.9155	0.3	86.25	Type 1	148	0	
41	137.5	225.95	25	5	0	215.95	43.9155	0.3	86.25	Type 1	146	0	
42	112.5	225.05	25	5	0	215.05	43.9155	0.3	86.25	Type 1	145	0	
43	87.5	224.15	25	5	0	214.15	43.9155	0.3	86.25	Type 1	115	0	not included in mass balance
44	62.5	223.25	25	5	0	213.25	43.9155	0.3	86.25	Type 1	35	0	not included in mass balance
45	37.5	222.35	25	5	0	212.35	43.9155	0.3	86.25	Type 1	7	0	not included in mass balance
46	12.5	221.45	25	5	0	211.45	9999	0.3	86.25	Type 1	0	0	not included in mass balance

Table 5-3
Slice 2 Model Parameters for Different Cell Types

Model Parameters for Cells Types	cells 1-3, 8-9 **Cell Type 1**	cells 4-7 **Cell Type 2**	cells 10-13 **Cell Type 3**	cells 14-28 **Cell Type 4**	cells 29-43 **Cell Type 5**	cells 44-46 **Cell Type 6**
Surficial Soil	removed	removed	removed	removed	removed	removed
Aquifer Materials	outwash stringers	outwash stringers	outwash stringers	outwash stringers	outwash stringers	outwash stringers
Land Cover	embankment	embankment	embankment	embankment	embankment	embankment
Wetland/Upland	upland	upland	upland	upland	upland	upland
Bottom Layer Hydraulic Conductivity (ft/d)	6	6	6	6	6	6
Top of Bottom Layer (ft above till)	39.5	45	28.25	15	15	15
Middle Layer Hydraulic Conductivity (ft/d)	300	300	300	300	300	300
Top of Middle Layer (ft above till)	43.5	49	32.25	19	19	19
Upper Layer Hydraulic Conductivity (ft/d)						
Top of Upper Layer (ft above till)						
Maximum Saturated Thickness (ft)	43.5	49	32.25	19	19	19
Gradient of Top of Till (ft/ft)	0.0908	0.0908	0.0908	0.0908	0.0507	0.0165
Full Thickness Hydraulic Conductivity (ft/d)	33.03448276	30	42.46511628	67.89473684	67.89473684	67.8947368
Maximum Subsurface Flow (cfd)	130.4796	133.476	124.3506	117.132	65.403	21.285
Maximum Downgradient Flow (cfd)	133.476	65.403	21.285	117.132	65.403	21.285
Cell Length (ft)	30	30	30	30	30	30
Specific Yield	0.3	0.3	0.3	0.3	0.3	0.3
Maximum Storage (cubic ft)	391.5	441	290.25	171	171	171
Bottom Layer Storage (cubic ft)	355.5	405	254.25	135	135	135

Model Constants	
Till Thickness (ft)	10
Till Permeability Beneath Uplands (ft/d)	0.004
Till Permeability Beneath Wetlands (ft/d)	0
Outwash Permeability (ft/d)	6
Peat Permeability (ft/d)	1
Percent Outwash in Peaty Aquifer	33%
Peaty Aquifer Permeability (ft/d)	2.65
Drain Material Permeability (ft/d)	300
Till Derived Soil Permeability (ft/d)	4
Outwash Derived Soil Permeability (ft/d)	4
Wetland Surficial Soil Permeability (ft/d)	1
Minimum Saturation Considered for h and T (ft)	0.0001
user defined model timestep (d)	0.1

NOTE: All values are for a vertical slice of 1-foot width.

Table 5-4
Slice 2 Model Cell Parameters

Cell ID	Distance from Outlet	Top of Till Elevation	Cell Length (ft)	Cell Type	Till Perme-ability (ft/d)	Head at Bottom of Till	Maximum Subsurface Outflow (cfd)	Specific Yield	Maximum Storage (cf)	Fill Material	Embankment Thickness (ft)	Modeled "Effective" Embankment Thickness (ft)	
1	1365	371.9939	30	1	0.004	361.9939	130.4796	0.3	391.5	Type1	0	0	drain only, no overlying fill
2	1335	369.0941	30	1	0.004	359.0941	130.4796	0.3	391.5	Type1	0	0	drain only, no overlying fill
3	1305	366.1944	30	1	0.004	356.1944	130.4796	0.3	391.5	Type 2	0.5432	0	
4	1275	363.2946	30	2	0.004	353.2946	133.476	0.3	441	Type 2	1.3605	0	
5	1245	360.3949	30	2	0.004	350.3949	133.476	0.3	441	Type 2	2.1778	0	
6	1215	357.4951	30	2	0.004	347.4951	133.476	0.3	441	Type 2	9	10	
7	1185	354.5954	30	2	0.004	344.5954	133.476	0.3	441	Type 2	25	-99	taxiway/unspec., no recharge
8	1155	351.6956	30	1	0.004	341.6956	130.4796	0.3	391.5	Type 2	32	30	
9	1125	348.7959	30	1	0.004	338.7959	130.4796	0.3	391.5	Type 2	39	-99	taxiway/unspec., no recharge
10	1095	345.8961	30	3	0.004	335.8961	124.3506	0.3	290.25	Type 2	44	50	
11	1065	342.9964	30	3	0.004	332.9964	124.3506	0.3	290.25	Type 2	49	-99	taxiway/unspec., no recharge
12	1035	340.0966	30	3	0.004	330.0966	124.3506	0.3	290.25	Type 2	51	50	
13	1005	337.1735	30	3	0.004	327.1735	124.3506	0.3	290.25	Type 2	53	-99	taxiway/unspec., no recharge
14	975	334.2466	30	4	0.004	324.2466	117.132	0.3	171	Type 2	54	50	
15	945	331.3197	30	4	0.004	321.3197	117.132	0.3	171	Type 2	55	-99	taxiway/unspec., no recharge
16	915	328.3928	30	4	0.004	318.3928	117.132	0.3	171	Type 2	58	50	
17	885	325.4658	30	4	0.004	315.4658	117.132	0.3	171	Type 2	59	50	
18	855	322.5389	30	4	0.004	312.5389	117.132	0.3	171	Type 2	62.6913	70	
19	825	320.0984	30	4	0.004	310.0984	117.132	0.3	171	Type 2	66.5809	70	
20	795	317.669	30	4	0.004	307.669	117.132	0.3	171	Type 2	70.4705	70	
21	765	315.2396	30	4	0.004	305.2396	117.132	0.3	171	Type 2	74.3601	70	
22	735	312.8102	30	4	0.004	307.8102	117.132	0.3	171	Type 2	77.8707	-99	runway, no recharge
23	705	310.3808	30	4	0.004	305.3808	117.132	0.3	171	Type 2	81.0024	-99	runway, no recharge
24	675	307.9514	30	4	0.004	302.9514	117.132	0.3	171	Type 2	84.1341	-99	runway, no recharge
25	645	305.5219	30	4	0.004	300.5219	117.132	0.3	171	Type 2	86.9	-99	runway, no recharge
26	615	303.0925	30	4	0.004	298.0925	117.132	0.3	171	Type 2	89.3	-99	runway, no recharge
27	585	300.6631	30	4	0.004	295.6631	117.132	0.3	171	Type 2	91.1885	-99	runway, no recharge
28	555	298.4282	30	4	0.004	293.4282	117.132	0.3	171	Type 2	92.2579	-99	runway, no recharge
29	525	296.9078	30	5	0	286.9078	65.403	0.3	171	Type 2	92.7119	-99	runway, no recharge
30	495	295.3875	30	5	0	285.3875	65.403	0.3	171	Type 2	93.1833	90	
31	465	293.8671	30	5	0	283.8671	65.403	0.3	171	Type 2	93.7422	90	
32	435	292.3468	30	5	0	282.3468	65.403	0.3	171	Type 2	94.301	90	
33	405	290.8264	30	5	0	280.8264	65.403	0.3	171	Type 2	94.8599	90	
34	375	289.3061	30	5	0	279.3061	65.403	0.3	171	Type 2	95.1136	90	
35	345	287.7858	30	5	0	277.7858	65.403	0.3	171	Type 2	95.0621	90	
36	315	286.2654	30	5	0	276.2654	65.403	0.3	171	Type 2	95.0105	90	
37	285	284.7451	30	5	0	274.7451	65.403	0.3	171	Type 2	94.9444	90	top of embankment and western edge of area receiving recharge
38	255	283.2247	30	5	0	273.2247	65.403	0.3	171	Type 2	83.3366	-99	no recharge
39	225	281.7044	30	5	0	271.7044	65.403	0.3	171	Type 2	71.7288	-99	no recharge
40	195	280.184	30	5	0	270.184	65.403	0.3	171	Type 2	60.1209	-99	no recharge
41	165	278.6637	30	5	0	268.6637	65.403	0.3	171	Type 2	48.5131	-99	no recharge
42	135	277.1433	30	5	0	267.1433	65.403	0.3	171	Type 2	37.6989	-99	no recharge
43	105	275.623	30	5	0	265.623	65.403	0.3	171	Type 2	27.0434	-99	no recharge
44	75	274.7676	30	6	0	264.7676	21.285	0.3	171	Type 2	16.388	-99	no recharge
45	45	274.2734	30	6	0	264.2734	21.285	0.3	171	Type 2	5.5944	-99	no recharge
46	15	273.7791	30	6	0	263.7791	21.285	0.3	171	Type 2	0	-99	no recharge

Table 5-5
Slice 3 Model Parameters for Different Cell Types

	Cell Type 1	Cell Type 2	Cell Type 3
Surficial Soil	removed	removed	removed
Aquifer Materials	outwash stringers	outwash stringers	outwash stringers
Land Cover	embankment	embankment	embankment
Wetland/Upland	upland	upland	upland
Bottom Layer Hydraulic Conductivity (ft/d)	6	6	6
Top of Bottom Layer (ft above till)	2.5	2.5	4.75
Middle Layer Hydraulic Conductivity (ft/d)	300	300	300
Top of Middle Layer (ft above till)	3	6.5	8.75
Upper Layer Hydraulic Conductivity (ft/d)			
Top of Upper Layer (ft above till)			
Maximum Saturated Thickness (ft)	3	6.5	8.75
Gradient of Top of Till (ft/ft)	0.1711	0.0518	0.0518
Full Thickness Hydraulic Conductivity (ft/d)	55	186.9230769	140.4
Maximum Subsurface Flow (cfd)	28.2315	62.937	63.6363
Maximum Downgradient Flow (cfd)	28.2315	62.937	63.6363
Cell Length (ft)	25	25	25
Specific Yield	0.3	0.3	0.3
Maximum Storage (cubic ft)	22.5	48.75	65.625
Bottom Layer Storage (cubic ft)	18.75	18.75	35.625

Model Constants	
Till Thickness (ft)	10
Till Permeability Beneath Uplands (ft/d)	0.004
Till Permeability Beneath Wetlands (ft/d)	0
Outwash Permeability (ft/d)	6
Peat Permeability (ft/d)	1
Percent Outwash in Peaty Aquifer	0.33
Peaty Aquifer Permeability (ft/d)	2.65
Drain Material Permeability (ft/d)	300
Till Derived Soil Permeability (ft/d)	4
Outwash Derived Soil Permeability (ft/d)	4
Wetland Surficial Soil Permeability (ft/d)	1
Minimum Saturation Considered for h and T (ft)	0.0001
Time Stepping	
user defined model timestep (d)	0.1

NOTE: All values are for a vertical slice of 1-foot width.

Table 5-6
Slice 3 Model Cell Parameters

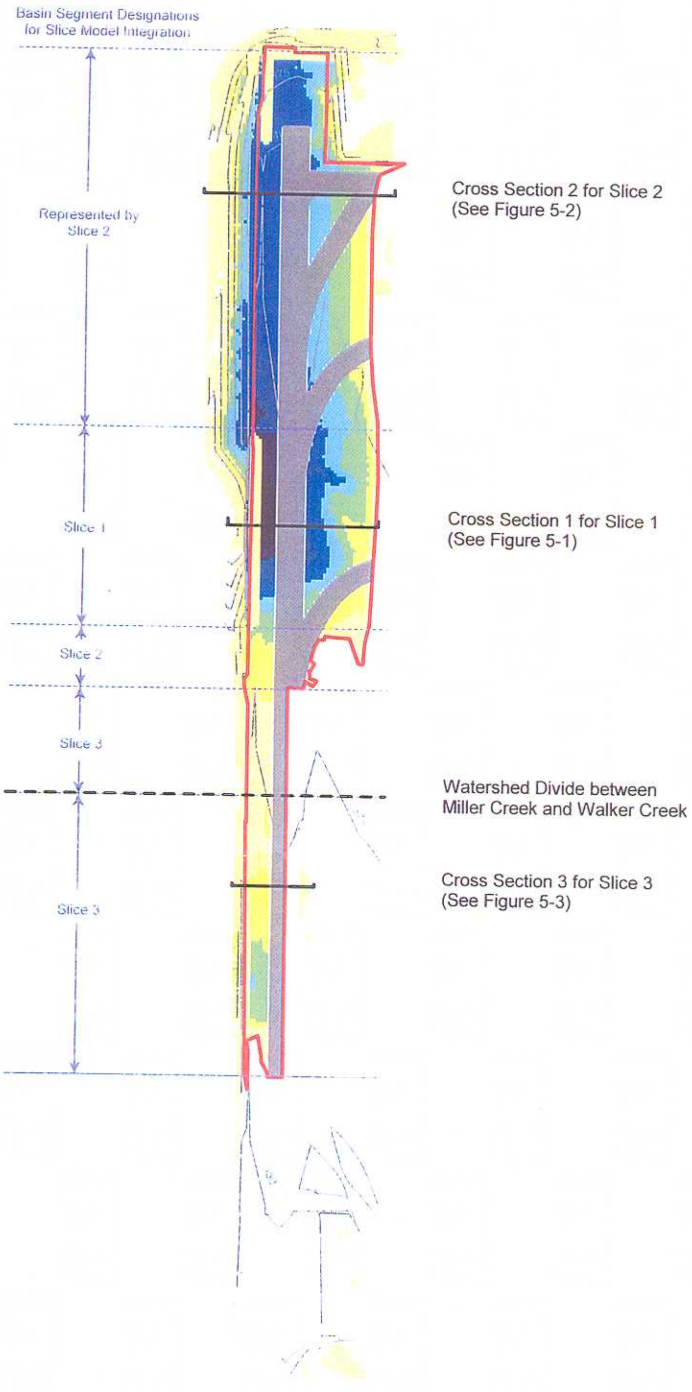
Cell ID	Distance from Outlet	Top of Till Elevation	Cell Length (ft)	Cell Type	Till Perme-ability (ft/d)	Head at Bottom of Till	Maximum Subsurface Outflow (cfd)	Specific Yield	Maximum Storage (cf)	Fill Material	Embankment Thickness (ft)	Modeled "Effective" Embankment Thickness (ft)	
1	612.5	368.7677	25	1	0.004	358.7677	28.2315	0.3	22.5	Type 2	0	-99	drain only, no overlying fill, excluded from model via zero recharge
2	587.5	366.3032	25	1	0.004	356.3032	28.2315	0.3	22.5	Type 2	0	-99	drain only, no overlying fill, excluded from model via zero recharge
3	562.5	363.9638	25	2	0.004	353.9638	62.937	0.3	48.75	Type 2	0	-99	drain only, no overlying fill, excluded from model via zero recharge
4	537.5	362.6697	25	2	0.004	352.6697	62.937	0.3	48.75	Type 2	0.8512	-99	excluded from model via zero recharge
5	512.5	361.3756	25	2	0.004	351.3756	62.937	0.3	48.75	Type 2	2.1642	-99	excluded from model via zero recharge
6	487.5	360.0815	25	2	0.004	350.0815	62.937	0.3	48.75	Type 2	3.6315	-99	runway, no recharge
7	462.5	358.7874	25	2	0.004	348.7874	62.937	0.3	48.75	Type 2	5.3445	-99	runway, no recharge
8	437.5	357.4933	25	2	0.004	347.4933	62.937	0.3	48.75	Type 2	7.0575	-99	runway, no recharge
9	412.5	356.1992	25	2	0.004	346.1992	62.937	0.3	48.75	Type 2	8.7706	-99	runway, no recharge
10	387.5	354.9051	25	2	0.004	344.9051	62.937	0.3	48.75	Type 2	10.4836	-99	runway, no recharge
11	362.5	353.611	25	2	0.004	343.611	62.937	0.3	48.75	Type 2	11.8881	-99	runway, no recharge
12	337.5	352.317	25	2	0.004	342.317	62.937	0.3	48.75	Type 2	12.8011	-99	runway, no recharge
13	312.5	351.0229	25	2	0.004	341.0229	62.937	0.3	48.75	Type 2	13.5926	-99	runway, no recharge
14	287.5	349.7288	25	2	0.004	339.7288	62.937	0.3	48.75	Type 2	14.3831	-99	runway, no recharge
15	262.5	348.4347	25	2	0.004	338.4347	62.937	0.3	48.75	Type 2	15.1737	-99	runway, no recharge
16	237.5	347.1406	25	2	0.004	337.1406	62.937	0.3	48.75	Type 2	15.7615	20	
17	212.5	345.8465	25	2	0.004	335.8465	62.937	0.3	48.75	Type 2	16.1106	20	
18	187.5	344.5524	25	2	0.004	334.5524	62.937	0.3	48.75	Type 2	16.5094	20	
19	162.5	343.2583	25	2	0.004	333.2583	62.937	0.3	48.75	Type 2	16.9081	20	
20	137.5	341.9642	25	2	0.004	331.9642	62.937	0.3	48.75	Type 2	17.3068	20	
21	112.5	340.6701	25	2	0.004	330.6701	62.937	0.3	48.75	Type 2	17.7056	20	
22	87.5	339.376	25	2	0.004	329.376	62.937	0.3	48.75	Type 2	18.1308	20	
23	62.5	338.0819	25	3	0.004	328.0819	63.6363	0.3	65.625	Type 2	19.1419	20	
24	37.5	336.7878	25	3	0.004	326.7878	63.6363	0.3	65.625	Type 2	17.3761	20	top of embankment and western edge of area receiving recharge in this cell
25	12.5	335.4937	25	3	0.004	325.4937	63.6363	0.3	65.625	Type 2	6.5615	-99	no recharge

Table 5-7
Summary of Effective Basin Widths for Walker and Miller Creek Flow Estimates

Basin & Slice Representation	Impermeable Area, IA (sf)	Permeable Area, PA= FS+OPA (sf)	Modeled Fill Area (MFA) = IA+PA (sf)	Slice Active Cell Count	Slice Model Cell Length (ft)	Active Slice Length (ASL, ft)	Effective Basin Width (EBW, ft)	Approx. Mapped Basin Width (MBW, ft)	Fraction of EBW
Walker Creek	277,072	452,475	729,547						
Slice 3				14	25	350	2,084	2,300	100.0%
Miller Creek	1,797,702	3,203,503	5,001,205				5,229	6,230	
Slice 1				42	25	1,050	1,600	1,600	30.6%
Slice 2				37	30	1,110	2,699	3,700	51.6%
Slice 3				14	25	350	930	930	17.8%

Note: lengths are measured east-west and widths are measured north-south.

FIGURES



Depth of Fill (feet)

- 0 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- 101 - 120
- 121 - 140
- 141 - 160

Approximate Area Modeled by Hydrus and Slice (Clipped from HSPF)*

Impervious Area

"Built" Elevation Contours (25 ft interval)

N

0 1000 Feet

1:12,000

Figure 2-1

Site Features for Hydrus-Slice Modeling

SeaTac Third Runway
Embankment Fill Modeling
JE0105

Pacific Groundwater Group

k:/pony/seatac_ii/3rdrunway_depthoffill/3rdrunway_010511.apr (figure 2-1), 11/15/01

Figure 4-2 - Hydrus Model Output for Walker Creek Fill - Water Years 1991 - 1994

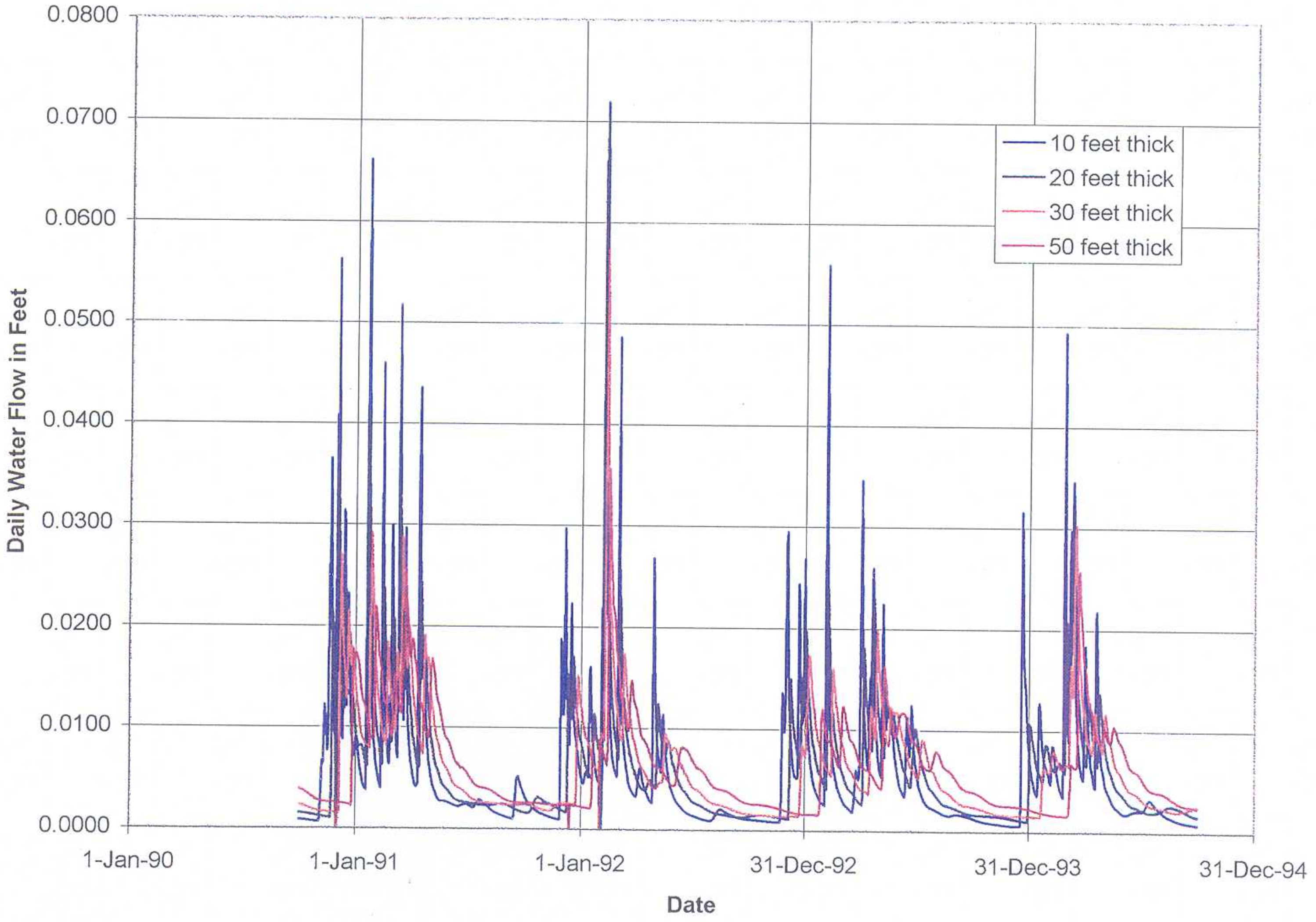
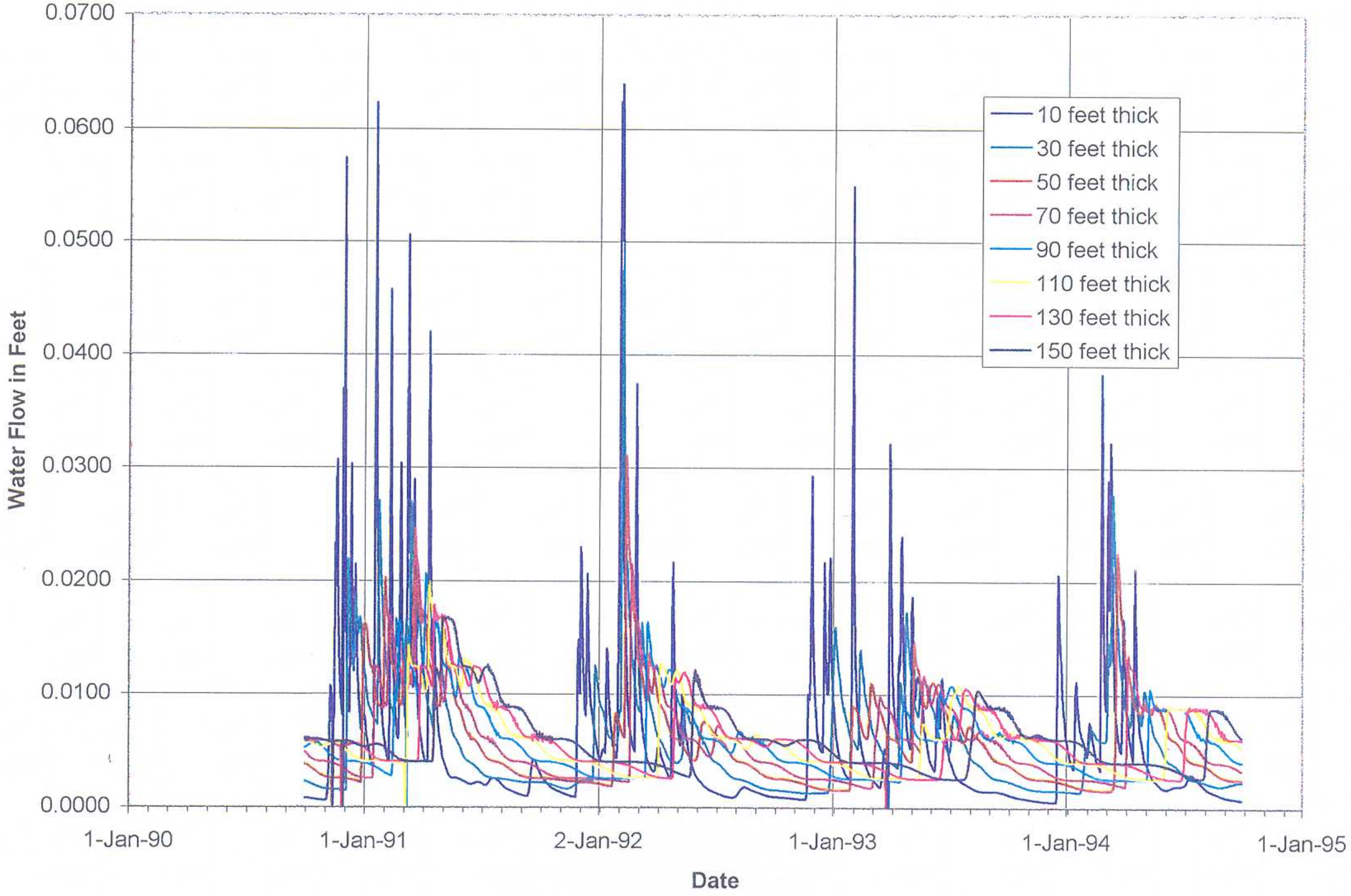
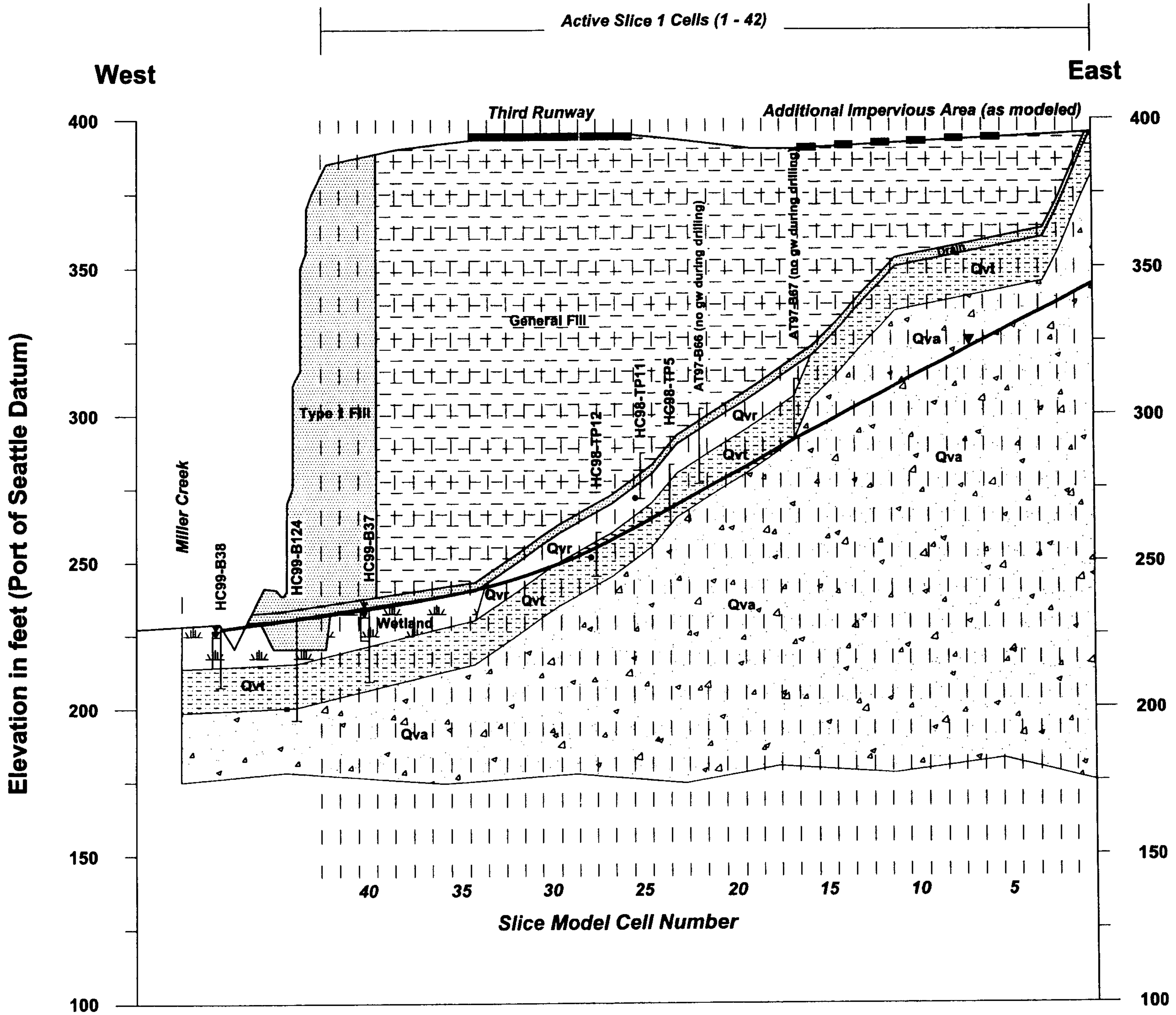


Figure 4-1 - Hydrus Model Output for Miller Creek Fill - Water Years 1991 - 1994





LEGEND

Groundwater Elevation
Groundwater Seepage Elevation
Conceptual Water Table

General Fill
Type 1 Fill
Wetland

Qvr - Vashon Recessional Outwash
Qvt - Vashon Till
Qva - Vashon Advance Outwash

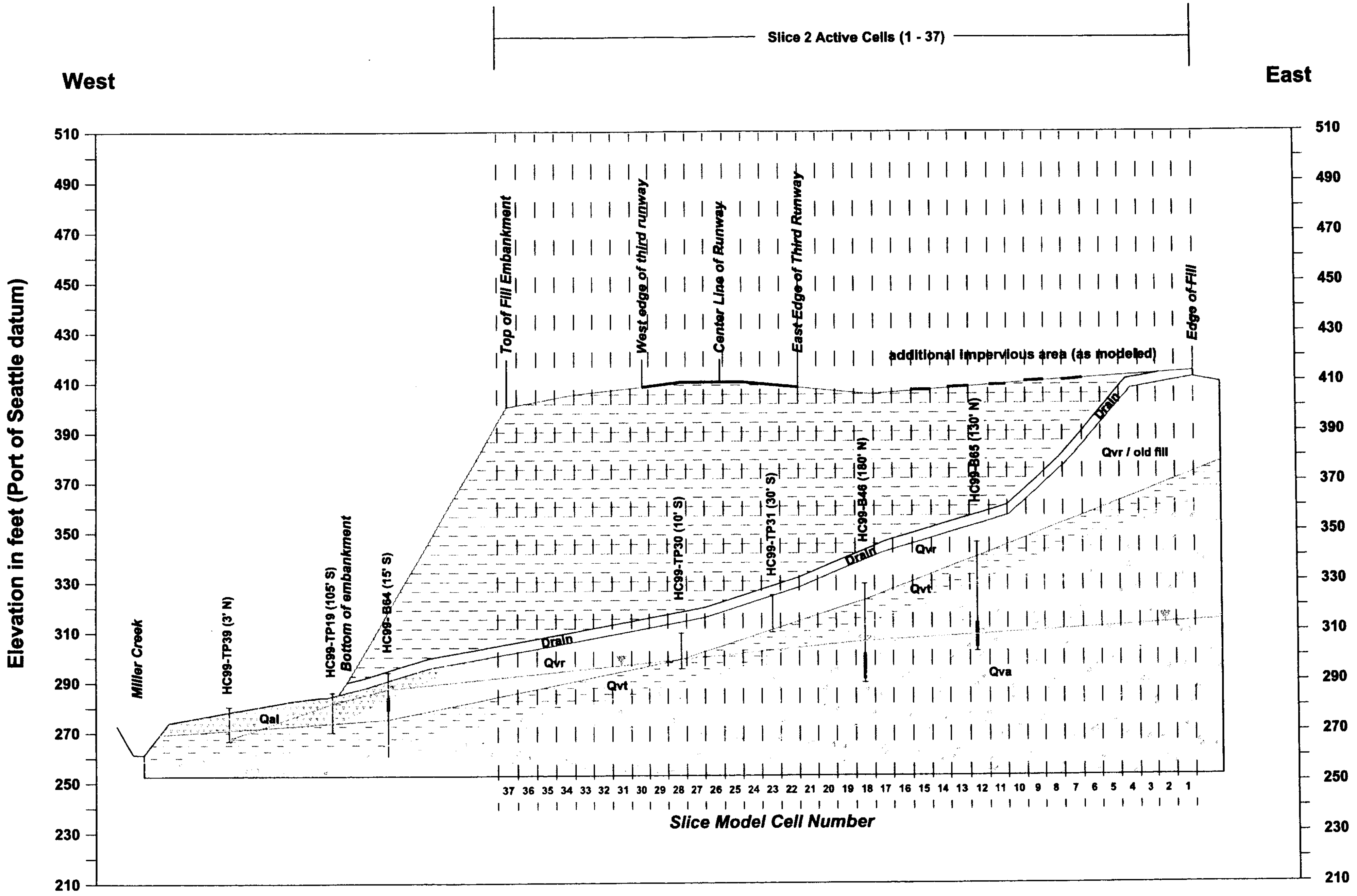
HC99-B38 Well with high and low water level and identifier

Horizontal Scale in Feet
0 100 200
0 25 50
Vertical Scale in Feet

FIGURE 5-1
Simplified Cross Section for Slice 1

SeaTac Third Runway
Embankment Fill Modeling
JED105, Runway-Section1.dwg, 11/01

Pacific Groundwater Group



LEGEND

Groundwater Elevation
Groundwater Seepage Elevation
Conceptual Water Table

General Fill
Qvr - Vashon Recessional Outwash
Qvt - Vashon Till
Qva - Vashon Advance Outwash

Qal - Recent Alluvium

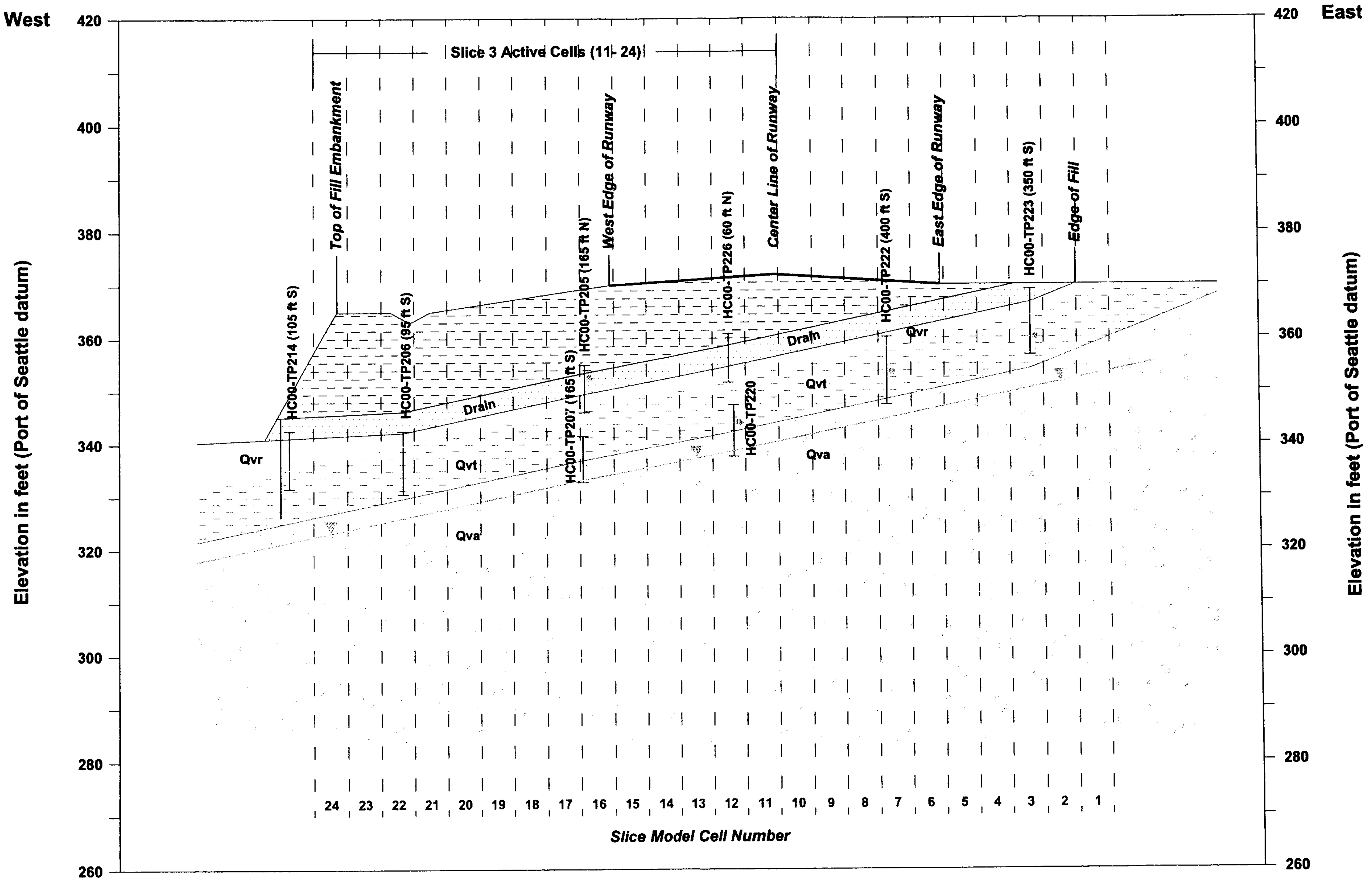
HC99-B38
Well with high and low water level and identifier

Horizontal Scale in Feet
0 100 200
0 25 50
Vertical Scale in Feet

FIGURE 5-2
Simplified Cross Section for Slice 2

SeaTac Third Runway
Embankment Fill Modeling
JE0105, Runway-Section2.dwg, 08/01

Pacific Groundwater Group



LEGEND

Groundwater Elevation
Groundwater Seepage Elevation
Conceptual Water Table

General Fill
Qvr - Vashon Recessional Outwash
Qvt - Vashon Till
Qva - Vashon Advance Outwash

HC99-B38
Well with high and low water level and identifier

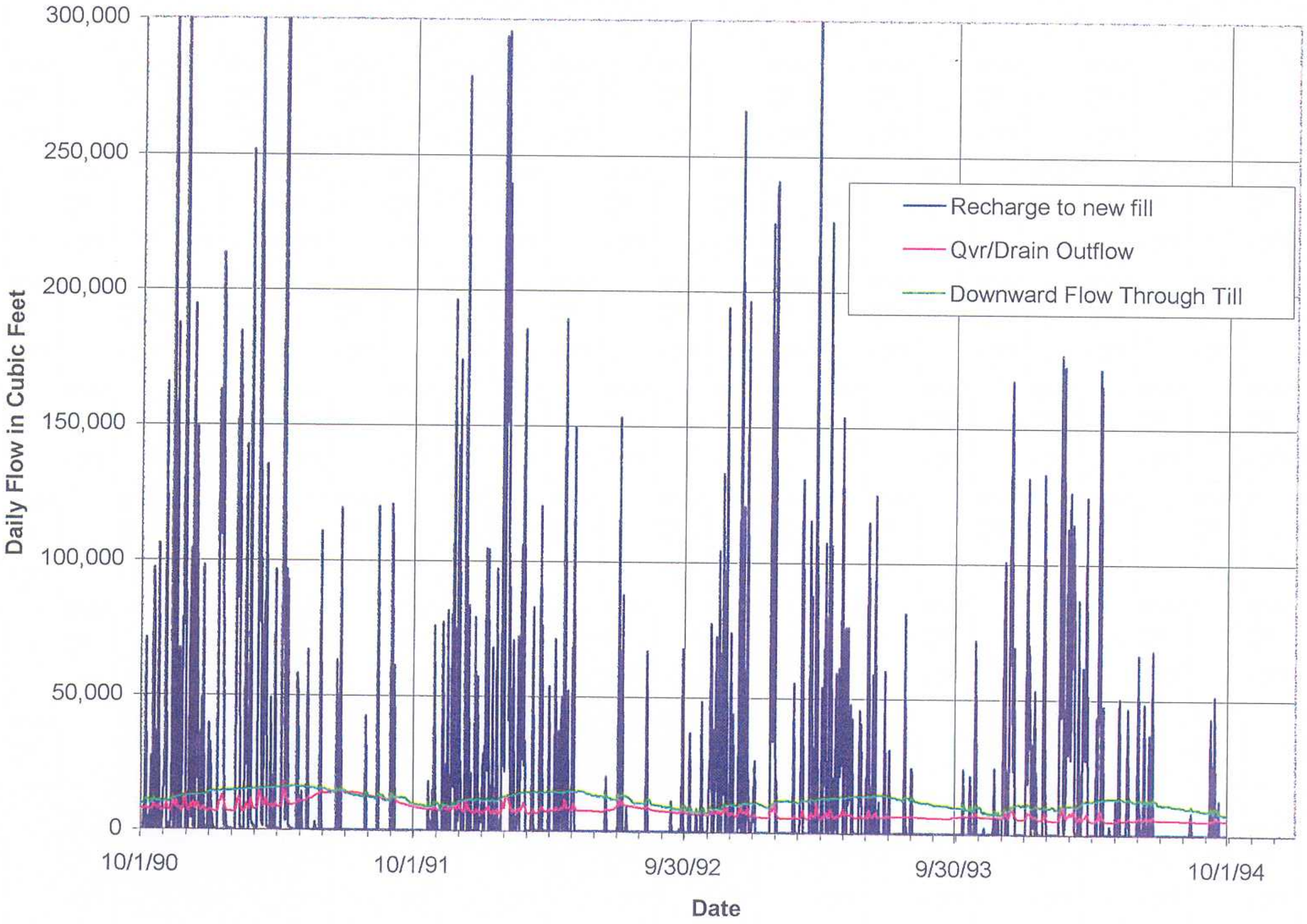
Horizontal Scale In Feet
0 40 80
0 10 20
Vertical Scale In Feet

FIGURE 5-3
Simplified Cross Section for Slice 3

SeaTac Third Runway
Embankment Fill Modeling
JED105, Runway-Section3.dwg, 08/01

Pacific Groundwater Group

Figure 5-8 - Miller Creek Fill Inflow and Outflow for Test Period



12/6/01

Miller Integrated.xls,test period plot

Figure 5-7 - Walker Creek Fill Inflow and Outflow for Test Period

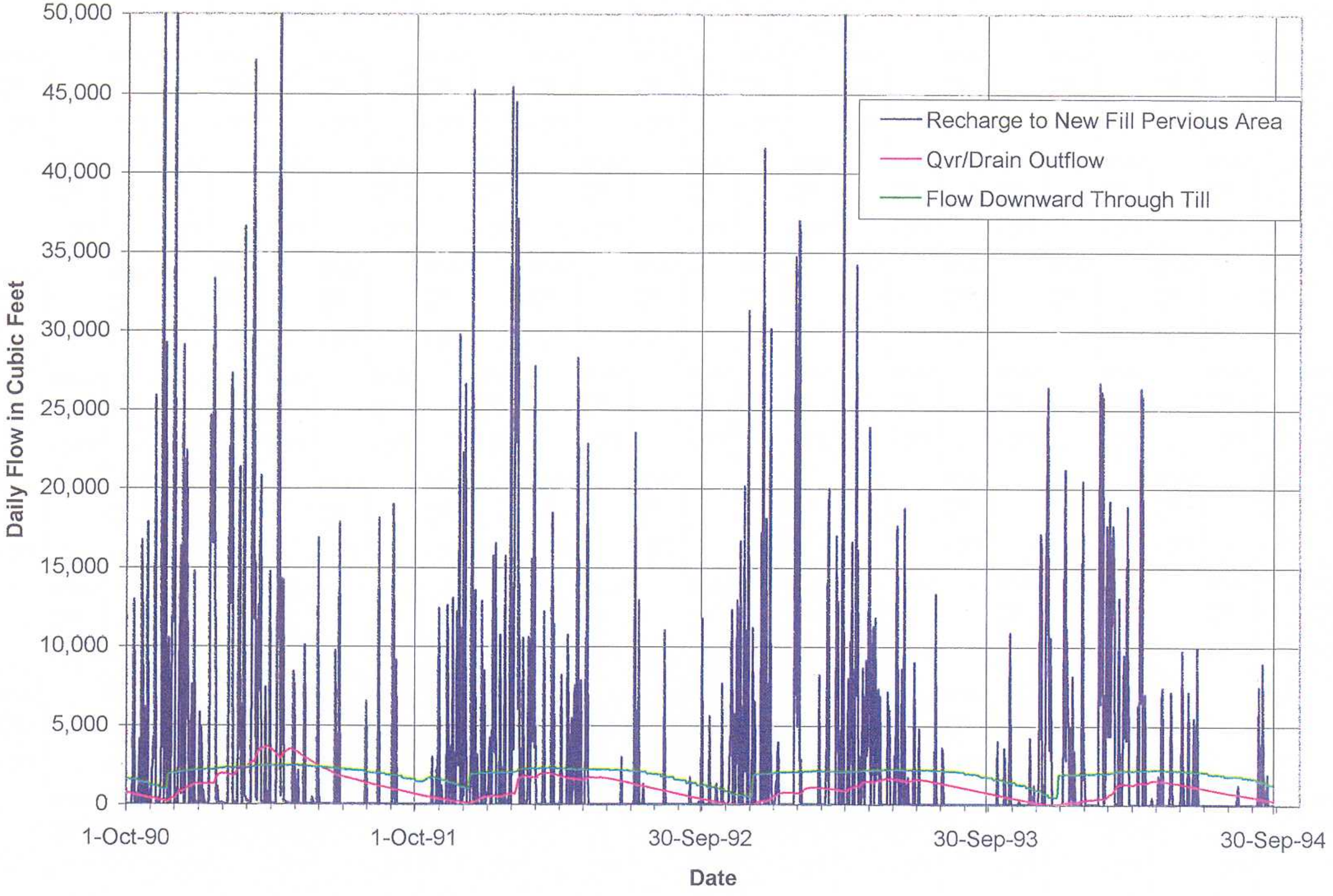


Figure 5-6 - Slice 3 Model Output for Test Period

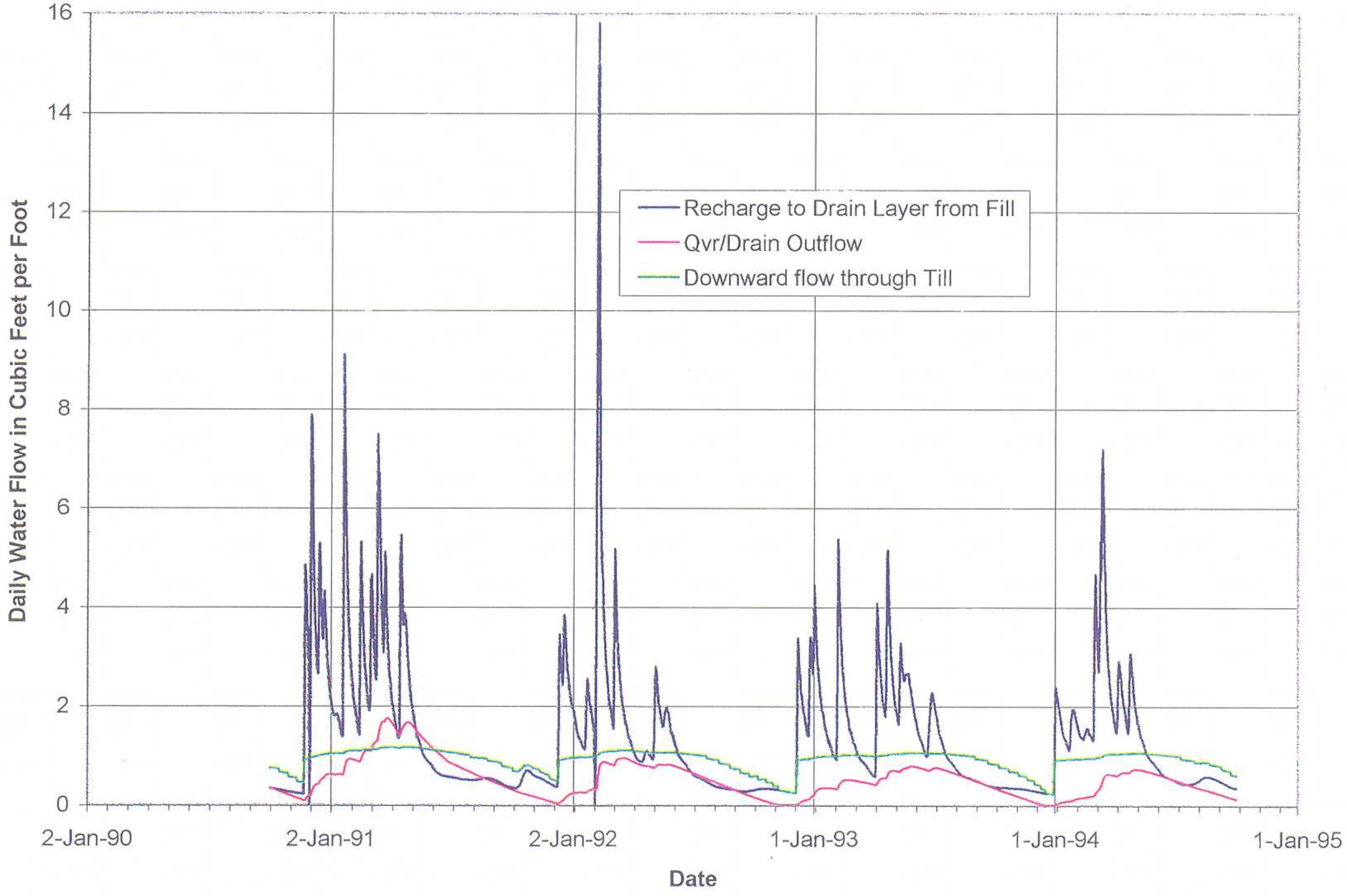


Figure 5-5 - Slice 2 Model Output for Test Period

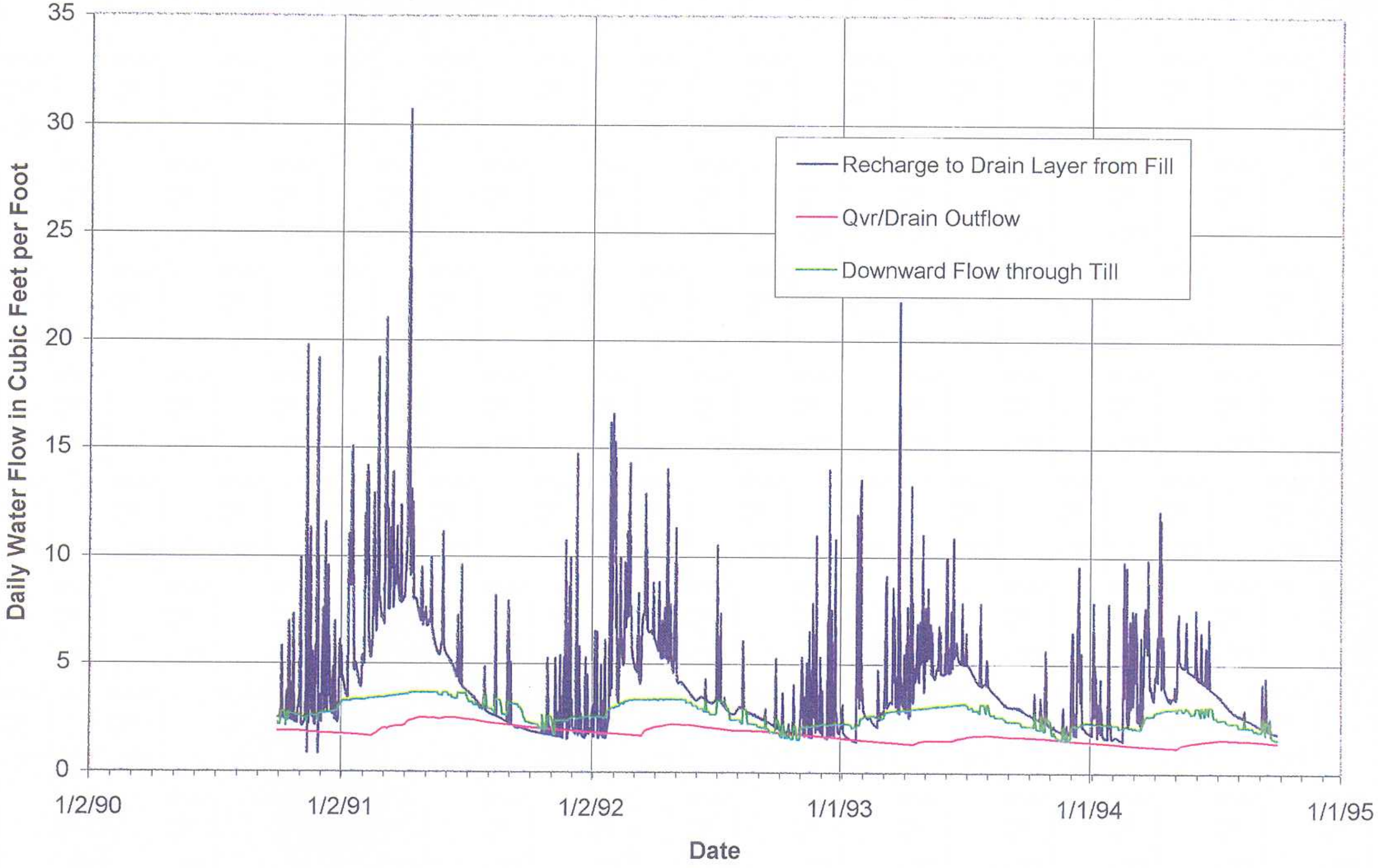
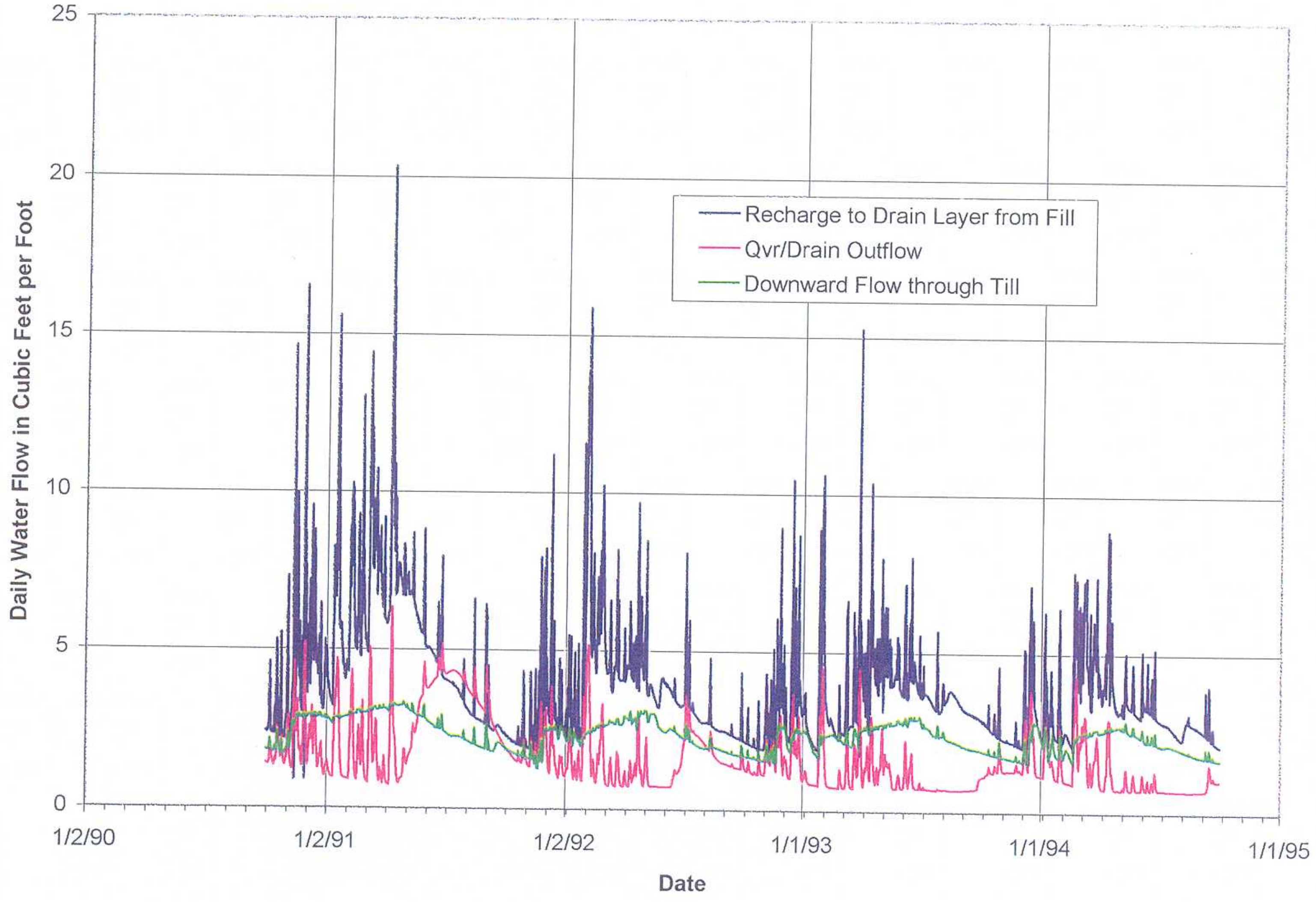


Figure 5-4 Slice 1 Model Output for Test Period



Appendix G

APPENDIX G

ANALYSIS OF DEWATERING IMPACTS AT THE AUBURN WETLAND MITIGATION SITE

APPENDIX G

ANALYSIS OF DEWATERING IMPACTS AT THE AUBURN WETLAND MITIGATION SITE

This appendix provides information regarding future hydrologic conditions in wetland areas that are located adjacent to the excavation areas for the Auburn wetland mitigation project. The analysis addresses the movement of water from existing wetlands into the excavated areas and the changes this movement could have on the hydrology of adjacent wetlands.

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HWA GEOSCIENCES INC.
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FAX. 425-774-2714
www.hwageosciences.com

PROJECT MEMORANDUM

PROJECT: **Auburn Wetland Mitigation Site**

PROJECT#: 97168-809

TO: Jim Kelley, Parametrix, Kirkland

FROM: Larry West & Arnie Sugar

DATE: May 25, 2001

SUBJECT: **Contours of Dewatering Impacts Due to Water Table Drawdown on Existing Wetlands at the Proposed Auburn Wetland Mitigation Site**

The attached contour maps (Figures 1a-1c) illustrate the estimated winter-early spring drawdown of the perched ground water table in the vicinity of existing wetlands that results from excavation and maintenance of a pond at elevation 42 feet. We evaluated the three areas where impacts were most likely (Phase 1 southwest corner, Phase 1 northwest corner, and Phase 2 southeast corner) due to excavation adjacent and within existing wetlands.

Our analytical approach included estimating the drawdown with distance from the pond in the Phase I area based on Sichart's Formula, where:

$$R = 300(h_o)\sqrt{K}$$

and R = the radius of influence for the maximum drawdown (h_o) and for a given hydraulic conductivity (K).[1] This approach assumes continuous horizontal flow from a subsurface recharge source and no recharge from precipitation or vertical subsurface upwelling (both of which occur at the Auburn Mitigation Site). Given the maximum anticipated drawdown in the excavated basin and the calculated hydrologic radius of influence, we assumed proportional drawdowns with distance from the point of maximum drawdown based on curves from an electrical analog model[2] (see attached maps).

---

[1] Refer to Powers, J. Patrick, 1992, *Construction Dewatering – New Methods and Applications*, John Wiley and Sons, New York.

[2] The electrical analog curve provides the proportional relationship between the change in potentiometric head (drawdown) and distance (radius of influence). C.V. Theis, 1938 (The Significance and Nature of the Cone of Depression in Ground Water Bodies, *Economic Geology* 38:889-902) recognized that ground water flow responds to changes in potentiometric head the same as the flow in electric current responds to electric potential.

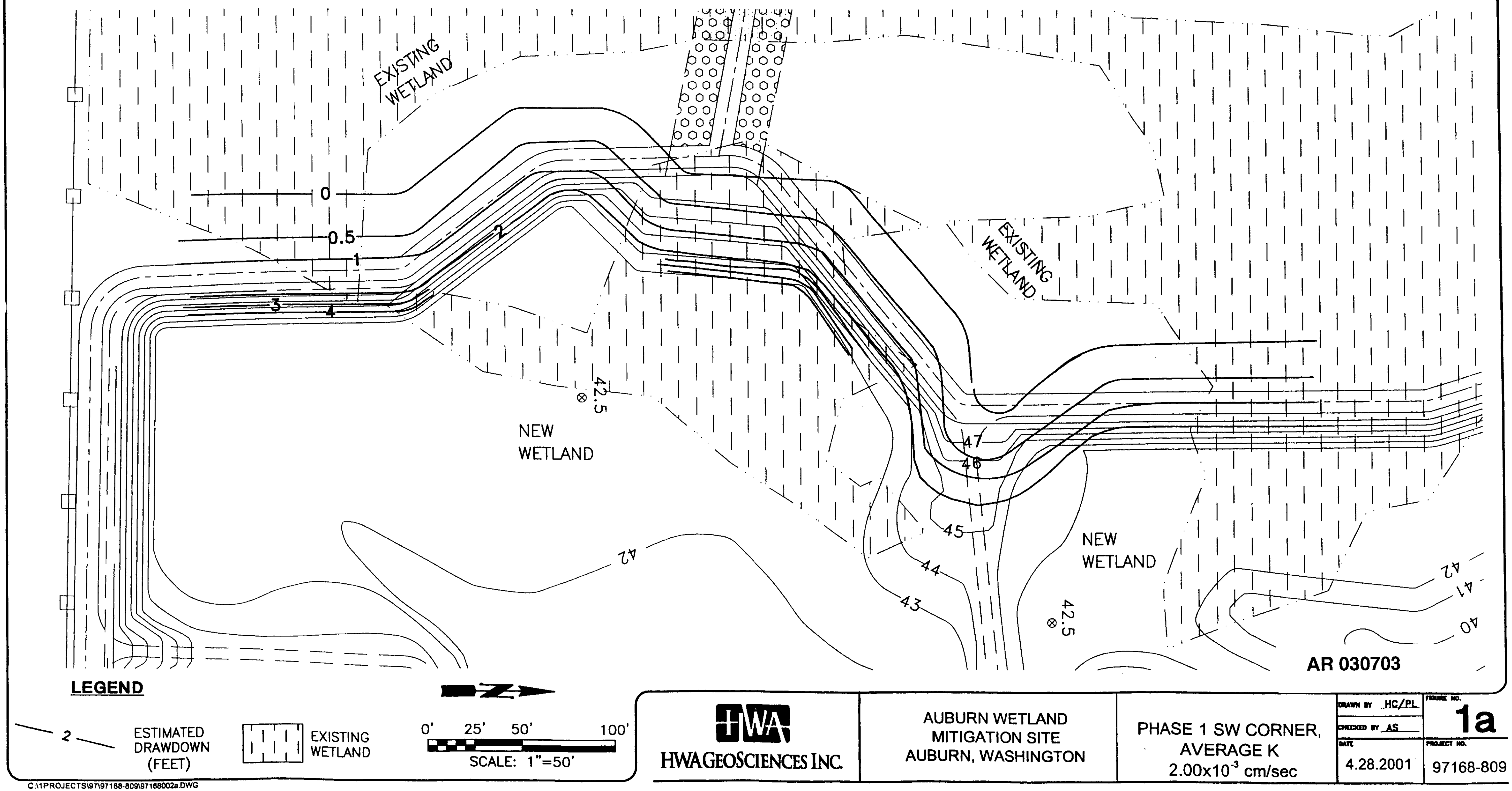
Based on short-term aquifer tests in the perched aquifer, horizontal hydraulic conductivities (K) for soils on the site range from 1.9×10^{-4} to 3.8×10^{-3} centimeters/second. The attached contour maps show estimated dewatering impacts for the average hydraulic conductivity. Estimated dewatering impacts at the low end of the hydraulic conductivity range did not extend beyond the perimeter slope of the excavation.

Ground water elevation data taken during 2000 from observation wells indicate water levels in the perched aquifer ranged from about elevation 38 feet to 49 feet. Assuming a maximum ground water elevation of 49 feet in the winter with a drawdown to elevation 42 feet, the maximum anticipated drawdown is 7 feet. Consequently, the radius of influence (zero impact) for soils with an average K of 2.00×10^{-3} cm/sec is about 79 feet.

Because the Sichart analytical approach assumes no recharge from precipitation, it does not account for any soil wetting or saturation that may occur due to rainfall. The period of maximum drawdown will generally occur from about the end of December to the end of March, also a period of relatively high rainfall. Therefore, during the early growing season (late February to early March) the estimates presented overestimate the zone of influence.

Variations in distance from toe of the pond boundary, grade and elevation of the toe of the slope will influence drawdown and the distance of impact in the existing wetland. The attached contour maps approximate the influence of these factors. Actual conditions will vary. To determine actual drawdowns of the perched water table, post-construction monitoring using shallow (5 to 10 foot deep) piezometers in areas of concern is recommended.

SEE SHEET C4, APPENDIX E



HWA GEOSCIENCES INC.

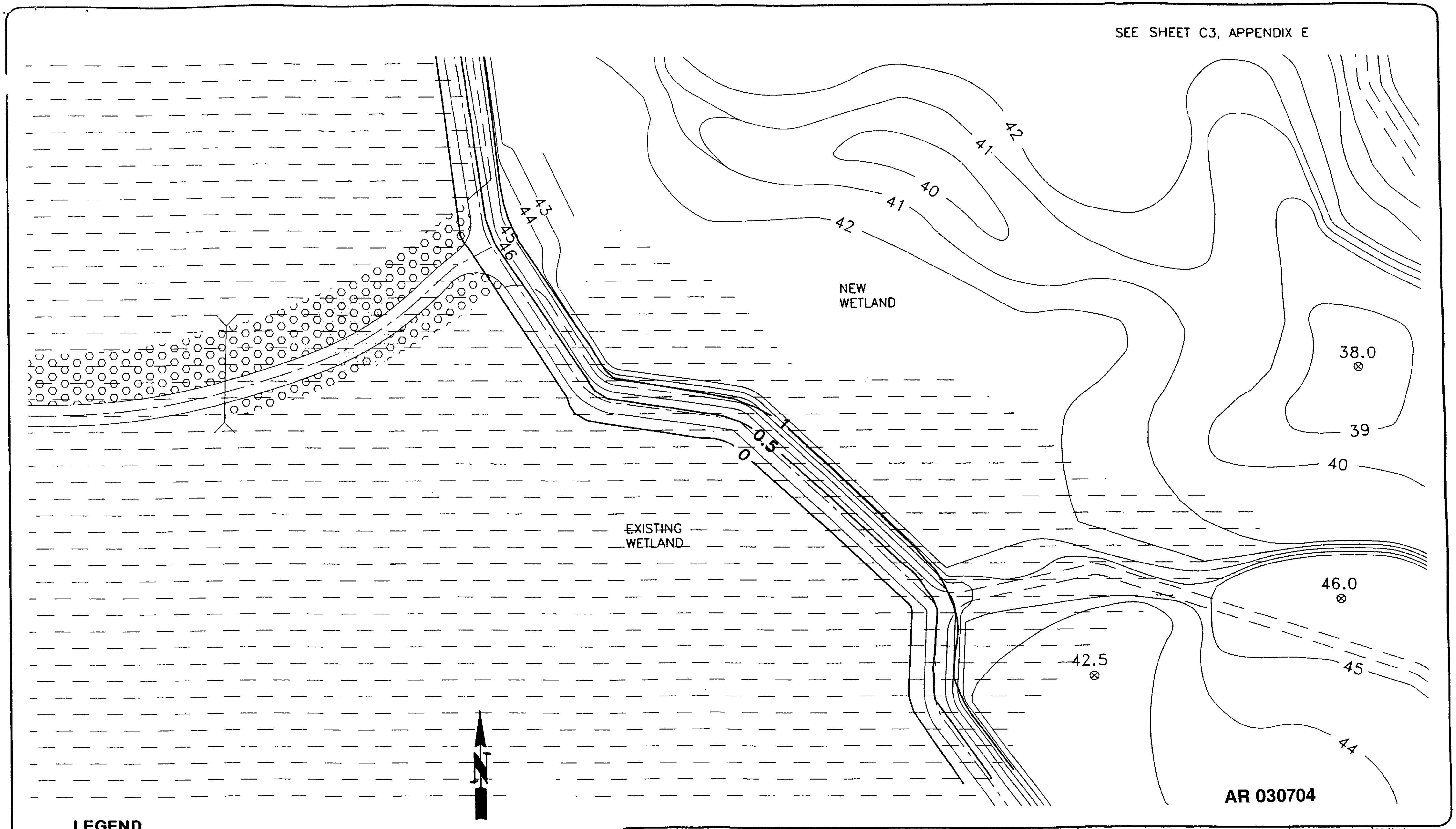
AUBURN WETLAND
MITIGATION SITE
AUBURN, WASHINGTON

PHASE 1 SW CORNER,
AVERAGE K
2.00×10^{-3} cm/sec

DRAWN BY HC/PL	FIGURE NO. 1a
CHECKED BY AS	
DATE 4.28.2001	PROJECT NO. 97168-809

C:\1PROJECTS\97\97168-809\97168002a.DWG

SEE SHEET C3, APPENDIX E



AR 030704

LEGEND

HWA GEOSCIENCES INC.

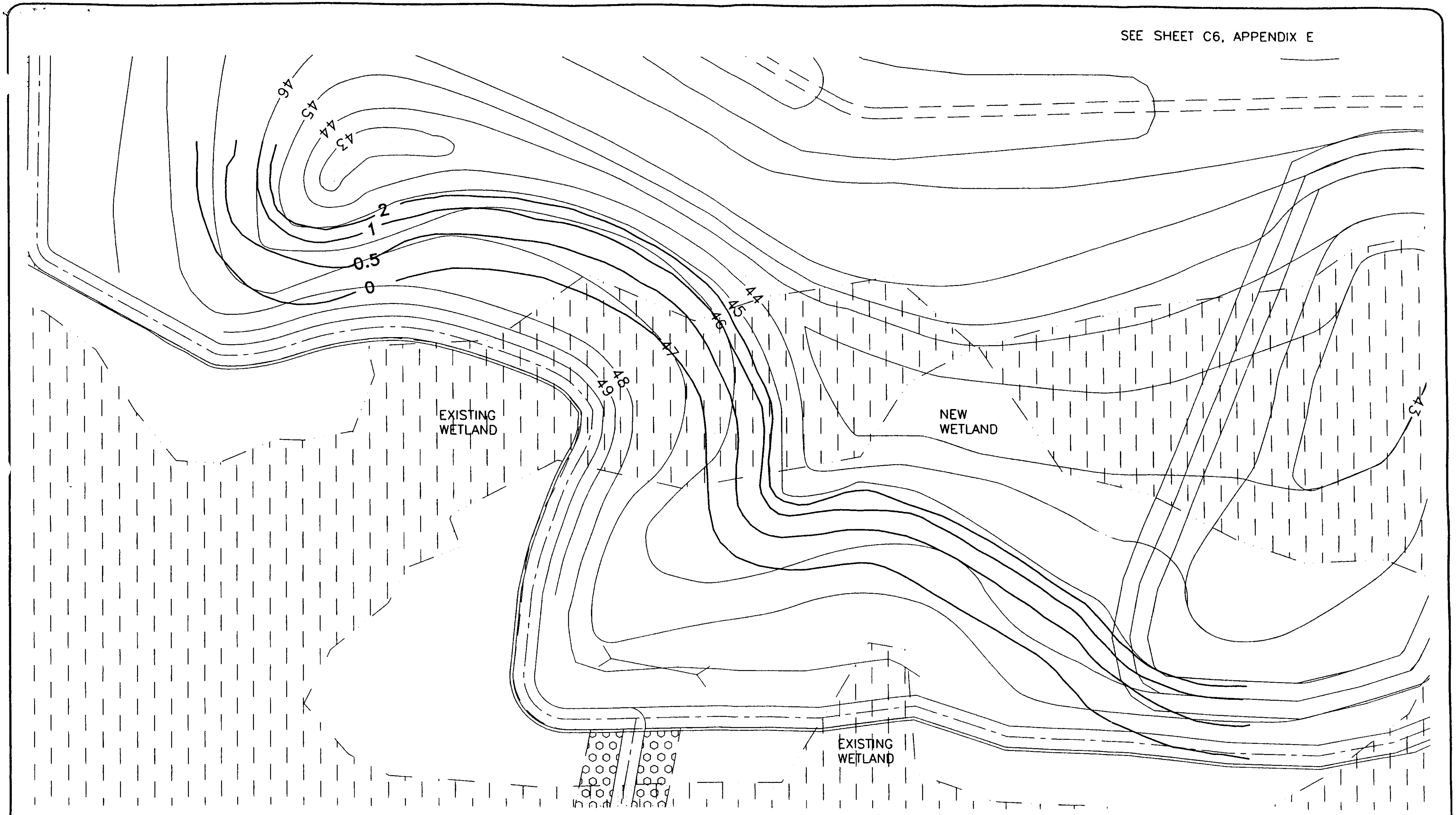
AUBURN WETLAND
MITIGATION SITE
AUBURN, WASHINGTON

PHASE 1 NW CORNER,
AVERAGE K
2.00×10^{-3} cm/sec

DRAWN BY HC/PL	FIGURE NO. 1b
CHECKED BY AS	
DATE 4.28.2001	PROJECT NO. 97168-809

C:\1PROJECTS\97\97168-809\97168002b DWG

SEE SHEET C6, APPENDIX E



LEGEND

AR 030705

HWA GEOSCIENCES INC.

AUBURN WETLAND
MITIGATION SITE
AUBURN, WASHINGTON

PHASE 2 SE CORNER,
AVERGE K
$2.00x10^{-3}$cm/sec

DRAWN BY HC/PL	FIGURE NO. 1c
CHECKED BY AS	
DATE 4.28.2001	PROJECT NO. 97168-809

C:\1PROJECTS\97\97168-809\97168002c.DWG

Appendix H

APPENDIX H

ANALYSIS OF INDIRECT IMPACTS TO WETLANDS FROM SR 509 TEMPORARY INTERCHANGE

Parametrix, Inc. Consultants in Engineering and Environmental Sciences
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425-822-8880 • Fax: 425-889-8808 • www.parametrix.com

MEMORANDUM

To: Jonathan Freedman, U. S. Army Corps of Engineers

From: Jim Kelley, Wetland Ecologist

cc: Elizabeth Leavitt, Port of Seattle

Date: May 3, 2000

Re: ***Analysis of indirect impacts to wetlands from the temporary SR-509 interchange – Seattle-Tacoma International Airport***

This memorandum provides an overview of the SR-509 Temporary Interchange at South 176th Street, a description of current conditions at the site, and evaluates the potential impacts to adjacent wetlands that may result from the project. The interchange project involves no discharge of fill material into waters of the United States including wetlands. Furthermore, we have analyzed potential indirect impacts to wetlands and concluded that no significant indirect impacts to wetlands will occur. The interchange is also constructed on existing road fill and other disturbed areas that do not act as buffers to protect the functions of adjacent wetlands.

PROJECT OVERVIEW

To provide construction vehicles direct access from SR-509 to the west side of Seattle-Tacoma International Airport (STIA), a temporary interchange would be constructed near the existing South 176th Street overpass. The half-diamond interchange would consist of an exit ramp from southbound SR-509 to South 176th Street and an entrance ramp from 176th Street to northbound SR-509.

The Port will use the interchange as part of its fill haul route during construction of the third runway, as described in the 1996 Final Environmental Impact Statement (EIS) and 1997 Final Supplemental EIS prepared pursuant to the National and State Environmental Policy Acts (see Federal Aviation Administration Record of Decision dated July 3, 1997 for a discussion of the EISs). This facility will be dedicated to haul vehicles for the third runway construction at STIA and will be removed upon completion of the third runway construction. The Port will be responsible for operation and maintenance of temporary and permanent drainage features throughout construction of the third runway project as stated in the Temporary Interchange Design, Construction and Operation Agreement.

As explained in the following sections, the temporary interchange was designed to avoid any direct fill impacts to wetlands. The interchange will be largely constructed on existing SR-509 road fill. Where necessary, short (less than 30 ft high) retaining walls are used to assure the project can be constructed on the existing road. Stormwater detention facilities, water quality treatment facilities, construction methods, and construction monitoring procedures have been developed to assure that impacts to the wetlands do not occur.

SITE CONDITIONS

Proximity to wetlands

Portions of the temporary interchange are located between Wetland 43 and Wetland 44. Wetland 44 is located generally east of and Wetland 43 is generally west of SR-509 and the project.

Construction of the southbound exit ramp will be between the existing SR-509 and the delineated edge of Wetland 43. Construction will occur more than 55 feet from the wetland edge. The land between the wetland and SR-509 consists of the SR-509 fill prism, including a gravel maintenance road. The area is vegetated with grass, invasive shrubs (Scots broom and Himalayan blackberry), and red alder saplings. This vegetation is periodically mowed and does not serve to protect the wetland from ongoing and adjacent disturbances.

Construction of the northbound entrance ramp of the temporary interchange generally occurs greater than 50 feet from the edge of Wetland 44. The ramp lies 20 to 50 feet from the wetland for about 100 linear feet near its start at South 176th Street. The ramp is 12 to 50 feet from the wetland edge for about 200 linear feet near its mid-point. The land between the wetland and SR-509 consists of the SR-509 fill prism and fill placed on Parcels 494, 496, 497, and 498. The area is vegetated with grass and invasive shrubs (Scots broom and Himalayan blackberry). This vegetation is periodically mowed and does not serve to protect the wetland from ongoing and adjacent disturbances.

Both Wetlands 43 and 44 lie within the Walker/Miller Creek Watershed. Walker Creek begins at the western edge of Wetland 43. Adjacent land use consists of single-family housing and SR-509 (which bisects the originally contiguous wetland). Wetland 44 is forested and Wetland 43 has forested, shrub, emergent and open-water components.

Historical aerial photos from 1961 (attached) show the wetland areas (prior to construction of SR-509) were once contiguous, largely farmland, with a drainage ditch crossing the area. In 1978 the wetlands were bisected by the construction of SR-509, and the hydrologic connection between the wetlands maintained via a 36-inch diameter culvert installed under the roadway.

Previous Earthwork

SR-509 from milepost 22.98 to milepost 24.11 including the South 176th Street bridge, was constructed in 1978. Generally, the section of road north of the South 176th Street bridge is predominantly fill. Approximately 200 feet north of the South 176th Street bridge SR-509, is constructed in a cut, which continues south of the bridge on both sides of SR-509. A portion of the northbound temporary interchange will cross Parcels 496, 497, and 498. The steep slope along the north and western edges of these parcels suggests that they are also fill materials. These parcels once contained a residence and a metal outbuilding, which have recently been demolished.

The majority of the southbound portion of the temporary interchange will also be constructed on the existing SR-509 fill trapezoid. However, as the temporary interchange approaches South 176 Street through the SR-509 right-of-way it will cross disturbed native soil (greater than 100 feet from the wetland edge). The northbound portion of the temporary interchange will be constructed on the existing SR-509 fill within the right-of-way trapezoid and on the existing fill of Parcels 496, 497, and 498.

Existing Drainage Features

Existing drainage facilities associated with SR-509 are described in the *Hydrologic Report- SeaTac International Airport Third Runway Direct Access* (HNTB 2000) (See Attached).

The existing drainage in the vicinity of the SR-509/South 176th Street bridge is composed of two primary systems, a groundwater collection system and a storm water runoff collection system.

The groundwater collection system for SR-509 is located in the vicinity south of the South 176th Street bridge. This system, which consists of perforated pipes within the roadway sub-grade, collects the groundwater surfacing in the SR-509 cut section. The collection system conveys collected water to drain lines near the east and west edge of SR-509. The drain line on the eastside crosses SR-509 just north of the South 176th Street overpass to connect with the drain line on the west side. The combined flow is conveyed down the west edge of the highway, bypassing the stormwater detention system at the base of the SR-509 embankment. The flow is then discharged to Wetland 43.

Three storm drain sub-basins collect the runoff from SR-509, the bridge, and their vicinity. The total collection area is approximately 45 acres, including approximately 8 acres of impervious surface (primarily SR-509 and South 176th Street) and 37 acres of pervious wetland and residential land uses. Detention and water quality facilities intended to treat this runoff are generally undersized when compared to the standards used to design the temporary interchange.

The south sub-basin is approximately 12.6 acres; it collects the roadway runoff from the southern end of SR-509 to just north of the South 176th Street overpass. Runoff from the northbound roadway is collected at the median barrier in catch basins and conveyed to an enclosed drainage system at the west edge of the pavement. The runoff from the southbound roadway is collected in a roadside ditch and combined with the runoff from the northbound roadway in the storm sewer.

The middle sub-basin is approximately 20.7 acres and extends approximately 1,150 feet north of the South 176th Street overpass. Roadway runoff is collected in roadside catch basins that outlet to the ditch and wetland east of SR-509. The wetland east of SR-509 drains to the stormwater facility on the west side of SR-509 through a 36-inch diameter culvert crossing.

The north sub-basin is approximately 11.7 acres and extends approximately 1,300 feet south from South 168th Street. The runoff from this sub-basin is collected at the roadside gutter in catch basins and conveyed to a ditch (on the east side of SR-509) that crosses to a stormwater detention pond on the west side of SR-509 through a 24-inch diameter culvert.

PROJECT DESIGN

The temporary interchange has been designed to avoid significant hydrologic and water quality impacts to wetlands or Walker Creek. Hydrologic designs and their potential impacts are discussed in the following sections.

New Groundwater Management

Drainage for the structural earth walls of the interchange will be the only new subsurface drainage systems for this project. These will consist of "weep-holes" (see WL-1 and WL-2 in the Attached Plan Sheets) that will allow the small amounts of water that may infiltrate the fill to seep from behind the wall to the surface.

The existing subsurface drainage conveyance system serving SR-509 in the vicinity of the South 176th Street bridge will be modified (by adding a bypass pipe segment [see Sheet D1]) to avoid damage to the system from construction of the proposed southbound off-ramp. This modification will not alter the flow volume or timing of groundwater flow that eventually discharges to Wetland 43.

New Stormwater Management Facilities

The stormwater drainage system has been designed to capture runoff from the new impervious surface area and to detain accumulated runoff consistent with King County Level 2 requirements. The stormwater system will capture and detain runoff from an additional 40 percent of the existing road surface consistent with the *Stormwater Effects Guidance* provided by WSDOT and National Marine Fisheries Service (NMFS) for salmon listed under the Endangered Species Act (ESA). All collected runoff will be treated to improve water quality prior to discharge into the existing WSDOT pond system and outfall.

The drainage design was completed using the King County Surface Water Design Manual (1998 edition). Runoff volumes were modeled using the King County Runoff Time Series (KCRTS) model, but for comparison, the project was also analyzed using the

Santa Barbara Unit Hydrograph method (using "WaterWorks" software). The results showed that the KCRTS model offers a more conservative design, providing facilities that are more protective of downstream wetlands and creeks. The detention pond sizing and release rates meet Level 2 Flow Control requirements.

The temporary interchange will add approximately 1.66 acres of impervious surface and reduce the pervious surface in the vicinity by the same area. The system will also collect runoff from an additional 40 percent (0.67 acre) of the existing roadway's impervious surface to meet requirements of the NMFS retrofit agreement. A total of 2.47 acres would flow to the new detention and water quality facilities. The areas draining to the new detention pond would account for approximately 26 percent of the total impervious surface in the three sub-basins (calculated after the interchange construction).

An existing roadside drainage ditch would be modified to develop the water quality treatment facilities required for the project. This existing ditch drains to an existing stormwater pond outfall (at Station 932+00), that will be redeveloped as a wet biofiltration swale. The outlet pipe from new ponds will discharge into the wet biofiltration swale at approximately Station 929+00, storm water will flow north to the swale, with treated water exiting into the discharge channel from the existing pond. The wet biofiltration swale will be designed and constructed to meet the King County Surface Water Design Manual standards.

The detention facility for the project is designed to comply with King County Level 2 Flow Control, which requires the developed discharge durations to match 50 percent of the pre-developed 2-year to the full 50-year peak flow. The 50 percent release rate is intended to minimize the erosive effects of runoff on creeks and streams (for this project, a large area of Wetland 43 will be provided with additional protection above the Level 2 standard). The specified release rates (see below) will be achieved using an outlet control structure with multiple orifices that allows staged discharge from the detention pond. For all storm events, the post-project peak flow rate will be below the existing peak flow rates.

	Peak Flow (cfs)	
Storm Event	Existing	Proposed
2-year	0.189	0.092
10-year	0.232	0.190
25-year	0.238	0.225
50-year	0.345	0.230
100-year	0.398	0.232

The Hydraulic Report for this project has been reviewed and approved by the WSDOT Olympia Service Center Hydraulics Office, as well as the WSDOT Northwest Region Hydraulics Office. In addition, comments concerning detention and treatment from an independent reviewer were received and addressed. The comments raised by the independent reviewer were researched, and an independent evaluation by King County has indicated that the design meets the current detention and treatment requirements. The stormwater conveyance system was analyzed using current WSDOT methods and is also compliant.

The hydraulic design also meets the requirements for "No Effects" prescribed under the WSDOT stormwater guidance concerning ESA agreed upon by NFMS.

The stormwater detention pond and biofiltration facilities will remain in place following demolition of the temporary interchange; thus, the benefits derived from the stormwater facilities will be permanent.

Construction stormwater, sediment, and erosion control

A Stormwater Pollution Prevention Plan (SWPPP) details stormwater management for the SR-509 interchange during construction and operation (See Attached). These plans identify the BMPs necessary to protect adjacent wetlands and surface water from potential water quality impacts during construction.

The BMPs—combined with the small size of the project, construction timing, and other site conditions—provide a high level of protection to adjacent sensitive areas. Construction of the project will result in a small, linear disturbance footprint, from which stormwater can readily be collected and conveyed to treatment facilities. The linear configuration reduces the likelihood that, even if BMPs failed, significant amounts of stormwater could concentrate and cause significant damage.

A proactive monitoring plan will be implemented to assure that all planned BMPs are properly implemented and maintained. Monitoring of the BMPs during storms will verify that they are effective and help identify maintenance needs to prevent potential failures. Monitoring of BMPs includes the following actions:

- Inspection during and following construction to assure that they are constructed properly,
- Inspecting each BMP following 0.5 inch of rain to determine whether any maintenance is required,
- Monitoring discharge and receiving waters to verify that permit conditions are met and that BMPs are effective,
- Use of advanced treatment methods as a contingency treatment method if monitoring demonstrates this need.

The SR-509 interchange includes the following features to assure the project can be constructed to meet water quality standards and protect adjacent wetlands:

- Protect wetland and buffers with installation of 2 layers of silt fence,

- Minimize disturbance of vegetation and soil when installing and maintaining sediment and erosion control measures,

- Treat unworked areas with erosion control cover measures according to the *King County Surface Water Design Manual,*

- Apply water to the site as necessary to control dust,

- Limit clearing and grubbing to areas that will be worked within the next 7 days,

- The contractor shall construct a temporary sedimentation pond at the site of the new stormwater detention pond at the north end of the project on the east side of the embankment prior to other land-disturbing activities (See D-1 through D-3 and details on DD-1 in Attached Plan Sheets),

- The contractor shall operate the two existing ponds on the west side of SR-509 and the new pond as sedimentation ponds. Runoff shall be diverted to the ponds (See D-3 and details on ST-1 in Attached Plan Sheets),

- The contractor shall install catch basin inserts into all existing storm drains and into all storm drains (as they are made operational).

POTENTIAL FOR DIRECT AND INDIRECT IMPACTS TO WETLANDS 43 AND 44

Ecological Conditions

No Direct or indirect impacts to water quality conditions. Based on the stormwater management facilities and BMPs described above, the temporary interchange project will not degrade water quality conditions in the wetlands. Stormwater management facilities meet King County Stormwater Manual standards and WSDOT/NMFS treatment and retrofit guidelines for "no effect." Following demolition of the interchange, stormwater quality facilities that treat stormwater which is currently untreated, will remain. This will result in a net long-term benefit to water quality conditions in the wetland.

No Direct or indirect impacts to water quantity

Based on the stormwater management facilities and BMPs described above, the temporary interchange project will not significantly alter runoff rates that could impact downslope wetland or stream habitat. Stormwater management facilities meet King County stormwater requirements. The new detention facilities result in no significant delay in stormwater runoff reaching the wetlands because Level 2 control matches past project runoff to pre-project conditions. This effect is beneficial overall in that it potentially moderates water level fluctuations that can be detrimental to some aquatic species. The separation of the existing groundwater collection system from stormwater management systems will prevent any changes to the water quantity (volume and timing) of groundwater flow that currently reaches Wetland 43.

Ecological Functions

Five biological functions were examined. These functions determine the degree to which the wetlands: (1) support resident and anadromous fish, (2) provide songbird habitat, (3) provide waterfowl habitat, (4) provide amphibian habitat, and (5) provide small mammal habitat. Four physical functions provided by wetlands were also examined. These functions examined the wetlands' ability to: (1) export organic matter to downslope systems, (2) maintain groundwater exchange, (3) provide flood storage, and (4) enhance nutrient retention and sediment trapping.

Based on evaluations of the physical and biological indicators of wetland function observed in each wetland, professional judgement, and knowledge of other wetland ecosystems in the Puget Sound region (urban and non-urban), the functional performance of these wetlands was evaluated. Functional performance ratings were assigned as follows:

> **High-** The wetland contains several important characteristics required to perform the function, and lacks indicators that prohibit the function from occurring in the wetland.
>
> **Moderate-** The wetland contains one or more characteristics required to perform the function; however, several of these may be secondary indicators. The wetland may contain one or more characteristics that interfere with or prevent optimal performance of the function in question.
>
> **Low-** The wetland lacks significant indicators that the wetland could perform the function in question. One or more indicators that the wetland does not perform the function are typically present.

Supports resident and anadromous fish.

Wetland 43 rates as moderate for this function because the wetland has persistent open water that is connected to Walker Creek, it is likely that this wetland directly supports resident fish. Walker Creek provides habitat for coho salmon downstream of Wetland 43. ESA listed fish species are not reported in the creek or Wetlands 43 and 44. The creek and wetlands do not provide habitat for listed species due to the small size of the creek, hydrologic conditions in the wetlands, and lack of suitable habitat features. There are no historical records indicating listed species once used these habitats. No salmonid or resident fish use is likely in Wetland 44, and it is rated low for this function. Wetland 44 has a seasonal hydrologic connection to Wetland 43 via a 36-inch diameter culvert under SR-509, but it does not contain significant fish habitat due to the lack of persistent surface water at sufficient depth. Both wetlands indirectly support fish by providing hydrologic functions, as described below.

Direct impacts to fish habitat will not occur during the construction and operation of the temporary interchange because no stream channel, fish habitat, or riparian area will be modified. The 36-inch diameter culvert connection between each wetland will remain and will not be altered. No vegetation that provides shade or organic matter input to streams will be removed.

Indirect impacts to fish habitat will not occur during the construction or operation of the temporary interchange, as explained in sections addressing project design, stormwater management, and wetland protection strategies

Provides habitat for song (passerine) birds

Wetlands 43 and 44 provide moderate to high habitat for songbirds. The vegetation of both wetlands provides multi-layered structure, standing dead snags, and abundant sources of food for various songbird guilds. Because Wetland 43 is larger, contains a greater number of habitat types, and contains areas more isolated from areas of human use, it provides higher quality habitat than Wetland 44. However, the location of these wetlands within an urban environment and in relation to SR-509 results in human disturbance that limits the types of species that may use the wetlands as habitat. Species using the wetland are typically tolerant of human disturbance.

No direct impacts will affect the wetlands' ability to provide habitat for songbirds during the construction and operation of the temporary interchange, because no habitat characteristics of the wetland will be changed by the project.

Increased noise from the construction and operation of the temporary interchange will not result in significant indirect impacts to passerine birds because the resident or transient bird populations that use the wetland are adapted to the high levels of noise and human disturbance that are currently present in the area. For example, the wetland adjacent to the entire project already lies near SR-509, South 176th Street, or other developed property that generate human disturbance and noise impacts. The vegetated slopes of the existing SR-509 road bed (the construction site for most of the project) are maintained as highway right-of-way through mowing and periodic clearing of woody vegetation. The portions of several parcels subject to construction are largely clear of woody vegetation as a result of former residential land uses. As a result, constructions near the wetland will neither remove any significant habitat for passerine birds nor remove any vegetation barrier that would screen the wetlands from adjacent disturbances.

Provides waterfowl habitat

Wetland 43 rates as moderate to high and Wetland 44 rates as low for this function. Wetland 43 has persistent open water and emergent vegetation that provide habitat for a variety of nesting and foraging waterfowl species. Wetland 44 does not contain open water or suitable habitat for nesting, foraging, or migrating waterfowl. Neither wetland provides suitable nesting (critical habitat) or foraging habitat for marbled murrelets. Bald eagles have not been observed in Wetland 44, but they could potentially prey upon waterfowl that use the wetland.

No indirect impacts to the characteristics of the wetland that provide waterfowl habitat functions will occur from construction or operation of the temporary interchange. Significant waterfowl habitat is not present in Wetland 44. In Wetland 43, waterfowl habitat is located over 800 feet from the project site and is densely screened from the project by forested vegetation. Thus, the project is unlikely to significantly affect levels of human disturbance in this wetland.

Provides amphibian habitat

Wetland 43 rates as moderate to high for this function, while Wetland 44 rates as low for this function. Wetland 44 contains significant open water, emergent vegetation, and downed woody debris that are key habitat features for amphibians. Wetland 44 lacks these features. Amphibian habitat adjacent to both wetlands is poor due to a variety of land-uses. In addition, the wetlands are isolated from other suitable breeding habitat that further limits the habitat value of the wetlands for amphibians.

Because interchange construction and operation will not alter wetland vegetation or hydrology, no direct impacts to amphibian habitat will occur. The project will not remove forested areas potentially used by adult amphibians, nor will it create any migration barrier between breeding habitat in the wetland and suitable terrestrial habitat elsewhere in the watershed. As explained elsewhere, Level 2 storm water management and water quality treatment facilities will prevent increased water level fluctuations or water quality impacts that could affect amphibian populations. Indirect impacts to amphibians through increased noise are unlikely.

Provides small mammal habitat[1]

Wetland 43 and Wetland 44 are rated moderate to high for this function. The vegetation in the wetlands provides heterogeneity, standing dead snags, and offers good cover and food for small mammals. Both wetlands are adjacent to SR-509 and residential development, noise and other human disturbances are prevalent in each wetland. This condition has also eliminated and fragmented habitats in adjacent upland areas, such that use of the wetlands by small mammals is limited to those tolerant of human activity.

Small mammals that are expected to use the wetlands include raccoon, opossum, coyote, mice, rats, and squirrels. Beavers inhabit portions of Wetland 43.

Significant indirect impacts, including human disturbance, to the wetlands' small mammal habitat functions will not occur. For example, while construction activities will occur near the wetland, the wetland adjacent to the entire project is already bisected by SR-509 and is near South 176th Street or other developed property. This results in ongoing human disturbance and noise. The vegetated slopes of the existing SR-509 roadway (the construction site for most of the project) are maintained as highway right-of-way through mowing and periodic clearing of woody vegetation. Portions of several parcels that are part of construction are clear of woody vegetation due to past residential landuses. As a result, construction near the wetland will neither remove any significant habitat for small mammals nor remove any vegetation barrier that may screen the

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[1] The wetlands do not provide significant habitat for large mammals because they are too small to independently support the habitat requirements of large mammals found in western Washington. Large mammals cannot use the wetlands because adjacent development and habitat fragmentation prevents access.

wetlands from human disturbance. The project will not create any new barriers that would significantly alter movements of small mammals between the wetlands and other areas of suitable habitat because the existing SR-509 roadway is already a significant barrier to wildlife movement.

Exports organic matter

Both Wetlands 43 and 44 rate as high for the export of organic matter to downslope aquatic systems (i.e., Walker and Miller creeks). This function is enhanced by seasonal (Wetland 44) and perennial (Wetland 43) channelized flow, presence of open water, and a deciduous forest overstory.

Direct or indirect impacts to this function will not occur during the construction and operation of the temporary interchange because the stream channels, hydrologic conditions, or riparian area will not be modified. The 36-inch diameter culvert connection between each wetland will remain and will not be altered. No vegetation that provides organic matter input to streams will be removed.

Maintains groundwater exchange

Both Wetlands 43 and 44 rate as high for this function. Each wetland is predominately an area of groundwater discharge, as evidenced by springs and seepage areas in several locations.

No direct or indirect impacts will interfere with the wetland's ability to maintain groundwater exchange during the construction and operation of the temporary interchange. Existing groundwater collection facilities located beneath SR-509 will be maintained during construction and operation. They will remain isolated from new and existing stormwater conveyance systems, so that no change in the rate or quality of groundwater entering the wetland will occur. Existing road fill upon which the project will be built does not provide groundwater discharge functions because the fill is elevated above the ground surface and thus isolated from groundwater tables. The SR-509 pavement surface prevents infiltration of rainwater into the fill, so there is no source of water to discharge from the fill. Drainage for the structural earth walls will contain subsurface drainage systems that allow the small amount of groundwater that could otherwise collect behind them to discharge to the wetland. Infiltration through stormwater detention facilities will likely replace the small reductions in infiltration through the existing fill due to new impervious surfaces[2].

Provides flood-storage and runoff de-synchronization

Wetland 43 rates as high and Wetland 44 rates as low to moderate for this function. Wetland 44 is a slope and offers hydrologic roughness that slows and temporarily detains stormwater. Wetland 43 is a large depression that detains floodwater and moderates peak flows in Walker Creek, which has its source in this wetland.

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[2] Infiltration into fill immediately adjacent to the wetland would not affect creek base flows because the time of travel between the point of infiltration and downslope discharge site 10 – 50 feet away would be very short. Therefore, the effect of reduced infiltration due to new pavement would not be significant.

No direct or indirect impacts will occur to these wetlands' ability to provide flood-storage and moderate peak flows during the construction and operation of the temporary interchange, because no physical modification to the wetland will occur. Wetland area, existing hydrologic connections, wetland topography, and wetland vegetation will not be altered by the project.

Enhances nutrient retention and sediment trapping

Wetland 43 rates as high and Wetland 44 rates as moderate for this function. Wetland 44 is a slope with channelized flow that exits the wetland through a 36-inch diameter culvert at SR-509. The wetland may act as a sink for sediment that enters the perimeter of the wetland. However, due to the high gradient and eroded channel in the base of the ravine, it is also likely to be a source of sediment to Wetland 43. The large area, dispersed channels, low-flow velocities, and dense vegetation in Wetland 43 create nearly optimal conditions for nutrient retention and sediment trapping. The open water in Wetland 43 would be subject to high solar radiation during the summer months and would contribute to high stream temperatures in the upper portion of Walker Creek.

No direct or indirect impacts will interfere with the wetland's ability to retain nutrients and trap sediments during the construction and operation of the temporary interchange. Wetland area, existing hydrologic connections, and wetland vegetation will not be impacted during the project.

Buffer Functions

As explained above, the temporary interchange project will not result in significant indirect impacts to the functions provided by Wetlands 43 and 44. The modification to the wetland buffer through development of the interchange will not alter characteristics of the wetland that are critical to providing the various functions analyzed above. Neither will the modifications alter the protective functions that a buffer could provide (i.e., screening of the wetland from human activities or protection of water quality), because significant woody vegetation is removed through periodic maintenance and because stormwater is not conveyed to the buffer for treatment. Therefore, it is apparent that the areas modified for the interchange do not provide significant protective functions as a wetland buffer. Their ability to function as wetland buffer has been eliminated by past filling and their existing land uses (i.e., as highway, street, and residential areas) that result in periodic mowing and elimination of most native vegetation.

CONCLUSION

The proposed interchange project involves no discharge of fill material to waters of the United States. Further, the proposed interchange project has been exhaustively evaluated for potential direct and indirect impacts to the condition and ecological functions provided by the wetlands. Based on the project design and analysis presented above, no direct impacts and no significant indirect impacts to the wetland will occur.

Attachments:

Plan Set
Hydraulic Report
1961 and 1995 aerial photographs
Wetland delineation map

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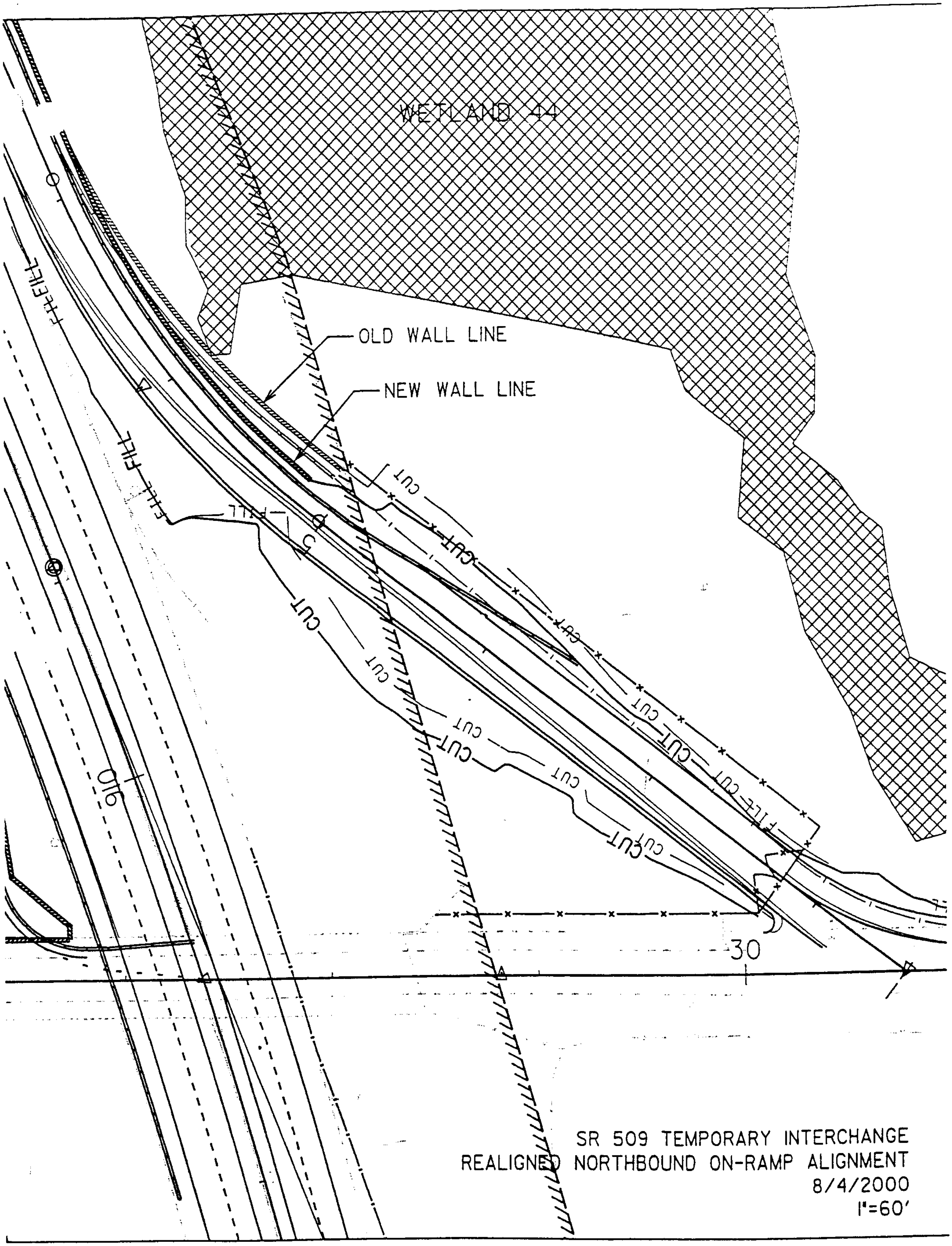
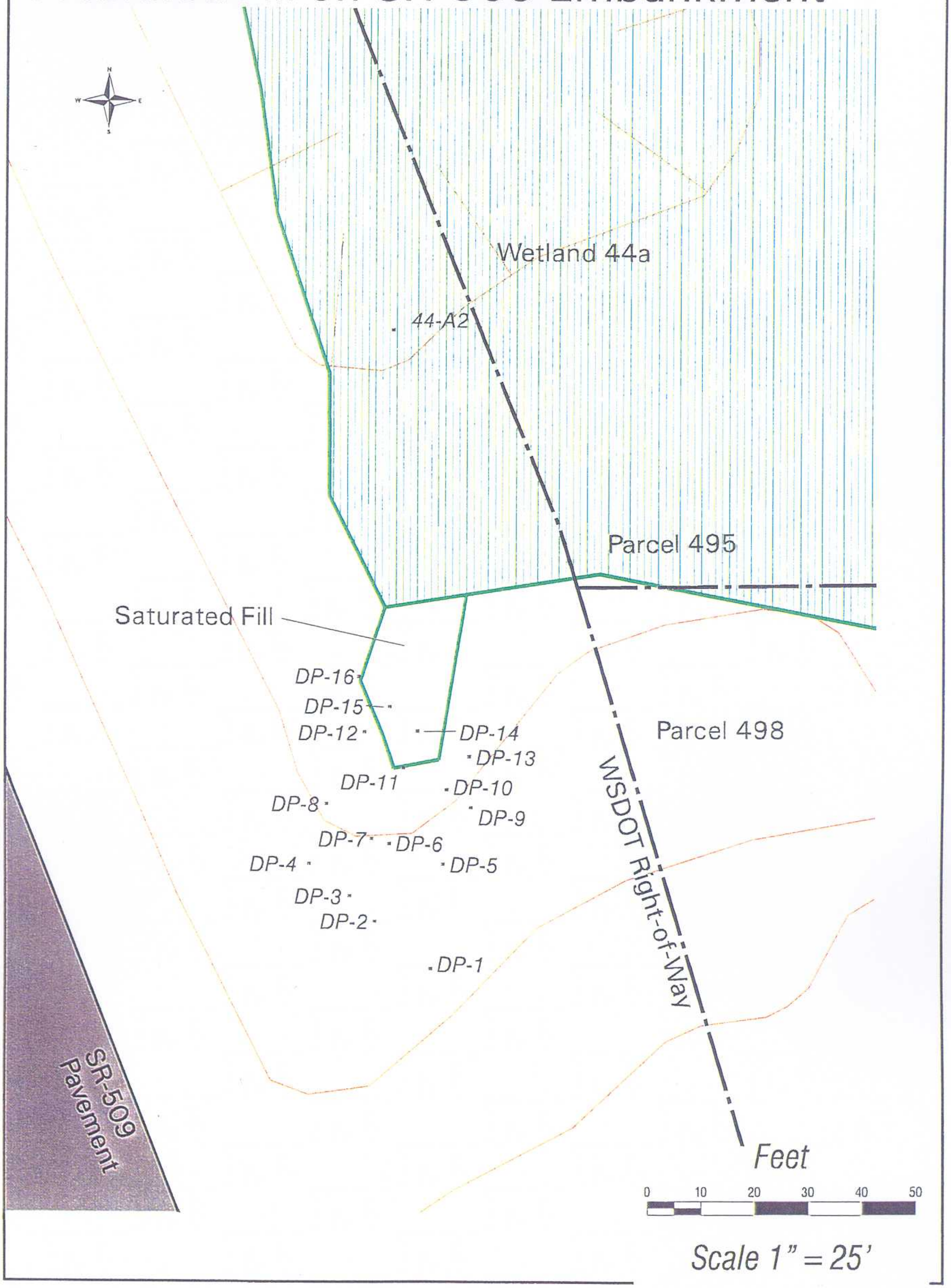


SR 509 TEMPORARY INTERCHANGE
REALIGNED NORTHBOUND ON-RAMP ALIGNMENT
8/4/2000
1"=60'

Saturated Fill on SR-509 Embankment



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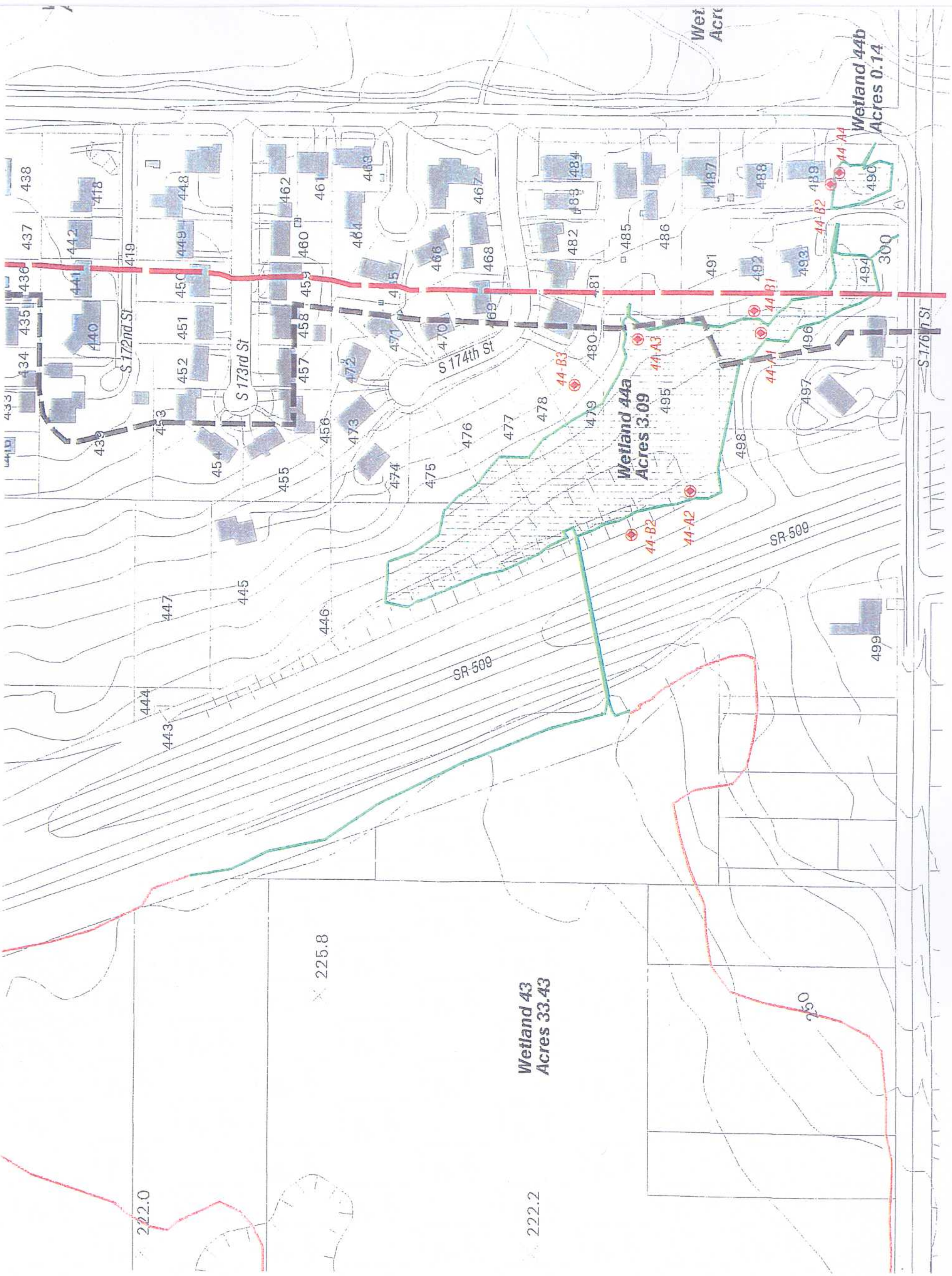
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Wetland 43
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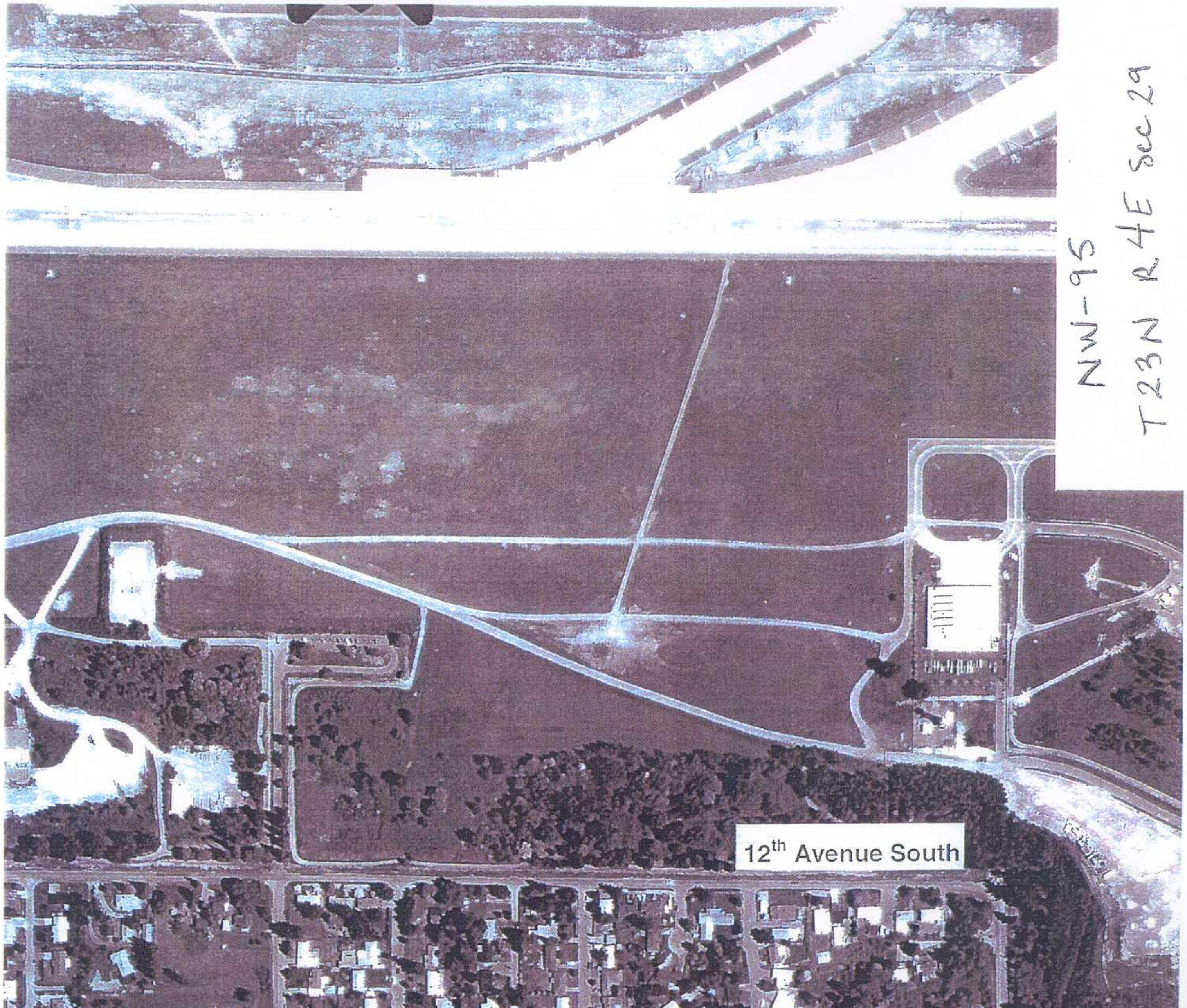

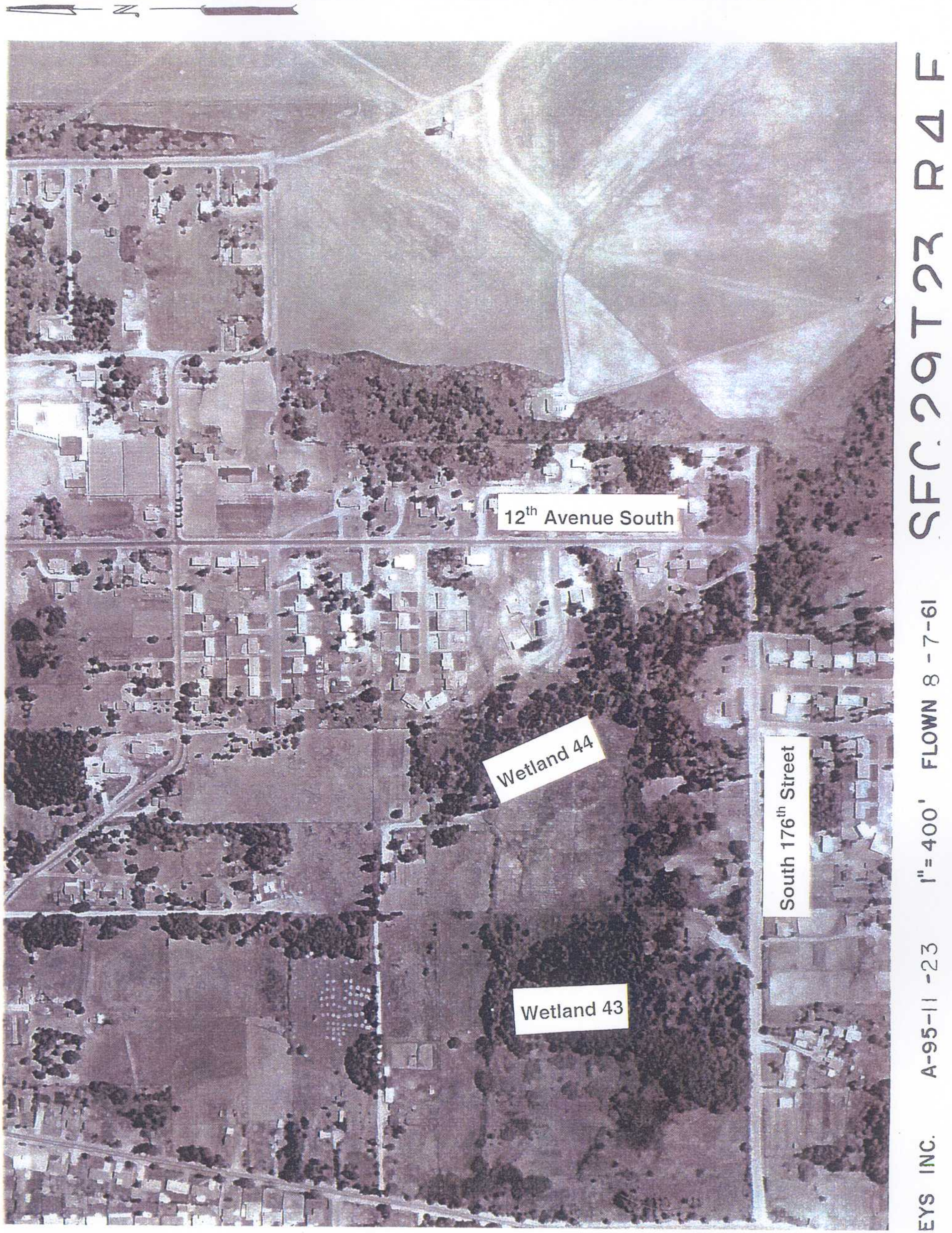
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DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
SEATTLE DISTRICT, CORPS OF ENGINEERS
P.O. BOX 3755
SEATTLE, WASHINGTON 98124-3755

REPLY TO
ATTENTION OF

Regulatory Branch

AUG 24 2000

Elizabeth Leavitt
Manager, Aviation Environmental Programs
17900 International Blvd., Suite 301
Sea-Tac WA 98188-4236

Reference: 1996-4-02325
Seattle, Port of

Dear Ms. Leavitt:

Enclosed is a copy of our Memorandum for the Record confirming the final jurisdictional determination for your proposed SR 509 Temporary Interchange. We concur with the boundaries as outlined in the map submitted by Parametrix Inc. on your behalf, dated June 15, 2000. Our concurrence is also based on site visits performed by U.S. Army Corps of Engineers (Corps) staff on May 25, 2000, and June 8, 2000, and preliminary field data submitted by Parametrix on June 12, 2000.

This new information warrants revision of the southern boundary of Wetland 44a, previously confirmed by the Corps based on the revised draft "Wetland Delineation Report, Master Plan Update Improvements for Sea-Tac International Airport", prepared by Parametrix Inc., dated August 1999. This wetland delineation confirmation revision may be appealed if you so choose. Enclosed is the March 9, 2000, administrative appeal rule package.

The most recent plans for the proposed SR 509 Temporary Interchange, dated May 3, 2000, include the discharge of fill material into 0.011 acres, or approximately 500 square feet of a jurisdictional wetland. We will analyze this additional impact together with all of the project impacts for the Sea-Tac Master Plan update project in making a permit decision. You are not authorized to proceed with the work outlined in the SR 509 Temporary Interchange plans before we reach a permit decision for the entire project. If you decide to redesign the project to avoid Corps jurisdiction, please submit new project plans to the Corps for review.

For your information, when the Corps has completed revising the original Memorandum for the Record for all waters of the United States, including wetlands in the project area, we will provide you a copy. If you have any questions, feel free to contact Mr. Jonathan Freedman, the project manager at (206) 764-6905.

Sincerely,

SIGNED

Thomas F. Mueller
Chief, Regulatory Branch

Enclosures

Copy Furnished: Parametrix Inc., Attn, Jim Kelley

NWS-OD-RG 13 June 2000

MEMORANDUM FOR RECORD: Jurisdictional Determination

1. **Applicant.** Port of Seattle - Third Runway Project
1996-2-02325

2. **Background/Project Description.** The U.S. Army Corps of Engineers (Corps) is currently reviewing the Port of Seattle's (Port) proposal to construct a third runway and related facilities at Sea-Tac International Airport (STIA), located at the city of Sea-Tac, Washington. The Corps has not, to date, made a permit decision on the proposal. It came to the Corps' attention that the Port had plans to begin construction on a temporary interchange at S. 176th St. and SR 509 during the summer of 2000. The temporary interchange would facilitate truck access for fill material for the third runway, which is being stockpiled on upland portions of the Port's property. The Port is fully aware that any construction they do related to the Third Runway project on uplands before the Corps has made a permit decision, they do so at their own risk. The Corps will consider any of those activities preceding our permit decision in our final determinations for the project as if they were still prospective.

The Port, concerned citizens and scientists, Washington State Department of Transportation (WSDOT), and Congressional entities have all requested that the Corps make a jurisdictional determination on the construction of the temporary interchange. The Corps has reviewed the following documents in making our determination in relation to this specific action for the project:

Project Manual, Including Specifications for SR 509 Temporary Interchange at South 176th Street, prepared by the Port of Seattle, dated March 1, 2000. This appears to be a bid document.

Port of Seattle Advertisement for Bids document (SR 509 Temporary Interchange at South 176th Street), dated March 22, 2000.

Letter from the City of Burien to Mayor of Sea-Tac expressing concern over the temporary interchange, dated March 28, 2000.

Letter from Hesell/Fetterman to WSDOT and Washington State Department of Ecology (Ecology) concerning temporary interchange, dated April 6, 2000.

Hydraulic Report (Seatac International Airport Third Runway Direct Access, Temporary Interchange at SR 509 and South 176th Street, SR 509 M 23.19 to 23.71), prepared by HNTB Corporation, dated April 12, 2000. The report was addressed to WSDOT.

Memorandum (Analysis of indirect impacts to wetlands from the temporary SR-509 interchange - Seattle-Tacoma International Airport), prepared by Parametrix, dated May 3, 2000.

A full set of construction plan drawings for the Temporary Interchange project, prepared by HNTB Corporation. The Corps received this set of drawings on May 8, 2000. The drawings are dated February 24, 2000.

Letter from Peter Eglick, Attorney (Helsell Fetterman) for Airport Communities Coalition (ACC), dated May 24, 2000.

Report prepared by Azous Environmental Sciences (Review of Wetlands Impacts Resulting from Construction of Temporary Intercahnge at SR 509 and S. 176th Street), dated May 24, 2000.

Letter from the Law Offices of Helsell/Fetterman concerning the ACC's Supplemental 60 Day Notice of Intent to Sue, dated June 2, 2000.

Report prepared by Azous Environmental Sciences (Review of Wetland 44a in Relation to proposed Temporary Interchange at SR509 and S. 176th Street), dated June 5, 2000.

Letter from the Law Offices of Helsell/Fetterman to Mr. Phil Schneider, Habitat Biologist, Washington Department of Fish and Wildlife (WDFW), dated June 6, 2000.

Report prepared by Columbia Biological Assessments (Sea-Tac International Airport SR-509 Temporary Interchange at S 176th Street and Its Potential Impacts on Fisheries Resources of Walker Creek), dated June 6, 2000. This report was addressed to Phil Schneider (WDFW) with a copy to the Corps.

Preliminary information (map, data sheets, soil descriptions) for the east side area of the proposed temporary interchange, submitted by Parametrix, dated June 12, 2000.

> ***A series of e-mail exchanges between Ecology, the Corps, and King County (King County is the lead on reviewing the Port's most recent Stormwater Plan for the proposed Third Runway Project), concerning the temporary interchange. E-mails from Ecology were forwarded to the Corps on May 23, 2000; May 26, 2000; June 2, 2000.***

It should be noted that the above document list is not an exhaustive list. The Corps has received letters of concern from citizens in regards to the temporary interchange project stating that there may be direct and indirect impacts to wetlands. The Corps has considered all submittals for our decision relevant to the temporary interchange. All information, documentation, reports, letters, etc., which the Corps received in response to the Ports proposal to move forward with construction of the temporary interchange remain a part of the official Corps record for this permit action.

3. Site Visits. In addition to the Corps reviewing all of the relevant information concerning the temporary interchange, the Corps conducted site visits to this area on three separate occasions. These include the following:

> <u>Summer of 1998</u>. The Corps conducted dozens of site visits to the area of the Third Runway Project during this period of time, as the Port acquired properties in the buy-out and project impact areas. The Corps does not have specific data sheets correlating to Wetland 43 (located on the west side of SR 509) or Wetland 44a (located on the east side of SR 509). There is conflicting information presented in the Wetland Delineation Report (Report), prepared by Parametrix, and dated August 1999, for Wetland 43. According to Figure 4 of the Report, the Corps never did confirm the boundaries of Wetland 43, but we had confirmed the entire boundary for Wetland 44a. Table 3 of the Report (Summary of wetland and other waters of the U.S. areas in the STIA Master Plan Update improvements area), does not even list Wetland 43, nor is it described in the Report. However, Map #10 in the Report shows part of the eastern boundary of Wetland 43 as being surveyed and confirmed by the Corps. In addition, the Report shows the northern edge of Wetland 44a was neither surveyed, nor confirmed by the Corps (the Corps points this out in our MFR for the wetland delineation - final document in progress). The Corps did not concentrate our efforts in confirming the wetland delineation lines in this area since during the summer of 1998, we were not made aware of any construction impacts (either direct or indirect) that were proposed or anticipated in this area.

Parametrix contends that the Corps did look specifically at the wetland delineation line for Wetland 44a in the area closest to the proposed temporary interchange; however, neither the project manager nor the environmental analyst who conducted all site visits can recall with any certainty that we **specifically** (as in which flags) looked at the entire line in this area. After receipt of the information regarding the SR 509 temporary interchange, the Corps determined it was appropriate to conduct another site visit to accurately confirm the delineation in this area due to the proximity of the proposed temporary interchange to wetlands 43 and 44a.

<u>May 25, 2000</u>. Corps staff met with Parametrix and the Port on site at the proposed interchange location to review project plans and to consider comments we had received from Azous Environmental Sciences concerning the wetland delineation in the project plans - specifically concerning Wetland 43. While on site, Corps staff requested that we closely look at the " pinch" point for Wetland 44a (that point at which the proposed retaining wall for the interchange comes closest to the delineated wetland - approximately 12 feet). During that inspection, it became apparent that the wetland delineation was inaccurate for the western boundary of Wetland 44a, since there was hydrology and wetland vegetation expression above and east of the wetland delineation line flagged by Parametrix in the summer of 1998 and presented in the wetland delineation report, dated August 1999). Soils dug in this area were clearly hydric. Several plots which the Corps took outside of the delineated area, contained the 3 wetland parameters (hydrophytic vegetation, wetland hydrology, and hydric soils). We collected some data (see attached data sheets). The potential wetland continued upslope from the Wetland 44a boundary. We also inspected the rock lined highway swale, which had clearly not been maintained for quite some time. Much of the site in this location was dominated by Himalayan blackberry, with an understory of horsetail, and grasses (fescue, some velvet grass, and bentgrass). We asked the Port to remove the blackberries by hand and to look at the area and submit a report of their findings. Based on the information we collected and observed in the field, and the Port's own data, there appears to be an area within the footprint of the retaining wall for the temporary interchange which meets the three parameters for a wetland. It was agreed that the Corps had to make a decision on whether this wetland was jurisdictional and to consider all relevant factors for making a decision. One relevant factor to be considered was that the wetland had formed in fill soils placed in 1978 for

construction of SR 509 (see more discussion below in jurisdictional determination).

In addition to inspecting the area around Wetland 44a, we also inspected the area on the west side of SR 509, inclusive of Wetland 43. The discrepancy between HNTB's project plans and the wetland delineation, as pointed out in the Azous Report, became apparent during our site visit. The area in question contained two older and vegetated (PSS/PEM/POW) stormwater ponds constructed by WSDOT for SR 509. The ponds were excavated in hydric soils (wetlands), and as such, would be considered jurisdictional, if the project included discharges into these ponds. Maintaining the ponds to original depths and configuration could be authorized via Nationwide Permit 3, but as of the date of this MFR, the Port does not have plans to impact these ponds either by filling or maintaining them to original contours. In the wetland delineation which Parametrix prepared for the project as a whole (August 1999), the stormwater ponds in this area were included within the boundaries of Wetland 43. HNTB excluded the stormwater ponds from Wetland 43 per the request of WSDOT. According to HNTB, WSDOT requested that the ponds not be included in the wetland area because it is within WSDOT's right-of-way, and WSDOT (erroneously) assumed that the ponds would not be jurisdictional. Since the ponds are jurisdictional, HNTB will revise the temporary interchange drawings to reflect this.

Based on this site inspection, the Corps was able to confirm the wetland delineation line for Wetland 43 - it is clearly demarcated by a compacted gravel fill access road. The wetland edge starts at this fill prism and continues westward into a large wetland system (known as the Airport Park Wetland). There will be no direct impacts to this wetland from the construction of the temporary interchange on the west side of SR 509. This statement is based on the Port's assertion that the stormwater outfall into the stormwater ponds does not need to be retrofitted for the construction of the temporary interchange. We will not know that for sure until all the stormwater issues are worked out between Ecology, WDFW, King County, and the Port.

In addition, the Corps has determined that it is appropriate to confirm the delineation of the northern edge of Wetland 44a since the Port now has access to this property and it is in the vicinity of the proposed temporary interchange. The Corps plans on doing this in the near future.

June 8, 2000. The Corps (Gail Terzi, Tom Mueller, Geoff Mueller), EPA (Steve Roy, EPA attorney - Deborah Hilsman), Port (Elizabeth Leavitt, Tom Walsh - Port attorney), Parametrix (Jim Kelley), and HNTB engineer (Jim Soukup) all visited the site. During this site visit, the Port presented information that they believed should lead the Corps to conclude that it should not regulate those areas adjacent to the western boundary of Wetland 44a which met the 3 wetland parameters.

The Port's contention is that the hydrology associated with the subject area is due to either (1) the unmaintained rock lined highway swale leaks laterally during storm events to express hydrology in that area of the fill material, or (2) all/some of the subsurface drains installed by WSDOT when SR 509 was built are not functioning properly, thereby leaking subsurfacely, and expressing on the surface at the base of the fill slope. The Port also stated that the catch basin (located at the top of the fill slope between the SR 509 fill embankment and the highway) which captures groundwater from the subsurface drains in the cut for SR 509 construction may be cracked and leaking, thereby allowing groundwater and/or stormwater to infiltrate in the fill area, which is being expressed through the now hydric fill at the base of the slope for SR 509. We all had a long discussion of the potential source(s) of hydrology in the field. Several plots were dug - no official data was taken during this site visit. All in attendance agreed that the area in question met the three wetland parameters.

One option presented to the Port was that they could maintain the highway drainage system (ie - fix the leakage problem, reconstruct and line the rock lined swale, inspect the catch basin, etc.). Then the Corps could revisit the site later, such as in the early spring of 2001, to see if the subject area still met the 3 wetland parameters. If it did not meet the three wetland parameters, this would potentially substantiate their opinion that the hydrology was artificially created from leakage from the stormwater swale constructed in the fill embankment or the subsurface drains. The Port has declined to take this option.

4. **Jurisdictional Determination.** The following factors were considered in our decision:

- Preceding the construction of SR 509 around 1978, Wetlands 43 and 44a were one very large contiguous wetland system. Construction of the highway bisected the wetland into two parts. Inspection of aerial photography has substantiated this.
- A majority of the fill for this area of SR 509 was placed in a wetland. It appears from the surrounding landscape, that some hillsides were cut and some wetlands were filled for construction of SR 509. The drainage patterns in this entire area have been substantially altered, and the present condition has existed for at least 22 years.
- This area does not meet the definition of discharges not requiring permits as described at 33 CFR, Section 328.3(e). It is not a " waterfilled depression created in dry land incidental to construction activities."
- The fill material for the SR 509 embankment has been in place for some 22 years. It would now be considered a new normal circumstance. It is apparent that the wetlands have formed at the area where two fill slopes intersect. This is at the point where the slopes briefly flatten out before continuing easterly, down another fairly steep slope to the native wetland in the original landscape position.
- The delineation for Wetland 44a, as depicted in the wetland delineation report, included an area upslope (west of) the native soils and wetland. The Corps accepted this as a new normal circumstance and considered this area as jurisdictional wetland. The wetland conditions presented further upslope (continuing in a westerly direction) and outside of the original wetland delineation line for Wetland 44a have the same characteristics as the area included in the original delineation. It should be noted that the Port contends that the hydrology associated with the area of Wetland 44a in the fill slope which was included in the original delineation is driven by capillary fringe of the wetland hydrology immediately downslope. The Port has stated that they believe that capillary action could not account for the wetland hydrology further upslope (it is generally accepted that capillary fringe action can occur in about 12 inches of non-sandy soils).
- The hydrology associated with the subject area appears to be coming from either groundwater, subsurface seepage of

Appendix I

APPENDIX I

STORMWATER DETENTION POND DESIGNS FOR THE MILLER CREEK BASIN

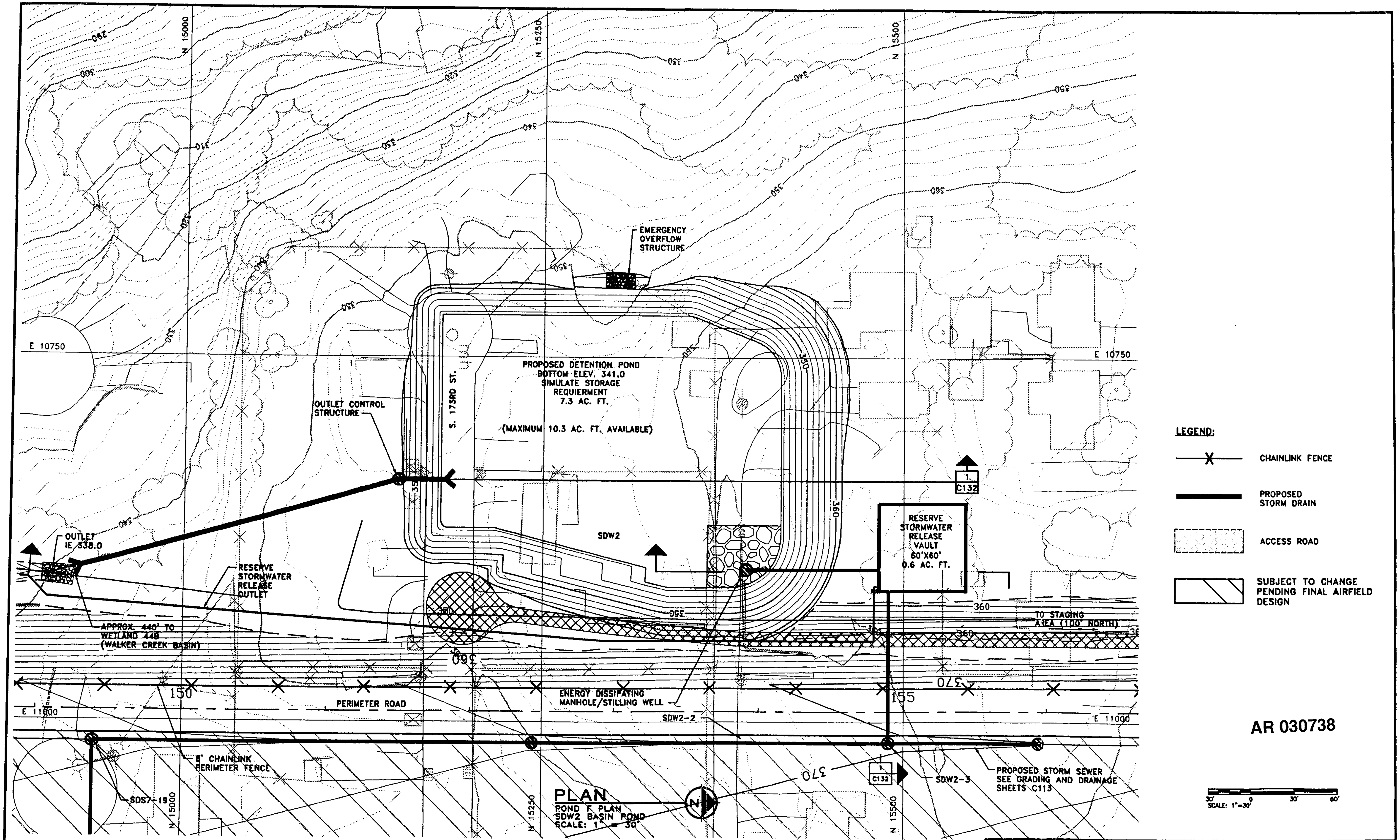
APPENDIX I

STORMWATER DETENTION POND DESIGNS FOR THE MILLER CREEK BASIN

The drawings in this appendix show the location and design cross sections for the new stormwater detention ponds planned for the Miller and Walker Creek basins. These designs were used, in part, to evaluate the potential direct and indirect impacts of the new facilities on nearby wetlands.

POND PLAN AND PROFILES

Plan Ref. No.	Sheet Title
C131	POND F PLAN
C132	POND F PROFILE
C133	POND D OUTLET PLAN
C133.1	POND D PLAN
C134	POND D PROFILE
C134.1	POND D SECTIONS
C135	POND G PLAN
C135.1	PONDG MISCELANEOUS PROFILES
C136	POND G PROFILE
C137	POND C PLAN
C138	POND C PROFILE
C139	SDS4 BASIN VAULT PLAN AND PROFILE
C140	SDS7 BASIN VAULT PLAN AND PROFILE
C141	SDS3, 3A, AND 5 BASIN VAULT PLAN AND PROFILE
C142	NOT USED
C143	NOT USED
C144	NOT USED
C145	SDN3 BASIN VAULT PLAN AND PROFILE
C146	SDN2/SDN4 BASIN VAULT PLAN AND PROFILE
C147	M6 BASIN VAULT (NEPL) PLAN AND PROFILE
C148	SDN1 BASIN VAULT PLAN AND PROFILE
C149	SDN6 BASIN (CARGO) VAULT PLAN AND PROFILE
C150	SDN3A BASIN VAULT C1 AND C2 PLAN AND PROFILE
C151	SDN1A BASIN VAULT G1 PLAN AND PROFILE



AR 030738

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

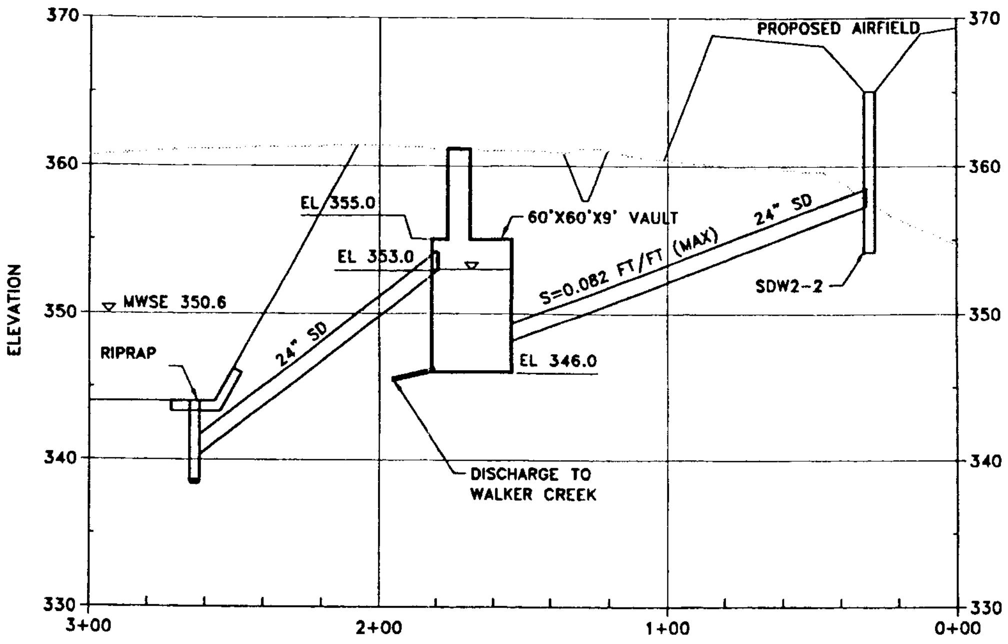
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6

SHEET TITLE: POND F PLAN
SDW2 BASIN POND

DATE
DEC. 15, 2000

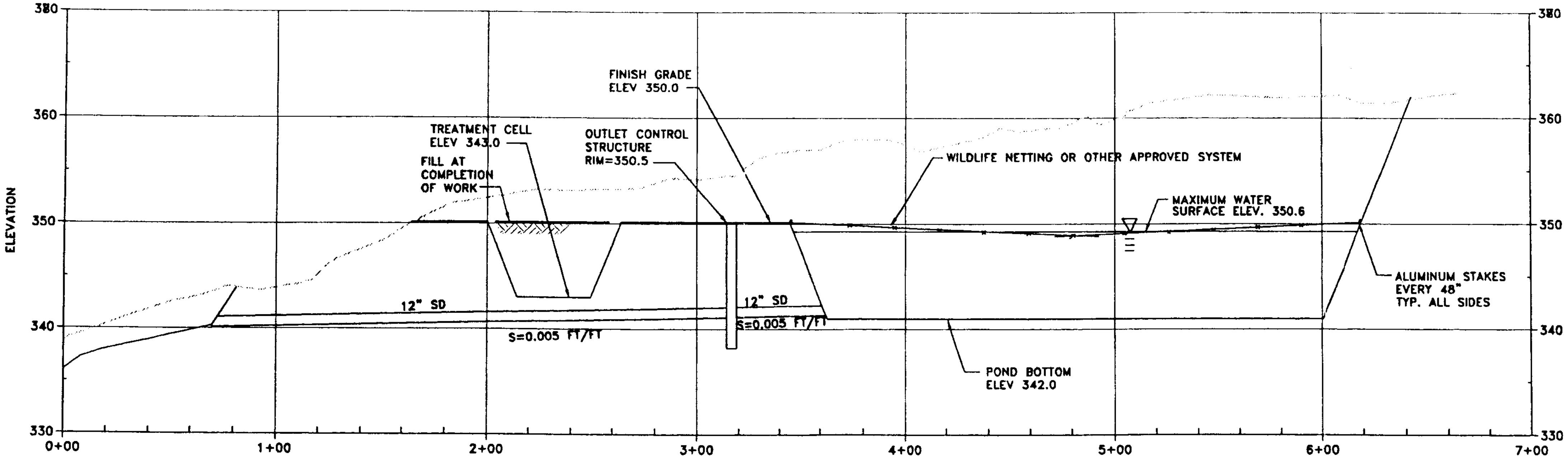
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C131



PROFILE
STORM DRAIN AND RESERVE
STORMWATER RELEASE VAULT PROFILE
SCALE: 1" = 30'

2
C131



GROUND WATER AT ELEV. 260±

PROFILE
POND F PROFILE
SDW-2 BASIN POND
SCALE: 1" = 30'

1
C131

AR 030739

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

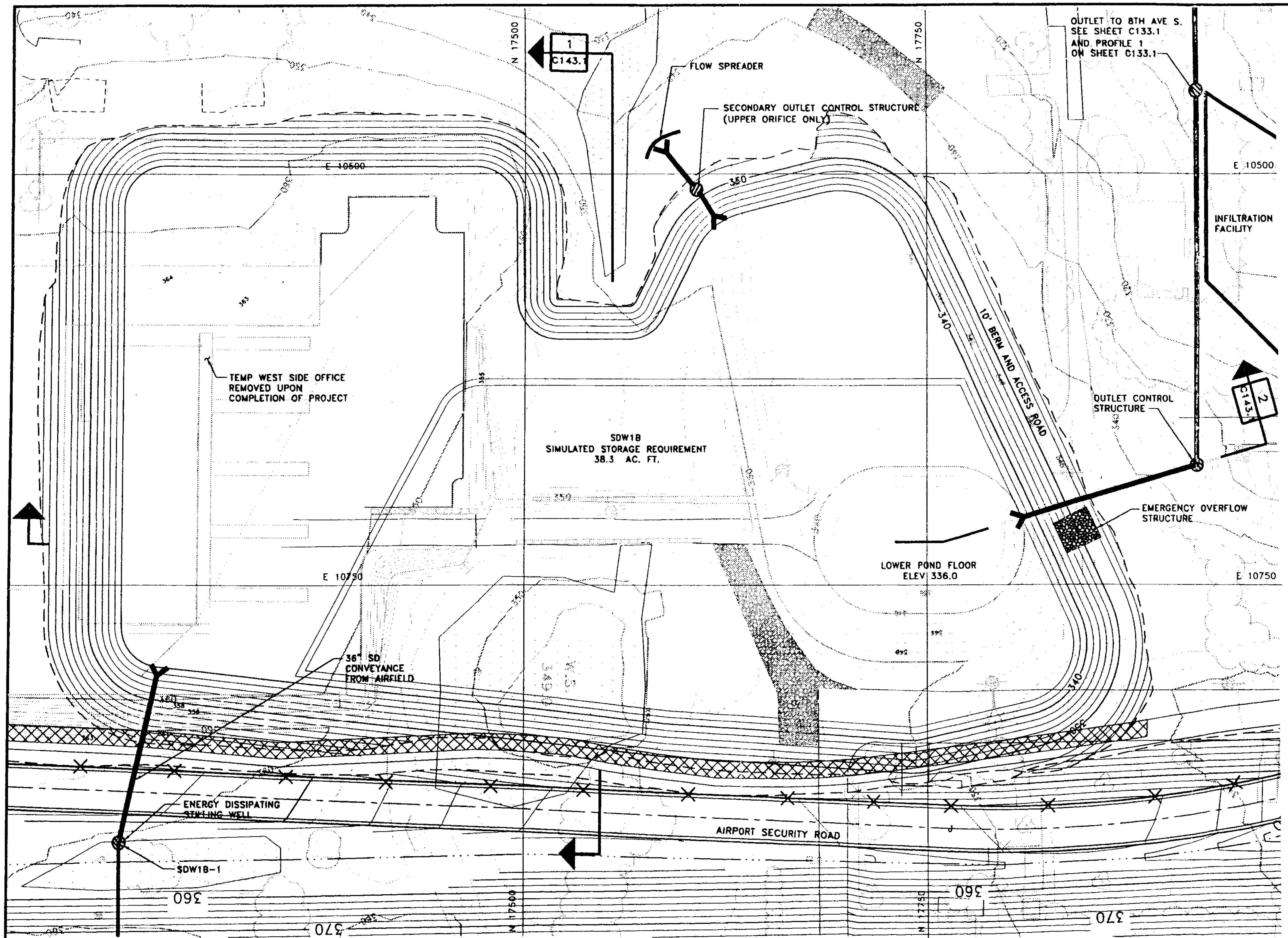
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6

SHEET TITLE: POND F PROFILE
SDW2 BASIN POND

DATE
DEC. 14, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_C132



NOTE:

THE DESIGN WILL ACCOMMODATE A TOTAL POND VOLUME OF 38.34 AC. FT. BY EXPANDING POND D TO THE SOUTH AS SHOWN.

LEGEND:

	TEMPORARY SWALE
—×—	CHAINLINK FENCE
━	PROPOSED STORM DRAIN
┆	ACCESS ROAD AROUND POND G
☐	WETLANDS

AR 030740

30' 0 30' 60'
SCALE: 1"=30'

PLAN
POND D PLAN
SDW1B BASIN POND
SCALE: 1" = 30'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

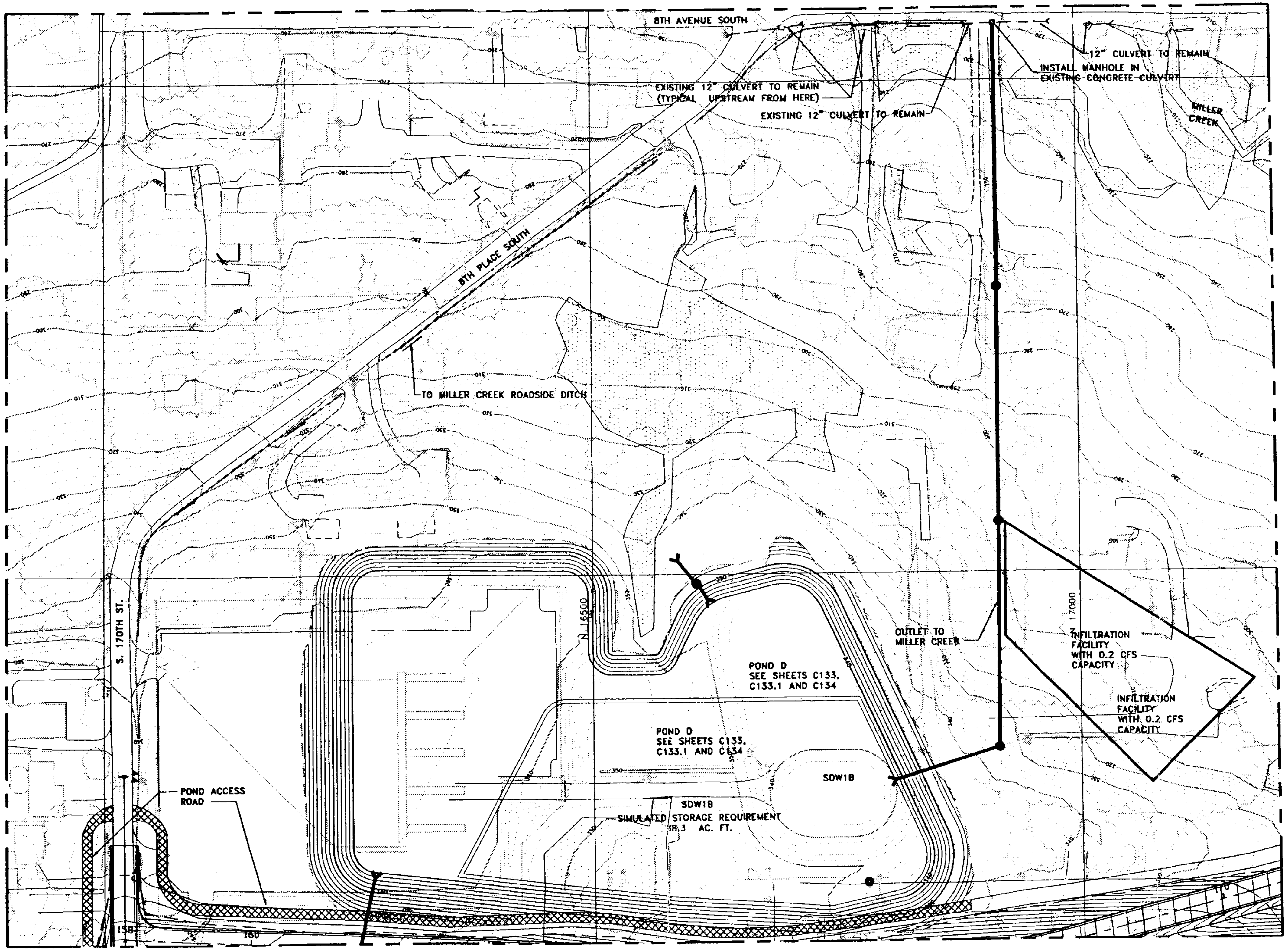
SHEET TITLE: POND D PLAN
SDW1B BASIN POND

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C133

NOTES:

LEGEND:

———	STORM DRAIN PIPE

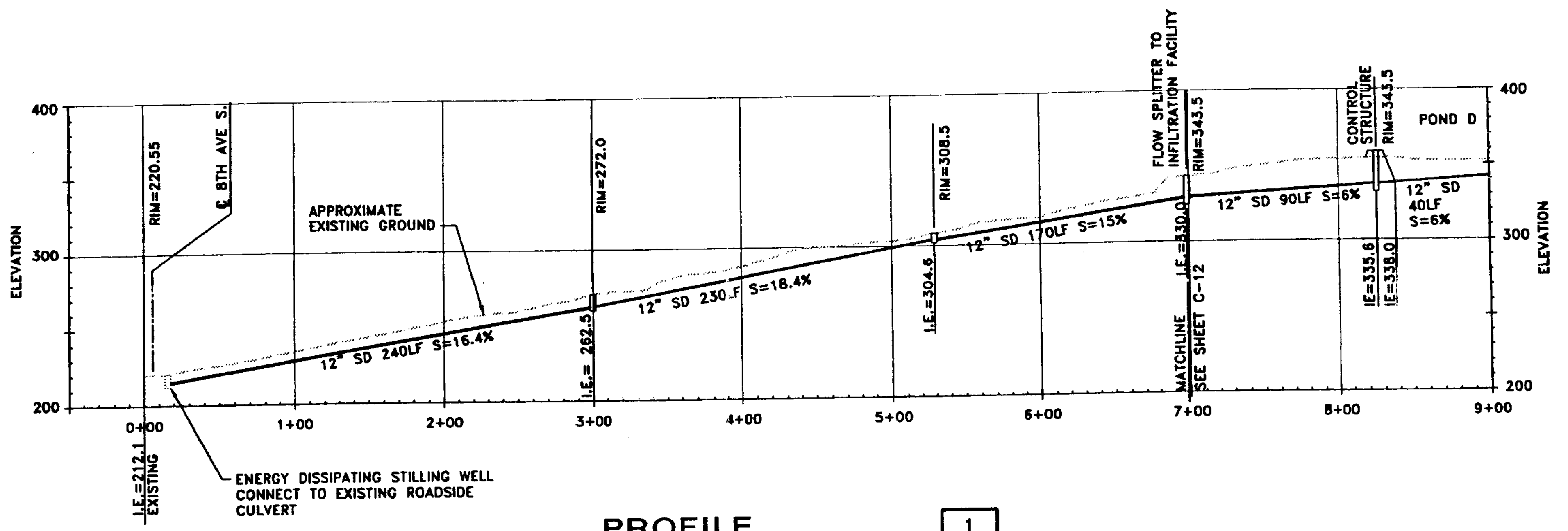


Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **POND D - OUTLET PLAN**

DATE	DEC. 15, 2000
CONSULTANT'S NO.	
PORT OF SEATTLE NO.	EXHIBIT_ C133.1



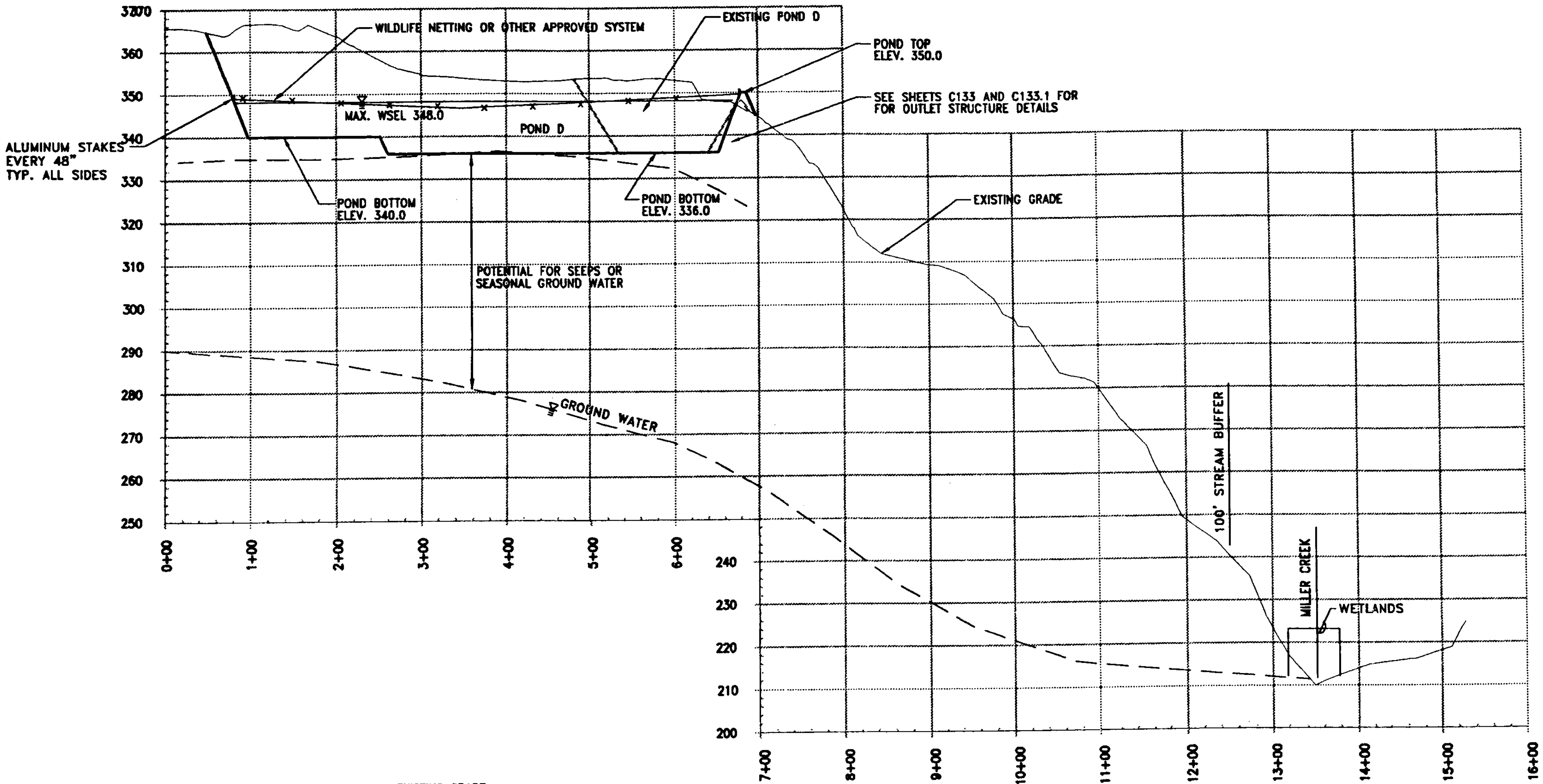
PROFILE
POND D DISCHARGE TO MILLER CREEK
SCALE: H 1" = 50'
V 1" = 50'

1
C131

AR 030742

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: POND D PROFILE
SDW1B BASIN POND

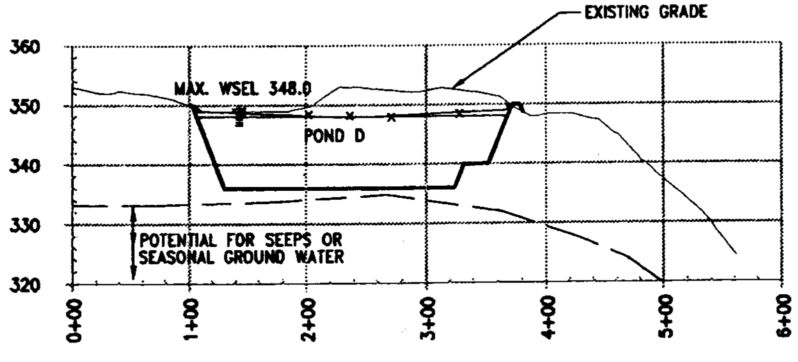
DATE
DEC. 14, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_C134



SECTION

DETENTION POND
SECTION LOOKING WEST
N.T.S

1
C134.1



SECTION

DETENTION POND
SECTION LOOKING SOUTH
N.T.S.

2
C134.1

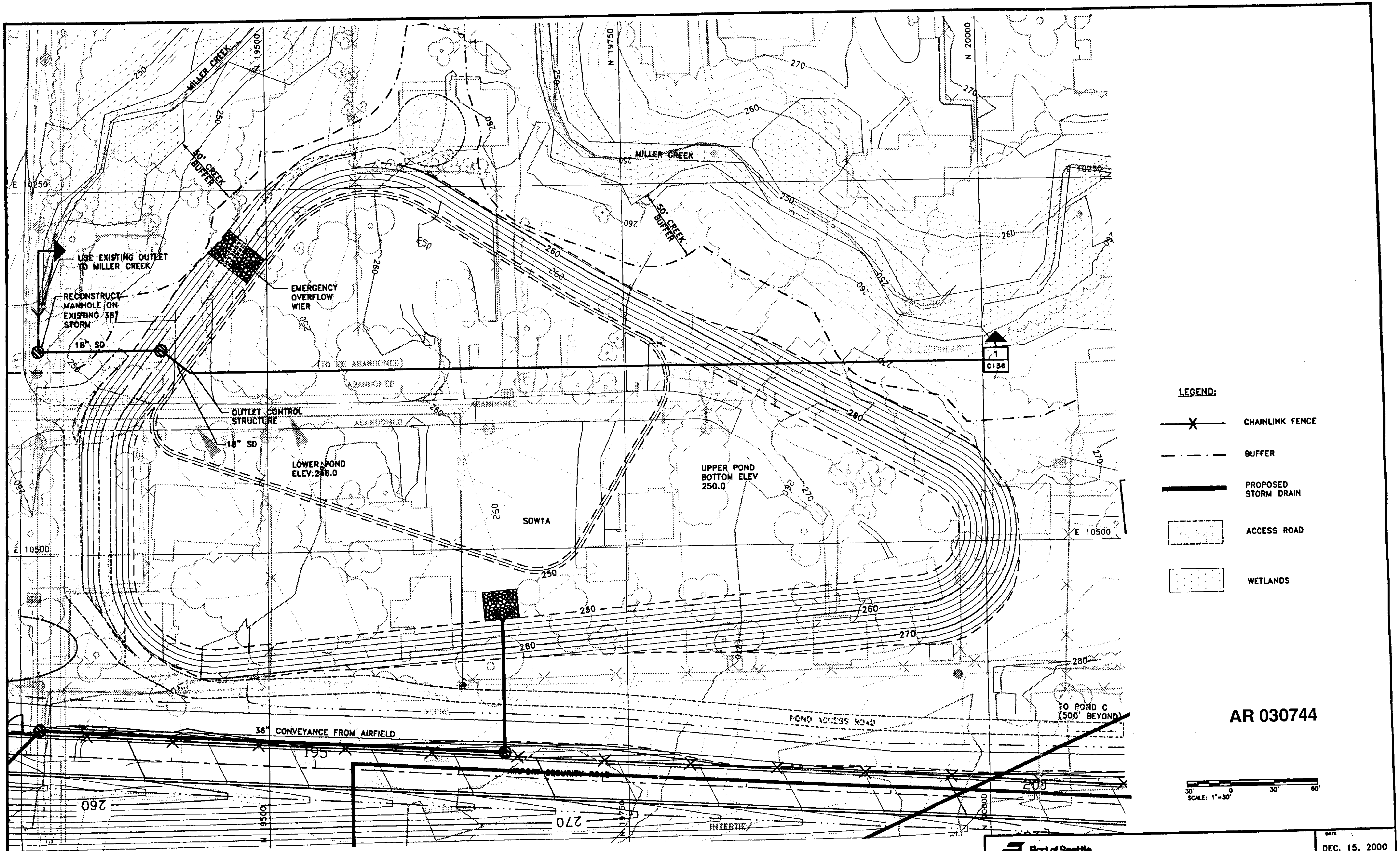
NOTES:

1. GROUND WATER ELEVATIONS ARE APPROXIMATE BASED ON AVAILABLE GEOTECHNICAL INVESTIGATIONS AND HYDROGEOLOGIC ELEVATION WILL BE INCLUDED AS PART OF THE FINAL DESIGN ANALYSIS.
2. FINAL POND CONFIGURATION MAY VARY TO MAINTAIN STORM WATER STORAGE ABOVE THE OBSERVED GROUND WATER.

AR 030743

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: POND D SECTIONS AND DETAILS

DATE
DEC. 14, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C134.1



AR 030744

PLAN

POND G PLAN
SDW1A BASIN POND
SCALE: 1" = 30'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

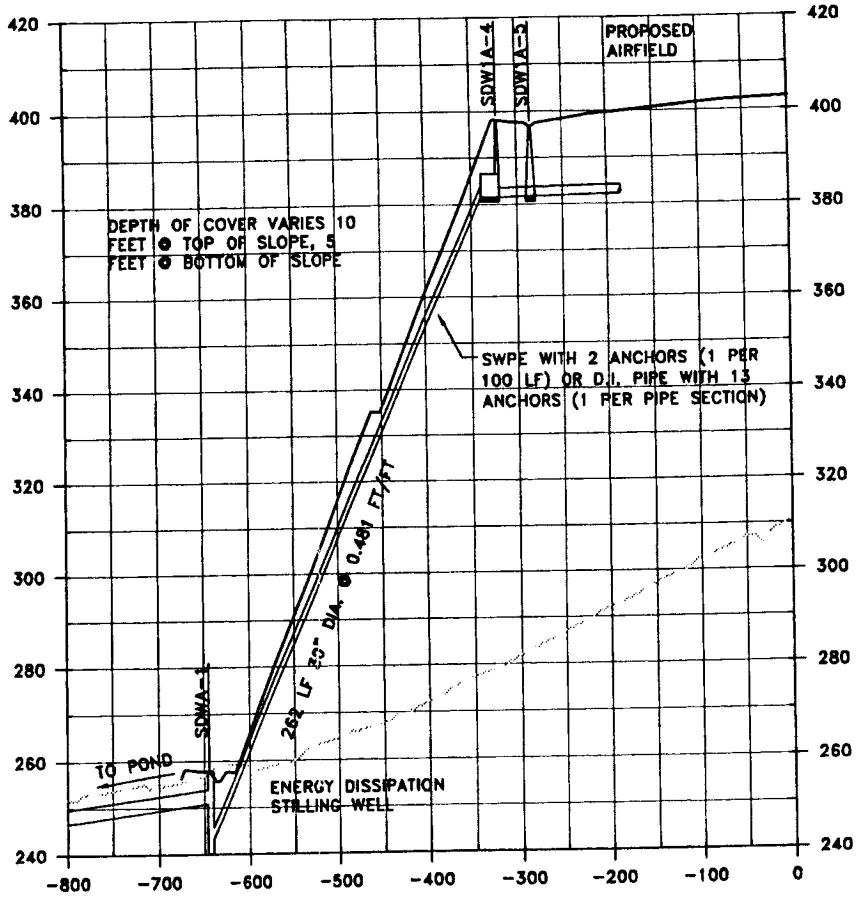
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: POND G PLAN
SDWIA BASIN POND

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C135



PIPE DOWN EMBANKMENT WITH OR WITHOUT BENCHES

PROFILE

POND G – STORM SEWER PROFILE
SDW1A BASIN
SCALE: 1" = 100'

1
C-135

AR 030745

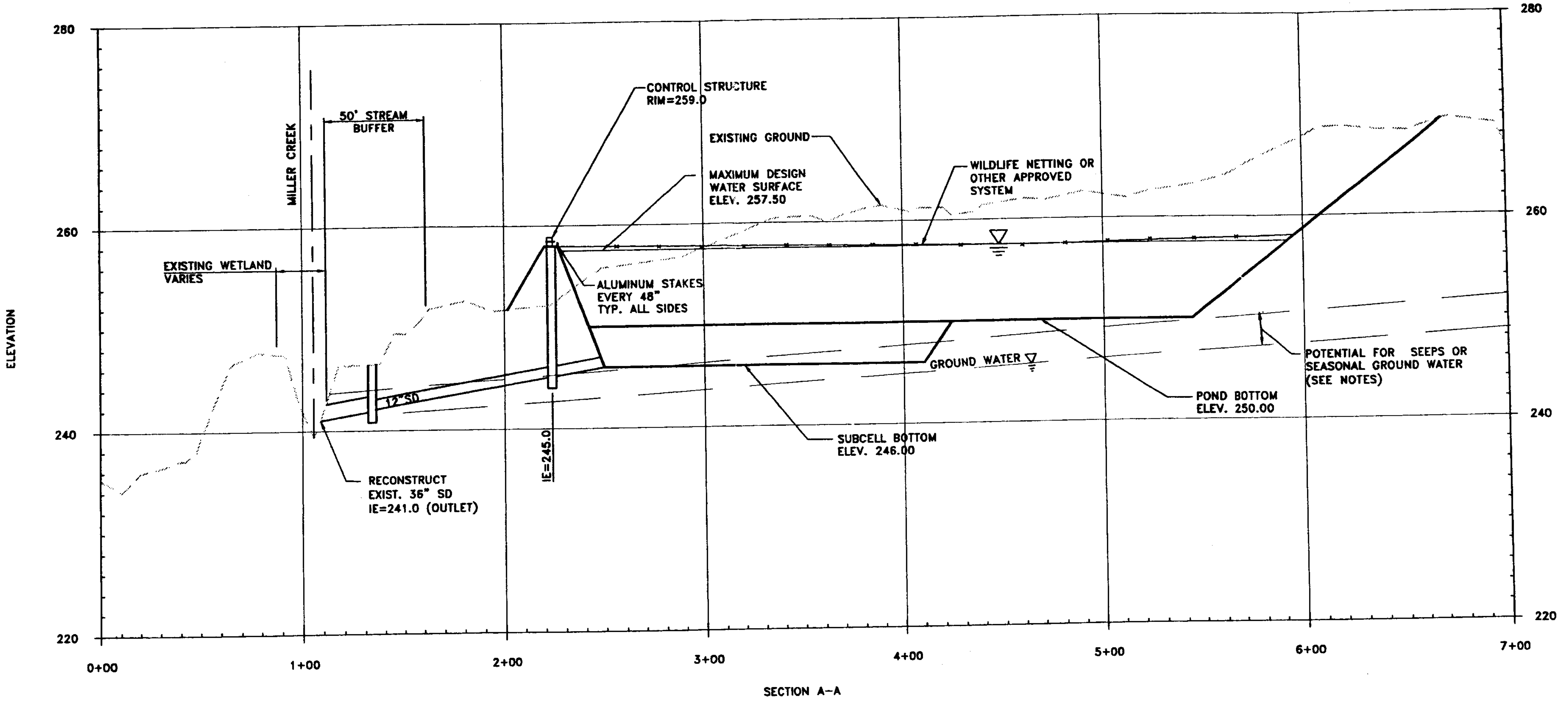
100' 0 100' 200'
SCALE: 1"=100'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: POND G -MISCELANEOUS PROFILES
SDW1A BASIN

WORK ORDER NO.
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C135.1



PROFILE

POND G PROFILE
SDW1A BASIN POND
SCALE: N.T.S.

NOTES:

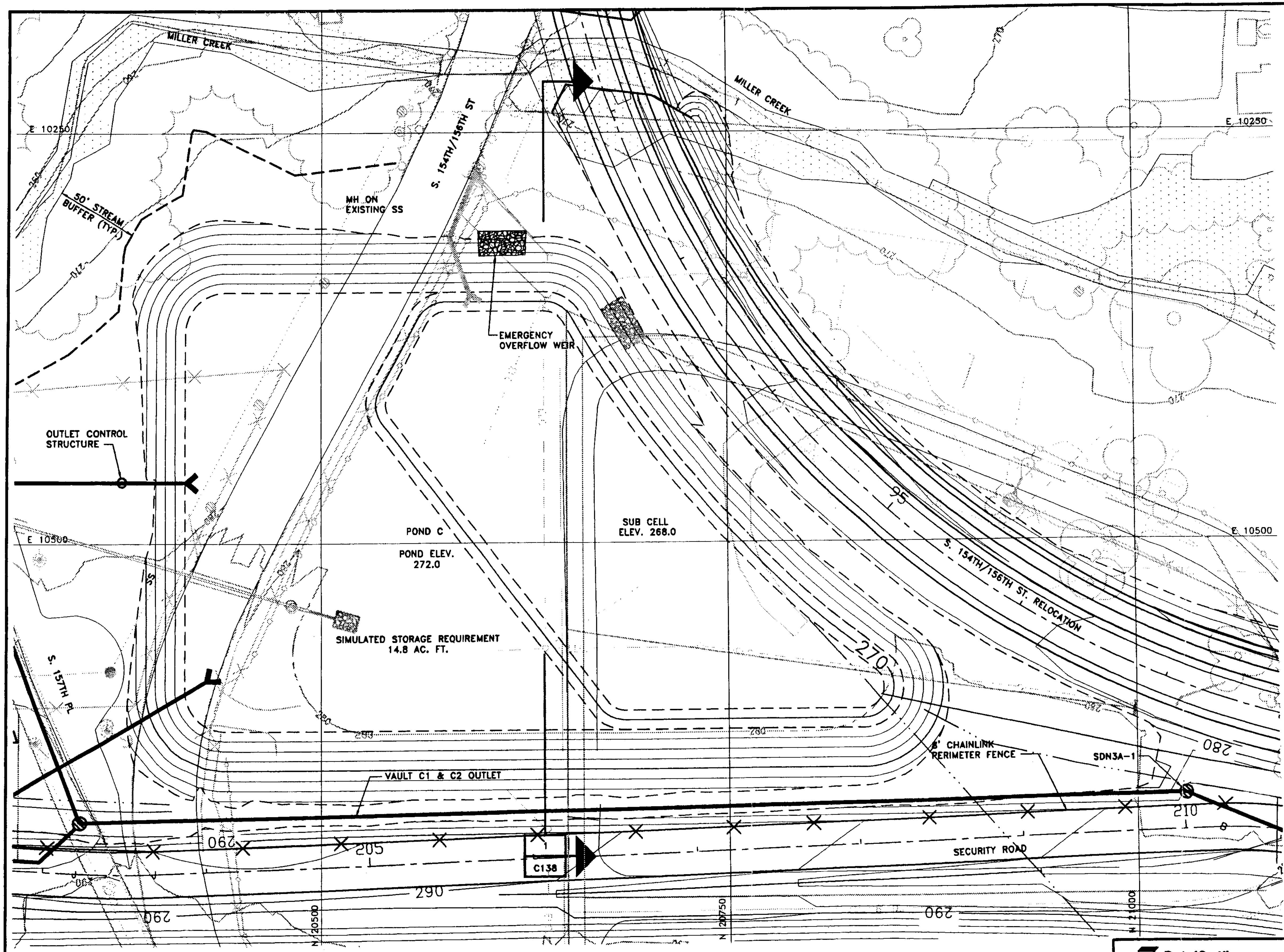
1. GROUND WATER ELEVATIONS ARE APPROXIMATE BASED ON AVAILABLE GEOTECHNICAL INVESTIGATIONS AND HYDROGEOLOGIC ELEVATION WILL BE INCLUDED AS PART OF THE FINAL DESIGN ANALYSIS.

2. FINAL POND CONFIGURATION MAY VARY TO MAINTAIN STORM WATER STORAGE ABOVE THE OBSERVED GROUND WATER.

AR 030746

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: **POND G PROFILE SDW1A BASIN**

DATE: DEC. 14, 2000
CONSULTANT'S NO.:
PORT OF SEATTLE NO.: EXHIBIT_ C136



PLAN
POND "C" PLAN
SCALE: 1" = 30'

LEGEND:

┅	ACCESS ROAD

AR 030747

30' 0 30' 60'
SCALE: 1"=30'

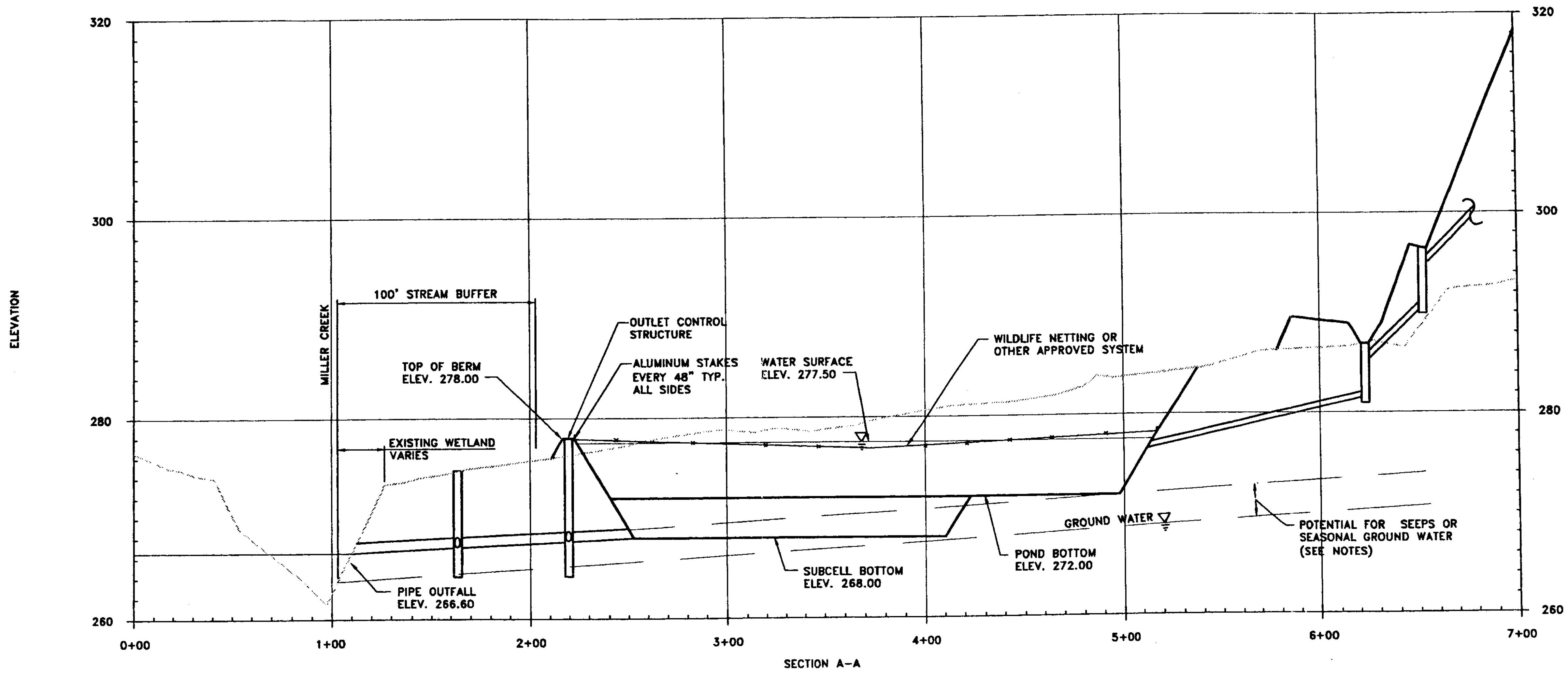
Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: POND C PLAN
SDN3A BASIN POND

DATE
DEC. 15, 2000
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C137



SECTION A–A

NOTES:

1. GROUND WATER ELEVATIONS ARE APPROXIMATE BASED ON AVAILABLE GEOTECHNICAL INVESTIGATIONS AND HYDROGEOLOGIC ELEVATION WILL BE INCLUDED AS PART OF THE FINAL DESIGN ANALYSIS.

2. FINAL POND CONFIGURATION MAY VARY TO MAINTAIN STORM WATER STORAGE ABOVE THE OBSERVED GROUND WATER.

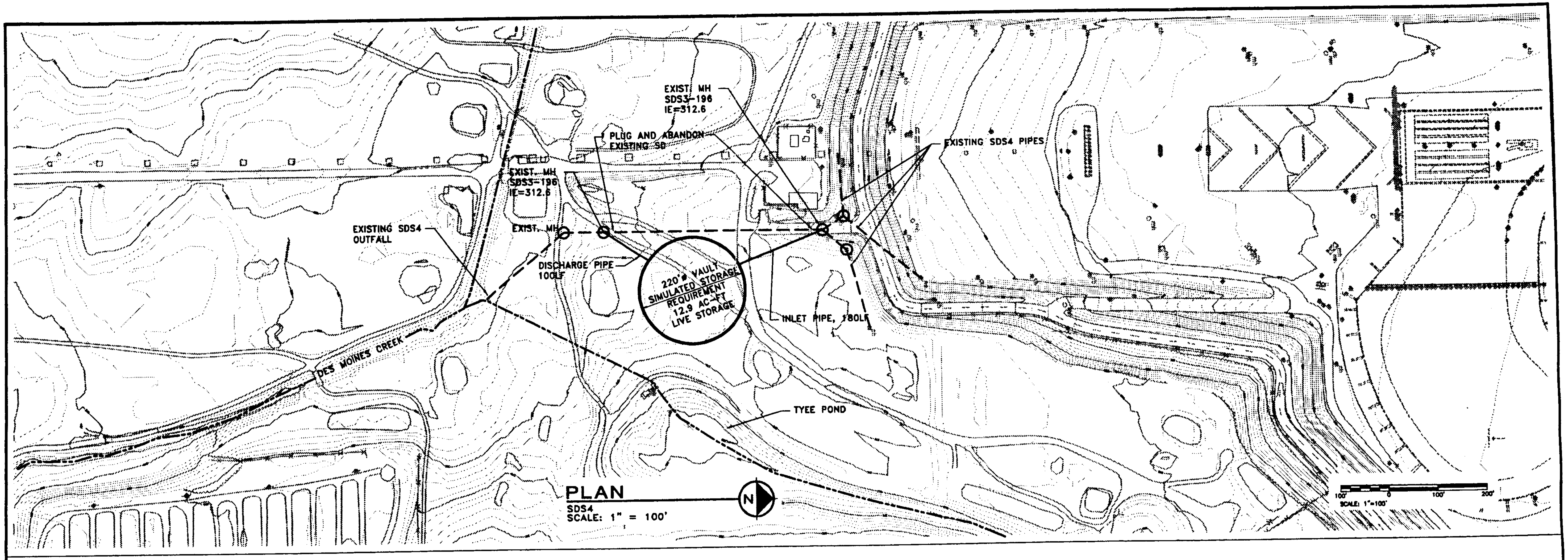
AR 030748

20' 0 20' 40'
SCALE: 1"=20'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: POND C PROFILE
SDW1A BASIN POND

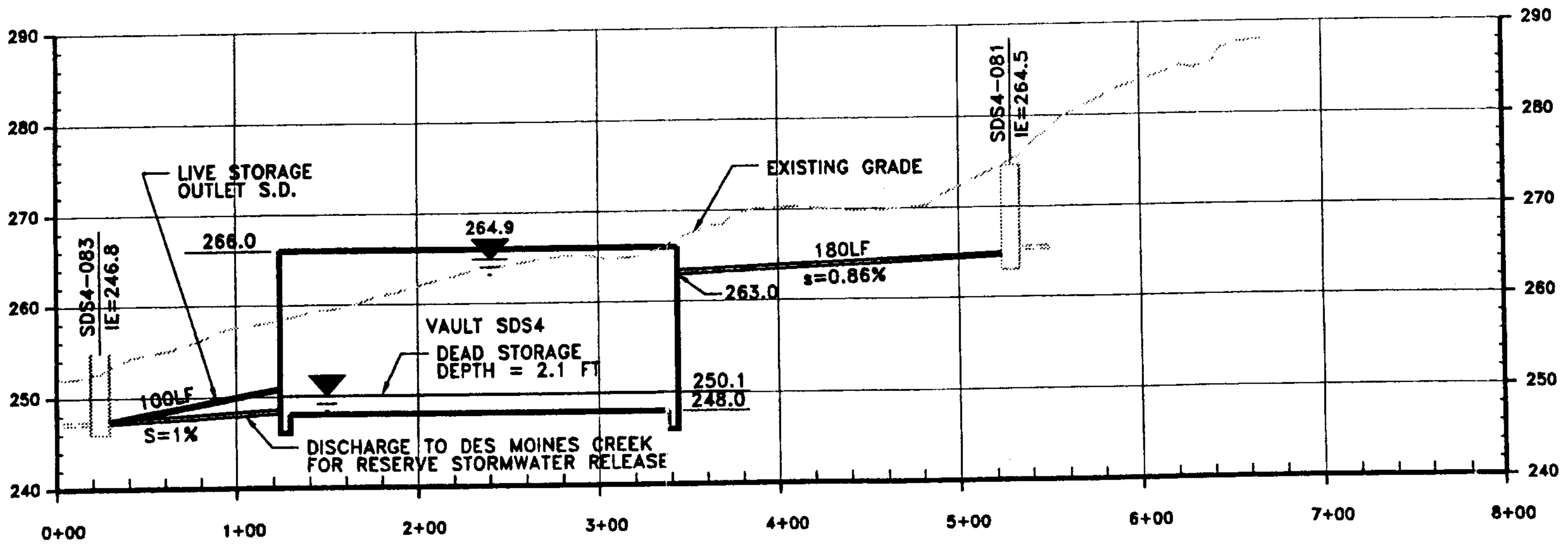
DATE
DEC. 14, 2000
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_C138



PLAN

SDS4
SCALE: 1" = 100'



PROFILE

SDS4
SCALE: 1" = 50'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

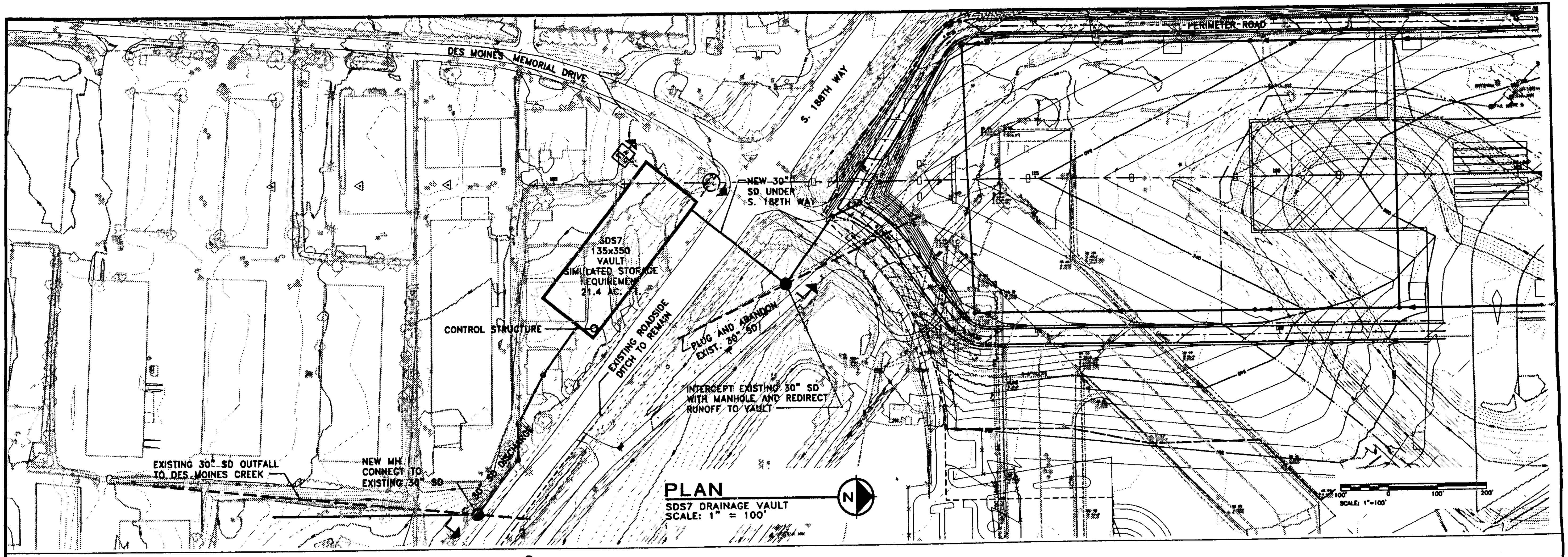
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 6

SHEET TITLE: **SDS4 BASIN VAULT**
PLAN AND PROFILE

DATE
DEC. 15, 2000

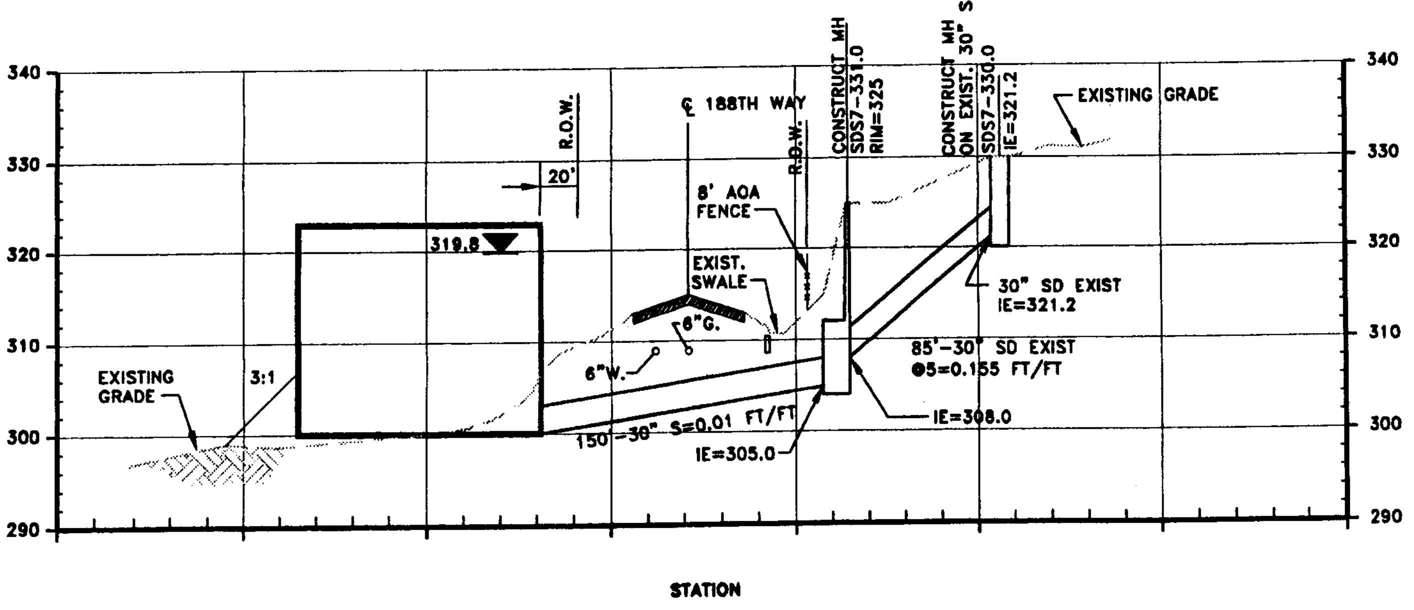
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C13



PLAN

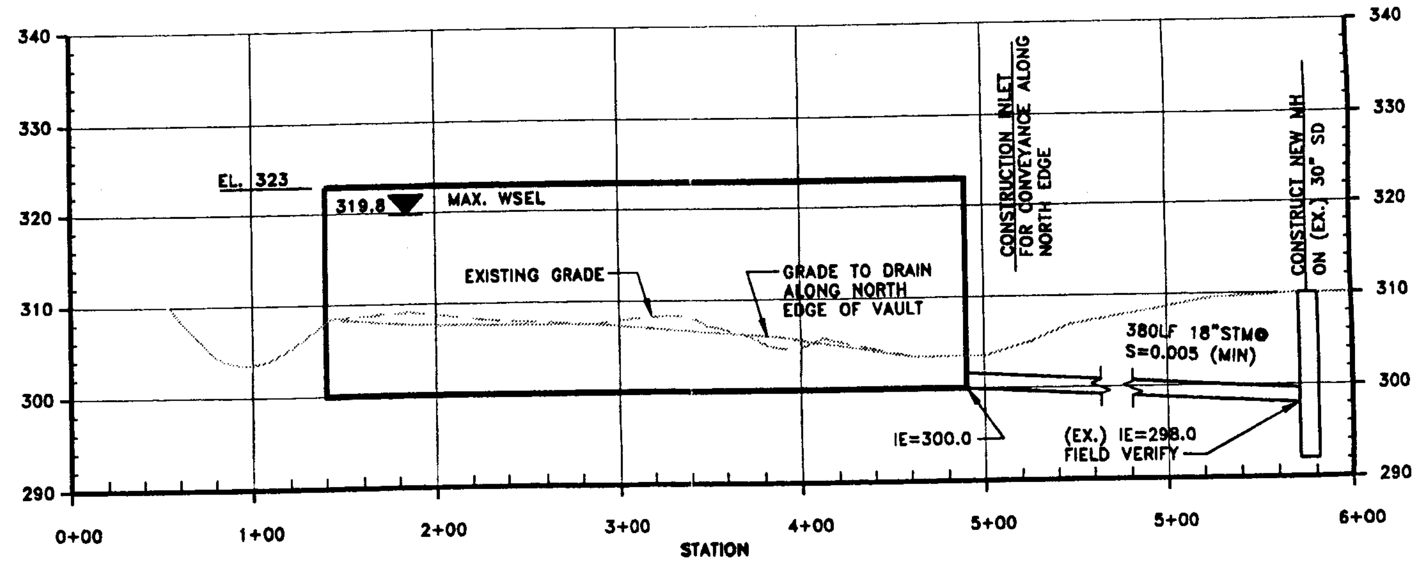
SDS7 DRAINAGE VAULT
SCALE: 1" = 100'



SECTION A

1
C-18

SDS7 DRAINAGE VAULT
SCALE: 1" = 40'



PROFILE

SDS7 DRAINAGE VAULT
SCALE: 1" = 50'

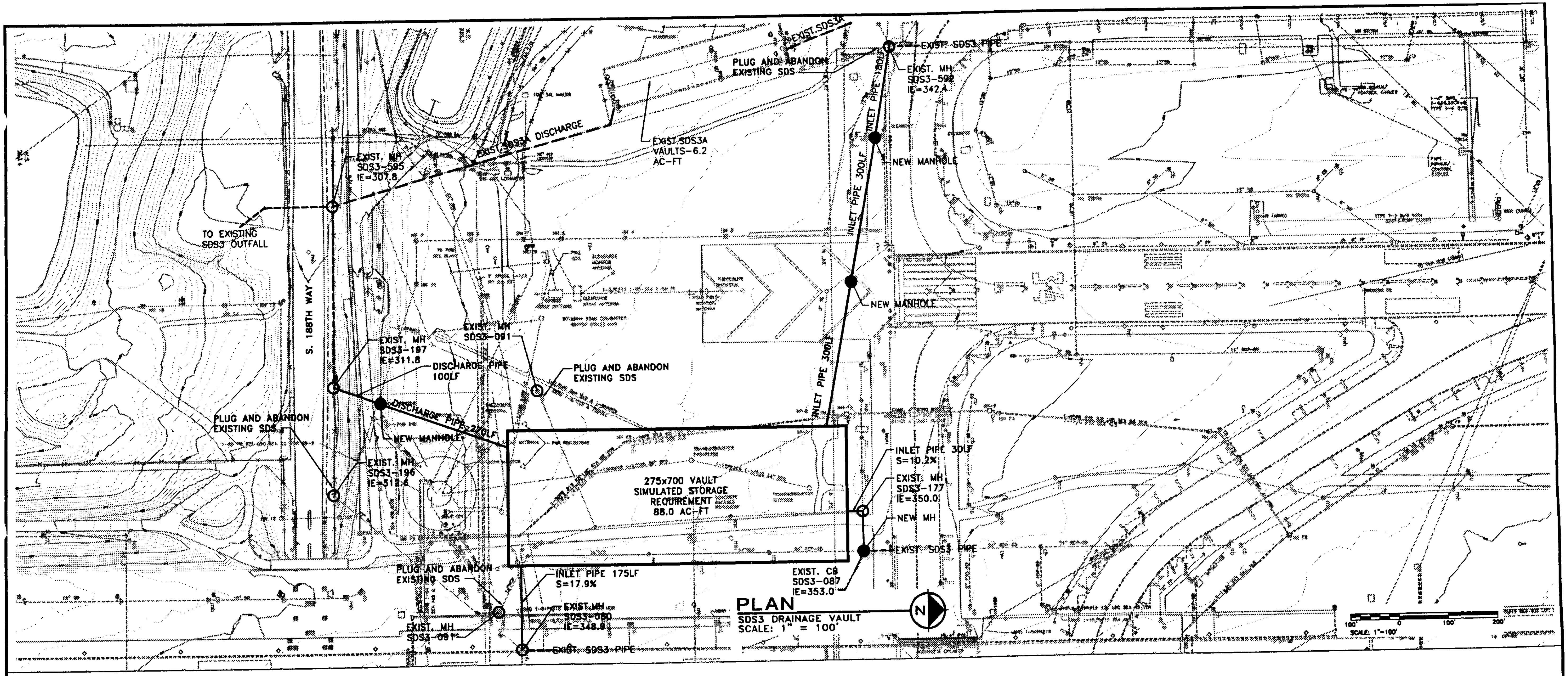
Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **SDS7 BASIN VAULT PLAN AND PROFILE**

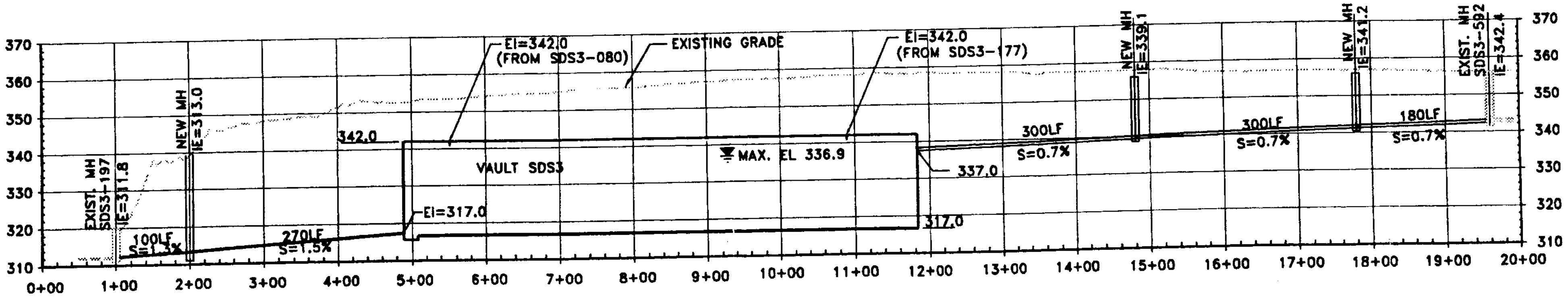
DATE
DEC. 15, 2000
CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C140



PLAN

SDS3 DRAINAGE VAULT
SCALE: 1" = 100'



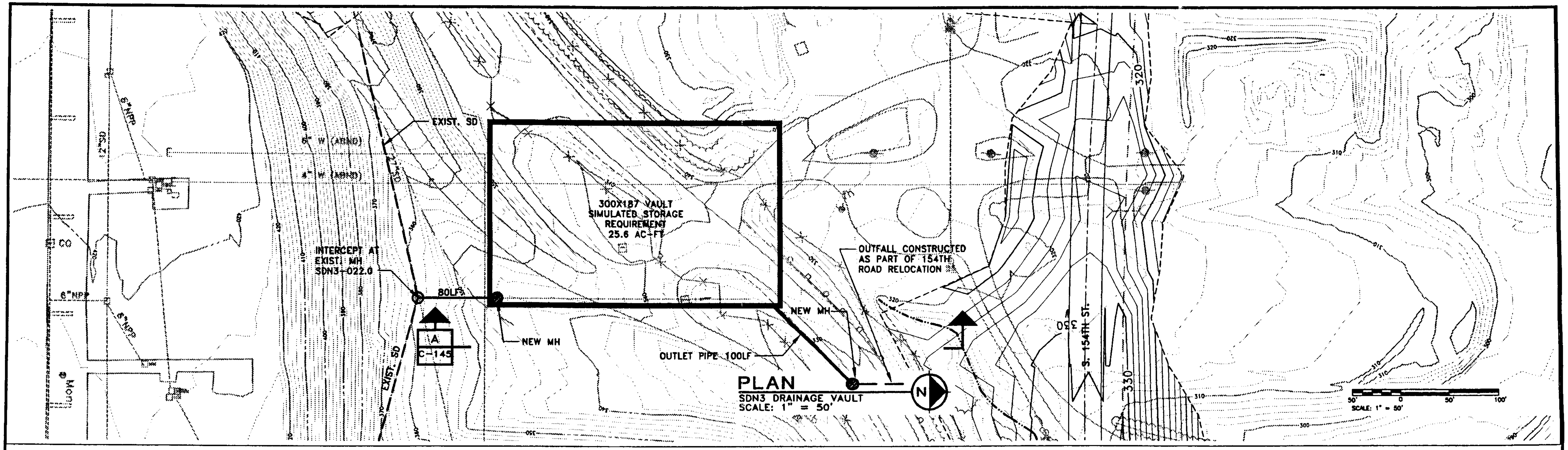
PROFILE

SDS3 DRAINAGE VAULT
SCALE: HORZ 1" = 100'
VERT 1" = 20'

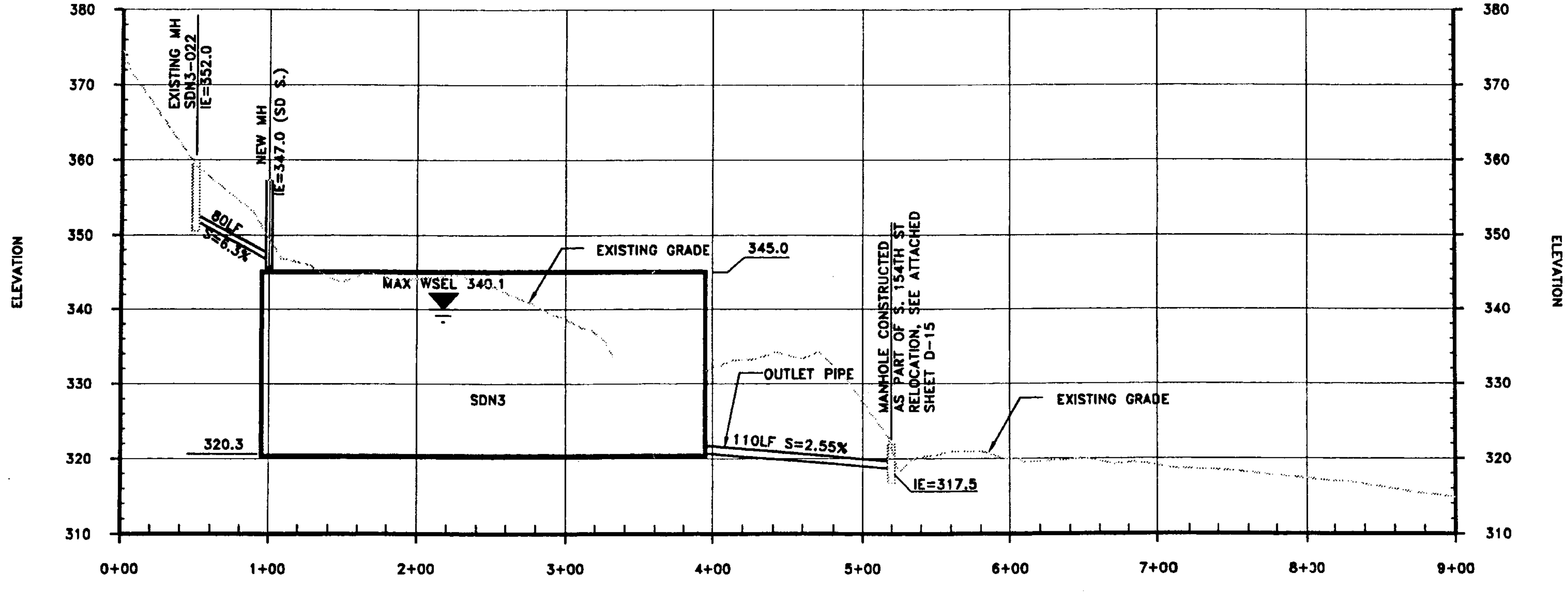
AR 030751

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: SDS3, SDS3A AND SDS5 BASIN VAULT / PLAN AND PROFILE

DATE
DEC. 14, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C141



PLAN
SDN3 DRAINAGE VAULT
SCALE: 1" = 50'

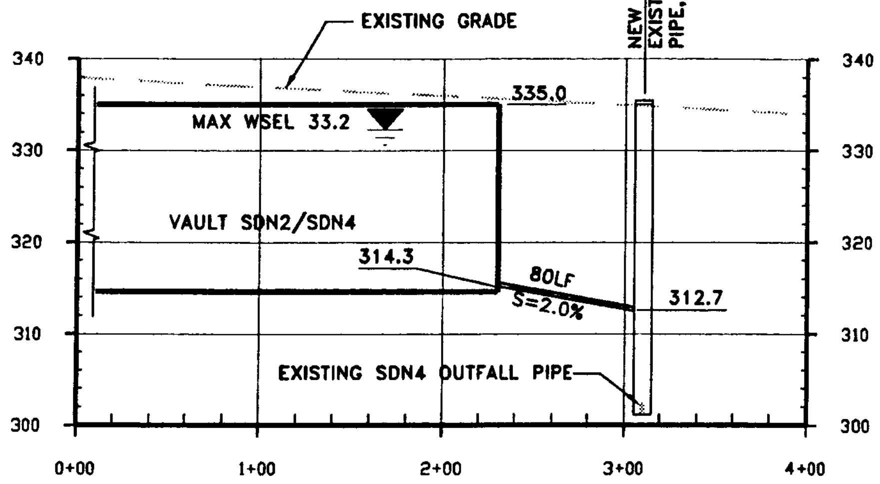


SECTION A | 1 / C-145
SDN3 DRAINAGE VAULT
SCALE: HORZ 1" = 50'
VERT 1" = 10'

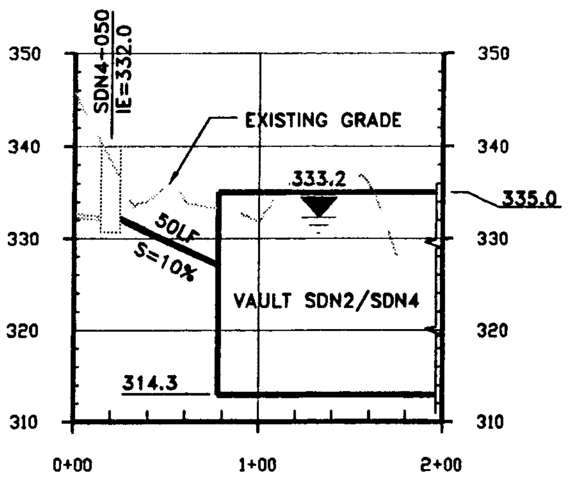
AR 030752

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: SDN3 BASIN VAULT
PLAN AND PROFILE

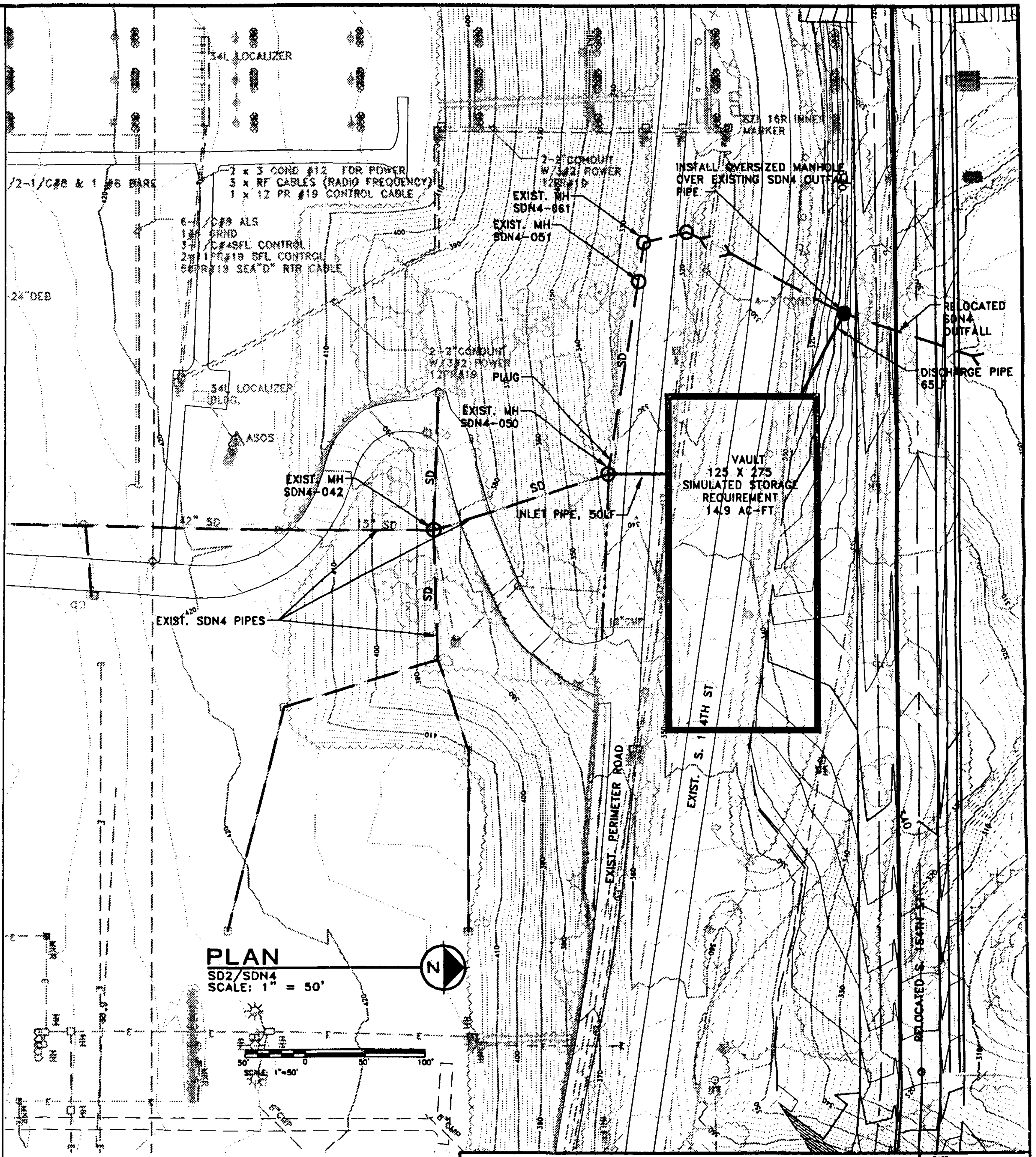
DATE
DEC. 14, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C145



PROFILE
SDN2/SDN4
SCALE: HORZ 1" = 50'
VERT 1" = 10'



PROFILE
SDN2/SDN4
SCALE: HORZ 1" = 50'
VERT 1" = 10'



PLAN
SD2/SDN4
SCALE: 1" = 50'

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

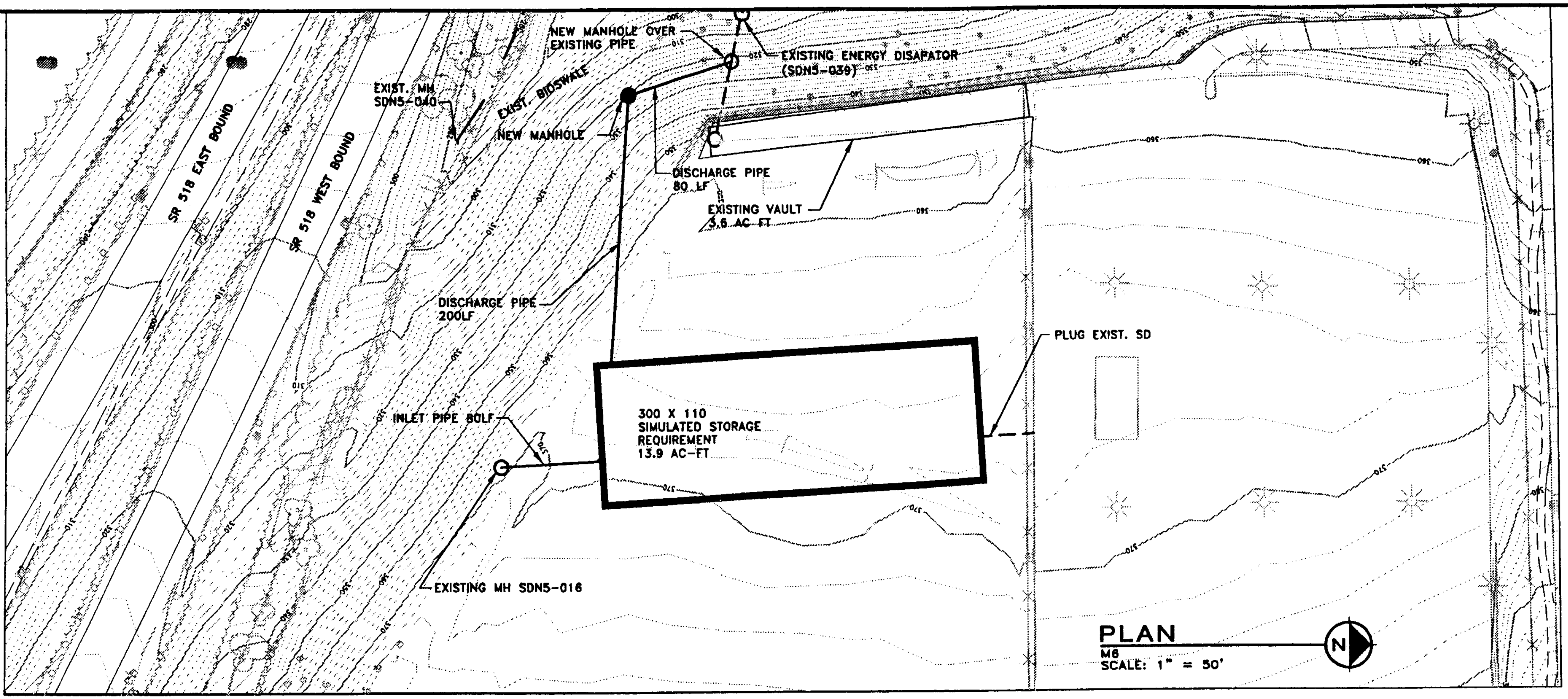
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: SDN2/SDN4 BASIN VAULT
PLAN AND PROFILE

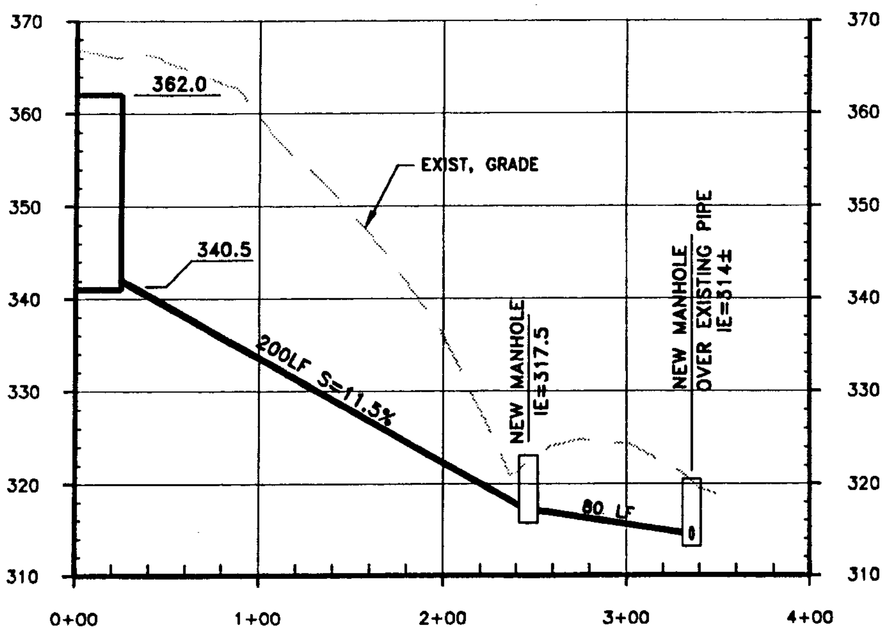
DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C146



PLAN
M6
SCALE: 1" = 50'



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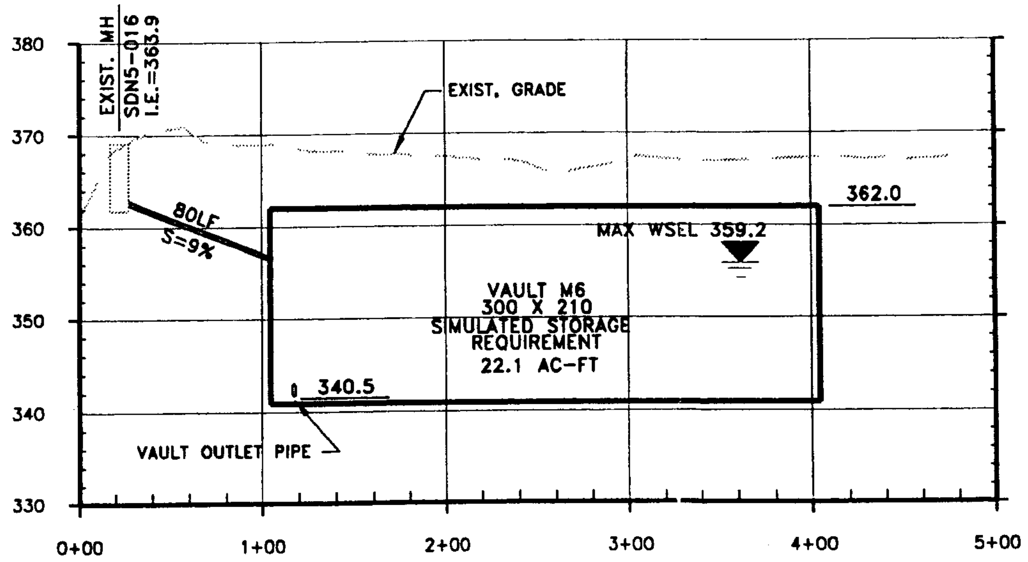
VERT 1" = 10'



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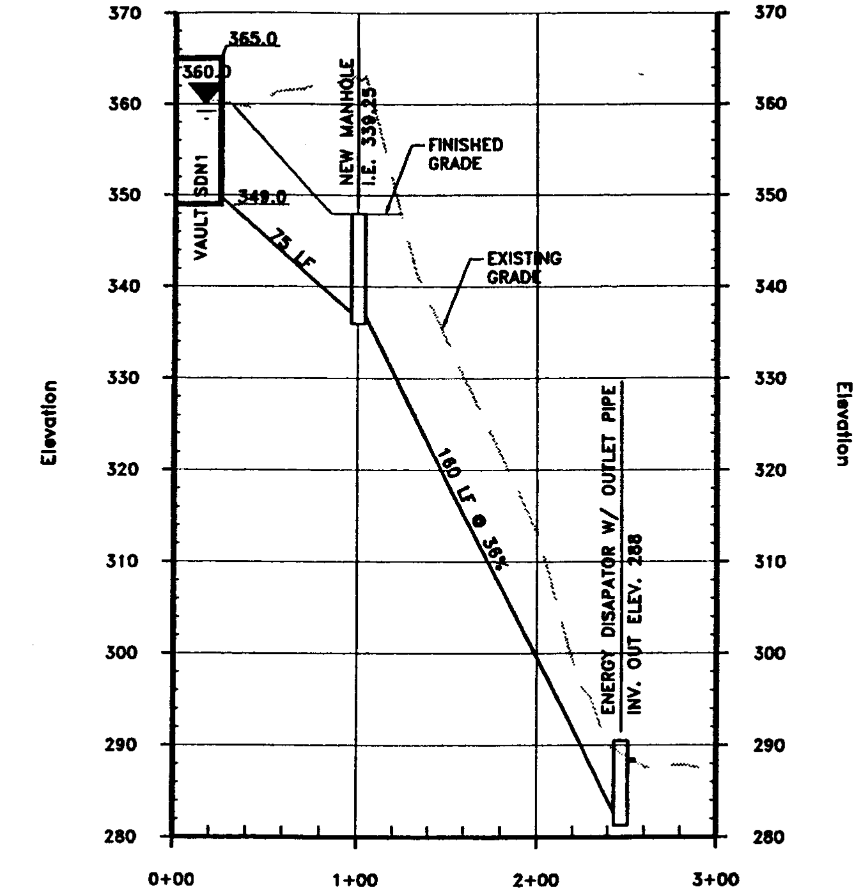
Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: **M6 BASIN VAULT (NEPL)**
PLAN AND PROFILE

DATE
DEC. 14, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C147



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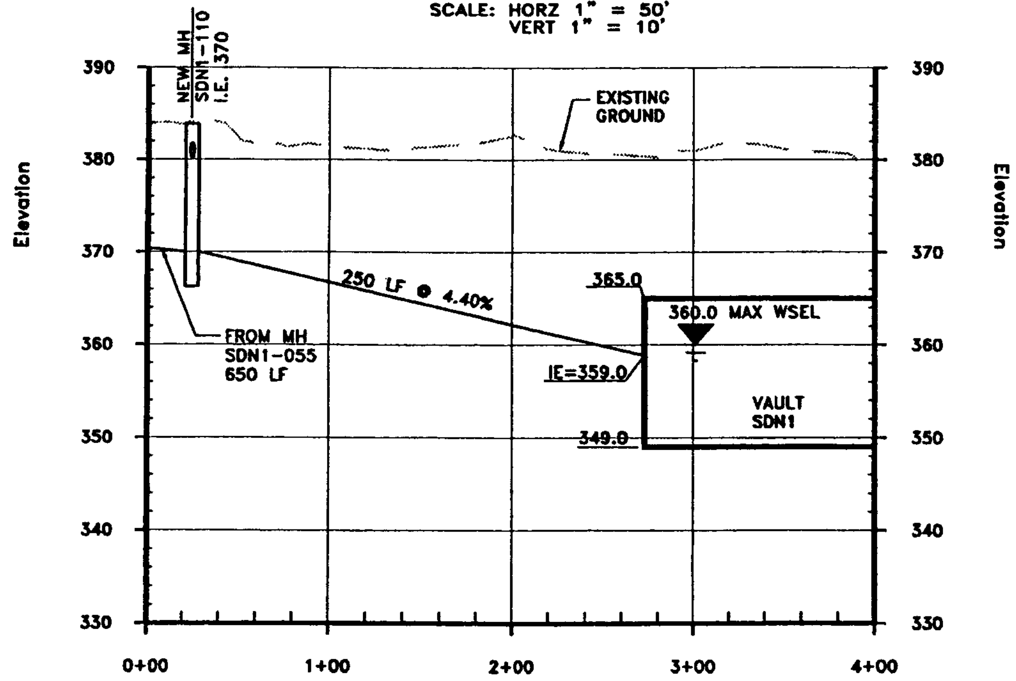

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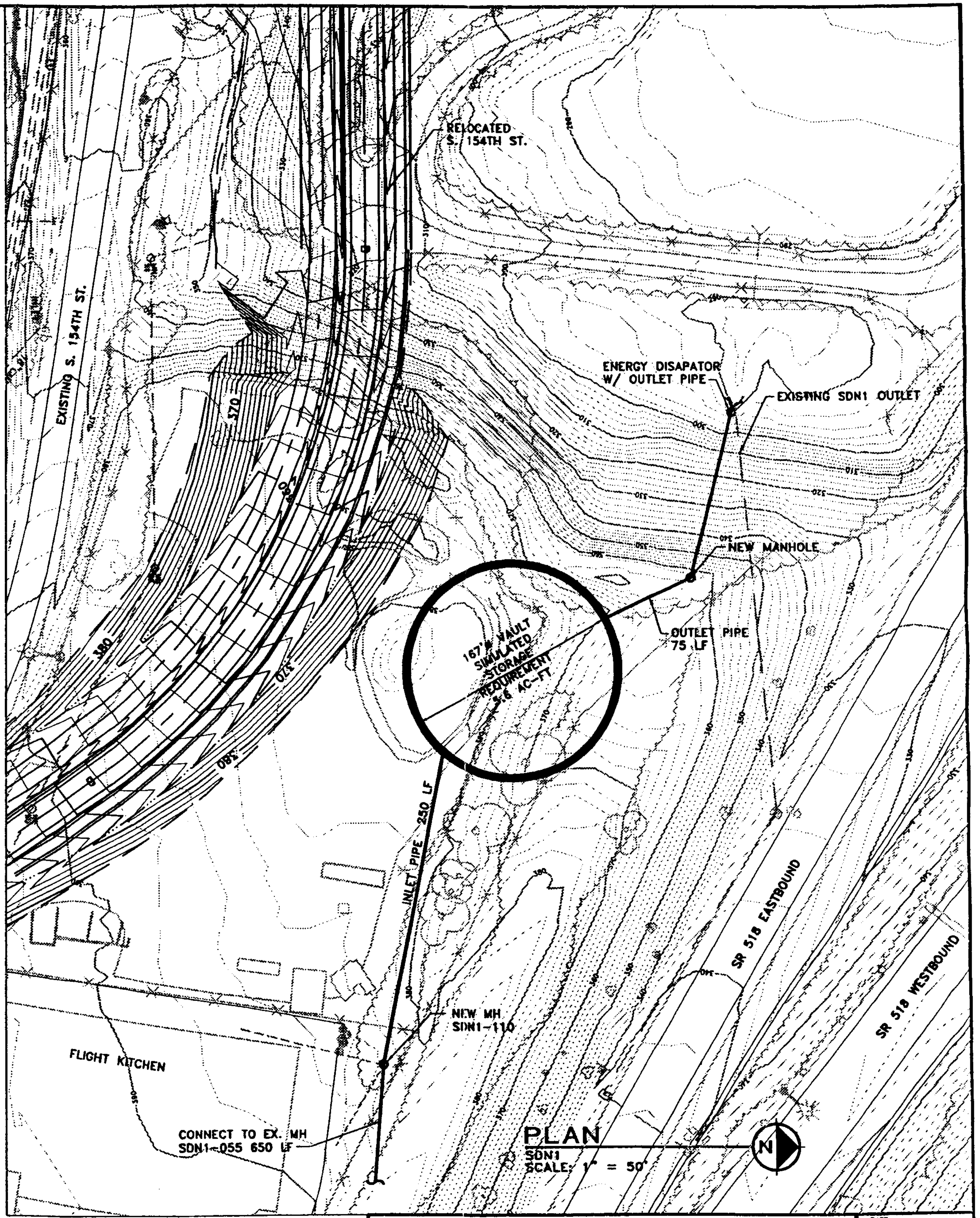
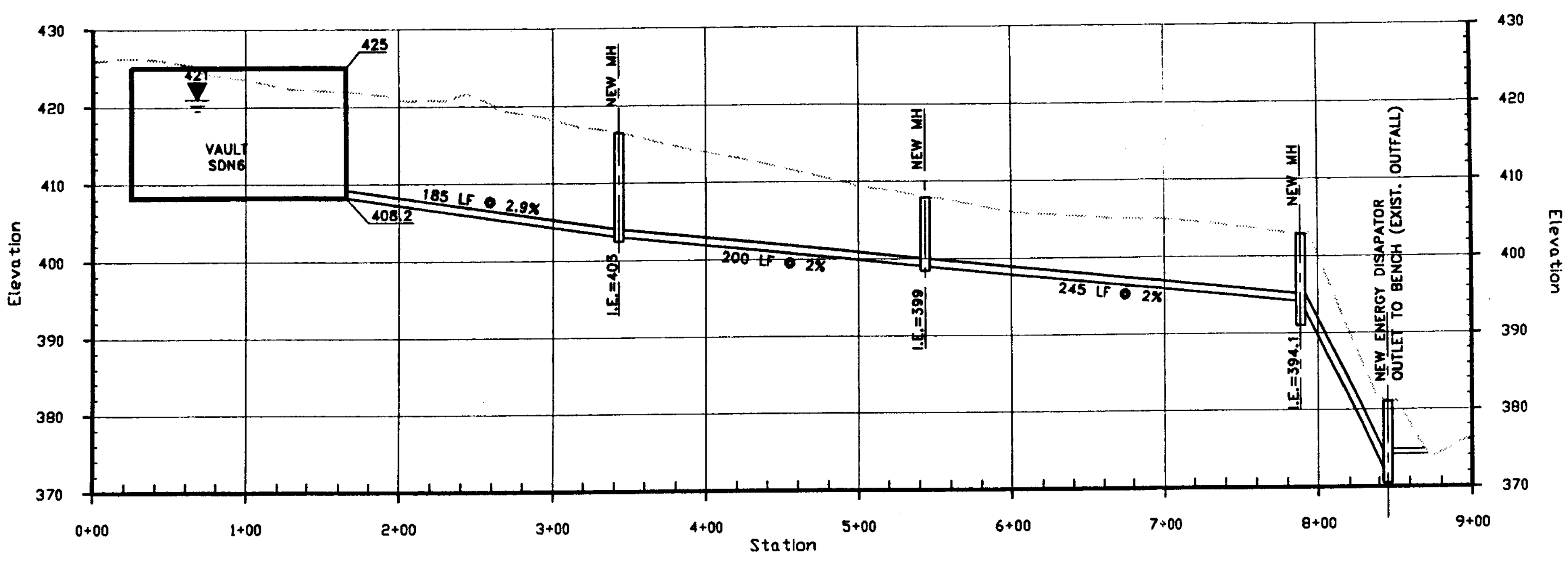


PLAN
SDN1
SCALE: 1" = 50'

AR 030755

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5
SHEET TITLE: SDN1 BASIN VAULT
PLAN AND PROFILE

DATE
DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C148



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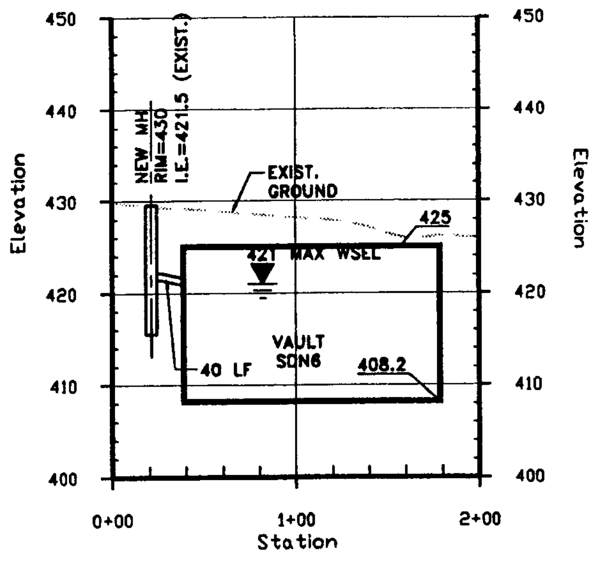

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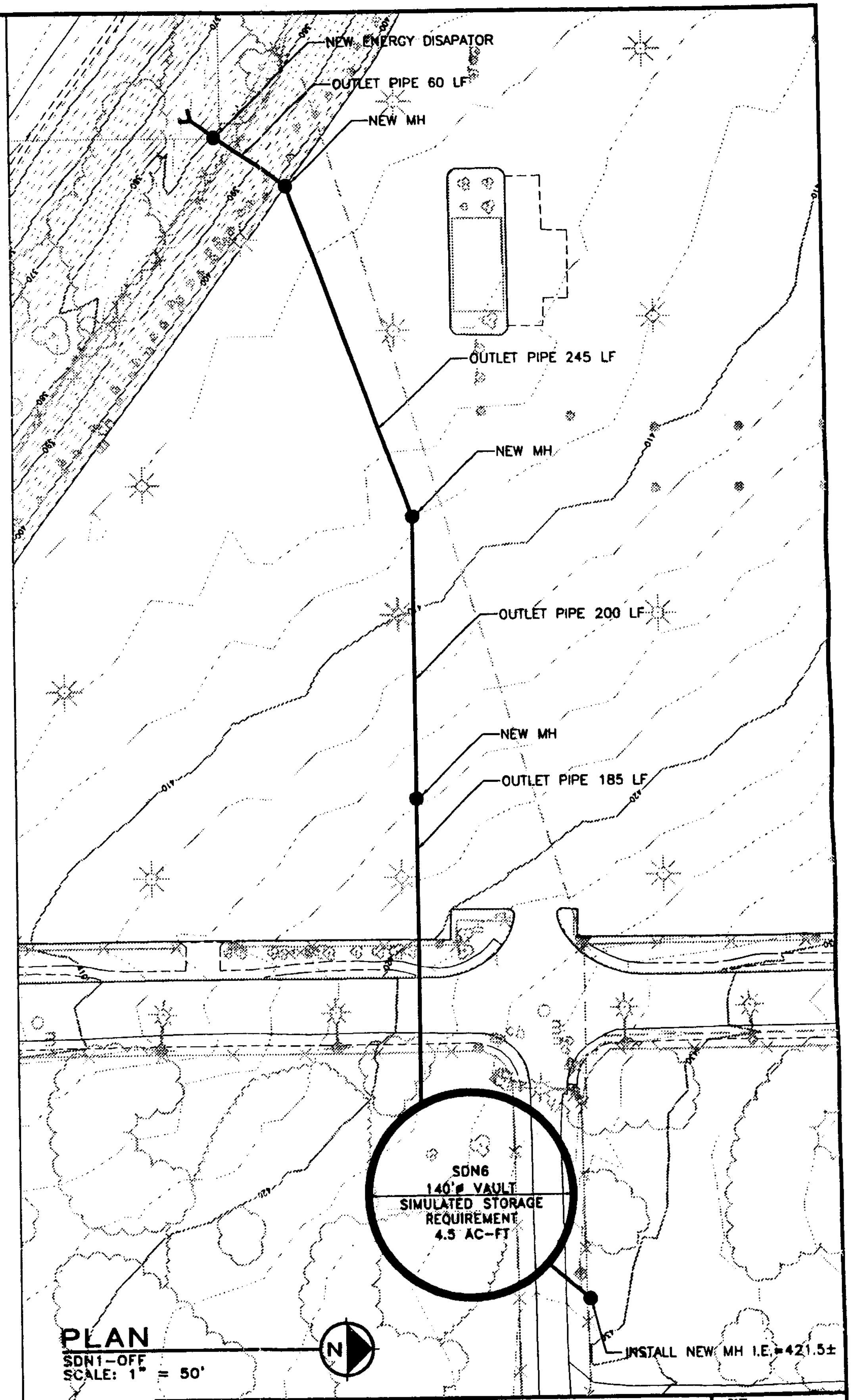


PLAN
SDN1-OFF
SCALE: 1" = 50'

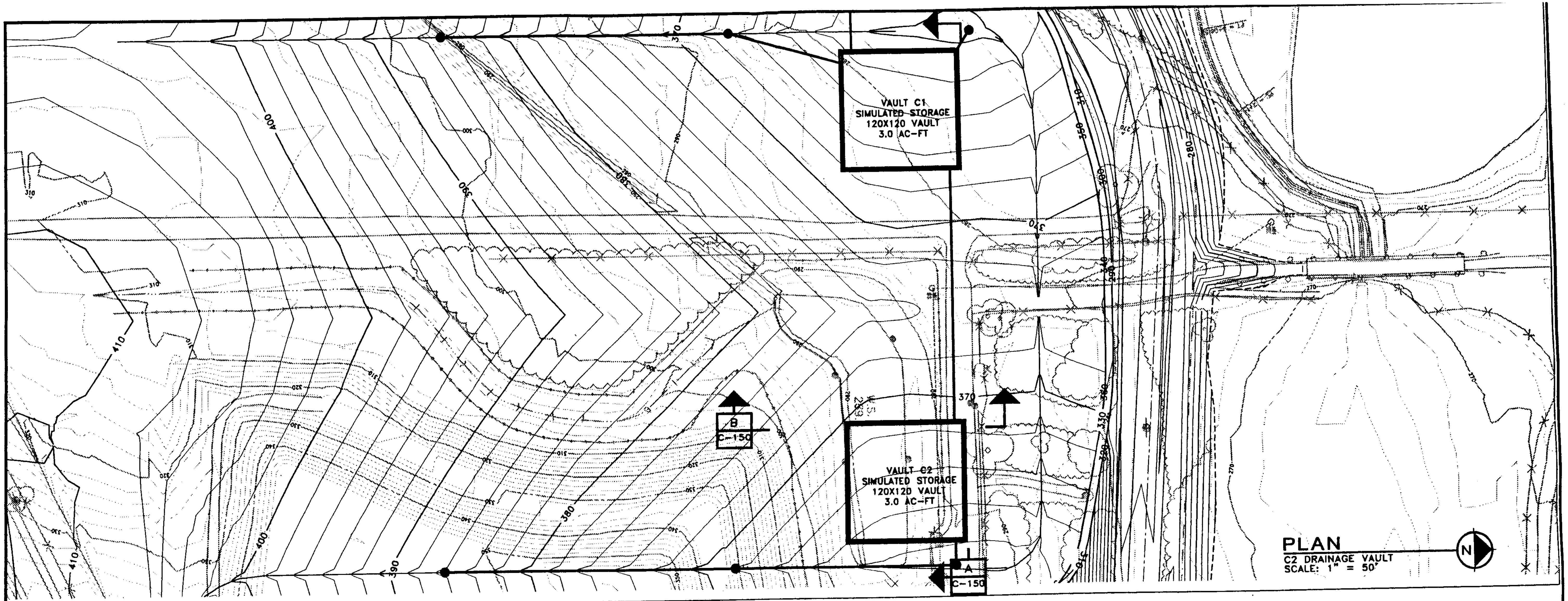
AR 030756

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

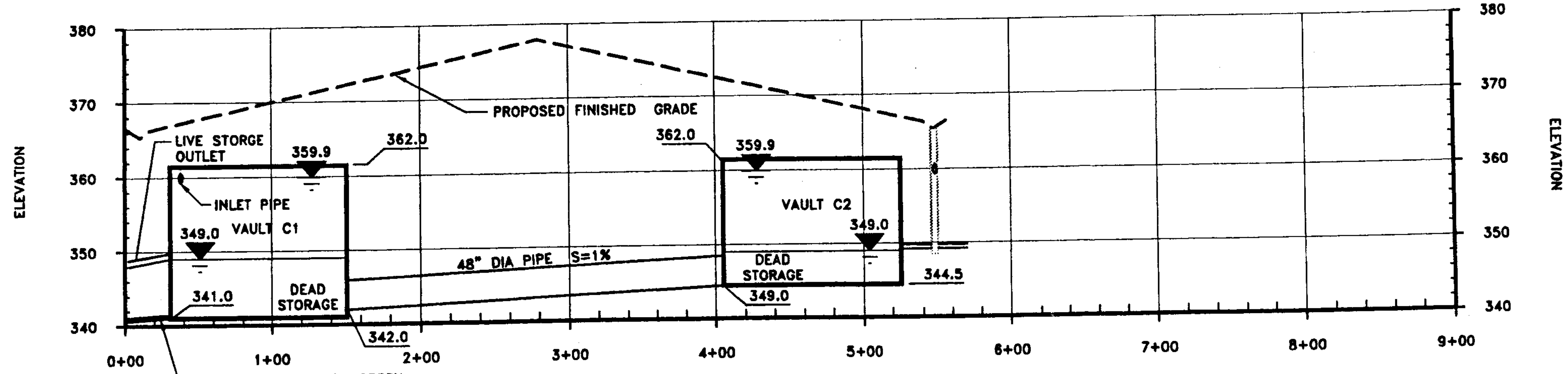
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: SDN6 (CARGO) BASIN VAULT
PLAN AND PROFILE

DATE
DEC. 14, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO.
EXHIBIT_ C149



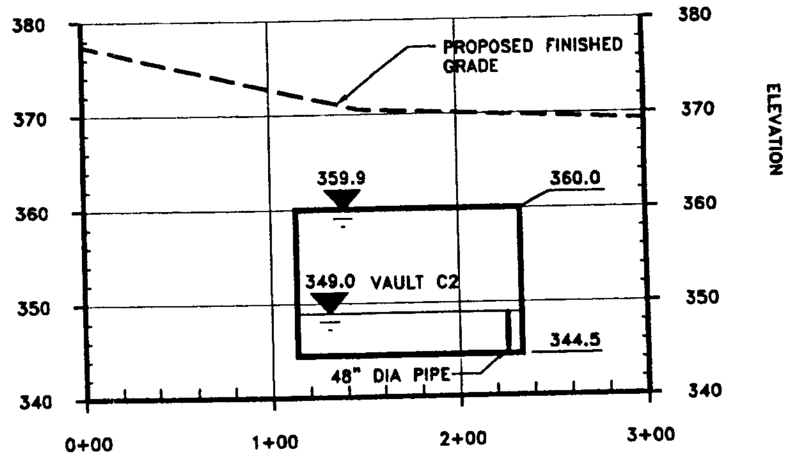
PLAN
C2 DRAINAGE VAULT
SCALE: 1" = 50'



SECTION A

1
C-150

C2 DRAINAGE VAULT
SCALE: HORZ 1" = 50'
VERT 1" = 10'



SECTION B

1
C-150

C2 DRAINAGE VAULT
SCALE: HORZ 1" = 50'
VERT 1" = 10'

AR 030757

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

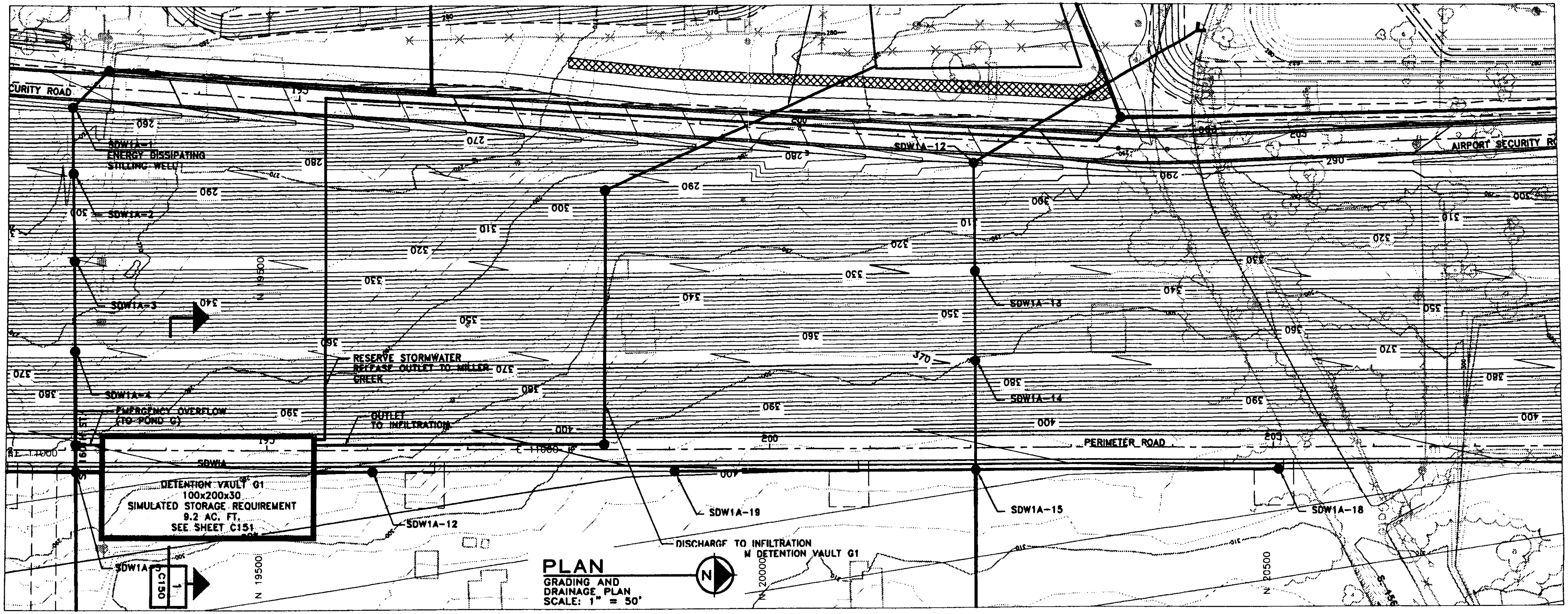
PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **SDN3 BASIN VAULT C2**
PLAN AND PROFILE

DATE
DEC. 15, 2000

CONSULTANT'S NO.

PORT OF SEATTLE NO.
EXHIBIT_ C150



PLAN
GRADING AND DRAINAGE PLAN
SCALE: 1" = 50'

NOTES:

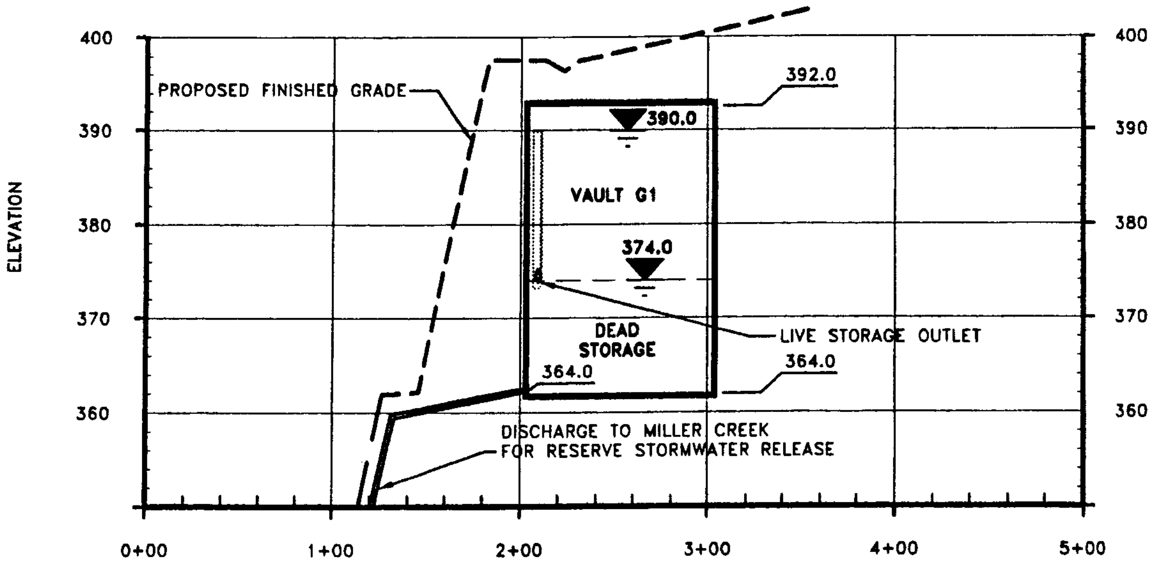
LEGEND:

▬	STORM DRAIN PIPE
▨	WETLANDS

50' 0 50' 100'
SCALE: 1"=50'

						128	129	130
110	111	112	113	114	115	116	117	118
119	120	121	122	123	124	125	126	127

KEY PLAN



SECTION A 1 / C-150
SDW1A DRAINAGE VAULT
SCALE: HORZ 1" = 50'
VERT 1" = 10'

AR 030758

Port of Seattle
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: THIRD RUNWAY - EMBANKMENT CONSTRUCTION PHASE 5

SHEET TITLE: **SDW1A BASIN VAULT G1 PLAN AND SECTION**

DATE DEC. 15, 2000
CONSULTANT'S NO.
PORT OF SEATTLE NO. EXHIBIT_ C151

Appendix J

APPENDIX J

FEASIBILITY OF STORMWATER INFILTRATION

Feasibility of Stormwater Infiltration
Third Runway Project
Sea-Tac International Airport
SeaTac, Washington

Prepared for
Port of Seattle

December 14, 2000
J-4978-06

CONTENTS

Page

TABLES

FIGURES

APPENDIX A
EXPLORATION LOGS

FIGURES

FEASIBILITY OF STORMWATER INFILTRATION
THIRD RUNWAY PROJECT,
SEA-TAC INTERNATIONAL AIRPORT
SEATAC, WASHINGTON

SUMMARY

Infiltration tests have been performed for selected sites on the west side of the proposed runway embankment to evaluate the feasibility of infiltration as part of the Stormwater Management Plan (SMP) for the Sea-Tac Third Runway project. The testing performed to date shows infiltration is feasible in two of the areas tested (Areas 1 and 3). Preliminary design infiltration rates have been developed from the field tests using methods stipulated by King County (1998) as listed in Table 1. Based on these results, potential infiltration capacities (in cubic feet per second [cfs]) at the individual sites have been developed for nominal 8-foot-wide infiltration trenches totaling 400 feet in length:

- Infiltration Area 1 can accommodate stormwater disposal at an average rate of 0.30 cfs; and
- Infiltration Area 3 can accommodate stormwater disposal at an average rate of 0.15 cfs.

Additional trenches may be located in these areas to increase infiltration capacity, depending on site logistics.

These data are suitable for conceptual infiltration facility design. The infiltration capacity of any site will depend on the detailed design and layout (i.e., area and elevation) of the infiltration facility, and the degree of variability in soil conditions beneath the facility. Additional infiltration tests and soil borings will be needed to meet all the requirements of the King County Surface Water Design Manual (1998) and should be completed once provisional footprints of the facilities are established.

This report summarizes design requirements for infiltration facilities, field data collection performed by Hart Crowser, and results of our work to date for Infiltration Areas 1 and 3.

INTRODUCTION

As a result of increased stormwater storage capacity requirements in the SMP, Hart Crowser was tasked to investigate potential sites for infiltration of detained stormwater on the west side of the proposed Third Runway project area (see Figure 1 for general location). Based on the location of detention ponds C, D, and G, three sites were identified as potential sites for infiltration of water discharged from detention ponds and/or vaults on the airfield. Additionally, the footprint of detention ponds C, D, and G were also considered for potential infiltration capacity. Locations of the detention ponds and Infiltration Areas 1, 2, and 3 are shown on Figures 2 and 3.

Infiltration testing was conducted along with the collection of soils and groundwater data that are needed to establish if infiltration can be implemented in each area in accordance with the requirements of the King County Surface Water Design Manual (KCSWDM - King County, 1998). The overall requirements for infiltration facilities are summarized in the following section.

INFILTRATION FACILITY REQUIREMENTS

The following summary outlines the General Requirements (Section 5.4.1 of the KCSWDM) for infiltration facilities (ponds, tanks, and trenches) associated with the natural site conditions. Additional requirements identified below under "Other Engineering Considerations" need to be addressed by the engineering design team.

Soils

- The basic requirement is a minimum of 3 feet of permeable soil below the bottom of the facility and at least 3 feet between the bottom of the facility and the maximum wet-season water table.
- A minimum of two test pits or soil borings per 10,000 ft^2 of infiltration area are required to characterize the site.
- Test pits or borings should extend at least 5 feet below the bottom of the infiltration facility, and at least one test hole should reach the water table.

Measured Infiltration Rates

- The measured infiltration rate should be determined using either the double-ring infiltrometer test (ASTM Method D 3385, 2000) or the EPA falling head percolation test procedure (EPA, 1980).
- Sufficient tests should be performed to determine a representative infiltration rate but at least three tests shall be performed for each proposed infiltration facility.

Design Infiltration Rate

- The design infiltration rate should be calculated by Equation 5-9 of the KCSWDM, using the correction factors listed in that Section 5.4.1.

Off-site Groundwater Impacts

- The impacts of infiltration should be considered for the potential to provide increased water to landslide areas, increased groundwater resources available, increased water levels in closed depressions, and higher groundwater levels.

Groundwater Protection

Groundwater protection requirements call for implementing one of the following actions when infiltrating water from pollution-generating surfaces:

- Provide water quality treatment prior to infiltration; or
- Demonstrate that the soil beneath the infiltration facility has properties which reduce the risk of groundwater contamination from typical stormwater runoff.

Other Engineering Considerations

- 100-Year Overflow Conveyance
- Spill Control Devices
- Pre-settling
- Protection from Upstream Erosion
- Construction Guidelines.

This report by Hart Crowser provides a preliminary assessment of the soils, infiltration rates, and hydrology of each site to establish the feasibility of infiltration. Engineering aspects and site logistics will be addressed by the design team as part of final design.

APPROACH

The type of infiltration test chosen at each location was dependent on the depth of the target soil strata or pond elevation. Generally, for tests less than 4 to 5 feet below ground surface, test pits were dug and the double-ring infiltrometer method was used. This method involved repeatedly measuring a small (< 1/4 inch) change in water level in both the inner and outer rings while consistently maintaining a head between 5.5 and 6 inches in both rings until a relatively constant rate was obtained. Pre-soaking the test area is not required; however, to limit the amount of inconsistent readings at the beginning of the test, a pre-soaking period of approximately one hour was employed.

For testing depths below 5 feet, the EPA method was used in an augered hole with a 6-inch-diameter temporary casing inserted to prevent caving of the borehole walls. This method involved repeatedly measuring the water level drop from an initial head (6 inches above the base of the hole) over a given period until a relatively constant rate was obtained. At the end time interval the water level was adjusted back to the original head level prior to starting the next measurement. A minimum of four hours or overnight pre-soaking of the test zone was performed.

The seasonal high groundwater level was estimated by measuring current groundwater levels in existing or recently installed monitoring wells at each site and comparing these with longer records from existing nearby wells in similar hydrogeologic settings. Additionally, soil profile characteristics such as low chroma mottling were also reviewed to assess the seasonal high groundwater levels.

RESULTS

We have completed infiltration tests and soil borings at one pond location and three potential infiltration areas:

- Pond G;
- Infiltration Area 1 (between Pond C and Pond G);
- Infiltration Area 2 (south of Pond G); and
- Infiltration Area 3 (northwest of Pond D).

Results of the double-ring infiltrometer tests are listed in Table 2; results of the EPA method falling head percolation tests are listed in Table 3.

Work on Pond D is still in progress. A third pond location (Pond C) was considered but the presence of groundwater seepage precluded further consideration of infiltration at Pond C. Infiltration in Pond G and Area 2 proved to be unfeasible due to low permeability soils and/or high groundwater levels. Logs of soil borings and test pits are included in Appendix A for Infiltration Areas 1 and 3.

In the following summaries, we include an estimate of the design infiltration rate for each area. This is currently based on the average values of the measured infiltration rates for each area, factored by our estimate of the appropriate correction factors, as stipulated by King County (1998). However, given the variability of the soils encountered to date, the mean value may not be appropriate for the entire facility at each location. Final design would take into account the results of additional facility-specific testing, the actual geometry of the proposed facilities, and additional design adjustments to provide an adequate "factor of safety."

Final measured infiltration values will be recommended for the design of the proposed facilities after completion of the additional borings and tests needed to fulfill KCSWDM requirements.

Infiltration Area 1

Investigative explorations show a consistent slightly silty fine to medium sand occurring across the site. The sand unit starts just below the surface and extends to depths of 8 feet (approximately 268 feet elevation) where deeper material increases in silt content.

The groundwater level measured in the new monitoring well HC00-B333, during November 2000, had an elevation of 268.5 feet. Table 4 lists the seasonal water level variations for two comparable wells east of Infiltration Area 1 with water level records that include last year's seasonal high. Based on the average seasonal fluctuation in these wells, and assuming currently observed water levels correspond to the seasonal low, the projected seasonal high water level for HC00-B333 is 273.1 feet (approximately 8 feet below ground surface).

The locations tested exhibited medium to high infiltration capacities ranging from 4.6 to 20.4 in./hr. Results are summarized in Table 1.

To illustrate the infiltration potential of this site, we have estimated the infiltration capacity of 400 lineal feet of 8-foot-wide infiltration trench(es). Using a design infiltration rate of 4.2 in./hr, such trenches in Area 1 may be expected to infiltrate 0.30 cfs of stormwater from SMP area SDW1A.

Infiltration Area 3

Three test pits revealed varying shallow soil composition. The northern two test pits (HC00-TP338 and HC00-TP339) encountered silty fine to medium sand at elevations between 297 and 308 feet. Test pit HC00-TP337 in the southern portion of the site revealed dry silt from the surface at approximate elevation 309 feet, to the bottom of the test pit (approximate elevation 301 feet). Although not determined at this time, the groundwater level in Infiltration Area 3 is expected to be at a depth of at least 10 feet, based on the absence of seepage into the test pits. Local water table mapping by AESI (2000) suggests that the groundwater elevation in the shallow regional aquifer is around 230 to 240 feet at this location.

Double-ring infiltrometer tests were conducted in test pits approximately 3 to 4 feet below the ground surface (i.e., approximately 302 to 309 feet elevation). Two were located in a silty sand deposit and provided moderate infiltration rates of 7.5 and 5.0 in./hr. The third test was performed in finer-grained silty soil and gave an infiltration rate of 0.94 in./hr.

Using an estimated design infiltration rate of 2.7 in./hr and assuming overall trench dimensions of 400 feet by 8 feet, Area 3 should infiltrate approximately 0.2 cfs of stormwater from SMP area SDW1B. Additional trenches may be an option in this area; however, the proximity of the adjacent slope (greater than 15%) may require regrading to create benches. The KCSWDM indicates that a geotechnical assessment of slope stability would likely be required for construction of an infiltration facility in Area 3.

CONCLUSIONS

The results of our soil borings and infiltration tests show that Areas 1 and 3 are suitable for infiltration of detained stormwater. The infiltration capacities quoted in this report are provisional; the appropriate design infiltration rate for each area depends on the chosen location, layout, depth, and length of infiltration trenches. The implementation of infiltration facilities will necessitate full consideration of relevant engineering requirements as outlined in the KCSWDM.

Sincerely,

HART CROWSER, INC.

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Project Hydrogeologist

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Project Manager

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REFERENCES

King County, 1998. King County Surface Water Design Manual, King County and Department of Natural Resources.

EPA, 1980. EPA Falling Head Percolation Test Procedure, Design Manual - Onsite Wastewater Treatment and Disposal Systems, EPA.

ASTM, 2000. Double Ring Infiltrometer Test, ASTM Method D 3385, Annual Book of ASTM Standards, Soil and Rock (1): D 420 - D 5799.

AESI, 1999. Seattle-Tacoma International Airport Ground Water Study, Associated Earth Sciences, Inc. and S. S. Papadopulos & Assoc.

Table 1 - Summary of Infiltration Testing Results; West Side of Third Runway Embankment

Location ID	Approximate Ground Surface Elevation in Feet (msl)	Measured Infiltration Rate in in./hr	Assumed Correction Factors $F_{testing}$	$F_{plugging}$	$F_{geometry}$	Design infiltration rate in in./hr	Estimated Infiltration Capacity in cfs using 200ft x 8ft trench(es) Number of Trenches 1 (200 linear ft)	2 (400 linear ft)	3 (600 linear ft)
Infiltration Area 1	(SDW1A)								
HC00-B327	276.1	20.40	0.3	0.9	1	5.51	0.20	0.41	0.61
HC00-B328	275.4	4.65	0.3	0.9	1	2.06	0.08	0.15	0.23
HC00-B329	280.8	18.45	0.3	0.9	1	4.98	0.18	0.37	0.55
Infiltration Area 2									
HC00-TP301	245.6	0.00	0.5	0.8	1	NA	NA	NA	NA
HC00-TP302	244.2	0.33	0.5	0.8	1	NA			
HC00-TP303	253.5	0.43	0.5	0.8	1	NA			
Infiltration Area 3	(SDW1B)								
HC00-TP307	309.2	0.94	0.5	0.9	1	0.42	0.02	0.03	0.05
HC00-TP308	304.9	5.00	0.5	0.9	1	2.25	0.08	0.17	0.25
HC00-TP309	311.7	7.50	0.5	0.9	1	3.38	0.13	0.25	0.38
Pond G									
HC00-B310A	264.9	0.24	0.3	0.8	0.25	NA	NA	NA	NA
HC00-B313A	260.2	1.68	0.3	0.8	0.25	NA			

Notes:

(1) Infiltration rates determined by double-ring infiltrometer (ASTM method D 3385) or a modified EPA falling head percolation test procedure (Design Manual - Onsite Wastewater Treatment and Disposal Systems, EPA, 1980)

(2) Correction Factors: per King County Surface Water Design Manual (1998)

$F_{testing}$ = 0.5 for ASTM method D3385 and 0.3 for EPA method

$F_{plugging}$ = 0.8 for fine sands and loamy sands, 0.9 for medium sands

$F_{geometry}$ = 0.25 to 1.0, values for the trenches all exceeded 1.0 and Pond G was < 0.25

Design infiltration rate = measure rate x $F_{testing}$ x $F_{plugging}$ x $F_{geometry}$

Table 2 - Double Ring Infiltrometer Tests

Test ID	Final Reading from Inner Ring in Inches	Time Increment in Minutes	Infiltration Rate in in./hr	Soil Descrpition
Infiltration Area 2				
HC00-TP301A *	0.11	191	0.03	SILT
HC00-TP302A	0.25	46	0.33	Gravelly, silty SAND
HC00-TP303A	0.28	39	0.43	Slightly gravelly SAND
Infiltration Area 3				
HC00-TP307A	0.25	16	0.94	SILT
HC00-TP308A	0.50	6	5.00	Slightly silty, fine to medium SAND
HC00-TP309A	0.50	4	7.50	Slightly silty, fine to medium SAND

* water seeping into test pit and pooling outside the rings

Table 3 - Falling Head Percolation Tests

Sheet 1 of 2

Location ID	Test Number	Elapsed Time in min	Change in Head in feet	Percolation Rate in in./hr	Soil Type
Infiltration Area 1					
HC00-B327A	1	2	0.06	21.60	Slightly silty, fine to medium SAND
		5	0.15	21.60	
	2	2	0.06	21.60	
		5	0.14	20.16	
	3	2	0.06	21.60	
		5	0.14	20.16	
	4	2	0.05	18.00	
		5	0.14	20.16	
	5	2	0.05	18.00	
		5	0.14	20.16	
	6	2	0.06	21.60	
		5	0.14	20.16	
HC00-B328A	1	2	0.02	5.40	Slightly silty, fine to medium SAND
		5	0.05	7.20	
		10	0.10	7.20	
	2	2	0.02	7.20	
		5	0.06	8.64	
		10	0.11	7.92	
	3	2	0.02	7.20	
		5	0.05	7.20	
		10	0.11	7.92	
	4	2	0.03	10.80	
		5	0.06	8.64	
		10	0.11	7.92	

497806/3rd_infil_tests.xls Table 3

Table 3 - Falling Head Percolation Tests

Location ID	Test Number	Elapsed Time in min	Change in Head in feet	Percolation Rate in in./hr	Soil Type
Infiltration Area 1					
HC00-B329A	1	2	0.05	16.20	Slightly silty, fine to medium SAND
		5	0.10	14.40	
		10	0.20	14.40	
		15	0.29	13.92	
		20	0.37	13.32	
		25	0.45	12.96	
	2	2	0.05	18.00	
		5	0.12	17.28	
		10	0.23	16.56	
		15	0.33	15.84	
		20	0.44	15.84	
	3	2	0.05	18.00	
		5	0.12	17.28	
		10	0.26	18.72	
		15	0.37	17.76	
		20	0.49	17.64	
	4	2	0.06	21.60	
		5	0.14	20.16	
		10	0.26	18.72	
		15	0.39	18.72	
Pond G					
HC00-B310A	1	30	0.01	0.24	Slightly silty, fine to medium SAND
	2	30	0.01	0.24	
	3	30	0.01	0.24	
HC00-B313A	1	30	0.07	1.68	Silty, gravelly SAND
	2	30	0.06	1.44	
	3	30	0.07	1.68	
	4	30	0.07	1.68	

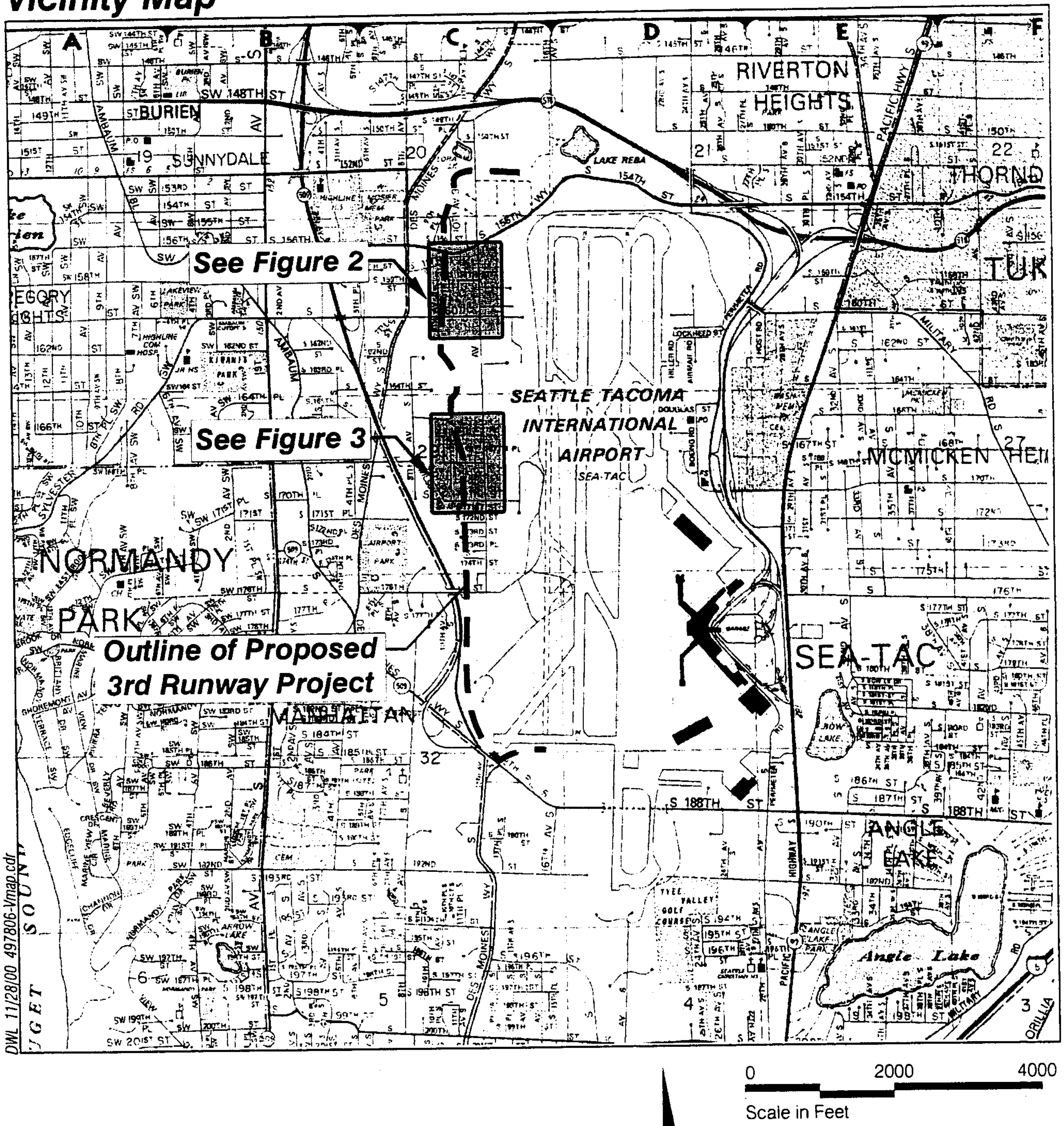
497806/3rd_infil_tests.xls Table 3

Table 4 - Estimation of Seasonal High Water Level in Infiltration Area 1

Monitoring Well ID	Ground Surface in Feet (msl)	Top of Casing in Feet (msl)	Seasonal Water Level Range				Period of Record	Range of Fluctuation in Feet
			Minimum in Feet (msl)	Date	Maximum in Feet (msl)	Date		
HC99-B64	292	294.2	284.9	Nov-00	288.2	Jan-00	12/99 to 10/00	3.3
HC99-B73	291.7	293.80	283.42	Oct-99	289.3	Mar-00	10/99 to 10/00	5.88
HC00-B333	281	283.5	268.5	Nov-00				

Projected Seasonal High Groundwater Level in HC00-B333 = **273.09** = 268.5 + (3.3+5.88)/2

Vicinity Map



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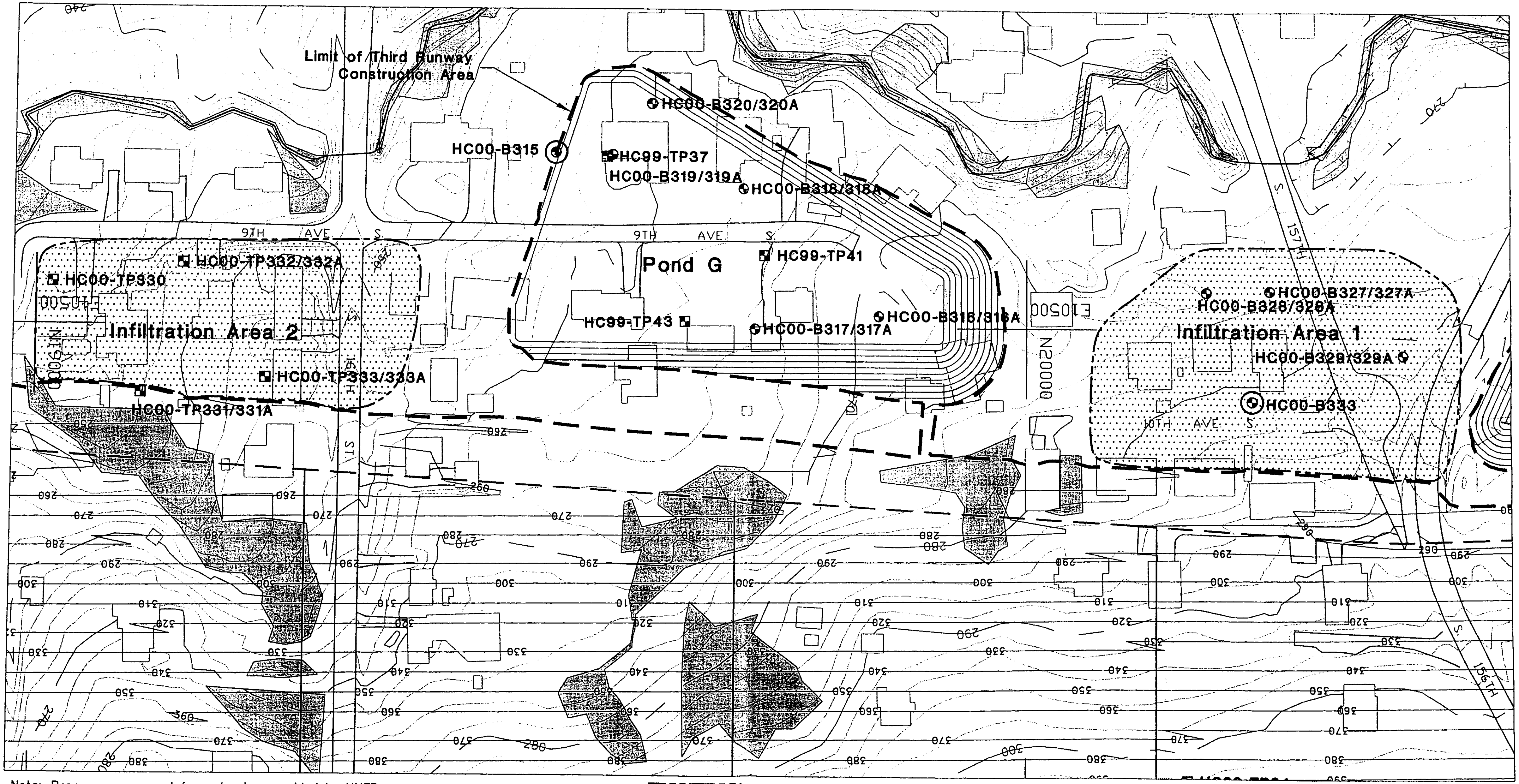
HARTCROWSER

J-4978-06 11/00

Figure 1

Site and Exploration Plan

Infiltration Testing



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetland delineation prepared from drawing provided by Parametrix entitled, "W_110800.dwg", dated November 8, 2000.

▨ Infiltration Area

Exploration Location and Number

HC99-TP37 ◪ Test Pit

HC00-B311/311A ⊕ Soil Boring

HC00-B315 ⊚ Soil Boring Completed as Monitoring Well

N

0 100 200

Scale in Feet

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J-4978-06 12/00

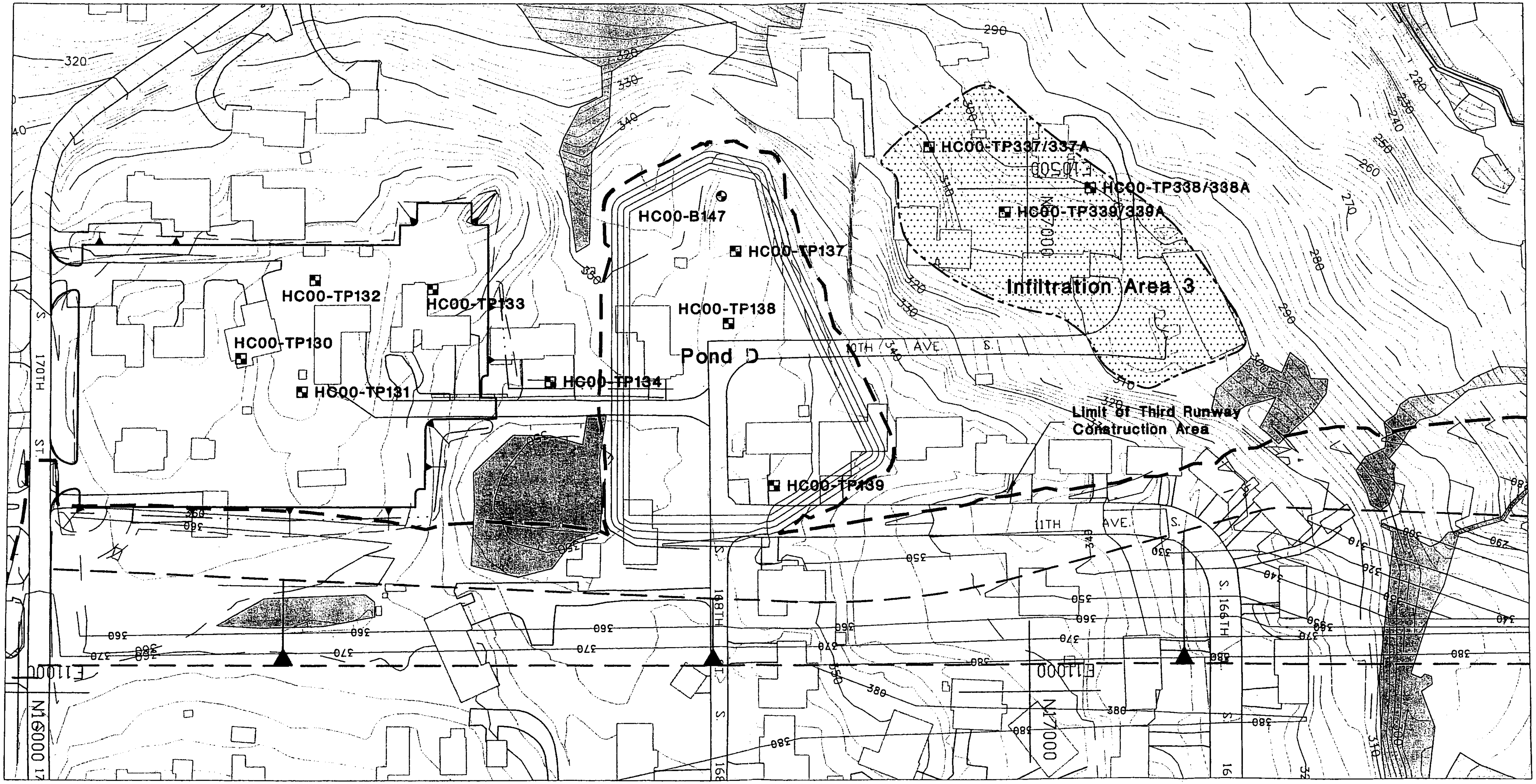
Figure 2

AR 030777

hd 12/5/00 1=1 (xref)see drawing file/charlie.pc2
49780648

Site and Exploration Plan

Infiltration Testing



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetland delineation prepared from drawing provided by Parametrix entitled, "W_110800.dwg", dated November 8, 2000.

▨ Infiltration Area

Exploration Location and Number

HC99-TP37 ◪ Test Pit

HC00-B311/311A ⊕ Soil Boring

N

0 100 200

Scale in Feet

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J-4978-06 12/00

Figure 3

hel 12/5/00 1=1 (xref)see drawing file/charlie.pc2
49780649

APPENDIX A
EXPLORATION LOGS

Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling Test Symbols

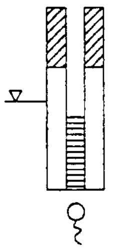
BORING SAMPLES

☒	Split Spoon
⧅	Shelby Tube
▥	Cuttings
◫	Core Run
✱	No Sample Recovery
P	Tube Pushed, Not Driven

TEST PIT SAMPLES

☒	Grab (Jar)
⧄	Bag
⧅	Shelby Tube

Groundwater Observations



Surface Seal

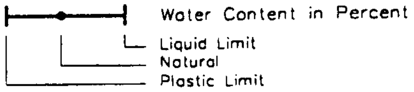
Groundwater Level on Date (ATD) At Time of Drilling

Observation Well Tip or Slotted Section

Groundwater Seepage (Test Pits)

Test Symbols

GS	Grain Size Classification
CN	Consolidation
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits



PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	*In Situ* Density Test

BORING1.DWG
1=1

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Figure A-1

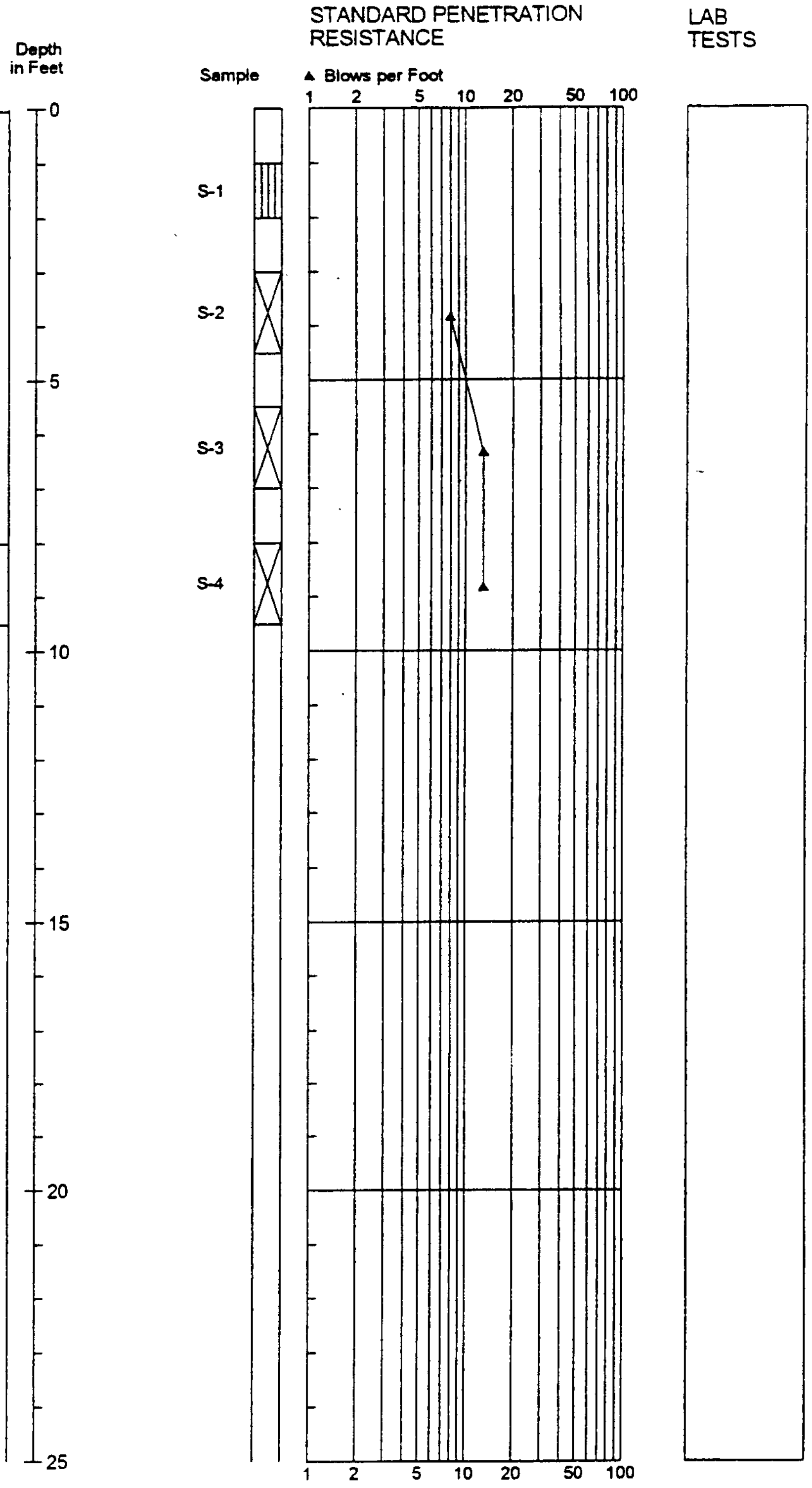
Boring Log HC00-B327

Soil Descriptions
Ground Surface Elevation in Feet: 276.1

Medium dense, moist, brown, slightly silty, fine to medium SAND, grading to slightly gravelly, fine to medium SAND.

Medium dense, moist, gray, slightly gravelly, very silty SAND.

Bottom of Boring at 9.5 Feet.
Completed 11/10/00.



BORING LOG 497808.GPJ HC_CORP.GDT 12/1/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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J-4978-06 *11/00*

Figure A-2

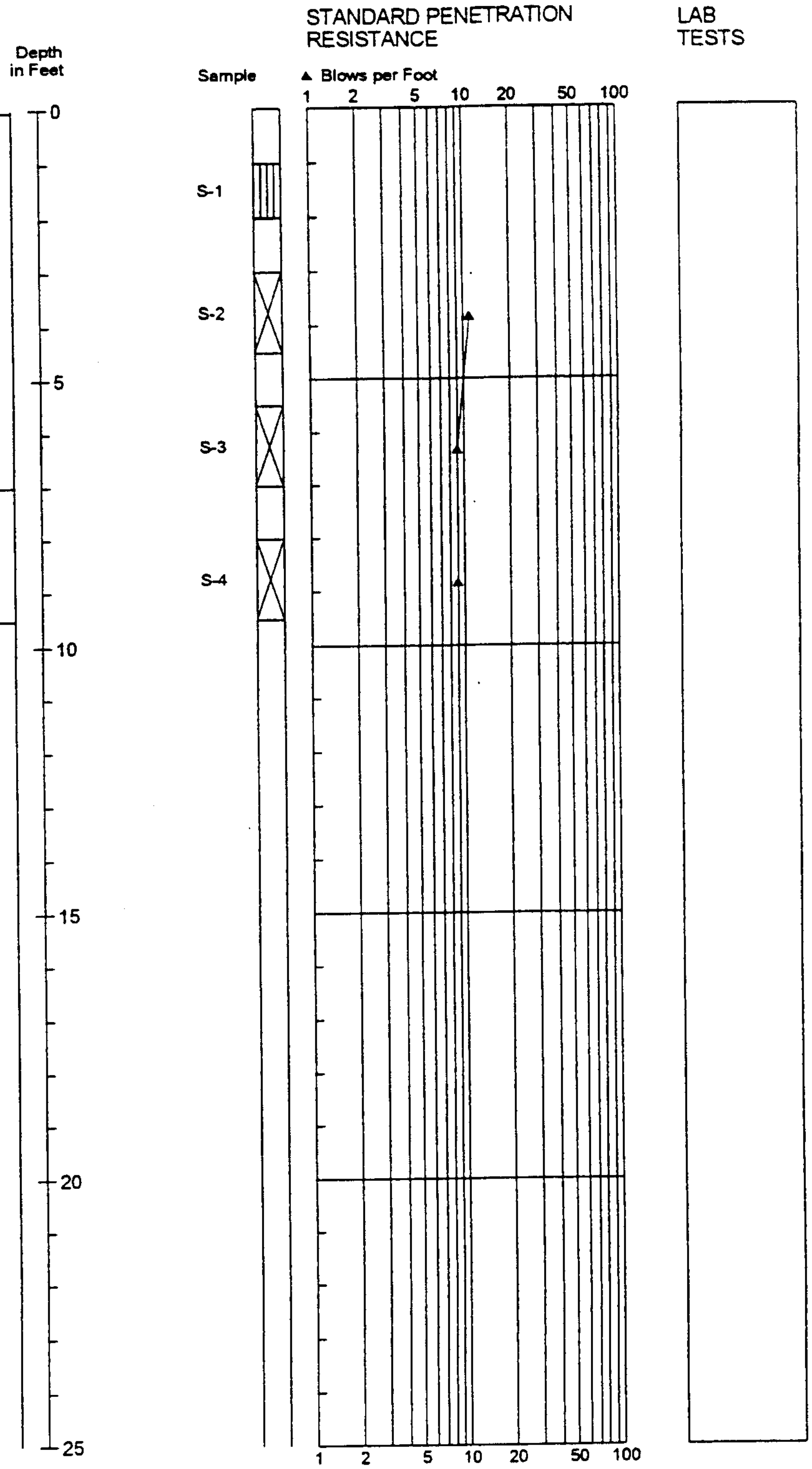
Boring Log HC00-B328

Soil Descriptions
Ground Surface Elevation in Feet: 275.4

Medium dense, moist, brown, slightly silty, fine to medium SAND.

Loose, moist, brown, slightly gravelly, very silty, medium to coarse SAND.

Bottom of Boring at 9.5 Feet.
Completed 11/10/00.



BORING LOG 497808.GPJ HC_CORP.GDT 12100

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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J-4978-06 *11/00*

Figure A-3

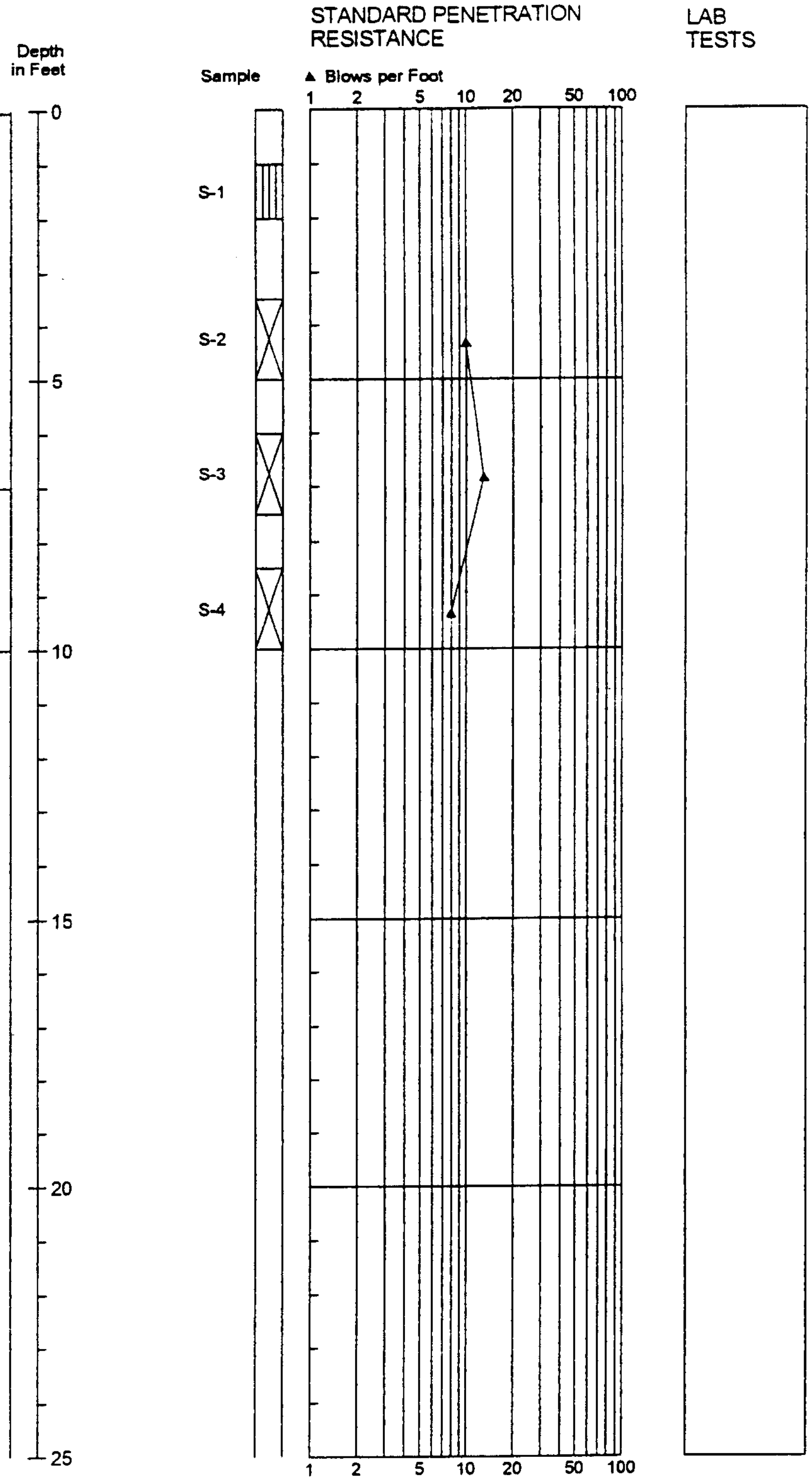
Boring Log HC00-B329

Soil Descriptions
Ground Surface Elevation in Feet: 280.1

Medium dense, moist, brown, slightly silty, fine to medium SAND.

Loose, moist, brown, slightly gravelly, very silty, fine to medium SAND.

Bottom of Boring at 10.0 Feet.
Completed 11/10/00.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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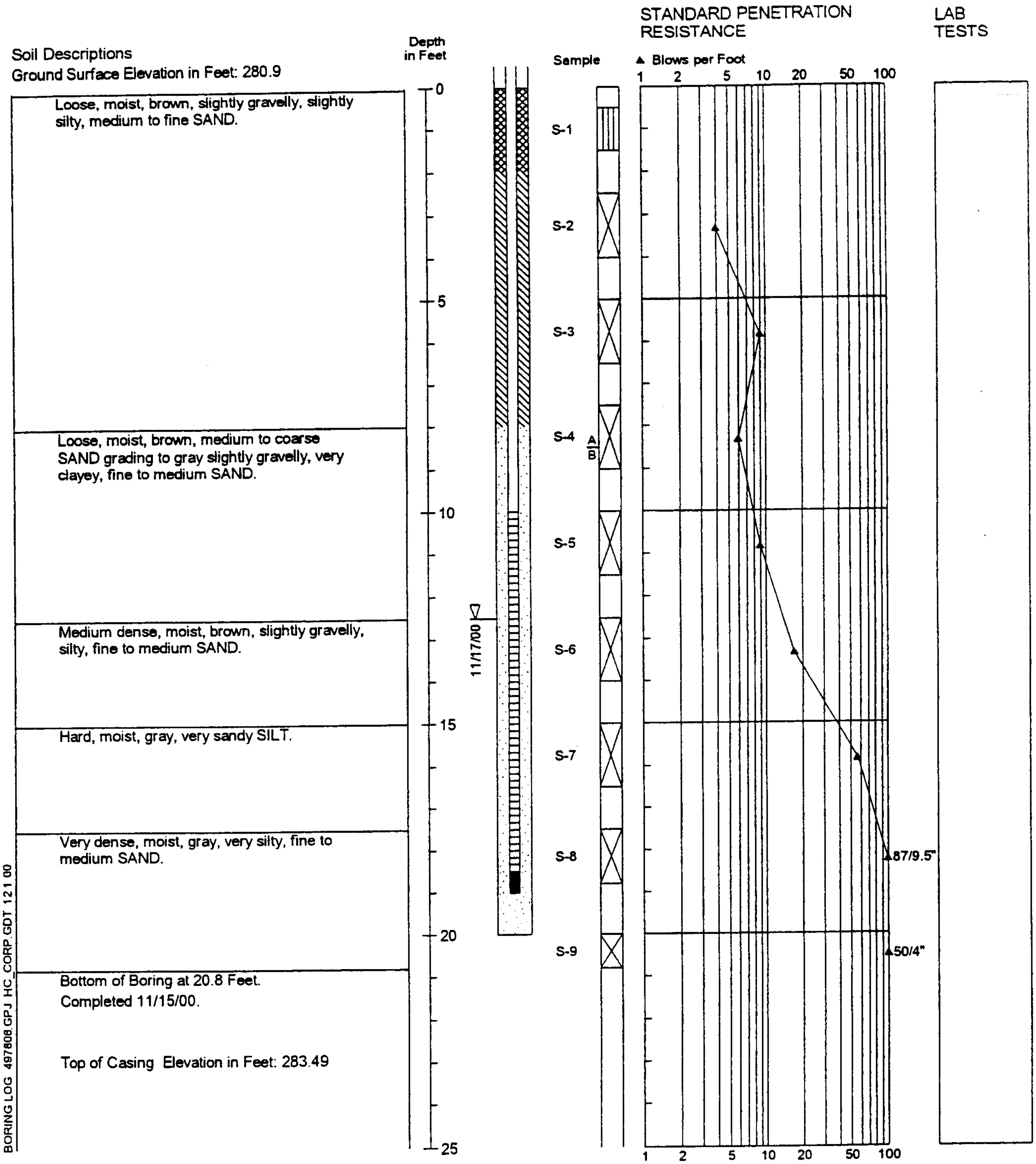
J-4978-06 11/00
Figure A-4

Monitoring Well Log HC00-B333



Soil Descriptions
Ground Surface Elevation in Feet: 280.9

Loose, moist, brown, slightly gravelly, slightly silty, medium to fine SAND.

Loose, moist, brown, medium to coarse SAND grading to gray slightly gravelly, very clayey, fine to medium SAND.

Medium dense, moist, brown, slightly gravelly, silty, fine to medium SAND.

Hard, moist, gray, very sandy SILT.

Very dense, moist, gray, very silty, fine to medium SAND.

Bottom of Boring at 20.8 Feet.
Completed 11/15/00.

Top of Casing Elevation in Feet: 283.49

BORING LOG 497808.GPJ HC_CORP.GDT 12100

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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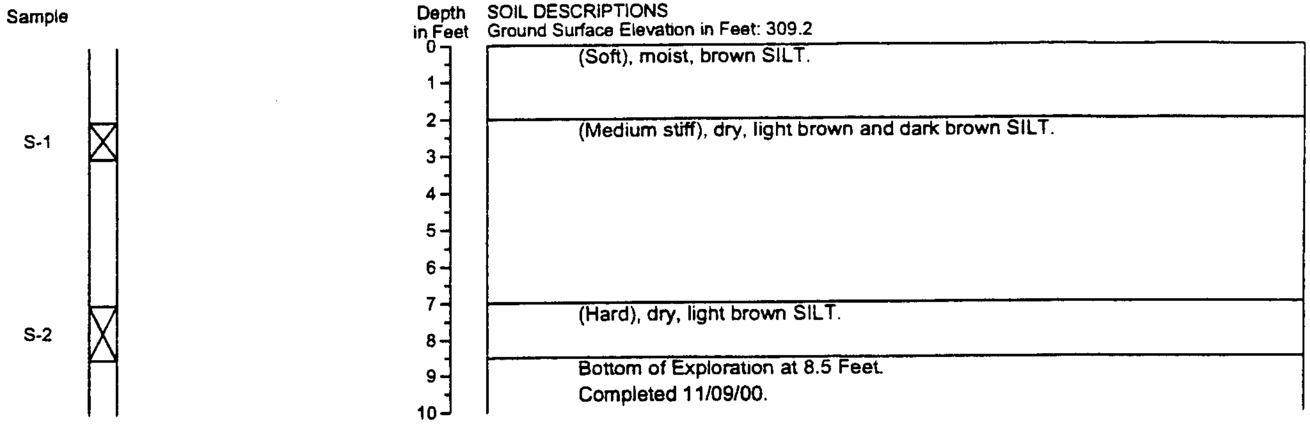
J-4978-06 *11/00*
Figure A-5

Test Pit Log HC00-TP337



SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 309.2

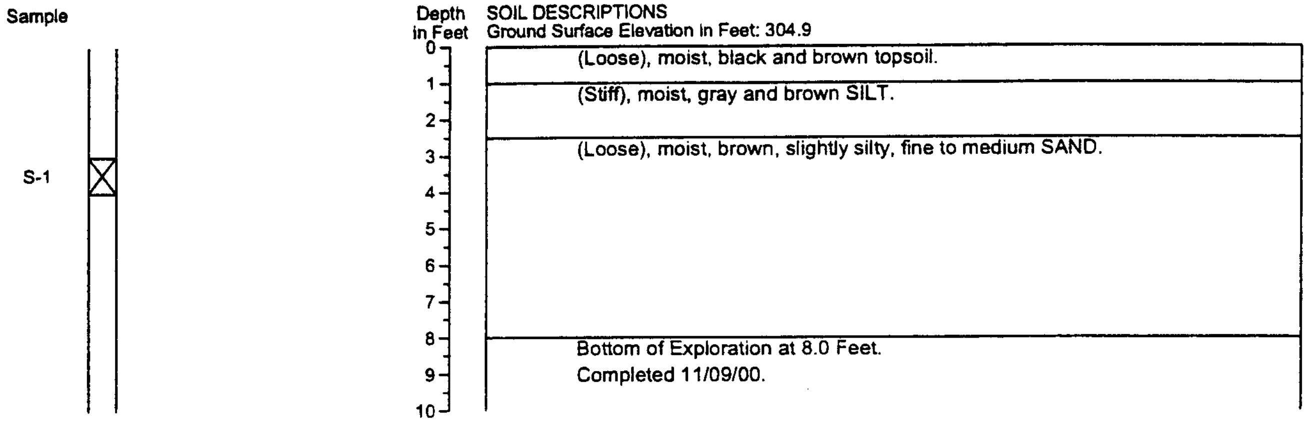
(Soft), moist, brown SILT.

(Medium stiff), dry, light brown and dark brown SILT.

(Hard), dry, light brown SILT.

Bottom of Exploration at 8.5 Feet.
Completed 11/09/00.

Test Pit Log HC00-TP338



SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 304.9

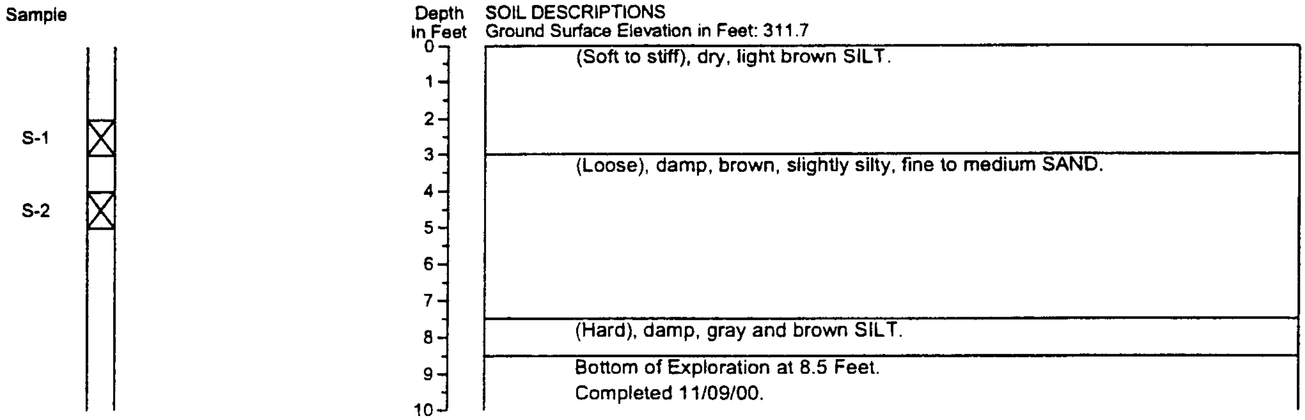
(Loose), moist, black and brown topsoil.

(Stiff), moist, gray and brown SILT.

(Loose), moist, brown, slightly silty, fine to medium SAND.

Bottom of Exploration at 8.0 Feet.
Completed 11/09/00.

Test Pit Log HC00-TP339



SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 311.7

(Soft to stiff), dry, light brown SILT.

(Loose), damp, brown, slightly silty, fine to medium SAND.

(Hard), damp, gray and brown SILT.

Bottom of Exploration at 8.5 Feet.
Completed 11/09/00.

3 LOGS PER PAGE 497806TP.GPJ HC_CORP.GDT 12/5/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground conditions, if indicated, are at time of excavation. Conditions may vary with time.

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J-4978-06 **11/00**

Figure A-6

Appendix K

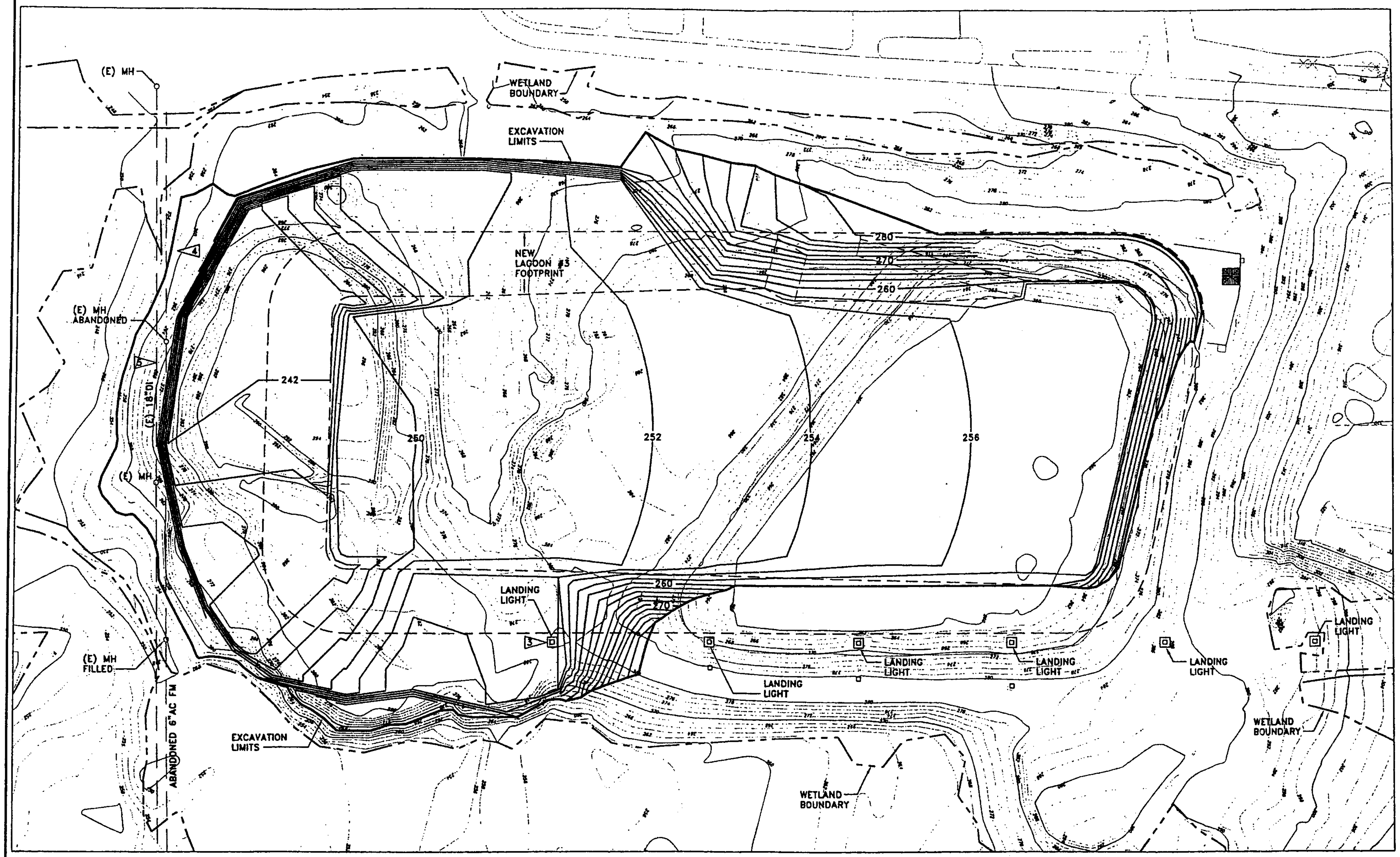
APPENDIX K

IWS LAGOON #3 EXPANSION FOOTPRINT

APPENDIX K

IWS LAGOON #3 EXPANSION FOOTPRINT

The drawing in this appendix shows the IWS Lagoon #3 expansion project in relation to adjacent wetlands and streams. The IWS Lagoon #3 project is not part of the Master Plan Update Improvements and was designed to avoid impacts to Wetland 28 Wetland IWSa, and Wetland IWSb.



CONSTRUCTION NOTES:

1. THE AREA TO THE SOUTH OF THE EXISTING LAGOON IS KNOWN TO CONTAIN BURIED CONSTRUCTION DEBRIS SUCH AS CONCRETE, WOOD, ASPHALT GRINDINGS, AND UNSUITABLE SOIL. SEE GEOTECHNICAL REPORT, BY ZIPPER ZEMAN ASSOC., FEBRUARY, 2000.
2. OVER-EXCAVATION BEYOND FINISH GRADE SHALL BE TO ELEVATIONS AS DETERMINED BY ENGINEER IN THE FIELD.

3. CONTRACTOR SHALL PROVIDE SHORING AS REQ'D TO PROTECT EXISTING LANDING LIGHT TOWERS IN EXCAVATION AREA AT ALL TIMES.

4. CONTRACTOR SHALL PROVIDE SHORING AS REQ'D TO PROTECT ACCESS ROAD DURING OVER-EXCAVATION.

5. CONTRACTOR SHALL VERIFY LOCATIONS AND DEPTHS OF EXISTING UTILITIES AND PROVIDE SHORING OR OTHER PROTECTION AS REQUIRED DURING OVER-EXCAVATION.

PLAN
LAGOON #3 EXCAVATION
SCALE: 1"=60'-0"

AR 030789

1"=60' 60 0 60 120 scale feet

CALL 48 HOURS
BEFORE YOU DIG
1-800-424-5555

Kennedy/Jenks Consultants
FEDERAL WAY, WA

MJW
TJK
RJS/KNG
AS NOTED
2/23/00
RCG

REVISIONS

PORT OF SEATTLE

SEA-TAC INTERNATIONAL AIRPORT
INDUSTRIAL WASTEWATER SYSTEM
LAGOON #3 EXPANSION PROJECT

EXCAVATION PLAN

C-100888
K/J 996111.00
STIA-0009-C-3

996111.00\P9C003 XREF: BASE, LAGOON, SURVEY