Declaration of
John Strunk

POLLUTION CONTROL HEARINGS BOARD
FOR THE STATE OF WASHINGTON

AIRPORT COMMUNITIES COALITION, Appellant, v. STATE OF WASHINGTON DEPARTMENT OF ECOLOGY, and THE PORT OF SEATTLE, Respondents.	PCHB No. 01-133 DECLARATION OF JOHN J. STRUNK IN SUPPORT OF THE PORT OF SEATTLE'S RESPONSE OPPOSING ACC'S MOTION FOR STAY

AR 012507

John J. Strunk declares under penalty of perjury as follows:

1. I am over the age of 18, am competent to testify, and have personal knowledge of the facts stated herein.

2. I am a geologist by training, having received my Bachelors of Arts degree in geology and coordinate major in environmental studies from the University of Vermont in 1984 and have attended numerous professional training seminars associated with the field of environmental science. I have over seventeen years of professional experience and since 1995, I have been employed by Associated Earth Sciences, Inc. ("AESI"). *See* Exhibit A.

3. In 1995, AESI began work for the Port of Seattle ("Port"), planning for and conducting an in-depth groundwater evaluation at the Seattle-Tacoma International Airport ("STIA"). The Port's efforts in this regard were in response to concerns expressed in public comments that existing sources

ORIGINAL

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of contamination at the STIA's Aircraft Operations and Maintenance Area ("AOMA") might have the potential to impact drinking water or surface waters. More recent public comments have focused on whether AOMA contamination could migrate to the Third Runway construction area due to the presence of backfilled subsurface utility trenches acting as pathways of contaminant migration of perched ground water, and/or the natural westward flow of groundwater in the upper most regional aquifer (the "Qva" or "Qva aquifer").

4. Specific goals and elements of this groundwater evaluation were subsequently identified in both Governor Locke's June 30, 1997 letter ("Governor's Letter") approving the project's Supplemental Environmental Impact Statement and in the May 25th, 1999 Agreed Order between the Department of Ecology ("Ecology") and the Port ("Agreed Order"). Additional elements regarding the fate and transport of contaminants migrating preferentially in STIA subsurface utility lines were identified in the 401 Certification.

5. AESI has completed a substantial portion of this evaluation. The following deliverables have been provided by the Port to Ecology:

(a) presentation of the Conceptual Flow Model and Graphics Package, June 30, 1999;

(b) submission of STIA Monitoring Well Plan Map for the Qva aquifer, September 16, 1999;

(c) presentation of Conceptual Boundary Conditions and Graphics Package, December 8, 1999;

(d) submission of Till Thickness Map, January 24, 2000;

(e) submission of 1st and 2nd Quarter Qva Aquifer Ground Water Flow Measurements and Flow Directions Maps, January 31, 2000;

(f) presentation of Ground Water Flow Model Set-up, February 3, 2000;

(g) submission of memorandum responding to Ecology comments on Conceptual Flow Model Boundary presentation, 2000;

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(h) submission of four Quarters of Qva Ground Water Flow Measurements and Flow Direction Maps, July 31, 2000;

(i) presentation of Conceptual Fate & Transport Model, October 4, 2000; and

(j) submission, Draft Technical Memorandum Analysis of Preferential Ground Water Flow Paths Relative to Proposed Third Runway, June 19, 2001.

The Port and AESI's evaluation of AOMA groundwater conditions to date is sufficient to have developed meaningful and reliable conclusions regarding potential contamination transport and migration from the AOMA to the proposed Third Runway site, as set forth below.

6. Contamination does exist in shallow perched groundwater zones within the AOMA. *See* Exhibit B (Technical Memorandum) at 2. However, AESI has determined that these zones are isolated, discontinuous, and remotely located relative to the proposed Third Runway site (the Third Runway site is located approximately 2,800 feet from the AOMA). *Id.* at 2-3, Figures 2-5. Moreover, contaminated perched ground water zones in the AOMA appear to be contained laterally to areas adjacent to the source releases and ground water flow directions in those zones within the AOMA predominantly flow away from the proposed Third Runway. *Id.* at 11.

7. Environmental data does not indicate that the numerous subsurface utility lines within the AOMA are a preferred pathway of contaminant migration to the proposed Third Runway site. *See* Exhibit B (Technical Memorandum) at 9. The depth to perched ground water generally exceeds the typical depth of STIA utilities, therefore much of the impacted perched ground water is vertically isolated from utility backfill areas. *Id.* at 11. Moreover, Third Runway construction will only involve construction of one utility between the AOMA and the Third Runway area, the trenches for which will be backfilled with low permeability materials to restrict or prevent potential contaminant migration within the trench. *Id.* at 9. This utility is not located in an area of the AOMA containing known contamination. *Id.* at 9-10. As part of the 401 Certification permit conditions, additional analysis of the utility line backfill will be performed to evaluate the as-built conditions of the utility lines that intersect impacted perched ground water zones. An evaluation of the ability of select utility lines to act as a potential contaminant transport pathways to the Third Runway will be made.

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Based on the conclusion of this evaluation, appropriate monitoring activities will be initiated along select utility lines, if necessary.

8. Ground water flow of the Qva aquifer is in a west to northwest direction between the AOMA and the proposed Third Runway construction area. *See* Exhibit B (Technical Memorandum), at 7-8, 10. However, Qva contamination remains localized and contained with the vicinity of AOMA contaminant sources. *Id.* Data from ground water monitoring wells completed in a downgradient direction from known Qva impacted ground water sites confirms that contaminant concentrations are within MTCA standards and provide a defined plume boundary for contamination of the Qva aquifer. *Id.* Moreover, given the location of the proposed Third Runway embankment and utilities relative to the Qva aquifer, Third Runway construction is not likely to significantly impact or increase migration of Qva contamination. *Id.*

9. While additional evaluations will be conducted on contaminant pathways, in accordance with the 401 Certification, AESI has concluded that, based on the extensive analysis performed to date of STIA groundwater conditions and contamination present at the AOMA, no reasonable threat exists that contaminated ground water will migrate from the AOMA to the Third Runway area, either due to the properties of groundwater flow or due to the presence of subsurface utilities or perched zones to act as preferred contaminant transport pathways. *See* Exhibit B (Technical Memorandum), at 2, 10-11.

I declare under penalty of perjury under the laws of the State of Washington that the foregoing is true and correct.

DATED this 28 day of September, 2001 at Bainbridge Island, Washington.

John J. Strunk

AR 012510

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EXHIBIT A

JOHN J. STRUNK
Associate Geologist

Associated Earth Sciences, Inc.

EDUCATION

B.A., Geology, Coordinate Major in Environmental Studies, 1984, University of Vermont

Continuing Education

40-hour OSHA Health and Safety Trained
Sampling for Hazardous Materials
Hazard Evaluation and Risk Assessment
Introduction to Ground Water Investigations
Ground Water Monitoring at Hazardous Waste Sites
CERCLA RI/FS Workshop
Ground Water Computer Modeling Workshop
Onsite Ground Water and Soil Remediation
Seminar on Characterizing and Remediating DNAPL at Hazardous Waste Sites
Bioremediation Engineering
Transport and Fate of Contaminants in the Subsurface
GSA Field Trip - Pleistocene Geology of Puget Lowland
Visual MODFLOW Shortcourse
Brownfield Redevelopment Seminar

PROFESSIONAL REGISTRATIONS

Registered UST Site Assessor: Washington State Department of Ecology - 1991

PROFESSIONAL ASSOCIATIONS

Association of Ground Water Scientists and Engineers
Northwest Geology Society
Washington Hydrologic Society

EMPLOYMENT

Associated Earth Sciences, Inc. / Bainbridge Island, WA / Associate Geologist / 1995-present
Converse Consultants NW / Seattle, WA / Project Geologist / 1989-1995
State of Vermont, Department of Environmental Conservation / Waterbury, VT / Hydrogeologist / 1985-1989
Wagner, Heindel & Noyes / Burlington, VT / Staff Geologist / 1984-1985

PUBLICATIONS

McCormack, D.H., Strunk, J.J., and Cocks, G.J., April 2000, Stratigraphy of the Des Moines, SeaTac and Burien Areas, South King County, Washington, 2000 Program, The Geological Society of America, 96th Annual Meeting Cordilleran Section, Vancouver, British Columbia, Abstract p. A49.

SUMMARY

Mr. Strunk is an Associate Geologist with over sixteen years of experience in the environmental and ground water industry. His experience in environmental industry includes evaluating hazardous waste sites as required under federal CERCLA and RCRA regulations as well as sites regulated under Washington State Model Toxics Control Act, Dangerous Waste Regulations and Underground Storage Tanks Regulations. His experience includes environmental sampling for hazardous materials, aquifer testing and analysis, geophysical surveys, evaluation of remedial alternatives, data interpretation and technical report writing. Mr. Strunk has conducted hydrogeologic investigations for landfills, hazardous waste contamination studies, water supplies, liquid waste disposal, sludge disposals, and geotechnical studies.

Ground Water Resources

Mr. Strunk has served as a field geologist in supporting the design, installation and testing of water supply wells throughout Washington. His expertise includes well siting studies including geophysical surveys, development of construction documents, on-site geologic logging and construction management, well design, specifying well development techniques, and hydraulic testing and analysis. Washington State Department of Ecology-specified conditions for several of these projects including monitoring for salt water intrusion, impacts to nearby wells and impacts to adjacent surface water bodies. Mr. Strunk has significant experience in evaluating ground water conditions related to construction. He has served as field geologist on several projects including construction dewatering, evaluation of seasonal ground water inflow into infiltration ponds, and evaluation of impacts of hillslope dewatering on ground water gradients using numerical ground water flow models. He has performed aquifer analyses and designed dewatering systems for several sewer line construction dewatering projects. In addition, he has evaluated the effects of construction dewatering on contaminant migration at nearby hazardous waste sites and developed alternatives to reduce the impact of dewatering.

Landfills
Mr. Strunk is an Associate Geologist with significant experience in environmental monitoring at landfills throughout Washington and Vermont. Mr. Strunk has served as field operations coordinator and project manager for design and implementation of ground water, surface water, and gas monitoring at multiple landfill facilities. He has provided ground water monitoring systems for landfills in San Juan, Snohomish, King counties. He has been involved in the design and construction of a ground water and gas detection monitoring system at the Houghton Custodial Landfill in King County. In the last five years, Mr. Strunk has been involved with landfill site characterization investigations at the Duvall, Cedar Falls, South Park, Enumclaw and Cedar Hills landfill facilities for King County. Currently, Mr. Strunk is the project manager for the South Park Custodial Landfill and manages a multi-disciplinary team in evaluating the environmental, geotechnical and redevelopment issues related to the landfill. Mr. Strunk has assisted in the development of a work plan designed to characterize the hydrogeologic conditions for permitting Area 6 of the Cedar Hills Landfill.

PROFESSIONAL EXPERIENCE

HYDROGEOLOGIC PROJECTS

AREA-WIDE GROUND WATER STUDY
SEATTLE-TACOMA INTERNATIONAL AIRPORT
SeaTac, Washington
Project manager for an ongoing ground water study at the Seattle-Tacoma International Airport for the Port of Seattle. The ground water study is being conducted under a MTCA Agreed Order between Ecology and the Port of Seattle. The purpose of the study is to gain a more complete understanding of the direction and behavior of ground water flows beneath the airport and to evaluate that contamination that exists beneath portions of the airport is not a threat to drinking water supply wells or surface water bodies in the area. The study will be conducted in two phases. The first phase includes the development of a comprehensive database that catalogs environmental data collected at the airport and ground water wells located on airport property and in the USGS Des Moines Quadrangle. Select wells on the airport property will be included as part of a site-wide ground water monitoring network. A computer model of ground water and contaminant transport flow throughout the study area will be developed. The computer modeling will help to identify the potential risk of contaminants in ground water reaching public and private drinking water supply wells and nearby surface water bodies including: Bow Lake, Des Moines Creek and Miller Creek. The second phase of the study will include drilling additional ground water monitoring wells that could be used to verify Phase I study results and to perform additional ground water monitoring. Information from the study may be used by the parties conducting cleanups at the airport and could provide a basis for consistent approach to cleanup actions within the airport.

THIRD RUNWAY PROJECT SUPPORT
Seattle-Tacoma International Airport
SeaTac, Washington
Project manager for providing technical support to Third Runway project team regarding ground water and contaminant transport issues. Provided technical data compiled for ground water studies to numerous consults involved in the design of the Third Runway embankment. Provide technical review regarding the development of ground water monitoring plans associated with embankment monitoring. Developed an initial evaluation regarding

the preferential pathways of contaminant migration via subsurface utility lines in regards to the Third Runway construction area.

INDUSTRIAL WASTE SYSTEM HYDROGEOLOGIC STUDY
Seattle-Tacoma International Airport
SeaTac, Washington
Project manager for a hydrogeologic study at the Port of Seattle's Industrial Waste System (IWS) facility and treatment lagoons. The purpose of the study is to evaluate if historic and current wastewater management practices have the potential to impact ground water resources in the immediate area. The study will conform to Washington Department of Ecology's Ground Water Quality Standards. Historic monitoring data on the treatment processes, soil, sediment, and ground water monitoring data were reviewed. A ground water monitoring network of wells was installed in the regional aquifer at Lagoons 1 and 2. Perched ground water wells were completed at Lagoon 3. AESI has coordinated with engineering activities associated with Lagoon 3 expansion throughout the design process. A long-term ground water monitoring program was implemented in May 1999. Background water quality was statistically evaluated for potential impacts to the ground water resource from the IWS facility infrastructure and lagoons.

CONCOURSE D GROUND WATER REMEDIAL INVESTIGATION/FEASIBILITY STUDY
Seattle-Tacoma International Airport
SeaTac, Washington
Developed work plan for the execution of field activities to define the nature and extent of ground water contamination resulting from waste management practices associated with aircraft maintenance facilities. The RI was performed in accordance with the Washington State Department of Ecology Model Toxics Act (MTCA) and with federal CERCLA legislation. Five ground water monitoring wells have been installed in areas where elevated levels of soil contamination were detected during focused soil RI. Quarterly ground water monitoring events were conducted for a one-year period. Sampling efforts did not indicate an impact to the glacial outwash aquifer. A deep monitoring well installed at the site has shown that the shallow and intermediate regional aquifers appear to be interconnected. Soil samples collected from the monitoring well borings were field screened using flame ionization detection and compound specific detector tubes. Samples exhibiting elevated responses were submitted for chemical analysis. A "no further action" status was issued by Ecology.

PORT OF SEATTLE SOUTHWEST HARBOR PROJECT - REMEDIATION AREA 4 (PACIFIC SOUND RESOURCES)
Seattle, Washington
Participated on project that redeveloped the Pacific Sound Resources (Wyckoff) site in Elliott Bay, Seattle, Washington, as part of the Port of Seattle Southwest Harbor Project. The project included remediation investigations, feasibility study, cleanup action plan, and design plans and specifications for cleanup activities. Affected media include soil, ground water, and sediment contaminated with creosote, pentachlorophenol (PCP), polynuclear aromatic hydrocarbons (PAHs), and metals including arsenic, chromium, copper, and zinc. Role on the project includes remedial investigations for ground water and sediment. Ground water investigations include dissolved phase contaminants, sinking product (creosote and PCP) thickness, floating product (carrier solvents) thickness, and bail down tests and water level measurements over tidal cycles. Sediment investigations focus on offshore areas in Elliott Bay and include both surface sediment and sediment core sampling. Mr. Strunk was responsible for the feasibility study elements related to ground water including treatability testing for ground water treatment, ground water modeling for ground water migration, fate, and extraction analysis, and evaluation of recovery systems for floating and sinking product through both interim actions and long-term recovery.

PORT OF SEATTLE ON-CALL TECHNICAL SERVICES
Seattle, Washington
Provide various environmental and database/GIS management to the Port of Seattle on an on-call basis. Work has included the refinement of the Port's field sampling data acquisition system, ground water sampling at marine terminal sites, database design and well logging software evaluation.

BLUE MOUNTAIN GOLF COURSE
Perry, Oregon
Performed preliminary evaluation of the ground water conditions at the proposed Blue Mountain Golf Course site in Perry, Oregon. The purposes of this evaluation was to provide a hydrogeologic framework and establish existing ground water conditions at the site, and evaluate potential ground water impacts and mitigating measures. Union County Planning Department required information that would mitigate potential domestic well contamination resulting from site development. A door-to-door survey of residents in lower Perry was conducted to gather information regarding drinking water wells. Where permission was granted and the well was readily accessible, a ground water level measurement was obtained. Subsurface and ground water conditions at the site were explored in a series of eight test pits using a backhoe. A visual reconnaissance of the site and surrounding area was performed. In addition, available geologic and ground water reports and maps were reviewed for the project area.

MUNICIPAL WELL GROUND WATER RESOURCE INVESTIGATION
Yakima, Washington
Collected and interpreted hydrogeologic data for a proposed 3000-gpm municipal well for the City of Yakima. Specifically addressed the water-bearing potential of the basalt aquifer in a structurally complex area. Compiled and interpreted water quality data to assess potential water quality problems at the proposed location. Interacted with Washington State Department of Ecology, drillers, and neighboring water districts to determine final well location. Recommended well location was drilled and completed at 1100 feet. Performed 24-hour pump test at a pumping rate of 2500 gpm. Designed and implemented automatic data acquisition system to gather water level data at pumping well and an observation that was under 35 psi of shut-in pressure.

PRESTON INDUSTRIAL PARK ENVIRONMENTAL IMPACT STATEMENT
Preston, Washington
Evaluated existing ground water conditions, impacts, and mitigating measures for a proposed 129-acre industrial park in eastern King County. Analysis included potential ground water depletion impacts on an adjacent wetland, on-site septic system impact on ground water quality, and development of alternative well locations and pumping schemes to mitigate wetland impact. Acted as task leader for stream gauging and ground water sampling.

TAMOSHAN SUBDIVISION WELL
Thurston County, Washington
Managed construction of a water supply well for a subdivision in Thurston County. Responsibilities included logging samples, determination of completion zone, and well screen design. Performed periodic water quality analyses during drilling to ensure completion zone was low in iron and magnesium. Designed, monitored and analyzed step drawdown test and 24-hour pump test in tidally influenced aquifer. Monitored water quality parameters in nearby wells to evaluate potential of saltwater intrusion.

ENVIRONMENTAL PROJECTS

CONCOURSE A EXPANSION PROJECT, ENVIRONMENTAL SERVICES, PROJECT COORDINATION
Seattle-Tacoma International Airport
SeaTac, Washington
AESI is providing project support to the Floyd & Snider, Inc. project team on the Concourse A Expansion Project. AESI has provided the project team with database queries of relevant historic environmental data in the Concourse A area to be used for risk based unsaturated contaminant transport modeling. Subsurface geologic interpretations were also developed through the project area to gain an understanding on the glacial stratigraphy underlying the site and its relationship to contaminated soil distribution. AESI project team members are also interfacing with the Concourse A project team regarding the use of the unsaturated soil modeling methods and results for integration into the ground water fate and transport modeling being performed as part of the airport wide ground water study.

AIRCRAFT FUEL SYSTEM STUDY
Seattle-Tacoma International Airport
SeaTac, Washington
AESI key personnel member of a relatively large and diverse project team responsible for evaluating existing fuel supply and delivery operations at Seattle-Tacoma International Airport on behalf of the Port of Seattle and various

airline companies. Reviewed and compiled existing subsurface contamination information within the aircraft fuel facilities and operational areas to develop an approach for addressing soil and ground water contamination which could be encountered during construction of additional fuel delivery systems.

CONCOURSE D CONTAMINATED SOIL REMOVAL PROJECT
Seattle-Tacoma International Airport
SeaTac, Washington
Field manager for compliance monitoring and sampling for the excavation of approximately 35,000 cubic yards of contaminated soil from an airport expansion project site.
Petroleum hydrocarbons and chlorinated industrial solvents were detected during demolition of a commercial airline hanger. The Port elected to perform an independent interim remedial action to clean up the contaminated soil under the State of Washington's Model Toxics Control Act cleanup regulations. The remedial action selected was excavation with performance and confirmation monitoring to document that the cleanup action had attained the established cleanup standards. Soil samples were collected from deep excavations (>20 feet in depth) and field screened throughout the excavation process. A northing and easting field coordinate system was established at the site that enabled field staff to accurately locate and track where samples were collected. The sample tracking system proved very effective in providing direction to the contractor of areas of the site requiring over excavation. Flame ionization detectors and compound specific detector tubes were used to monitor the excavation. Over 300 soil samples were collected for chemical analysis by on-site and off-site laboratory facilities. Ambient air conditions were also monitored for worker health and safety. Submitted approximately 30 samples per day to on-site laboratory for 24-hour turnaround of target chlorinated volatile organic compounds and total petroleum hydrocarbons. The on-site laboratory data proved instrumental in monitoring the performance of the excavation activities and providing direction to the excavation contractor.

PROPOSED JUNIOR HIGH SCHOOL No. 6 TANK REMOVAL
Kent, Washington
Two underground storage tanks were decommissioned by removal. A release of diesel fuel oil was confirmed from the area of the former diesel tank. The diesel tank excavation encountered ground water at approximately 14 feet below ground surface and petroleum product was observed floating on the ground water surface. Confirmation sampling in the vicinity of the gasoline tank indicated that no release of petroleum resulted from the gasoline tank. Surficial soil contaminated with petroleum products and low-level chlorinated solvents was also excavated from the site. Approximately 3,075 cubic yards of petroleum-contaminated soil was processed and treated on-site by a mobile thermal processor. Established a survey grid system to track samples collected within the excavation. This system proved very effective in directing the contractor where soil removal should occur based on field screening and laboratory analysis. Excavated material was screened prior to treatment to remove oversized cobble size material. Ground water samples collected from an existing on-site monitoring well and from ground water pooled in the bottom of the diesel tank excavation contained levels of total petroleum hydrocarbons above the Washington State Department of Ecology cleanup level. Recommendations were made to investigate the extent of ground water contamination at the site.

POINT WELLS FUEL DISTRIBUTION CENTER
Richmond Beach, Washington
AESI provided soil and ground water remedial services at the Chevron Point Wells fuel storage and distribution center (110-acre site) located at Richmond Beach on Puget Sound. The facility has been in operation since 1914 and has above ground refined petroleum product storage capabilities of approximately 700,000 barrels. Installed, monitored and maintained over 80 ground water monitoring wells at the facility as part of soil and ground water characterization, and subsurface liquid hydrocarbon recovery operations. Designed, installed, and operated large-scale interim liquid hydrocarbon recovery systems in two areas of the facility. Prepared an interim remedial action plan to implement liquid hydrocarbon recovery at three additional areas including the adjacent asphalt plant. Extensive modeling using FLOWPATH was performed to evaluate capture zones. Prior to development of the interim remedial action plan, a 72-hour tidal study was performed to determine the effect of tidally-induced ground water level changes on liquid hydrocarbon thickness and to determine the net ground water flow direction. Results of the tidal investigation were used for siting additional liquid hydrocarbon recovery wells and specifying timer cycles for skimmer pumps.

EMBASSY SUITES HOTEL SITE/GAS STATION DEMOLITION
Bellevue, Washington
In response to Phase II recommendations, documents were prepared by the previous gas station owner's consultant. Then reviewed the environmental work covered in documents. The site consisted of underground storage tanks, sump, and a pesticide wash area. Specific recommendations were made for removal of underground storage tanks, storm drain and sump demolition and cleanup of pesticide residues prior to the purchase of the property.

PACIFIC NORTHERN OIL - PIER 91
Petroleum Contamination Site Assessment
Seattle, Washington
Involved a phased hydrogeologic assessment to determine the extent of contamination resulting from a release of diesel fuel. A preliminary hydrogeologic assessment was the first phase of this assessment followed by a Phase I remedial investigation. Ground water levels have been monitored utilizing a datalogger for a 24-hour cycle to determine how ground water gradients are affected by tidal fluctuations. A free-product recovery test was performed on an existing monitoring well to determine the true thickness of diesel fuel floating on the water table. Four existing wells have been sampled for total petroleum hydrocarbons. The Phase I remedial investigation will consist of installing four new monitoring wells based on results obtained during the preliminary hydrogeologic assessment. Based on the results of this phase, recommendations will be made for continuing remedial investigation and/or remedial action.

LARRY'S ARCO
Everett, Washington
Performed a subsurface investigation at a former Arco station for the Washington Department of Ecology to assess the extent and degree of hydrocarbon contamination resulting from a release in an underground storage tank (UST) system. Initial work included the development of a site work plan, which contained a sample and analysis plan, quality assurance project plan, and a health and safety plan. Prepared technical specifications for drilling and laboratory subcontractors. Ten soil borings were completed by hollow-stem drilling methods through dense glacial deposits consisting of glacial till overlying advance glacial outwash sand and gravel. Borings were located in areas surrounding the UST and service islands. Seven borings were advanced to a depth of 40 feet below ground surface (bgs) and three borings were drilled to 80 feet bgs. Soil samples were collected by split-spoon samples lined with brass sleeves. Field screening was performed by head space methods using a photoionization instrument. Three soil gas recovery wells were installed in zones exhibiting elevated levels of hydrocarbons based on field screening results. Results of the investigation indicated that hydrocarbon levels were limited to areas surrounding the UST system and soil gas vapors were elevated beneath a silt horizon that acted as a stratigraphic barrier for vapor migration.

SEAFIRST BANK RAINIER AVENUE SITE
Seattle, Washington
Level II site assessment of a used car lot. Project consisted of identifying fuel and solvent contamination in soil, ground water, and drains. Developed sampling plan, managed installation of monitoring wells, soil and ground water sampling and drain sediment sampling. Developed remedial action plan and coordinated subcontractors and confirmation sampling.

ABANDONED FIRE STATION
Auburn, Washington
Remedial investigation for a leaking underground fuel tank. Managed monitoring well installation and ground water sampling. Interfaced with the Department of Ecology to gain approval for location of monitoring wells. Site listed as a confirmed contaminated site on the Department of Ecology's SMIS data base.

OLYMPIC AUTO WRECKING CONTAMINATED SOIL REMEDIATION
Everett, Washington
Conducted an environmental investigation to determine the extent of petroleum hydrocarbon and lead soil contamination resulting from an automobile wrecking yard. The initial phases of the project involved the completion of test pits and shallow soil borings to determine the areal extent of contamination and develop volumetric estimates of soil elevated above MTCA cleanup levels. Approximately 7 cubic yards of lead-contaminated soil was characterized as dangerous waste using TCLP testing procedures. The lead soils were containerized, manifested and transported to a certified hazardous waste disposal facility located in Arlington, Oregon. Soil contaminated with petroleum hydrocarbons was excavated and stockpiled on-site. Soil samples were collected in excavations ranging in depth from about 5 to 15 feet. Stockpiled soil was screened to remove oversized rubble and wood debris prior to placement into on-site bioremediation treatment cells. Approximately 400 CY of soil was processed and placed in the treatment cells. Nutrient additives and microbe inoculation were made to the treatment cell. The treatment cell was monitored for nutrient levels and moisture content on a weekly basis and nutrients and water were applied as needed to maintain optimum conditions for microbe activity. The treatment cell was also tilled periodically to promote oxygenated conditions. Monthly soil samples were collected and submitted for analytical testing to monitor the progress of the bioremediation. Total petroleum hydrocarbon contamination below MTCA levels were achieved within a 3-month time period. The treated soil was designated as a Class 2 soil and was recommended to be used as fill during on-site construction.

ELLIOTT BAY OFFICE PARK
REMEDIAL INVESTIGATION AND SITE REMEDIATION
Seattle, Washington
Level I and II site assessments indicated levels of hydrocarbons above Ecology's MTCA Method A Cleanup levels in soil and ground water affected this former service station. In response to these findings, a RI/FS was conducted to determine the extent and volume of soil and ground water contamination. Contracted with Laucks Testing Laboratories to provide on-site analytical services during the soil boring investigation. Preliminary cost estimates for alternative remedial technologies were calculated as part of a feasibility screening study. Remediation by soil vapor extraction was determined to be the best remedial alternative available. Designed, permitted, and installed the vapor extraction system that consisted of dual soil venting ground water monitoring wells, dedicated vertical soil venting wells, and horizontally screened soil venting pipes. Performed monthly hydrocarbon removal calculations from each venting port to evaluate performance and to verify compliance with Puget Sound Air Pollution Control Agency (PSAPCA) permitted emission levels. The system was adjusted in the field to allow maximum removal of hydrocarbons without exceeding permitted levels.

SUBSURFACE INVESTIGATION SUMMARY
Everett, Washington
Project manager for the contract with The Boeing Company to perform subsurface investigations at six potential solid waste management units located at the Boeing Commercial Airplane Group, Everett facility. Two of the SWMUs were former fire training pits, three SWMUs were former underground storage tank locations, and one site is adjacent to aboveground distillation tanks. The purpose of the investigation is to evaluate potential impacts to soil and, if appropriate, ground water, resulting from former waste management practices. Twenty-three soil borings were completed to a depth of 15 feet and 60 soil samples were submitted to laboratory analysis of select volatile

organic compounds, semivolatile organic compounds, metals, total petroleum hydrocarbons and tributyl phosphate. Ground water was encountered at three of the SWMUs and one-time samples were collected for laboratory analysis.

BOEING EVERETT FACILITY - BUILDING 40-56
Everett, Washington
Project involved removal of two underground storage tanks (USTs) located north of Building 40-56 at the Boeing Everett facility. At the time of the excavation, petroleum odors and staining were detected in the sandy backfill surrounding the tanks. Laboratory testing confirmed the presence of total petroleum hydrocarbons (TPH) above the Washington State Department of Ecology, Model Toxics Control Act (MTCA) standards in the south sidewall adjacent to the diesel tank and in the excavation stockpiles. Re-excavation of the south sidewall occurred and resampling from this area indicated levels of TPH below the MTCA standards. Also included confirmation soil sampling data from an area located southeast of the UST excavation.

THE BOEING COMPANY
BOEING COMMERCIAL AIRPLANE GROUP EVERETT DIVISION
FLIGHTLINE STALL 112 DIESEL UST
Everett, Washington
Contracted by Boeing to perform a subsurface investigation to determine the extent of hydrocarbon impacted soil resulting from a release of diesel fuel form an underground storage tank UST. Soil borings were completed and soil samples and one-time ground water samples were collected as part of the investigation. The borings completed during this investigation were used to supplement existing data in an effort to characterize the extent of hydrocarbon-impacted soil and to aid in estimating the quantity of soil which would be require removal during UST closure. A UST closure by removal was conducted which conformed to the Ecology UST site assessment guidelines. Confirmation soil samples were collected from the excavation sidewalls and bottom. Soil samples from the excavation bottom were collected from about a depth of 12 feet. An estimated 80 cubic yards of soil were removed and stockpiled at the Everett facility. Soil samples collected from the stockpile indicated levels of petroleum hydrocarbons above MTCA cleanup levels. Boeing arranged for the disposal of the stockpile.

THE BOEING COMPANY
BOEING COMMERCIAL AIRPLANE GROUP EVERETT DIVISION
UNDERGROUND STORAGE TANKS EV-48 AND EV-49
Everett, Washington
Project involved removal of two underground storage tanks (USTs), EV-48 (10,000 gallon) and EV-49 (5,000), located north of Building 40-56 at the Boeing Everett facility. At the time of the excavation, petroleum odors and staining were detected in the sandy backfill surrounding the tanks. Laboratory testing confirmed the presence of total petroleum hydrocarbons (TPH) above the Washington State Department of Ecology, Model Toxics Control Act (MTCA) standards in the south sidewall adjacent to the diesel tank and in the excavation stockpiles. Reexcavation of the south sidewall occurred and resampling from this area indicated levels of TPH below the MTCA standards. Also included confirmation soil sampling data collected from an area located southeast of the UST excavation.

THE BOEING COMPANY
BOEING COMMERCIAL AIRPLANE GROUP EVERETT DIVISION
SOUTH FUELING STALL EQUIPMENT
Everett, Washington
Phased investigation to determine the extent of jet fuel contamination resulting from the release of product from an overflow containment tank (OCT EV-110-1). An interim remedial action was conducted to remove approximately 10 cubic yards of petroleum contaminated soil in order that an utility construction could proceed on schedule. A soil gas survey and geophysical survey was conducted to estimate the extent of the contamination and map out buried utility lines which may be acting as preferential pathways for contaminant migration. Soil borings and ground water monitoring wells were installed to confirm the petroleum hydrocarbon distribution.

THE BOEING COMPANY
BOEING COMMERCIAL AIRPLANE GROUP EVERETT DIVISION
SOUTH FIRE TRAINING PIT
Everett, Washington

Completed an investigation to investigation to identify the impact of the use of a fire training pit at the Everett Division facility. Twelve soil borings were completed in the area of the fire training pit and related oil/water separator to evaluate potential impact to soil. It is estimated that approximately 55 cubic yards of soil contains petroleum hydrocarbons above the MTCA cleanup level.

STRATTEN MOUNTAIN SKI RESORT
Winhall, Vermont
Investigated a number of upland sites to dispose of 300,000 gpd of wastewater effluent. Study involved establishing and monitoring surface water stream gauging stations, ground water monitoring well installation and monitoring, and testing of simulated spray irrigation system model to determine aquifer response.

MOUNT ASCUTNEY SKI RESORT
Brownsville, Vermont
Performed site evaluations for disposal of 125,000 gpd of wastewater effluent by subsurface high rate system and spray irrigation. Installed stream gauging stations to develop rating curves for receiving surface water. Performed large-scale aquifer testing to calculate loading rates.

BARRE COAL TAR SITE
Barre, Vermont
Performed a hydrogeologic investigation to determine the nature and extent of contamination associated with an abandoned coal gasification plant. The investigation included the installation of ground water monitoring wells to locate and measure the location of a dense non-aqueous phase liquid (DNAPL). The site was located adjacent to the Winooski River and the DNAPL was found to be migrating off-site and seeping through the river bottom. Remedial measures such as hydraulic control and physical containment systems were evaluated to control the seepage of the DNAPL into the river.

LANDFILL PROJECTS

SOUTH PARK CUSTODIAL LANDFILL
Seattle, Washington
Mr. Strunk is project manager for hydrogeologic, engineering, industrial development assessment and public involvement services related to the South Park Custodial Landfill. The landfill is a brownfield site located within the Duwamish River corridor. The first phase of the project consisted of reviewing available information for the purpose of evaluating environmental conditions at the site and surrounding area, evaluating the development potential of the site, and making recommendations on how to proceed to complete an understanding of the site with respect to environmental conditions and development potential. Environmental characterization of the landfill was conducted to evaluate ground water, surface water, and gas migration. Additional work consisted of the completion of soil borings and monitoring wells, installation of gas probes, evaluation of the soil and waste fill conditions from a both an environmental and geotechnical standpoint, and risk-based decision-making for development of alternative cleanup standards. Conducted environmental monitoring of ground water field parameters, ground water sampling, aquifer testing and hydrogeologic interpretation. Seasonal ground water potentiometric maps were constructed and ground water flow velocities were calculated for the alluvial aquifer. Week-long ground water monitoring was conducted using pressure transducers and datalogger system to evaluate the potential for tidally induced ground water level changes from the Duwamish River.

Data Gap Evaluation
Compiled and reviewed existing data at the site including aerial photograph review from 1936 through 1997, compilation of ground water well, gas and surface water data. Reviewed a number of off-site geotechnical investigation reports, which provided information on subsurface soil conditions from a construction standpoint.

Cover Soil Evaluation
Completed over 60 shallow test pits and completed soil laboratory testing to evaluate shallow soil contamination. Identified fuel component hydrocarbon contamination and calculated risk-based TPH cleanup standards for the impacted soils. Recommended hot spot removals and site capping as potential remedial alternatives.

Geotechnical Evaluation
Supervised geotechnical evaluation based on historic site data and new data generated to evaluate liquefaction conditions, feasibility of building foundation design, review of piles systems and settlement issues.

Surface Water / Wetland Evaluation
A limited surface water evaluation was conducted to gain a better understanding of existing storm water runoff from the site and evaluate some engineering controls. Preliminary alternatives including a wet pond and underground retention systems were evaluated. A wetland assessment was performed and no regulated wetlands were identified at the site.

Ground Water and Gas Monitoring
Established a ground water and landfill gas monitoring system around the perimeter of the 41-acre site. Ground water samples are collected on a quarterly basis using dedicated sampling equipment. Gas monitoring has been conducted on a monthly basis. Hydrogeologic services included monitoring well design, well development, aquifer testing and ground water flow condition evaluation. Ground-water-to-surface-water pathway analysis is currently being evaluated.

Public Participation
Coordinated facilitation support to King County Solid Waste Division in a public involvement program. The team has developed consensus among an active Citizens Advisory Committee regarding issues affecting site redevelopment.

ENUMCLAW LANDFILL
Enumclaw, Washington
Mr. Strunk is serving as project manager for improvements to the Enumclaw Landfill ground water and gas monitoring network. Gas probes and ground water monitoring wells located on private property were evaluated for abandonment. New gas probes and wells were designed along the western landfill property boundary. Well development of the replacement wells was performed. A pneumatic slug test method was designed to estimate the hydraulic characteristics of a very permeable sand and gravel aquifer. Ground water potentiometric surface maps were produced and an updated ground water velocity was calculated. Mr. Strunk provided negotiation support to King County Solid Waste Division for well construction approval and gas probe variance. AESI prepared a report for review and approval by Washington State Department of Ecology Solid Waste and Seattle-King County Department of Public Health representatives.

DUVALL CUSTODIAL LANDFILL
King County, Washington
Mr. Strunk provided project support for a landfill investigation that included evaluation and corrective action for the ground water monitoring system, leachate collection system, cover, site drainage, and landfill gas conditions. Existing hydrogeologic, landfill gas, climatic, water quality and landfill closure engineering data was compiled and reviewed. Regional hydrogeologic data were incorporated with site-specific data to develop a conceptual model of the geologic/hydrogeologic framework at the landfill and surrounding vicinity. Low-flow sample and purge methods were utilized to prove the presence of false metal detections at the site that exceeded MCLs. Landfill gas chemistry was evaluated in conjunction with ground water chemistry to assess gas/ground water transfer of contaminants. An evaluation of the current ground water monitoring well system was made based on the position of the well in the hydrogeologic system, historic water quality data and construction details. Previous well construction methods caused the need for replacement of selected wells. Additional wells were installed to complete a comprehensive ground water monitoring system in three aquifer systems beneath the site. A gas monitoring network is currently being installed.

CEDAR FALLS LANDFILL
King County, Washington
Mr. Strunk assisted in performed a landfill investigation that included evaluation of the ground water monitoring system, site drainage, landfill cover and gas collection system. Existing hydrogeologic, landfill gas, climatic, water quality and landfill closure engineering data was compiled and reviewed. Regional hydrogeologic data was incorporated with site-specific data to develop a conceptual model of the geologic/hydrogeologic framework at the

landfill and surrounding vicinity. An evaluation of the current ground water monitoring well system was made based on the position of the well in the hydrogeologic system, historic water quality data, construction details, and results of the well redevelopment. Surface water data, rainfall and cover installation were reviewed to evaluate the effectiveness of the cover material. A water balance was developed that was used in the evaluation of the cap effectiveness, volume of leachate generation and recharge/ discharge characteristics of the aquifer system. Evaluation of water quality data showed the geomembrane cover to be very effective in reducing contaminant levels in ground water. Recommendations were provided for improvements to the ground water monitoring system.

CEDAR HILLS LANDFILL
King County, Washington
Mr. Strunk assisted in the preparation of a work plan designed to characterize the hydrogeologic conditions per Washington Administrative Code (WAC) 173-351 for permitting Area 6 of the Cedar Hills Landfill. Attended negotiations with Washington State Department of Ecology and King County Solid Waste regarding the design of the hydrogeologic investigation. Identified perched ground water bearing target zones and recommended sonic drilling methods to collect continuous soil cores to classify the thickness and extent of perched water bearing units.

ALKI TRANSFER/CSO PROJECT
West Seattle Pump Station
Slurry Trench Design and Ground Water Modeling
Seattle, Washington
A steady-state two-dimensional horizontal aquifer simulation model, FLOWPATH, and three-dimensional model, MODFLOW, were used to aid in the design and configuration of a slurry trench at the proposed West Seattle Pump Station as part of the Alki Transfer/CSO project. A drainfield was to be installed on the west side of the pump station to lower the ground water surface and stabilize a landslide mass located in the vicinity of the pump station. Preliminary analyses indicated that the lowering of the ground water around the drain field would cause a reversal of the regional ground water flow direction. Ground water flow from a portion of the former West Seattle Landfill would be directed toward the pump station and finally to the drain field. Concern was raised that the reverse flow may cause migration of the contaminants from the landfill to the drain field. A slurry trench was proposed to be installed between the drain field and Harbor Avenue SW to reduce the ground water flow gradient and to prevent the potential migration of the contaminants toward the pump station. The purpose of the ground water modeling task was to delineate the capture zone for the drain field and to determine the length and configuration of the slurry trench required to cut off the ground water flow reversal. Worked closely with hydrologists and engineers in the design of the slurry wall.

HOUGHTON CUSTODIAL LANDFILL
Kirkland, Washington
Mr. Strunk was the field operations hydrogeologist for ground water studies at the Houghton Custodial Landfill. The project involved ground water/gas investigation at a 40-acre closed landfill in Kirkland, Washington. Designed and implemented an eleven-monitoring-well network in two aquifers including two off-site residential wells. Identified contaminants including chlorinated solvents and conventional leachate constituents. Mr. Strunk was involved in the design and implementation of a ground water monitoring program for the abandoned landfill. Geologic and ground water data within a one-mile radius of the landfill were collected and tabulated to evaluate the first aquifer beneath the facility and determine ground water flow direction. Nearby residential wells were field checked and the water levels measured. Residential wells adjacent to the landfill were sampled. In addition, eight gas probe wells were sited. Performed hydrogeologic interpretation, aquifer testing and analysis, development of ground water flow direction maps and calculated ground water gradient and velocities for the two-aquifer system.

SNOHOMISH RIVER CSO - REMOVAL OF LANDFILL REFUSE / STOCKPILING / SAMPLING
Everett, Washington
Provided on-site environmental construction services for the City of Everett as of the Snohomish River CSO project. The environmental phase of the project consisted of trenching through the northern portion of the former City of Everett Landfill to place a 12-inch and a 60-inch combined sewer and overflow line. The trench section through the landfill was about 500 feet in length to a depth of about 10 feet for the 12-inch line. Provided oversight of the excavation contractor and directed the stockpiling of the material. Stockpile samples were collected for waste classification profiling.

CATHCART LANDFILL HYDROGEOLOGIC AND METHANE INVESTIGATION
Snohomish County, Washington
Extensive investigation of ground water, surface water, and landfill gas migration at this 1000 ton/day solid waste facility. Sited and oversaw the installation of over 25 monitoring wells in three separate phases. Monitoring wells were completed in a shallow glacial aquifer and a deeper bedrock aquifer. A terrain-conductivity survey of the site was performed to assess the extent of leachate-impacted ground water and assist in locating additional wells. Interpreted water quality data using graphical and statistical methods. Recommended locations for large diameter extraction well for remediation of leachate-impacted ground water. Designed and directed installation and plumbing of the extraction well. Interpreted water quality data using graphical and statistical methods. Sited, designed and directed installation of over ten gas probe wells to monitor methane migration. In addition, interacted closely with Washington State Department of Ecology and local health department officials.

CATHCART LANDFILL WATER BALANCE
Snohomish County, Washington
Project involved in a water balance investigation at Cathcart Landfill. Purpose of developing water budget was to investigate leachate entrainment pathways and leachate migration. Development of water budget entailed review of as-built construction diagrams; interviews with people present during construction; gauging of precipitation, stream flow, underdrain and leachate collection; and calculation of ground water flow and evapotranspiration.

CATHCART LANDFILL HYDROGEOLOGIC STUDY
Snohomish County, Washington
Interpreted water quality and terrain conductance survey results to determine depth and extent of leachate-impacted ground water. Prepared water quality portion of hydrogeologic study report, which presented a comprehensive overview of monitoring results to date.

SAN JUAN COUNTY LANDFILLS
Orcas Island and Friday Harbor, Washington
Developed ground water monitoring plans to bring Orcas Island and Friday Harbor Landfills into compliance with state regulations for ground water at solid waste facilities. The Orcas Island facility is a 20-acre solid waste landfill located on glacial outwash and till. Friday Harbor Landfill is comprised of a closed solid waste area and an active ash fill portion, sited on bedrock. Performed preliminary hydrogeologic assessment, sited monitoring wells, oversaw monitoring well installations, performed pump tests, installed dedicated sampling pumps and developed sampling and analysis plan. Analyzed data and prepared report on lateral and vertical extent of leachate impacted ground water. County employees were familiarized with sampling techniques and equipment and to perform quarterly monitoring.

LAKE GOODWIN LANDFILL
Snohomish County, Washington
Lake Goodwin Landfill stopped accepting refuse in 1982 and final cover was placed in 1983. Developed a ground water monitoring plan for this closed facility specifying ground water monitoring well locations and depths and analytical testing parameters. Mr. Strunk was in charge of the monitoring well drilling and installation, well development, and installation of dedicated sampling pumps were completed. Performed pump tests on the wells to determine aquifer characteristics. Throughout the drilling process, reevaluated the ground water flow direction to ensure three wells were sited downgradient and one well upgradient of the waste area in accordance with the MFS for solid waste facilities. Interpreted data and prepared report. This project was completed under a grant from Department of Ecology and required close interaction with both the Department of Ecology and local health department.

REGIONAL LANDFILL
Snohomish County, Washington
Performed a hydrogeologic investigation to evaluate ground water flow conditions and water quality prior to the start of landfilling at a new regional solid waste facility. Project included the installation of ground water monitoring wells, aquifer testing and analysis of water quality data. Developed a ground water velocity model to aid county personnel in updating future ground water flow conditions.

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LAKE STEVENS LANDFILL
Snohomish County, Washington
Assisted in preparation of ground water monitoring plans, compiled and interpreted regional well log data, and provided locations of eleven monitoring wells to monitor shallow, perched and deep, regional aquifers.

BRYANT LANDFILL
Snohomish County, Washington
Evaluated four years of ground water quality data for this closed facility and prepared monitoring report. Closure of Bryant Landfill was completed in 1989. Time series analysis and statistical techniques using graphical methods (box plots), single factor analysis of variance and student t tests were applied to the data to determine temporal and spatial trends in leachate impacted ground water. Prepared final report and provided recommendations for continued monitoring.

BOEING COMMERCIAL AIRPLANE GROUP
PROPOSED SITKA INDUSTRIAL LANDFILL
Sitka, Alaska
Performed a preliminary geotechnical investigation to determine the depth to bedrock and refusal on glacial sediments. Evaluated a 30-acre site to determine siting feasibility.

PROPOSED JARVIS STREET LANDFILL
Sitka, Alaska
Conducted a preliminary investigation to obtain information regarding the subsurface conditions at a site under consideration for a new landfill site by the City of Sitka. Scope of work included site reconnaissance, test probe and hand-auger explorations, geotechnical analysis and design recommendations.

SITKA LANDFILL SITING STUDY
Sitka, Alaska
Evaluated five alternative landfill sites under consideration for a new landfill in Sitka, Alaska. Work included site reconnaissance and mapping, test probe explorations, observation and description of existing site use, topographic conditions, surface water, adjacent property use and surficial geologic features. Developed siting criteria and performed a numerical ranking to aid in the planning/feasibility stage of the siting process.

LANDFILL EXPANSION AND CLOSURE
Sitka, Alaska
Performed geotechnical investigation for the proposed closure of the City of Sitka landfill. Work included geologic reconnaissance, subsurface explorations consisting of test pits, ground water level determinations, field permeability tests, water quality sampling and testing, water temperature measurements, laboratory soil testing, and engineering evaluations and development of design recommendations.

SITKA LANDFILL EXPANSION PROJECT
Sitka, Alaska
Conducted a preliminary geotechnical evaluation on a expansion site located adjacent to the existing landfill in Sitka, Alaska. The scope of work consisted of test pit and hand probe explorations, measurement of the ground water level in the test pits, laboratory soil testing, settlement analysis and engineering evaluations and development of design recommendations.

BENNINGTON LANDFILL
Bennington, Vermont
Performed a CERCLA Pre-Remedial Site Inspection, which included developing a work plan, conducting a sampling program of environmental media that included ground water, surface water, leachate, soil and sediment. Published in the Federal Register the Hazard Ranking System (HRS) scoring package. Provided EPA personnel and contractors with technical support and field assistance. Provided assistance in early Remedial Investigation/ Feasibility Study project start-up.

BURGESS BROTHERS LANDFILL
Woodford, Vermont
Initiated the responsible parties to conduct a hydrogeologic investigation to determine the nature and extent of contamination resulting from former disposal practices. Reviewed and commented on technical reports resulting from the study. Conducted sampling of ground water and surface water for compounds on the hazardous substance list. Performed geologic mapping to determine the orientation of bedrock fractures and possible pathways of preferred ground water flow.

OLD POULTNEY DUMP
Poultney, Vermont
Provided technical support to the town of Poultney to evaluate the environmental conditions of an inactive dump. Assisted in the development of a RFP, aided in the selection of a consultant, reviewed work plans, oversaw the installation of shallow and bedrock monitoring wells, developed and implemented a ground water and residential drinking water sampling program.

WILLIAMSTOWN LANDFILL
Williamstown, Vermont
Hazardous waste site investigation to determine the nature and extent of contamination resulting from the disposal of dry cleaning sludges. Site evaluation included geologic reconnaissance, subsurface exploration, soil gas survey, soil sampling for perchloroethene, design and implementation of long-term ground water monitoring program.

YOUNG LANDFILL
Highgate, Vermont
Performed CERCLA Pre-Remedial Site Inspection Sampling, which included analysis of Hazardous Substance List compounds from ground water, surface water, leachate, soil and sediment. Some investigations involved the installation of ground water monitoring wells.

EXHIBIT B

Associated Earth Sciences, Inc.

DRAFT
TECHNICAL MEMORANDUM

ANALYSIS OF PREFERENTIAL GROUND WATER FLOW PATHS RELATIVE TO PROPOSED THIRD RUNWAY

SEATTLE-TACOMA INTERNATIONAL AIRPORT

PREPARED FOR:
PORT OF SEATTLE

AESI PROJECT NO. BV99122C
JUNE 19, 2001

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DRAFT
TECHNICAL MEMORANDUM
JUNE 19, 2001

ANALYSIS OF PREFERENTIAL GROUND WATER FLOW PATHS RELATIVE TO PROPOSED THIRD RUNWAY

SEATTLE-TACOMA INTERNATIONAL AIRPORT

1.0 INTRODUCTION

The Port of Seattle (Port) presents this technical memorandum in response to a request from the Washington Department of Ecology (Ecology). Ecology has asked the Port to respond to a concern expressed by members of the public and certain State legislators opposed to construction of the proposed Third Runway at Seattle-Tacoma International Airport (STIA). The issue presented is whether known contaminated ground water conditions located below the principal aviation operations and maintenance area (AOMA) of STIA will migrate to the third runway construction area due to the presence of subsurface utilities and/or perched zones acting as pathways of contaminant migration, and/or the natural westward flow of ground water in the upper-most regional aquifer (Qva).

The purpose of this technical memorandum is to report the findings of the Port's evaluation of potential contaminant migration from the AOMA to the third runway area.

The scope of this technical memorandum is to review and evaluate available data to enable a technical conclusion in response to the issues raised about proposed construction of the third runway. The issue is the potential for ground water flow and contaminant migration from the AOMA to the construction area. Of particular interest to the reviewers is the likelihood of migration of perched ground water contamination via preferred flow paths formed by constructed utility trenches and similar subsurface infrastructure.

This scope of inquiry is different from the scope of the STIA Ground Water Study being performed by the Port under a Model Toxics Control Act (MTCA) Agreed Order. The purpose of the MTCA Ground Water Study is to determine whether contamination in the Qva aquifer below the AOMA constitutes a risk to ground water at identified potential local receptors. The scope of that study includes only the Qva aquifer, making the conservative technical assumption that all contaminants released from sources in the AOMA reach the Qva, rather than remaining in soil or in perched ground water zones. The scope of the Ground Water Study also excludes consideration of the third runway. Some of the analysis presented here will inform the Ground Water Study inquiry.

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As presented below, the findings of this evaluation lead to our conclusion that there is no reasonable threat that contaminated ground water will migrate from the AOMA to the Third Runway area, either due to the properties of ground water flow or due to the presence of subsurface utilities or perched zones to act as preferred contaminant transport pathways.

2.0 EXISTING CONDITIONS WITHIN THE AOMA

2.1 GENERAL

As described in the May 1999 Agreed Order, the AOMA is the area of the airport where most aircraft fueling and maintenance operations have historically occurred. Within the AOMA, contaminated ground water exists in several localized, discrete sites as a result of nearly fifty years of airport operations. The boundaries of the contaminated ground water have been defined by site investigation data that were obtained through the placement and sampling of ground water monitoring wells, and data and observations obtained in other subsurface data collection activities. Ground water monitoring continues at active remediation and post-remediation sites (subject to temporary disruption due to construction).

Within the AOMA, areas of contaminated ground water exist in both shallow perched zones and in the Qva. The perched zones are isolated and discontinuous, while the Qva is continuous. Figure 1 is a conceptual diagram illustrating the typical hydrogeologic properties and relationships below the AOMA. Figure 1 significantly simplifies typical conditions, but identifies key features:

- Perched Zone – The perched zone is discontinuous and is present in isolated areas of the AOMA. Perched ground water may appear on local till surfaces (where present) and may also collect in interbeds and lenses within the till. Therefore, multiple discontinuous perching "layers" are frequently identified as discrete water bearing zones within the same area. To the extent there is horizontal perched flow, it is typically localized and flows along the top surface of the till unit, but becomes more vertical at the edge of perching surface; there is no regionally extensive predominant horizontal perched flow direction. Typical low permeability geologic units (glacial till), that result in perched ground water conditions, are located from the near surface to about 40 feet below ground surface (about 10 to 32 feet below ground surface below most AOMA contaminated sites); the unsaturated region between the perching zone and ground water surface in the Qva is approximately 20 to 50 feet thick. Glacial till and perching conditions are not uniformly present below the AOMA. Till is absent in some locations due to natural processes, as well as construction related activities (such as deep excavations for building foundations, excavation for transit tunnels, and site grading activities) which appear to have breached the till unit at several locations at STIA.

- Qva aquifer in the STIA area – The Qva aquifer is the uppermost aquifer of regional extent. It is continuous throughout the AOMA and STIA and is in most areas of STIA classified as an unconfined aquifer. In some locations it is interconnected with the underlying regional aquifer which is identified in the South King County Groundwater Management Plan as the "intermediate" regional aquifer. Typical ground water flow in the Qva aquifer is to the west, varying from northwest to southwest as a result of influence of local discharge zones such as Miller Creek, Des Moines Creek and associated wetlands. Typical depth to the Qva aquifer below the AOMA is about 60-90 feet below ground surface, with the variability primarily due to changes in surface elevation across STIA.

Figure 2 is a site map that presents the major features at STIA. The AOMA is shown in the southeastern portion of STIA and contains the main terminal area and airport concourses. The majority of the impacted ground water resulting from airport operations is located within the AOMA. The third runway construction area is located approximately 2800 feet to the west of the AOMA. Figure 2 also presents the typical Qva ground water contours and flow direction, a west to northwest flow direction in the Qva aquifer. The location of a conceptual cross section through the AOMA, extending to the proposed third runway embankment area, is shown as A-A' (see Figure 6 and Figure 7).

2.2 EXISTING CONDITIONS – PERCHED ZONE

Soil and ground water samples collected during individual site investigations, together with other subsurface observations within the AOMA, indicate that existing perched zone contamination has remained localized near source areas and release points within the AOMA. The sampling data show that the ground-water contaminants have not migrated significantly along constructed utilities or infrastructure, despite the dense array of underground facilities in the AOMA (see Figure 8 for location of utilities relative to existing areas of impacted ground water).

The following paragraphs describe the figures provided with this report. Data and observations for each site at which contaminant concentrations in perched ground water exceed MTCA standards are discussed in the subsequent subsections.

- Figure 3 – Figure 3 is a map that indicates the extent of impacted perched ground water in the area of the AOMA. Ground water monitoring wells completed in perched water bearing zones are plotted based on the most recent ground water quality data in the Ground Water Study database. The ground water quality data are compared to MTCA standards, and wells are distinguished by colors indicating whether sample data contain compounds exceeding MTCA standards. Figure 3 also includes a portion of the conceptual cross section line A-A', which extends to the proposed Third Runway area (see Figure 2 for the entire cross section line; the cross sections are illustrated in Figures 6 and 7. The map also presents data for the following conditions:
    - Monitoring wells with measurable fuel product floating on the perched ground water surface are indicated in green.
    - Monitoring wells that contain concentrations of compounds exceeding the MTCA Method A or B standards are shown in red.
    - Monitoring wells that do not contain concentrations of compounds exceeding the MTCA Method A or B standards are shown in blue.

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- The maximum western boundary of impacted soil is shown as a light blue line. This boundary indicates the area between the AOMA and proposed Third Runway project where soil boring data indicate no MTCA exceedences at depth.

Four sites within the AOMA are shown in yellow shading, indicating the approximate area of fuel impacted perched ground water. These sites include the United/Continental Fuel Farm Area, the PanAm Avgas Tanks, the Northwest Airlines Bulk Fuel Farm and the Delta Autogas Tank site. Two additional areas in the AOMA, the Northwest Airlines Former Hanger Tank site and monitoring well AGC-5 at the Delta Autogas Tank site, shown with gold shading, represent areas that contain solvent impacted perched ground water. The shaded boundaries were established within areas surrounding monitoring wells that have exhibited ground water quality that has exceeded MTCA standards.

Figure 3 also illustrates additional evidence of the limit of the extent of impacted perched ground water in the AOMA. The hatched blue lines shown on Figure 3 at the south end of the AOMA are based on environmental investigations at several potential sites in that area. The unhatched blue lines around the northern and western AOMA are based on environmental soil boring data adjacent to the fuel hydrant pits and along fuel supply lines. The unbroken sections of the blue lines indicates soil conditions that do not exceed MTCA standards. The criteria for establishing this boundary was that the two deepest soil samples collected at a specific location were below MTCA standards. Areas that do not meet this requirement are shown by breaks in the lines and are of a very limited extent. Likewise, areas where no soil data currently exist are between the jagged ends of the blue lines (e.g., between the South Satellite and Concourse B).

- Figure 4 – Figure 4 provides supporting evidence that perched ground water is limited in extent at several locations within the AOMA. The inferred western extent of the perched zone horizons at each of the known release sites appears to be bound by soil conditions that do not indicate wet, saturated or perched ground water conditions. Data points presented on Figure 4 as brown solid circles indicate soil conditions that do not contain evidence for wet soil conditions or perched ground water conditions at the time of drilling. These data were obtained from environmental and geotechnical explorations performed at areas surrounding known perched ground water zones. These data show that the extent of the perched zones are limited in a western direction and that the perched ground water is confined to isolated areas.

  Figure 4 also presents generalized perched ground water elevation contours and associated flow directions. The ground water contours were developed by plotting the average ground water surface elevation that has been measured in monitoring wells completed in the perched zones at the various sites. The contoured data set also includes the elevation of saturated conditions noted on logs of the boreholes and wells completed below the perched aquifer. An average ground water level was used where multiple measurements were available from a well. This reduced variability from seasonal fluctuations and simplified complex perching levels in areas that contain multiple perched zones. Flow direction arrows indicate the general direction of ground water flow and indicate that the perched ground water flow is

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variable and generally in directions that are away from the proposed Third Runway construction area.

- Figure 5 – Figure 5 presents the extent of impacted ground water in the Qva aquifer within the AOMA. See Section 2.3 for a description of this figure.

- Figure 6 – Figure 6 is a conceptual cross section that shows a generalized representation of geologic formations, ground water conditions, typical STIA utility trench depths, monitoring well completion details and general AOMA site features. The cross section is developed from the eastern boundary of the AOMA past the western end of the proposed Third Runway embankment, oriented generally parallel to the Qva ground water flow direction. Isolated perched ground water zones are identified within glacial till horizons within the AOMA and in recessional sandy outwash soils near the proposed Third Runway horizon. The inferred thickness of the glacial till horizon has been determined based on available subsurface soil data compiled throughout STIA. These data indicate an irregular till surface with variable thickness and show several areas along the cross section where the till unit is absent as a result of either natural processes or construction activities.

- Figure 7 – Figure 7 presents an enlargement of the Figure 6 cross-section through the AOMA area. The enlarged cross section is developed through the Northwest Bulk Fuel Farm and the Pan Am Avgas Tanksites, areas where impacted perched ground water has been characterized. The perched ground water observed at the Pan Am Avgas Tank site represents the western-most area within the AOMA that contains impacted perched ground water exceeding MTCA standards. The cross section shows wells completed in the perched horizons at both the Northwest Bulk Fuel Farm and Pan Am Avgas Tank sites and indicates the perched water level elevation as shown by the blue triangle. Utility lines are shown on the cross section, which are positioned at a typical construction depth of 10 feet.

2.2.1 United/Continental Fuel Farms Area

The United/Continental Fuel Farms Area site is located in an area where three discontinuous perching zones between the surface and about 40 feet below ground surface have been mapped (Figure 4). Area utilities are located from the near surface to a depth of about 20 feet below ground surface. Local perched water contours suggest radial flow, although the multiple perching layer stratigraphy also suggests a strong vertical component of flow. In addition, it appears that localized mounding of perched ground water is occurring at this site as a result of infiltration resulting from precipitation collecting in the tank farm backfill and surrounding unpaved areas. This mounding has resulting in a radial direction of perched ground water flow. However based on soil data collected to the west of this area, it appears that the perched water condition is limited to the tank farm area. Boring logs for adjacent site wells on the west suggest no perched water is present. Remediation is ongoing, including planned installation of additional perched wells to the southeast.

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2.2.2 Pan Am Avgas Tanks

The Pan Am Avgas Tanks site is located in an area in which at least two perching zones have been recognized. The local perched zones extend from about 10 feet to about 31 feet below ground surface. Area utilities are located from the near surface to a depth of about 12 feet below ground surface (Figure 4). The perched ground water flow direction at this site is to the northeast. As shown on Figure 4, the area to the west of Pan Am Avgas Tank contains a number of soil borings that did not encounter perched ground water. The unsaturated soil borings delineate the western extent of perched water at this location. The perched ground water appears restricted to lenses within the till unit. In addition, it appears that the perched ground water is generally at a lower elevation than the bottom of typical utility trenches. Remediation continues through current construction; monitoring will be reinitiated following construction.

2.2.3 Northwest Hangar Tanks

The Northwest Hangar Tanks site is located in an area where perched ground water occurs at about 18 feet to about 32 feet below ground surface in the immediate vicinity of the tanks excavation area (Figure 4). Area utilities are located from the near surface to a depth of about 12 feet below ground surface. Frequent observation of unsaturated well conditions just outside the tank excavation area, and the absence of perched water in the boring for the nearest down gradient (west) well indicate the perching zone is localized to the tank area. The inferred direction of perched ground water flow in this area appears to the south towards the Northwest Airlines Hanger building. It appears that perched ground water is at a lower elevation than the depth of utilities, however, the deep foundation structure at the Northwest Airlines Hanger could provide a vertical pathway for perched ground water migration through the glacial till zone. Data from ground water monitoring wells indicated solvent-impacted perched ground water at this site. It appears that solvents in the perched ground water have migrated vertically and caused an impact to the Qva. Remediation continues through current construction; monitoring will be reinitiated following construction.

2.2.4 Northwest Fuel Farm

The former Northwest Fuel Farm is located above a perched zone measured at about 18 feet to 29 feet below ground surface (Figure 4). Area utilities are located from the near surface to a depth of about 20 feet below ground surface. The absence of contamination and the absence of perched water in site wells to the west and northwest suggests that the contamination is bounded in these directions. The absence of a perched zone in borings for an adjacent site to the southwest also implies a perched zone boundary. Dissolved contamination is bound on the west side, as evidenced by the absence of wet soil conditions which define the western extent of the perched zone and a southerly inferred perched ground water flow direction (Figure 4). It also appears that the perched zone water level elevations are predominantly at depths that are below the depth of utilities in the area (Figure 6 and 7). Remediation was completed in 1999, and ground water monitoring will be reinitiated following construction.

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2.2.5 Delta Auto Gas Cluster

The former Delta tank installation was located in an area where multiple perching zones were identified, with zones between about 9 to 22 feet, and about 33 to 45 feet below ground surface (Figure 4). Area utilities are located from the near surface to a depth of about 10 feet below ground surface. Shallow perched ground water was observed to occur within the vicinity of the tank excavation but has not been observed beyond the tank excavation. The perched ground water flow direction appears to be towards the south. Dissolved contamination is bound on the west side by the presence of unsaturated soil conditions, suggesting the perched zones are restricted to the backfill areas of the tank excavations. Planned remediation was completed in conjunction with construction in 2000; additional evaluation of current conditions is pending.

2.3 EXISTING CONDITIONS – QVA AQUIFER

Figure 5 is a map that shows the extent of Qva impacted ground water. Ground water flow direction in the Qva aquifer is to the west/northwest between the AOMA and the proposed Third Runway project (Figure 2). Figure 5 indicates that the impacted ground water areas in the Qva are bounded by data from downgradient monitoring wells that do not exceed MTCA standards. The wells that generate data below MTCA standards are located to the west of the impacted ground water areas, between the contaminant release areas and the western AOMA boundary.

Ground water and soil samples collected from individual site investigations within the AOMA have also indicated that existing Qva aquifer contamination remains localized, despite the presence of several facilities that have been constructed at depth within the AOMA. For example, the maximum measured migration of impacted Qva ground water is about 550 feet in a down gradient direction from a specific source (tanks that were installed around 1949 and removed in 1990). This area is well within the AOMA and suggests that impacted Qva ground water is not migrating beyond the AOMA boundary. Natural attenuation and dispersion conditions are also probably limiting the extent of migration of impacted Qva ground water. Contaminant source control and remediation measures also function to limit the size of the ground water plumes observed in the Qva aquifer.

2.3.1 RAC "Rental Car" Tank Site

The former tank site for a group of rental car businesses appears to have no underlying perched ground water, but has impacted ground water in the Qva (Figure 5). The impacted area is bound in the downgradient (west and northwest) direction, as evidenced by data from a series of perimeter wells reporting contaminant concentrations below MTCA standards. Ground water monitoring continues.

2.3.2 Budget Rent-a-Car Pipe Leak Site

This site was impacted by a break in a fuel line, and has been undergoing remediation, which continues. The site appears to have no underlying perched ground water, but has impacted ground water in the Qva (Figure 5). The impacted area is bound in the downgradient (west)

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direction, as evidenced by data from a downgradient well reporting contaminant concentrations below MTCA standards.

2.3.3 Pan Am Avgas Tank Site

Perched zone contamination at the Pan Am Avgas Tank site was discussed above in Section 2.2.2. The Qva-impacted area is bound in the downgradient (west) direction, as evidenced by data from a series of downgradient wells reporting contaminant concentrations below MTCA standards (Figure 5).

2.3.4 Northwest "Closed" Fuel Hydrant System

Fueling operations at the Northwest "Closed" hydrant system were discontinued in about 1996. This facility caused Qva impacts in three locations (shown on Figure 5), a fuel release at the South Satellite Baggage Tunnel Site, and indications of ground water impact near two fuel hydrant pits.

The South Satellite Baggage Tunnel Site was impacted by a leak from the hydrant line. No perched ground water was observed in the impacted area, but contamination was observed in the Qva. The impacted area is bound in the downgradient (west) direction, as evidenced by data from a series of downgradient wells reporting contaminant concentrations below MTCA standards. Ground water monitoring continues.

Fuel system closure characterization activity for this facility indicated two locations where ground water in the Qva may have been impacted. In both locations data from wells associated with other sites indicate contaminant concentrations downgradient (west) from these borings are below MTCA standards, although the southernmost of the hydrant borings is not directly upgradient of the wells providing the observation data.

2.3.5 Northwest "Abandoned" Fuel Hydrant System

Fueling operations at this facility were discontinued in about 1976. Fuel system closure characterization activity for the Northwest "Abandoned" hydrant system indicated a location where ground water in the Qva may have been impacted (Figure 5). The impacted area is bound in the downgradient (west) direction, as evidenced by data from a downgradient well reporting contaminant concentrations below MTCA standards.

3.0 GROUND WATER FLOW – THIRD RUNWAY EMBANKMENT

3.1 EMBANKMENT AREA GROUND WATER FLOW CONDITIONS – PRE- AND POST-CONSTRUCTION.

Ecology has developed ground water flow information relevant to third runway embankment construction. This information was presented in the SeaTac Runway Fill Hydrologic Studies (Pacific Ground Water Group (PGG) June 19, 2000). For one part of that study, PGG compared predicted changes in ground water flow and recharge due to the construction of the third runway embankment by modeling pre-construction and post-construction conditions. In comparison, the scope of the MTCA Agreed Order Ground Water Study is limited to modeling of flow and contaminant fate and transport within and below the Qva aquifer. The MTCA model was designed specifically to model pre-third runway conditions.

The PGG ground water findings concerning ground water flow predict runway construction will not significantly impact the flow direction or flow volume of the Qva aquifer or any aquifer below it. The findings and conclusions of the Ecology's PGG study include the following:

- The third runway embankment will have no significant impact on aquifers below the Qva.
- The third runway embankment will have no significant impact on Qva flow direction.
- In the pre-construction condition, the Qva contribution to base flow is small.
- Post-construction, the volume of water from all sources (including Qva and shallower ground water zones, precipitation, and other sources) discharging to baseflow could decrease slightly. However, the volume of seepage water through the till to the Qva will be about the same as in the pre-construction condition.

3.2 CONSTRUCTION OF THE THIRD RUNWAY AND PREFERENTIAL FLOWPATHS: PERCHED GROUND WATER

The perched ground water conditions observed in the AOMA appear to be present in areas of tank backfill and isolated and discontinuous zones within the glacial till. Flow of perched ground water in the AOMA appears to be generally east and southeast, with a strong downward vertical component.

Perched ground water at the Third Runway area appears to be mainly associated with recessional outwash deposits and or alluvial deposits overlying the till. Alluvial deposits were generally not deposited in the uplands of the STIA operational area, and recessional outwash deposits were removed from much of the central STIA operational area during past site grading. Figure 6 presents a conceptual cross-section through the AOMA and Third Runway area. The absence of recessional outwash and thick fill deposits in the central and western AOMA, and the discontinuous nature of the till surface suggest that natural recessional outwash pathways are not laterally extensive and are unlikely to accommodate extended horizontal migration of perched ground water from the AOMA to the Third Runway area.

The environmental data indicate utility backfill corridors are not preferred pathways of migration. The ground water and soil data show very limited contaminant migration despite the existing array of STIA subsurface utilities and infrastructure as shown in Figure 8, and despite the long term of contamination presence in the subsurface. There is no evidence of extended migration of perched zone contamination along existing utility backfill corridors. Construction of the third runway embankment includes completion of only one utility, a new section of a communications ductbank, which establishes a direct connection from the AOMA to the embankment. The trench excavated for the ductbank is about 4-1/2 feet deep and backfill for the new section will consist of concrete and controlled density fill. This combination of backfill material results in very low trench permeability, and would restrict or prevent the movement of water within the backfill between the Third Runway construction area and the AOMA.

Note also that any utilities that would cross directly from the airfield to the Third Runway construction area would cross locations where the till unit is absent. In areas absent of till, there is no evidence of perching zones, and vertical flow predominates. Lateral contaminant migration is expected to be very limited.

The bottom of the ductbank is approximately 70 to 75 feet above the Qva water table. Infiltration by precipitation and stormwater runoff is virtually immeasurable because of the impermeable cover over the ductbank and the routing of stormwater runoff away from it to the airport's Industrial Waste System (IWS). The ductbank is covered with about 18-inches of concrete.

3.3 CONSTRUCTION OF THE THIRD RUNWAY AND PREFERENTIAL FLOWPATHS: QVA GROUND WATER

The Qva aquifer is present as a continuous aquifer throughout STIA, including areas of the proposed Third Runway construction area. The Qva aquifer is located at a depth that is, in most instances, below the proposed embankment construction area; and therefore construction activities associated with the proposed runway will not significantly impact the Qva. As noted above, the Ecology study conducted by PGG concluded that the proposed runway construction would not affect the current ground water flow direction or significantly affect the amount of recharge to the Qva aquifer system. There is no indication that ground water in the Qva that has been impacted as a result of historic STIA operations has migrated beyond the western boundary of the AOMA.

As described above, the single newly constructed utility that is proposed as part of the Third Runway is not a preferred pathway for contaminant to migration toward the runway embankment. In addition, it will be constructed well above the depth of ground water in the Qva. Likewise, no deep infrastructure is proposed for the third runway that would establish a direct connection from the AOMA to the embankment. Therefore, the construction should not create a preferred pathway for the existing Qva contamination in the AOMA to migrate to the third runway area.

4.0 CONCLUSIONS

Based on our analysis of the available geologic, environmental, and historical data, it appears unlikely that contaminated ground water is migrating from or would migrate from the AOMA to the proposed Third Runway area either as a result of natural ground water gradients or from preferential flow through existing or proposed STIA utilities. The following conclusions regarding preferential ground water pathways have been developed:

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4.1 PERCHED GROUND WATER

- Ground water flow directions in the perched water bearing horizons within the AOMA are variable and with a predominant direction away from the proposed Third Runway.
- Impacted ground water in the perched zones appears to be contained laterally to areas adjacent to the source releases.
- Perched ground water will tend to move as vertical flow especially in areas where the till is discontinuous or in areas where construction activities have breached the till.
- The depth to perched ground water generally exceeds the typical depth of STIA utilities. Therefore much of the impacted perched ground water is vertically isolated from utility backfill areas.
- Any perched ground water moving along utilities that cross areas where the till horizon is absent will drain vertically towards the Qva aquifer.
- There is no indication of contaminated ground water outside the western extent of the AOMA.
- Existing contaminated perched ground water has not migrated far from source areas, and there is no evidence to suggest contaminant migration beyond the western boundary of the AOMA will occur.

4.2 QVA GROUND WATER

- Ground water flow in the Qva aquifer is in a west to northwest direction between the AOMA and the proposed Third Runway construction area.
- Impacted ground water is contained within the AOMA with the maximum migration of impacted water no greater than 550 feet in length from its contaminant source.
- Data from ground water monitoring wells completed in a downgradient direction from known Qva impacted ground water sites are below MTCA standards and provide a defined plume boundary.
- Ground water in the Qva aquifer is at a depth of between 60 to 90 feet below ground surface, well below the depth of typical utilities, and no deep infrastructure is planned to be constructed for the third runway that would establish a direct connection from the AOMA to the embankment.

W:\STIA 3rd Runway Project Support BV99122\BV99122C Pref Flow Path Draft.doc

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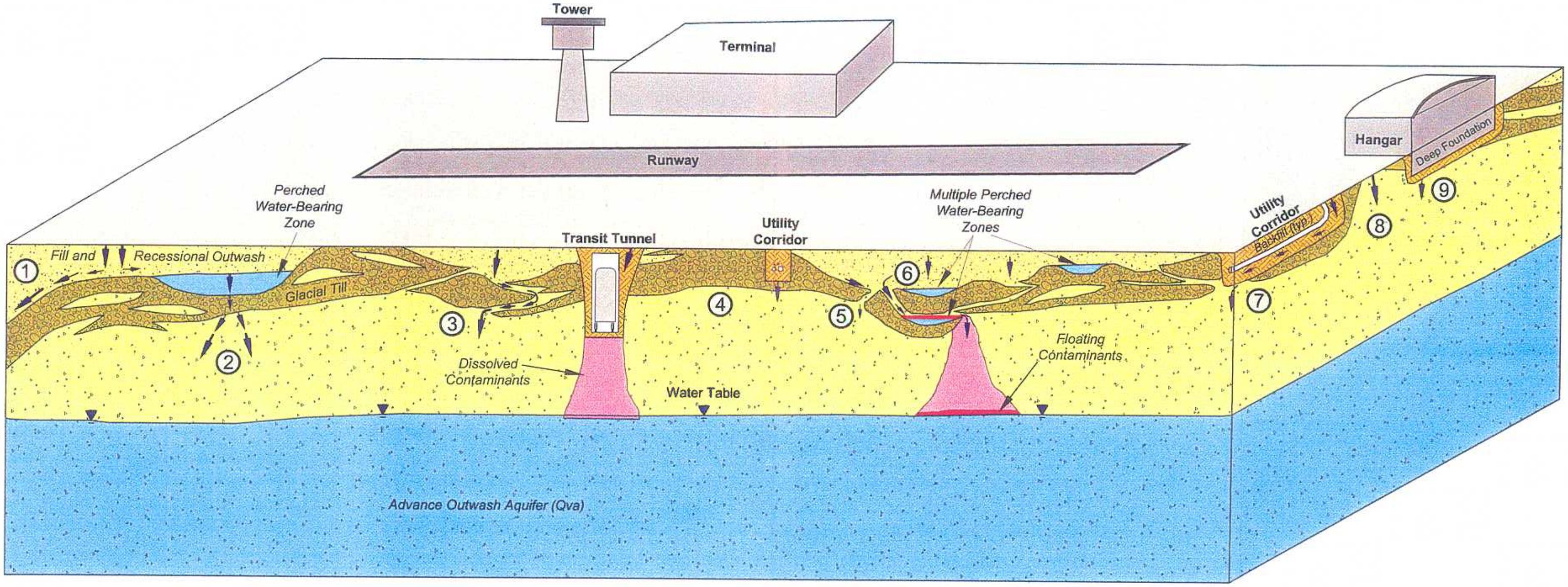
Conceptual Model of Potential Perched Ground Water Flow Paths

Seattle-Tacoma International Airport

Figure 1



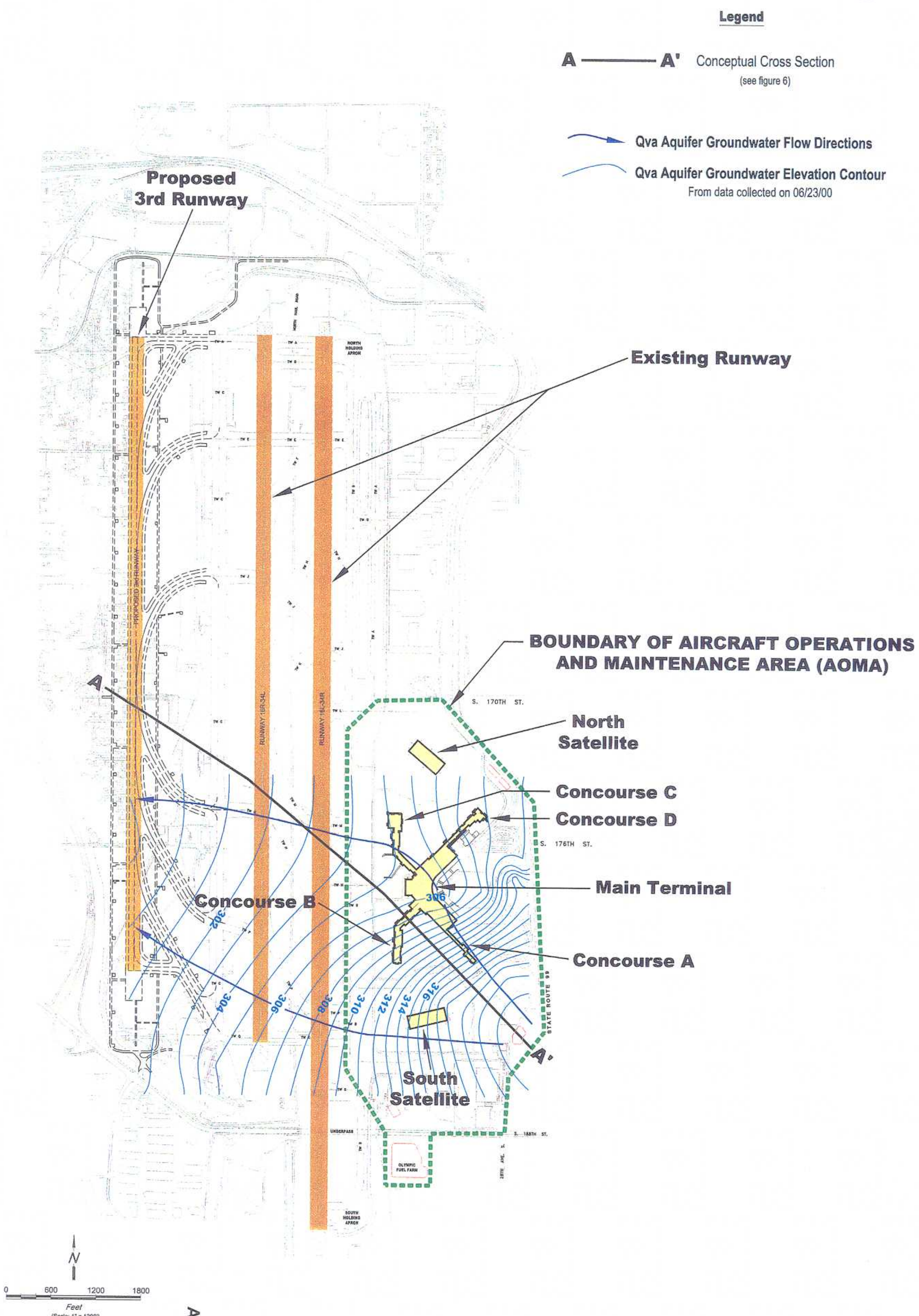
POSSIBLE PERCHED GROUND WATER FLOW PATHS ON AND THROUGH GLACIAL TILL

1. Lateral migration on till surface - slow where slope is gentle, faster where slope is steep
2. Slow seepage through till where perched
3. Flow where till is discontinuous or through sand and gravel lenses
4. Vertical flow through backfill for transit tunnels or utility corridors
5. Vertical flow where till was not deposited
6. Flow between multiple perched zones
7. Lateral flow along utility corridors
8. Vertical flow where till has been removed by grading
9. Flow where till has been penetrated by deep foundations

Potential Flow Path

- Relatively slow
- Relatively fast
- Floating Contaminants
- Dissolved Contaminants

BV99122-CTN.dwg



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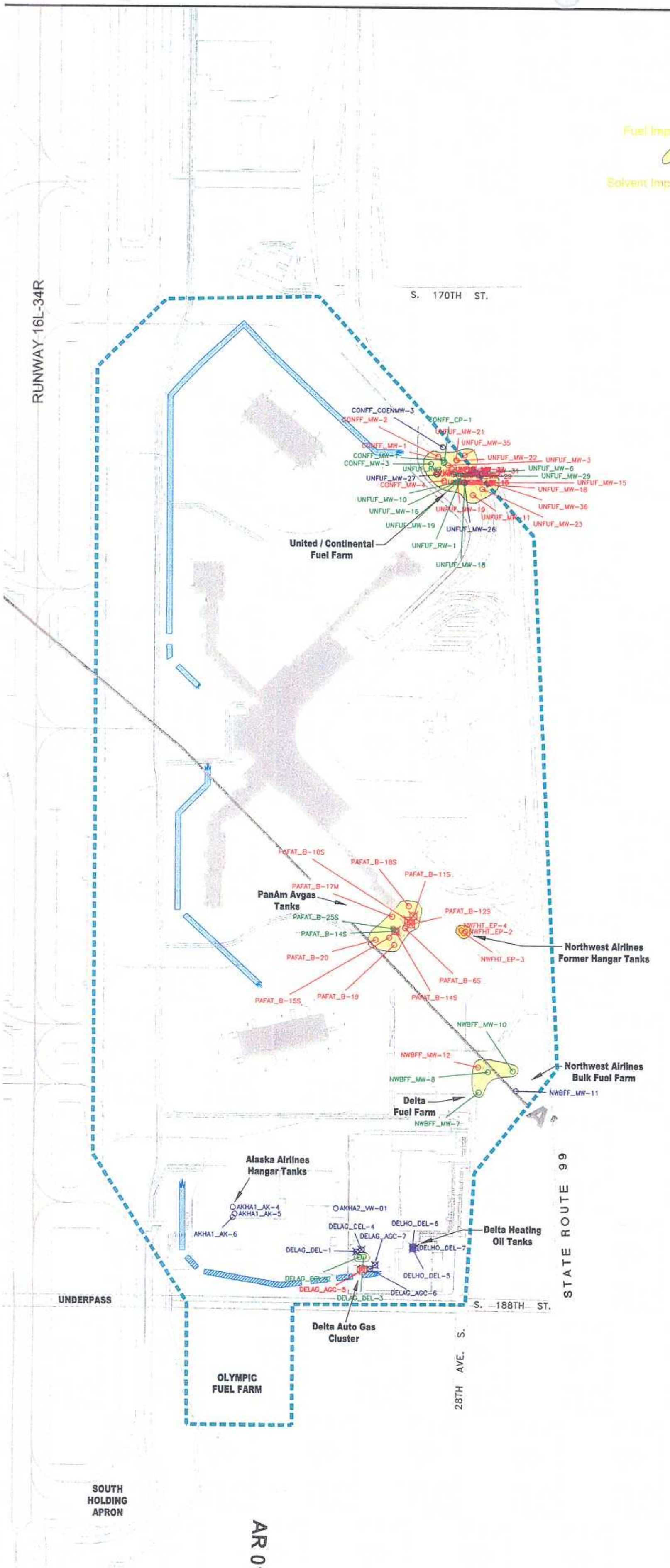
Seattle Tacoma International Airport

Site Reference Map

DATE:	06/14/01
FILENAME:	BV99122-RE.dwg
FIGURE NO.	2



Legend

A ——— A' Conceptual Cross Section (see figure 6)

Fuel Impacted / Solvent Impacted — **Extent of MTCA Method A or Method B Cleanup Level exceedance in perched water bearing zone.** *Perched zones are discontinuous, and appear at various depths from 0 to approximately 40 feet below ground surface.*

Monitoring Wells with Measured Fuel Product At the most recent monitoring event

Monitoring Wells Exceeding MTCA Standards At the most recent monitoring event

Monitoring Wells Not Exceeding MTCA Standards At the most recent monitoring event

Abandoned Monitoring Wells Exceeding MTCA Standards At the most recent monitoring event

Abandoned Monitoring Wells Not Exceeding MTCA Standards At the most recent monitoring event

AOMA Boundary

Maximum Boundary of Impacted Soil
Note: Location of downgradiant AOMA perimeter where soil boring data indicates No MTCA Exceedance at Depth. Boundaries based on environmental investigations of fuel hydrant system lines and fuel pits.

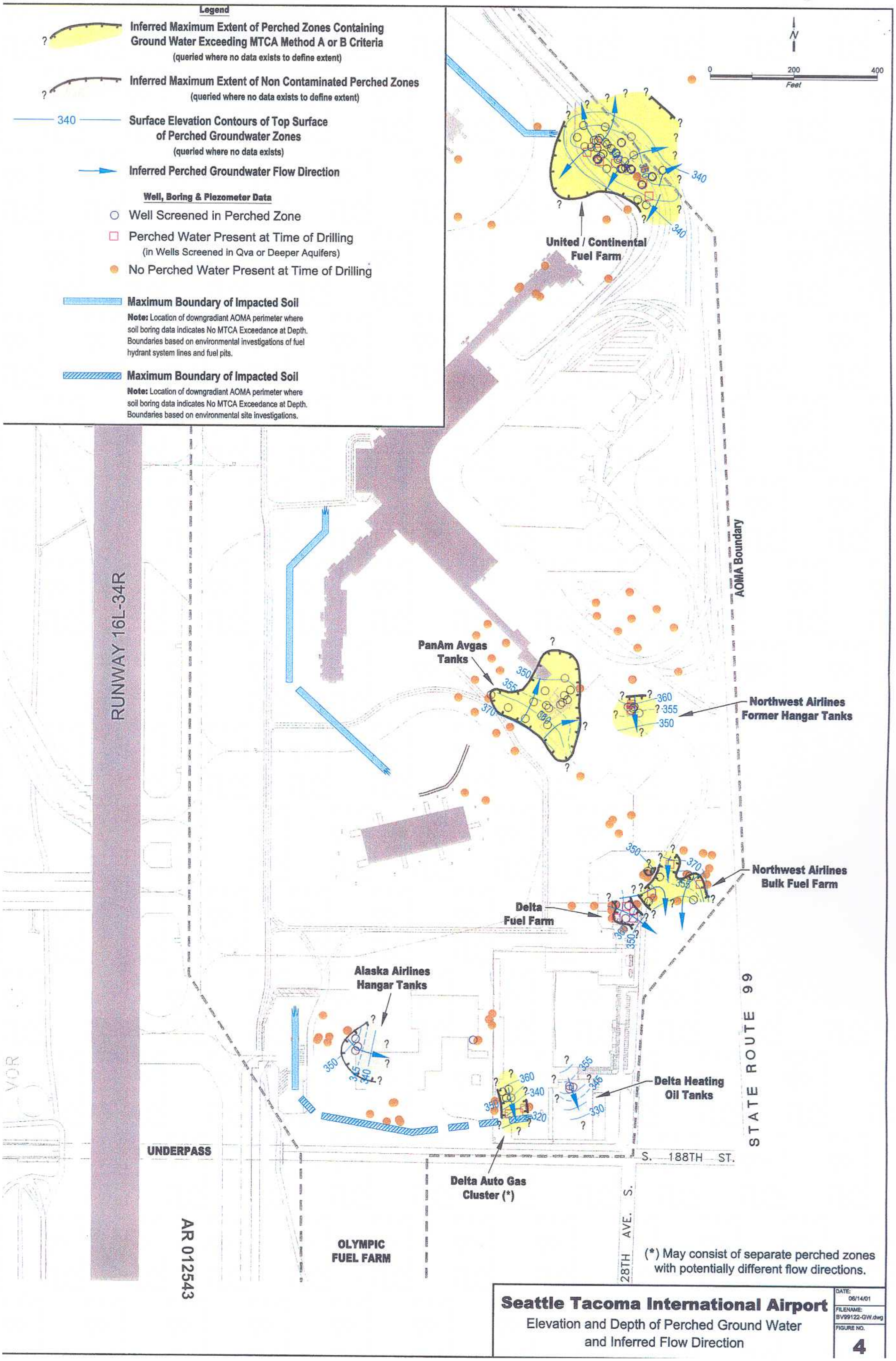
Maximum Boundary of Impacted Soil
Note: Location of downgradiant AOMA perimeter where soil boring data indicates No MTCA Exceedance at Depth. Boundaries based on environmental site investigations.

N

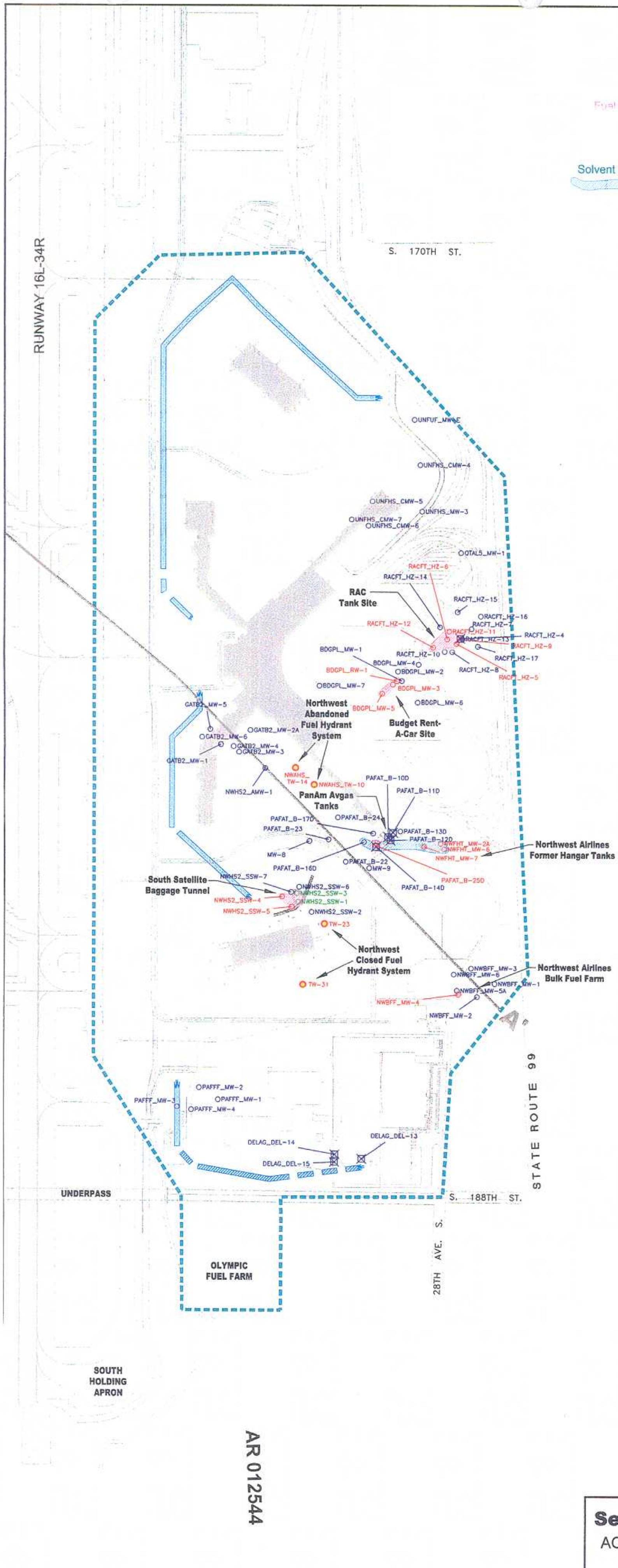
0 300 600 900
Feet (Scale: 1" = 600')

Seattle Tacoma International Airport
AOMA Wells in Perched Water Bearing Unit W/ MTCA Ground Water Standard Exceedances

DATE:	06/21/01
FILENAME:	SV99122-Perched.dwg
FIGURE NO.	3



Legend
Inferred Maximum Extent of Perched Zones Containing Ground Water Exceeding MTCA Method A or B Criteria
(queried where no data exists to define extent)
Inferred Maximum Extent of Non Contaminated Perched Zones
(queried where no data exists to define extent)
340
Surface Elevation Contours of Top Surface of Perched Groundwater Zones
(queried where no data exists)
Inferred Perched Groundwater Flow Direction
Well, Boring & Piezometer Data
Well Screened in Perched Zone
Perched Water Present at Time of Drilling
(in Wells Screened in Qva or Deeper Aquifers)
No Perched Water Present at Time of Drilling
Maximum Boundary of Impacted Soil
Note: Location of downgradiant AOMA perimeter where soil boring data indicates No MTCA Exceedance at Depth. Boundaries based on environmental investigations of fuel hydrant system lines and fuel pits.
Maximum Boundary of Impacted Soil
Note: Location of downgradiant AOMA perimeter where soil boring data indicates No MTCA Exceedance at Depth. Boundaries based on environmental site investigations.
N
0
200
400
Feet
United / Continental Fuel Farm
RUNWAY 16L-34R
AOMA Boundary
PanAm Avgas Tanks
Northwest Airlines Former Hangar Tanks
Northwest Airlines Bulk Fuel Farm
Delta Fuel Farm
Alaska Airlines Hangar Tanks
Delta Heating Oil Tanks
Delta Auto Gas Cluster (*)
STATE ROUTE 99
UNDERPASS
S. 188TH ST.
28TH AVE. S.
OLYMPIC FUEL FARM
VOR
(*) May consist of separate perched zones with potentially different flow directions.
Seattle Tacoma International Airport
Elevation and Depth of Perched Ground Water and Inferred Flow Direction
DATE: 06/14/01
FILENAME: BV99122-GW.dwg
FIGURE NO. 4



Legend

A ——— A' Conceptual Cross Section (see figure 6)

Fuel Impacted — **Extent of MTCA Method A or Method B Cleanup Level exceedance in Qva aquifer.**

Solvent Impacted — *Approximate depth 60 to 100 feet below ground surface.*

- **Monitoring Wells with Measured Fuel Product** — At the most recent monitoring event
- **Monitoring Wells Exceeding MTCA Standards** — At the most recent monitoring event
- **Monitoring Wells Not Exceeding MTCA Standards** — At the most recent monitoring event
- **Abandoned Monitoring Wells Exceeding MTCA Standards** — At the most recent monitoring event
- **Abandoned Monitoring Wells Not Exceeding MTCA Standards** — At the most recent monitoring event
- **Temporary Well with One Time Ground Water Sample Exceeding MTCA Standards**

AOMA Boundary

Maximum Boundary of Impacted Soil
Note: Location of downgradiant AOMA perimeter where soil boring data indicates No MTCA Exceedance at Depth. Boundaries based on environmental investigations of fuel hydrant system lines and fuel pits.

Maximum Boundary of Impacted Soil
Note: Location of downgradiant AOMA perimeter where soil boring data indicates No MTCA Exceedance at Depth. Boundaries based on environmental site investigations.

N

0 300 600 900
Feet
(Scale: 1" = 600')

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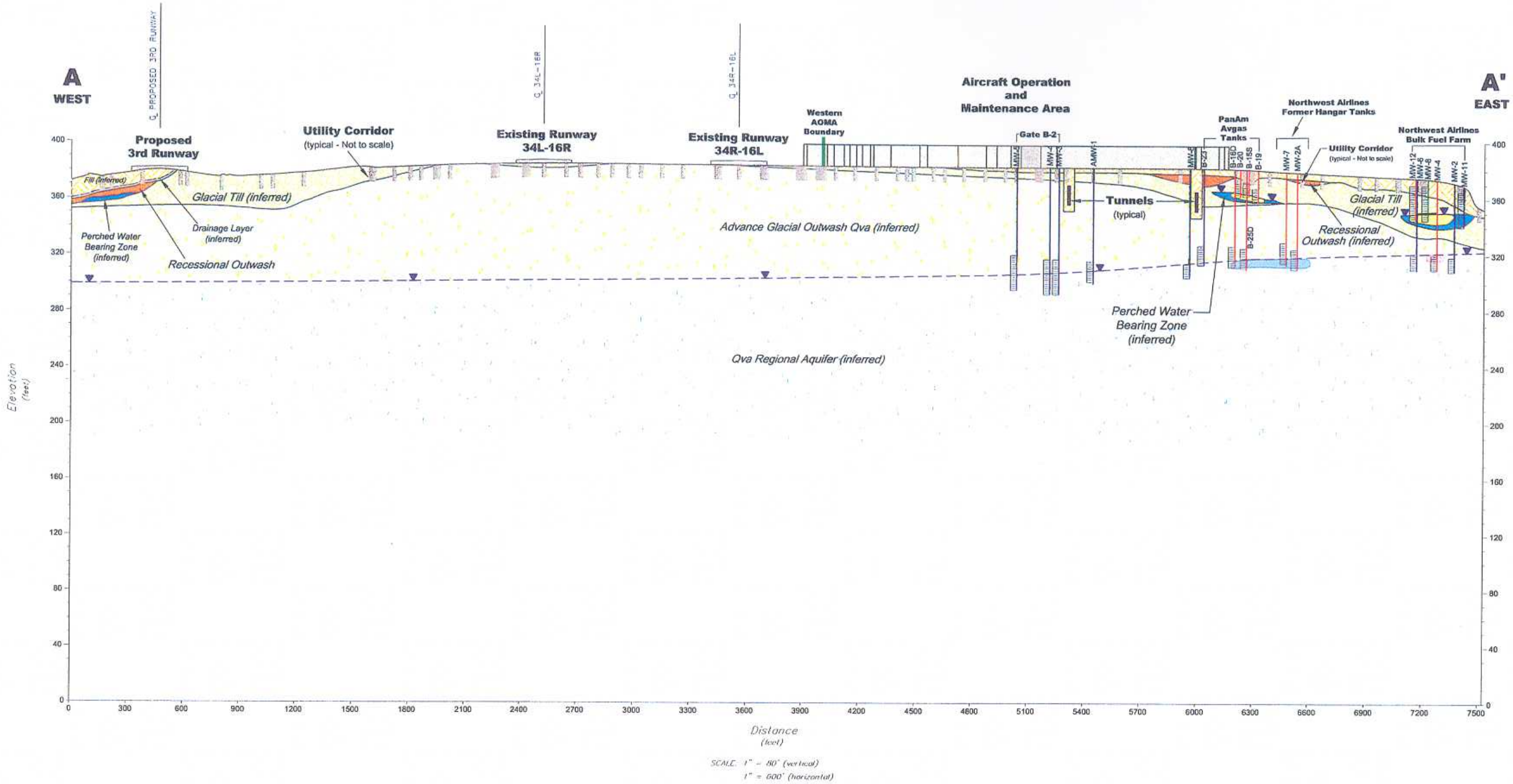
Seattle Tacoma International Airport AOMA Wells in Qva Aquifer W/ MTCA Ground Water Standard Exceedances	DATE: 06/21/01 FILENAME: BV99122-QVA.dw FIGURE NO. **5**



Legend

Extent of MTCA Method A or Method B Cleanup Level exceedance in perched water bearing zone.
Perched zones are discontinuous, and appear at various depths from 0 to approximately 40 feet below ground surface.

Fuel Impacted / Solvent Impacted — Extent of MTCA Method A or Method B Cleanup Level exceedance in Qva aquifer.
Approximate depth 60 to 100 feet below ground surface.

Ground Water Surface

Monitoring Well with Measured Fuel Product

Monitoring Well Exceeding MTCA Standards

Monitoring Well Not Exceeding MTCA Standards

Well Screen

Note: *Typical depth of 3rd Runway utilities, including water, sewer, IWS lines, electrical and communications ductbanks, etc. are 5 - 10 feet below ground surface, with a maximum depth of 15 feet . Proposed stormwater detention vaults and outlet piping may be located as deep as 40 - 45 feet below ground surface.*

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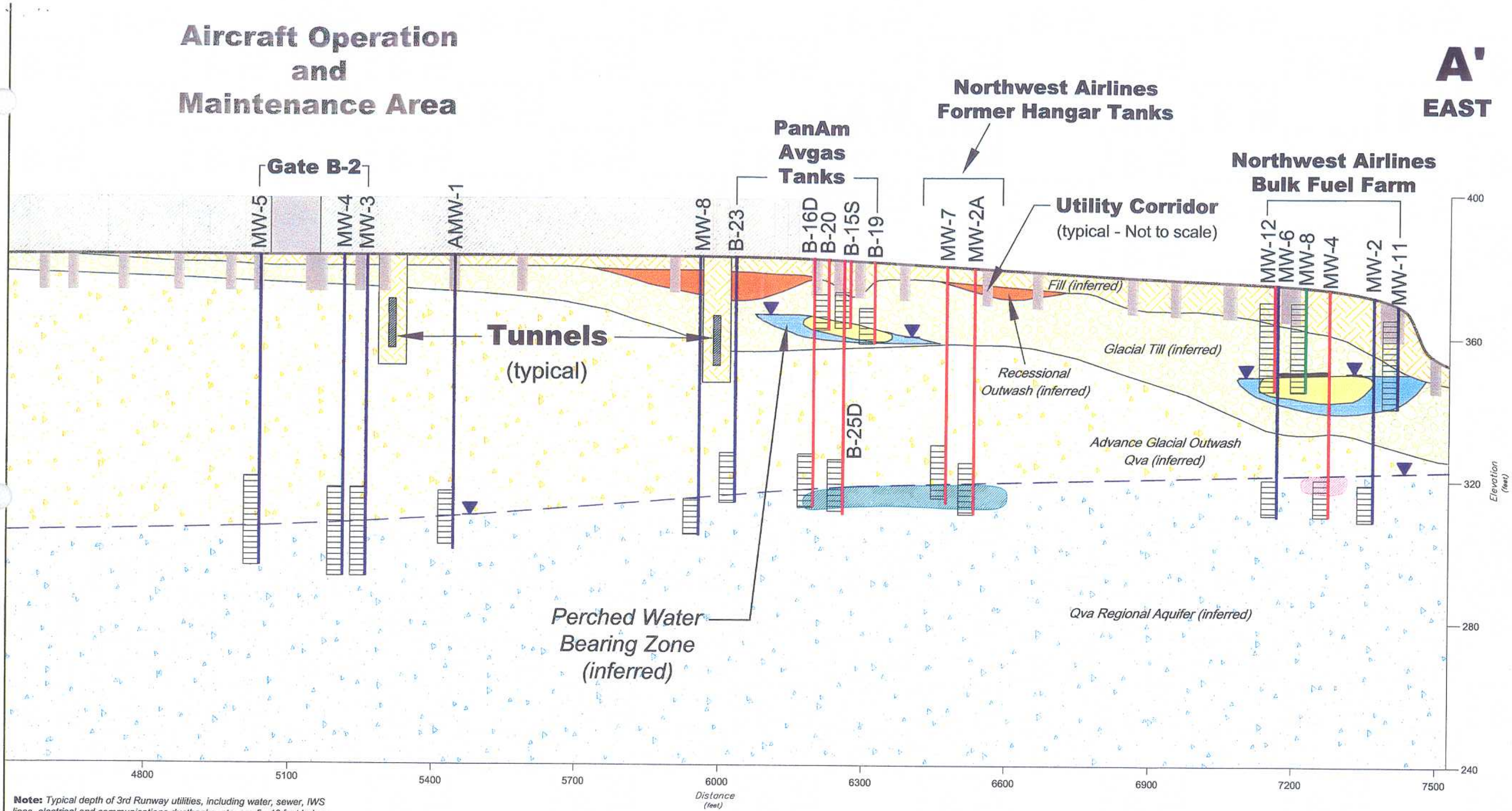
The yellow, aqua and lavender shaded areas represent locations where ground water quality has exceeded MTCA Method A or Method B Cleanup Levels in perched water bearing zones and in the Qva aquifer. These areas are illustrated using the most recent chemical analysis data and may not represent present day conditions. The shaded areas are not compound specific, but were drawn based on an exceedance value for any one of the suite of constituents analyzed.

Seattle Tacoma International Airport
Conceptual Cross Section A-A', Showing Underground Utilities and MTCA Ground Water Exceedances

DATE:	06/21/01
FILENAME:	BV99122-SE1.dwg
FIGURE NO.	6



Note: *Typical depth of 3rd Runway utilities, including water, sewer, IWS lines, electrical and communications ductbanks, etc. are 5 - 10 feet below ground surface, with a maximum depth of 15 feet. Proposed stormwater detention vaults and outlet piping may be located as deep as 40 - 45 feet below ground surface.*

The yellow, aqua and lavender shaded areas represent locations where ground water quality has exceeded MTCA Method A or Method B Cleanup Levels in perched water bearing zones and in the Qva aquifer. These areas are illustrated using the most recent chemical analysis data and may not represent present day conditions. The shaded areas are not compound specific, but were drawn based on an exceedance value for any one of the suite of constituents analyzed.

Legend

- **Extent of MTCA Method A or Method B Cleanup Level exceedance in perched water bearing zone.** *Perched zones are discontinuous, and appear at various depths from 0 to approximately 40 feet below ground surface.*
- Fuel Impacted / Solvent Impacted: **Extent of MTCA Method A or Method B Cleanup Level exceedance in Qva aquifer.** *Approximate depth 60 to 100 feet below ground surface.*
- **Ground Water Surface**
- **Monitoring Well with Measured Fuel Product**
- **Monitoring Well Exceeding MTCA Standards**
- **Monitoring Well Not Exceeding MTCA Standards**
- **Well Screen**

AR 012546

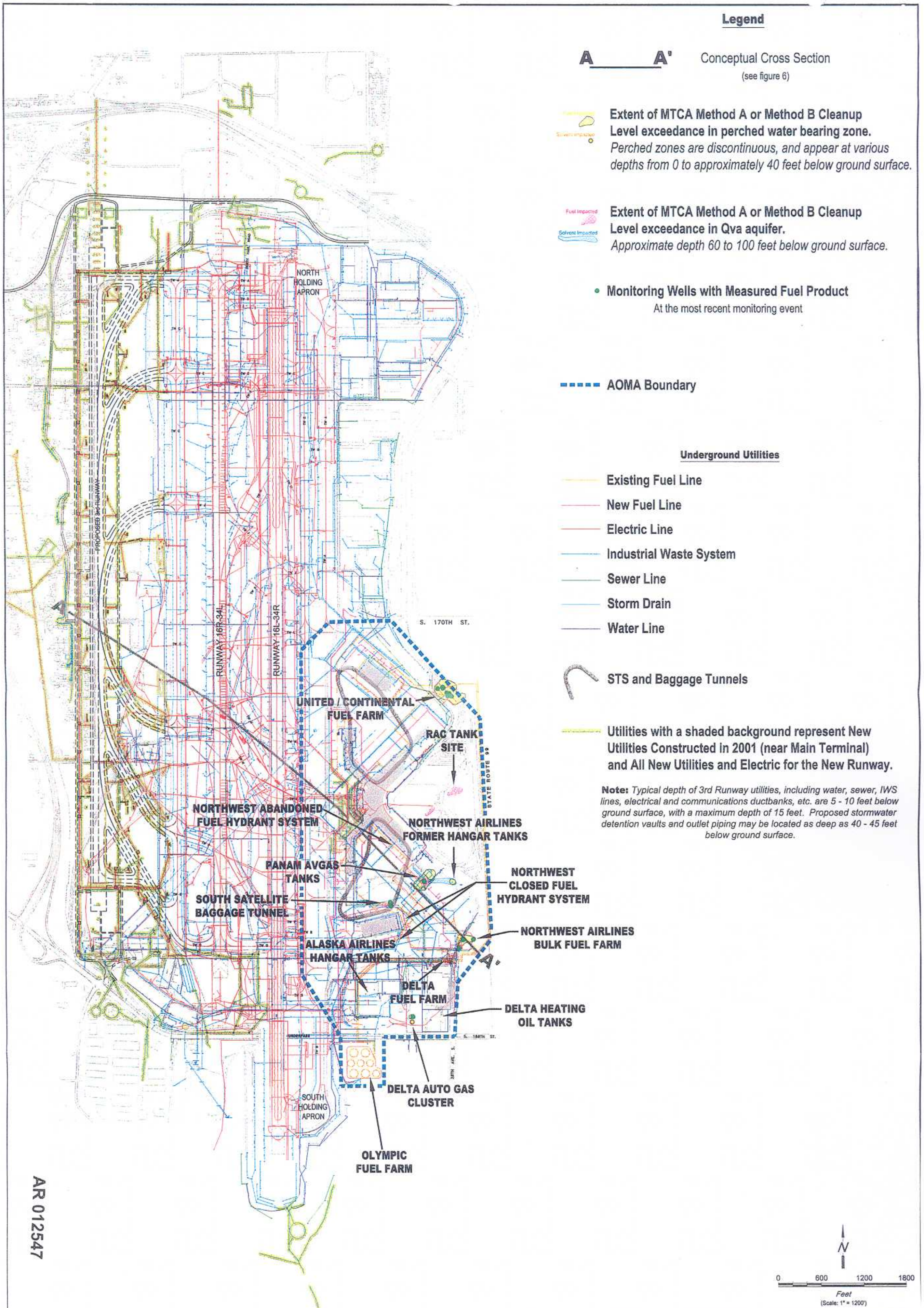
Seattle Tacoma International Airport

Expanded View of Conceptual Cross Section A-A', Showing Monitoring Well Detail

DATE: 09/20/01

FILENAME: BV99122-SE2.dwg

FIGURE NO. 7



The yellow and lavender shaded areas represent locations where ground water quality has exceeded MTCA Method A or Method B Cleanup Levels in perched water bearing zones and in the Qva aquifer. These areas are illustrated using the most recent chemical analysis data entered in the Port of Seattle Environmental Management Information System database, and may not represent present day conditions. The shaded areas are not compound specific, but were drawn based on an exceedance value for any one of the suite of constituents analyzed.

Seattle Tacoma International Airport

Underground Utilities, with MTCA Ground Water Standard Exceedances

DATE: 06/20/01

FILENAME: BV99122-MTCA.dwg

FIGURE NO. 8