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RE: Review of Wetlands Mitigation Plan for Construction of SeaTac Third Runway

Dear Mr. Luster, Mr. Stockdale, Ms. Terzi, Mr. Freedman, Ms. Breenan-Dubbs, Ms. Kirkpatrick, Mr. Landino and Ms. Daneker,

At the request of the Airport Communities Coalition (ACC) I have reviewed the wetland mitigation plan proposed by the Port of Seattle to compensate for impacts to wetlands resulting from the construction of the third runway at Seattle Tacoma International Airport. As you may know, I am an environmental scientist and a professional wetland scientist (SWS certification number 001067). A package describing my background and experience is attached to this report. This letter presents my comments and in particular explains my

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conclusion that the proposed mitigation is wholly inadequate to compensate for the expected losses in wetland functions stemming from the construction of the third SeaTac runway.

The following conclusions are detailed in this report:

- The mitigation proposed is not sufficient to reduce the total adverse impacts of the project to an acceptable level within the Walker Creek, Des Moines Creek and Miller Creek watersheds.
- The functions provided by the proposed out of basin mitigation are not comparable to the losses that are expected to occur and do not compensate for the appropriate losses in wetland functions occurring within the Water Resource Inventory Area (WRIA).
- The proposed mitigation at the Auburn site is subject to multiple risks and is unlikely to be sustainable.

The following documents were reviewed in preparation for this report:

- Assessment of Spawning and Habitat in three Puget Sound Streams, Washington (BioAnalysts, Inc., April 1999);
- Wetland Functional Assessment and Impact Analysis Draft, Parametrix, Inc., July 1999;
- Wetland Functional Assessment and Impact Analysis, Revised Draft, Parametrix, Inc., August 1999;
- Wetland Delineation Report, Revised Draft, Parametrix, Inc., August 1999;
- Wetlands Re-Evaluation Document, Draft, Port of Seattle, August 1999;
- Natural Resources Mitigation Plan, Draft, Parametrix, Inc., July 1999;
- Natural Resources Mitigation Plan, Revised Draft, Parametrix, Inc., August 1999;
- Appendices A-E Design Drawings Natural Resource Mitigation Plan, Seattle-Tacoma International Airport, Parametrix, Inc. No Date.
- Implementation Addendum, Natural Resource Mitigation Plan, Master Plan Update Improvements, Seattle-Tacoma International Airport, Parametrix Inc., June 2000.
- Supplemental Airport Site Wetland and Stream Analysis Parametrix, Inc., November 1999.
- Addendum to the Final Supplemental Environmental Impact Statement, Auburn Wetland Mitigation Project, Port of Seattle, May 5, 2000
- Biological Assessment, Revised Draft, Parametrix, November 1999;
- Biological Assessment, Master Plan Update Improvements, Seattle-Tacoma International Airport, Parametrix Inc., June 2000.
- SeaTac Runway Fill Hydrologic Studies Report, Pacific Groundwater Group, June 19, 2000.

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Mitigation Strategy: Dead is Dead

Overall, the mitigation strategy mirrors a controversial environmental philosophy proffered by Dr. Brian Marr from the University of Washington Department of Environmental Engineering and Science, called "Dead is Dead"[1]. This philosophy states that since certain natural resources have been degraded by human activities over time (in this case by urbanization and the construction of the existing airport), it makes sense to sacrifice those degraded systems to create other sites that are (theoretically) better protected. This philosophy seems to underlie comments made to me by different Department of Ecology staff, who have on separate occasions, stated that the wetlands and creek stretches that will be filled and impacted within the Miller and Des Moines Creek watersheds are highly degraded, and therefore do not constitute a significant loss. This argument can be persuasive, however it is in conflict with the reviewing agencies duty under the law. For example, Ecology's regulatory responsibility under Chapter 173-201A-070 WAC, requires that "existing beneficial uses shall be maintained and protected and no further degradation which would interfere with or become injurious to existing beneficial uses shall be allowed." Permitting further degradation in one watershed in exchange for mitigation in another watershed cannot be scientifically supported as protecting beneficial uses within the watershed nor within the WRIA.

This antidegradation policy is what underlies the basis of Ecology's process for wetland mitigation sequencing and for assessing the adequacy of a compensatory wetland mitigation location and design. (This policy has equally stringent parallels in the other federal agencies involved here.) Ecology may not permit any alteration of a wetland that impairs the functions of the wetland as they relate to any of the defined beneficial uses unless functionally equivalent mitigation is provided. Ecology is allowed to permit filling and alterations of wetlands and riparian areas, only if the net result of the action does not result in long-term harm to the environment.

Discussion of Planning Area Issues: Relationship of WRIA to Watershed Functions

Best professional wetland science stipulates that wetland mitigation occur within the affected drainage basin to adequately compensate for losses. This core mitigation principal is reflected in Ecology's Publication 97-112 (Revised April 1998) *How Ecology Regulates Wetlands*, which says that "it is difficult to replace hydrologic and fish habitat functions in a different drainage basin and *impossible* to replace them in a different watershed" (italics added).

The proposed areas for wetland impacts and the proposed mitigation site for wetland losses are located in the same water resource inventory area (WRIA). WRIA9 covers the entire Green and Duwamish River Basin and also includes eight coastal watersheds that are tributary to Puget Sound. The Green and Duwamish River Basin is a large inland river system, characterized by open landscapes, with large floodplains, forested and scrub-shrub wetlands and a wide historically meandering channel. Although in the same WRIA, the coastal watersheds are a significant contrast to the Green Duwamish River system, having

[1] Mar, B. W., Dead is Dead, Urban Ecology Vol. 5, pp, 103-112, 1980/1981.

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very different hydrogeologic structures, habitat and food and nutrient webs. These watersheds are characterized by complexes of headwater wetlands and hillslope seeps which form tributaries to larger streams that ultimately discharge to Puget Sound, providing sources of nutrients and freshwater to coastal estuarine habitats. Upland wetlands are important sources of nutrients and hydrology to lower stream reaches. Wetlands in these coastal watersheds tend to be forested or scrub-shrub hillslope wetlands and depressional flow-through wetlands in flatter areas and are typically associated with springs, creeks or streams.

The proposed wetland creation mitigation site within WRIA9 is located adjacent to the Green River. The ecosystem function of this proposed wetland creation is entirely different from the coastal wetland and riparian systems that are being impacted. The proposed mitigation is to create black cottonwood and willow, Oregon ash and Western red cedar plant associations typical of a floodplain wetland.[2] This is incorrectly equated with providing mitigation for habitat losses that are of an entirely different vegetative and hydrologic character. Even if the Auburn mitigation project were to be sustainable (an outcome that is not at all certain), it will not replace the hydrologic functions being eliminated within WRIA9. Neither will it function on behalf of the community of species that are being permanently impacted in WRIA9, wetland and riparian coastal communities. It cannot be emphasized enough that wetland losses will occur in three coastal freshwater salmonid supporting streams, a public resource that is becoming increasingly rare both within and outside of WRIA9.

Ecosystem processes operate over ranges of spatial and temporal scales. Although society may define the boundaries of management jurisdictions without reference to such processes, the scientific importance of context in determining the behavior of ecosystems at a particular location is, nevertheless, well documented.[3,4,5] Impact assessment and mitigation evaluation *must* consider context to be scientifically relevant.

As an example, San Juan County, which is comprised of several islands, is all in WRIA2. Using this project as a precedent, mitigation would be allowed on Orcas Island for wetland filling that was permitted on San Juan Island simply because they are both located in WRIA2. It is not possible to justify such a policy if protecting against degradation of public beneficial uses is the goal. Whether DOE relies on state statute for a narrower view, the reviewing federal agencies are clearly obligated to do more, and must have a clear and scientifically defensible position on this matter.

If a decision is made to allow mitigation to occur outside the watershed, there must be a clear link between the value, type and extent of wetland functions being eliminated and the beneficial uses obtained from the mitigation. This link is not adequately discussed and demonstrated in the available documentation. This constitutes a serious deficiency and relegates evaluation of the mitigation to an accounting of acreage without regard to ecosystem functions. The lack of identification and discussion of the cumulative functional

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2 Addendum to the Final Supplemental Environmental Impact Statement, Auburn Wetland Mitigation Project, Port of Seattle, May 5, 2000, p. 12.

3 Noss, R.F. 1991. Sustainability and wilderness. Conservation Biology 5:120-122.

4 Noss, R.F. and L.D. Harris 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environmental Management 10:299-309.

5 Sherman, K., L.M. Alexander, and B.D. Gold (eds.). 1990. Large marine ecosystems: patterns, processes, and yields. AAAS Symposium Series.

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losses related to the entire third runway project trivializes the role of state and federal agencies, which is to prevent degradation of wetland functions as well as acreage.

An evaluation of whether the mitigation adequately offsets the impacts cannot be completed without an analysis of the cumulative losses of wetland functions within the watersheds. These cumulative losses include impacts to regional and local recharge, hydrologic and habitat functions of remaining wetlands and uplands, degradation due to planned and unplanned disturbances resulting from construction and airport operations, and whether the regional scope of alterations occurring to wetland resources affecting the future sustainability of the fisheries resources of Walker, Miller and Des Moines Creeks.

The unique watersheds that are within WRIA9 are distinct and can be characterized. Beneficial uses within these watersheds can be clearly articulated. Therefore, protecting the public interest demands that the functions lost in the Miller Creek and Des Moines Creek watersheds be viewed in context of their ecosystem function within WRIA9. Protection of beneficial uses from further degradation would require in-kind compensation in context of the spatial loss. This would require that mitigation replace similar functions in the same or a similar watershed that is characterized by a coastal freshwater creek system capable of supporting salmonids.

Inadequate Link Between the Impacts to Wetland Functions and the Functions Gained From the Proposed Mitigation

The proposed mitigation plan involves both in-watershed and out of watershed activities involving wetland enhancement, restoration and creation. However, the proposal fails to provide adequate mitigation for wetland functions that will be lost or seriously impaired within WRIA9. There are also deficiencies in the analysis of wetland acreage that will be permanently impacted by the third runway construction

The problem stems from the limited scope of the wetlands assessment methodology. Although the third runway will affect numerous wetlands and several creek systems, wetland impacts were evaluated discretely and not as a system. Wetland functional assessment models are typically used with individual wetlands and are often not adequate for assessing the landscape role of a system of wetlands within a watershed. This case is a particularly good example of how beneficial uses can be lost when wetland functions are evaluated individually instead of cumulatively on a landscape scale. Regardless of the argument that many of the wetlands proposed for filling are degraded systems and, in isolation, have low value, viewed together, in context of the watershed and as a system, the affected wetlands clearly provide functions that are greater than the sum of their individual roles.

The goals of the proposed mitigation projects, detailed in Table 4.1-2 of the Natural Resource Mitigation Plan, are dominated by activities that replace losses in riparian habitat, enhance riparian buffers and replace flood storage.[6] This is a very narrow scope of functions to be mitigated and does not provide equal value for the significant losses to the watershed ecosystem that will occur as a result of the third runway construction. Significant wetland losses will affect riparian ecosystem functioning in the Miller, Walker and Des Moines Creek watersheds and include:

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[6] Summarized from Table 4.1-2 in the Natural Resources Mitigation Plan, Parametrix, Inc., Revised Draft, August 1999.

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- Permanently altered hydrology through losses of wetlands associated with Miller, Walker and Des Moines creeks that currently provide baseflow support to three creek systems. These creek systems are documented to support both native and hatchery salmonid species including Coho and cutthroat trout.[7,8,9,10]
- Loss of wetland and riparian ecosystems which currently provide resistance to and resilience from disturbances particularly hydrologic changes resulting from weather, climate change or future water resource allocations.
- Loss of wetland and riparian habitat complexity and species diversity, which also imparts resistance to disturbance, by providing source populations to recolonize disturbed areas and a genetic pool necessary to adapt to long term change.

These losses will permanently affect the occurrence, functioning and quality of freshwater coastal stream resources within WRIA9. Moreover these losses will seriously impact the sustainability of biological diversity including wetland and salmonid resources in the Miller Creek and Des Moines Creek watersheds.

Unaccounted for Wetland Functional Losses in Miller Creek and Des Moines Creek Watersheds

Hydrologic Functions: The wetland delineation report prepared by Parametrix accurately describes much of the hydrology of the wetlands located in the Miller creek watershed. Specific mention is made of hillside seeps as the source of water for wetlands 18, 19, 20 and 37.[11] The report acknowledges that wetlands 18 and 37 are hydrologically connected and contiguous although they received separate number designations. For reasons that are not explained, the areas are evaluated and tallied as separate wetland systems. Wetland 18/37 is an associated wetland to Miller Creek that captures water from hillslope seeps originating in the Vashon Recessional Outwash (Qvr) aquifer.[12] This wetland system provides an important function in the watershed by buffering Miller creek from hydrologic and temperature extremes through groundwater baseflow support.

Walker Creek basin is included in the watershed of Miller Creek. Walker Creek discharges to the main stem of Miller creek within approximately one mile of the outlet to Puget Sound. Each of the project documents I reviewed did not accurately describe or illustrate that the headwater of Walker Creek is located east of Wetland 44b on the east side of 12th Avenue S.[13] Walker Creek emerges from a hillslope seep that flows west to Wetland 44, crosses SR509 through a culvert and continues west through Wetland 43.

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7 SeaTac Runway Fill Hydrologic Studies Report, Pacific Groundwater Group, June 19, 2000, p. 3-4.
8 Hillman, T.W., Stevenson, J.R., and D. J. Snyder. 1999. Assessment of Spawning and Habitat in Three Puget Sound Streams, Washington. Prepared for the Airport Communities Coalition, Des Moines, Washington by Bioanalysts, Inc., Redmond, Washington.
9 Natural Resources Mitigation Plan, Parametrix, Inc., Revised Draft, August 1999.
10 Note that all naturally spawned populations of Coho salmon and cutthroat trout are considered members of the Puget Sound Strait of Georgia Evolutionary Significant Unit and are candidate species under the Endangered Species Act.
11 Wetland Delineation Report, Revised Draft, Parametrix, Inc., August 1999.
12 SeaTac Runway Fill Hydrologic Studies Report, Pacific Groundwater Group, June 19, 2000.
13 Please review list provided on Page 2 of this report.

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Both the headwater seep that begins Walker Creek and portions of associated Wetland 44 will be filled and impacted by construction activities. Clearly, filling the headwaters of Walker Creek, will change its hydrology in the upland reaches of the basin. Once again, although the subject is discussed in the SeaTac Runway Fill Hydrologic Studies Report and in the Geotechnical Engineering Report found in Appendix B of the Wetland Functional Assessment and Impact Analysis, neither document provides a comprehensive documented analysis of the hydrologic impacts of filling the headwaters of Walker Creek on the creek's seasonal hydrology, even though the creek is documented to support salmonid production and fish inhabit Wetland 43.[14] Ignoring impacts to the upland tributary is again consistent with the "Dead is Dead" philosophy but inconsistent with the obligation of the reviewing agencies.

The plans to enhance the buffer along Miller Creek may benefit already disturbed portions of the creek buffer, but do not adequately mitigate for the loss of important hydrologic functions provided by the seeps and wetlands that currently buffer Miller Creek and Walker Creeks. The Vaca Farm floodplain and wetland restoration provide stormwater storage but, again, do not provide a functional equivalent to the losses that effect the resiliency of the creek system. Relying on the Vaca Farm restoration and buffer enhancements to Miller Creek for mitigation will result in further degradation of the Miller and Walker Creek systems.

In the Des Moines Creek watershed the hydrologic issues related to wetlands and riparian areas are different from those in Miller Creek. The impact of the borrow sites on the hydrology of remaining wetlands and Des Moines Creek is not adequately addressed. The SeaTac Runway Fill Hydrologic Studies Report states that the borrow areas will not affect the shallow aquifer, said to feed nearby wetlands. This conclusion is not supported by an independent analysis by Pacific Groundwater Group but is assumed by them from discussions in the original Geotechnical Engineering Report located in Appendix B of the Wetland Functional Assessment and Impact Analysis.

The proximity of Borrow Site 4 to Wetland 28 in the Des Moines Creek Watershed is cause for concern as is the proximity of some of the other wetlands to borrow sites, such as wetlands B15 and 48. Wetland 28 is the headwaters of the western tributary to Walker Creek. Appendix C Borrow Areas 1, 3 and 4 of the Wetland Functional Assessment and Impact Analysis does not identify Wetland 28 as being adjacent to Borrow Area 4 and does not discuss how the wetland may be impacted by excavation activities.[15]

Enough information to assess the impacts of the borrow sites is simply not provided. Appendix C provides conceptual excavation plans that show excavation contours. The maps show excavations occurring immediately adjacent to and within wetlands, yet only the area of wetland located within the borrow area is included in the impact assessment tabulation. No details are supplied within the supporting documents that can account for concluding there would be no direct impacts to adjacent wetlands.

The reduction of summer baseflows predicted for Des Moines Creek and the plan to augment summer flows as needed raises another significant issue related to hydrologic

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[14] June 27, 2000. Memo from John A. Strand, Ph.D to Peter Eglick. Columbia Biological Assessments, 1314 Cedar Avenue, Richland, WA 99352, See Attachment A to the report.

[15] Appendix C Borrow Areas 1, 3 and 4, Wetland Functional Assessment and Impact Analysis, Revised Draft, Parametrix, Inc., August 1999.

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functions. Suggested sources for this augmentation have included a well with a contested water right or a municipal water supply involving chlorine and other chemical treatment. Municipal water sources are not necessarily viable, permanent water sources for the creek as future growth occurs and water resources become more scarce and costly. Des Moines creek is known to be inhabited by wild and fishery stock Coho salmon and cutthroat trout. Therefore a clear understanding of how the hydrology of Des Moines Creek will be protected is vital. That clarity cannot be gained from the current documentation for the project.

Habitat Functions: The existing system of hillslope seeps and wetlands feeding Walker and Miller Creeks has a dendritic habitat structure. The original complexity has been degraded by past property development practices but what remains is a system of wetland habitats that are hydrologically connected to each other and to the hillslope to the east.

The best illustration of the existing habitat complexity existing along Miller Creek can be found on Project Plan C-2 of Appendices A-E Design Drawings Natural Resource Mitigation Plan.[16] The plan shows at least four drainages that originate on the hillslope east of 12th Avenue S, that feed associated wetlands and Miller Creek. Although some wetlands are fragmented (isolated) in the landscape, most are connected hydrologically or through adjacent uplands.

The proposed mitigation states it will improve habitat functions in exchange for filling the upland wetlands and seeps that produce the existing topographic and habitat complexity. On the surface, the proposed stream enhancements appear to be improvements, however, long-term sustainability of an ecosystem must be viewed within its landscape context.[17] At project completion the habitat remaining in the Miller Creek watershed will be a far more contained system, in large part channeled by a uniform wall, producing a simpler, more limited habitat system, lacking in complexity and therefore less resilient to losses in biodiversity due to disturbance events such as drought, toxic spills or sustained heavy rainfall. This view is confirmed by the independent review by Pacific Groundwater Group, which states that "To prevent a significant decline in local [species] populations, mitigation would be required to provide alternative habitat on-site."[18]

Maintaining biological diversity is central to the productivity and sustainability of wetland ecosystems. Specific examples of the critical role of biodiversity in ecosystem functioning include providing for:

- essential processes such as nutrient and water cycling,
- ecosystem resistance to and recovery from disturbances, and
- adaptability to long-term changes in environmental conditions[19].

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16 Appendices A-E Design Drawings Natural Resource Mitigation Plan, Seattle-Tacoma International Airport, Parametrix, Inc. No Date.
17 Note: Landscape is used to mean the ecosystem character and functions of the land in a particular watershed or region.
18 SeaTac Runway Fill Hydrologic Studies Report, Pacific Groundwater Group, June 19, 2000, p. 8.
19 The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management, US Forest Service, U.S.D.A., May 1996.

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The importance of ecosystem complexity and the vast array of interconnections that underlie ecosystem function is one of the most important lessons of ten decades of ecological research and natural resource management experience.[20] Complexity and diversity also impart resistance to and resilience from disturbance, and provide the genetic resources necessary to adapt to long-term change. Protecting wetland beneficial uses also includes protecting the complexity of species interactions that underlie ecosystem functioning and the role that diversity plays in maintaining processes across complex environmental gradients through space and time.

Biological diversity provides for both stability (resistance) to and recovery (resilience) from disturbances that disrupt important ecosystem processes. Resistance in wetlands results in large part from complex linkages among organisms, such as riparian areas that provide alternate pathways for flows of energy and nutrients. The presence of numerous organisms with similar capabilities in a complex habitat structure produces redundancy that is beneficial for ecosystem stability. On a watershed scale species populations are less variable because of the connections among habitats and the ability of species to migrate and reestablish after disturbances occur in a main stem or associated tributary.

Just as the presence of numerous hillside seeps and hillslope wetlands buffers against the loss of hydrologic function in Miller and Walker Creeks, these same seeps, wetlands and adjacent upland habitats buffer against isolation and extirpations of small mammals and amphibians. These are system level wetland function that makes it more likely that important processes (such as baseflow support to the creeks and nutrient uptake by the plant communities) will be optimized in the face of seasonal variations and periodic disturbances

Long-term adaptations of wetlands to changes in climate and other environmental variables are strongly dependent upon available biological diversity. The reservoir of genetic diversity within individual species and populations is central to their ability to adapt to environmental change.[21] Greater numbers of species and greater genetic variability within species provides for a larger number of biological building blocks for ecosystem response and species evolution. Maintaining habitat complexity provides the capacity to adapt and that is central to the long-term sustainability of beneficial uses.

Unaccounted for Wetland Acres Lost in Miller Creek Watersheds

The tabulation of wetland acres impacted by the third runway project, listed in Table 3.1-1 of the Natural Resource Mitigation Plan, is based on the assumption that if you fill only part of a wetland, the remaining portion of wetland retains its original functions and values, just located in a smaller area. For example, the table shows that 4.08 acres of the 5.74 acres comprising Wetland 37 will be filled and 2.6 acres of 3.56 acres belonging to Wetland 18 will be filled. Less than 29% of each wetland remains yet the wetland loss is accounted for as though the beneficial uses provided by the original wetlands were equal to what remains with only the spatial area having changed.

This mitigation strategy assumption that the remaining wetland area will function as it did previous to the fill, is unlikely to be true due to altered hydrology, reduced resource of

[20] Peterson, C.H., 1993. Improvement of environmental impact analysis by application of principles derived from manipulative ecology: lessons from coastal marine case histories. Australian Journal of Ecology 18:2152.
[21] Antonovics, J., 1968. Evolution in closely adjacent plant populations. Heredity 23:219-238.

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wetland habitat and because local species and populations will change depending on what remains. The functional value of the remaining wetland would likely decrease resulting in a greater cumulative loss of wetlands than what is represented in the accounting of acreage alone.

In actuality, at least 35% of the wetlands will be removed from the area adjacent to the middle stem of Miller Creek. This is a significant permanent loss to the watersheds. The lack of discussion identifying the landscape (system level) role of these wetlands exemplifies how viewing natural systems as discrete elements unconnected to their landscape context can lead to significant losses of beneficial uses in our remaining wetland landscapes.

The mitigation impact analysis is also flawed because, for reasons that are not very well explained, wetlands along the western shore of Miller Creek are not identified. All of the wetlands associated with the affected reaches of Miller Creek are hydrologically connected and should be analyzed from a systems perspective as part of the wetland functional assessment. The assumption that impacts will stop 50 feet from the base of the retaining wall or fill base is not believable given the scale of wetland filling and the hydrologic connectivity of the wetlands and creek systems being altered. The omission of the western wetlands associated with Miller Creek is, unfortunately, also misleading as the mitigation plan (Figure 5.2-1) shows buffer enhancement area all along the western shore of Miller Creek when some of that area is also wetland. It appears that existing wetlands are being counted as buffer enhancement area.

The Natural Resource Mitigation Plan suggests that only 2.17 acres of wetlands will be temporarily disturbed due to construction activities.[22] However that number is probably much higher because the level of function in remaining wetlands cannot be maintained at the existing condition. Long-term secondary effects to remaining wetlands will include compaction of soils, reduced adjacent habitat, disturbance to remaining habitat and losses of localized species affecting both biological and genetic diversity. All of these impacts should have been acknowledged and addressed. These omissions indicate that the mitigation ratio claimed by the mitigation proposal is inaccurate and inadequate to offset losses in beneficial uses.

Additional Hydrologic Concerns

The Sea-Tac Runway Fill Hydrologic Studies Report summarizes investigations conducted to assess the hydrologic effects of constructing a fill embankment for the proposed third runway. The report states that it did not consider all Master Plan Improvements proposed by the Port of Seattle, did not address all hydrologic issues required for permitting nor did it consider all the possible effects related to the embankment and borrow areas.[23] Although the report claims that there will be no significant impacts to remaining wetlands and the Walker and Miller Creek systems, it also concedes that "a confident assessment of basin-wide recharge and baseflow impacts is currently lacking".[24] This is a critical point. To date there has been no other reported evaluation of basin-wide recharge and baseflow impacts. The importance of understanding and mitigating the full

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22 Natural Resources Mitigation Plan, Revised Draft, Parametrix, Inc., August 1999, p. 3-3.
23 SeaTac Runway Fill Hydrologic Studies Report, Pacific Groundwater Group, June 19, 2000, p. 1.
24 Ibid, p. 6

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extent of impacts to recharge in Miller, Walker and Des Moines Creek basins cannot be emphasized enough. As discussed previously, these are increasingly rare functional coastal creek systems that support cutthroat trout and other salmonid species.

The review report predicts an uncontrolled release of stormwater at some time during construction. Although the authors declined to predict the size and quantify the effects on fish, they noted that uncontrolled releases of turbid water would likely result in a decline of cutthroat and Coho salmon. The report goes on to conclude that the proposed mitigation for fisheries effects is limited in that "it will only effect localized Miller Creek habitat and resident cutthroat trout. Indirect construction and post-construction effects such as alterations to baseflow, peak flow, and sediment input could affect the entire stream systems, not just the airport project area."[25] This statement identifies and confirms the lack of attention to watershed ecosystem level impacts and identifies the inherent failure of the mitigation strategy to prevent degradation of beneficial uses.

Wetlands, Airports and the Siting of Incompatible Uses

The off-site habitat mitigation located in Auburn is designed to provide in-kind replacement of avian habitat and other wildlife habitat off site so as to comply with FAA Advisory Circular 150/5200-33.[26] This circular contains guidelines that suggest limiting the development of avian habitat within 10,000 feet of existing facilities to minimize the hazard of potential air strike by birds. RCW 36.70A.510 requires that jurisdictions discourage the siting of incompatible land uses near airport zones. These guidelines are referred to repeatedly in the reporting as a basis for reducing habitat values in the Miller Creek watershed as if these values did not already exist and would be new. The guidelines are said to require a mitigation strategy (out of kind and out of watershed) that is less than effective for protection of beneficial uses. It is important to note that both the FAA guidelines and the RCW address *existing* conditions. Neither is intended to apply to new airport facilities that will eliminate existing wetlands and beneficial uses. They are intended to discourage unsafe developments adjacent to existing airports. It is misleading to use the guidelines or the RCW as a basis for allowing out-of-watershed mitigation in lieu of preventing further degradation of the existing Miller and Des Moines Creek watershed resources.

Moreover, if the Port's interpretation of the regulations were correct, then the Port's own proposal for an expanded third lagoon system will have waterfowl-attractant issues, as will the proposed expansion to the Miller Creek Regional Detention Facility. The proposed third lagoon expansion will be used to store (and possibly pre-treat) liquid industrial wastes and would therefore fall under the FAA definition of a wastewater treatment facility. Section 2 of the FAA Advisory Circular, "Land Uses that are Incompatible with Safe Airport Operations" recommends that any new wastewater treatment facilities or associated settling ponds be sited no closer than 10,000 feet from turbine aircraft movement areas. The existing third lagoon is located within 2,000 feet of the runway, and the proposed expansion area is within 3,000 feet of the runway, therefore the proposed lagoon expansion would not comply with the FAA recommendations on hazardous wildlife attractants.

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[25] Ibid, p. 6-7

[26] Natural Resources Mitigation Plan, Revised Draft, Parametrix, Inc., August 1999, p. 7-1.

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Finally, Section 2-4(2)(b)(2) of AC 150/5200-33 of the FAA circular specifically states that exceptions to locating mitigation activities outside the separation criteria may be considered if the affected wetlands provide unique ecological functions, such as critical habitat for a threatened or endangered species or ground water recharge. With the recent listings of salmon, there may be additional requirements for mitigating degradation of salmonid habitat.

Auburn Mitigation Proposal

The wetland mitigation site in Auburn is located adjacent to an older channel of the Green River that has become a wetland over time as the river has altered its channel. Because the river has historically altered its channel in the mitigation area there is significant likelihood that it will do so again. The site is subject to tremendous river forces and located in an area that could be retaken by the Green River. Creating additional wetland areas may compromise the stability of the old channel. The Addendum to the Final Supplemental Environmental Impact Statement for the Auburn site briefly describes the hydrologic regimes that are proposed and a plan to use adjustable weirs to control water levels for optimum plant establishment.[27] The lack of detailed plans for implementing hydrology is a serious deficiency, particularly when adequate hydrology is one of the wetland functions that is least often successfully mitigated.[28] In light of these conditions, the absence of detailed information in the documentation provided to the agencies describing exactly the functioning of hydrology in the Auburn wetland is a significant void and leaves little basis on which to evaluate the mitigation plan's success. In addition the wetland design suggests the possibility that fish strandings could occur.

The proposed mitigation site along the Green River is also subject to impacts from activities in numerous up-river watersheds that pose risks of increased flooding, water quality degradation to downstream stretches, and catastrophic events such as toxic spills and impacts from continued urbanization. Numerous stretches of the Green River and its tributaries are on DOE's 303d list of impaired water bodies, including a listing for temperature exceedences in the area of the oxbow bends just northwest of the mitigation site. Temperature issues are a significant concern as highly valued Chinook spawning areas are located in the vicinity. Yet, the wetland design may well produce elevated water temperatures, especially until the forest canopy matures, that are not beneficial to Chinook who may use the area.

Finally, the presence of reed canary grass on the mitigation site is a significant management concern. The proposed strategy is to remove a foot of soil from the site and replace it with organic material mixed into the subsoil. This is unlikely to remove reed canary grass from the site. In addition, there are numerous avenues (water, wind, equipment, and boots) for new colonizations to occur as reed canary grass is well established along the Green River. This plant species is known for its invasive character and has

[27] Addendum to the Final Supplemental Environmental Impact Statement, Auburn Wetland Mitigation Project, Port of Seattle, May 5, 2000, p. 4.

[28] Wetland Mitigation Evaluation Study Phase 1, Department of Ecology Publication No. 00-06-016, June 2000, p. 16.

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seriously affected the successful establishment of some of the targeted plant habitats in another nearby large wetland constructed as mitigation for a sports facility.[29,30]

In summary, the Auburn mitigation cannot provide a reasonable assurance that the project will supply adequate mitigation for lost beneficial uses, not only because it fails to provide the functional equivalent for what is being replaced, but also because it is at high risk for disturbances (which the Port of Seattle will have no control over) that will likely degrade the habitat values of the mitigation. This will result in an overall loss of beneficial uses from the third runway project.

Consistency Between Wetland Mitigation and Delineation Plans and Construction Drawings

It has been reported to me that Wetland 28 is shown as paved over on the construction drawings for the SASA area.[31] I have not had the opportunity to review the construction drawings to date so cannot verify whether this report is true. However, based on my recent experience reviewing the Port of Seattle's plans for the temporary SR509 interchange, it is very important that the reviewing agencies carefully crosscheck all construction drawings for consistency with the wetlands delineations and mitigation plan. In the case of the temporary interchange, a review of the Port's construction plans showed that a planned stormwater facility was located in an existing wetland and also revealed that the location of the temporary interchange was incorrectly shown on the topography, and had been shifted 40 feet or more, so it appeared further from existing wetlands than it actually was.

Summary

Although the June 2000 Implementation Addendum to the Natural Resource Mitigation Plan states that "the Port's mitigation plan will result in increased functional performance of the wetlands and creeks in the mitigation site relative to degraded wetlands" it offers no clear presentation of why that would be true and the available data suggests otherwise.[32] In reality, there is a functional and spatial reduction of wetlands that supply nutrients, baseflow, food web support and habitat to the stream systems with no mitigation for those direct functions. In reality, Walker, Des Moines and Miller Creeks are going to endure repeated disturbances from truck and fill operations, construction impacts, stormwater discharges, settling dust and unforeseen events that will continue to reduce the resiliency of the remaining wetlands and streams.

Uncertainties regarding the distribution and functional importance of many species and ecosystem elements, as well as our limited understanding of the complex relationships of organisms to wetland structure and functions, argue for a highly conservative approach to protecting the functions of wetlands. This is particularly important given the lack of success of related to wetland mitigation. DOE's own study of wetland mitigations found that only

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29 Wetland Mitigation Evaluation Study Phase 1, Department of Ecology Publication No. 00-06-016, June 2000, p. 47.
30 Pers. Comment, Erik Stockdale.
31 E-mail, Kimberly Lockhard, Airport Communities Coalition, August 11, 2000.
32 Implementation Addendum, Natural Resource Mitigation Plan, Master Plan Update Improvements, Seattle-Tacoma International Airport, Parametrix Inc., June 2000.

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35% of wetland mitigation sites were meeting all performance standards.[33] It is also revealing that when individual functions were assessed in the DOE study, water regime was among the least often obtained successfully in mitigation.[34] The third runway project will degrade without effective mitigation two watersheds with salmonid streams known to be inhabited by species that are candidate for listing and where no degradation of hydrologic functioning can be acceptable.

Thank-you for your time spent in reviewing this material. Please call me or email me if you have any questions or comments.

Sincerely,

Amanda Azous

Attachment A: June 27, 2000. Memo from John A. Strand, PhD to Peter Eglick. Columbia Biological Assessments, 1314 Cedar Avenue, Richland, WA 99352.

Attachment B: Vita for Amanda Azous

Cc:
Airport Communities Coalition (ACC)
Dr. John Strand, Columbia Biological Assessments
Mr. Bill Rozeboom, Northwest Hydraulic Consultants
Mr. Tom Sibley, NMFS
Ms. Joan Cabreza, EPA

[33] Wetland Mitigation Evaluation Study Phase 1, Department of Ecology Publication No. 00-06-016, June 2000, p. v.
[34] Ibid, p. 16.

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Subj: Review and Evaluation of *Sea-Tac Runway Fill Hydrologic Studies Report.* Prepared for the Washington State Department of Ecology by Pacific Groundwater Group, Seattle, Washington; Ecology and Environment, Seattle, Washington; and Earth Tech, Inc., Bellevue, Washington. June 19, 2000.

Dear Mr. Eglick:

At your request, I reviewed and evaluated Washington Department of Ecology's (WDOE's) independent study to investigate hydrologic impacts of the subject fill project on aquifers, wetlands, and Miller, Walker and Des Moines Creeks. Of particular interest was WDOE's assessment of potential hydrologic impacts on fishery resources and other aquatic life inhabiting area streams. In undertaking this effort, I have relied on my education, specialized training, and professional skills acquired over a 40-year career as a Fisheries Biologist (see attached Curriculum Vitae).

My review and evaluation focused on five areas of the Report:

- Functional assessment of study area wetlands (Sect 3.3.3.2)
- The description of fishery resources in study area streams (Sect 3.4.1.-3.4.5.)
- The assessment of impacts on fish habitat in Miller Creek as a consequence of its relocation in the Vacca Farm area (Sect 1.4.3).
- The methods employed to estimate stormwater flows and sizing flow-control facilities for purposes of mitigating impacts to fish and other aquatic life (Sect 3.6.2.).

- The assessment of impacts of warm water runoff from runways and taxiways entering area streams following summer rains (3.6.10).

My opinions and the detailed evaluations on which they are based are found in the succeeding sections:

Opinions

- **The functional importance of area wetlands to support fish, both resident and anadromous, is understated.**

Ecology & Environment (E&E) understates the ecological importance of wetlands to support fish. They say in Sect 3.3.3.2 that "most project wetlands have little direct bearing on resident fish populations and are therefore all equally considered to be of low quality." They offer as the only exceptions to this rule Wetlands 18 and 37. In my opinion they have overlooked the very important wetland at the head of Walker Creek, Wetland 43, which supports both resident and anadromous fish.

E&E makes no attempt to describe the fishes of Wetland 43, nor is there any evidence that they recently conducted fish surveys in this wetland or upper Walker Creek. If they had surveyed the wetlands including upper Walker Creek, they would have found the very abundant cutthroat trout in addition to juvenile coho salmon. They also would have noted that of all the small streams draining this region of King County, i.e., Walker, Miller and Des Moines Creeks, Walker Creek supported the most coho spawning in recent (1998-1999) spawning surveys (Hillman et al. 1998). Even Parametrix (2000b) rated this wetland as moderate in supporting resident and anadromous fish. Based on my own observations, Walker Creek is the most undisturbed of the three drainages (Miller, Walker, Des Moines Creeks), which could account for its greater salmonid production. E&E also does not acknowledge the ecological importance of wetlands as critical habitats supporting other aquatic life, e.g., dragonflies, damselflies, caddisflies, mayflies, and crayfish, many of which are important prey species for trout, salmon, and other fishes.

- **Fishery resources of area streams are not accurately described.**

E&E does not accurately describe the fishes inhabiting the Miller Creek and Des Moines Creek Watersheds (Sect 3.4.1 - 3.4.5), which in my opinion, trivializes the ecological importance of area streams. In addition to coho salmon, chum salmon, and cutthroat trout, E&E reports in this study that three-spined stickleback and pumpkinseed sunfish occur in Miller Creek but not other species. The Airport Communities Coalition (ACC) Pollution Investigation Team found both prickly sculpin and yellow perch during recent (April 2000) water quality studies conducted in area streams. Parametrix (2000) reported finding three-spined stickleback, pumpkinseed sunfish, and black crappie in upper Miller Creek, which suggests that E&E's surveys were neither comprehensive nor quantitative.

E&E also says that "steelhead and pink salmon runs" have been reported in Des Moines Creek, when it is more likely that only "stray" steelhead or pink salmon occur there. Hillman et al., in 1998, document finding only one steelhead in Miller Creek and two in Des Moines Creek.

Furthermore, E&E says "adult coho and chum salmon use of Miller and Walker Creeks was verified up to First Avenue South" yet Hillman et al. (1999) reports finding coho redds above First Avenue South. I question whether or not E&E surveyed above First Avenue South. Similarly, WDOE reports that adult coho and chum exploit Des Moines Creek up to Marine View Drive, while Hillman et al. (1999) reported finding coho spawning up as far as S 212th Street, a kilometer above Marine View Drive. If either the Port's consultant or E&E had employed a more systematic and comprehensive survey approach, they also would have found an abundant cutthroat population, not the "small population of resident" fish as stated in this report. The ACC Pollution Investigation Team has captured or observed cutthroat trout at all water quality sampling locations during April 2000 surveys, up to 157th Avenue on Miller Creek, and up to S 200 Street on Des Moines Creeks.

Finally, E&E reports in Sect 1.4.4.3 that because no 0-age chum salmon and steelhead were found during juvenile fish surveys conducted March 24 and 25, 2000, that it was unlikely that viable spawning populations of these species exist on Miller, Walker, or Des Moines Creeks. In my opinion, this conclusion is premature and careless, particularly as it applies to chum salmon. Clearly adult chum have been observed in area streams in 1998 by Hillman et al. (1999) and by E&E in 1999 (this study). Hillman et al. (1999) also found that chum entering Miller and Des Moines Creeks in 1998 all voided their eggs indicating that chum, in fact, do spawn in area streams. To suggest that a viable spawning population of chum does not exist in area streams based on only one year's sampling of juveniles is not good science. To only look for juveniles over the very narrow window of March 24-25, 2000, is careless. How sure was E&E that the chum had already hatched and emerged from the gravel? The chum also could have hatched, emerged and outmigrated by March 24th or 25th. Chum are found in freshwater for only a few days (Wydowski and Whitney 1979) and outmigrate from late February to mid-July in Washington streams and rivers (Wydowski and Whitney 1979; Warner and Fritz 1995). It is likely that E&E missed the chum outmigration.

- **The effects of construction on fish habitat in Miller Creek are substantially understated.**

The impacts on fish habitat of relocating Miller Creek are not even addressed (see Sect. 1.4.3). Clearly, relocation of Miller Creek will result in nearly total elimination of the fish and invertebrate communities presently found in the 980 feet of Miller Creek to be filled accommodating the embankment of the runway. Ecology is remiss for not requiring the Port to address the magnitude of this impact, and appears to have been dazzled by the Port's suggestion that relocated Miller Creek, complete with new riffles, pools, and replacement of woody debris, will provide a net gain in fish habitat. It could be years before the relocated creek will attain the level of production achieved presently, assuming that the Port or WDOE knows what level of fish production presently occurs. Unfortunately, neither the Port nor WDOE has recently undertaken a quantitative fishery survey in Miller Creek, or for that matter, in Des Moines Creek.

The WDOE also indicates that "an uncontrolled release of stormwater is likely to occur sometime during construction," given the size of the project and human error; however, the size and quality of a release cannot be predicted, nor can its impacts on fish be quantified." I agree, you can't predict impacts if you don't know the kinds and abundances of fish and other aquatic life that inhabit the site.

- **Methods for establishing target flows and sizing flow-control facilities do not work.**

The WDOE and the Port cannot guarantee that stormwater peak flows and durations generated during operation of the third runway will not harm fishery resources in Miller Creek.

As indicated in Sect 3.6.2, the Port proposes to control stormwater runoff from the airport using a combination of local and regional detention facilities to regulate the rate of stormwater released to Miller Creek. Their consultant has employed a Hydrological Simulation Program-FORTRAN (HSPF) computer model to determine the size of detention facilities needed to control stormwater at different flow rates and durations.

As pointed-out by WDOE, the HSPF model as presently configured for Miller Creek predicts higher than observed flow volumes at two reference locations, indicating that the model is not well calibrated. The Port, therefore, could seriously underestimate the size of detention facilities needed to control stormwater releases to Miller Creek. The Port then, can't conclude that flows in Miller Creek will be fish-friendly.

The model requires substantial modification and additional calibration before another evaluation of the proposed stormwater controls can be undertaken. What is missing from WDOE's assessment, however, is what will be the next step. Will, in fact, the model be modified and re-calibrated? Clearly, WDOE must require the Port to develop a reliable method to design flow-control facilities in Miller Creek that will preserve habitat for fish and other aquatic life. The public should be assured that construction will not proceed without this additional step.

- **Warm runoff from runway and taxiways during summer rains could impact area streams (Miller, Walker, and Des Moines Creeks).**

The potential for warm runoff from runway and taxiway paved areas to enter streams and elevate temperatures has been considered but, in my opinion, incompletely. WDOE indicates that this is essentially a non-problem but presents no data to document the temperature of warm runoff entering area streams or what the volume of warm runoff entering area streams will be under different sized storm events.

The third runway and connecting taxiways will cover about 32 percent of the new embankment surface, and will produce varying volumes of stormwater, dependent on the rate and duration of rainfall events. To be able to calculate flow rates and to limit peak flows and durations, the Port employs the HSPF computer model.

Water running off the paved surfaces is proposed to flow into low areas at the bottom of the filter strips, then into catch basins. Water entering the catch basins would be conveyed through pipes to detention vaults, then ultimately into the streams. Clearly, if the Port has the ability to estimate the volumes of water released to the creeks, they also have the ability to estimate the change in stream temperature from the addition of warm runoff. In Miller Creek, the potential problem is compounded by not having a model that is properly calibrated.

At minimum, WDOE should present data to document their assertion that the volume of warm runoff entering Miller Creek is negligible, or require the Port to generate this data if WDOE's consultants only approached this problem qualitatively.

Summary

It is my opinion that WDOE's independent study does not address all possible impacts on area fishery resources from the subject construction project. Notable omissions are the impacts on fish and fish habitat from relocating Miller Creek in the Vacca Farm area. Also, neither WDOE nor the Port provide any data proving that warm runoff from the new runway and taxiways will not impact Miller Creek. Perhaps the greatest weakness is the failure to accurately describe the fish communities at risk. Recent attempts to survey the fish resources of area streams were, unfortunately, neither comprehensive nor quantitative.

Thank you for the opportunity to comment on this Report.

Yours very truly,

John A. Strand, Ph.D.
Principal Biologist

Cc: Kimberly Lockhard
Mary Ortega
Bill Rozeboom

References

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Dr. Strand is an internationally recognized fisheries biologist specializing in studies to determine potential effects of human activities on aquatic resources. During his 30 years of experience, he has conducted and managed a wide variety of projects, large and small, in Washington, California, Alaska, British Columbia, Guam, and Venezuela. These included field studies to evaluate environmental impacts of engineered structures, and field and laboratory studies to assess ecological risks from discharge of contaminants to surface waters, including sewage, storm water, oil, other organic chemicals, radionuclides, and heavy metals. Of key interest is the design of strategies to mitigate impacts on threatened, endangered, or sensitive aquatic species, and their habitats.

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Education:

Ph.D.; University of Washington; Fisheries Biology; 1975
M.S.; Lehigh University; Biology; 1962
B.A.; Lafayette College; Biology; 1960

Employment:

1999- Principal Biologist, Columbia Biological Assessments, Richland, WA. Also, Adjunct Faculty, Environmental Sciences and Regional Planning Program, Washington State University Tri-Cities, Richland, WA.
1996-1999; Water Quality Planner, King County Department of Natural Resources, Seattle, WA.
1993-1995; Senior Biologist and Group Leader, EA Engineering, Science, and Technology, Inc, Redmond. WA.
1990-1993; Manager and Co-Chair, *Exxon Valdez* Oil Spill Restoration Planning Working Group, NOAA/NMFS, Auke Bay, AK.
1969-1990; Senior Research Scientist and Manager, Battelle, Pacific Northwest Laboratory; Richland and Sequim, WA. Also, Affiliate Faculty (1987-1991), School of Fisheries, University of Washington, Seattle, WA.

Registration/Certification:

Fellow, American Institute of Fisheries Research Biologists; 1993
Certified Fishery Scientist (No. 442), American Fishery Society; 1969

Specialized Training:

Health and Safety Training for Hazardous Waste Sites; 1996; 1997; 1998
Wetland Delineation, Shoreline Community College; 1996
Litigation Support Short Course, EA Engineering, Science, and Technology, Inc.; 1994
Project Manager Training, EA Engineering, Science, and Technology, Inc.; 1994
NEPA Refresher Training, US Forest Service; 1991

Experience:

Resource Management and Planning--- From 1992-1993, was Federal Co-chair of *Exxon Valdez* Oil Spill Restoration Planning Work Group in Anchorage, Alaska. Responsible for developing a restoration plan, and for designing, implementing long-term restoration and monitoring projects for injured resources and human services. Served as member of the Sequim Bay Watershed Management Committee from 1987-1990 and helped prepare the *Sequim Bay Watershed Management Plan*. The Plan focused on mitigation of cumulative effects on salmon and other fishery resources of nonpoint source pollution from timbering, road building, agriculture, marina operations, and failed septic systems throughout the watershed. In 1999, served as member of King County Biological Review Panel with responsibility to evaluate King County policies and programs (e.g., Sensitive Areas Ordinance, Clearing and Grading Code, Surface Water Design Manual, and basin plans) most relevant to conservation of threatened chinook salmon.

Regulatory Compliance----From 1970 to 1990, conducted and managed numerous reviews of Section 316 (a) (b) Demonstrations of Compliance with the Clean Water Act. As a basis for applying Section 316 requirements and procedures, conducted assessments of power plant impacts on marine and estuarine resources. In 1988, performed chemical analyses and bioassays in support of National Pollution Discharge Elimination System (NPDES) Permit renewals at oil industry facilities in Port Valdez and Cook Inlet, Alaska. In 1994, designed monitoring plans to address "special conditions" of NPDES permit renewals at two coastal power plants in California. Following provisions of Endangered Species Act (ESA), in 1995 evaluated agency biological opinion and conducted field studies to assess potential impacts of construction and operation of a proposed gold mine on habitat use by endangered spring and summer run chinook salmon in the Salmon National Forest, Salmon, Idaho.

Environmental Impact Assessment----From 1970 to 1994, conducted and managed numerous studies to assess impacts of technology development on aquatic and terrestrial ecosystems, including wetlands. Assessed environmental impacts for nuclear power plants, petroleum and synthetic fuel refineries, mines and smelters, an acoustic measurement station, a marine mammal holding area, a solid waste management facility, an aviation fuels pipeline, and a bridge. In 1994, directed an environmental assessment of alternate sites for construction of replacement housing at McChord Air Force Base, Washington.

Aquatic Toxicology and Risk Assessment----From 1970 to 1999, studied fate and effects of chemical contaminants in aquatic systems. In 1980, developed exposure pathway models and determined potential ecological and human health risks associated with metals and radionuclides released from a hypothetical uranium mine and smelter at three locations in British Columbia. In 1989, studied persistence of spilled Bunker C fuel oil in beach sediments and in shellfish found intertidally in Olympic National Park, Washington. In 1990, evaluated survey design and sampling procedures to determine the fate of oil refinery and coking plant wastes in sediments and benthic biota in Amuay Bay, Venezuela. In 1995, prepared sampling plans to study fate of metals and organic contaminants in groundwater and marine sediments in Liberty Bay, Washington. From 1996 to 1998, studied ecological risks of combined sewer overflows in the Duwamish River and in Elliott Bay, Washington, with particular interest on potential impacts to out migrating chinook and chum salmon.

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