Puget Sound Notes

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Editors: Lori Scinto and Melissa Pearlman, PSWQAT

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King County forum works to identify sites for nearshore rehabilitation and protection

Marine Science Expert Panel Session

Jacqueline Reid, King County Department of Natural Resources

Balancing the cart and horse in a climate of action

Puget Sound Chinook are listed as threatened under the Endangered Species Act (ESA). To meet federal requirements and mandates under the act, local jurisdictions must develop steps to recover the species. There is an urgent call to action and some available funding, but also an ongoing debate about whether we know enough about habitat utilization, factors of decline, and salmon recovery steps to jump start "on-the-ground" projects. Common questions include: What are the implications associated with waiting for more data? What are the implications associated with moving forward without definitive information for project identification? How, in this climate, is a jurisdiction to achieve a pragmatic balance between action, analysis and planning?

The **Central Puget Sound Watershed Forum**, a consortium of cities within King County and in unincorporated King County (Figure 1), has wrestled with this quandary first hand. The Forum has identified estuary and nearshore rehabilitation as its highest resource management priority and would like to begin design and implementation of site-specific projects to improve nearshore natural systems and resources. (Habitat rehabilitation is distinguished from habitat restoration for the purposes of this paper. While the term restoration implies returning a system to its pre-European settlement state, the term rehabilitation means making improvements to existing conditions in degraded sites, while not necessarily restoring the system to conditions found prior to European settlement.)

Available data indicate that the central Puget Sound basin has been severely modified, presumably resulting in degradation of ecological function and value. An inventory of specific King County nearshore resources is being developed and scientists are completing an analysis of the factors contributing to their decline. This work will assess natural and anthropogenic forces that impede the ability of an ecosystem to meet its expected or historic carrying capacity and productivity. In the nearshore, factors of declining ecosystem functioning might include degraded water quality, interruption of shoreline sediment transport and blockage of fish passage. Completion of an inventory and a factors of decline analysis will facilitate identification of sites for acquisition, rehabilitation and protection with a goal of providing the best opportunities for increased salmon productivity and wildlife utilization. This analysis will necessarily take a couple of years to complete, yet funding for and interest in on-the-ground projects exists now.

Photo courtesy of Washington Department of Ecology: Marina, City of Des Moines, WA (May 1993)

WADNR estimates that almost 80 percent of the eastern nearshore of Puget Sound's central basin has been modified.

Identifying nearshore and estuarine rehabilitation projects: The Marine Science Expert Panel

To capture the moment, the Central Puget Sound Watershed Forum has moved forward to develop projects, adopting the following hypothesis: There is sufficient information and local expertise available to identify specific nearshore sites in King County warranting early action to preserve or rehabilitate natural systems. (Early action can be defined as action to be taken prior to development of salmon recovery plans or longer-term analyses.) In fall 1999, the Marine Science Expert Panel—a group of highly respected scientists (see page 4)—convened to develop a list of nearshore rehabilitation, restoration and protection projects at specific sites in King County. The expectation was that certain sites would be identified for early action based upon existing knowledge and information, without the need to wait for the shoreline inventory and limiting factors analysis to be completed.

Scientists were invited to the Panel based on the following considerations:

- Specific knowledge of King County's nearshore (mainland and Vashon/Maury Islands)
- Expertise in specific nearshore disciplines

Two major outcomes of the Expert Panel were desired:

- Develop a list of specific projects on King County's nearshore for early action based on ecological and technical considerations
- Create ecological criteria for use in evaluating future proposed projects for early action

Through preservation, restoration, or rehabilitation, identified projects would protect or improve ecological functions of King County's nearshore systems, resulting in increased fish and wildlife utilization and productivity.

These so-called "no regret" projects could be identified and put on a fast track for detailed assessment, design, funding and implementation. Identifying early action sites would not require completion of a detailed nearshore inventory. (Projects identified as "early action/no regrets" may not necessarily represent the highest priority projects. Development of the highest priority projects might not be known until completion of the more detailed nearshore inventory currently underway. Projects identified on the following page represent those considered in the meeting to have sufficient value for future assessment and a sufficient likelihood of success in meeting the stated goal.)

Meeting preparation

Prior to the meeting, members of the Expert Panel were asked to submit site-specific projects in King County's nearshore worthy for consideration as early action/no regrets sites. The members were asked to consider how each project would measure against the following screening devices:

How important is the project? Is the project expected to have significant influence on ecological processes and functions both at the scale of the site itself and systemwide (central Puget Sound basin-scale)?

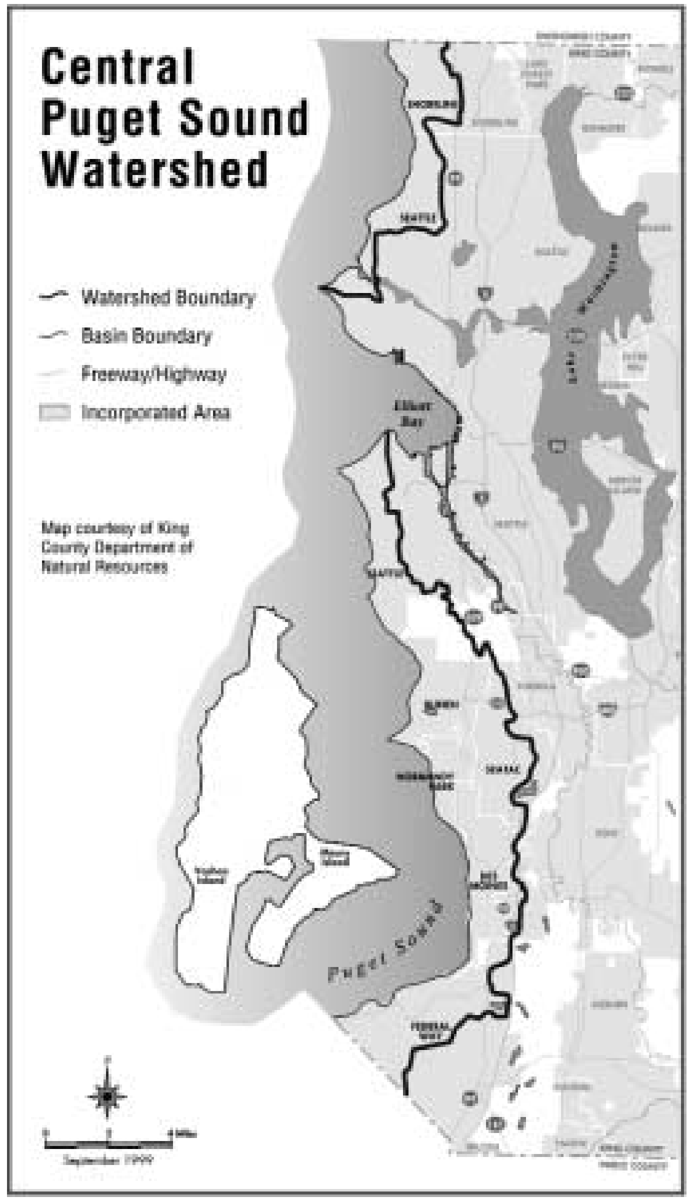


Figure 1.

What is the likelihood that this is a **no regrets** project? Do we know enough about the site (scientific factors) to be able to promote it and move it into a design phase; i.e., is this a project where we could, with a degree of confidence, move forward without having to wait for more data?

Panel members were given the following disclaimer: It is recognized that (1) more data is always desirable and (2) uncertainty of specific outcomes is intrinsic in the development of natural resources projects. Use of "adaptive management" to address this intrinsic uncertainty will be advocated for all potential projects. Receptivity by managers and policy makers to the unknowns inherent in managing natural resources and a willingness to take responsible risks for the greater good of resource protection are approaches increasingly being embraced. (Adaptive management acknowledges that management activities can be improved by learning from mistakes. In developing a list of no regrets projects, the Panel accepts that responsible risk-taking and adaptation to lessons learned is an appropriate management approach.)

Meeting results

Criteria

Panel members were asked to brainstorm criteria that should be considered in the exercise to develop early action/no regrets projects. Criteria were developed separately for:

- **Importance**
- **No Regrets**

The lists below represent the criteria established by the panel for the two categories.

EXPERT PANEL MEETING—CRITERIA FOR IMPORTANCE FOR EARLY ACTION PROJECTS:

- Improves linkages between natural processes
- Availability of property
- High probability of ecological success
- Makes a pertinent improvement in habitat
- Replicates or restores natural processes
- Contributes to research
- Improves linkages in systems that affect declining species
- Addresses habitat displaying identified limiting factors to ecosystem health
- Measurable outcomes possible
- Location connected to areas where similar habitat destroyed
- Associated with natural and protected shorelines
- Removes existing threat or ongoing harm
- Helps ESA-listed species
- Problem is recognized by public
- Has wide applicability across the landscape and is repeatable at other locations
- Low engineering and low maintenance needs
- Now or never: threat of loss if no action taken in near term
- Finite time for completion certain
- Protection in perpetuity after completion
- Likely to be funded
- Appropriate scale: larger is better
- Will spur other shoreline rehabilitation/restoration/preservation actions

EXPERT PANEL MEETING—CRITERIA FOR NO REGRETS EARLY ACTION PROJECTS:

- Already nominated/being pursued
- Enhances public access
- Addresses future information needs
- Addresses potential "lost opportunities"
- Doesn't preclude other options
- Addresses many trophic levels
- Has a pre-/post-monitoring component so we can learn from it
- Project not compromised by dynamic of the system
- Unlikely to have to do major fixes
- Not be stirring up other toxics
- No major adverse risk to crucial resources/habitats
- Low cost
- Long-term viability
- Benefits to the public obvious
- Protects important habitat
- Long-term benefits
- Good educational component
- Integrate different habitat types
- Absence of objections

The Expert Panel identified the following sites and general projects for consideration for more detailed assessment for early action. The Panel focused on sites in the central Puget Sound watershed area. While a number of sites and projects were discussed, the following four specific sites and one general classification of sites elicited the most interest and discussion.

1) Shilshole Bay Fish Passage Improvements

Passage of both adult and juvenile salmon between the fresh water of the Lake Washington basin and the marine environment of Puget Sound is known to be problematic. Currently, the U.S. Army Corps of Engineers, Muckleshoot Indian Tribe, Washington Department of Fish and Wildlife, King County and City of Seattle are conducting studies to improve salmon passage at the Hiram Chittenden Locks. Early action/no regrets projects that would complement existing work on fish passage improvements include:

- Preservation of identified valuable habitat through incentives, purchases or easements
- Enhancement of native riparian vegetation to increase the availability of prey for juvenile salmon

2) Dumas Bay/Joe's Creek Rehabilitation

An eelgrass project is already being planned for Dumas Bay. Complementary rehabilitation efforts at Joe's Creek were supported by the Panel for early action. Improvements included:

- Bank stabilization
- Placement of large woody debris
- Culvert improvements in Joe's Creek

3) Quartermaster Harbor/Judd Creek/ Ellisport Creek/Portage

Vashon and Maury islands provide most of the pristine nearshore habitat of King County. Potential areas of focus include:

- Preservation projects (purchases and conservation easements) in Quartermaster Harbor and Judd Creek
- Water quality improvements in Quartermaster Harbor
- Purchase of Ellisport Creek mouth, riprap removal and culvert modifications
- Restoration of salt marsh at Portage (the strip of land connecting Vashon and Maury islands)

4) Golden Gardens Railroad Grade

Potential projects associated with the railroad grade north of Golden Gardens included:

- Developing demonstration projects on alternatives to bulkheads
- Reconnecting uplands with shoreline by elevating parts of proposed track for a commuter line
- Placing sediment along nearshore corridor at drift convergence zone and monitoring movement along shoreline. Considering side-dumping from railroad or barge-dumping of dredged Snohomish River sediments
- Engineering logjams
- Studying the Woodway slide

5) General Habitats

Habitats/substrates of key importance to migrating juvenile salmon were identified and acknowledged as critical for consideration of early action projects:

Stream mouths – for refuge and feeding (Pipers Creek and Des Moines Creek were identified as potential rehabilitation sites)

Eelgrass/mudflats – for refuge and feeding between stream mouths

Fine sediments – for beach development

As a general observation, the Panel identified the need for tracts of habitat as a key consideration in developing projects to support successful juvenile salmon migration in the nearshore. In addition, the Panel underscored the importance of considering shoreline-hardening and overwater structures and their cumulative effects on the development of management policies.

Conclusions: Learning by doing

At the end of the meeting, it was determined that there were a few issues of caution. First, because other groups were going through similar exercises, the Central Puget Sound Watershed Forum wanted to avoid duplication of effort from both process and geographic standpoints. Second, with respect to meeting the identified goals for the session, it was acknowledged that significant expectations had been set and considering the work session was only one day long, the goals had perhaps been too ambitious.

Despite caveats, the meeting provided the guidance needed to move forward in implementing site-specific rehabilitation projects in King County's nearshore. It was agreed that there was sufficient knowledge available to identify potential projects, but that each of the projects needed to be more thoroughly fleshed out. Clearly some additional assessment of identified projects is needed before projects can be promoted for early action. Finally, the Expert Panel met the goal of developing criteria that could be used in evaluating future projects.

Other observations from the meeting included the following:

Sufficient information and knowledge seems to exist to allow exploration of early action projects without the need to wait on more detailed, long-term assessments. There are limitations that must be acknowledged, however:

- In the absence of more detailed assessments, the highest priority projects might not be the ones chosen.
- Nearshore rehabilitation is not an exact science. There is value in designing projects for experimental and research purposes.
- Identified projects will require additional ecological and technical assessment before implementation of the projects at specific sites.
- This is an iterative process; the process used to identify projects and criteria for screening projects should not be viewed as definitive. The process and the criteria can act as a model and a starting point for future evaluations.
- There is a wealth of marine science expertise in our region. Subsequent to the convening of the Expert Panel, the Central Puget Sound Watershed Forum developed the Nearshore Technical Committee. The Nearshore Technical Committee is composed of many of the scientists from the Expert Panel, along with additional marine scientists. The Committee will be developing an assessment of nearshore conditions in King County, and will include identification of projects to improve or preserve ecological functioning in the nearshore environment.

EXPERT PANEL MEMBERS:

Gail Arnold- *Seattle Public Utilities*
George Blomberg- *Port of Seattle*
Jim Brennan- *King County Department of Natural Resources*
Bob Brenner - *King County Department of Natural Resources*
Pat Cagney - *United States Army Corps of Engineers*
Jon Houghton, Ph.D. - *Pentec Environmental*
Steve Jeffries - *Washington State Department of Fish and Wildlife*
Tom Mumford, Ph.D. - *Washington State Department of Natural Resources*
Dave Nysewander - *Washington State Department of Fish & Wildlife*
Dan Penttila - *Washington State Department of Fish & Wildlife*
Klaus O. Richter, Ph.D. - *King County Department of Natural Resources*
Hugh Shipman - *Washington State Department of Ecology*
Allan Solonsky - *Seattle City Light*
Charles (Si) Simenstad - *University of Washington School of Fisheries*
Kim Stark - *King County Department of Natural Resources*
Ron Thom, Ph.D. - *Battelle Marine Science. Laboratory.*
Jacques White, Ph.D. - *People for Puget Sound*

The disciplines represented in the panel included coastal geomorphology; oceanography; aquatic biology and ecology (sea grasses; kelp; saltmarshes; estuaries; fisheries; shellfish; birds; mammals); water quality; hydrology; and coastal engineering.

Credits: Acknowledgement is given to the King Conservation District for funding the Expert Panel meeting, the Central Puget Sound Watershed Forum for hosting the Panel, the scientists for providing their time and input, staff from forum jurisdictions for designing the event, and Ross and Associates Environmental Consulting Ltd. for meeting facilitation.

Innovative process reduces turbidity and pollutants from construction site stormwater runoff

The polymer-assisted stormwater clarification process was originally developed by Chris Heger of Sellen Construction and Guy Oliver of the City of Redmond with the guidance of Ron Devitt of the Department of Ecology.

Please refer all inquiries about this article to Guy Oliver, lead inspector, City of Redmond, 425-556-2725.

Abstract

Experience at six construction sites has demonstrated that treatment of stormwater runoff with polymers provides a 95 to 99 percent reduction in turbidity and associated pollutants. Acute bioassays have shown that Calgon Catfloc 2953, the polymer currently in use, is not toxic at the concentrations necessary for effective treatment. Cost of using the polymer has ranged from 0.5 to 1 percent of the total construction cost. Contractors have expressed satisfaction with the system.

Introduction

The city of Redmond, Washington, wanted to document experiences with the use of polymer-assisted stormwater clarification at six construction sites. This paper is a summary of a more extensive report (Resource Planning Associates, 1998) and covers a general description of the treatment system, regulatory requirements, process experience, polymer dosage rates, removal efficiencies and costs.

Experience at the six construction sites has shown that polymer-assisted clarification provides exceptional reductions in turbidity and associated pollutants. Initial turbidities of several hundred to several thousand NTU (Nepholometer Turbidity Units) were routinely reduced to less than 10 NTU, frequently to less than five NTU and sometimes to below 1 NTU. The median turbidity of the discharges from the six sites ranged from four to 11 NTU. Phosphorus was typically reduced by 95 to 99 percent, to concentrations of less than 0.025 mg/L.

Polymer-assisted clarification provides more effective reduction of stormwater pollutants than the standard erosion and sediment control best management practices (BMPs), such as silt fences, temporary site cover and sediment ponds. The turbidities of the untreated stormwater represent what would be expected from a site if standard BMPs were used. Polymer-assisted clarification reduced these values by 95 to 99 percent. Without polymer-assisted clarification it is likely that water quality standards are frequently not met at construction sites using currently accepted BMPs.

Acute bioassays with juvenile rainbow trout (*Salmo gairdneri*) and two species of daphnia (*Daphnia magna* and *Daphnia pulex*) have shown that Calgon Catfloc 2953, the polymer primarily used in treatment, is not toxic at the concentrations necessary for effective turbidity reduction. Further, the concentration likely to cause toxicity is considerably greater than that required for turbidity reduction. This is an important environmental safeguard. The tests found it is not the polymer itself that is toxic, but rather the tendency of the polymer to reduce the pH of the stormwater to toxic levels. The addition of baking soda to raise the alkalinity can prevent the pH from becoming too low. At the polymer dosages routinely used, the alkalinity of the stormwater needs to be about 50 mg/L. Operating the treatment system in a batch mode after each storm, rather than as a flow-through system during the storm, adds considerable operational control and environmental protection.

The Reason For Treatment

The city of Redmond is located in the Seattle metropolitan area. A rapidly growing community, Redmond requires site developers to use BMPs such as silt fences and temporary cover to control erosion and sediment during site development. However, these standard BMPs do not reduce turbidity and sediments to the level desired by the city or required to meet state water quality standards for receiving waters. Several salmon-bearing streams are located within the city and the city has therefore sought methods to improve the control of sediments from construction sites.

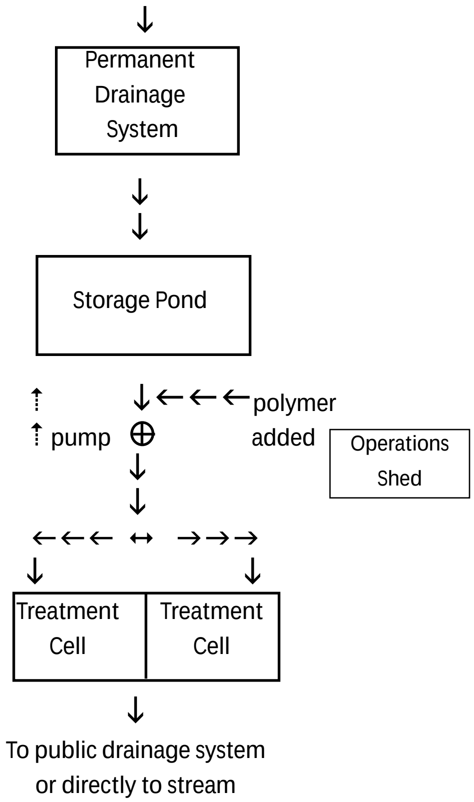
State water quality standards limit the increase in turbidity above the background (natural) turbidity of the receiving waters to five NTU. During a storm, the background turbidity in streams is typically on the order of 25 to 75 NTU. In contrast, the turbidity of stormwater from construction sites routinely exceeds several hundred NTU, even with effective use of standard BMPs. Consequently, the turbidity standard may not be met in the small streams common in the Pacific Northwest.

The Treatment System

Figure 1 (page 6) is a schematic diagram of the polymer treatment system. Site conditions have resulted in variations between the six sites in this assessment. Typically, stormwater is collected by the permanent drainage system and/or the building excavations and is stored for treatment. The stormwater is then treated in batches and released. The polymer injector, secondary containment for acid, and monitoring equipment consisting of meters for pH, turbidity and conductivity, are located in a small operations shed.

The first step is to check the pH of the stormwater in the storage pond because it is frequently not within the range of 6.5 to 8.5, which is the optimum range for treatment with the polymer. Exposure of the stormwater to recently poured concrete elevates the pH. In the absence of this activity, the naturally acidic nature of stormwater can produce a pretreatment pH lower than 6.5. Acid or baking soda is added depending on the pH of the stormwater. Baking soda increases alkalinity, needed to buffer against the tendency of the polymer to lower the pH. Acid is added immediately downstream of the transfer pump as the water is circulated from and back to the storage pond. Baking soda is added directly to the storage pond and water is similarly recirculated until the pH is within the proper range. The stormwater is then pumped from the storage pond to a treatment cell while polymer is added. Two

FIGURE 1. SCHEMATIC OF THE TREATMENT SYSTEM



treatment cells are always provided to allow settling of treated water in one cell while the second cell is filled.

The period of settling in each treatment cell ranges from a few hours to several days. However, excellent clarification typically occurs within a few hours. The most common practice has been to settle the water overnight. After settling, the water is discharged from the treatment cell via a float device holding the discharge line. The float has adjustable struts that prevent it from reaching the bottom of the cell. This reduces the possibility of picking up previously settled sediment from the bottom. The struts are usually set to provide a clearance above the bottom of about 12 inches. Samples are taken from the surface or near-surface of the cell and analyzed for turbidity and other parameters.

Prior to and early in the operation of the first two sites, several polymers were evaluated for effectiveness and toxicity. Catfloc 2953 was found to be the most effective.

Regulatory Requirements

The city of Redmond and Washington State specify facility size, operational procedures, and reporting requirements for stormwater treatment. The city does not require the contractor to use the polymer treatment system. Rather, the city states that the contractor must meet the receiving-water standard for turbidity. Experience has shown that it is not possible to meet the standard if the contractor wishes to work during the wet season (approximately mid-October to mid-May) unless some form of treatment is used. The choice then rests with the site owner as to whether to work during the wet season or employ a polymer treatment method that will achieve the standard.

The city specifies that the discharge rate of the treated water from the site not exceed 50 percent of the 2-year event unless treatment occurs during a storm larger than the 10-year event (in which case the allowable discharge rate is that of the 10-year event). The city has not specified the size of the polymer treatment facilities. It requires that an experienced contractor train each contractor using polymer treatment for the first time. This has been accomplished by experienced contractor staff assisting new contractors with startup operation of the system.

The use of polymers to treat stormwater requires a permit from the Washington State Department of Ecology. To date, Ecology has limited the use of polymer-assisted clarification to construction sites with disturbed areas equal to or greater than five acres.

The Department of Ecology's requirements are contained in its permit. With the exception of the first permitted site, Ecology has specified the size of the "treatment/retention/detention ponds." The specification has changed as permits have been issued for the six sites—a reflection of the experience gained with polymer-assisted clarification at previously permitted sites. In the most recent permits, the specification requires retention of the average volume of rainfall in the 1-day/24-hour, 100-year event.

As confidence in the treatment system grows, the amount of toxicity testing has been reduced. Currently, at each new site, the practice is to run bioassays on the first five to 10 batches, or until such time as the dosage rate has stabilized. Acute tests are run with rainbow trout and *Daphnia pulex*.

Ecology has specified that monitoring include sampling for turbidity, settleable solids, conductivity, pH, total suspended solids, total phosphorus, ammonia and hardness prior to and after treatment. With the exception of the last three parameters, the measurements are to be made each day of operation and recorded on a form. Although not required, contractors have also recorded the total volume treated, the type and amount of chemical used for pH adjustment (acid or baking soda) if it occurred, and the approximate settling time of the treated water before discharge on each day of treatment.

As part of the permit, the site owner is required to prepare and follow a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP outlines all aspects of pollutant control, not just erosion and sediment control. The SWPPPs have typically included testing at one or more locations downstream of the site, to be certain that water standards are being met.

Process Experience

Table 1 (page 7) presents information about each site and treatment system. All sites are commercial developments with multi-story office buildings. Five of the six sites involve multiple buildings. The site areas vary from seven to 65 acres.

A storage requirement was not specified for Site 1 partly because it was the first site permitted when criteria were still under development and also because the treated stormwater was disposed of by infiltration. Sites 3, 4 and 6 were the next sites to be permitted and received what most might consider to be a very conservative criterion: the 7-day/100-year event, which represents the maximum total rainfall over a seven-day

TABLE 1. SITE INFORMATION

SITE	AREAS (acres)	SITE SLOPE (percent)	PERIOD OF OPERATION	RELEASE RATE (gallons/minute)
1	65	flat	February '96 to January '97	NA
2	15	5 to 10	June '96 to February '97	500
3	7	flat	November '96 to June '97	250
4	18	0 to 5	October '97 to December '97	250/90
5	20	3 to 5	September '96 to April '98	200
6	9	flat	September '97 to April '98	75

TABLE 2. SUMMARY OF TREATMENT VOLUME INFORMATION

		STORAGE VOLUME			TREATMENT CELLS		
System	Area	# Ponds	Total (CF)	CF/Acre	# Cells	Total (CF)	CF/Acre
2A	6.6	1	9,750	1,477	1	9,750	1,477
2C	8	1	12,300	1,538	1	2,300	1,538
3	7.2	1	57,500	7,968	2	13,400	1,861
4 #1	18	3	719,000	39,950	4	121,400	6,744
4 #2	12	1	55,700	4,642	2	24,000	2,000
5 #1	20	3	58,200	2,910	4	10,884	544
5 #2	20	3	58,200	2,910	2	19,287	964
6 #1	9	3	56,550	6,283	3	56,550	6,283
6 #2	9	3	71,200	7,911	3	71,200	7,911

**All storage was done in the building excavations, subsequently underground parking garages.*

TABLE 3. PERFORMANCE

	POLYMER DOSAGE (mg/L)		INFLUENT TURBIDITY (NTU)		EFFLUENT TURBIDITY (NTU)		pH CONTROL	
SITE	RANGE	MEDIAN	RANGE	MEDIAN	RANGE	MEDIAN	FREQ[1]	TYPE[2]
1	25 – 250	75	12 - 2,960	200	1 - 45	6	45 percent	acid
2	10 – 200	100	31 - 4,700	2,000	1.9 - 39	11	16 percent	both
3	50 - >100	100	12.9 - 900	150	0.5 - 45	7	18 percent	soda
4	50 – 200	100	8 - 4,000	400 <	1 - 32.5	6	0 percent	-
5	300 – 400	350	2780 - 17,000	14,000	0.8 - 23	8	97 percent	soda
6	85 – 140	110	17 - 6,650	117	1.7 - 18	4	85 percent	both

[1] Approximate percentage of batches in which pH adjustment occurred

[2] Most frequent form of pH adjustment: baking soda or sulfuric acid

period with a 100-year return frequency (about seven inches in the mild marine climate of the coastal Pacific Northwest). For the more recently permitted sites, the requirement was diminished to 24-hour rainfall, which is about four inches. The “allowable release rate” refers to the rate at which the stormwater can be discharged from a treatment cell.

Table 2 presents information on unit process volumes. Information for Site 1 is not included. It had three systems operating at various overlapping periods, preventing the matching of each treatment system to its catchment area. At three of the sites more than one system was used, either because of the demands of site topography (Sites 2 and 5) or because of project phasing (Sites 4 and 6). The unit volumes of the storage facilities and treatment cells varied considerably between the sites. The variation was due to site constraints, the varying ability to use building excavations to store untreated stormwater and differences in permit requirements. The large storage volume allowed the contractors to treat the stored stormwater between storms rather than during each storm.

The system configuration at each site differed to some extent from the basic system previously described. For example, Site 2 had two systems treating different portions of the site at different periods. Each system consisted of one pond split by a wall with one half serving as the storage pond and the second half serving as the treatment cell. Stormwater was intercepted in the building excavations from which it was pumped to the respective ponds. Site 3, on the other hand, had one large pond split into three bays. The largest bay served as the storage pond and two equally-sized but considerably smaller bays served as the treatment cells.

The allowable discharge rate was the peak, rather than 50 percent, of the 2-year event prior to development of the land because of the large capacity of the public storm drainage system receiving the treated stormwater. The volume per acre of storage varied between sites because of the two different criteria: one- versus seven-day rainfall.

Table 3 presents a summary of operating performance data. All sites achieved excellent performance. Median turbidities of the untreated stormwater varied between the sites. The reason(s) for the variation between the sites as well as within the sites is not known. Possible reasons for variations in median turbidities between the sites are the differences in the slopes, percentage of fines in the soils, and application of standard BMPs upstream of the treatment systems. Site 5 had a substantially higher turbidity, which the contractor attributed to more fines and less aggressive application of the standard BMPs (the contractor had also worked at Site 3). While all sites had essentially the same type of soil, the site soils were not characterized with respect to the percentage of fines.

No correlation was found within each site either between polymer dosage and effluent turbidity, between influent and effluent turbidity, or between settling time and effluent turbidity. The settling time at all sites was typically overnight, but there were many instances of settling times of only a few hours. These short settling times did not appear to adversely affect final effluent quality.

There appears to be some difference between Sites 2 and 6, the sites with the highest and lowest values, respectively, for median effluent turbidity. The highest median effluent turbidity, found at Site 2, could be due to the site's higher median influent turbidity. It could be also due to the fact that Site 2 was one of the first sites to use the polymer system when experimentation was still underway.

Contractors at Sites 2 and 6 attempted to enhance flocculation (the process by which small particles are aggregated into larger particles to increase the rate of clarification) by recirculating the water for one to three hours after the polymer was added. Site 2 had the highest median effluent turbidity while Site 6 had the lowest. The benefits of recirculation are therefore not clear. It is possible the pump was inhibiting good floc formation. This tends to happen with high molecular weight polymers. However, Calgon 2953 is a low molecular weight polymer, relatively speaking, and therefore floc breakup by the pump is not likely. Alternatively, the pump may not provide sufficient energy for effective flocculation. More data are needed with regard to settling times, polymer dosages, and their relationships to final turbidity before firm conclusions can be drawn about the benefits of recirculation.

The median polymer dosage rate was essentially the same at all six sites, except for Site 5. The reason(s) for Site 5's difference with regard to dosage rate is not entirely clear. The operating period at Site 5 was too short to allow complete evaluation of the question. The much higher influent turbidity is a factor and a secondary factor may be iron interference. Site 5 used Baker tanks as the treatment cells. It is possible that iron entering the stormwater from the tank walls decreased the effectiveness of the polymer.

As noted previously, Department of Ecology permits required periodic sampling of several chemical parameters. The data show effective reduction of all these constituents; removal efficiency typically exceeded 95 percent, and frequently exceeded 99 percent.

The amount of sediment removed from each site was substantial. With few exceptions, the ponds were cleaned once each operating season and at the time of decommissioning. The sediment was either disposed of on site or trucked to an appropriate landfill.

All sites continued to use standard erosion control BMPs such as silt fences, temporary cover of inactive areas and asphalt lining of temporary drainage ditches in addition to polymer treatment. All contractors reasoned that continued use of these BMPs within the site would reduce the costs of operating the polymer system. However, several contractors indicated that their use of the standard BMPs was less intensive, given the presence of the treatment system. Treatment allowed the contractors to be somewhat more relaxed with regard to being on site during major storms to check the BMPs.

Contractors' Views of the Treatment System

Contractors like the polymer treatment system. The principal advantages identified by the contractors are the system's speedy removal of fine sediments and its reliability compared with standard BMPs. They also said the system gives them the ability to work through the wet weather season; creates less stress about tending to standard BMPs during storms; and gives more positive control on the quality of the stormwater.

Cost

With any new system the costs prior to and after treatment are often greater than the costs over the long run. Developers provided cost information in different formats. Two provided cost as a percentage of the total construction cost: 0.8 percent and 1.5 percent. A third developer said the treatment system cost about one dollar per square foot of building footprint. Two developers provided an estimate of the breakdown of costs according to the categories presented in Table 4. The cost of the treatment system is offset by reduction in the use of within-site BMPs and in some cases, the use of the permanent detention system for a portion of the treatment storage. It is believed that the net cost of the treatment system ranged between 0.5 and 1 percent of the total construction cost, and will likely decrease further as contractors gain experience with the method.

TABLE 4. APPROXIMATE BREAKDOWN OF COSTS

COST CATEGORY	BREAKDOWN RANGE
Temporary storage and treatment ponds	40 to 54 percent
Piping, pumps, operation shed, polymer equipment	24 to 34 percent
Labor	9 to 10 percent
Chemicals	4 to 5 percent
Sediment disposal	3 to 12 percent
Monitoring consultant and laboratory costs	5 to 10 percent

Recent Developments

Other communities in the Pacific Northwest are now using the polymer treatment system. Two other coagulants are being tried: alum and chitosan. Various filtration methods are also being tried at several construction sites to reduce or eliminate the need for treatment cells. The Department of Ecology has removed the restriction that the treatment system be used only on sites greater than five acres.

References

Department of Ecology, *Stormwater Management Manual for the Puget Sound Basin*, 1992.

Resource Planning Associates (RPA). (1998.) Polymer-Assisted Clarification of Stormwater from Construction Sites. 45 pages plus a supplement for Site 7 completed subsequent to the report.

Cruising with PRISM:
Student monitoring contributes to our understanding of Puget Sound water quality

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The Puget Sound Regional Synthesis Model (PRISM) is a program that began in 1997 with funding from the University of Washington (UW). External grants and partnerships with organizations throughout the region have also provided significant sources of funding. PRISM was created by UW faculty, staff and students. It aims to promote education and research about Puget Sound, with the goal of aiding regional planning. Through PRISM-sponsored cruises on UW's 274-foot research vessel Thomas G. Thompson, college students are learning oceanographic and environmental sampling techniques. As a result, these students are helping UW and Puget Sound Ambient Monitoring Program (PSAMP) scientists gain further oceanographic knowledge about the Puget Sound ecosystem.

PRISM's objective is to develop a dynamic, integrated description of the environmental and societal factors that shape the Puget Sound region as it moves into the 21st century. The integrating theme is the movement of water through the atmosphere, across the land, into rivers and streams and throughout the waterways of Puget Sound. Visit PRISM's Web site at **http://www.prism.washington.edu/** for examples of PRISM in action.

PRISM has been funding data collection on cruises aboard the research vessel Thomas G. Thompson with the joint purpose of gathering oceanographic data from Puget Sound and educating and involving both undergraduate and graduate students in data collection and analyses. The ship time for these cruises is funded by the State of Washington in an ongoing education partnership with UW. There have been five cruises so far: June and December 1998, and June, August and December 1999. A sixth cruise is planned for June 2000. On each four-day cruise, 39 stations are sampled, ranging from south Puget Sound to the Strait of Juan de Fuca and from Hood Canal to Whidbey Basin. Data collected include basic hydrographic data (salinity, temperature, density, depth) as well as nutrient, oxygen, chlorophyll, phaeopigment and light/depth profiles. Special sampling for chlorofluorocarbons, primary productivity, plankton, and stable isotopes also occurs at some stations. The PSAMP partners, including the marine waters monitoring and assessment groups from the Washington State Department

Students aboard the research vessel Thomas G. Thompson sample a rosette of water bottles for water quality variables such as dissolved oxygen, nutrients and chlorophyll.

Photo by Ruth Fruland

of Ecology (Ecology) and the King County Department of Natural Resources (KC-DNR), have also participated in these cruises. Student participation is essential to the success of PRISM. There have been as many as 16 students onboard in past cruises. It would be difficult to accomplish the volume of work on these cruises without the volunteer labor of the students, but it is a two-way positive exchange. Students receive direct training in marketable skills, such as how to sample and analyze water quality variables like dissolved oxygen (see photo), how to operate the computer interfaces that run the automated sensors and how to collect and organize environmental data. Since PSAMP scientists from Ecology and KC-DNR participate, students also meet and work with scientists who can provide future job and internship contacts. The students are recruited from UW oceanography classes and from announcements.

Data from the PRISM cruises are used for analyzing oceanographic processes and water quality and provide critical insight into the dynamic processes that occur in Puget Sound. The data complement the information provided by PSAMP marine waters monitoring programs. For instance, Ecology must split its sampling of Puget Sound (done with a seaplane) into three separate flight days on consecutive weeks in order to cover stations spanning from north to south. However, the comprehensive transects completed on the four-day PRISM cruises provide a synoptic snapshot of properties Soundwide. These combined processes will allow Puget Sound scientists to gain a better sense of spatial and temporal variation in the estuary as well as the mechanisms that are responsible for these variations.

Adding to the current database of Puget Sound's hydrography is a high priority for the purpose of assessing year-to-year and long-term changes in the Sound's condition. Differentiating water quality impacts from humans versus climate variation requires a comprehensive data baseline as well as an understanding of mechanisms. The circulation of Puget Sound waters reflects a delicate balance between input of freshwater from rivers and input of saltwater from the Pacific Ocean. Both riverine and oceanic waters are strongly affected by climatic variability, on interannual to decadal time scales and beyond. For instance, freshwater input depends on the amount of seasonal rainfall and may fluctuate along with the El Niño-Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO); oceanic input is affected by coastal winds and other weather-related anomalies. Evidence for impacts from climatic variability on hydrographic measurements has been observed in data collected by PRISM and PSAMP.

Another important use of the data collected on PRISM cruises is as input values for models of the physical, chemical and biological aspects of Puget Sound developed by PRISM. A hydrodynamic model has already been constructed for Puget Sound, and a team of UW, Ecology and KC-DNR scientists is currently working on a biological/chemical model. For more information on the hydrodynamic model, see **http://www.prism.washington.edu/science/projects/circ.html**, and for more information on the biological/chemical model, see **http://www.prism.washington.edu/science/projects/nutrient.html**.

An example of the scientific collaboration fostered by the PRISM-PSAMP connection is the investigation of dissolved oxygen dynamics in Hood Canal. Through the PRISM cruises, recent cruises funded by Ecology, and UW student cruises, we (Newton and Warner) have been studying low dissolved oxygen concentrations in Hood Canal. Hood Canal is known to undergo seasonal depletion of oxygen in its bottom waters; however, it is not well known whether the condition is worsening with time. Ecology has collected data that indicate that the temporal duration and spatial coverage of the waters with low dissolved oxygen content may be increasing over that recorded by UW in the 1950s. However, there is uncertainty about the factors that may be involved (Newton et al. 1998); eutrophication, changes in circulation due to changes in freshwater delivery, the effect of the Hood Canal floating bridge, and climate variation all need to be considered. UW and PSAMP scientists have been studying oxygen concentrations in Hood Canal for several years (*Puget Sound Notes, Issue #37, 1995* article by Glen Shen) and greatly benefit from the added data collected on the PRISM cruises.

Figure 1 (page 11) portrays a transect down the main axis of Hood Canal showing dissolved oxygen concentrations collected over several months. This is an example of the type of data collected on PRISM cruises. The April transect was collected during the spring UW undergraduate class cruise, the June transect on a PRISM cruise, and the others during cruises supported by a one-time grant by Ecology.

The data in Figure 1 show that low dissolved oxygen concentrations (below 5 mg/L) persisted in the bottom waters of Southern Hood Canal throughout 1998. Oxygen concentrations were low despite flushing that occurred during summer months due to an intrusion of high salinity and high temperature waters from the main basin. Interestingly, Hood Canal appeared to flush in the summer of 1998 but not in the winter preceding it, as is more typical. Our hypothesis is that flushing did not occur in Hood Canal during the fall-winter of 1997-98 due to suppression of coastal upwelling during the 1997-98 El Niño and thus a lack of high-density cold, salty waters intruding into Puget Sound. Work by Warner shows that chlorofluorocarbons are proving to be highly useful as conservative tracers to track water mass movement within Hood Canal. With a longer time-series provided by data collected through projects such as PRISM, we are hoping to further understand the variation in dissolved oxygen in Hood Canal and whether humans or other stressors are affecting the dissolved oxygen content.

As this example shows, there is much that we do not understand regarding Puget Sound water quality. The key to developing a better understanding is increased observations and a multi-faceted approach. Modeling and additional observational techniques and analyses all can enhance our emerging view of the Puget Sound ecosystem. The PRISM program adds significantly to these goals and actively involves students in the process.

FIGURE 1 (page 11). Example of the type of data collected from transects down the main axis of Hood Canal showing dissolved oxygen concentrations collected over several months.

Numbers 1 - 12 on the upper x axis of graphs A, C, D and E represent Department of Ecology's monitoring stations in Hood Canal.

Numbers 7 - 17 on graph B represent PRISM's corresponding monitoring stations in Hood Canal.

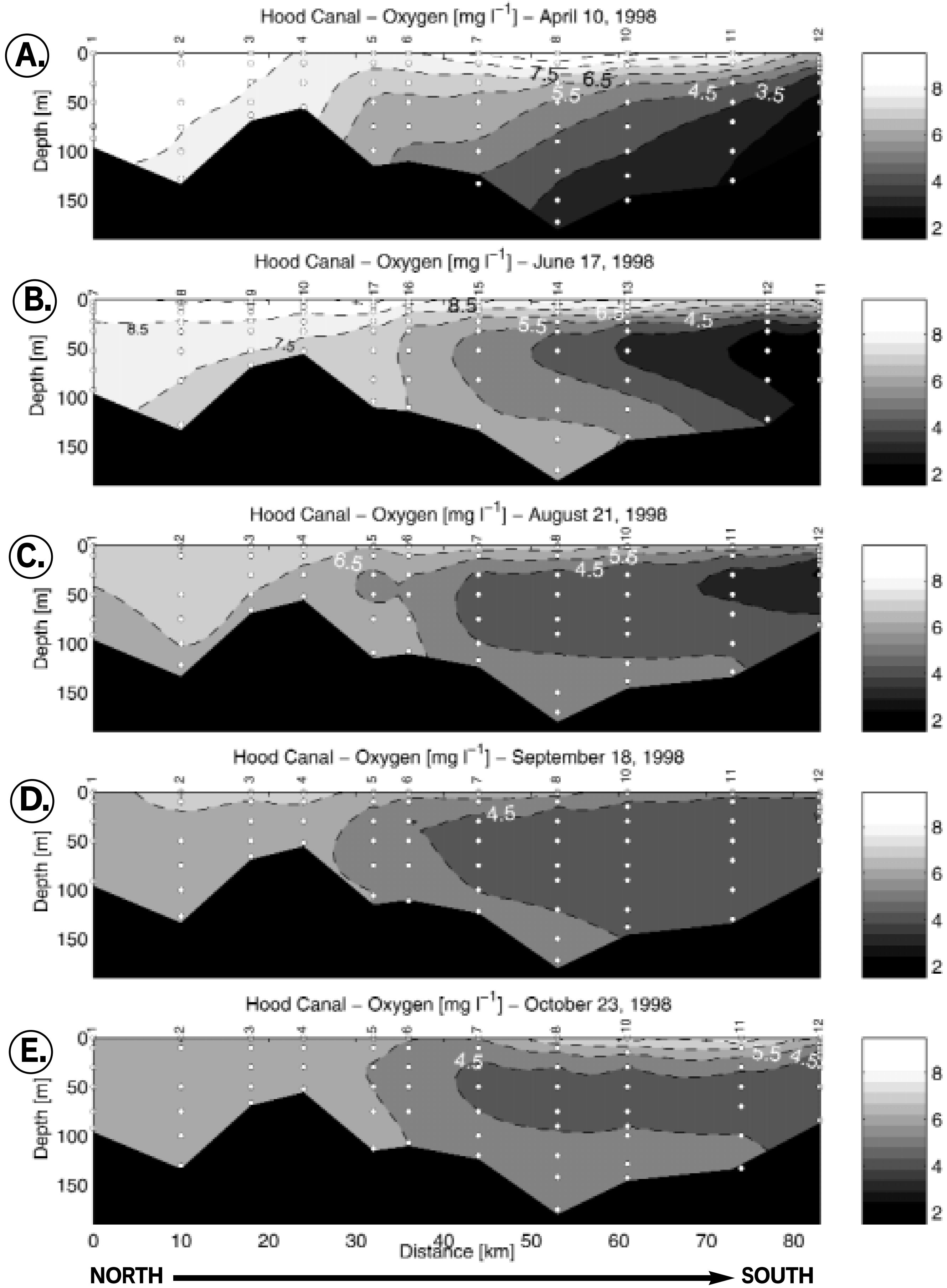
Station 1 (7 on graph B) is located in Admiralty Inlet and Station 12 (11 on graph B) is located in The Great Bend of Hood Canal. Distance on the lower x axis of the graphs represents distance from Station 1 (or 7 on graph B).

(Graphic created by Mark Warner)

References

Newton, J.A., S.L. Albertson, K. Nakata, and C. Clishe. 1998. *Washington State Marine Water Quality in 1996 and 1997.* Washington State Department of Ecology Environmental Assessment Program. Olympia, WA.

Figure 1


Hood Canal – Oxygen [mg l⁻¹] – April 10, 1998
A.
Depth [m]
7.5
6.5
5.5
4.5
3.5
Hood Canal – Oxygen [mg l⁻¹] – June 17, 1998
B.
8.5
7.5
5.5
6.5
4.5
Hood Canal – Oxygen [mg l⁻¹] – August 21, 1998
C.
6.5
4.5
5.5
Hood Canal – Oxygen [mg l⁻¹] – September 18, 1998
D.
4.5
Hood Canal – Oxygen [mg l⁻¹] – October 23, 1998
E.
4.5
5.5
Distance [km]
NORTH
SOUTH

Corrections and errata:

• In Issue #42 of *Puget Sound Notes* (June 1999), the non-indigenous species, *Nippoleucon hinumensis*, was described on page 8 as a copepod crustacean. This species should have been described as a **cumacean**.

• Two errors were discovered in the initial printing of the *2000 Puget Sound Update.*

Figures 56 and 57 on pages 91 and 92, respectively, are missing y-axis scale and label information. For both of these figures, the y-axis indicates scoter density indices presented as number of birds per square kilometer. In both figures, the y-axis scale extends from 0 to 60 birds per square kilometer.

Please contact the Puget Sound Water Quality Action Team at 360-407-7300 or 1-800-54-SOUND to request corrected copies of pages 91 and 92 of the *2000 Puget Sound Update.*

PSWQAT is online:

Have you visited the Puget Sound Water Quality Action Team website?
http://www.wa.gov/puget_sound

Puget Sound Notes *is intended to inform the interested public about events that affect Puget Sound, to disseminate information about the Puget Sound Estuary Program, and to encourage public participation in the government policy-making process. Publication of this newsletter has been funded wholly or in part by the U.S. Environmental Protection Agency under cooperative agreement CE-990622-02 to the Puget Sound Water Quality Action Team. It is distributed free of charge as a public service. Address corrections or mailing list additions should be mailed to:* **Puget Sound Notes**, *Puget Sound Water Quality Action Team, P.O. Box 40900, Olympia, WA 98504-0900.*

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