Puget Sound Partnership

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DISCUSSION PAPER

WATER QUALITY

August 1, 2008

Puget Sound Partnership

Introduction to the Topic Forum Discussion Paper

The attached topic forum discussion paper is one of five papers designed to provoke and inspire enduring community conversation and critical thinking about the specific problems facing Puget Sound, and the strategies and actions needed to overcome the threats we face. These papers are being used to help create the 2020 Action Agenda. Background on the topic forum process and how this information is being used can be found on our website at www.psp.wa.gov in the Action Agenda Center.

The papers represent the first effort in our region to comprehensively synthesize and document what we know about the Sound's problems, solutions that work, our current approach to solving problems, and what approaches we need to continue, add, or change. These papers address broad science and policy questions, providing an overview of each topic that looks at Puget Sound ecosystem from the crest of the Cascades to the Strait of Juan de Fuca, and documenting the basis of our conclusions and recommendations. They are fundamental to establishing strong connections between science and policy as we develop the 2020 Action Agenda.

The Partnership asked small groups of science and policy experts to prepare each of the draft discussion papers as a starting point. The authors were instructed to rely on readily available existing information and provide a high-level overview of the key issues pertaining to each topic. The draft papers were reviewed by a broad audience, and were discussed at individual topic forums held in April and May. More than 500 people attended the topic forums, and dozens more provided comments on line. During the review period, over 1,200 pages of public comment from were received from 229 people or entities. The Partnership, in conjunction with the papers' authors, reviewed and considered all of the comments as we prepared these revised discussion papers. Summarized comments and responses are included as appendices to the papers. A complete set of comments will also be posted on the Partnership's webpage.

The discussion papers are intended to be concise and as brief as possible, providing a synthesis of existing readily available information and an initial list of recommendations for moving forward to achieve the Partnership's six main goals. Work to integrate the products from the respective topic forums within an ecosystem management framework is ongoing, and will be used to support the Action Agenda. In reading the revised discussion papers, several concepts should be considered:

- The discussion papers provide an overview of the topic, summarizing and synthesizing existing documentation. These papers are intended to provide a framework for future management strategies, but are not intended to address in detail all available data on the topic.
- The Partnership will be identifying priority actions that are based on science. There is currently a wide range of opinion about the Sound's problems and literally hundreds of ideas for how to solve them. This was evidenced by the broad range of opinions expressed during the topic forum process. Our goal is to find reasonable consensus on the general

nature and magnitude of the documented threats to Puget Sound, so that we have a better chance of prioritizing durable and effective solutions.

- The papers mainly focus on the Sound as a whole. We know that there are variations in information availability, type and extent of threats, and workable solutions in different parts of our region. The action area profiles that we are also preparing will help highlight local issues.
- The papers are organized to logically step through three initial questions (two are science and one is policy) that build to a rational conclusion (the fourth question) about the strategies and actions that we will need continue, add, or change as a region. The design is intentional so that 1) our policies are based on science and 2) scientists and policy experts talk to one another.
- The discussion papers will be used to develop cross-topic priorities for the Action Agenda. A number of key themes emerged from the topic forum process, which are being used to help define priorities for management strategies.
- The intent of papers is to focus on WHAT the problem is and WHAT solutions are needed, rather than HOW to implement specific solutions. The Partnership will identify "how" with those who have to implement the solutions.
- The recommendations to the Partnership in the papers represent the conclusion of the authors based on their expertise and comments received. The recommendations will be considered by the Partnership, but should not be interpreted as a Partnership endorsement. This is an intentional design of the topic forum process.
- The papers intentionally do not focus on the need for more education/outreach, new funding strategies including creative incentives, and a coordinated monitoring and adaptive management program. The Partnership knows that these three aspects are critical to long-term success and is using other processes to address them. That work is linked to the development of the Action Agenda. By addressing the system-wide needs, we will be able to more effectively focus the education/outreach, funding, and adaptive management and monitoring strategies.
- A Partnership Quality of Life topic paper is being prepared to follow the other five topic forum papers and pull together human well-being information from each.
- The Partnership Science Panel will review the papers with a specific focus on how well the responses to the two science questions capture current understanding of the topic and key areas of uncertainty. This review is intended to help develop a targeted scientific research program.

The Partnership greatly appreciates the level of interest and participation that reviewers have shown by attending topic forums and providing thorough, thoughtful comments. The comments that we received have greatly expanded and deepened the overall level of discussion, and moved our knowledge forward on these topics. We are committed to continuing this level of engagement.

Contributors and Affiliations

Pam Bissonnette, Bissonnette Environmental

Derek Booth, PhD, PE, PG, Stillwater Sciences

Bill Derry, CH2M HILL

Anne Fairbrother, DVM, PhD, Parametrix

John Ferguson, PhD, University of Washington

Joan Lee, PE, Parametrix

Bill Moore, PE, Department of Ecology

Erin Nelson, PE, Parametrix

Randy Shuman, PhD, King County

Charlie Wisdom, PhD, Parametrix

Bruce Wulkan, Puget Sound Partnership (LID)

The Puget Sound Partnership (Partnership) convened topic forums in early March 2008 to address several topics related to the health of Puget Sound. One of those topics was water quality. The water quality topic forum group consisted of professionals with regional expertise in water quality, surface water management, toxicology, wastewater engineering, oceanography, local and state government, and private consulting. The group met twice in brainstorming sessions to address the water quality threats to Puget Sound. The primary questions to be addressed included the following:

S1. What is the status of water quality in Puget Sound?

S2. What are the management approaches to addressing water quality?

P1. What are the policy approaches to address water quality in Puget Sound?

P2. What are the strategies to improve water quality in Puget Sound?

A draft discussion document addressing these four questions was posted on the Puget Sound Partnership website on April 14, 2008. Many reviewers provided comments in the on-line discussion forum, and many others submitted comments in writing to the Partnership. Subsequent to the paper being posted, an all-day topic forum was held on April 25, 2008. Over 100 interested professionals and the general public attended the forum and participated in small group discussions regarding the draft document and water quality in Puget Sound. Over 700 pages of comments were submitted between the on-line and written comment submittals.

This final draft document represents the author's best efforts to consider and address the compilation of comments that were rolled up into categories of similar sub-topics. The document was completely reorganized from the original draft with the hope that this new format is easier to read and understand. Definitions are provided at the beginning, as these form the foundation for how water quality was addressed. The contributors express gratitude for the privilege of working on this topic in this region where the dedication to the health of Puget Sound and its people remains strong.

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Definitions for Frequently Used Terms

Certainty and Professional Judgment – For the purposes of this paper, statements followed by citations represent best available information, such as peer reviewed literature. Assertions lacking citations imply professional judgment based on the experience and informed opinion of the contributor.

Low Impact Development (LID)–An approach to “stormwater management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrologic functions” (Puget Sound Action Team, 2005).

Nutrients– Natural and synthetic substances that stimulate plant growth. Although nutrients occur naturally, excessive loading of nutrients can have significant effects on the condition of marine and freshwater systems, stimulating algal blooms, depressing oxygen levels, and leading to losses of aquatic vegetation and fish kills.

Pathogens– Illness-causing microorganisms that include a variety of protozoa, bacteria, and viruses, some of which occur naturally in the freshwater or marine environment, but most of which are associated with human and animal wastes.

Receiving Water– A body of water (rivers, streams, lakes, wetlands, marine) that receives water from an upstream catchment (drainage). The Puget Sound basin is comprised of numerous receiving waters and their catchments. Puget Sound itself is the receiving water for the entirety of all these individual catchments from the ridge lines of the Cascades and Olympic Mountains to the shoreline of the Sound.

Retrofit–The addition of new technology or features to older systems, such as the addition of a pollution control device on an existing facility or modification of existing structures, water control systems, or sewers to incorporate changes not available at time of original construction.

Source Control–Any method used to prevent or reduce the amount of pollutants available for transport by stormwater or other means to receiving waters; for example, proper materials storage at industrial sites or use of less toxic materials.

Surface Water Runoff– For conceptual purposes, the water generated by rainfall or irrigation that after saturating land surface runs overland or is conveyed by ditches, pipes or other means to a receiving water body. This includes urban stormwater runoff in constructed drainage courses, agricultural runoff in ditches or overland, and other types of runoff.

Threats–The actions that have the potential to result in harm to an ecological system or system component. Population growth, land use conversion, and the discharge of contaminants all have the potential, the threat, to cause harm. The actual components of those threats that result in harm, such as increased impervious area or specific pollutant discharges, are the "stressors." One "threat" may result in multiple "stressors."

Toxic Pollutant– Those pollutants, or combinations of pollutants, including disease-causing agents, which cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions…or physical deformations, in such organisms or their offspring. (33USC1362, 2006).

Water Pollution–The man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water (33USC1362, 2006).

Introduction

Water quality conditions in the Puget Sound basin have broad-ranging impacts on human health, biodiversity, and regional prosperity. Clean water supports basic needs of human and aquatic life, including safe drinking water, healthy habitats for aquatic organisms, and safe consumption of food grown in aquatic environments. Clean water also is important to a wide variety of economic activities. This paper documents what is known about water quality conditions in the entire Puget Sound basin, including fresh water that drains from the crests of the Cascade and Olympic Mountains to the salt water in Puget Sound, and recommended strategies for forward progress towards clean water.

This paper was reorganized from the original draft posted on the Partnership website, April 12, 2008, based on comments received. The paper is now organized to provide potential threats in the context of pollutant generation, pathways for pollutant movement to Puget Sound, and the ultimate fate of potential pollutants (such as degradation or bioavailability) in Section 2.

In Section 3, policy and management approaches currently used to address water quality are described along with a description of effectiveness. In the final Section (4), strategies to improve water quality in Puget Sound are described.

While this document strives to express the existing state of the quality of the fresh and marine waters in Puget Sound, the contributors recognize that clean water is a critical but not independent component of Puget Sound ecosystem health (Karr, 1995). This (and other) topic forum papers focus on specific symptoms (in this case water quality degradation) of the underlying landscape-scale changes that have occurred and continue in the Puget Sound basin. Our analysis of the specific symptoms is one element in the Partnership's development of a holistic understanding of the large-scale drivers of ecosystem degradation (e.g., population growth and related consumption of resources and land use transformations).

Water quality improvement measures can only be one part of a successful suite of actions to address human-derived impacts to the Puget Sound basin. To that end, the Partnership has initiated multiple efforts to develop larger strategies for ecosystem recovery and health. In addition to this paper, the Partnership undertook topic forums to gather similar input on human health, biodiversity, habitat/land use, water quantity, and quality of life. The Partnership has also been collecting local data through action area groups, an inventory of programs and management strategies underway across the Sound, the NOAA indicators and threats analysis, and the pending findings of the PSP Science Panel. It is the hope of the contributors that this paper might in some way contribute to one step forward in the long history of progress and effort towards Puget Sound health.

1. S1 - Status of Water Quality in Puget Sound

Note: In preparing this overview, information reviewed is based on best available studies from the scientific literature, monitoring data, and the best professional judgment of the contributors and outside commenters familiar with water quality issues in general or specific to the Puget Sound basin. In many cases, the available data are geographically skewed as governments and organizations with more funds to study water quality and those with larger population centers generally have larger datasets. This presents a barrier to complete understanding of the extent of water quality issues or for drawing Sound-wide inferences. For example, if there are no data to indicate that pesticides may be a problem in the Hood Canal action area, it does not necessarily follow that no pesticide pollution problem exists; all that can be stated with certainty is that a gap in our knowledge exists, and we are unable to assess the potential or comparative risks in that area. Additionally, some kinds of data are easier and cheaper to collect than others (i.e., temperature, pH, and dissolved oxygen are easy to measure, while chemical pollutants are more difficult). Therefore, there generally are more data for these standard water quality parameters than for pollutants such as polycyclic aromatic hydrocarbons (PAHs).

Based on personal observations and work on hundreds of miles of Puget Sound streams, rivers, and lakes, and the preparation of dozens of basin plans, it is the professional judgment of the contributors to this paper as well as the findings of coarse-level analyses (Hart Crowser et al., 2007) that the present primary transporter of pollution throughout the Puget Sound basin is surface water runoff. In effect, increasing levels of surface water runoff (including stormwater) appear to have become a predictable and telling expression of large-scale and ongoing land use change. Though pollutant runoff via surface water may be most prominent, as described in the rest of this section, an array of other contaminants from a variety of sources and transport mechanisms adds to the mix of pollutants ultimately reaching Puget Sound waters.

Along with the regional-scale land use changes underway, there are larger, global changes occurring. The most prominent of those transformations is climate change with its potential effects on temperature, salinity, water elevations, tides, currents, and other fundamental components affecting water quality and the overall state of the aquatic ecosystem. Coupled with rapidly increasing human populations throughout the basin, these global changes present the potential for severe challenges when setting a long-term strategy to protect and restore water quality in Puget Sound. This complexity also confounds our attempts to define causality or to demonstrate clear linkages between management strategies and ecosystem improvement, particularly since the complexities related to climate change are expected to occur at virtually all spatial scales, from the site-specific to the landscape. It may be that clean water alone is insufficient as an indicator of Puget Sound health, unless considered in the context of landscape-scale effects such as loss of habitat, urbanization, and changes in water quantity.

In the remainder of Section 1, pollutants, pathways for pollutant transport, fate, and threats are presented.

1.1 Pollutants of Concern

Everyday human activities generate compounds that, when transported to the water in our environment, can cause adverse effects on people, plants and animals. Evaluating the existing water quality found in the Puget Sound basin is aided by understanding what these potential pollutants are (Table 1), how and where these pollutants are generated, how they move through and are stored in the environment, and the types of risks each chemical poses to the organisms that are exposed to it. In a number of documents describing Puget Sound (such as Puget Sound Action Team, 2007) these common pollutants have been grouped as pathogens, nutrients, or toxics. Conventional water quality parameters also cause adverse effects when present at concentrations or units outside of natural background levels, including temperature, dissolved oxygen, biochemical oxygen demand, and acidity among others.

Table 1. Common pollutant types found in the Puget Sound Basin

Pollutant	Definition
Toxics*	
Metals	Any of several chemical elements that are usually shiny solids that conduct heat or electricity and can be formed into sheets. When dissolved in water and sediments, these inorganic chemicals can be very toxic to aquatic organisms.
Oil and Petroleum Products	A thick, flammable, yellow-to-black mixture of gaseous, liquid, and solid hydrocarbons that occurs naturally beneath the earth's surface, can be separated into fractions including natural gas, gasoline, naphtha, kerosene, fuel and lubricating oils, paraffin wax, and asphalt, and is used as raw material for a wide variety of derivative products.
Polychlorinated Biphenyls (PCBs)	Any of a family of industrial compounds produced by chlorination of biphenyl, noted primarily as an environmental pollutant that accumulates in animal tissue with resultant pathogenic and teratogenic effects.
Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs are a group of over 100 chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat.
Phthalates	A family of chemicals, produced from phthalic anhydride and alcohols, frequently used as plasticizers to give flexibility to PVC.
Pesticides	Chemical compounds used to control undesirable plants and animals. Major categories of pesticides include insecticides, miticides, fungicides, herbicides, and rodenticides.
Pharmaceuticals and Personal Care Products (PPCPs)	Any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock. PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, and cosmetics.
Endocrine Disruptor Compounds (EDCs)	Chemicals having potential to cause effects within the endocrine system and thereby alter physiology, including development and reproduction. Such compounds as xenoestrogens, anti-androgens, and thyroid hormone mimics may include some pesticides and industrial substances, among others.
Polybrominated Diphenyl Ethers (PBDEs)	Polybrominated diphenyl ethers (PBDEs) are a group of additive flame-retardant chemicals.

Pollutant	Definition
Pathogens	
Fecal bacteria	Bacteria associated with human and animal feces or digestive waste.
Pathogenic Bacteria	Bacteria that cause human diseases.
Pathogenic Viruses	Viruses that cause human diseases.
Nutrients	
Nutrients	Chemicals that are needed by plants and animals for growth (e.g., nitrogen, phosphorus).
Fertilizers	Agents or mixes that stimulate plant growth.
Human waste products	Feces and urine.
Other	
Temperature	The degree of hotness or coldness of a body or environment.
Biochemical Oxygen Demand (BOD)	The amount of oxygen used when organic matter undergoes decomposition by microorganisms.
Dissolved Oxygen (DO)	The amount of oxygen dissolved in water.
Acidity	A measure of the hydrogen ion activity in water.
Glycol ethers	Group of solvents based on alkyl ethers of ethylene glycol commonly used in deicing products.
Exotic organisms	Non-native species.
Total Suspended Solids (TSS)	Solids that are visible and suspended in water.

*Some but not all of these pollutants are categorized as Persistent Bioaccumulative Toxics (PBTs) by the EPA.

1.2 Relationship of Types of Pollutants to Land Use

The most significant threats to fresh and marine water quality appear to be associated with both the process of changing land use as well as the pollutants associated with particular land uses and their subsequent transport via surface water runoff (Hart Crowser et al., 2007). Land use also affects how pollutants move from their sources to downstream receiving waters, whether by constructed stormwater drainage infrastructure, through wastewater treatment facilities, accidental spills, surface flows, and/or groundwater. The geographic distributions of forest, agricultural, urbanizing and urban lands and their effects on surface water runoff have been documented in a number of sources (such as EPA Region 10, 2005).

1.2.1 Land Conversion

The conversion of once-forested land to agriculture, urban and suburban development, and scheduled tree harvesting across Puget Sound poses a significant threat to the aquatic health of the region. As land is converted from one use to another, the water quality threats change to reflect that new use. The close association between ecosystem degradation and urbanization has been recognized for decades in both western Washington and nationally (e.g., Steedman, 1988; King County, 1990; Booth, 1991; House et al., 1993; Booth and Reinelt, 1993; Horner et al., 1997; Wang et al., 1997; Chang and Carlson, 2005; Davies and Jackson, 2006; Barbour et al., 2006).

Increasing rates of urbanization, in particular, have led to greater volume and intensity of surface water runoff (see Section 1.3.1), a significant source of pollutants to the Puget Sound.

1.2.2 Urban Pollutant Sources

Urban pollutants are generated by a range of activities, including temporary sources during construction as land is converted from one purpose to another (Table 2).

Table 2. Pollutants Associated with Urban Land Uses

Urban Land Use	Sources	Types of Pollutants	Citations
Industrial	Pulp and paper mills, manufacturing	Toxics (metals, oil, PCBs, PAHs, phthalates)	Brinkmann, 2004; Stein et al., 2007; Barco et al., 2008; and Minton, 2005
Residential	Vehicle use, home and vehicle maintenance, lawn and yard care, personal care and hygiene products, medicinal use and disposal, building materials, human and pet wastes	Toxics (metals, PAHs, phthalates, pesticides, , pharmaceuticals, endocrine disruptor compounds [EDCs, PBDEs]), pathogens (fecal bacteria, other bacteria, viruses), nutrients (fertilizers, human waste products), temperature (removal of riparian vegetation)	Van Metre et al., 2000; Stein et al., 2007; Schiff and Sutula, 2004; Pitt et al., 2005a; Pitt et al., 2005b; Barco et al., 2008
Commercial/ Institutional	Vehicle use and repair, laboratory and hospital waste, landscaping, personal care and hygiene, building materials	Toxics (metals, PAHs, phthalates, pesticides, herbicides, pharmaceuticals, EDCs), pathogens (fecal bacteria, other bacteria), nutrients (fertilizers, human waste products), temperature (removal of riparian vegetation)	Van Metre et al., 2000; Stein et al., 2007; Schiff and Sutula, 2004; Pitt et al., 2005a; Pitt et al., 2005b; Barco et al., 2008
Construction	Ground disturbance, construction equipment use	Erosion (sediment inputs), toxics (oil, metals, PAHs)	Stein et al., 2007; Barco et al., 2008

1.2.3 Sources of Transportation-Generated Pollutants

A common activity spanning each of the land use categories is transportation, with each mode of transportation producing different types of pollutants (Table 3).

Table 3. Pollutants Associated with Transportation

Transportation Type	Sources	Types of Pollutants	Citations
Land-based (roads and rail)	Brake pads, road surfaces, leaks, emissions, roadside and railside maintenance and landscaping	Toxics (oil, metals, PAHs, herbicides, phthalates), nutrients (fertilizers)	Woodward Clyde Consultants, 1994; UNECE, 2003; Stein et al., 2007; Brewer, 1997
Aviation (planes)	Brake pads, combustion emissions, deicers	Toxics (metals, PAHs, glycol ethers)	Holzman 1997
Recreational and Commercial Ships	Boat materials, emissions, fuel leaks, personal care and hygiene products, anti-fouling materials, ballast water	Toxics (metals, oil, PAHs, pharmaceuticals, EDCs, phthalates), pathogens (bacteria, fecals, viruses), nutrients (human waste products), exotic organisms	EPA, 2008

1.2.4 *Rural Pollutant Sources*

Rural areas can include the same activities found in urban areas that generate pollutants, as well as agriculture, forestry, mining and rural residential activities and land uses. Other uses, such as industries that are co-located with the availability of raw materials, also are present in some rural areas. Pollutants commonly generated from rural land uses are shown in Table 4.

Table 4. Rural Pollutant Sources

Rural Land Use	Sources	Types of Pollutants	Citations
Agriculture	Livestock, farming, land application of animal manure as fertilizer	Nutrients (fertilizers, animal waste products), pathogens (animal waste), sediment (erosion from agricultural practices), temperature (removal of riparian vegetation), toxics (pesticides, EDCs)	Schiff and Sutula, 2004; Minton, 2005; Inkpen and Embrey, 1998; Hutchinson et al., 2005; Bradford and Schijven, 2002; Lewis et al., 2005; Mishra et al., 2008; Soupir et al., 2006; Reilly, 2001; Lucasa and Jones, 2006; Hanselman et al., 2003
Aquaculture	Geoduck farming, oyster and clam beds, salmon net pens	Sediment (geoduck harvesting), antibiotics, nutrients	Entrix, Inc. 2004; Simenstad and Fresh, 1995; Washington Department of Natural Resources 2006
Forestry	Timber harvesting	Nutrients (forest waste products, fertilizers), sediment (erosive forestry practices), temperature (removal of riparian vegetation), toxics (pesticides), biosolids application (nitrogen)	Binkley and Brown, 1993; Ecology, 1999

Rural Land Use	Sources	Types of Pollutants	Citations
Mining	Gravel quarries, hard rock mines	Sediment (erosive practices), toxics (mining equipment, metals, acid mine drainage)	Younger, Banwart, and Hedin, 2002
Rural Residential	Same as urban (see Table 2)	Same as urban (see Table 2)	Same as urban (see Table 2)

1.3 Pollutant Pathways

There are several pathways by which human-generated pollutants are transported from the sources described above to receiving waters in Puget Sound, with the primary pathways being surface water runoff and wastewater discharges (Hart Crowser et al., 2007). Secondarily, pollutants reach receiving waters through the air, direct discharge, and groundwater.

1.3.1 Surface Water Runoff

The physical effects of surface water runoff from human-altered landscapes have been documented for decades. In the Puget Sound region, increased impervious surfaces from urbanization are strongly associated with decreases in aquatic habitat quality (e.g., Booth and Reinelt, 1993, Booth et al., 2002, Horner et al., 1997; May et al., 1997, Morley and Karr, 2002; McBride and Booth, 2005), with the best documented consequences associated with changes in runoff rates and volumes (Booth et al. 2004; Konrad et al., 2005). Rural environments, such as forest and agricultural lands, also result in surface water runoff consequences in the aquatic environment. Timber harvesting changes runoff rates and volumes (LaMarche and Lettenmeier 2001) and agricultural and timber harvesting practices can cause erosion, temperature changes, and increased inputs of nutrients and pesticides (Beschta 1997; Wigington and Beschta 2000; Ongley 1996). Further discussion of the critical effects of surface water volumes on habitat and biodiversity can be found in the Water Quantity, Land Use, and Biodiversity topic forum papers. Pollutants generated by land uses described in previous paragraphs are mobilized by rainfall and transported via surface water runoff to receiving waters and sediments in the marine environment (Ruckelshaus and McClure, 2007).

Urban runoff is widely recognized to exhibit higher average concentrations, fluctuations, and loadings of pollutants than runoff in undeveloped open space areas (Stein et al., 2007). The presence of copper in urban runoff has been implicated in the death of coho in several urban streams of Puget Sound (Sandahl et al., 2007). Because of the extensive network of conveyance for stormwater drainage in urban areas, the potential exists for transport of accidental spills of hazardous substances directly to storm water outfalls. Additionally, in some urbanizing Puget Sound watersheds, land use-based causes of fecal coliform loading, such as failing septic systems from vacation homes, have been confirmed through source identification (Sargent, 1999).

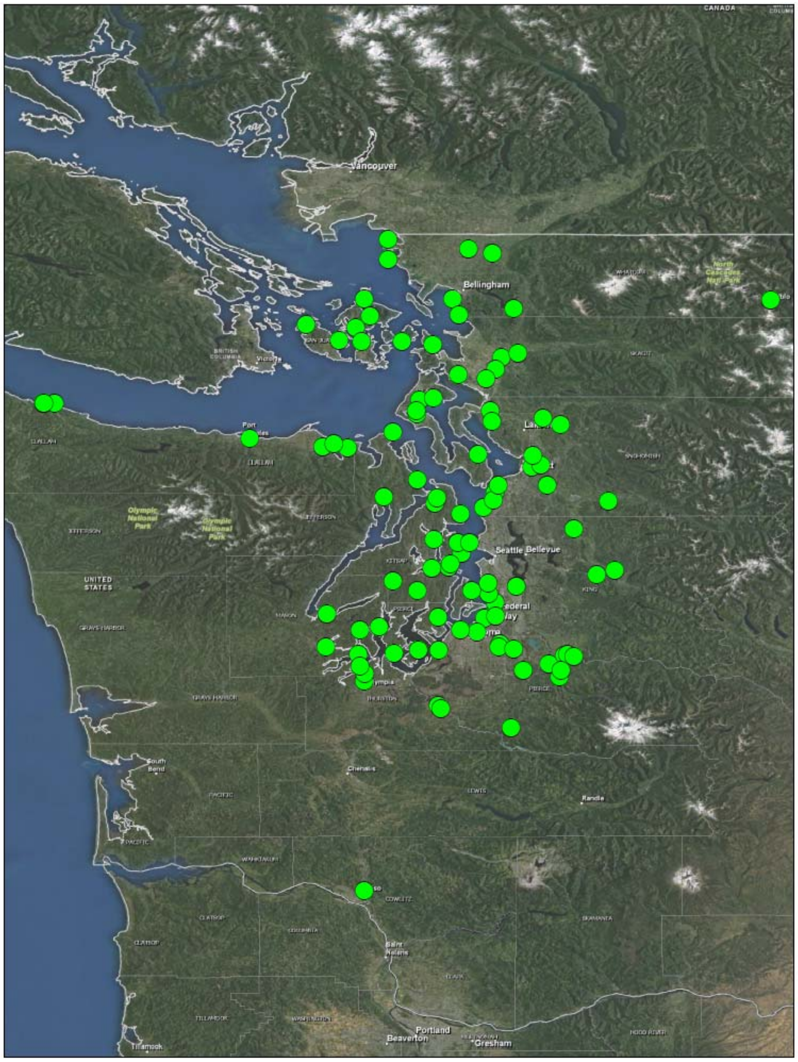
The ability to trace direct cause-effect relationships of surface water runoff however, is the exception rather than the rule. It may also reflect the absence of unifying hypotheses between various monitoring efforts (Conquest and Ralph, 1999; Ralph and Poole, 2003). In part, this is a consequence of the high levels of variability observed from differing land uses (Pitt et al., 2005a,b). The tremendous range of measured water-quality parameters reflects variable concentrations and loadings reported from different storm events, land uses, and periods within the same storm, or data sets collected from the same region (Woodward-Clyde Consultants, 1994; Brewer, 1997; Legret and Pagotto, 1999; Washbusch et al., 1999; Van Metre et al., 2000; Westerlund, 2001; Kayhanian et al., 2002; UNECE, 2003; Brinkmann, 2004; Schiff and Sutula, 2004; Barr Engineering Company, 2005; Pitt et al., 2005a,b; Egodawatta et al., 2007; Gobel et al., 2007; Stein et al., 2007). Although a few local examples, such as the recontamination of Commencement Bay sediments below stormwater outfalls, strongly suggest a linkage between urban runoff and sediment toxicity (City of Tacoma, 2006), such opportunities to demonstrate a strong cause-and-effect relationship are too rare to draw many generalized conclusions.

1.3.2 Wastewater

Pollutants are present in municipal, industrial, and residential wastewater originating from industrial processes, and human use and consumption of food, medicinal, and personal care products. Wastewater is a source of a broad spectrum of pollutants, nutrients, and pathogens (King County, 1991). Wastewater treatment removes or transforms many, but not all, contaminants, and treated municipal sewage contains a mixture of personal care products (e.g., shampoo), caffeine, endocrine-modulating chemicals (such as birth control pills), and other pharmaceuticals (USGS, 2002, 2008). Many municipal wastewater treatment plants discharge treated wastewater directly into Puget Sound, mostly at great depths and distances from shore (Figure 1). A study by the University of Washington for the Washington State Department of Health (DOH) estimated that land-based wastewater treatment plants contribute nearly 400 million gallons per day of treated water into Puget Sound (www.doh.wa.gov/ehp/sf/Pubs/cruise-ship-report.pdf). The City of Victoria also discharges wastewater that has received primary treatment to the Strait of Juan de Fuca.

Combined sewer overflow (CSO) outfalls sometimes discharge mixed stormwater and untreated wastewater to Puget Sound during wet weather when conveyance or plant capacities are exceeded. Episodic CSO discharges contribute relatively little to the total loading of toxic chemicals to Puget Sound on a Sound-wide basis, although discharges may still be significant in the local area around the discharge (Hart Crowser et al., 2007). The local impacts from these discharges may be seen in the water column presence of fecal coliform bacteria and other wastewater components and the deposition of sediment in the vicinity of the discharge.

Figure 1. Location of permitted municipal wastewater discharges in Puget Sound (Canadian discharges are not shown).



Another potential pathway for the distribution of water quality pollutants through the wastewater stream is the use of wastewater byproducts, such as biosolids for land application as fertilizer. King County, for example, began using biosolids as fertilizers in commercial forests in 1987 (http://dnr.metrokc.gov/wtd/biosolids/forest.htm), and continues to see enhanced growth rates of trees as a result of increasing soil nutrients. The Washington State Department of Ecology (Ecology) is directed by statute to maximize the beneficial uses of biosolids and recycle as appropriate. New state rules for biosolids management, including establishing what comprises clean biosolids, came into effect in June 2007 (http://www.ecy.wa.gov/programs/swfa/biosolids/ruleDev.html). Biosolids can be used anywhere plants are grown, most notably forests, agriculture, and land reclamation. Excess nitrogen runoff is the greatest water quality concern from use of biosolids (Ecology, 1999); other toxics and pathogens are regulated by EPA under the Clean Water Act (Cogger et al., 2000).

There are approximately 500,000 individual on-site wastewater (septic) systems in the Puget Sound basin according to previous estimates by DOH. Septic systems generally are intended to provide adequate removal of pathogens for low-density residential and commercial development. Sited and designed properly, they can provide adequate pollutant removal; however, they are not typically designed for nitrogen removal. When systems are located near streams or marine waters, the effluent may be a significant source of nitrogen (Mackas and Harrison, 1997). If systems are not designed well or leach fields become clogged, leachate is not properly treated in the soil column, and septic systems can also be a major source of pathogens (both bacteria and viruses).

1.3.3 *Marine Oil Spills*

Oil spills from marine traffic are another source of potential direct discharge to receiving waters. Large oil spills occur relatively infrequently and have ranged from 23,000 gallons of diesel in 1995 (Barge 101 in transit near Padilla Bay) to 230,000 gallons of crude oil in 1985 (Tank Ship Arco Anchorage in 1985 at anchor in Port Angeles) and Bunker C fuel oil in 1988 (Barge Nestucca off Grays Harbor) (http://www.uscg.mil/d13/publicaffairs/news/oil_spill_response_in_puget_soun.htm). However, most oil discharged to the Sound is from small leaks of a few ounces to gallons, often from outboard motors, plus surface runoff from land-based oil (Hart Crowser, 2007).

1.3.4 *Groundwater*

Groundwater is a secondary pathway for the transport of pollutants to Puget Sound receiving waters. Pollutants reach groundwater through infiltration from the surface or leaking subsurface utilities (such as sanitary or storm sewer pipes, underground storage tanks, or septic systems). Once in the groundwater, pollutants can reemerge into surface water bodies where there is a hydrogeologic connection. Shallow groundwater in urban residential areas has been reported to contain chemicals related to transportation and household activities (Ebbert et al., 2000). In addition, shallow groundwater in these areas can contain elevated levels of nitrate from use of fertilizers on lawns, gardens, and septic system drainage (Ebbert et al., 2000). Cropland applications in the Nooksack River basin caused nitrate exceedances above the drinking water quality standard in about 60% of groundwater sampled (Ebbert et al., 2000).

1.3.5 *Air*

Nearly all land uses contribute pollutants to the air via emissions from vehicle use, machinery, and burning of fuel for a variety of uses. Additionally, wind transports fine pollutant particles from agricultural fields, industrial and construction sites, and other land surfaces. Atmospheric deposition of pollutants directly to the marine water surface of Puget Sound and those washed from land surfaces appear to be a potentially widespread source of loading for some chemicals of concern (Hart Crowser et al., 2007, Landers et al., 2008). Recent efforts to compare the importance of atmospheric deposition among other sources (Hart Crowser et al., 2007) suggested that the atmospheric loading represented a fraction of the surface runoff loading, with the possible exceptions of Polybrominated Diphenyl Ether (PBDEs) and some Polycyclic Aromatic Hydrocarbons (PAHs). Toxic pollutants, including mercury, PBDEs, Dichloro-Diphenyl-Trichloroethane (DDT), Polychlorinated Biphenyls (PCBs), found in pristine Olympic National Park lakes, may also arrive through air currents from as far away as Russia and China (Landers et al., 2008).

1.4 Pollutant Fate and Threats

Pollutant fate refers to transformations that occur when a substance reaches a receiving water, including its availability for uptake by marine organisms, its interaction with the receiving water biota and plant life, and its persistence. Pollutant fate can depend on the type of pollutant, the characteristic rate at which it moves out of the water column, and receiving water conditions (pH, temperature, ions and dissolved organic carbon) (Santore et al., 2001; Paquin et al., 2005). Pollutants can end up dissolved in fresh or marine waters (Gobel et al., 2007), adsorbed onto sediments (Gobel et al. 2007), taken up by plants, degraded by sunlight or other processes, volatilized into air, or bioaccumulated in organisms. The resultant potential effects of the pollutant on human, plant, or animal life are referred to here as "threats."

Below is an overview of the range of pollutants and their threats known to be present in fresh and marine water in Puget Sound.

1.4.1 Water Column Pollutants

1.4.1.1 Toxics

Emerging Contaminants (EDCs, PPCPs)

Few data for endocrine disrupting compounds (EDCs) in freshwaters are available, and there are little or no data available for most pharmaceuticals and personal care products in fresh waters within the Puget Sound basin with the exception of a limited survey by King County (King County 2007). However, several studies have correlated the presence of estrogenic compounds to impaired reproduction in fish, amphibians, and other animals, which has raised significant concern in the scientific community about the long-term impacts of these chemicals (Ketata et al., 2008; Stoker et al., 2008; Anway and Skinner, 2006; Anway et al., 2005). A more recent study, focused on the bioaccumulation of these compounds in worms, showed effects to the worms' predators higher in the food chain (Markman et al., 2008). Other studies are starting to document the presence and transfer of these chemicals in human placentas (Tsutsumi, 2005) and the potential implications for human fetal development and reproduction (Takeuchi et al., 2004, Ikezuki et al., 2002, Pauwels et al., 2001).

In 2003, King County conducted a limited survey of a select group of 16 endocrine disrupting chemicals (7 phthalates, 6 hormones, total 4-nonylphenol [surfactant], bisphenol-A [plasticizer] and vinclozolin [pesticide]) in surface waters (streams, lakes and marine waters) within the county (King County, 2007). Of those, five compounds were never detected. In general, all detected concentrations were low; however, the highest levels and greatest frequency of detection were found in streams. Endocrine disruptors, generally associated with wastewater discharges (USGS, 2008), have been observed both upstream and downstream of freshwater outfalls in King County, implying additional sources of these substances beyond wastewater outfalls, such as on-site wastewater system discharges, wastewater cross connections, or agricultural wastes (King County 2007).

Metals

Both acute and chronic toxicity can occur for humans, plants, and animals from exposure to metals (Thornburgh and Williams, 2000; Minton, 2007). Receiving water conditions (ions and dissolved organic carbon) strongly influence the toxicity of metals (Santore et al., 2001; Paquin et al., 2005). Recent monitoring by Ecology of six Puget Sound rivers found no exceedances of 2006 water quality chronic criteria for recoverable and dissolved metals including arsenic, cadmium, chromium, copper, lead, zinc, silver, mercury, and nickel (Ecology, 2007)[1]. However, studies on the impacts of surface water runoff on salmonids suggest that metals concentrations below those commonly observed in surface water runoff can adversely affect a salmon's sense of smell (Sandahl et al., 2004). Research by scientists at the Northwest Fisheries Science Center has shown that olfactory response to copper in coho salmon occurs at levels of 2 parts per billion (ppb) over background concentrations (Baldwin et al., 2003). The comparable marine standards currently are 4.8 ppb acute and 3.1 ppb chronic. Coho prespawn mortality rates in Longfellow Creek in Seattle demonstrate the concern for surface water runoff effects on salmon (McCarthy et al., 2008). No causative agent has been identified for pre-spawning mortality of Chinook salmon in King County streams (Berge et al., 2006).

In 2000, Michelson found that measured dissolved metals were significantly below the relevant marine water quality criteria in samples collected at 5 and 50 meters below the surface in several cross transects of the middle Puget Sound basin (Michelson, 2000).

1.4.1.2 Pathogens

Fecal coliform bacteria are common bacteria from the guts of warm-blooded animals. While fecal coliforms cause only mild disease in humans (such as gastroenteritis), their presence indicates the possible presence of human or mammalian wastes and, therefore, potential risk from other more harmful fecal organisms such as viruses, thus making them important indicator organisms.

Fecal coliform bacteria is the most widely monitored indicator of pathogens in the Puget Sound basin and is one of the most ubiquitous pollutants. Approximately 137 stream segments, lakes, and marine water bodies are listed on Ecology's 303(d) Category 5 2004 and draft 2008 lists for impairment by fecal coliform bacteria. The use of these indicators to manage both shellfish harvest and swimming contact has been largely successful in minimizing water-borne disease transmission.

Since 1980, over 30,000 acres of commercial shellfish tidelands have been closed to harvesting due to water pollution, including fecal contamination (Newton et al., 2007a). However, positive gains have been made. Between 1995 and 2004, 8,000 acres of shellfish beds were upgraded from their previously impaired status, indicating that water quality conditions had improved (EPA Puget Sound Georgia Basin Ecosystem Indicator Report, accessed on June 20, 2008, http://www.epa.gov/r10earth/psgb/indicators/shellfish/media/pdf/Shellfish%20Indicator%20Summary.pdf).

1.4.1.3 Nutrients

Nutrient loading to enclosed fresh and marine water bodies can lead to accelerated aging (eutrophication). Many marine embayments in Puget Sound show a high sensitivity to hypoxia and other problems related to nutrients (Puget Sound Action Team, 2007; Newton et al., 2007b). In Puget Sound freshwater lakes, point and non-point sources and failed or poorly sited septic

[1] Ecology bi-monthly monitoring sites included the following Puget Sound river sites: Fauntleroy Creek near the mouth, Miller Creek near the mouth, South Fork Snoqualmie River near 468th Avenue SE, Dungeness River near the mouth, Puyallup River near Meridian Street, and Deschutes River at East Street Bridge

systems are suspected as the primary inputs of nutrients. In larger basins, like the Lake Washington watershed, non-point sources from urban and forestry land uses are more significant sources of nutrients than contributions of lakeside resident activities (Ecology, 1997). Ammonia-nitrogen impairment in freshwater lakes, rivers, and streams was seen in only approximately 1% (+/- 2%) of the stream miles sampled as part of Ecology's 305(b) water quality assessment in 2002.

1.4.1.4 Physical Parameters

Temperature

Elevated temperatures can affect biological communities, including cold water fish species, such as salmonids. Approximately 141 stream segments, lakes, or marine water bodies are listed on Ecology's 303(d) Category 5 2004 and draft 2008 lists for impairment by high temperatures. This condition is likely to worsen under potential future climate scenarios (Booth, personal correspondence, 2008).

Dissolved Oxygen

Oxygen is essential for life. Low dissolved oxygen levels are documented in many freshwater streams in Puget Sound, and several stream segments are listed on Ecology's 2004 303(d) list for impairment due to low dissolved oxygen. Additionally, many marine water areas also are listed on Ecology's 303(d) list for low dissolved oxygen. A particular area of concern is South Puget Sound. South Puget Sound historically has shown signs of periodic low oxygen and susceptibility to nutrient enrichment (Ecology, 2002a). Although low concentrations of dissolved oxygen in Hood Canal have been observed during late summer and early fall as far back as the 1950s, available data suggest that concentrations of dissolved oxygen vary from year to year, but have been trending lower over time, with longer durations of low concentrations (USGS, 2008).

1.4.2 Groundwater

Groundwater is a component of the interconnected water resources of the Puget Sound basin. Although this paper's efforts were largely focused on surface waters and their connectivity, the potential for groundwater to be contaminated by pollutants is flagged here for subsequent consideration. Groundwater can contribute to the contamination of surface water when it discharges to streams or rivers. Groundwater is a source of drinking water in some locations.

The sites of most concern for groundwater-related contamination of Puget Sound are located within a kilometer of the edge of Puget Sound or its drainages, because of the potential for groundwater movement into marine waters. As of June 2006, there were 1,014 listed contaminated sites within 0.8 kilometers (0.5 miles) of Puget Sound, although 34% of these had been cleaned up (Washington GMAP 2006).

1.4.3 Freshwater and Marine Sediments

Contaminated sediments are an avenue of toxic exposure for marine aquatic organisms. Some toxics are known to bioaccumulate in these organisms and are transported through the food web. The toxicity of metals in sediments depends on their bioavailability (DiToro et al., 1990) and the relative sensitivity of the organisms that are exposed. Many pollutants, including metals, PAHs, and PCBs, are adsorbed onto sediment. Some of these pollutants are actively transported from upland or airborne sources on particle surfaces, whereas others are no longer in use but reside in sediments as a result of historical activities (these are known as "legacy" pollutants). Different pollutants attach to different sediment particle sizes. For example, metals typically are associated with finer grained sediment, while PAHs associate with fine to coarse sediments (Robertson and Taylor, 2007).

Freshwater sediments in the Puget Sound basin show variable conditions. Data collected from 27 small streams between 1987 and 2002 indicated that sediment collected from about half of the streams had at least one exceedance of sediment quality guidelines (King County, 2005).[2] Sediment data collected from 70 stations covering 16 creeks indicated that approximately half of the sites exceeded sediment quality guidelines. Contaminants included metals, phthalates, PAHs, DDT, and PCBs (King County, 2008).

Sediment data collected from Lakes Washington, Sammamish, and Union as well as the Sammamish River indicated that out of over 70 sites, approximately one-third of the samples exceeded sediment quality guidelines. Contaminants included metals, phthalates, PAHs, DDT, and PCBs (King County, 2005; Moshenberg, 2004). Historic sediment patterns measured in urban lakes such as Lake Ballinger show decreasing trends for DDT and PCBs, but an increasing trend for PAHs (Van Metre and Mahler, In Press). Several freshwater areas in Puget Sound lakes and rivers (e.g., Lower Duwamish River) are recorded as contaminated and require cleanup under CERCLA regulations (EPA, 2008, Long et al., 2005). Sediment samples collected from on-site industrial catch basins near the Lower Duwamish Waterway indicated concentrations of metals (copper, lead, mercury, and zinc), PAHs, PCBs, and Bis (2-ethylhexyl) phthalate (BEHP) at concentrations above the sediment cleanup screening level (King County and Seattle Public Utilities, 2005).

A large-scale survey of Puget Sound marine waters undertaken by NOAA and Ecology in 2005 showed widespread marine sediment contamination, but at levels lower than regulatory criteria (Long et al., 2005). Some of the pollutants most prevalent in marine sediments are PCBs. PCB contamination varies among Puget Sound basins, with the Seattle area showing the highest concentrations (O'Neill, 2004, Long et al., 2005). Approximately 5,700 acres in Puget Sound exceed toxicity standards for sediments (Figure 2); cleanup of 553 sites is underway (Ecology, 2005a).

1.4.3.1 Bioaccumulation

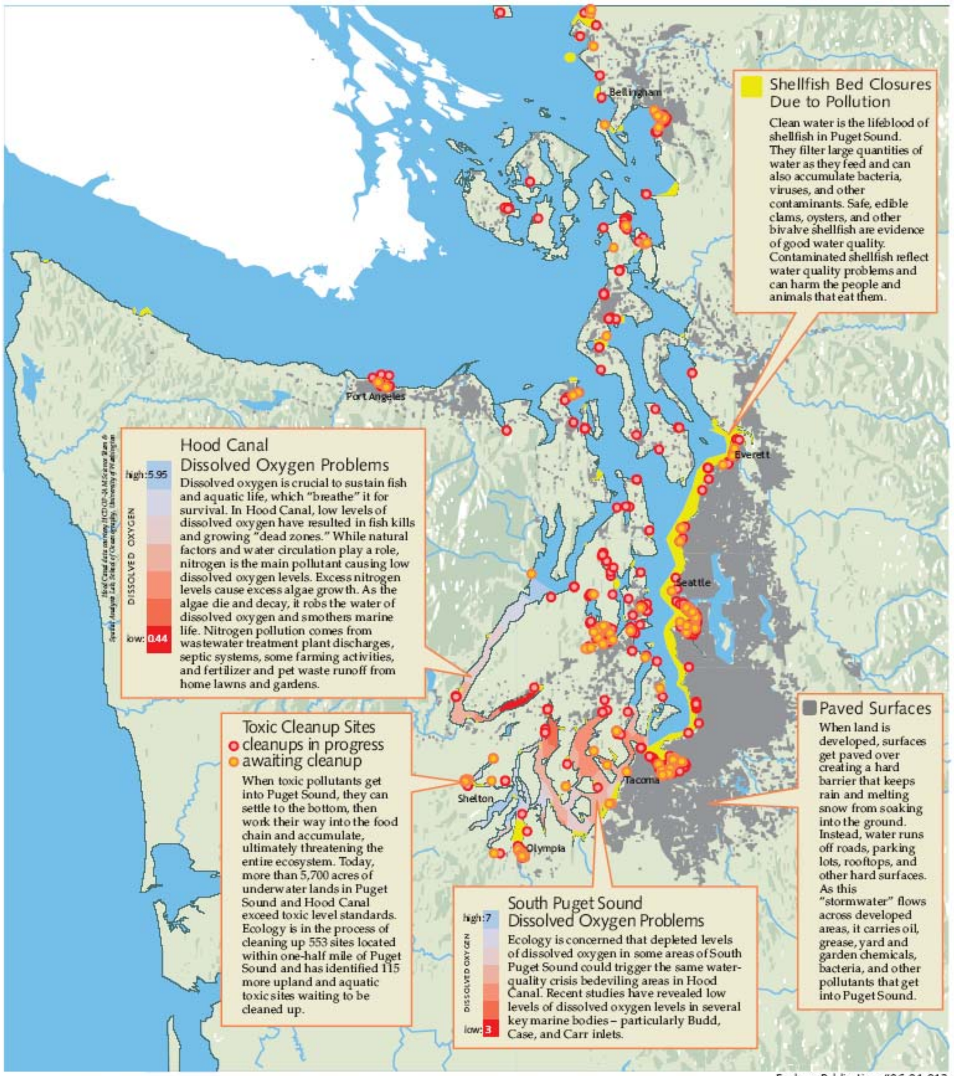
As they move up the food web, concentrations of persistent, bioaccumulative chemicals may become much greater and pose an important health risk for top-level feeders such as salmon, raptors, marine mammals, and humans (Ruckelshaus and McClure, 2007). The DOH has completed an assessment of contaminants in numerous lakes in the Puget Sound basin and issued health advisories for the amount of fish that is safe to consume per month. The known contaminants of concern are PCBs and mercury, which, once released into the environment, move up through the food chain into high concentrations in fish and marine mammals. Mercury and PCBs have been shown to cause behavioral and learning deficits in children exposed in the womb, so meal limits of certain fish are especially important for women of childbearing age and young children (National Research Council, 2000; EPA, 2001; Food and Drug Administration, 2001).

PCB accumulation in benthic and demersal fishes is correlated with sediment concentrations. The highest correlation is for fish with small home ranges, and accumulations increase with trophic level (biomagnification) (O'Neill, 2004). Researchers have found that sediment-associated flatfish from polluted sites had high incidences of liver disease and cancer. English sole in urban embayments

[2] Data for organic compounds were limited.

such as Elliott Bay and Sinclair Inlet have particularly high levels of mercury and PCBs in their tissues (EVS, 2003). These levels often exceed toxic amounts for people or wildlife. Additionally, PCBs are one of the few contaminants observed to accumulate in adult salmon, especially Chinook; the relative contribution of contaminants accumulated by salmon as they outmigrate through contaminated estuaries during their juvenile life stage is considered negligible, so it is difficult to say if these contaminants come from Puget Sound sources or from open ocean exposures (EVS, 2003).

Figure 2. Location of toxic cleanup sites in Puget Sound (from Ecology)



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Metal concentrations in harbor seals in Puget Sound are comparable to pinnipeds in other parts of the world, but PCB concentrations are elevated (although lower than they were in the 1970s) (EVS, 2003). The concentration of PCBs in Puget Sound killer whales is higher than in the whales from any other industrialized area in North America and northern Europe, while dioxins and furans are low (Ross et al., 2000). Gray whales, which filter sediments for benthic invertebrates, have lower contaminant concentrations (EVS, 2003), and their long migrations make it difficult to attribute contaminant load to any one place. These contaminant levels in marine mammals of Puget Sound are high enough to potentially impair the immune system (Ross et al., 2000), although studies on disease incidence are lacking.

There is a lack of data on concentrations of contaminants in Puget Sound sediment invertebrates, with the exception of mussels deployed in the Mussel Watch monitoring program; arsenic, PCBs, and DDT are the major contaminants in mussels (EVS, 2003). Discussion about the effects of bioaccumulation and biomagnification of contaminants in Puget Sound organisms is presented in the Biodiversity and Human Health Topic Forum papers.

1.4.4 *Plant Uptake*

Plants can be a route of removal of pollutants from contaminated soils or water. Metals, in particular, are hyperaccumulated (i.e., highly concentrated in the plant as compared to what is in the soil) in some plant species. For example, water hyacinth (*Eichhornia crassipes*) absorbs and translocates significant amounts of cadmium, lead, copper, zinc, and nickel to its roots and leaves (Liao and Chang, 2004). Common non-native wetland plants, such as *Spartina alterniflora* and *Phragmites australis,* also sequester metals in their roots (Weiss and Weiss, 2003). These non-native species can negatively impact ecosystems, and therefore must be carefully evaluated for use in removing contaminants.

1.4.5 *Natural Degradation*

Many chemicals are detoxified or lost from aquatic systems through natural processes such as photolysis, hydrolysis, or biodegradation. This is represented in the length of the chemicals' half-lives ($t_{1/2}$), which is the amount of time it takes for half of the amount initially present to disappear. For example, PAHs are photo-oxidized and break down to simple carbon and oxygens. Some, such as benzo(a)pyrene, may have half-lives as short as a few hours (http://www.epa.gov/ogwdw/dwh/t-soc/pahs.html). PCBs and other organochlorines are much more persistent as they are broken down only slowly by microbial processes; thus, they have environmental half-lives of 3 to 30 years. Many pesticides, such as the organophosphate chemicals, are rapidly hydrolyzed and have very short half-lives in water.

1.5 Water Quality in the Context of Naturally Occurring Processes

Water quality conditions in Puget Sound are not entirely the result of human activities. There are many natural processes, both routine and catastrophic, that can contribute to water quality degradation. These include naturally occurring viruses, phytoplankton organisms, pathogens, such as *Vibrio parahaemolyticus*, and harmful algal blooms. Additionally, episodic fires and volcanic activity produce great amounts of ash and aerosols containing toxic chemicals that are released into the atmosphere and re-deposited elsewhere. Landslides contribute to temporary sediment and turbidity water quality problems in some freshwater streams and nearshore marine waters.

Large quantities of water flow into Puget Sound from the Pacific Ocean, the Strait of Georgia, and rivers discharging directly into Puget Sound and into the Strait of Georgia such as the Fraser River (relative contributions of freshwater sources are provided in the Water Quantity Topic Forum Paper). These flows into Puget Sound contain large quantities of nutrients and sediment. Pacific Ocean water also seasonally introduces pulses of low oxygen water into the Puget Sound basin, related to the dynamics of the ocean occurring on the Washington, Oregon, British Columbia shelf and the strength of movement into the Puget Sound basin.

There is an increasing concern over the spread and impacts of toxins generated by harmful algal blooms (HAB) (Jewett et al., 2007). With an increase in the population near coastal areas, along with the apparent spread of harmful algal blooms, it is reasonable to expect an increase in the incidence of poisoning by natural phytoplankton-related toxins. These toxins can cause both short- and long-term health impacts, including death to humans, marine mammals, and other organisms, such as fish species, both wild and farmed (Ruckelshaus and McClure, 2007, Trainer et al., 2007). While the details of the conditions leading to these blooms are not completely understood, as with all phytoplankton, increases in nutrient supply and water column stratification can be expected to cause favorable conditions for these blooms, especially in restricted water bodies.

1.6 Gaps in Knowledge

The gaps in our understanding of current water quality conditions in Puget Sound include technical and data gaps (temporal and spatial distribution, as well as limited range of pollutants). Other data gaps include studies that provide understanding of more widespread distribution of receiving water quality data for pollutants that we know are in surface water runoff, including metals and PAHs. Emerging contaminants of concern and their relative importance (or lack of importance) merit much greater study. Such lists of knowledge gaps and research needs have been generated by Puget Sound scientists for nearly two, if not more, decades (see the work of the Puget Sound Authority and the Puget Sound Action Team, 2007, for example). With respect to the latter work, what is notable is the amount of work that has remained unfunded and, therefore, for which no progress has been made. Each of these areas is of interest and importance to the set of scientists working in that particular arena, whether the topic is fate of pollutants or the air-water interface.

Perhaps the most profound and confounding gap is the absence of a well articulated statement of Puget Sound health against which to measure the impacts of the range of substances being discharged. Absent such clarification, the robust definition of water pollution and risk remains elusive, as does its place in the context of overall ecosystem health. A well-designed monitoring and data collection program, with a clearly stated overarching scientific purpose or hypothesis, can guide robust choices for recovery of water quality and a sustainable Puget Sound ecosystem if based on sound science and strong statistical links and inferences (Conquest and Ralph, 1999; Ralph and Poole, 2003).

2. S2/P1- Policy and Management Approaches to Addressing Water Quality

2.1 Regulations and Policy Approaches

Federal, state, and local regulations form the basis for policy and management approaches addressing water quality in Puget Sound (Table 5). These regulations are implemented by multiple agencies and address many of the factors that affect water quality. The Federal Clean Water Act (CWA) (1972) is the most widespread legal driver for the regulations and management programs that are in place to protect and restore water quality in Puget Sound. The CWA establishes the framework and minimum requirements for setting effluent limitations and water quality and sediment quality standards that address dissolved oxygen, nutrients, pathogens, and a limited array of toxic compounds. Washington State has used its authority to establish water quality and marine sediment standards unique to the state and that meet or exceed federal standards.

Other federal and state regulations are in place for the use and transport of pollutants, which affect their introduction into the environment. Equally important are the regulations that address land use, water resources, waste reduction, and air quality.

Although several of these acts and regulations are promulgated through federal or state legislation, implementation often occurs at the local level. In several cases, federal authority has been delegated to the state level, or state authority to the local level. Because there is flexibility in local compliance with these acts, there can be wide variability in what is allowed across jurisdictions.

Table 5. Partial list of federal and state regulations that affect water quality in Puget Sound

Type of Regulation	Federal	State
Land Use and Environment	National Environmental Policy Act (NEPA)	State Environmental Policy Act (SEPA)[RCW 43.21C]
	Coastal Zone Management Act	Floodplain Management Act (RCW 86.16)
		RCW 90.36A, Growth Management Act
		RCW 90.58, Shoreline Management Act
		RCW 76.09, Forest Practices Act
Source Control and Use	Federal Insecticide Fungicide and Rodenticide Act (FIFRA)	RCW 70.105D, Model Toxics Control Act
	Federal Food Drug and Cosmetic Act (FDCA)	
	Toxic Substances Control Act (TSCA)	
Clean Water	Federal Clean Water Act	

Type of Regulation	Federal	State
Water Resource Management		RCW 90.42, Water Resources Management Act
		RCW 90.46, Reclaimed Water Use
		RCW 90.54, Water Resources Act of 1971
		RCW 90.71, Puget Sound Water Quality Program
		RCW 90.82, Watershed Planning Act
Pollution Prevention		RCW 70.146, Water Pollution Control Facilities Financing Act
		RCW 78.56, Metals, Mining and Milling Act
		RCW 88.40, Transport of Petroleum Products – Financial Responsibility
		RCW 88.46, Vessel Oil Spill Prevention and Response
		RCW 90.48, Water Pollution Control***
		RCW 90.50A, Water Pollution Control Facilities Federal Capitalization Grants
		RCW 90.56, Oil and Hazardous Substance Spill Prevention and Response
		RCW 90.64, Dairy Nutrient Management Act
Clean Air	Federal Clean Air Act	State Clean Air Act (RCW 70.94)
		RCW 70.120, Motor Vehicle Emission Control
Waste	Federal Resource Conservation and Recovery Act	RCW 70.105 (1976), Washington's Hazardous Waste Management Act
	Federal Emergency Planning and Community Right-to-know Act (part of CERCLA)	WAC 173-303, Dangerous Waste Regulations (2000)
		RCW 70.95, Hazardous Waste Reduction Act
		RCW 70.95C, State Solid Waste Act
		RCW 70.95E, Hazardous Waste Fees
		WAC 173-307, Pollution Prevention Plans (1991)
		WAC 173-305, Hazardous Waste Fees (1992)
		RCW 70.105D (1989), State Hazardous Waste Clean Up (MTCA)
		RCW 70.102.020, Hazardous Substance Information Act
		RCW 49.70, State Worker and Community Right-to-Know Act
		RCW 15.54, Fertilizer Regulation Act (Clarifies the Department of Ecology's oversight authority over waste-derived fertilizers)

Land ownership can also affect how regulations are implemented. The Puget Sound basin contains large tracts of land owned by tribes; federal, state, and local governments; special districts; and private citizens. Although many of the policies listed above overlap or are shared among regulatory tiers, how the land is developed and environmental review requirements differ among jurisdictions. Additionally, different or modified water quality standards can be implemented in certain instances, as occurred in the case of the Puyallup and Port Gamble S'Klallam Tribes (http://www.epa.gov/waterscience/standards/wqslibrary/tribes.html).

A more complete discussion of land use regulations and environmental implications is in the Land Use Topic Forum paper. The balance between economic and environmental considerations is discussed in the Quality of Life Topic Forum paper.

2.1.1 Criteria and Standards

Ambient Water Quality Criteria (AWQC) are developed by EPA to protect aquatic life from contaminant effects, and are applicable nation-wide. States may choose to adopt these criteria for application to their waters, or may modify them to account for regional differences in water chemistry or species of concern. The modified criteria are referred to as Water Quality Standards, and must be approved by EPA. The specific standards for fresh versus marine waters differ because of the varied susceptibilities of aquatic communities, circulation patterns, effects of salinity, and ways that pollutants behave in fresh or marine water. Although there are standards for many of the pollutants present in Puget Sound, many more, particularly the emerging contaminants, such as pharmaceuticals and EDCs, do not have associated numeric criteria. This is problematic, as there is no regulatory basis for determining whether or not aquatic organisms and people are at risk from exposure to those constituents.

2.1.1.1 Water Quality Criteria

Ecology is required to conduct a review every three years, as required by federal rule, which consists of public hearings held around the state. The review is not part of a rule-making proceeding, but instead is used to (1) provide a forum for discussing water quality standards and their implementation, (2) discuss new initiatives being developed by EPA, (3) solicit suggestions for implementation of current standards, (4) solicit suggestions for new or revised criteria, (5) discuss progress with ongoing standards-related efforts, and (6) formally modify the long-term strategy and timeline for developing guidance and revising the surface water quality standards. Triennial reviews also include a discussion on waters where non-CWA uses are assigned, as required by federal rule.

2.1.1.2 Sediment Standards

There also are state standards for marine sediments (toxics). The Sediment Management Standards (SMS), WAC 173-204 (www.ecy.wa.gov/programs/tcp/smu/sed_standards.htm) administered by Ecology's Toxics Cleanup Program (TCP), are promulgated under the authority of Chapter 90.48 RCW, Water Pollution Control Act, and Chapter 70.105D RCW, Model Toxics Control Act (MTCA), to establish marine, low salinity, and freshwater surface sediment management standards for the state of Washington. Washington State is currently the only state with adopted standards for marine sediment quality. These standards have led to the identification and often the subsequent cleanup of a number of areas of urban sediment contamination, including

Elliott Bay, Eagle Harbor, Commencement Bay, and Bellingham Bay. There are currently no standards or criteria for freshwater sediments.

2.1.1.3 Relative Protectiveness of Standards

Despite the number of regulations and programs designed to address water quality in Puget Sound, there are still numerous receiving water segments that are not achieving the existing standards. Most of the receiving water segments not achieving existing standards are listed for conventional parameters such as temperature, dissolved oxygen, and fecal coliform bacteria. Metal concentrations in Puget Sound sediments have been declining for the past 15 years, but PAH concentrations recently started increasing again (Ecology, 2005a). There is also concern about potentially increasing concentrations of copper from stormwater runoff, but there is a lack of monitoring data to ascertain where exceedances might be occurring.

More importantly, we do not know if the existing standards are adequately protective of aquatic life and human health in the fresh and marine ecosystems of Puget Sound. Site-specific physical and chemical properties of a water body can substantially change the bioavailability of a chemical, affecting the degree to which organisms can take up the pollutant into their bodies. Because standards and criteria are developed for each chemical separately, the cumulative impacts of chemical mixtures are not known. Furthermore, there is scientific dissension about the freshwater ambient water copper criterion, and there are no pollution standards or criteria for freshwater sediments. Emerging pollutants, such as pharmaceuticals and personal care products or industrial chemicals such as phthalates, have no national criteria or state standards. Therefore, simple statements about meeting/exceeding ambient water quality criteria are very limited in regard to their ability to adequately predict adverse effects of pollutants in aquatic systems. Despite the challenges and limitations, there are regulatory tools that have provided for progress towards improvements with respect to specific water quality parameters as described in the following sections.

2.1.2 Regulatory Tools

2.1.2.1 Total Maximum Daily Loads (TMDLs)

The CWA established a process to identify and clean up polluted waters. Every two years, states are required to prepare a list of water bodies that do not meet water quality standards. This list is called the 303(d) list, because the process is described in Section 303(d) of the CWA.

CWA requires that a water cleanup plan be developed for each of the water bodies on the 303(d) list. The technical name for a water cleanup plan is a total maximum daily load, or TMDL. A TMDL identifies how much pollution can be loaded into the system on a daily basis from all sources. In doing so, it identifies the load reduction necessary to achieve clean water and can apportion that reduction among known point sources (through permit changes). TMDLs must account for loading from diffuse and non-point sources, as well, and institute “best management practices” (BMPs) where possible to reduce inputs.

Ecology has completed over 600 TMDLs in Washington State; for each nonpoint part of these TMDLs, the same BMPs have been recommended. In Puget Sound, Ecology has started TMDL work specifically for addressing nutrients tied to point source management.

2.1.2.2 Incentive Programs

Incentive programs for voluntary source control or waste reduction can decrease the regulatory burden on local governments and often are stated preferences by private sector interests. Ecology has staff committed to pollution prevention (http://www.ecy.wa.gov/programs/hwtr/p2/index.html) including providing advice and grant money to help business work in an environmentally sustainable manner. EPA also has a pollution prevention program that provides grants and other resources to businesses and local governments (http://www.epa.gov/opptintr/p2home/). EPA Region 10 also offers grants under the Clean Water Revolving Fund to study pollution sources and conduct remediation projects (http://yosemite.epa.gov/r10/ecocomm.nsf/6da048b9966d22518825662d00729a35/7b68c420b668ada5882569ab00720988?OpenDocument).

2.1.2.3 General NPDES Permits

The National Pollutant Discharge Elimination System (NPDES) is one of the regulatory tools for demonstrating compliance with the CWA. The NPDES program is implemented by Ecology. Ecology issues NPDES general permits for a number of point and non-point source dischargers, including municipal wastewater treatment plants, industrial facilities, boat builders, shipyards, confined animal feeding operations (CAFOs), sand and gravel mining operations, construction, and municipal separated storm sewers (MS4). Individual permits are also issued for dischargers that do not fit into one of the general permit categories.

2.1.2.4 Site Cleanups

CERCLA can require cleanup of contaminated sites (Superfund). MTCA is the corresponding state law. Such cleanup efforts can extend over decades.

2.1.3 Regulatory Effectiveness

The degree to which regulatory programs are effective depends on a number of factors, including the relevance of the regulation to current-day pollutant sources and types, knowledge of effective and appropriate cleanup levels or discharge limits, ability to incorporate cumulative effects of multiple sources and contaminant mixtures (versus requirements to permit one source and chemical at a time), enforcement/compliance rates, multi-jurisdictional cooperation, and staff and budgets that are aligned with the regulatory mission.

Implementation of new regulations sometimes lags far behind the creation of the regulations themselves because of state vesting laws. Under the current state law, projects are vested at the time of application (i.e., if the law changes between time of issuance of the permit and start of construction, the project only has to comply with what the law was at the time the permit was issued). The effect of vesting is to delay implementation of new requirements such as stormwater BMPs. In many cases, it may be many years or decades before newly adopted stormwater requirements are actually implemented in new projects.

For the most part, there are tools and regulations in place for individual point discharges, such as NPDES permitting of municipal wastewater treatment plants and industrial facilities. As of March 2007, there were 103 municipal sewage treatment plants, 10 combined sewage overflow systems (CSOs), and 15 major industrial facilities discharging in the Puget Sound basin. Total design flow from sewage treatment plants is over 260 billion gallons per year, and is almost 43 billion gallons per year from major industrial facilities. Treating this volume of water represents a major regulatory success story that began with the building of treatment plants in the 1970s.

However, these water quality treatment requirements were instituted primarily to address point sources rather than non-point sources and to reduce nutrient input, control biological oxygen demand (BOD), and stop the discharge of human pathogens. Subsequent additions of a general list of toxics (including metals and organic substances) to permits have further reduced loading of many of the more common pollutants. But significant questions remain about what is a safe concentration in various types of water bodies and how to account for multiple discharges into the same water system. Furthermore, emerging contaminants such as pharmaceuticals or personal care products are not yet regulated and discharge limits have to be written for these chemicals. Largely because transaction costs associated with NPDES permits (issuance plus required follow-up monitoring) are high for both the regulated community and the county or state governments, development of new treatment plants or expansion of existing facilities often lags behind the need.

Non-point source discharges are more difficult to regulate due to the diffuse nature of their sources. Therefore, regulatory authorities and the NPDES permits associated with non-point source pollution lean more heavily toward pollution prevention through stormwater control BMPs or incorporation of low impact development (LID) methods into planning and design. Ultimately, the effectiveness of stormwater management to control non-point source pollution will depend upon combining land use planning to manage changes in land cover in conjunction with BMPs and LID, as well as sustainable forest and agricultural practices. Public education will also be an important piece of the strategy. This necessitates cross-agency cooperation under several different regulatory authorities, which frequently creates roadblocks to implementation.

2.1.3.1 Coordination among Agencies

There is a lack of integrated planning among surface water runoff, wastewater, non-point source control, and water supply programs at the state and local levels. This has led to geographic gaps in coverage and functional gaps in how well programs perform. The pursuit of separate goals (and segmented programs and standards) to address human health and ecosystem constraints has led to the design and operation of facilities that do not address both objectives effectively. Historically, land use planning has not been strongly influenced by the provision for water supply, wastewater treatment, or stormwater management from an ecological perspective. More typically, land use decisions determined how water supply, wastewater disposal, and stormwater management would occur.

2.1.3.2 Enforcement and Compliance

Many jurisdictions lack funding for adequate enforcement and outreach programs, particularly given the large number of federal, state, and local regulations pertaining to water quality (see Table 5). The training of staff for preparing or reviewing designs, monitoring, and conducting enforcement is highly variable. This results in uneven application of existing rules and regulations, with attendant differences in environmental (and water) quality around the Sound.

2.2 Technical Approaches

2.2.1 *Source Control*

Source control measures include programs that prevent pollutants from being available for transport by surface water, and programs that reduce the use and availability of pollutants in the environment. Many of the federal, state and local regulations listed in Table 5 either directly or indirectly address source control of pollutants that could reach Puget Sound receiving waters. Techniques of source control management are discussed below by general land use categories.

2.2.1.1 Urban Source Control

NPDES permits are required for construction, industrial, and municipal wastewater treatment operations. These permits include requirements for educational programs, business outreach, and other methods of communicating the benefits of clean water. Some of the types of source control programs implemented in urban environments are listed in Table 6. Permits may include both source control and treatment provisions.

Table 6. Urban Source Control Programs

Land Use	Permits and Programs	Purpose	Implementing Agency
Industrial	NPDES Industrial Permits	Prevent pollutants from reaching receiving waters via stormwater runoff	Ecology
	Stormwater Pollution Prevention Plans		
	Staff Training		
	Covered Facilities		
	Emergency Spill Control Kits		
	Communication Plans		
	Safeguards for the use, handling and disposal of hazardous materials	Prevents accidental spills	Ecology, EPA
	Secondary containment		
	Air quality permits	Limit amounts of pollutants discharged to the atmosphere from industrial activities	Puget Sound Clean Air Agency
	Industrial Reuse	Turn waste products into resources	Ecology
	Chemical use reduction	Reduce waste by reducing use	Ecology
	Chemical substitution	Reducing toxic effects through substitution with less harmful chemicals	Ecology
Jurisdictional (cities and counties)	NPDES Phase I and Phase II MS4 permits (>10,000 population)		Ecology
	Public Education and Outreach	Change public behavior to reduce surface water pollution	
	Illicit Discharge and Detection Elimination Programs	Respond to spills, and intercept illegal discharges at the source	
	Stormwater Infrastructure mapping	Supports Illicit Discharge Detection and Elimination (IDDE program through knowledge of infrastructure)	
	In-line technologies		Ecology
	Vacuum-assisted street sweeping	Reduce pollutant runoff from streets	Local Jurisdictions
	Pesticide reduction	Reduce chemical usage	EPA, State Department of Agriculture
Construction	NPDES Construction Permits (>1 acre in size)		Ecology
	Temporary Erosion and Sediment Control (TESC) Plans	Reduce erosion through project phasing and BMPs	
Land Conversion	Low Impact Development	Reduce stormwater runoff	Local Governments

Effectiveness and Example Programs

The effectiveness of urban source control programs is difficult to measure because the number of programs confounds the independent analysis of source control alone (EPA, 2005). Source control effectiveness depends on a number of factors including the motivation of the implementer, staffing, funding, and enforcement. Jurisdictions and NPDES permit holders that place a high priority on the environment and have adequate financial resources to minimize water quality degradation generally are more effective. Additionally, when agencies that are charged with enforcing permits and programs have adequate staff available for enforcement, permit holders are more apt to comply with requirements rather than risk fines and public embarrassment.

Industrial Reuse and Reduction

There are several examples of successful industrial source control programs that have either reused or reduced waste products in their operations. Dunkin & Bush in Redmond is a commercial painting contractor. Cleanup at job sites produces waste paint and dirty paint thinners that the company now recaptures and reuses. They also return unused product to vendors, rather than disposing it as hazardous waste. As a result, they have saved over $270,000 in disposal costs (http://www.ecy.wa.gov/programs/hwtr/P2/p2success.html). Precision Machine Works in Tacoma reduced its hazardous waste generation ten-fold by substituting lower-hazard chemicals in its manufacturing process. Through a process of trial and error innovation, employees eliminated most chlorinated solvents and chlorinated-paraffin cutting oils, thus significantly reducing the amount of hazardous waste generated (http://www.ecy.wa.gov/programs/hwtr/P2/p2success.html).

Public Education and Outreach

In response to the education and outreach component of Phase I and II NPDES MS4 permits, Pierce, King, Snohomish, and Kitsap Counties and a number of cities within those counties, recently developed the Stormwater Outreach for Regional Municipalities (STORM), whose mission is to change public behavior "to reduce surface water pollution and improve water quality in the Puget Sound." Goals include supporting jurisdictions in developing their public education and outreach programs, providing a forum to share information and resources, and identifying targeted actions to reduce stormwater runoff. Last, STORM will be coordinated with the Partnership and other regional efforts to promote public awareness and education on stormwater management. The permits require that permittees "measure the understanding and adoption of the targeted behaviors" in public education programs, so that not only can the effectiveness of the program be measured but the information can be used to modify the program accordingly. Limited effectiveness monitoring has occurred under the NPDES municipal permits.

In-line Technologies

Vacuum-assisted street sweeping has been shown to reduce pollutant washoff and may remove up to 80% of total suspended solids (TSS) (Sutherland and Jelen, 1996; Breault et al. 2005). In 2004-2005, Seattle Public Utilities evaluated the use of street sweeping to improve water quality and to attempt to decrease maintenance costs (http://www.seattle.gov/util/Services/Drainage_&_Sewer/Keep_Water_Safe_&_Clean/Street_Sweep_Project/index.asp). Street dirt and debris were removed from designated streets in the Southeast Seattle, West Seattle, and Duwamish Industrial Area neighborhoods during the year-long pilot project, with the final report on effectiveness and levels of water quality improvement to be published in the fall of 2008.

Low Impact Development (LID)

LID techniques are being encouraged in many local jurisdictions through local codes and incentives. Local, national, and international research indicates that LID techniques (such as bioretention, pervious pavement, and rooftop rainwater harvest) can significantly reduce the volume and release rate of stormwater. Bioretention can capture and infiltrate many small storms entirely, reduce overall volume, reduce peak flows, and slow runoff that is produced (Rushton, 2002; Hunt et al., 2006; Davis et al., 2006; Horner and Chapman, 2007, Horner et al., 2004). Capturing and reusing rainwater that falls on roofs for irrigation and household uses reduces or eliminates the contribution of rooftop runoff to the stormwater system. By significantly reducing stormwater volume, LID techniques reduce the mass loadings of many pollutants to surface waters, such as metals, hydrocarbons, total suspended solids, and nutrients (Davis et al., 2006; Horner and Chapman, 2007; Horner et al., 2004; Hunt, 2006).

2.2.1.2 Transportation Source Control

Transportation programs designed to address issues such as congestion, emissions, fuel use, or waste management indirectly impact water quality through reduction of pollutants entering the environment. Some of these programs are listed in Table 7.

Effectiveness and Examples

As discussed earlier, there have been limited studies on the link between air emissions and water quality degradation. Therefore, it is difficult to know if emission control programs are having any effect on improved water quality. However, historic data on lead reduction in dust or along roadways when leaded gasoline was phased out, demonstrate that control of air emissions can significantly reduce pollution (Wu and Boyle, 1997).

Table 7. Transportation-related Source Control Programs

Transportation	Permits and Programs	Connection to Water Quality	Implementing Agency
Land-based	Commute Trip Reduction	Reduce traffic, which indirectly affects water quality.	Local Jurisdictions
	Vehicle Emissions Standards	Fewer emissions to air indirectly affects water pollution.	EPA
	Integrated Vegetation Management Program	Minimize use of herbicides along roads.	WSDOT
	Vehicle Parts Standards	Affects materials used in brake pads (i.e., copper) and other vehicle parts, which can affect water quality.	Federal Government
Air-based	Airplane Emission Standards	Reduces air emissions, which indirectly affects water quality.	EPA
Water-based	Standards for non-road diesel engines (including boats) and marine compression-ignition engines (ocean-going vessels)	Reduce air emissions, which indirectly affects water quality.	EPA
	Substitution of toxic anti-fouling agents with new anti-fouling paint	Reduce toxicity from anti-fouling paint on ships.	EPA
	Oil Spill Prevention	Prevent oil spills from vessels and oil-handling facilities.	Ecology (Spills Program), WDFW (Oil Spill Team), DNR (Derelict Vessel Program), and Oil Spill Advisory Council
	Waste Management	Regulate waste management and discharge in Puget Sound waters.	Northwest Cruise Ship Association, Ecology, and Port of Seattle

Oil spill prevention programs may be working as well. The interval between major oil spills (>10,000 gallons) in Puget Sound has increased between 1988 and 2006 (Ecology MIS 2008), indicating that industry, federal, and state spill prevention work is effective.

One of the most common anti-fouling agents, tributyl tin, is being phased out in 2008. Whether replacement agents will be equally effective at preventing the buildup of barnacles, algae, and other organisms on ship hulls and be protective of water quality is to be determined.

2.2.1.3 Rural Source Control Programs

Pollutants in rural surface water runoff are typically generated from non-point sources. Rural source control programs that address non-point source pollution are listed in Table 8. Additionally, many of the urban source control programs listed in Table 6 also apply to rural environments where industrial practices occur, or construction and land conversions are taking place.

Table 8. Rural Source Control Programs

Land Use	Permits and Programs	Purpose	Implementing Agency
Agriculture	NPDES Confined Animal Feeding Operations (CAFO) permit		Ecology, Department of Agriculture
	Manure management	Develop management plans for the storage, treatment, and disposal of animal wastes to reduce water quality issues.	
	Farm Plans and BMPs	Protect environment from the impacts of livestock.	
	Livestock Grants	Provide landowners with technical resources and financial assistance to install BMPs to improve stream buffers that reduce sediment and bacterial and nutrient pollution.	Incentive-based programs through local conservation districts
	Conservation Reserve Enhancement Programs (CREP)		
	Farm Plan Implementation Grants (FPIG)		
	Integrated Pest Management	Ensure that pest management controls are applied in the most environmentally appropriate manner.	Department of Agriculture, Ecology, DNR
	Pesticide and Insecticide Management	Ensure that pesticides are used safely and appropriately.	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
	Agricultural Protection Districts	Propose areas for non-toxic farming methods to protect ecologically sensitive areas.	King County Council, Snoqualmie Valley Tilth
Aquaculture	NPDES Aquaculture permit	Minimize sediment disturbance during harvest and additions of feed, waste materials and additives such as antibiotics.	Ecology
Forestry	State Forest Practices Act	Regulates activities related to growing, harvesting, planting and maintaining forest lands, including use of fertilizers and pesticides.	DNR
	BMPs for Harvesting and Road Maintenance	Reduce erosion.	
	Rules Regarding Harvest in Sensitive Areas, Including Steep Slopes	Reduce erosion.	

Effectiveness and Examples

With the exception of NPDES permits for CAFOs and aquaculture, and implementation of the state Forest Practices Act, rural source control programs are largely voluntary. As such, monitoring programs to measure effectiveness are not readily available.

Forest Practices

A recent evaluation of the monitoring required under the Department of Natural Resources Habitat Conservation Plan for forest practices indicated that 81% of the 278 total activities reviewed were in compliance with the Forest Practices Rule (http://www.dnr.wa.gov/BusinessPermits/Topics/ForestPracticesHCP/Pages/fp_hcp_highlights07.aspx).

2.2.2 Treatment Measures (Pathways)

Treatment measures to remove or partially remove pollutants once they are in the waste stream (surface water runoff or wastewater) are mostly guided by NPDES permits, enforced by Ecology, and implemented at the local level. Additionally, treatment of air-borne pollutants prior to discharge is guided by requirements of the Puget Sound Clean Air Agency and permits issued for discharges to air.

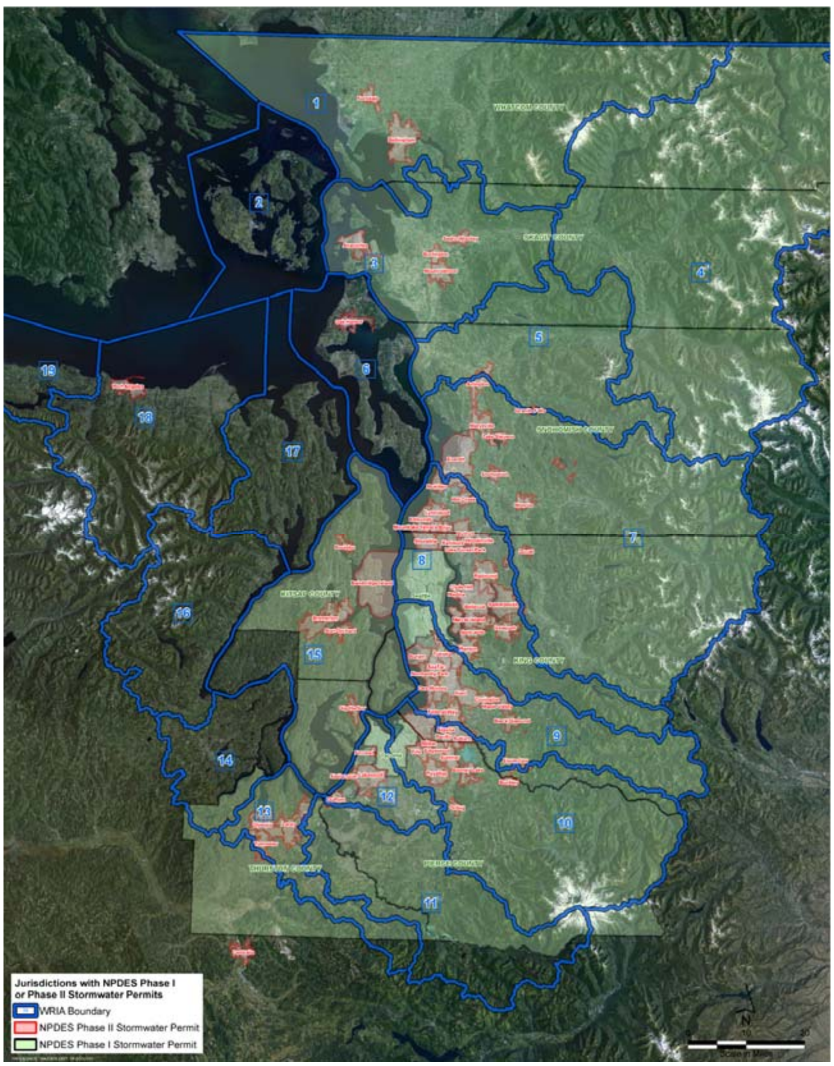
The effectiveness of treatment measures is both presumptive and demonstrative, depending on conditions of state and local permits followed. For instance, if prescribed treatment measures for surface water runoff are followed according to standard practices, it is presumed that the measures are effective at removing the targeted pollutants. Follow-up monitoring programs demonstrating ecological effects generally are not done, so effectiveness of permits, and control measures, etc. is largely unknown. However, for some types of waste discharges, such as at industrial facilities, monitoring must occur to demonstrate that conditions of the permit are being met. Descriptions of currently used treatment methods for the different pollution pathways are described below.

2.2.2.1 Surface Runoff

Urban Surface Water

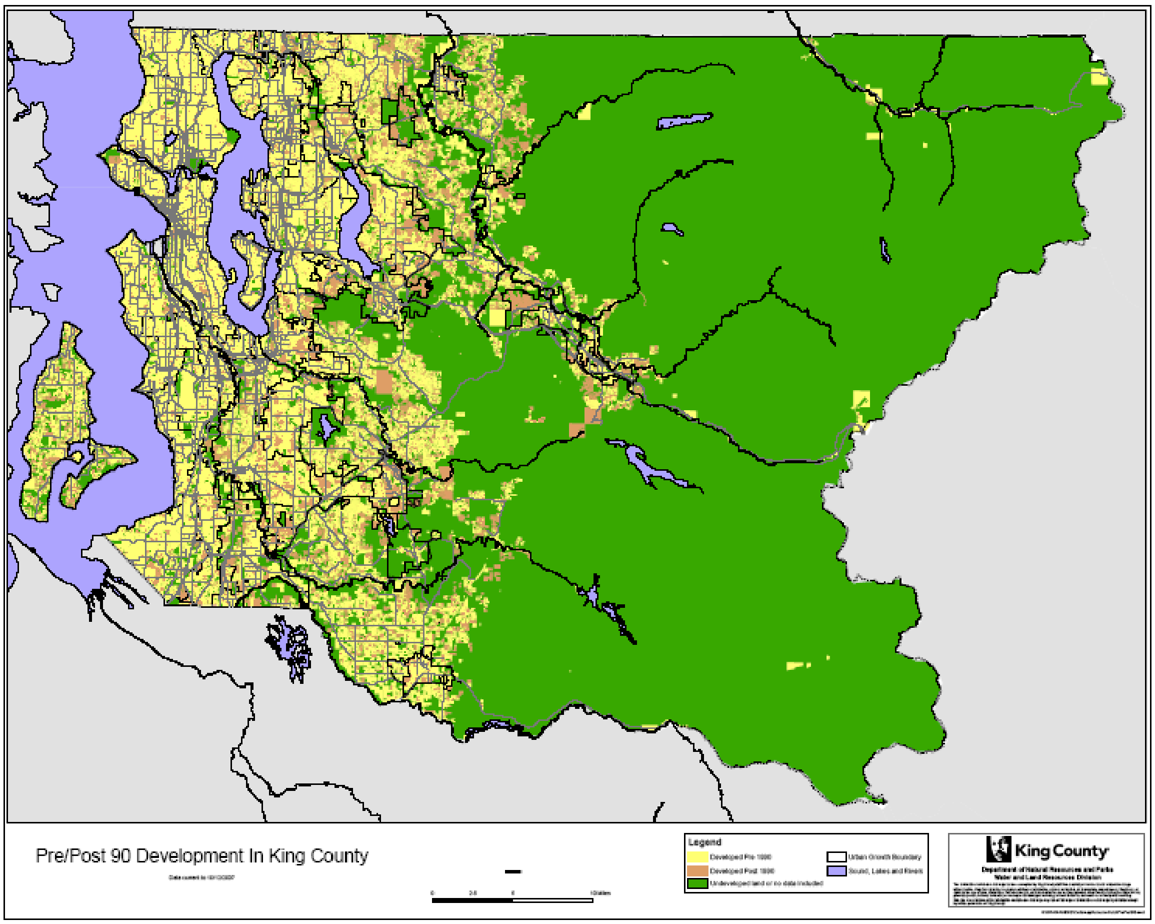
Stormwater treatment techniques started being implemented in the Puget Sound basin around 1990, with the production of the State's first stormwater manuals (1990 King County Stormwater Management Manual and 1992 Ecology Western Washington Stormwater Management Manual). The current Ecology Manual (Ecology, 2005b) includes prescribed treatment measures for new development and redevelopment that meet certain thresholds. Treatment techniques and requirements have evolved over the last decade, along with technical understanding of stormwater impacts. The techniques listed in the 2005 Ecology Manual are the measures most often used today; however, many jurisdictions use equivalent manuals specific to their jurisdictions. NPDES Phase II permits require Permittees to adopt the latest Ecology Manual by August 2009. Figure 3 shows the NPDES Phase I and Phase II communities in the Puget Sound region and the areas without NPDES MS4 coverage.

Figure 3. NPDES Phase I and Phase II communities



Most of the stormwater in the Puget Sound basin remains untreated because stormwater treatment requirements were not in place when the greater part of the region's development occurred. For example, Figure 4 provides a glimpse of pre- and post-1990 development in King County. In these areas, stormwater treatment retrofits sometimes (but not always) are incorporated with redevelopment of individual properties. Stormwater retrofit techniques are similar to treatment measures installed when properties are newly developed (such as construction of bioswales, reducing amount of impervious surfaces, or reusing "gray water" through the use of rain barrels).

Figure 4. Pre/Post 1990 Development in King County.



Surface water runoff from impervious surfaces is managed similarly, whether it is transportation-based or from urban development (commercial, institutional, and residential). Most urban areas around Puget Sound have established stormwater drainage utilities of some type to fund maintenance and operation of municipal stormwater systems and capital projects. Many utilities develop comprehensive plans that guide their programs, including treatment measures.

The different types of stormwater treatment measures typically used are listed in Table 9.

Table 9. Surface Water Runoff Treatment Measures

Treatment Measures	Purpose	Implementing Agencies	Effectiveness at Pollutant Removal
Traditional Stormwater BMPs	Treat stormwater runoff for common urban pollutants prior to discharge to receiving water bodies.	Ecology, local jurisdictions. Criteria for implementation depend on site specific- and project-specific conditions, including size of development and location relative to receiving water bodies.	Highly variable, depending on many factors including design, maintenance and influent conditions (Geosyntec and Wright Engineers, Inc., 2007)
Retention/Detention Facilities			
Bioswales			
Wet Vaults			
Constructed Wetlands			
Media Filters			
Hydrodynamic Devices			
Low Impact Development BMPs	Treat stormwater runoff through installation of facilities that manage stormwater closer to its source and attempt to mimic natural hydrological conditions.	Same as above	
Pervious Asphalt, Pavers And Concrete			Shown to reduce metals, petroleum hydrocarbons and TSS (Brattebo and Booth, 2003, Berbee et al., 1999, Dierkes et al., undated, Pratt et al., 1995)
Rain Gardens			No data reported
Green Roofs			Reduces stormwater volume, which indirectly reduces pollutant loading
Bioretention			Removal of metals and hydrocarbons is excellent (>90%) (Davis et al., 2001, Hunt 2003, Davis, et al., 2003, Hong, 2006) and removal of nutrients is variable (Davis et al., 2001, Hsieh, 2005a,b, Hunt 2006, Hsieh, 2007a,b)

Effectiveness and Limitations

Current design and application of BMPs for stormwater have not been demonstrated to consistently achieve water quality standards in receiving waters, nor are water quality standards for BMP design explicitly stated in most watersheds. For water bodies with TMDL requirements, treatment and source reduction are typically presumptive and not linked to achieving specific numeric standards. Coupled with the limited or absent water quality monitoring conducted in many local watersheds, this presumptive approach prevents the possibility of drawing scientific conclusions on treatment measure effectiveness (http://www.ecy.wa.gov/programs/eap/models.html).

A review of LID effectiveness completed by EPA in 2000 showed that, in general, LID measures are more cost effective and lower in maintenance than conventional, structural stormwater controls. However, not all sites are suitable for all types of LID techniques. Considerations such as soil permeability, depth of water table, and slope must be considered, in addition to other factors.

Further, the use of LID may not completely replace the need for conventional stormwater controls, particularly with respect to drainage facilities removing runoff from large storms under saturated soil conditions. When appropriately applied, LID techniques can reduce the amount of effective impervious area (EIA)[3] in a watershed.

Maintenance

Maintenance of stormwater treatment BMPs is an important factor in the successful removal of stormwater pollutants. Maintenance issues can be more complicated for LID than for conventional stormwater controls, because the LID measures may reside on private property. In most instances, homeowners agree to only the first year of maintenance under the terms of their purchase agreement. Homeowner associations could be a mechanism for providing long-term maintenance to these areas. Generally, bioretention facilities require replacement of dead or diseased vegetation, remulching as needed, and replacement of soils after 5 to 10 years. Grass swales require periodic mowing and removal of sediments. Maintenance of permeable pavements requires annual high-powered vacuuming of the area to remove sediments.

Presumed Pollutant Removal

The applications of water quality treatment BMPs for urban surface water runoff is presumed to achieve water quality standards, which may be true in some situations, but not in others. Existing stormwater BMPs prescribed in the Ecology 2005 Manual are not effective at removing all of the constituents associated with surface water runoff from new development. However, in general, most are fairly effective at removing TSS. A currently contentious aspect of the NPDES MS4 permits pertains to the possible exposure of municipal stormwater dischargers to third-party lawsuits for failure to meet water quality standards that are unachievable with current programs, policies, projects, or funding levels. Current Phase I permits attempt to make progress in the linkage of select BMPs and loading reductions.

Long-term Performance

The use of BMPs has been studied in United States since at least the 1980s with the notable National Urban Runoff Program research (EPA, 1983). The use of LID in the United States is relatively new and not extensively widespread. Most of the available data on effectiveness are from Prince George's County, Maryland, which pioneered the use of LID. The only available data for a long-term study are from the Aquarium parking lot in Tampa, Florida, and the Washington permeable pavement project. As with traditional treatment facilities, which also have almost no long-term performance data, more long-term analysis is required to more accurately assess the effectiveness of LID and to determine long-term trends.

Monitoring Data

Monitoring requirements for Phase 1 NPDES permits will begin in February or August of 2009. Permittees will submit data and analyses with their annual reports. The Phase II Western Washington permit does not require monitoring.

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[3] EIA is the impervious area directly connected to the storm drain system and contributes to increased watershed volumes and runoff rates.

NPDES permits for other specific urban land uses or activities, such as the industrial general permit, construction permit and others, generally require monitoring to demonstrate permit compliance and effectiveness.

2.2.2.2 Wastewater

Technical approaches to treating wastewater vary depending on the type of waste. Municipal, on-site and combined sewer overflow treatment facilities primarily focus on removing pathogens, biochemical oxygen demand (BOD), and suspended solids with a primary objective of protecting human health. Industrial facilities generally have treatment systems unique to their waste products, and sometimes discharge to municipal systems following pre-treatment. Municipal dischargers also monitor for acute and chronic toxicity and an extensive list of toxic pollutants, which are not controlled primarily by industrial pre-treatment. Treatment for nutrient removal is not standard practice in the Puget Sound region.

Municipal Wastewater Treatment

Most urban communities in Puget Sound have local or regional wastewater utilities to fund operation and maintenance of municipal wastewater treatment plants. These utilities develop comprehensive wastewater management plans coincident with Growth Management Act comprehensive plan updates, as required by their authorizing legislation.

Municipal wastewater treatment plants are operated under NPDES wastewater treatment permits. NPDES permitting of municipal and industrial wastewater discharge includes both the use of individual permits and general permits covering a range of facilities. Permits are good for five years, and application for permit renewal must be made one half year before the permit expires. The permit process imposes technology-based requirements, then evaluates whether more stringent water quality-based effluent limits are needed. Imposition of water-quality-based effluent limits in turn can drive additional actions, such as source control. Permits also evaluate the need for limits of the toxicity of an effluent and may require other studies, such as sediment quality evaluation, and verification that the underwater outfalls are intact and functioning properly.

Combined sewer overflows (CSOs) also are subject to NPDES permits and requirements. The current state standard for CSOs is one uncontrolled overflow per year per CSO outfall, compared to the current federal standard of approximately four uncontrolled overflows per outfall per year. Many municipalities, including the City of Seattle, are on a compliance schedule to achieve this standard. In general, CSO treatment programs are not driven by overall achievement of water quality standards, but to achieve a standard based on the number of untreated overflows allowed per year. In many areas, adding stormwater to the combined sewer system is no longer allowed except in special cases.

A description of municipal wastewater treatment techniques and their effectiveness is listed in Table 10.

Table 10. Municipal Wastewater Treatment Techniques and Efficacy

Wastewater Treatment Type	Description	Conventional Pollutant Removal	Pathogen Removal	Emerging Contaminant Removal
Primary Wastewater Treatment	Screening out of large solids and gravitational settling out of a portion of the remaining solids before discharge.	Small fraction (10%-30%) removed through removal of solids	Small fraction (10%-30%) removed through removal of solids	None documented
Secondary Wastewater Treatment	Primary followed by aerobic biological treatment. Disinfection common.	Removal of ≥85% of the BOD and TSS; oxidation of ammonia to nitrite and nitrate reduces potential ammonia toxicity	Large percent removal (80-90%) through disinfection practices	Emerging evidence of partial removal of some select compounds through biological treatment systems (Jiang et al. 2005, Nasu et al. 2001)
Tertiary Wastewater Treatment	Secondary treatment followed by filtration and disinfection.	Removal of ≥95% of the BOD and TSS; oxidation of ammonia to nitrite and nitrate reduces potential ammonia toxicity	Large percent removal (~99%) through filtration and disinfection practices	Same as secondary wastewater treatment
Biological Nutrient Removal (BNR)	Secondary or tertiary treatment where biological treatment systems are operated to remove nitrogen and phosphorus.	Similar BOD and TSS removal rates as secondary, with ≥80% nitrogen and phosphorus removal	Large percent removal (~99%) through filtration and disinfection practices	Same as secondary wastewater treatment
Advanced Treatment	Membrane bioreactors (MBRs), advanced denitrifying filters, advanced disinfection (UV), advanced oxidation processes.	MBRs can be operated as BNR systems with the same results; 100% TSS removal, >99% BOD removal	Close to 100% in MBRs because of membrane filtration and disinfection practices	Varying evidence that MBRs perform better than conventional systems (Oppenheimer, et al.2007, Clara et al. 2005); emerging evidence that advanced oxidation processes can remove some emerging contaminants (Esplugas et al.,2007, Hu et al. 2007, Snyder et al)

Other Municipal Treatment Measures

The *reuse of treated wastewater*, although most commonly associated with conservation efforts, can be implemented as a pollution control measure in some instances. A reduction in effluent discharge through reuse translates into a reduction in nutrient and toxic loading to the receiving waters.

Reclaimed effluent is being utilized for wastewater treatment plants at various sites such as Lacey, Olympia, and Tumwater (LOTT), King County, and Sequim; however, there are numerous barriers that hinder its widespread application, as discussed below under effectiveness.

"Flow blending" is another treatment technique used to reduce loading over secondary treatment, as it is less expensive than other advanced treatment techniques. Flow blending involves treating base flows to a high standard and then blending them with storm flows, which are treated to a lower standard. The aggregate result is lower pollutant loading over the traditional secondary treatment approach. In addition, the integrity of the treatment process is protected from damage.

Dilution is another treatment method used by municipal and industrial discharges to discharge pollutants at concentrations that exceed water quality standards at the end of the pipe, but comply with standards at a point of compliance some distance away from the pipe. These areas of higher concentrations are known as "mixing zones." Mixing zones provide a useful link between water quality criteria and discharge permits, as the state's water quality criteria are not directly comparable to concentrations in a discharge. The criteria not only have a concentration component, but also duration and frequency of exposure components. Both EPA and the state recognize that water-quality-based effluent limits are derived from and comply with water quality criteria and may incorporate dilution based on the state's mixing zone regulations. Mixing zones do not cover the entire range of pollutants potentially discharged from treatment plants.

Effectiveness of Treatment

There are several barriers to the effective treatment or reduction of pollutants in municipal wastewater discharges. These include technical barriers (such as the ability of treatment plants to remove nutrients or EDCs), cost barriers (such as the ability of wastewater utilities to fund higher levels of treatment), and institutional barriers (such as the liabilities associated with the use of reclaimed water). Some of these barriers are discussed below.

Emerging Contaminants

The discharge of micro-constituents such as pharmaceuticals presents an emerging challenge for treatment in municipal systems. These compounds are discharged in human waste in very low levels and are ever-changing in composition, number, and complexity. Not only are there technical barriers regarding detection, but sampling protocols are largely undeveloped, and testing is expensive. Effective treatment options are not well developed, but may require expensive upgrades to treatment facilities. Existing regulatory procedures do not provide guidance on acceptable concentrations for these contaminants. This is due to gaps in knowledge about the extent to which these compounds negatively affect the ecology and human health.

Reclaimed Water Use

Technological barriers to reclaimed water production are few. Methods for treating wastewater to Class A reclaimed water standards are known and commonly employed. One of the primary challenges with reclaimed water is economics. Although the cost of treatment to reclaimed water standards may be modest for new facilities, it can be prohibitively expensive when retrofitting existing systems. There is an additional economic impact to existing water purveyors associated with introducing another source of water into the current water supply system (King County 2006). Exclusivity of service area may give water utilities veto power over water reuse in their areas, because water reuse is viewed by some water utilities as competition for their customers. While water systems with greater than 1,000 connections are required to evaluate water reuse in their supply planning, non-potable demand is not adequately accounted for as a separate demand. Pricing policies for non-potable water vary widely, ranging from free to on par with potable rates, and the cost recovery policies are not uniform. For example, some areas of the country charge reclaimed water at 80% of potable rate, regardless of the cost of production.

Another barrier to using reclaimed water is the potential liability to the producer (wastewater treatment plant), purveyor (water utility), and the end user. Finally, there is a psychological barrier with regard to the use of what is still perceived as wastewater effluent despite its substantial treatment. As water supplies dwindle and education about the treatment and safety of reclaimed water for non-potable uses becomes more comprehensive, this natural aversion may decline.

Funding

Funding higher levels of treatment at wastewater treatment facilities requires significant financial resources. During the 1970s, when many plants converted from primary to secondary treatment, funding was supported at the federal and state levels. Current wastewater treatment plant upgrades face funding shortages in non-urban areas because most of the funding is through local sewer utility fees. A paradox exists that to fund higher levels of treatment with local financial resources, greater population densities are needed to keep utility rates affordable. And, greater densities drive the need for higher levels of treatment. This is especially problematic in areas that already present risks to Puget Sound water quality health but cannot support the densities necessary to make high levels of wastewater treatment affordable.

The Growth Management Act (GMA) helps steer growth into already urbanized areas, which goes some way toward helping reconcile population density and affordable wastewater treatment plant facilities (King County, LOTT).

Monitoring

Municipal wastewater treatment must comply with NPDES permits for wastewater discharges. These permits outline requirements for discharge limits (frequency, concentration of key constituents, and volume), as well as water quality monitoring to document compliance. In general, municipal and industrial wastewater treatment plant operators routinely monitor effluent quality to document compliance with NPDES permit conditions. Monthly discharge monitoring reports (DMRs) are submitted to Ecology.

Industrial Wastewater Treatment

Industrial wastewater treatment systems are designed specifically to deal with each industry's waste stream. Increasingly, industrial discharges are being diverted into municipal systems following pre-treatment to make the waste compatible with municipal domestic waste. Because of the unique nature of industrial waste streams, treatment methods are specialized, and the effluent is monitored for the specific waste constituents that are to be removed. When municipal treatment plant operators accept industrial waste following pre-treatment, the operators are required under their NPDES permits to ensure that waste from industrial facilities does not adversely impact the receiving water bodies where treated municipal sewage is discharged. While municipal facilities conduct regular effluent quality monitoring for effluent toxicity and for many toxic compounds, however, they generally do not conduct receiving water monitoring.

Effectiveness

Industrial dischargers must have NPDES permits that involve monitoring effluent and reporting to Ecology. Municipal pre-treatment programs can be effective; however, they are administered by individual municipalities without much support on a state level. Seattle, Tacoma, Bremerton, Everett, and Bellingham are all areas in Puget Sound with substantial industry and industrial waste streams.

Perhaps the most significant gap in effectiveness is a lack of industrial oversight by Ecology. There is a need for the air and water components of industrial pollution to be linked. While industry stacks may be permitted for air quality, further investigation should be done regarding how the permitted air pollution values may partition to and impact Puget Sound waters.

On-site Septic System Treatment Measures

Rural communities in Puget Sound do not have regional wastewater treatment facilities, and residents typically use on-site wastewater treatment techniques for sewage treatment. Ecology and the Washington State Department of Health (DOH) have a 30-year history of regulating on-site sewage systems in collaboration with local health jurisdictions. DOH estimates that there are approximately 500,000 on-site septic systems in the Puget Sound basin, many located directly adjacent to marine waters.

Advances in treatment technology have accelerated over the last ten years (http://www.metrokc.gov/health/wastewater/owners/types.htm), and the regulatory framework changed in 2006 for managing large on-site septic systems.

Washington House Bill 1458, adopted in 2006, established new laws requiring the 12 counties surrounding Puget Sound to (1) identify "marine recovery areas" where failing septic systems threaten water quality, (2) locate and track those systems that threaten public health, and (3) work with system owners to make necessary repairs. Additional state appropriations enacted in 2007 (HB 1092 and SB 5156) provide low-interest loans and grants specifically to repair and replace failing septic systems in the Hood Canal region. These efforts will have to be monitored to evaluate whether any discernable improvements in water quality will stem from this legislation. Nevertheless, there is obvious attention being paid and legislative action being taken in attempts to ameliorate this problem (http://www.leg.wa.gov/pub/billinfo/2007-08/Pdf/Bills/House%20Bills/1092.pdf).

Effectiveness

Well sited, designed, and constructed on-site wastewater systems are effective in removing pathogens and indicator bacteria from wastewater. However, on-site wastewater system siting standards, while protecting human health, may not protect receiving waters from effects of nutrients, especially nitrogen. Technologies for nitrogen removal from on-site systems are not routinely utilized at this time, increasing the challenges of adequate treatment in areas subject to hypoxia and other side effects of excess nutrient discharges. Existing land use regulations, including the GMA, limit the areas where centralized wastewater treatment systems can be used to existing Urban Growth Areas (UGAs). This can result in prohibitions against wastewater treatment systems in some localized areas of higher-than-rural density that current exist outside of designated UGAs.

Maintenance

The state DOH estimates there are about 500,000 on-site septic systems throughout the 12-county Puget Sound region. About 5% of these systems are estimated to be failing and causing pollution problems. Ecology provides low-interest loans to local governments and tribes to support the repair and updating of malfunctioning systems.

Hood Canal has had particular difficulty with failing septic systems which resulted in the formation of The Hood Canal Regional Septic Loan Program. This program has distributed over $600,000 of loans and grants to address pollution problems caused by failing septic systems throughout Kitsap, Jefferson, and Mason counties and on Port Gamble S'Klallam and Skokomish Indian tribal lands. Whether this loan program has been effective at improving water quality in Hood Canal has not been determined.

Funding and Ownership

In spite of the aforementioned legislation, funding and incentives for repairing, replacing and maintaining on-site sewage systems—and for connecting on-site systems to municipal sewage treatment plants or for consolidating on-site systems to form a large on-site system—are limited. Decentralized wastewater infrastructure deals with other related barriers associated with private ownership of the systems and the lack of coordinated planning to guide infrastructure investments.

Monitoring

Unlike pollutant loads from permitted point sources where effluent monitoring is mandated, pathogen and nutrient loads to Puget Sound from on-site systems are not easily quantified. Surface water quality monitoring for 303(d) compliance may identify sources of nutrient impacts.

On-board Waste Treatment Measures (boats, RVs, airplanes)

On-board treatment systems commonly consist of a simple holding tank that permits wastewater to be stored until a receiving facility or dumping station can be reached.

Because these tanks do not usually contain the same percentage of dilution water that a municipal sewer would, the wastewater is of much higher strength and contains more nutrients and pollutants by volume than conventional wastewater. Deodorizing chemicals such as formalin (another name for formaldehyde, a known carcinogen) are added to the tanks; these chemicals are potentially toxic to both humans and other biota. Other less toxic additives are available as well, but there are no data on the use of these additives relative to the more harsh varieties (http://www.epa.gov/region09/water/groundwater/uic-docs/rv-wastewater.pdf).

Large naval and cruise ships may have higher-level treatment systems such as Membrane Bioreactors (MBRs) aboard. Cruise ships in particular are more likely to have these units after International Maritime Organization regulations mandated on-board sewage treatment systems (or large enough holding tanks) for ships making international voyages and which are larger than 400 tons or carrying more than 15 passengers (IMO, 2005) (http://www.imo.org/Newsroom/mainframe.asp?topic_id=1018&doc_id=5078).

Marine waste treatment systems may be both "treat and discharge," as with the cruise ship industry, and "store and dispose," where marinas or shoreline campgrounds provide receiving tanks. Unfortunately, boat users often dump untreated waste directly into water bodies.

Airports typically have their own store and dispose facilities to which airplanes discharge. The waste is diverted to municipal sanitary sewers for treatment. Rarely are there accidental or illegal discharges from the airplanes themselves.

Effectiveness

There is variability in the treatment and disposal of on-board wastewater. On-board systems are not specifically designed to treat waste, but merely contain it until a proper treatment facility is reached. Marine systems range in their treatment capabilities, producing something akin to primary effluent (see Wastewater – Municipal Treatment Measures) to high-quality effluent comparable to reclaimed water. There is variability among ports regarding marine dumping versus pumping the ship's sewage to a tank for hauling to a municipal treatment plant.

Agreements between Ecology and the cruise industry have outlawed dumping untreated sewage in Puget Sound, and the Port of Seattle is investigating the possibility of taking cruise ship wastewater to a land-based municipal treatment facility (http://seattlepi.nwsource.com/local/363993_cruise22.html).

2.2.2.3 Air

Pollutant discharges to air are regulated by the Puget Sound Clean Air Agency under the authority of the state and federal Clean Air Acts. Typically, permits are granted within certain limits for discharges without treatment. For industrial dischargers, treatment is sometimes necessary to bring pollutant levels down to accepted levels. Other diffuse sources of air pollution also are regulated by the PSCAA but are more difficult to control, for example vehicle emissions. Control of such emissions can have an enormous benefit for large areas. This is exemplified by the switch away from lead as an oxygenating factor in gasoline; significant reductions in lead pollution of soils and runoff were achieved across the country. Large ocean-going vessels (including cruise ships) are implementing similar pollution reduction programs in Puget Sound, such as burning low-sulfur fuels and trying innovative seawater exhaust scrubber technologies that will significantly reduce sulfur oxides, particulate matter, and nitrogen oxides (http://maritimeairforum.org/EI/PSEI_Projects.pdf).

Industrial Treatment Measures

The Clean Air Act requires pollution reduction for priority pollutants using best available technology (BAT). The type and effectiveness of BAT varies depending upon emitter type (M.J. Bradley & Associates 2005). In general, the type of raw material being combusted, the process conditions, and the emission control technology used will all influence final pollutant discharge levels.

There are four general categories of pollutants that can be reduced through emission control technologies: nitrogen oxides, particulates, volatile organics, and sulfur dioxide. Emission technologies include (1) nitrogen oxide (NO_x) controls such as low-NO_x burners, (2) particulate controls, such as wet scrubbers, (3) volatile organic compound (VOC) controls, such as condensation techniques, and (4) sulfur dioxide controls, such as wet or dry scrubbers (M.J. Bradley & Associates 2005).

2.2.3 Remediation Measures

One of the last options for dealing with water quality concerns, after pollutants have been used or disposed of, picked up in the waste stream, and not effectively removed, is to clean up the water or sediment in which they are present. Usually, this involves groundwater; sediment in deltas, estuaries and quiescent depositional zones; and freshwater lakes. Federal and state programs that deal with site cleanup include CERCLA (Superfund) and MTCA through voluntary and mandatory cleanup programs. Sites given priority for federal cleanup are those on the National Priority List (NPL). Placement on the list occurs either through EPA's formal Hazard Ranking System (HRS), by nomination from a state as a top-priority site, or by meeting three requirements: 1) the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Public Health Service issues a health advisory recommending removing people from the site; 2) EPA determines the site poses a significant threat to public health; and 3)EPA anticipates it will be more cost-effective to use its remedial authority than to use its emergency removal authority to respond to the site.

These programs address the threat of sediments containing a number of legacy contaminants such as organochlorines (DDT, PCBs) that impact water quality and can bioaccumulate in aquatic organisms. Oftentimes, there are multiple sources and responsible parties involved in the cleanups. Some of the techniques used to remediate contaminated water and sediment and improve water quality conditions are discussed below.

2.2.3.1 Groundwater Contamination

Contaminated groundwater typically is associated with the release of toxic substances to the ground surface or subsurface. Subsurface release sources include leaking underground storage tanks or conduits such as dry wells.

Contaminants of concern include volatile and semivolatile organic compounds (including non-aqueous phase liquid [NAPL] and dissolved phase), polychlorinated biphenyls, metals, solids, bacteria, and conventionals (such as pH and ammonia). There are several techniques used to remediate groundwater. The remediation technique chosen depends upon the contaminant(s) and properties of the site. The techniques most often used include (1) bioremediation, which is used in the treatment of organic substances that can be broken down by bacteria, (2) in situ chemical oxidation and reduction, which is similar to bioremediation except a chemical agent is used to break down the pollutants, and (3) vapor extraction, for volatile or semivolatile organic compounds. Vapor extraction remediation techniques typically extract vapors and release them into the atmosphere, and require permits from the Puget Sound Clean Air Agency.

2.2.3.2 Sediment Contamination

Almost one-half of the 115 contaminated marine sediment sites in Puget Sound (51 sites) are undergoing active cleanup (Ecology, 2005a). These include sites with ongoing initial investigations, remedial investigations, feasibility studies and remedial design. Nearly two-thirds (75 sites) of the marine sediment sites identified above are in the process of being cleaned up, including those in some type of post-cleanup monitoring. Eagle Harbor, once highly contaminated with polycyclic aromatic hydrocarbons (PAHs) from creosoting operations, is one notable success story among many others. Fish tissue monitoring two years after a clean cap was placed over the site indicated a significant drop in liver lesions of bottom fish. Additional information on the status of cleanup sites can be found in Ecology's 2005 status report (Ecology, 2005a).

In 2007 Ecology partnered with local government and launched the Urban Waters project (Ecology, 2007a). The purpose of this project is to find the sources of toxic contamination and help businesses and other entities reduce or eliminate those sources in ways that allow Ecology to measure results. The current focus is on three waterways: the Spokane River, the Lower Duwamish River and Commencement Bay (Ecology, 2007a). Significant cleanup investments have been made in the Lower Duwamish and Commencement Bay and work has recently begun in the Spokane River.

Source control programs are integral to the remedial strategies at sediment cleanup sites throughout Washington and are particularly important for preventing future recontamination.

2.2.3.3 Streams and Rivers

Water quality conditions in freshwater streams and rivers are monitored through various federal, state, local, tribal and not-for-profit programs. The process used most to improve water quality conditions in these environments is to establish total maximum daily loads (TMDLs) for the pollutants of concern and to implement watershed-wide actions to achieve load reductions. Many water quality issues can be addressed by establishing more riparian vegetation and planting, and improved baseflow conditions (cold groundwater inputs). Riparian buffers keep out bacteria and other toxic contaminants coming from stormwater runoff. They also improve the water temperature, dissolved oxygen content, and physical structure.

2.2.3.4 Lakes and Marine Water

Ecology monitors freshwater lakes and marine waters, and also establishes TMDLs for problem constituents. One of the biggest concerns in lakes and certain marine waters in Puget Sound is the input of nutrients and associated eutrophication. In-water treatment measures to control nutrients and slow the process of eutrophication in lakes have included alum treatments, importing fish that will eat the plants, physically cutting aquatic plants and disposing of them, and aeration. The TMDL process described above is similar for impaired lakes and marine waters.

2.3 Emerging Programs and Programs Used Elsewhere

2.3.1 *Market-based Incentive Programs*

Recently, market-based incentive programs have been emerging in the private sector. Cap-and-trade for carbon credits (for control of greenhouse gasses) is the most well known. Mitigation banks for wetland preservation also have been developed in the region.

2.3.2 *Other Coastal Restoration Programs*

There are a number of regional-scale efforts directed towards mitigating and restoring estuaries and coastal ecosystems. In a report released in April 2004, the U.S. Commission on Ocean Policy recognized that the cost and complexity of coastal habitat restoration efforts requires the participation of a wide range of stakeholders (http://oceancommission.gov/documents/prelimreport/chapter11.pdf). One mechanism that was highlighted for bringing together federal departments and agencies with local governments and nongovernmental organizations is the Coastal America Partnership. Since its inception in the late 1990s, the Coastal America Partnership has facilitated over 600 collaborative projects, including federal departments, state and local governments, and over 300 private businesses and organizations. Project activities have included wetlands restoration, dam removal, species protection, and pollution mitigation.

The Estuary Restoration Act, enacted in 2000 and administered by NOAA, is a source of funding for restoration and mitigation actions. The Act states that NOAA is responsible for developing and maintaining a database of information concerning estuary habitat restoration projects and for developing standard data formats and requirements for project monitoring. Several projects within the Puget Sound basin have been funded under this mechanism (e.g., Nisqually National Wildlife Refuge restoration). The database provides an opportunity to review similar actions at estuaries around the country (including the Great Lakes, which were defined by the Act as estuaries). NOAA's review reported many common elements among successful plans, including effective partnerships, education and outreach efforts, availability of funds, use of best available technology, implementation of a scientifically sound monitoring protocol, use of defined success criteria, and a standard tracking system (http://www.csc.noaa.gov/coastal/expert/natreview/natreview05.htm).

3. P2 - Strategies to Improve Water Quality

3.1 Introduction

As a nation and region, tremendous strides have been made in water quality improvements since the middle of the twentieth century. Systems for treatment of human and industrial wastes are largely in place. Remediation efforts have occurred at the worst of the contaminated sediment sites. And, as described in the previous section, there are a wide array of facilities, programs, laws and standards intended to reduce pollution and provide a clean environment from more intractable non-point sources of pollution.

Still the definition of what constitutes Puget Sound health and the measurements of ecosystem recovery remain elusive. Ultimately the strategies affecting Puget Sound health will need to answer the following questions:

- How much will we invest to restore what we are certain can be restored?
- How much are we willing to invest to improve our certainty?
- Given what will still remain confounding, what can we best do to preserve options for future generations?

Since Puget Sound water quality is likely to remain uncertain for some time to come, the latter question will test the beliefs of the region at the rough interface between the presumed carrying capacity of the natural systems, the individual rights of property owners, and the tragedy of the commons (the place where actions harmless on an individual basis combine to create dysfunction at a societal level). It will press us to answer the question, “must we have measurably fouled waters and threatened species and illness in the human population before we take action to restrain our actions?” And in the final analysis, “will we be able to align the fundamental American notion of property rights and the ethic of environmental stewardship for the sake of the long-term prosperity of the region?”

Answering these questions will continue to challenge the region at many levels. It will challenge our courage to be willing to examine any sector of our society and ask for accountability in the substances that are created, used and discharged. It will challenge our ability to accept risk and manage information that requires course corrections without sacrificing those who have been courageous enough to create a hypothesis. And it will challenge those who have advocated courageously for change to let go of beliefs when facts contradict.

David L. Feldman, Professor and Chair of Planning, Policy, and Design at UC Irvine, argues:

> [What is needed is an approach built on adaptive management principles. This approach] requires: (1) an organizational design that permits policymakers to recognize mistakes; (2) an ability to monitor and measure change, especially environmental change brought about by prior decisions; (3) a capacity to adopt mid-course corrections; and (4) an ability to apply what’s been learned to more complex challenges. [The latter best occurs] when water managers adopt a decision-making structure that permits broad ethical and policy debate, accept a kind of “humble anthropocentrism,” and make tentative and reversible decisions. Monitoring and measuring change requires gathering and disseminating good data

and rejecting "advocacy science" – that is, science designed to promote a specific policy at the outset of a process. (Feldman, 2007)

3.2 Top Priority Actions

In previous sections, the stressors and threats associated with water quality health have been described along with the programs in place and their challenges in addressing those threats. Stressors include the continued demands we make on the resources of our region through ubiquitous use of chemicals, ongoing population growth and land conversion. Stress also results from the development that has occurred prior to concern about the patterns of development and their effects on the Sound. And while an array of regulations and programs exist, it is challenging to find a program that is staffed and funded at a level that allows for rigorous analysis of the effectiveness of a particular existing regulation or standard. In this mix, decision-makers and the public are left with an array of programs and actions, complicated in substance and implementation, and yet requiring year-to-year prioritization as budgets are approved.

The following top priority recommendations represent those efforts which the Water Quality topic forum core group believes will make the greatest difference in aligning the resources of the region towards Puget Sound health through the lens of this water quality topic, but with an eye to water quality's place in the larger discussion of ecosystem health.

1. Accept that in the near term we will remain in the tension between uncertainty regarding provable progress and the obligation to act. To that end, lacking more definitive statements of Puget Sound health and specific aspects of that related to water quality, it is recommended that near term funding priority be given to proposals that meet the principles outlined in Section 3.3.
2. Develop hypotheses for each of the recommendations undertaken. Based on the hypotheses to be tested, design and implement an adaptive management monitoring program that is geared to answering the questions of baseline conditions and trends in the context of hypotheses posed. Align funding to ensure that hypotheses are funded at a level that provides for robust learning from findings. In the course of this effort consider forming subcommittees to the Science Panel comprised of topic specialists, regulators, implementers and regulated to ensure the full range of implementation issues is reflected in the hypotheses and monitoring program formulation.
3. Articulate a measurable, adaptable statement of Puget Sound health and the components that pertain specifically to water quality; sharply frame the questions that need answering to establish health or dysfunction.
4. Develop a Puget Sound model to allow the hypotheses, monitoring of efforts, and desired health (from items 1-3 above) to be captured in an ongoing disciplined and transparent manner and against which to test potential benefits and impacts of alternative future scenarios and actions. Sharply frame the questions intended to be explored with the model and create an accountability mechanism for development of the model, such that regular reporting of actions and findings is provided in an open public context. This is a significant task, complex in construct, and one that will require the best minds of the region. While there are several existing models in the region, the contributors are not aware of any model that is ready for this type of application. In the near term, a focus on NPDES stormwater monitoring programs and strategic turning of those resources towards

testing the hypotheses advanced by the Partnership for progress in stormwater may be most advantageous and attainable.

3.3 Principles for moving forward in the absence of a clear definition of Puget Sound health

In this section, the following principles are suggested as a way of considering potential interim and longer term actions until the top priority actions can be completed.

- Recognize that water quality improvement opportunities need to be closely orchestrated with land use/habitat and water quantity strategies and with the decisions of individual land owners. Water quality strategies alone, without consideration for the interrelated issues associated with land use and water quantity, cannot be expected to be successful. Success is unlikely without common intent across jurisdictions and cooperation and collaboration with property owners.
- Focus on ecosystem function improvement. While some individual water quality components may need particular focus and attention (such as improved stormwater control), we believe that strategies that work to address the natural ecosystem function (including human health) will have a better chance of being sustainable in the long term, and should be considered high priority. These include actions such as maintaining forested land cover in critical areas of the watersheds, restoring coastal habitat, enhancing waterways through increasing woody debris and shade, controlling bank erosion via revegetation rather than riprap, and protecting existing wetlands, swales, and natural drainages.
- Control sources of known pollutants without introducing new and ultimately more problematic constituents (reduce, reuse, recycle). To the extent we can reduce our consumption and promote wise choices in substance selection before those substances enter "pollutant pathways," there will be a positive ripple both from the prevention of problems along the pathway and the elimination of the need for treatment or remediation.
- Increase feasibility for new and emerging strategies by resolving regulatory and technical barriers. Many of the water quality strategies identified in this paper have regulatory or technical barriers that need to be resolved. Promising projects or strategies that have no barriers to implementation should be given highest priority. However, less feasibility does not necessarily imply lesser promise and may simply suggest the need for more effort to determine how to remove barriers to implementation.
- Wherever possible, create incentives and processes that respect the entire water cycle and pathways as water resources (stormwater, wastewater, irrigation water, groundwater, surface water). This principle would seek to promote reuse, reclamation and other actions to recover water from what has historically been considered waste or discharge pathways, for both economic and stewardship benefits.

3.4 Other Strategies and their Relationship to Stressors

Although the need for clarity in vision and direction is fundamental to future declarations of success in attaining Sound health, there is obvious merit in continuing existing programs and potentially in forging new ground on a number of fronts. In the following paragraphs, a variety of strategies are recommended for consideration. Table 11 depicts the relationship of the strategies to the stressors identified in previous sections. Attachment A provides a general comparison of strategies opposite the principles for action listed in Section 3.3.

Table 11. Relationship of Threats or Stressors and Proposed Strategies for Improvement

Threats or Stressors	Existing Approaches: Approach	Existing Approaches: Problems with Existing Approaches	Proposed Strategies (P2)
Ubiquity of pollutants in the environment	Source control programs	Limited data on effectiveness	Evaluate effectiveness of existing programs
		Enforcement	Increase staffing levels to improve enforcement of mandated source control programs
		Funding	Increase Ecology funding to increase staff levels
	Chemical reduction	Limited enforcement	Expand outreach efforts to reduce emerging pollutants in personal care products such as EDCs and pharmaceuticals
			Coordinate with regional transportation efforts to reduce vehicle use
	Chemical substitution	Limited enforcement	Implement more comprehensive chemical management in Puget Sound, such as REACH
Impairment by high temperatures, low dissolved oxygen, fecal coliform bacteria	Establish TMDLs	Effectiveness uncertain	Develop scientific basis for TMDLs and institute monitoring to document results
	Repair failing septic systems	Funding, private property	Continue funding septic system replacement and repair in areas with low DO, shellfish bed closures and demonstrated water quality problems. Consider providing centralized treatment or septic utilities in areas of ongoing concern and inability to adequately fund system replacements
Lack of information on pollutant effects	Water quality standards	Not enough data to know if standards are exceeded or if impacts are occurring	Expand Puget Sound-wide monitoring program for pollutants of concern
		Standards don't exist for some compounds, including emerging compounds	Evaluate existing water quality standards Develop standards for new and emerging contaminants
Contaminated sediments and groundwater	Contaminated site cleanup programs through EPA and Ecology	Cleaned up sites may be recontaminated by pollutants in stormwater runoff	Continue cleanup programs, while moving ahead on strategies to treat stormwater
		Role of contaminated sediments in water quality degradation is not fully understood	Conduct research on the role of sediment in water quality issues

Threats or Stressors	Existing Approaches: Approach	Existing Approaches: Problems with Existing Approaches	Proposed Strategies (P2)
Stormwater runoff and pollutants	Traditional and LID stormwater treatment techniques for water quality and quantity	Existing techniques are not effective at removing all pollutants present in stormwater	Research to advance the understanding of LID and traditional stormwater treatment effectiveness in Puget Sound
		There are large areas of existing urban development with no treatment measures in place	Begin or accelerate retrofits of impervious surfaces in untreated urban areas
		Long-term performance of treatment techniques is not known	Continue monitoring stormwater treatment facilities for longer periods of time to measure performance
	NPDES Phase I and II permits with requirements for source control and treatment	NPDES Phase I and Phase II permits do not cover all geographic areas in Puget Sound	Expand municipal permit coverage
Wastewater discharges	Municipal treatment facilities (mostly secondary treatment)	Nutrients are not effectively removed	Require tertiary or advanced treatment and/or other performance measures in areas with water quality problems due to nutrients
			Increase ability to reuse reclaimed water for non-potable uses
Air emissions of hazardous materials and oil	Air and water are managed independently	Little information on links between air emissions and water quality	Conduct research on links between air emissions and water quality
Accidental spills contributing to degraded water quality	Oil spill prevention programs	Emergency response time can be slow when a spill occurs, lack of funding, and interagency coordination	Obtain federal delegation from Coast Guard for local inspections Reduce oil and wastewater dumping Increase spill response capabilities
Land conversions from forest to urban or suburban uses	Growth Management Act to concentrate growth in urban areas and limit sprawl	Water resources planning is not coordinated with land use planning	Integrate land use and water resources (freshwater, wastewater, and stormwater) planning
		High quality lands and intact watersheds are not always preserved	Focus protection efforts on intact and high-quality lands and watersheds
Cumulative impacts of point and non-point source pollution	With the exception of water bodies with TMDLs, discharges are permitted separately and pollution is managed at multiple levels of government by multiple agencies	Overlapping and conflicting regulations, inequitable treatment of dischargers	Establish watershed area-wide permits

3.4.1 *Potential Near-Term Strategies for Action*

The strategies listed below are endeavors that the contributors agreed could be enacted immediately because they are highly certain to have a positive effect on water quality in Puget Sound.

3.4.1.1 Stormwater

- Begin or accelerate retrofits of impervious surfaces in untreated urban areas where potential for groundwater contamination currently is low. The majority of urban development occurred in the years prior to current stormwater management standards. This action would require jurisdictions to develop and implement a plan for the prioritized installation of water quality and water quantity treatment (retrofit) for existing impervious surfaces for which no or inadequate treatment exists. This would address the threat of pollutant transport from urban landscapes to streams, lakes, groundwater, and marine waters of Puget Sound. It would reduce pollutant and hydrologic loadings from existing urban land developed without stormwater controls. A high priority of the retrofit effort would be to reduce system connectivity (e.g., removing areas from the larger drainage system) without concurrently increasing potential flood damages or inadvertently injecting polluted surface waters to critical aquifers.

  Because of recent gains in knowledge on how to support development while reducing the extent of impervious surfaces along with new technical approaches (such semi-permeable pavements), the certainty of effectiveness and feasibility, not including funding considerations, are both high if the effort remains in the public sector. However, the potential exists to create economic incentives to spur the private sector into action as well. While coordination with private property owners would introduce additional challenges both for near-term agreements and long-term maintenance, it could also provide additional finances that would accelerate the extent of retrofits undertaken. Absent private sector participation, financial resources required to fulfill this strategy are expected to be at least on the order of the funds it took to move primary wastewater treatment to secondary treatment in the 1970s.

- Aggressively seek pilot opportunities to reuse stormwater generated from rooftops for non-potable uses. Rooftops constitute a significant portion of impervious surfaces in developed areas. State water rights law currently presents road blocks to the reuse of rooftop water. While rainwater collection is being promoted at both the state and local level to address urban stormwater issues, work is needed at the state level to amend water rights law to exempt the reuse of rooftop runoff. With the regulatory pathway cleared, significant progress could be made in addressing degradation that results from modified hydrology that occurs during land conversion. Benefits could include: (1) reduced volume of stormwater entering infrastructure, thereby reducing treatment facility sizes (including retrofit treatment sizes), (2) reduced demand on domestic water supplies, and (3) reduced water quality impacts resulting from stream-channel peak flows.

- **Coordinate with regional transportation efforts.** As noted in Section 2, many pollutants in stormwater are associated with the byproducts of vehicle operation. There is a high level of certainty that reducing the total vehicle miles traveled would coincidentally reduce the amount of wear on brakes and the byproducts of that wear (such as copper and zinc), would reduce road wear, and would reduce vehicle emissions with potential for air deposition and transport through stormwater. Note that of all the pollutants routinely measured in Puget Sound sediments, only PAHs (a constituent of vehicle emissions) are increasing. Clearly there is much work underway in the region to address this issue. Opportunities exist with efforts such as the Puget Sound Regional Council (PSRC) update of the long-range transportation plan with its new regional growth strategy, which will include analysis of climate change and environmental effects of alternative approaches to transportation in its three county region. PSRC is only one of five current regional councils around Puget Sound. Extensive and timely coordination will be needed between the Partnership and the regional councils to afford opportunities for water quality (and other Action Agenda) priorities to be considered in the land use, population and transportation plans of the councils.
- **Complete mapping and conduct economic analyses of interjurisdictional stormwater networks.** The network of stormwater pipes and ditches represents thousands of miles of existing and future opportunities for prevention of pollutant transport and implementation of retrofits in the years ahead as aging infrastructure is replaced. In the near term, many jurisdictions have mapped their stormwater systems, or will be completing the effort under the NPDES Phase I and II stormwater permits. As a first step, ensuring that cross-jurisdictional systems are linked in GIS format will provide an invaluable tool for first responders to spills on private property or transportation corridors. Secondly, the rollup of this effort affords the region with an opportunity to assess the anticipated 30-50 year investment in stormwater facilities, and pose questions related to standards for water quality, climate change, material availability and other factors that could influence jurisdictional decisions on facility replacement. Strategic investments based on cradle-to-grave analysis of these variables could provide for wiser asset management, smarter use of available financial resources, and the possibility of private sector investments under potential cap-and-trade scenarios for impervious areas, for example.

3.4.1.2 Wastewater

- **Require tertiary or Class A wastewater treatment and reuse or other performance measures at wastewater treatment plants to reduce nutrient loadings in nutrient-sensitive areas of Puget Sound.** Require either tertiary wastewater treatment, or treatment to Class A standards for reuse or other performance measures, to address the potential for hypoxia, algal blooms, and other related threats in nutrient-limited waters such as South Puget Sound. Effective wastewater treatment technologies exist to address nitrogen and other nutrient loadings. Benefits would be a reduction in nutrient loading to nutrient-limited areas of Puget Sound (tertiary treatment) and ability to reuse wastewater (Class A treatment) where uses (synergies) for the treated wastewater can be identified. Reusing treated wastewater has the added benefit of supporting the freshwater ecosystem through the reduction in dewatering.

The primary barriers would be the availability of funding, identification of access to customers for reclaimed water (Class A treatment), public acceptance, and state water rights law. This nutrient reduction strategy may only need to be used for critical parts of the year when receiving waters are most sensitive; also the increased expense in energy and other operating costs to the wastewater system must be considered in the balance.

- Expand outreach efforts to reduce emerging pollutants in personal care products such as EDCs and pharmaceuticals. We know enough from the research conducted with English sole to have concerns about the potential for unintended consequences associated with the levels of EDCs in wastewater and nonpoint pathways to the Sound. Efforts to reduce EDCs and other pharmaceuticals may have the potential for significant pollutant reduction prior to more costly investments in enhanced wastewater treatment systems. While additional technology exists to reduce EDCs through wastewater treatment processes, social marketing educational efforts are a feasible alternative to reduce EDCs input from human sources into the wastewater stream.
- Identify and replace failing septic systems, with particular focus in areas with demonstrated water quality problems such as shellfish closures and hypoxia. This will address both human health concerns (shellfish closures generally occur because of high levels of *E. coli* that can result in illness) and ecological effects (hypoxia is a result of buildup of nutrients resulting in overgrowth of algae that remove the oxygen from the water). Building on the recently adopted state septic system utility law, establish septic system utilities to serve sensitive drainages throughout the Sound to ensure that existing septic systems are well maintained, but particularly in South Sound areas prone to increasing levels of hypoxia. The septic system utilities would provide a means to monitor septic system performance, increase the maintenance (and potentially longevity) of existing systems, and provide a mechanism for funding community systems in areas where densities, soils, or other site conditions preclude appropriate use of on-site wastewater systems. The utilities could also provide an increasing focus on emerging technologies related to nutrient removal. Existing on-site wastewater system design in Washington does not focus on nutrient removal. Benefits include the potential reduction in failed on-site systems and the related potential for untreated wastes to migrate to receiving waters or create human health risks. Coordination with the Washington State Department of Health would be necessary.
- Review wastewater outfalls for potential decommissioning. At least 95 municipal marine outfalls, 166 industrial marine outfalls, and 60 individual marine outfalls discharge into Puget Sound. Because few existing wastewater treatment plants remove nitrogen and endocrine disruptors, or other dissolved contaminants, a plan to explore possibilities for combining and potentially reducing the number of outfalls could yield reduced shellfish bed closures and other potential reductions in exposures to salmon, other fisheries and marine mammals; efficiencies of scale in operations and costs would be realized as well.

3.4.1.3 Land Use

- **Focus protection efforts on intact and high-quality lands and watersheds.** Continue the support, through grant programs and public-private partnerships, to set aside portions of Puget Sound watersheds that remain in pristine condition. Protect (through direct acquisition, conservation easements, or other mechanisms) high-quality watersheds in Puget Sound that support ecological functions and are largely intact. Preservation of intact ecosystems reduces the potential for pollutant loadings, and preserves existing hydrologic regimes with a high level of certainty. The Cascade Land Conservancy, The Trust for Public Land, The Nature Conservancy, and others are important partners in efforts to secure intact ecosystems. This strategy may have important synergies with both recreational and wildlife protection goals.
- **Integrate land use and water resources planning.** As covered in Sections 2 and 3 of this paper, land use and stormwater, wastewater, septic systems, and other water uses are inextricably intertwined, but are not yet managed together in alignment with goals for Puget Sound health. Creating a clear statement of Puget Sound health and a model and monitoring program against which to test hypotheses for recovery (Top Priority Actions) would provide the necessary underpinnings for progress in integrated planning that moves towards common goals. Section 208 of the Clean Water Act may provide the appropriate tool for moving forward with such a planning effort.

3.4.2 Regulatory Strategies

3.4.2.1 Stormwater, Wastewater, and Land Use

- **Increase the clarity of stormwater regulatory programs.** A variety of adjustments in existing stormwater regulations could reduce the threat of pollutants contributed by sources that aren't fully captured by existing stormwater regulations.
    - Expand municipal separated storm sewer system (MS4) permits geographically to include communities that fall under the population threshold for areas contributory to 303(d) listed water bodies. Phase I and Phase II permits do not include all the area within watersheds. While the permits have progressed, the need remains to synchronize efforts within watersheds to increase efficient use of limited staff and financial resources typical of many jurisdictions, and to adopt area-wide approaches to receiving water improvement.
    - Implement source control for existing developed commercial areas.
    - Develop a strategy for treating urban pollutants such as copper, zinc, phthalates, and PAHs.
    - Develop and implement creative approaches for agricultural-related discharges that reflect the realities of food production while reducing impacts from more diffuse rural land uses such as non-commercial livestock facilities and nurseries.
    - Use Sound-wide modeling efforts to establish relative priorities for NPDES-required monitoring programs.

- Address the lag in adoption of new stormwater standards with state vesting laws (e.g, many properties may be "grandfathered in" and not subject to current regulations).
- Improve the rate of compliance with existing permits, which may require additional staff trained in both the science of stormwater and the realities of construction.
- Conduct monitoring to determine if permits and programs are effectively implemented and effective in intent (water quality improvement).

  Correcting some or all of the above gaps could increase the effectiveness of our stormwater regulatory programs and resource use.

- **Establish watershed area-wide permits** that focus on the multitude of discharges that occur in logical geographic areas, rather than discharge-specific inputs or jurisdictional boundaries. A legal methodology for doing this is already in place through Section 208 of the Clean Water Act. Improved coordination of the discharges, land uses, and human stressors that impact a watershed will lead to better answers for improving overall watershed health and potentially to a reduction in the number of discharges needed. The threat of unintended cumulative impacts potentially could be reduced by looking at the wastewater and industrial discharges in a larger context. This effort could potentially be used to bring federal, tribal, state, and local agencies into alignment both in coordination of efforts and in the development of flexibility and incentives to ensure that the rule of law is upheld, progress in water quality is achieved, and unintended regulatory burdens or processes on industry and individuals are minimized.

3.4.2.2 Source Control

- **Implement more comprehensive chemical management in Puget Sound.** One of the concerns of addressing or reducing contaminants is that the alternative may produce more unintended consequences than the contaminants. To address the human and environmental concerns associated with chemical manufacturing and use, the European Union has moved forward with a regulatory program that requires cradle-to-grave understanding of chemicals prior to allowing their import or use within the European Union. Implementation of the regulation is in its early stages, but a part of the effort that may be of immediate use to the Partnership is the "REACH" database that is being assembled to assess relative risks and potential for source reduction of commonly used chemicals. The intent of the program is to provide information to industries and the public about potential for chemical substitutions in different industrial, commercial, and residential applications, reducing the potential for more harmful chemicals to enter receiving waters (and other parts of the environment). The Partnership could begin by tracking the REACH database and bringing the available information to bear on decisions in the Puget Sound region. EPA has a similar effort underway to rank existing chemicals in regard to hazards to human health and/or the environment. This program is known as ChAMP (Chemical Assessment and Management Program) and will be completed in 2012. The Partnership can use the information to develop approaches for chemical substitutions, encouraging the use of less hazardous substances over current use of more toxic chemicals.

3.4.2.3 Improved Predictive Capability

Improve predictive capability of ecosystem function through the development and refinement of modeling tools. Development of a predictive model will take thoughtful scoping and preferably an open process. Ultimately the model will likely consist of a linking of a number of different models. Some elements of the model might include:

- **Prioritization and performance assessment tool.** Create a modeling tool that links scientific knowledge and management decisions in the recovery of Puget Sound to assess threats such as increasing nutrient loadings, increasing temperatures, toxic loadings, and complex food web interrelationships. The intent of the model (or series of linked models) would be to provide better capabilities for predicting ecological and human health outcomes of specific recovery actions in specific geographical areas. Actions could be prioritized based on their positive impacts. Barriers would include the challenges inherent in representing complex hydrodynamic, chemical, and biological reactions and the related uncertainty of predicted outcomes. The benefits include the deepening of understanding complex ecosystem processes that cannot be readily measured or quantified directly, providing the ability to simulate the outcome of proposed management actions. These tools will also point to the gaps and uncertainties in our knowledge, and the resulting uncertainties in the degree and speed of progress toward recovery as a result of our actions.
- **Risk assessment tool.** The risk to human health or aquatic life due to changes in water or sediment quality is a daunting task when taken on at the scale of the Puget Sound watershed. However, methods are available for assessing relative risk within a spatial context in a qualitative sense ("healthy," "moderately impaired," "severely impaired") (see, for example, Landis and Wiegers 2007). This would build from existing conceptual models (e.g., Simenstad et al., 2006; NOAA's Integrated Ecosystem and Assessment [http://www.ncddc.noaa.gov/activities/iea-patt]) and use existing datasets such as Ecology's monitoring of Puget Sound sediments, 303(d) lists of impaired waters, Toxic Release Inventory release levels, and publicly owned treatment works permitted discharges. Sources and transport modes would be linked with land use to provide a spatial representation of areas at greatest risk (note that this will differ depending upon the target of concern such as people, fish, or wildlife). Such a risk analysis would require integration of multiple disciplines, such as water quality/quantity experts with biodiversity experts.
- **Models that simulate circulation patterns in Puget Sound.** Pollutant fate and transport is very different in the South Sound than the pelagic zones of the mid-Sound areas near the Straits of Juan de Fuca. The model will need to include a component for assessing the hydrodynamics of the entire Puget Sound water body.
- **Improve understanding of the dynamics and levels of nutrients in Puget Sound.** Nutrients are creating an increasing challenge in Puget Sound, particularly in embayments and areas with low circulation. However, the dynamics and levels of nutrients from natural sources such as the Pacific Ocean and undeveloped landscapes are less well known. Additional questions include:

- How do increased nutrient levels affect the Puget Sound food web? In this case we lack both the basic monitoring information on the dynamics and extent of the phytoplankton and zooplankton constituents of the food web and an understanding of the dynamics related to nutrient additions.
- How do specific forms of nitrogen and phosphorus affect the biological community? Can harmful algal blooms can be triggered by changes in the availability or form of nitrogen or other nutrients?
- What is the role of groundwater in nutrient delivery to nearshore areas? Are there geographically vulnerable areas within the Sound?

3.4.3 Recommendations for Further Assessment

There are gaps in our current understanding of the nature and transport of pollutants that cause water quality impairments and ecological harm. To lessen these gaps and move forward in our scientific understanding so that our strategies become more effective, the contributors have assembled the following preliminary list of recommended actions for discussion by the working group:

- Evaluate the role of sediment in water quality issues to better define the relative contribution of previously contaminated sediment to the overall health of Puget Sound, including the effectiveness of sediment cleanup programs, recontamination issues, and source control program effectiveness. Focus of the analysis would include the mechanisms for contaminated sediments presenting threats to the ecosystem and related risks, and the relative effectiveness of current regulatory programs in effecting cleanups opposite the cost of arriving at cleanup agreements. In addition, this analysis would include an evaluation of sediment cleanup standards for protectiveness of aquatic ecosystems, and development of protective freshwater sediment standards. In particular, there may be opportunities for expediting cleanup efforts that move public funds from contentious to cooperative efforts.
- Evaluate the link between stormwater pollutant loads and ecological effects. While it is clear that changes in stormwater hydrology affect aquatic organisms through damage to habitat, the effects of stormwater pollutants on the organisms themselves is much less understood. This study would be used to increase the understanding of the conditions producing high concentration storms as well as the frequency, duration, and magnitude of stormwater concentrations that harm and do not harm aquatic organisms. This study would be used to evaluate the effectiveness of existing stormwater BMPs, determine if they treat the right constituents or right part of the storm, and increase certainty in the selection of appropriate BMPs.
- Advance the understanding of the effectiveness of LID in the Puget Sound region. Because of the relative newness of LID approaches there are a variety of studies that could advance the efficacious use of LID in the watersheds of Puget Sound including LID effectiveness, development of modeling protocols for predicting the role of LID in watershed health, determining recommended standards for initial and long-term LID effectiveness, establishing LID technique longevity, prevention of transference of pollutants captured in LID to groundwater, and providing for maintenance and long-term aesthetics of facilities.

- **Evaluate existing federal water quality criteria.** The question of the level of protection provided by our current water quality standards is at the core of any effort to determine the effects of pollutants on aquatic habitats. Existing water quality criteria need to be reviewed for protectiveness to local water conditions and sensitive aquatic and wildlife species. Site-specific water quality standards should be developed for water bodies that may be more sensitive to the input of particular pollutants.
- **Evaluate state water quality standards.** Washington State's toxic substances criteria, codified in the Washington Administrative Code (WAC) 173-201A-240 Table 240(3), are the basis of all regulatory assessments conducted by Ecology about the status of the state's waters. Two basic concerns have been raised concerning these criteria: (1) the numeric values do not adequately prevent adverse effects to sensitive species; and (2) no standards have been adopted for some common pollutants. Additionally, the criteria do not account for simultaneous exposures to multiple contaminants. Ongoing efforts to establish cleanup goals and standards for Puget Sound will need to resolve each of these concerns. The strategy would include a recommendation that the Washington Department of Ecology: (1) review and modify as necessary existing standards (e.g., copper); and (2) adopt numeric limits for common pollutants (e.g., phthalates) for which there are no current state criteria. However, because the task of establishing standards has wide ramifications to businesses and regulatory agencies, the top priority actions are recommended to be implemented first so that any focus on standards is linked to an overarching framework for Puget Sound health.

3.5 How will we know when we're making progress?

As with any problem or challenge, the first step occurs when the issue is framed in a way that reasonable people can consider and contrive reasonable responses and forward actions. It can be asserted with confidence, and gratitude for those with the courage to press forward, that the historic problems of wastewater, industrial pollution and to some extent contaminated sediments have been framed in a way that goals could be set, laws enacted, actions taken, results measured, subsequent actions adjusted and progress made. While the same cannot be said for the general effectiveness of nonpoint related actions, what can be said is that efforts have been and continue occurring on a variety of fronts, and that while still intractable, the challenge has not been ignored. Rather, it could be said that the challenges that remain, in spite of the array of efforts, underscore how challenging the issues of non-point source pollution are in the context of Puget Sound ecosystem health. To that end, progress will be made on the day when water quality program managers, stakeholders and informed members of the public can state with clarity the goals of Puget Sound health, can assert with humility the assumptions and risks attendant to those goals, can accept with grace the process of learning and adjustments, and can celebrate fulfillment of public commitments made and kept towards measurable improvements in Puget Sound health.

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4. Attachment A. List of Recommended Strategies

Issue Category	Issue Addressed from S1, S2, and P1	Strategy	Geographic Regions for Implementa-tion	Barriers? Technical (T) or Institutional (I)	Principles					
					Foc. On Ecosys Imp ?	Synergies with with other topic areas?		Controls sources?	Cert. of Suc-cess?	Resolves Reg. or Tech Barriers?
Wastewater, education	EDCs and pharmaceuticals are showing up in stormwater and wastewater discharges and effecting aquatic organisms (S1)	Expand outreach efforts to reduce emerging pollutants in personal care products such as EDCs and pharmaceuticals	Everywhere		X	X	Biodiversity, Human Health	X	X	
Wastewater	Most wastewater treatment plants are not designed for nutrient removal (S2)	Require tertiary wastewater treatment, reuse and/or other performance measures at WWTPs to reduce nutrient loadings	South Puget Sound	I	X	X	Biodiversity, Human Health		X	
	Failing septic systems are a source of nutrients that cause water quality degradation (S1)	Identify and replace failing septic systems, or create community systems, with particular focus in areas with demonstrated water quality problems such as shellfish closures and hypoxia	South Puget Sound, Hood Canal, Rural areas with high septic densities	I	X	X	Biodiversity, Human Health	X	X	
	Municipal wastewater treatment outfalls are a source of pollutants and discharge millions of gallons per day to Puget Sound (S1)	Review wastewater outfalls for potential decommissioning	Marine discharges?	T, I	X	X	Biodiversity, Human Health			
Wastewater	Reduction in wastewater effluent and toxic loading to receiving waters (S2/P1)	Reuse wastewater for industrial/nonpotable uses	in Puget Sound	I	X	X	Water quantity, biodiversity, human health	X		
Stormwater	Most untreated stormwater is from urban areas developed prior to existing stormwater regulations (S1)	Begin and accelerate retrofits of impervious surfaces in untreated urban areas	Urban areas (over 10,000 population)	I	X	X	Water quantity, Biodiversity		X	
Stormwater	Increased stormwater volumes affect water quality, habitat and biodiversity (S1), and controlling runoff is a source control technique (S2/P1))	Reuse stormwater generated from rooftops for non-potable uses	Everywhere	I	X	X	biodiversity, human health	X		
Stormwater	Roads are a leading contributor of stormwater pollutants (S1)	Coordinate with regional transportation efforts	Everywhere	I	X	X	Quality of Life, Biodiversity			
Stormwater	Interjurisdictional coordination of storm drainage mapping is necessary for successful source control programs (S2/P1)	Map interjurisdictional stormwater networks	Everywhere	I	X				X	X
Stormwater	As LID techniques are more frequently used in the Puget Sound region, additional studies on the long-term effectiveness should be conducted (S2/P1)	Need more LID studies to have a better understanding of local factors influencing LID and benefits	Everywhere	I	X	X	Water quantity, biodiversity, human health			
Stormwater	Vehicle use contributes to pollutants in stormwater runoff (S1)	Support mass transit	Everywhere	I	X	X	Biodiversity, Land Use	X		
Stormwater	Vehicle use contributes to pollutants in stormwater runoff (S1)	Collect and filter run off of gasoline/oil residue at all storm drains on city streets	Everywhere		X		Biodiversity		X	
Source control	Source reduction is one method to reduce pollutants in receiving waters (S2/P1)	Implement more comprehensive chemical management in Puget Sound, including chemical manufacturing and use database such as REACH	Everywhere	I	X	X	Biodiversity, Human Health, Quality of Life	X		

Issue Category	Issue Addressed from S1, S2, and P1	Strategy	Geographic Regions for Implementa-tion	Barriers? Technical (T) or Institutional (I)	Principles					
					Foc. On Ecosys Imp ?		Synergies with with other topic areas?	Controls sources?	Cert. of Suc-cess?	Resolves Reg. or Tech Barriers?
Source control	Source reduction is one method to reduce pollutants in receiving waters (S2/P1)	Source control should be a prominent management tool with an adaptive management approach	Everywhere	I	X	X	Biodiversity, Human Health, Quality of Life	X		
Source control	Vehicle use contributes to pollutants in stormwater runoff (S1)	Consider alternatives that promote increased attention to vehicle maintenance and reduced fluid loss	Everywhere	I	X	X	Biodiversity	X		
Science	The ultimate fate of many pollutants is in sediment, with the potential for biological uptake (S1)	Evaluate the role of sediment in water quality issues	Bays, quiescent areas	T	X	X	Biodiversity, Human Health			X
Science	Stormwater contributes loads of pollutants, but the ecological consequences are not fully understood (S1)	Evaluate the link between stormwater pollutant loads and ecological effects	Urban areas in particular	T	X	X	Water Quantity, Land Use, Biodiversity			X
Science	Standards are not available for all pollutants, and the effectiveness of some standards is not well understood (S2/P1)	Evaluate existing water quality standards	Everywhere	T	X	X	Biodiversity			X
Science	The interactions of pollutants and fate in the environment is not well understood (S2/P1)	Improve predictive capability of ecosystem function through the development and refinements of hypotheses, monitoring and predictive models	Everywhere	T	X	X	Land Use, Biodiversity, Human Health			X
Regulatory	Stormwater regulatory programs are fragmented (S2/P1)	Increase the clarity of stormwater regulatory programs	Everywhere	I		X	Water Quantity, Land Use,			X
Regulatory	Permitting is generally source and jurisdiction dependent, and doesn't factor in multiple discharges and overlapping jurisdictions (S2/P1)	Establish watershed area-wide permits and holistic approach	Everywhere	I	X	X	Water quantity, Land Use, Biodiversity, Human Health			
Regulatory	More monitoring data is available in urban areas, and existing programs lack consistent objectives (S1, S2/P1)	Need monitoring programs linked to clear hypotheses for PS health	Everywhere	I		X	Land Use, Biodiversity			
Regulatory	Institutional barriers exist to use of LID, including state laws regarding rainwater harvesting (S2/P1)\	Need to remove barriers to use of LID	Everywhere	I	X	X	Water Quantity			
Regulatory	Regulatory programs are understaffed and have difficulty keeping up with enforcement (S2/P1)	Adequately fund existing regulations prior to establishing new ones	Everywhere	I		X	Water Land Use			
Regulatory	State vesting laws allow development to outdated regulations (S2/P1)	Address “grandfathering” for regulations where legislative intent can be circumvented	Everywhere	I	X	X	Water Quantity, Land Use, Biodiversity			
	Land conversion results in water quality degradation	Focus protection efforts on intact and high-quality lands and watersheds	High quality watersheds	I	X	X	Water Quantity, Land Use, Biodiversity	X	X	
	Stormwater regulatory programs	Integrate land use and water resources					Water			

Issue Category	Issue Addressed from S1, S2, and P1	Strategy	Geographic Regions for Implementa-tion	Barriers? Technical (T) or Institutional (I)	Principles					
					Foc. On Ecosys Imp ?	Synergies with with other topic areas?		Controls sources?	Cert. of Suc-cess?	Resolves Reg. or Tech Barriers?
Land Use	need to incorporate land use planning to be effective (S2/P1)	planning	Everywhere	I		X	Quantity, Land Use			X
	Everyday life activities contribute to waste in the wastewater stream (S1)	Educate citizens about where their wastewater goes	Everywhere		X	X	Quality of Life, Biodiversity	X		
Education	Fertilizers and pesticides contribute to water quality problems (S1)	Education programs to reduce pesticide and fertilizer use	Everywhere		X	X	Land Use, Biodiversity	X		
Marine Traffic	Marine traffic contributes to pollution through accidental spills (S1)	Require tugs for shippers of hazardous materials	Puget Sound marine waters	I	X	X	Biodiversity, Human Health, Quality of Life	X	X	
Marine Traffic	Marine traffic contributes to pollution through accidental spills (S1)	Expanded emergency response	Puget Sound marine waters	I	X	X	Biodiversity, Human Health, Quality of Life			