Strategic Science Plan

9March 2009 Science Panel Draft

PROLOGUE

The Strategic Science Plan is endorsed by the Puget Sound Partnership demonstrating its commitment to science-based recovery of Puget Sound. The Partnership's vision is that science will lay the foundation for work identified in the Action Agenda by setting priorities for appropriate measures to improve understanding of the ecosystem, and monitoring effectiveness of actions that lead to clear pathways for informed decision making.

The purpose of this Strategic Science Plan is to provide the overall framework for development and coordination of the specific science activities needed to support protection and restoration of Puget Sound under the *Action Agenda*. Ecosystem recovery will require our most capable scientists using the best scientific tools, engaged in a constant two-way conversation with public policy makers. We need a common, systematic, structured decision-making process to pull the pieces together. To succeed, this process needs to continually define, refine, and invigorate recovery in light of new knowledge.

1. INTRODUCTION

1.1 Context and Recent History for Puget Sound

Ecosystem Decline

Puget Sound, like many coastal ecosystems worldwide, is showing symptoms of decline. Trends noted for coastal systems both globally and locally include increasing numbers of imperiled species, disrupted food webs, degraded habitat for many species, and increasing levels of toxic contaminants (Heinz Center, 2008, U.S. Commission on Ocean Policy 2004, Ruckelshaus and McClure, 2007,).

Healthy ecosystems are resilient, self sustaining systems that support human societies by providing goods and services in the form of energy, food, building materials, water purification, flood and erosion control, as well as spiritual enrichment, recreation, and aesthetic experiences (MA 2003). Human-caused stress on coastal environments such as Puget Sound can result in an ever-decreasing capacity to provide specific highly valued goods and services.

Ecosystem Level Response Needed

The general decline in coastal ecosystems has led to calls for natural resource conservation at a scale that encompasses the entire system, rather addressing components individually (Pew 2003, USCOP 2004, Leslie and McLeod, 2007). Ecosystem-based management is a strategy for integrating management activities across land, water, air, energy, and living resources in a manner that promotes conservation and sustainable use in an equitable way (United Nations Environment Program/Convention on Biological Diversity, 2000). At its core, ecosystem-based management requires an understanding of human behaviors and choices, and the implications of those choices on natural systems and the output of ecosystem goods and services. This approach integrates the natural and social sciences, stakeholders, and public policy development to fulfill a common vision for the future of the ecosystem.

In responding at the ecosystem scale, both science and policy must acknowledge that our ability to define an ecological baseline will diminish as population growth, climate change, and other drivers fundamentally change the ecosystem. Conditions in Puget Sound will no longer fluctuate within a definable envelope of historical variability (Milly et al., 2008); rather the entire system will likely be transformed through new states at a rate comparable to our maximal rate of scientific learning (Healy, 2007). In a setting of moving baselines, the traditional view of restoration—that is restoration to a set of historically defined conditions—may no longer be valid.

Finally, ecosystem structure, function, and processes are critical to restoration at the basin-wide scale but are not well understood aspects of Puget Sound. The Partnership is committed to protecting individual resources (say, salmon), but also committed to protecting supporting ecological functions that support the ecosystem with minimal human maintenance. Such functions might include production of forage fish within the food web, and related natural structures such as spawning beaches needed by the forage fish. In this example the critical structure is the beach, its function is provision of spawning habitat for surf smelt, and the critical process is natural beach nourishment. In practice, research on the ecological processes integral to healthy system functioning is therefore needed to develop models supporting adaptive management, and to appropriately design needed science elements such as monitoring (Williams et al., 2007; National Research Council, 1990).

State of Washington Initiative/Goals

Novel strategies are required if ecosystem-based management is to succeed. Fragmented governmental jurisdictions, which traditionally manage diverse natural resources separately must give way to collaborative problem identification, ranking, and solving. Because the scientific knowledge base needed to support this collaboration is itself fragmented, a larger integration is needed than has ever before existed. Such integration would knit together specific, diverse components of the human community: state and federal agencies, local governments, tribes, non-governmental organizations, business, and the populace itself.

The Puget Sound Partnership (Partnership) is the State of Washington's attempt to initiate ecosystem-based management of Puget Sound. The Partnership's effort is intended to compliment and coordinate ongoing state, federal, tribal, local, nonprofit, and volunteer efforts to protect and restore the Puget Sound ecosystem. The Partnership is founded on four fundamental beliefs. The first is that Puget Sound Ecosystem is a national treasure and in many ways the life-blood of Washington State. The second is that the Puget Sound ecosystem is in serious decline and likely will worsen through time. The third recognizes that current activities to protect and restore Puget Sound ecosystem are fragmented, uncoordinated, and mostly ineffective at the ecosystem scale. The fourth belief—and impetus for creation of the Partnership—is that the Puget Sound ecosystem is worth saving.

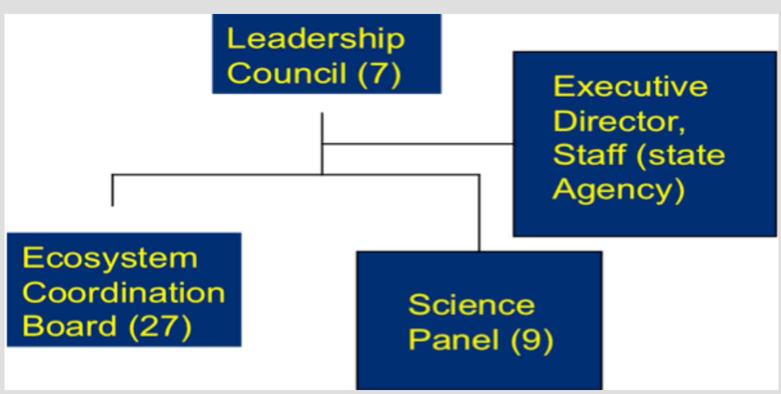
Previous efforts to coordinate protection and restoration efforts for Puget Sound have largely been aquatic in focus. Now, the Partnership has adopted the larger goal of maintaining and restoring the composition, structure, functions, and processes of natural and modified Puget Sound ecosystems for long-term sustainability. Common purpose to achieve this goal will be established through a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives (Groom et al. 2006). The process has already resulted in a broadly vetted (albeit incomplete) scientific analysis of our current understanding of the Puget Sound ecosystem (Ruckelshaus and Mclure 2007), and a series of "Topic Forum" papers developed through a broad, collaborative, public process.

Puget Sound Partnership Goals and Structure (Text Box)

The Washington State Legislature created the Partnership (Engrossed Substitute Senate Bill, or ESSB 5372) to restore and protect Puget Sound by striving to meet the following goals by 2020:

1. A healthy human population supported by a healthy Puget Sound that is not threatened by changes in the ecosystem
2. A quality of human life that is sustained by a functioning Puget Sound ecosystem
3. Healthy and sustaining populations of native species in Puget Sound, including a robust food web
4. A healthy Puget Sound where freshwater, estuary, near shore, marine, and upland habitats are protected, restored, and sustained
5. An ecosystem that is supported by ground water levels as well as river and stream flow levels sufficient to sustain people, fish, and wildlife, and the natural functions of the environment
6. Fresh and marine waters and sediments of a sufficient quality so that the waters in the region are safe for drinking, swimming, shellfish harvest and consumption, and other human uses and enjoyment, and are not harmful to the native marine mammals, fish, birds, and shellfish of the region.

These goals are to be achieved through development and implantation of a plan, the *Action Agenda*. The *Action Agenda*, released December 1, 2008, is the roadmap to health for the Puget Sound. It identifies and ranks a broad suite of activities that fit into one or more of five *Action Agenda* priorities, which include: 1) protect intact ecosystems, 2) restore ecosystems, 3) prevent water pollution at its source, 4) prioritize actions in a coordinated system, and 5) build an accountability system. Importantly, the *Action Agenda* coordinates federal, state, local, tribal and private resources, and ensures that the Puget Sound community is proceeding cooperatively.



The organizational structure of the Partnership consists of three working committees staffed by the Puget Sound Partnership, an agency of the State of Washington. This Strategic Science Plan calls for engagement of the Science Panel with the broader science community (via both networking and formal working groups) and for collaboration with both policy makers and stakeholder representatives on the Leadership Council and Ecosystem Coordination Board.

The Puget Sound Science Panel

Although Puget Sound has a rich history of scientific endeavor, our science has never addressed ecosystem-scale management, protection, or restoration until now. The Partnership needs science because of the uncertainty inherent in undertaking such a challenging mission. Our understanding of Puget Sound is incomplete—which in and of itself is unremarkable. However, this uncertainty takes on new importance as humans increasingly impact the environment and affect the ability of the ecosystem to provide the full suite of goods and services. Addressing this uncertainty becomes critical when policy makers define broad restoration end points (as in the *Action Agenda*), but are uncertain how to more specifically define actions and progress to achieve those end points. While some policy decisions on the path to restoration can proceed despite relatively high scientific uncertainty, others will require additional scientific understanding before proceeding. Wisely, the Partnership is committed to building a constructive interplay between science and policy so that decisions account for uncertainly in an explicit way.

The central role of science in the Partnership was embodied in creation of the Puget Sound Science Panel (Panel), a nine member independent group of scientists. Panel members were chosen based on professional credentials, not the organization they represent. The Panel was created to assist the partnership in developing an ecosystem level strategic science program that: 1) addresses monitoring, modeling, data management, 2) identifies science gaps and recommends research priorities; 3) develops and provides oversight of a competitive peer-reviewed process for soliciting, strategically prioritizing, and funding research and modeling projects; 4) provide input to the executive director of the Partnership in developing action agendas; and 5) offer an ecosystem-wide perspective on the science work being conducted across the Puget Sound ecosystem. Overall, the Panel is responsible for ensuring that science is an integral and sustained part of evolving Partnership activities.

The Panel's mission is shaped by the enabling legislation of the Partnership; Section 1(2)a of ESSB 5372 states that the Partnership will "Define a strategic action agenda prioritizing necessary actions, both basin-wide and within specific areas, and creating an approach that addresses all of the complex connections among the land, water, web of species, and human needs. The action agenda will be based on science and include clear, measurable goals for the recovery of Puget Sound by 2020." Relying in part on Science Panel deliberation, the Partnership released the Puget Sound *Action Agenda* on December 1, 2008 (citation).

1.2 Why a Strategic Science Plan?

Role of Science Defined by Adaptive Management

No matter how much science we carry out, we will never fully understand ahead of time how Puget Sound will respond to influences such as shoreline development, climate change, or—most critically—our own restoration actions. Snapshots of what we know, for example periodic State of the Sound reports, are needed to summarize and communicate progress. However, science can best help policy makers by deliberatively and continually discovering the causal links between restoration actions and actual measured outcomes in the ecosystem. That is, protection and restoration of Puget Sound is a continuous process through which we come to understand how the ecosystem is responding to change and then employ that understanding to make informed decisions about how to maintain important ecosystem goods and services consistent with the ecosystem's ability to provide those goods and services. Science and policy must perpetually interact to manage the risks of uncertainty.

Science Products of the Puget Sound Partnership (Text Box)

Guided by this Strategic Plan, several types of science products will be developed by the Partnership: [add brief descriptions]

State of the Sound

Puget Sound Science Update

Strategic Science Plan

Biennial Science Work Plan

RFP Project Reports

Final Peer-Reviewed Issue Papers

Integrated Ecosystem Assessment Technical Reports

  Preliminary Indicators Report

  Risk Assessment Report

  Conceptual Model Report

  Other

What would this science/policy interaction look like? The centerpiece of the connection between science and policy proposed in this Plan is *adaptive management*. Adaptive management involves the following elements, once restoration objectives have been identified and agreed upon (modified from Murray and Marmorek, 2004):

- exploring alternative actions to achieve restoration objectives;
- predicting outcomes explicitly (for example with process-based models);
- implementing one or more of these actions, recognized as somewhat experimental and therefore designed with evaluation in mind;
- measuring outcomes objectively with monitoring;
- adjusting the actions by comparing the measured outcomes to the predicted outcomes

Adaptive management is much easier to discuss than to practice, although many natural resource professionals erroneously believe they are already practicing adaptive management (Williams, et al., 2007). Adaptive management entails controlled risk-taking that challenges the status quo: "where science thrives on the unknown, politics if often paralyzed by it" (Gore, 1992). For example stakeholders of all stripes must openly confront unresolved uncertainties, change-resistant institutions must alter practices in fundamental ways, and policy makers may be faced with choosing between objective scientific findings and the desires of particular interest groups.

This is not to say these challenges are insurmountable; indeed adaptive management—if accepted by all participants as a guiding framework—may be the only available means by which scientists can be accountable to policymakers and policy makers can be accountable to the public for restoration results. It is therefore vitally important that participants understand what adaptive management is and is not (Van Cleve et al., 2004). This understanding should cut across all Partnership groups, in support of the scientific and policy rigor necessary for success. "A comparison of hypothesis-based predictions against evidence is an essential feature of scientific investigation, and a key reason why adaptive management is described as science-based." (Williams, et al., 2007).

The Puget Sound *Action Agenda* was a significant first step in establishing goals for the protection and restoration of Puget Sound. As these goals are better defined through collaborations within the Partnership to develop specific objectives, adaptive management will help us formalize the interface between science and policy. We need to understand Puget Sound well enough to predict the results of restoration. We need the ability to monitor outcomes of our actions to see if they work, and we need to be honest when they don't—honest enough to change the actions as a result. In this context the approach to science outlined here can support restoration solutions that are robust, but provisional and perpetually responsive to change (Healy, 2007).

Finally, substantial and very valuable scientific efforts are already underway in Puget Sound. Clearly, the one key component of developing an integrated, adaptive science program is identifying these efforts, determining what gaps are likely to be filled with ongoing work, and identifying how to best leverage cooperative scientific investigations. Among these efforts are: the Shared Strategy for salmon; Ecoregional Assessments (The Nature Conservancy and partners), the Puget Sound Nearshore Partnership; the Puget Sound Ambient Monitoring Program (PSAMP); the Forest and Fish Adaptive Management Program; and numerous programs of state, tribal, and federal agencies. The Panel and Partnership staff will identify past and current programs from which the Partnership can benefit and to which the Partnership could potentially add value. This theme of cooperating with the broader scientific community is consistent with the impetus for developing a Partnership in the first place, and is vital to providing the best science in a timely manner.

Uses and Organization of this Plan

This Strategic Science Plan defines how the Partnership will engage in the Puget Sound science enterprise to implement the Action Agenda. It supports the role of science in supporting public policy development and the adaptive implementation of policy decisions. It seeks to assure that the broader science community is engaged, the process is transparent to the public, that Puget Sound science is robust, responsive to external review, and receives permanent stable support. the Strategic Science Plan supports development of tools by which the Partnership measures, and is accountable for, progress toward Puget Sound recovery as defined in the Action Agenda. (http://www.psp.wa.gov/aa_what.php).

More specifically, this document is intended to provide foundational guidance to the development of the Biennial Science Work Plan (BSWP) on a two-year state budget cycle. We envision the BSWP as a funding plan to implement the Strategic Science plan's vision as it applies to the *Action Agenda*. The BSWP will address the most pressing scientific information gaps and most critical scientific capacities needs. Science needs will change as more is learned about Puget Sound, and as we come to better understand the Puget Sound ecosystem. Similarly, scientific questions driving monitoring, research and modeling may change in response to improved understanding or as we respond to early restoration outcomes and changing information needs of policy makers. Continual learning is a healthy aspect of the Partnership's commitment to adaptive management, and each BSWP will reflect the understanding gained as we proceed.

Within this plan, we first provide a brief summary of the Puget Sound ecosystem itself (Section 2), emphasizing features that make Puget Sound unique, tracing several of the trends that indicate the system is in decline. This is the real world context for our policy, science and on-the-ground actions. These characteristics are elaborated in more detail in several previous publications, cited in this Plan.

Next (Section 3) we explicate several important assumptions and principles agreed upon by the Panel that will guide implementation of science under the plan. This provides for transparency in the thinking behind our science, since unspoken but differing assumptions about the role of science within the Puget Sound community could make the job of protection and restoration much more difficult.

In Section 4 (reserved) we outline the scientific information required to achieve ecosystem recovery. This provides an explanation of the current state of knowledge on which ecosystem recovery efforts are based.

Section 5 describes the foundations of a rigorous, durable, and responsive Puget Sound science program including an outline of analytic questions addressed by the program and a discussion of the capacities and competencies to be developed in the program.

Finally, Section 6 presents an approach to implementation of a policy-relevant science program that builds from the principles and foundation discussed in prior sections to provide for adaptive management of Puget Sound ecosystem recovery.

2. DESCRIPTION OF PUGET SOUND CHARACTERISTICS AND TRENDS

System approach for Puget Sound: To address the mission and goals of the PSP, an ecosystem-wide framework has been adopted. However, to take a system approach, we must emphasize the unique natural attributes of the Puget Sound as a system that distinguish it from other estuaries and estuarine systems in the nation.

2.1 Marine and nearshore

Puget Sound is the second largest estuary in the United States, having 3,790 kilometers of shoreline []. The geomorphology of Puget Sound is somewhat unique in the United States. Most estuaries in this country are coastal plain or drowned river estuaries, which do not have significant restrictions to the coastal ocean, nor do these estuaries have the great depths and strong tidal currents of Puget Sound. Puget Sound is a fjord and the only urbanized fjord in the nation. The average depth of the Puget Sound is 140 meters with a maximum depth of 280 meters. The bottom of the Sound consists of a series of valleys and ridges which act to disrupt the movement of water and help it mix. The watershed of the Puget Sound is approximately 42,800 square kilometers with over ten thousand rivers and streams. The majority of surface water (80%) flowing into Puget Sound comes from the following major river drainages: Cedar/Lake Washington canal, Duwamish/Green, Elwha, Nisqually, Nooksack, Puyallup, Skagit, Skokomish, Snohomish, and Stillaguamish [].

Because of its geological history, much of Puget Sound's nearshore habitat is relatively steep-sided and narrow. In contrast, most estuaries in this country are shallow and support anchored vegetation over a much greater portion of the estuarine seabed. Some implications of Puget Sound's structure are that there is a comparatively narrower fringe of nearshore habitat that supports many species at some point in their life cycle. Because this habitat is restricted, there is less leeway regarding destruction of nearshore habitat. Removing or degrading a portion of the nearshore habitat in Puget Sound does not have the same proportional effect on the living system as in a shallow, flat estuary.

Puget Sound is deep, with strong tides, with bathymetric sills that result in retentive circulation. The sills are shallow and lie at narrow restrictions within the water flow of the Sound. The three major sills that affect the overall function of the Sound are at Admiralty Inlet (mouth of the Straits); Tacoma Narrows; and the mouth of Hood Canal. The general circulation of Puget Sound is that salt water from the nearby Pacific Ocean mixes with fresh water runoff from the surrounding watershed. The denser salt water sinks deeper and moves toward the land, while fresh water forms a surface layer that moves towards the ocean. Near sills, however, mixing between these two water masses increases, and a portion of the out-flowing waters return back in []. The implications of these conditions are that inputs to Puget Sound persist for a long time.

Therefore, long-lasting effects that can be de-coupled from source elimination. Puget Sound biota tend to have a high degree of residency which makes the Sound highly productive, but also highly retentive of contaminants.

Climate effects, like ENSO, droughts, and seasonal upwelling/down-welling, have a demonstrated and particularly strong effect on Puget Sound []. While climate has a strong influence on Puget Sound, there is a need to recognize the cumulative and diversified effects which come from global influence on three sources of influence: ocean conditions, watershed conditions, and local weather. Because variability due to climate forcing is strong it is extremely important to preserve resiliency, redundancy and representative diversity to assure ecosystem sustainability. This is even more profound in light of uncertain effects from climate change.

2.2 Watershed and landscape

Characteristics of he watershed of the Puget Sound Basin vary across the five PSP action areas. These lands generally occur at higher elevations and are typically managed less intensively under the Northwest Forest Plan than extensive private forestland, which occur at lower elevations in the Cascade foothills. While agricultural lands have a relatively long history in the lowlands and floodplains of major rivers systems, these land are giving way to urbanization particularly in the western portion of the central Puget Sound Basin (Pierce, King and Snohomish counties). The terrestrial landscape is is dominated by some of the most productive coniferous forest in the world (Franklin and Dyrness, 1988). Insterspersed among the forests, particularly at lower elevations are other notable features such as prairies, madrone forests, oak woodlands, and swamp and bog communities. At higher elevations there are glaciers, hemlock and mixed conifer forests. Hemlock and Douglas fir forests line higher elevation streams, becoming riparian woodlands and shrub lands along larger rivers in the lowlands. Fresh water habitats range from small, intermittent streams and lakes to major river systems such as the Duwamish/Green, Puyallup-White, Cedar and Sammamish. The Center for Biological Diversity (2005) ranks the Puget Sound basin as a "hot spot" for biodiversity nationally, with its more than 7,000 species. The primary reasons for this are the sharp environmental gradients or differences in elevation, precipitation, soils, over a small geograaphic area and the complex mix of terrestrial and aquatic environments.

The land cover of Puget Sound today exhibits a dramatic human presence. Although an historical account of change in land cover across the entire Puget Sound basin is not yet available, the dramatic changes show clearly the rapid effects of urbanization (Alberti et al, 2003). Between 1991 and 1999 alone, 1% of the total area in the Central Puget Sound region has been newly developed, the area designated as forest land decreased by a total of 55% during the same period and the overall forest cover decreased 8.5 percent. Highly developed land (i.e., greater than 75% impervious cover) increased by more than 6% and moderately developed land (i.e. between 15 and 75% impervious cover) increased by almost 8%. The most intense development occurred with the Urban Growth Boundary as defined by the State Growth Management Act, where forest cover has declined by 11.1%. Almost half of the land conversion to development has occurred in the Seattle Metro area (Alberti et al, 2003).

2.3 Human Dimensions

The Puget Sound Basin reflects significant ethnic and racial diversity including a rich Native American or tribal heritage as illustrated by the numerous tribes that live and work in the region. People from around the world are drawn to the area because of the relatively high quality of life For example the Puget Sound Basin is well connected at local and regional levels, residents have lower monthly energy bills than the national average, and there is a wide range of job opportunities. The lands and water of Puget Sound provide an array of ecosystem goods and services that humans enjoy such as commercial, recreational and tribal fisheries, local wastewater treatment, wildlife viewing, hiking and other recreational opportunities, and transportation. The Puget Sound is also at the heart of the State of Washington's prosperity. The Puget Sound region serves as the major North American gateway for trade with Pacific Rim countries. Together the ports of Seattle and Tacoma are number two in the nation for container traffic.

The diversified economy creates relative economic stability. The area has one of the largest shellfish producing regions in the U.S. and at the same time is the world center for software development and information technology. The historical natural resource extraction based economy and development of Boeing and more recent information technology boom have both impacted the long term sustainability of the environmental health of the Puget Sound. The Puget Sound Basin includes five of the top 10 fastest growing counties in the state of Washington.

According to the 2000 Puget Sound Water Quality Management Plan Managing and protecting Puget Sound, along with the rapid proliferation of human activities, is a challenge. What makes the task most daunting is the sheer number of government bodies that can potentially affect Puget Sound and its resources. There are [more than 100] cities, 12 counties, 12 conservation districts, 12 local health jurisdictions, 28 local port districts, 3 regional governmental bodies, 22 tribes, 14 state agencies and 9 federal agencies involved in the process. In addition, there are hundreds of special purpose districts for water, sewer, groundwater protection, drainage and irrigation. All of these government bodies have their own set of responsibilities. Each has a unique constituency and ability to raise money and make policy. This dispersion of power is consistent with and reinforces Washington's long tradition of limiting the power of state government and deferring important decisions to local authorities (Lombard, 2006). However, as a result, protecting Puget Sound can often take a back seat to other priorities.

The Washington Legislature, in discussing the institutional situation in the Puget Sound region as it affects Puget Sound recovery efforts, noted that the large number of governmental entities that now have regulatory programs affecting the water quality of Puget Sound have diverse interests and limited jurisdictions that cannot adequately address the cumulative, wide-ranging impacts that contribute to the degradation of Puget Sound…Coordination of the regulatory programs, at the state and local level, is best accomplished through the development of interagency mechanisms that allow these entities to transcend their diverse interests and limited jurisdictions. (Puget Sound Water Quality Protection Act of 1996, repealed effective 2007)

2.4 Forces of Change

Regardless of the past natural and human history of the Puget Sound Basin, the ecosystem's future will we shaped by two major drivers of change. First, the human population in Puget Sound basin will likely increase substantially by 2020 and beyond, adding some two million residents within the next 20 years (Ruckelshaus and McClure, 2007). Restoring Puget Sound will increase in complexity and difficulty through time because of the increasing intensity of human activities. While human development may be cyclical in response to the economy, people will continue to build homes along the shore, build roads and other infrastructure, and at the same time recreate in its waters and consume food from the near-shore zone. Land and water use, release of pollutants, shoreline modifications, and other results of population increase will be major drivers of ecosystem change.

Second, climate change will affect Puget Sound in ways that are both predictable and unpredictable, affecting the way we think about restoration (Ruckleshaus and McClure, 2007). For example, sea levels will rise and the seasonal timing and amount of stream and river inflow will change (Mote et al., 2005), propagating other changes throughout the ecosystem. Human infrastructure, natural habitats and living resources such as spawning salmon will be influenced by these changes. Local species extinctions will be more likely; invasive species (including perhaps disease microbes) will be more likely to find newly suitable habitats.

3. PRINCIPLES GUIDING SCIENCE FOR PUGET SOUND

Practicing science in an adaptive management framework will require that scientists, policy makers, managers, and stakeholders reach common understanding about the assumptions, driving forces, and limitations that influence chances for successful protection and restoration. Too often, participants in large-scale restoration programs agree on broad language, but later discover that they were actually working from different definitions, frames of reference, or beliefs about roles. If the assumptions underlying a science program are hidden, assumed, or undeclared, consensus on recovery is difficult. The discussion below is aimed at enlarging this common frame of reference for elements that shape the science need of Puget Sound. These elements emerge from the collective experiences of scientists and natural resource managers—some working in specific coastal ecosystems other than Puget Sound (a particularly good discussion of these can be found in Van Cleve, et al., 2004).

Expect Surprises. Science will inevitably yield counter-intuitive knowledge crucial to the success of protection and restoration. For example, the science program of the Galveston Bay National Estuary Program reversed previous conventional wisdom for 4 of the 17 major restoration needs identified for the ecosystem (Shipley and Kiesling, 1994). In Puget Sound, recent new science addressing Hood Canal oxygen depletion has fundamentally changed our understanding of the role of nutrients from the ocean and from alder trees (Newton, pers. comm), influencing the range of possible restoration actions. Flexibility is an asset in this setting. While planning often establishes goals, actions to achieve those goals, indicators to measure response, and benchmarks to gauge progress (predefined, desired indicator response levels), uncertainty requires that the process of restoration be continually experimental to some degree. That is, *benchmarks* *are not immutable,* and may need to change as surprises about the ecosystem are revealed by science.

Integrate the Science. As a particularly dynamic, complex ecosystem, Puget Sound requires an approach that is inherently interdisciplinary and multi-scalar. Collaboration and cross-disciplinary thinking to solve problems in a basin-wide context are particularly important. The entire science talent pool in the region needs to be tapped to address all elements of restoration including marine, lowlands and basin-wide influences. This approach brings to the table many different scientific disciplines: hydrology, marine biology, geomorphology, socioeconomics, terrestrial ecology, and many others. For example, to integrate human and ecological trends, simply adding people to ecological models may not be sufficient. Studying coupled human-natural systems requires us to recognize the effects of humans on the environment (how human stressors influence ecosystem processes) *and effects of environmental change and management responses on human behavior, as well as human activities and well-being*. Broadly speaking, human well-being is "produced" by the combination of two types of inputs; ecosystem capital, goods, and services; and human-built capital goods and services. Humans may serve as both agents of positive and negative change to the environment.

Seek Scientific Common Ground. Differing, often divisive beliefs about the ecosystem and its restoration can emerge when knowledge is incomplete. Science can help unify viewpoints by filling in some of the gaps. For this to happen, scientists must convert data into relevant information, translate complex ideas for a broad audience, work at a scale relevant to practical action, and have a ready answer to the question "so what?" about the findings of their work (Shipley and Kiesling, 1994; Van Cleve et al., 2004). "Agreement on the facts" is a good foundation for action within the Partnership and on the scale of broad public understanding. Scientist can also come to consensus despite uncertainty that cannot be *quickly* remedied with new data (e.g. as occurred through the work of the Intergovernmental Panel on Climate Change). Thus the lack of knowledge about some ecosystem dynamics can be addressed via concerted effort to document the common ground among experts, as opposed to allowing this disagreement to play itself out in the literature or in public.

Know the Limits of Science. Scientists should not be asked what should be done to achieve restoration, but rather to help narrow the possible range of actions by predicting their consequences. Decision makers, as keepers of societal values, should consider social, economic, and legal issues in addition to scientific input in choosing actions and setting their priority (Van Cleve et al., 2004). Furthermore, funding will be insufficient for research and monitoring to be undertaken for every restoration action. The challenge will be to design restoration and science strategically so that science best informs policy across a wide range of scales—up to and including the entire ecosystem. Scientist must convey to policy makers the implications of scientific uncertainty on ecosystem outcomes. In the context of ecosystem recovery, the precautionary principle is an admission of, and a means to account for, scientific uncertainty about influences of various ecological drivers.

Do Not Delay. Scientific uncertainty is not a good reason to delay action, since there will always be uncertainty. The risk of doing nothing outweighs the risk of taking actions without complete knowledge, at least for certain restoration applications. Under adaptive management, taking action in the face of uncertainty provides science with the experiment it needs to better inform future action.

(Note from Frank. If somebody knows what "anticipatory science" is, we talked about adding something. Also, I'm not sure whether we decided to include peer review in this section, or mention it here. It is now in section 5.3. If we want it here, we might need a section on roles and processes affecting science, not just peer review. An into paragraph followed by peer review and organizations structure, roles could be here.

"Further, agreement is needed on the participant roles and organizational processes that will ensure solid engagement between science and policy development. During development of the *Action Agenda*, much progress was made by the Partnership toward developing a necessary common frame of reference. Below are several elements that will help assure that this engagement is robust...peer review...principle of joint working groups, etc.")

4. SCIENTIFIC INFORMATION REQUIRED TO ACHIEVE THE SIX PS PARTNERSHIP GOALS

[RESERVED -- draft available for Science Panel in a separate document]

5. FOUNDATIONS OF A RIGOROUS, DURABLE, AND RESPONSIVE PUGET SOUND SCIENCE PROGRAM

Our collective knowledge of Puget Sound comes from decades of dedicated investigations and observations by a wide variety of people and organizations for a number of reasons. Indeed the very ideas driving the formation of the Puget Sound Partnership came from this earlier work documenting the systematic decline of this valued ecosystem. This Strategic Science Plan builds on prior findings and existing capacities in the region. While it is responsive to the specific needs of the Partnership today, it is meant to also continue to build and maintain a vigorous Puget Sound science program that discovers and explores the issues of importance to future generations.

Regardless of the specific issues facing an ecosystem restoration and management program, a fundamentally sound science program has the following core elements: the ability to analyze and synthesize existing information; the ability to develop and apply innovative tools to understand structure and function and to predict and document change; the ability to foster exploration and discovery; the ability to effectively communicate and integrate science; and the ability to continually review the quality, depth and breadth of our understanding in open, transparent, and constructive ways.

5.1 Analysis

Being able to analyze complex, incomplete and often contradictory data and information is critical to the restoration and protection of the Puget Sound. Many individuals, groups, organizations, and agencies in the Puget Sound region collect data, make observations, and develop analysis tools. The PSP should lead the integration (gathering together) and synthesis (developing coherent and consistent interpretations) of this information. This requires the capacity to address several types organizing questions:

5.1.1. How is the Puget Sound natural system structured and how does it work?

a. Why this question is important to PSP goals: We cannot manage a complex system that we don't understand. Just as medical professionals must first understand the anatomy (how is it structured?) and physiology (how does it work?) of healthy individuals before addressing injury and disease, environmental scientists must describe linkages among ecosystem components and quantify how materials (water, biota, pollutants) and energy move through the Puget Sound ecosystem. This knowledge is the foundation upon which more applied questions may be answered.

b. What is required:

- Conceptual models that describe the relationships among and flows of materials and energy between the key components of the natural system.
- Detailed studies to quantify specific processes and relationships, especially how they very in space and time in response to external drivers.
- Deterministic models of material and energy flows at appropriate spatial and temporal scales.
- Long-term, consistent monitoring and process research to refine and verify these models.

5.1.2. How can the Puget Sound community, which benefits from and impacts the natural system in a wide variety of ways, define a healthy, functioning natural system?

5.1.3. How has the Puget Sound natural system evolved in response to natural and human-induced stressors? How will the Puget Sound continue to change and what will it look like in 2020?

Given multiple, potentially competing objectives for the Puget Sound ecosystem in terms of the services is provides (e.g., protection of human health, support of a thriving economy and accommodation of future population growth, fisheries, biodiversity maintenance, flood control, production of crops and timber, provision of clean, fresh water, etc.).

- What are possible future states where at least minimum thresholds for multiple objectives are met?
- What ecosystem services are provided under the alternative futures?
- What are the major trade-offs in objectives or ecosystem services under potential future states?

a. Why this question is important to PSP goals: The Puget Sound ecosystem is not static, and will continue to change by both natural and anthropogenic influences. Identifying the drivers that caused prior changes and understanding previous rates of change allow us to build credible predictive capabilities. Unless we project the most likely conditions in 2020, it is not possible to develop assessment or restoration strategies. This must address not only natural science, but also industries, population demographics, and environmental services.

b. What is required:

- Long-term status and trends monitoring, analysis of natural variability at several temporal scales, and detailed studies of drivers of temporal change;
- Models that can explain previous trends (hindcasts) and evaluate future conditions under a variety of scenarios (forecasts). Of particular importance is the development of linked natural, social, and economic models at the ecosystem scale in Puget Sound.

5.1.4. What indicators of ecosystem function best track properties such as ecosystem resilience, stability, productivity, etc? How can such terms (or others that capture desired ecosystem conditions) be explicitly defined and then measured for tracking progress towards goals?

What thresholds are associated with specific changes in ecosystem condition or function/processes? (e.g., how do species growth rates or human health metrics change with changes in concentrations of one or more contaminants? What abundance and productivity of a species are associated with a certain probability of persistence? How is the distribution and total area of a given habitat related to species abundance? How are feeder bluff or shoreline erosion rates associated with the distribution and extent of nearshore habitats such as eelgrass or beaches?)

5.1.5. What are the individual and cumulative effects of restoration and protection actions?

The restoration and protection of the Puget Sound is inherently defined by the complex connections and interactions within and between the natural, social, economic, and political worlds. Yet, to date a piecemeal approach has been taken, as illustrated by single-species recovery plans. Restoration projects are often at a local scale, and it is unclear how these impact larger spatial regions.

a. Why this question is important to PSP goals: Deliberate actions may influence the future conditions in the ecosystem, but we must understand how effective each contemplated action will likely be on the desired outcome and how will it affect industry and individual quality of life and health. Actions may be synergistic and mutually beneficial, or may work at cross purposes.

b. What is required: The PSP needs analytical tools that allow individual and cumulative effects of restoration and protection actions to be better understood, including deterministic and probabilistic models, targeted monitoring and comparative studies at current restoration sites, economic analysis, futures analysis, and research and development of restoration/protection technologies.

5.2 Required Capacity and Competency

The Puget Sound Science Program should maintain a balanced portfolio that includes:

5.2.1. Integration, synthesis, and application of existing information

A significant need exists for a sustained intellectual and technical capacity to digest existing information and continuing and future observations of the Puget Sound ecosystem. In short, it is critically important to fully exploit this information through the lens of best available tools to develop a common understanding of the status, threats, and evolution of this complex system. This does not 'just happen', but requires dedicated resources to support a core multidisciplinary group to evaluate, integrate, and synthesize the available information. These efforts must be in fact and in perception open, self-critical, and unbiased. Efforts such as the State of the Sound and Puget Sound Science Update should continue under the auspices of the PSP, taking advantage of the revolution in information and community technologies.

5.2.2. Observations of current status and trends

The PSP Action Agenda is built on the principles of adaptive management, which in turn require a dedication to focused, sustained, high-quality observations. The PSP must lead coordination of ecosystem-wide monitoring, including insuring harmonization of monitoring programs across all groups and providing the community with comprehensive 'value added' integration and synthesis products. The PSP must work with partners to develop and insure strong and sustained funding for ecosystem monitoring.

5.2.3. Exploration of the natural system

Refining and improving the stewardship of Puget Sound in the future requires improving our knowledge of Puget Sound. Science is inherently inefficient, requires risk taking, and relies to a certain extent on serendipity. Exploratory, curiosity-driven research must be a component of a healthy science-based Puget Sound ecosystem program. The PSP, through its Science Panel, should play an important coordinating role insuring support across a variety of funding agencies for a balanced portfolio of exploratory and applied research.

5.2.4. Exploration of the social and economic systems

Systematic studies of the social and ecosystem systems in the Puget Sound region contributes to the restoration in several critical ways. First, understanding how the diversity of communities in the region value Puget Sound is key to setting restoration goals and in defining 'what is healthy?'. Second, effective restoration and protection strategies must work within the social, economic, and political structures of the region. As with the natural sciences, there are needs for both fundamental and applied research on the social and economic systems of Puget Sound.

5.2.5. Ecosystem-scale prediction

Tools to describe future conditions of the Puget Sound integrate what is known about structure, function, and process with estimates of future drivers. While the Puget Sound will continue to change, the exact trajectory it will follow is not precisely known. How effectively we might steer toward desirable conditions through policies and programs, requires ecosystem-scale prediction tools. The PSP science program must support development and implementation of quantitative tools for future analyses, in which various scenarios are systematically evaluated.

5.2.6. Anticipatory science

A rigorous science-based program includes anticipatory science, as we must adapt as new threats and drivers arise. There is a natural tendency to focus on known issues, but restoration efforts could be overcome if emerging threats are not considered. For example, altered hydrology driven by climate change may overwhelm restoration of salmon habitat structure. Emerging chemical threats, including nanoparticles, is another example. A healthy science portfolio must reserve resources for exploratory, anticipatory investigations. More importantly, the program must be able to incorporate these new issues in the science-policy loop of adaptive management.

5.2.7. Development of new tools including decision tools and integrated ecosystem/economic systems models

Adaptive management requires sophisticated tools to analyze current states, future directions, and effectiveness of actions. Existing tools are adequate to begin, but further progress will require development, validation, and use of new tools. In particular, new models that integrate across natural, economic, social, and political systems are required. This will catalyze significant interactions among a wide variety of technical and policy communities, which in itself will drive innovative thinking about restoration and protection.

5.2.8. A healthy scientific community in Puget Sound also requires investments in:

1. Training/education
2. Infrastructure
3. Communication (conferences, publications, outreach)

5.3 Peer Review

Peer review is a fundamental tenet of good science. Independent peer review is the accepted tool for rigorous, impartial evaluation of scholarly manuscripts, research proposals, complex institutional research programs, academic faculty and federal agency science staff promotions and most other decisions affecting how science is conducted and used to address human needs and problems. Peer review is a cornerstone of science and engineering research and funding agencies. For instance, the Ecological Society of America (ESA)[1] has described peer review as "…an integral component of scientific research and publishing. It allows the scientific community to maintain quality control of research through the review of research proposals, journal manuscripts and other reports. Academic peer review, although far from perfect, is the best tool scientists have to ensure high standards for their professional work."

Peer Review Components

Restoration and preservation of Puget Sound ecosystems under the oversight of PSP will involve extensive assessment of scientific direction and priorities, and scrutiny of background science and restoration performance; all of these aspects demand some level and type of peer review. Peer review under PSP will help to ensure that the "best available science[2]" is pursued. Moreover, peer review will help to avoid potential conflicts of interest and minimize the influence of other, subjective factors, such as funding sources or undue influence of special interest groups.

There are four fundamental types of peer review: (1) research proposal ranking and selection; (2) technical report and other product review; (3) review of scientific strategy and direction; and (4) program review.

Research Proposal Ranking and Selection - Any decision based on scientific and technical merit, such as evaluation of research proposals, should be based in peer review. Through peer review, the difficult decisions about research funding allocation and dissemination of results can be objectively based on scientific validity, originality, and importance and relevance.

Product Review - The second internal need for formalized peer review is to ensure the scientific credibility of PSP products, such as guidance documents, technical reports and data/metadata. The scientific community has a long history of peer review of scientific products that is characterized by effectiveness, competence, usefulness, and security.

Scientific Strategy and Direction. Peer review is also a critically important aspect of program guidance, contributing to pivotal decisions and advising on strategic directions. Such guidance typically involves a body (formal committee or panel) of experts from outside the region, who

1 Ecological Society of America (ESA) Public Affairs Office briefing to the US Congress, ESA Bulletin 86(1), January 2005; see: http://www.esapubs.org/bulletin/current/current.htm

2 See US federal and other institutional/legal definitions; Lessons Learned document (PSNERP-NST 2005) also provides detailed definition.

are completely disassociated with the program but familiar with the ecosystems and scientific concepts required to address the regional issues. Such peer review can serve internal direction in (1) an *advisory* role or can (2) provide critical *review* of program progress and performance. In addition, these roles may be exercised *internally* (operating as an explicit component of the organizational structure) as the Science Panel now performs or *externally* (operating outside of the organizational structure, reporting to an over-seeing or independent body).

There are some significant differences in the internal advisory vs. external review roles:

Internal advisory bodies do not always examine the fine detail aspects of a program, but more the program's fundamental goals and objectives, the strategic approach to addressing them and the organization structure and decision-making process. When applied most effectively, advisors are involved early in the program and meet periodically to review the program at critical stages, in an adaptive mode. Reporting is often brief and often the most critical exchange is verbal review with the program staff. They often report directly to a program's technical staff, but copy their advice to management levels.

External review bodies typically evaluate a program nearing its completion, or at least late in its maturity. The primary goal is often to assess whether or not the program has met its goals and objectives, and to provide pivotal evaluation for the decision of whether or not to continue a program. Such review panels or committees may stipulate their own approach to assessing the program, independent of the program or its sponsor.

Program Review - Designing the structure of a complex restoration program, such as the PSP, is a difficult task with seemingly endless alternatives to integrating and balancing science, management, governance and evaluation (VanCleve *et al*. 2004). Peer review, often associated with comparable tasks under Scientific Strategy and Direction (above), can also be utilized to help advise on and shape program structure to maximize the implementation of "best science".

6. IMPLEMENTATION

The Puget Sound Partnership proposes the Strategic Science Program described in this section as a means of building from the foundations described above (Section 5) to implement an adaptive management approach, with its inherent science-policy interactions, to recovery of the Puget Sound ecosystem. The Partnership proposes this program in recognition that the science-basis for recovery actions must be continually improved, in accordance with the guiding principles discussed above (Section 3), to advance our collective understanding of causal links between protection and restoration actions and outcomes in the ecosystem.

Existing mechanisms of science-policy interaction in the Puget Sound region are inadequate for adaptive management of ecosystem recovery; the program described in Section 6.1 is intended to make linkages where they are currently absent or lacking and to provide for the strategic application of science to support the region's evolving efforts at ecosystem recovery.

Given the close science-policy connection designed to enable an adaptive management approach for Puget Sound ecosystem recovery, the Partnership's strategic science program also includes a peer review component, described in Section 6.2, to ensure the credibility of the science used as the basis for ecosystem recovery efforts in the region.

Finally, Puget Sound ecosystem recovery will rely on engagement of local, regional, and global communities over many years. Section 6.3 introduces the Partnership's data management and communication systems as a means for ensuring that community members, peer networks, and local, regional, and international organizations have reliable access to information about the Puget Sound ecosystem and the region's recovery efforts. Section 6.4 describes a science education and outreach approach, developed as part of the Partnership's education and outreach program, that helps ensure that scientific information is conveyed and used appropriately in education and outreach and that the region invests in developing a dynamic, diverse and scientifically-competent workforce to continue ecosystem recovery efforts into the future.

6.1 Building a Strategic Science Program Around Science-Policy Work Groups

The Partnership's Strategic Science Program is organized around science-policy work groups, each of which provides for interaction across the four entities that comprise the Partnership: Leadership Council, Ecosystem Coordination Board, Science Panel, and Executive Director (i.e., Partnership staff). These science-policy work groups commission and oversee analyses, syntheses, and Partnership and community processes to ensure that (1) the best available science basis is used in implementing and adapting the action agenda and (2) the Partnership advances scientific understanding by continuing investments in scientific investigation and capacity.

Joint meetings of the science-policy work groups and/or of the Partnership's leadership council, ecosystem coordination board, and science panel will be used to coordinate and distribute the adaptive management activities of the entire Partnership and develop work plans for each science-policy work group. Through these joint meetings and work plans, the Partnership will identify elements of the action agenda that will be evaluated for potential adaptations (e.g., because information on actual outcomes can be compared to predicted outcomes)

In the spring of even numbered years, the Science Panel and staff will convene such joint meetings to solicit advice for the development of biennial science work plans. Joint meetings of the science-policy work groups and/or leadership groups may also be used to detail the specific content for and timing of material presented in Puget Sound Science Updates.

Each science-policy work group's specific tasks for a given period will be developed as work plans negotiated among the Leadership Council, Science Panel, and Executive Director. Each activity in the biennial science work plan will be coordinated by one of these work groups.

Each science-policy work group will include at least? (or two?) two members of the Leadership Council, three members of the Ecosystem Coordination Board, two members of the Science Panel, and key representatives of Partnership staff. One of these staff members will provide ongoing support to the work group and will facilitate the meetings and collaborative work of the work group.

Leadership group members and staff will be responsible to ensure that briefing, discussion, and decision items are prepared for agenda items at Leadership Council, Ecosystem Coordination Board, and Science Panel meetings. Staff and work group members will ensure that stakeholder groups are engaged through the Ecosystem Coordination Board, stakeholder caucuses and associations, or through workshops and public engagement processes.

In addition to relationships with the Partnership's leadership groups including the Science Panel, each work group may develop relationships with other Puget Sound science advisory bodies, especially the Nearshore Science Team and the salmon recovery Regional Implementation Technical Team.

Analyses, syntheses, and Partnership and community processes commissioned by the work groups will be conducted by Partnership staff, technical work groups, or other agencies and organizations. Staff will facilitate the development of scopes of work, work plans, and (if needed) contractual arrangements for work commissioned by the science-policy work groups. Technical work groups – comprised of science, program, and policy experts as appropriate – may undertake activities for more than one science-policy work group and from other groups and processes (e.g., the Puget Sound salmon recovery council, the transboundary coast and oceans task force). Technical work groups may be established ad hoc or as standing committees of the Partnership organization.

Science-policy work groups, and technical work groups, will not make policy for the Partnership, but will develop information, analyses, and syntheses to be used to inform decisions by the Partnership's leadership groups.

The Partnership intends to convene the four science-policy work groups described below to initiate its Strategic Science Program. The Partnership's Leadership Council and Science Panel may modify these groups at any time by mutual agreement.

6.1.1 Understanding progress toward recovery – status and trends, performance management

Under the direction of an “understanding progress” science-policy work group, the Partnership will develop and coordinate science program elements related to:

- identifying ecosystem recovery objectives
- monitoring ecosystem attributes to evaluate progress toward objectives.

Science program-driven tasks that might be commissioned and overseen by this science-policy group include:

- evaluation of the Partnership's purposes in developing indicators of and setting targets and benchmarks for ecosystem recovery
- evaluation to develop and/or refine the Partnership's indicators of ecosystem recovery
- evaluation of science-based thresholds, baselines, etc. that might inform the Partnership's selection of ecosystem recovery targets and benchmarks
- design and oversight of programs for monitoring status and trends of ecosystem attributes including indicators
- synthesis of status and trends information related to ecosystem recovery goals and objectives

The Partnership expects that standing committees to oversee a coordinated regional ecosystem monitoring program will be commissioned by and report through this work group. In addition, this work group will likely commission a number of ad hoc technical groups related to indicator development, setting ecosystem recovery objectives, and developing synthesis of ecosystem conditions and trends.

This work group would coordinate the Partnership's involvement with the Washington Monitoring Forum, guide the updating of the Question 1 portion of the Action Agenda, and coordinate the Partnership's involvement in program evaluations such as those conducted by the Joint Legislative Audit Review Committee and the Washington State Academy of Science.

6.1.2 Understanding threats to the Puget Sound ecosystem

Under the direction of an “understanding threats” science-policy work group, the Partnership will develop and coordinate science program elements related to:

- examining and describing (causal) relationships among ecosystem processes, structures,

and functions, especially attributes that might be affected by human influences on the ecosystem
- predicting ecosystem trajectories and futures.

Science program-driven tasks that might be commissioned and overseen by this science-policy group include:

- development of conceptual and numeric models to link terrestrial-watershed-nearshore-marine processes, structures, and functions
- prediction of ecosystem futures and trajectories given uncertainties about the nature and trajectories of factors influencing the Puget Sound ecosystem
- spatial analysis of key processes, structures, functions and threats to identify targets for protection and restoration
- evaluation of the current documented knowledge about current and future threats to ecosystem processes, structures, and functions as a result of human influences in the ecosystem

The Partnership expects that ad hoc or standing committees to evaluate specific threats (e.g., toxic loadings, nutrient loading effects on marine dissolved oxygen conditions, invasive species), will coordinate ecosystem modeling in the region, predict future conditions, and synthesize information about the relative threats to the ecosystem and will be commissioned by and report through this work group.

This work group would coordinate the Partnership's involvement with the Washington State Invasive Species Council and the Washington Biodiversity Council and oversee updates to the threats assessment portion of the Partnership's 2008 topic forum papers.

6.1.3 Exploring protection and restoration actions

Under the direction of an “exploring actions” science-policy work group, the Partnership will develop and coordinate science program elements related to:

- predicting outcomes of alternative protection and restoration actions
- evaluating the effects of implemented actions

Science program-driven tasks that might be commissioned and overseen by this science-policy group include:

- development of alternative management scenarios to be evaluated by predictive models
- modification and application of models to evaluate alternative management scenarios
- design and oversight of effectiveness monitoring for protection and restoration programs and projects

- evaluation of current documented knowledge of the effectiveness and certainty of protection and restoration approaches

The Partnership expects that standing committees overseeing and coordinating effectiveness monitoring will be commissioned by and reported through this work group. In addition, this group may commission ad hoc technical groups to address specific management issues (e.g., stormwater management and controls on land use and development practices, floodplain management, nearshore restoration, salmon habitat protection and restoration, toxics control, nutrient control).

This work group would coordinate the Partnership's involvement with Puget Sound Nearshore Ecosystem Restoration Program, the Salmon Recovery Council, Ecology's Water Quality Partnership, and ????… and oversee updates to the management strategy evaluation portions of the Partnership's 2008 topic forum papers.

6.1.4 Communicating to share information and stories

Under the direction of a "communicating information" science-policy work group, the Partnership will develop and coordinate science program elements related to:

- preparing reports on ecosystem conditions and progress toward ecosystem recovery objectives
- developing syntheses of scientific knowledge about the Puget Sound ecosystem
- communicating scientific information about the ecosystem, threats to ecosystem health, and protection and restoration actions

Science program-driven tasks that might be commissioned and overseen by this science-policy group include:

- interpretation of ecosystem indicator reporting for State of the Sound
- dissemination of information from the Puget Sound Science Update
- science-perspective review of Partnership materials and publications
- solicitation of public and stakeholder comment on Puget Sound science priorities
- development and sharing of conceptual models to convey understandings and information

This group may commission ad hoc technical groups to advance specific tasks (e.g., development of a Puget Sound Science Update, evaluation of the communication and education achieved by a Partnership publication).

This work group would coordinate the Partnership's work with that of other entities who are developing scorecards and indicator reports (e.g., Washington state biodiversity scorecard, State of Salmon in Watersheds report).

6.2 Peer Review

The integrity and effectiveness of scientific investigations undertaken for the PSP require peer review, preferably in multiple programmatic levels (described above in section 5.3). The PSP Science Panel presently performs the functions of providing Scientific Strategy and Direction and recommends that PSP establish peer review at two additional levels:

- Proposal and Product Review (Internal)
- Program Review (External)

Research Proposal and Product Review would provide the periodic review required for proposals and products from and to PSP. These would be based on an internal review process conducted by anonymous, independent experts not associated with the program. To prevent real or perceived conflict of interest, reviewers would be limited to individuals not related to any on-going PSP research or other direct or contractual activities. The reviewers and their disciplines would vary depending upon the topic of the review, but their expertise should overlap extensively with the proposal or product topic. Review of PSP products (e.g., reports, manuscripts, datasets) would typically be based on mail/e-mail exchanges. Proposal reviews would likely involve a combination of mail/e-mail review and panel meetings. Review participants would be volunteers (as is often the case for proposal and manuscript review) or be compensated on a review-by-review basis.

One specific example to improve the quality of science that is used by decision makers is to adapt the *Puget Sound Update* to become a document that is more similar to the International Panel for Climate Change (IPCC) Assessment Reports that come out every 5 years or so. The IPCC utilize a structured process involving a small working group of authors for each major section that writes from an outline that is given to them by the IPCC, and then there are several rounds of intensive peer-review before the document is finalized. Criteria for data or analyses that can be included are set in advance, and it is not limited to peer-reviewed journal articles (e.g., assessment data and evaluations can be included, as long as they meet peer review standards.) Such a peer review process for the *Update* would elevate the quality of the document, and broaden its scope to include priority science reporting needs defined by PSP. It also would contribute to a significant change in the scientific and policy communities (e.g., provide ease of access for major scientific conclusions and synthesis of most current science; elevate science quality by filtering it through rigorous peer review process, etc.)

Program Review would require a less frequent (e.g., every three years) assessment than that provided by the Science Panel but would address the broader goals and purposes of the PSP on the scale of a NRC review but with continued involvement rather than a one-time review. It would be composed of both national (or international) and regional experts, including representatives of scientific and technical expertise, social scientists and stakeholders. Optimally, members would have some experience in large, ecosystem-scale restoration in other regions (as might be represented by key individuals involved in the case study programs reviewed in Van Cleve *et al.* 2003). While their background should be science based, their perspective should be programmatic, e.g., to ensure that science is most effectively deployed and managed toward the goals of the PSP. They would report principally to the PSP Leadership Council. Participants would be compensated on an on-going contractual basis for each review period.

While peer review is the cornerstone to good science, stakeholder involvement is necessary to insure that the outcomes of the peer review processes are accepted by decision makers and the public. Sometimes knowledge can be a source of conflict, and conflicts between local and scientific knowledge can impede ecosystem management and restoration. A peer review process that includes both types of knowledge may mean that a project will meet with less resistance especially if the project will impact local people negatively. Meaningful stakeholder involvement improves the chances for successful ecosystem management and restoration. Meaningful involvement entails including stakeholders in every phase of the process, legitimizing all stakeholders' knowledge and beliefs, and ensuring that decision making is transparent. Though stakeholder involvement may slow down the peer review process, it is critical to breaking down sociopolitical boundaries.

6.3 Data Management and Communication

There is a critical need to integrate diverse data sets on environmental quality and ecological conditions within the Puget Sound to support the goals and objectives of the Puget Sound Partnership to protect and restore Puget Sound (PSP 2008a). Many organizations, including federal, state, and local agencies, tribes, educational and research institutions, private organizations, and citizen monitoring groups are involved in collecting data on the Puget Sound. Additionally, the Partnership itself will need to collect administrative and project-related data to evaluate the effectiveness of actions and policies implemented as part of the Action Agenda. The data vary from highly quantitative data, such as analytical chemistry results, to qualitative information such as observations reported by volunteers. The types of data formats may range from high resolution multi-spectral imaging data to hand written field notes recorded in a logbook. All these data represent important contributions to understanding the ecological condition and quality of the Puget Sound if they could be effectively integrated and made available to support site-specific to regional scale analyses. Data uses include everything from long term trend analysis to real-time decision support. Therefore a data management system must be developed that is flexible, capable of accessing data from various organizations and agencies, proficient at cataloging and archiving critical data and information to document Partnership activities, and accessible to a wide user community consisting of managers, researchers, stakeholders, and the general public.

A wide range of data sets are needed to support Puget Sound restoration including point data like contaminant levels in environmental media, time series of environmental processes like wind and currents, landscape scale features such as soil types, land uses, and population density, social and economic data, as well as synthetic data from model simulations and projections based on statistical analysis (Table 1). The data management system utilized by the Partnership should take advantage of the existing data repositories and clearing houses already established within the Puget Sound Region and work to provide connectivity that would foster and enhance a collaborative user network capable of responding to a wide variety of information needs.

An important starting point would be to catalog the existing information infrastructure available to support the Puget Sound Partnership and develop a plan to coordinate tasks that will contribute to increased connectivity and capacity of the existing system. For example, the

Northwest Environmental Data Network (NEDN 2008) has developed an initial inventory of publicly available environmental data sources in the northwest, while the Pacific Northwest Aquatic Monitoring Partnership has developed a plan to coordinate aquatic monitoring in the Pacific Northwest (PNAMP 2008). Meanwhile, the Partnership has initiated efforts to obtain inventories of monitoring and other environmental projects within each of the action areas in the Puget Sound (Jones and Stokes 2008). Important to this effort is to develop information on key indicators currently in use in the Pacific Northwest, how the indicators are being used, the metrics behind them (PNAMP 2008b). This information could be used to assess the importance of various data sources for meeting the Partnership's needs (Tetta 2008).

Table 1. Categories of data needed to support Puget Sound protection and restoration.

Categories of Data	Example
Point Data	Samples or measurements taken at specific location and analyzed for parameter of interest contaminants in environmental media nutrients in water column pathogens in water column biological assessments of aquatic and terrestrial resources
Time Series	Samples or measurements taken at specific location(s) over time weather tides currents stream flow
Feature Classes	Data collected or reported spatially across the landscape remote sensing data population density roads and infrastructure land use and cover data
Social/Economic Data	Data obtained from social and economic systems market statistics unemployment rate cost of living
Synthetic Data	Simulated or predicted data sets model results statistical projections historical conditions future predictions

Currently, a partnership among states, tribes, and the U.S. Environmental Protection Agency (USEPA) is underway to develop an Exchange Network to efficiently share and exchange water quality and other data over the internet (NOB 2008). The USEPA is also working to develop data registry services to provide information about data sets (metadata) for the myriad of environmental data managed by USEPA. The registry is designed to improve access, resuse, and standardization across a wide range of environmental information (USEPA 2008a). As part of the efforts to develop an integrated ocean observing system for the US, the Northwest Association of Networked Ocean Observing Systems (NANOOS) is implementing a regional observing system for the coastal waters of Washington and Oregon and developing technologies to forecast and model estuarine circulation, provide standards for metadata and data quality, and provide real time access to data and observations (NANOOS 2008). The Washington State Department of Ecology (Ecology) maintains an Environmental Information Management (EIM) system that houses environmental monitoring data collected by Ecology and other affiliated agencies (WDOE 2008). Among other things these data are used to support Ecology's Water Quality Assessment (303d list) process.

The Partnership and some of its copartners have begun efforts to develop an information management architecture in which the Partnership can function as the center of distributed system of data exchange nodes (RCO 2007). However, to assure that this effort can be effectively implemented, data element and metadata standards for fish and habitat monitoring need to be developed as well as metadata for restoration, mitigation, and conservation efforts (Tetta 2008, NRCS 2008). Additionally, metadata standards for socioeconomic data are also needed. This need may be satisfied by tapping into the Socioeconomic Data and Applications Center (SEDAC 2008) which is one of the Distributed Active Archive Centers (DAACs) in the Earth Observing System Data and Information System (EOSDIS) of the U.S. National Aeronautics and Space Administration, which specializes in developing and operating applications for integrating socioeconomic and Earth science data (SEDAC 2008).

Within the Puget Sound there are several data warehouses that are available to support queries and other applications (Table 2). Additional development is needed for these warehouses to function as repositories that could support indicator development and reporting functions (Tetta 2008). For example, RCO has proposed to "…establish a client application that would browse a variety of nodes to harvest data in more of a truly distributed data base environment. Successful completion of this task (currently scheduled for 2010) will be a major step in improving the utility of many of these data bases and warehouses for meeting cross agency reporting needs" (Tetta 2008). Additionally, other federal and state agencies have data sets that are not yet available via one of these data warehouses. For federal agencies, EPA recently did an informal survey and identified the US Navy, the Army Corps of Engineers, and the US Forest Service as having the largest sets of water and biota data relevant to Puget Sound, but not yet stored in one of the warehouses listed in Table 2 (Tetta 2008).

Table 2. Existing data warehouses in the Puget Sound that can provide functionality for queries and other applications and which are publicly available (from Tetta 2008).

- Ecology's Environmental Information Management (EIM) data warehouse at: http://www.ecy.wa.gov/eim/ EIM provides access over 4 million records on Washington's air, water, soil, sediment, aquatic animals and plants.
- USGS's NWIS data warehouse, at: http://waterdata.usgs.gov/nwis NWIS provides access

to water-resources data collected at approximately 1.5 million sites in all 50 States, the District of Columbia, and Puerto Rico. USGS is also working with EPA to make NWIS data available via web services.

- EPA's Water Quality Exchange, at: http://www.epa.gov/storet/wqx.html WQX makes it easier for states, tribes, and others to submit and share water quality monitoring data over the Internet. WQX is also developing a variety of analytic tools to support water quality related decision making.
- The NANOOS project (http://www.nanoos.org/) has several goals relevant to improved information sharing:, including: Discovery Service for Data Service Registration and Lookup; Metadata Repository Services for Cataloging Data Types and Formats; Data Provider Services for sensor observation data or modeling data; Data Aggregator Services that integrate sensor observations or modeling; and Portal Data Application Services for viewing Data on graphs or maps.
- Although slightly different in purpose, the University of Washington's Data Acquisition in Real Time project (DART - http://www.cbr.washington.edu/dart/dart.html) provides a wide range of analysis tools for both water quality/quantity and fish population data. DART is sponsored by the Bonneville Power Administration.

Much of the data and information needed by the Partnership is spatial in nature, therefore the Partnership will need to invest in the development of spatial data engines (SDE) that can link with point data contained in traditional databases and provide mapping services for GIS and other related services. The Partnership should establish a geography server that could publish and provide public access to all GIS data, layers, and feature classes developed for the Partnership and provide links to other GIS data repositories (UW 2008b, Washington State 2007) as well geospatial data maintained by Federal (USGS, USFWS, USEPA, etc), State (WADOT, WDOE, WDFW, WDNR, etc), and local agencies (county parcel, land use, and critical areas maps; cities; and other districts). Where possible, the Partnership should take advantage of metadata browsers, such as the Indigo Data Explorer (UW 2008c) facilitate data discovery within a spatial context.

The Partnership will also need to have access to synthetic data such as model simulation output statistical projections, and other types of analyses including historical conditions and future predictions (Watson et al. 1998). Currently, PSMEM-C and PRISM are maintaining hydrodynamic model simulation data in a standardized netCDF format (APL 2009) that can be accessed with a variety of software tools including the Virtual Puget Sound (Winn and Stahr 2004).

Ultimately, the data contained within the IM system must be accessible to scientists, managers, stakeholders and the general public. The Science Panel envisions an architecture that provides functions for users to discover, access, and visualize data that are maintained in dispersed information management systems that are intuitive and easy to access and manipulate. To this end the Partnership should invest in the development of Web 2.0 and Social Networking Tools – such as blogs, wiki's, list-servers, and other types of collaboration software including open standard geospatial formats like Keyhole Markup Language (KML 2008, see US FWS 2008, US EPA 2008, and FEMA 2008 for examples).

Short range tasks to be implemented during the 2009-2010 Biennium include:

1. Establish IM working group. Establish a multi-agency working group to coordinate data

management activities, identify opportunities and obstacles for data management, and develop a data management implementation plan for the Partnership.

2. Develop IM detailed work plan. Complete an assessment of Partnership's business needs for information access and management. For example, describe Partnership's needs interests in flows of information from monitoring on indicators for State of Sound reporting.
3. Participate in IM working group. Science Panel and Partnership staff will participate in the IM management working group and coordinate with data management initiatives being conducted as part of modeling and monitoring working groups addressing IM issues.
4. Develop data exchange for key data sets. Develop data exchange capabilities for key information flow needs and perform other foundational work to build regional data management capabilities
5. Implement information exchange network. Develop a process to make indicators and other assessment information available and accessible to a wide user community consisting of managers, researchers, stakeholders, and the general public.
6.

Longer Term Suggested Actions (Tetta 2008):

- Support collaboration amongst, the NW Executive Summit, PSP, and PNAMP to identify key data elements that are needed for Puget Sound trend analysis and decision making, but which are not currently captured in other nationally or regionally published standards. Data elements related to fish populations, mitigation projects and non-point source controls could be examples.
- Monitor and support the work of PNAMP in developing biota and habitat data standards and in improving metadata.
- Consider data standardization development for mitigation, restoration, and non-point source control projects.
- Using the NED inventory (or a similar listing) as a start, identify organizations with unique data holdings that are not currently accessible via web service technologies. Identify their interest in, making those data available through one of the options mentioned above, and the required funding for such efforts.
- Ensure that all federal and state agency water, biota and habitat data records relevant to the Action Agenda are in one of the above mentioned warehouses.
- Identify what common queries, indicators and reports are used by various agencies to support key Puget Sound environmental indicators and their related decisions. Focus on the High Level Indicators projects currently being developed by: 1) the Puget Sound Partnership and 2) the Northwest Environmental Information Sharing Executive Summit, as a start for this effort.
- Identify the most appropriate short term roles for the EIM, WQX, NWIS, and NANOOS warehouses within the overall data sharing network for Puget Sound.
- Work with the warehouses mentioned above to identify additional analysis tools that

would be needed to better support environmental decision making in Puget Sound, based on the results of the "indicators project" mentioned above.

- Consider sponsoring seminars or workgroup meetings on "Best Practice" query interfaces, targeting agency staff involved in water, wildlife and habitat monitoring or reporting in the NW as a key group.
- Develop a list serve for agency staff involved in water, wildlife and habitat monitoring or reporting in the NW, and include the data stewards listed in the NED inventory as well. Look to the members of this list serve for recommendations regarding development of web 2.0 technologies in support of data exchange and analysis efforts.
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6.4 SCIENCE EDUCATION AND OUTREACH PLAN

The goal of restoring and protecting Puget Sound requires a community effort of citizens, governments, tribes, scientists and business working cooperatively to prioritize projects, leverage resources and develop a cohesive plan that will hold people and organizations accountable. The success of Puget Sound restoration efforts will require an outreach and education strategy that optimizes gathering and dissemination of information and effective communication. Technological advancement, leadership in the sciences, and effective conservation and management of coastal and marine resources are not the only vital components necessary. Equally important is an informed and empowered society, a formally trained next generation of Puget Sound scientists, and a body of scientific information translated appropriately for use by management and policy decision makers.

A number of recent national and regional efforts, including the Puget Sound Conservation and Recovery Plan, the Oceans and Human Health Act and the work of the U.S. Commission on Ocean Policy have emphasized the importance of outreach and education. Targeted, high-quality outreach and education efforts will enable the Partnership to:

- Better fulfill its responsibilities to provide the scientific basis to meet Partnership's stewardship role by 1) ensuring resource managers have the scientific information they need to conserve and manage living resources and their habitat, 3) helping to create a well-informed public that understands the Puget Sound ecosystem and how their behavior affects it, 4) listening to and understanding the values of stakeholder groups and community members to allow for the creation of a set of social marketing strategies.
- Ensure a well educated, dynamic, diverse, and interdisciplinary (both natural and social science) workforce with competencies critical to advancing ecosystem research, both now and in the future.

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