REVISED DRAFT

Stormwater Monitoring and Assessment Strategy for the Puget Sound Region, Volume 1: Scientific Framework Volume 2: Implementation Plan

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Volumes 1 and 2

This document includes two key volumes that compose the *Revised Draft Stormwater Monitoring and Assessment Strategy for the Puget Sound Region*.

"Volume 1" describes the scientific framework for the stormwater-related monitoring and assessment that will be implemented: what decisions were needed and were made about priorities for data collection, what information needs to be collected, and what analyses need to be conducted. A draft of Volume 1 was available for peer review and public comment in November 2009, and this revised version reflects our discussion of those comments and additional progress made in the past six months.

"Volume 2" proposes an implementation plan for conducting the monitoring and assessment activities in the coming months and beyond: who will collect what data when, where, and how; what methods, protocols, and data reporting standards will they adhere to; and how the collective capacity and resources of the region will be brought together to provide the regional understanding of stormwater impacts and efficacy of management actions that is needed to recover Puget Sound and the waters that feed it.

The appendices, included in a separate document, provide supporting detail and explanation of the concepts presented in Volumes 1 and 2. The details included in Appendices E and F are provided as working examples upon which we are building the effort to launch the regional stormwater monitoring program.

How to Read this Document

- ***Key Recommendations*** are the executive summary: our high level recommendations for policy makers to see exactly what we are recommending be done to establish a regional stormwater monitoring and assessment program. Volumes 1 and 2 provide more detail and context for each of these recommendations, and the Appendices provide still more detail.
- ***Introduction*** describes our problem, our charge, and our approach. This section provides background information and context for establishing a regional stormwater monitoring program. It is revised from the November 2009 draft based on comments and streamlined to help orient the reader to focus on our Key Recommendations.
- ***Volume 1 Scientific Framework*** describes the stormwater problem in Puget Sound and the initial scientific priorities we recommend for establishing the regional stormwater monitoring and assessment program. This volume is revised from the November 2009

draft, with changes based on our consideration of peer reviews and public comments and upon new work completed since then. This volume includes our detailed recommendations for hypotheses and experimental designs, in more detail than in the *Key Recommendations* section.

  - *Monitoring Priorities* describes "the universe" of the stormwater problem, the monitoring priorities we recommend, and why.
  - *Experimental Designs for the three Monitoring Categories* describes the experimental designs we propose, and why.
  - *Additional Data and Tools* describes some of the additional support tools, activities, and coordination mechanisms needed to successfully implement a regional stormwater monitoring and assessment strategy
  - *Response to Peer Reviews* provides a summary of the key themes in the comments on the November 2009 draft scientific framework and our responses.

- ***Volume 2 Implementation Plan*** describes the next steps to establish the regional stormwater monitoring and assessment program, including: actions, roles, responsibilities, and costs. This is new work, informed by comments offered during the November 2009 comment period. This volume includes our detailed recommendations for who needs to do what, when.
  - *Regional Program Implementation Components* describes the recommendations for long-term program oversight, funding mechanisms, and data collection and reporting structures, and capacity for analysis that are needed to support and maintain the program.
  - *Implementation Plan for Status-and-Trends Monitoring* describes the steps needed to ramp up and implement regional status-and-trends monitoring in small streams and nearshore areas.
  - *Implementation Plan for Source Identification and Diagnostic Monitoring* describes the steps needed to implement local source identification and diagnostic monitoring efforts in a prioritized approach that informs regional efforts.
  - *Implementation Plan for Effectiveness Studies* describes the steps needed to finalize hypotheses and study designs and to implement the studies.
- ***Guide to Appendices*** describes the information contained in the eight appendices (provided in a separate document) to help readers find the details they need.

Suggested Citation

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Dear Reader:

This document represents the effort we have completed since November 2009 and continues to be a work in progress as approach our mandated June 30, 2010 deadline. Next we need to look at the entire strategy as a whole, with your comments. Thank you for your input!

Comments are due by COB Friday May 28, 2010. Please see http://sites.google.com/site/pugetsoundstormwaterworkgroup/home/april-30-2010-public-comment-draft-strategy for an online comment form and instructions for submitting comments via email.

We will submit our final recommendations for priorities and initial steps to establish a regional stormwater monitoring and assessment program to Ecology, the Partnership, and others at the end of June.

KEY RECOMMENDATIONS

Stormwater is a significant stressor affecting the health of the Puget Sound ecosystem. Efficiently and effectively managing stormwater to prevent, reduce, and mitigate harm to the ecosystem is a common goal of local, state, and federal governments and agencies, tribes, environmental groups, the business community, and the citizens of Puget Sound. To achieve that goal, a coordinated, integrated approach to quantifying the stormwater problem in Puget Sound and evaluating the effectiveness of stormwater management activities is needed and does not currently exist. The Puget Sound Stormwater Work Group (SWG) was created to recommend such an approach, and we will deliver our recommendations to the Washington State Department of Ecology (Ecology), the Puget Sound Partnership (Partnership) and others at the end of June 2010.

These are our key recommendations for establishing a regional stormwater monitoring and assessment program for Puget Sound:

Strategic Priorities and Overall Framework

1. The initial starting point for this regional stormwater monitoring and assessment program is focused on stormwater-related impacts from urban and urbanizing land uses. Robust, fully-scoped monitoring and assessment programs for other land uses need to be cooperatively developed in the future.
2. The initial starting point for this regional stormwater monitoring and assessment program is focused on stormwater-related impacts to small streams and marine nearshore areas. Robust, fully-scoped monitoring and assessment programs for other water bodies should be cooperatively developed as specific priority questions are identified.
3. The priorities identified for the initial regional stormwater monitoring and assessment program are rooted in an adaptive management framework and will inform important policy decisions.
4. The categories of experimental designs to be included in the initial stormwater monitoring and assessment program include status-and-trends, source identification and diagnostic monitoring, and effectiveness studies. Research activities may be added later as specific priority questions are identified.

Regional Program Implementation Components

5. Ecology and the Partnership should evaluate and decide upon a permanent Stormwater Work Group (SWG) charter, composition, host agency, and long-term funding and support of participation. In doing so they should make modifications as needed to improve the SWG's ability to perform our essential functions.
    a. Formalize the SWG as an ongoing part of the broader ecosystem monitoring program being created by the Partnership,
    b. Approve future SWG work plans,
    c. Continue to use the SWG to prioritize regional stormwater monitoring and assessment activities, and

   d. Maintain SWG roles of decision making and leadership, coordination, and advising the regional stormwater control strategy.

6. By the end of June 2010, the SWG will recommend the means to meet and sustain the overall funding needs of this proposed regional stormwater monitoring and assessment program via contributions from local, state, and federal governments, private sources, and others.

7. Support and maintain regional stormwater monitoring and assessment program components through funding contributions and/or in-kind services from all regional entities participating in the regional stormwater monitoring and assessment program.

8. In the next six months, identify the means to create an independent fund dedicated to stormwater-related monitoring and assessment activities that:
   a. Provides a “pay-in option” for entities covered under municipal stormwater National Pollutant Discharge Elimination System (NPDES) permits that:
      i. Allows permittees flexibility to meet requirements by either paying into the fund, or conducting monitoring activities themselves,
      ii. Ensures that permittees’ contributions are spent exclusively on stormwater-related monitoring and assessment activities, and
      iii. Is managed by an independent entity whose budget is permanently dedicated to monitoring and cannot be re-appropriated to other purposes by any legislative body.
   b. Allows and encourages all entities in the region to contribute to and participate in coordinated regional monitoring and assessment activities.
   c. Provides businesses and other NPDES permittees with a future pay-in option.

9. Entities conducting the regional monitoring and assessment activities should partner to share resources and reduce costs.

10. Create and maintain an ongoing inventory of monitoring and assessment activities in Puget Sound, which includes stormwater-related programs.

11. Analyze recent and ongoing stormwater-related studies and findings in Puget Sound, do a gap analysis, and conduct targeted literature reviews to help refine and direct future priorities and experimental designs.

12. Ensure that credible data are collected in a quality manner by ensuring that: data quality objectives are identified; project plans are approved and shared; standard field collection and data reporting protocols are followed; appropriate analytical accuracy, precision, detection, and reporting limits are used at accredited laboratories; and geographic information system (GIS) data follow state guidelines.
   a. Formulate and support a process to develop and approve standard methods,
   b. Populate an on-line library with approved methods,
   c. Maintain a prioritized list of methods that need to be developed, and
   d. Require NPDES permittees to select from a web-accessible list of approved analytical methods.

13. Create and maintain data management systems for the regional monitoring and assessment program data and findings that:
   a. Include data repository, storage, and management structures,
   b. Use appropriate meta-data, data descriptors, and qualifiers,

   c. Provide easy public access to all data and findings,
   d. Assign responsibility for providing quality assurance information and for correcting, editing, and updating data to the generators of data or findings, and
   e. Build upon existing regional data management systems.

14. Require monitoring conducted in all categories of the regional stormwater and assessment program to follow all applicable regional protocols; and require all data and findings to be submitted to a central data management system and readily available to the public.

15. Conduct a collective analysis and synthesis of the data and findings of the regional stormwater monitoring program and other relevant regional and national science activities at least once every five years.

16. Identify and prioritize regional stormwater-related modeling needs.

Status-and-Trends Monitoring

Scientific Framework for Small Stream Status-and-Trends Monitoring

17. Stormwater-related indicators for small streams:
    a. Water quality,
    b. Benthic macroinvertebrates,
    c. Physical features,
    d. Fish diversity and abundance,
    e. Flow,
    f. Temperature, and
    g. Streambed sediment chemistry (metals and toxics).

18. Experimental design for small streams:
    a. Probabilistic sampling of randomly selected sites to assess chemical, physical, and biological status and trends over time.
    b. Approach is compatible with Ecology's statewide status-and-trend monitoring program (State EMAP) methodology for wadeable streams.
    c. At the Puget Sound scale: use the existing 30 State EMAP sites located in Puget Sound and/or historical water quality monitoring sites that meet statistical considerations, collect samples for the current State EMAP parameters, and also collect:
        i. Grab samples for sediment toxic chemicals, and
        ii. Water quality samples.
    d. At a minimum of thirteen stations across Puget Sound, also monitor continuous flow and temperature at existing (non-random) stream gauging stations identified in the final study design.
    e. Within the first year, identify relevant existing data that could further refine the final sampling frequency and design.

19. Identification of small stream sites:
    a. Target second- and third-order "wadeable" streams that are more directly (but not exclusively) affected by stormwater,

b. Identify 30 sites at the Puget Sound scale for trend assessment
    i. Use sites selected for State EMAP, and
    ii. To the extent possible without compromising the probabilistic design, existing long-term monitoring sites should be included and used.
c. Focus on the watershed scale using a probabilistic site-selection approach that can be more densely focused within urban growth areas if appropriate,
d. Add sites to total 30 within each of the thirteen local salmon recovery areas in Puget Sound (Water Resource Inventory Areas (WRIAs) and combinations of WRIAs), for a total of 390 sites.
e. Island-based watersheds would not be included in this component of the monitoring program due to the limited number of wadeable streams.

20. Small stream monitoring frequency:
    a. At the regional scale: Follow State EMAP protocols, and conduct:
        i. Annual sediment chemistry sampling at the 30 State EMAP sites,
        ii. Monthly water quality sampling at the 30 State EMAP sites, and
        iii. Continuous measurements at the 13 flow and temperature stations.
    b. At the WRIA scale: Consider, as a target: Ramp-up and conduct two rounds of wadeable stream status-and-trends sampling within a five year cycle from 2012 to 2017 to match the municipal stormwater NPDES permit cycle (begins in 2012), and allow sufficient time for analyses to refine the monitoring program design and inform the following five-year cycle of permits and other efforts.

Implementation Plan for Small Stream Status-and-Trends Monitoring

21. Local governments and others will use protocols compatible with Ecology's statewide status-and-trend monitoring (State EMAP) protocols, coordinate with WRIA groups, and partner with others as needed to standardize data collection methods.

22. Local governments will help coordinate sampling among the WRIA groups and other entities involved in conducting monitoring of stream benthos, fish, habitat, water quality, and other parameters to avoid duplication of field efforts and achieve cost savings. Sampling is conducted by NPDES permittees, Ecology, and others. Within the first year, identify other opportunities for collaboration.

23. Salmon recovery entities, Ecology, the Partnership, and others will coordinate with local governments to fund and conduct two rounds in a five-year period of fish diversity and abundance monitoring and physical feature monitoring.

24. Ecology will fund and oversee the State EMAP program within the Puget Sound basin. Local Governments will coordinate with these efforts.

25. The SWG will compile information within the next year on current streamflow gauging stations in Puget Sound, analyze current regional streamflow monitoring capacity, and develop a regional network of stream gauges associated to the greatest extent possible with the water quality and habitat monitoring sites.

26. Local governments in Puget Sound covered under municipal stormwater NPDES permits will, collectively, fund and conduct the remaining elements of the regional small stream

status-and-trends monitoring program (most of the watershed-scale sampling) as part of their overall mandate. The financial contribution and/or level of effort required of each permittee will be based on equitable factors, and permittees will be allowed flexibility to either pay into a collective fund or conduct the monitoring themselves.

27. The SWG will coordinate with the Partnership, Puget Sound Salmon Recovery Council, and others to seek additional funding and in-kind contributions for this proposed monitoring and assessment.

Scientific Framework for Nearshore Area Status-and-Trends Monitoring

28. Stormwater-related indicators for nearshore areas:
    a. Fecal coliform,
    b. Bioaccumulation toxicity, and
    c. Sediment chemistry (metals and toxics).

29. Experimental design for nearshore areas:
    a. Probabilistic sampling of randomly selected stratified sites to assess biological and chemical status and trends over time.
    b. Approach is compatible with Washington Department of Health (WDOH) protocols for fecal coliform monitoring.
    c. Approach is compatible with NOAA's national Mussel Watch protocols for bioaccumulation toxicity.
    d. Approach is compatible with PSAMP protocols for sediment chemistry and other nearshore monitoring.

30. Identification of nearshore sites:
    a. Continue bioaccumulation toxicity monitoring at existing ambient Mussel Watch sites.
    b. Randomly select 30 new sites for conducting annual bioaccumulation toxicity monitoring near stormwater outfalls to Puget Sound.
    c. Continue to conduct PSAMP sediment chemistry and other monitoring at nearshore sites.
    d. Conduct sediment chemistry monitoring at 30 randomly selected depositional locations in Puget Sound. Evaluate, statistically and logistically, whether these can be aligned with the Mussel Watch sites.
    e. Focus on areas of the marine nearshore environment that meet Mussel Watch and PSAMP sediment monitoring criteria but are more directly (but not exclusively) affected by stormwater.
    f. Randomly select 50 sites for fecal coliform monitoring at the Puget Sound regional scale, utilizing WDOH, tribal, or other shellfish monitoring data in areas of overlap.

31. Nearshore monitoring frequency:
    a. Monthly fecal coliform sampling,
    b. Annual bioaccumulation toxicity monitoring, and
    c. Annual sediment chemistry monitoring.

Implementation Plan for Nearshore Area Status-and-Trends Monitoring

32. Local governments with stormwater outfalls to Puget Sound will partner with the Mussel Watch program to develop a probabilistic survey approach to select new sites for conducting bioaccumulation toxicity and sediment chemistry sampling.

33. Local governments with stormwater outfalls to Puget Sound will use protocols compatible with WDOH, Mussel Watch, and PSAMP, and partner with others as needed to standardize data collection methods.

34. Mussel Watch, WDOH, and PSAMP will help coordinate sampling among the entities involved in conducting monitoring of fecal coliform, bioaccumulation toxicity, and sediment chemistry to avoid duplication of field efforts and achieve cost savings. Sampling is conducted by local governments, WDOH, Washington Dept. of Fish and Wildlife, volunteers, Ecology, and others. Within the first year, identify other opportunities for collaboration.

35. Local governments in Puget Sound covered under municipal stormwater NPDES permits will, collectively, conduct the following elements of the regional program as part of their overall mandate. The financial contribution and/or level of effort required of each permittee is based on equitable factors and permittees are allowed flexibility to either pay into a collective fund or conduct the monitoring themselves.
    a. Monthly fecal coliform monitoring at 50 sites,
    b. Annual bioaccumulation toxicity (Mussel Watch) monitoring at 30 sites, and
    c. Annual nearshore sediment chemistry monitoring at 30 sites.

36. Local governments will coordinate with salmon recovery efforts, Puget Sound clean-up efforts, local Departments of Health, the Puget Sound Nearshore Restoration Partnership (PSNRP), and other existing nearshore monitoring efforts.

37. The SWG will coordinate with the Partnership and others to seek additional funding and in-kind resources for this proposed monitoring and assessment.

Source Identification and Diagnostic Monitoring

Scientific Framework for Source Identification and Diagnostic Monitoring

38. A comprehensive regional stormwater-related source identification framework is needed to help inform and prioritize both local and regional source control activities.

39. Source identification is conducted to address long-term receiving-water problems, as part of a broader effort to identify and eliminate pollution sources. Watershed-specific priorities should be set to target initial source identification efforts on the problems of greatest local concern. Regional and local monitoring data and assessment findings need to be reviewed at least once every five years to identify and prioritize problems to address.

40. Key components of source identification include:
    a. Determine the existing problem sources/impairments to beneficial uses,

   b. Prioritize sources/impairments,
   c. Set a target for source reduction,
   d. Locate sources/impairments,
   e. Plan the regulatory framework and actions to remove the source(s),
   f. Implement source removal actions/programs,
   g. Monitor to provide feedback on status of the source, and
   h. Sustain or implement monitoring to diagnose emerging sources.

These activities occur in an iterative process to track improvements in the receiving waters and to identify needs for additional controls. Multiple entities need to cooperate in situations where the impairment is not confined within the boundaries of a single jurisdiction.

Implementation Plan for Source Identification and Diagnostic Monitoring

41. Municipal stormwater NPDES permittees will coordinate with WRIA groups or watershed lead entities to initiate and oversee a process to prioritize problems in each watershed. After prioritization, lead entities will coordinate the development of a plan to address the top priority problem and proceed to implement early management actions and begin appropriate monitoring.
42. In the next six months, Ecology will lead a process, through the SWG, to recommend an approach to source identification monitoring for the municipal stormwater NPDES permits, including appropriate roles and responsibilities.
43. Source identification and diagnostic monitoring, TMDLs, toxic waste clean-ups, and other activities should be coordinated to share resources, reduce costs, and focus on the most important problems.
44. Review source identification and diagnostic monitoring data on a Sound-wide basis at least once every five years to inform and target regional source control initiatives.

Effectiveness Studies

Scientific Framework for Effectiveness Studies

45. Initial studies to assess effectiveness of stormwater best management practices (BMPs) and other urban/urbanizing stormwater management activities will be conducted to address the following three priority areas of investigation:
    a. Testing the effectiveness of low-impact development (LID) techniques to minimize impacts from future new development and in areas of redevelopment,
    b. Testing the effectiveness of retrofitting urban areas with various flow management and water quality treatment approaches to decrease impacts from the built environment, and
    c. Testing the effectiveness of non-structural (i.e., operational, behavior-change, planning) and programmatic approaches used in stormwater management programs, and in particular, of various provisions of the municipal NPDES stormwater permits.

Future studies should (d) evaluate new technologies and (e) fill key knowledge gaps about existing technologies to provide better tools for managing stormwater in the future. In general, studies will be directed to evaluating stormwater management *programs* as well as specific practices and activities. The SWG will reevaluate the focus of regional, prioritized effectiveness studies on a periodic basis.

46. Studies to assess effectiveness of stormwater BMPs will occur at the site scale, basin scale, and regional scale.

47. Studies to assess effectiveness of stormwater BMPs will be designed to answer specific questions with clearly articulated hypotheses for testing.

48. Studies to assess effectiveness of stormwater BMPs will include quantification of the cost of implementing the stormwater management activities being studied, so that cost-effectiveness can be judged by stormwater managers and policy makers.

49. Stormwater impacts from other land use management approaches and other stormwater permits also need to be addressed.
    a. An initial effort for agricultural land use will test the effects of agricultural BMPs.

50. In the area of evaluating new technologies, emerging techniques are a recommended focus. Examples include reducing fecal coliform and metals.

Implementation Plan for Effectiveness Studies

51. A literature review needs to be conducted as soon as possible to focus data collection efforts on studies that are needed and to avoid addressing questions that have already been answered and to build on existing work.

52. Requests for proposals will be issued for effectiveness studies, based on the guidance and priorities identified by the SWG. An open and transparent process will be developed to evaluate the submitted proposals and select those for initial implementation.
    a. The first round of this process needs to be expedited in fall 2010 in order to meet Ecology's needs to identify effectiveness studies that will be included for implementation in the coming municipal stormwater NPDES permit cycle..

53. A transparent public process will identify and prioritize future and more specific topics, questions, and hypotheses for effectiveness studies, applying the following criteria for evaluating and selecting effectiveness studies:
    a. Meets the criteria for a sufficiently defined working hypothesis.
    b. Important stressors are addressed,
    c. Selected studies address a range of the prioritized topics and categories,
    d. The practices to be evaluated are likely to result in improvements to beneficial uses,
    e. The study is likely to contribute to our collectively ability to implement more cost-effective stormwater management actions,
    f. The study is likely to generate results within a two-year time frame, and
    g. The study is strongly linked to the Puget Sound Action Agenda and results chains.

54. The Technology Assessment Program (TAP-E), which evaluates the effectiveness of new technologies, should continue with funding from new technology proponents and other long-term, reliable funding sources.

55. The Washington State Conservation Commission, Ecology, and other key entities and stakeholders will define a broader effort to assess stormwater impacts from agricultural areas and effectiveness of agricultural BMPs.

INTRODUCTION

Stormwater is a significant stressor affecting the health of the Puget Sound ecosystem. Efficiently and effectively managing stormwater flows and pollutant loads to prevent, reduce, and mitigate harm to the ecosystem is a common goal of local, state, tribes and federal governments and agencies, environmental groups, the business community, and the citizens of Puget Sound. A broad, comprehensive, regional stormwater monitoring and assessment strategy is needed for the Puget Sound basin to provide an unbiased assessment of whether management actions are resulting in genuine progress towards regional conservation targets. The monitoring and assessment results must be closely linked to potential management and regulatory actions to ensure that a cycle of adaptive management is created and maintained.

This project was initiated in response to requests for a regional stormwater monitoring program by the Puget Sound Partnership (Partnership) and the Washington State Department of Ecology (Ecology) in 2008. The Partnership is the state agency charged with overseeing ecosystem recovery efforts for Puget Sound. Ecology is the state agency delegated with federal Clean Water Act implementation. The Partnership is leading a concurrent effort to create a broader ecosystem monitoring program. The regional stormwater monitoring and assessment program is intended to be a functioning cornerstone of that broader ecosystem monitoring program. The Puget Sound Stormwater Work Group (SWG) assembles a group of technically and politically savvy stakeholders that understand stormwater and are creating a document that primarily supports stormwater efforts but also informs the Partnership's broader purposes.

The *Revised Draft Stormwater Monitoring and Assessment Strategy for the Puget Sound Region* provides critical science support for implementation of the *Puget Sound 2020 Action Agenda* (Partnership 2008). The program will provide key information about ecosystem status and trends (threats, drivers, state) and important effectiveness research within an adaptive management framework that is connected to policy makers. This document and subsequent implementation of the recommendations therein will fulfill *Near Term Action C.2.N1* in the *Action Agenda*: Create a regional stormwater monitoring program.

Volume 1 of this document describes the scientific framework, including the goals of regional stormwater monitoring, priorities for data collection, assessments that need to be performed, and ways the resulting information can be used to inform management activities.

Volume 2 of this document is an implementation plan detailing how the capacities of the region will be harnessed to take the necessary steps to successfully implement the strategy. These are the first of several steps toward developing an integrated, comprehensive stormwater monitoring and assessment strategy for the Puget Sound region. The SWG's efforts will be ongoing and iterative as monitoring and assessment are conducted, information is shared, and additional needs and future priorities are identified.

Background and Context

The Puget Sound region has been the locus of numerous widely-cited scientific studies designed to understand and reduce the effects of stormwater. Although many types of human activities threaten the health of the Puget Sound ecosystem, there is considerable agreement among regional scientists and community leaders that the alteration and loss of habitat and the ongoing

What is "Stormwater"?

"Stormwater" is a term that is used widely in both scientific literature and regulatory documents. It is also used frequently throughout this document. Although all of these usages share much in common, there are important differences that benefit from an explicit discussion.

Most broadly, stormwater runoff is the water associated with a rain or snow storm that can be measured in a downstream river, stream, ditch, gutter, or pipe shortly after the precipitation has reached the ground. What constitutes "shortly" depends on the size of the watershed and the efficiency of the drainage system, and a number of techniques exist to precisely separate stormwater runoff from its more languid counterpart, baseflow. For small and highly urban watersheds, the interval between rainfall and measured stormwater discharges may be only a few minutes. For watersheds of many tens or hundreds of square miles, the lag between these two components of storm response may be hours, a day, or more.

From a regulatory perspective under the Clean Water Act, stormwater must pass through some sort of engineered conveyance, be it a gutter, a pipe, ditch, concrete canal, or even along a roadside curb. If it simply runs over the ground surface, or soaks into the soil and soon reemerges as seeps into a nearby stream, it may be water generated by the storm but it is not regulated stormwater.

This document emphasizes the first, more hydrologically oriented definition. However, attention is focused mainly on that component of stormwater that emanates from those parts of a landscape that have been affected in some fashion by human activities. Mostly this includes water that flows over the ground surface and is subsequently collected by natural channels or artificial conveyance systems, but it can also include water that has infiltrated into the ground but nonetheless reaches a stream channel relatively rapidly and that contributes to the increased stream discharge that commonly accompanies almost any rainfall event in a human-disturbed watershed.

We also include in our overall framework non-stormwater runoff that is generated by human activities taking place between precipitation events such as car-washing, lawn-watering, *etc*. These discharges can contribute to receiving-water impairments and are managed within the same infrastructure and programs as precipitation-generated runoff.

Glossary definition (from NRC 2009)

Stormwater: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels, or pipes into a defined surface water channel or a constructed infiltration facility. According to 40 C.F.R. § 122.26(b)(13), this includes stormwater runoff, snow melt runoff, and surface runoff and drainage.

input of pollution are the most immediate and pervasive threats to the ecosystem (Beyerlein *et al.* 2006 and 2008; Partnership 2008). Surface water and stormwater runoff in urban and rural areas are now recognized as the primary, unaddressed transporters of toxic, nutrient, and pathogen pollutants to surface and groundwater resources throughout the Puget Sound basin (Ecology 2007), and are also now recognized a one of the primary causes of habitat degradation in small streams due to alterations in flow volumes, timing, and duration.

The types and magnitude of threats vary in different places, but the entire region faces challenges from a growing human population and a changing climate that will exacerbate the many existing pressures to Puget Sound. Water quality and stormwater management practices in the region need to be anchored within an ecosystem approach and better coordinated so they can effectively address the ubiquitous nature and diffuse sources of pollutants in our freshwater and marine systems. Current stormwater management programs in the Puget Sound region evolved from local programs focused on drainage and flooding problems; the pollution carried by stormwater was not a driving factor in creating these programs (or infrastructure) until relatively recently. Measures that address the site or project scale collectively fall short of protecting the ecosystem.

The Puget Sound Stormwater Work Group (SWG) includes representatives from cities, counties, tribes, and state and federal agencies responsible for monitoring and managing stormwater and water quality. We are charged with developing a regional, cooperative stormwater monitoring and assessment strategy focused on enabling us to know whether management actions are successfully reducing harm caused to Puget Sound by stormwater runoff from developed and developing lands.

Three approaches have been comingled in the creation of this document:

- Scientific understanding and inquiry serve as the foundation for the development of specific, testable hypotheses related to reducing the impact of stormwater throughout the Puget Sound basin.
- Tenets of adaptive management are adopted to ensure that the results of monitoring are relevant and used to inform management and policy decisions.
- Development of the strategy is an inclusive, transparent process.

A comprehensive monitoring and assessment program will be developed over time, in an iterative approach. This document represents our first steps, those of defining the initial scientific framework, setting priorities, and describing an implementation plan for launching the program. We must prioritize because, given limited resources and the need to efficiently uncover vital information to improve our stormwater management efforts, we cannot afford to undertake every potential stormwater monitoring and assessment activity. Our recommendations must be delivered in time to inform state agency budgets and the monitoring requirements in future municipal stormwater National Pollutant Discharge Elimination System (NPDES) permits.

This overall effort is intended to constitute one portion of an overall ecosystem monitoring program for Puget Sound by satisfying the need to learn more about the effects of stormwater on beneficial uses and the most effective stormwater management and mitigation measures to control those effects. In a separate but connected effort, an overall monitoring and assessment program for the Puget Sound ecosystem is being established so that the region can clearly see if the health of Puget Sound is improving, and whether the legislative goal of restoring the Puget Sound ecosystem by 2020 is being met.

What is Adaptive Management?

Adaptive management, as first outlined by Holling (1978) and later revised, renamed, and recast by others (*e.g.*, Walters 1986; Lee 1999), is an approach for overcoming uncertain ecological outcomes associated with land-use and natural resource management actions by treating management activities as experimental components within the larger structure of a monitoring program (Ralph and Poole 2003). Specific management decisions that affect ecological processes and functions are systematically evaluated in ways that affirm or refute expected outcomes. Uncertainty is embraced and serves as a focal point for more specific evaluations.

The process of adaptive implementation is iterative and continuous; new knowledge is actively incorporated into revised experiments, a practice best described as "learning while doing" (Lee 1999). The key difference between this approach and other environmental management strategies that are often implemented is the application of scientific principles, such as hypotheses-testing, to explicitly define the relationships between policy decisions and their measured ecological outcomes.

Purpose, Scope, and Timeline

The purpose of this document is to articulate the scientific framework and implementation plan for an integrated, coordinated and comprehensive stormwater monitoring and assessment strategy for the Puget Sound region. Both the Partnership and Ecology charged the SWG with this task. The agencies requested a stormwater monitoring and assessment strategy that provides meaningful management data; promotes greater understanding of stormwater and other surface water pollution source issues; and supports a larger, integrated effort to protect and restore the Puget Sound ecosystem by enabling managers to know whether or not stormwater management actions are reducing harm caused to Puget Sound.

The scope of our effort is limited to stormwater-related monitoring and assessment. Because the stormwater problem in Puget Sound is so extensive and complex this document has an even narrower scope: to describe the extent of the problem and define a scientific framework and initial steps for moving forward with implementation beginning in July 2010.

This Document is an Adaptive Management Tool

"Adaptive implementation is, in fact, the application of the scientific method to decision making" **(NRC 2001).**

This strategy invokes the principals of Adaptive Management, as first articulated over 30 years ago and more recently embraced through various conservation efforts worldwide.

Fundamental to this approach is the integration of management and monitoring, recognizing that any management action in the context of a complex ecological system is ultimately experimental, requiring feedback to make progress (see Figure 1). This principle has been articulated in a variety of past ecosystem monitoring and assessment efforts, both regionally and nationally. They provide worthwhile lessons (see the next section) to guide us in crafting a robust conceptual scientific framework in which to identify significant ecosystem threats from stormwater runoff; to stratify the landscape into major categories of land use and receiving water; and to articulate credible, testable hypotheses that can guide future monitoring and assessment efforts.

Figure 2. The Adaptive Management Cycle (Open Standards Conservation 2007). With this document, the Puget Sound Stormwater Work Group (SWG) is addressing Step 1 and Step 2 of this cycle for stormwater-related monitoring and assessment.

It is not within the scope of this document to describe the institutional framework for the full adaptive management cycle: that task is assigned to the Partnership. In parallel with our development of this strategy, an adaptive management approach is being pursued by the Partnership to implement the *Action Agenda* to recover the Puget Sound ecosystem by 2020 (Partnership 2008). The Partnership's evolving framework can be informed by our Key Recommendations. Nor is it within the scope of this document to define a comprehensive suite of stormwater monitoring actions. This document establishes an overarching scientific framework for stormwater-related monitoring that will allow otherwise independent efforts or whole programs to contribute to a greater understanding and evaluation of progress.

A robust scientific framework must ensure that the work fills gaps (*i.e.*, gathers information about outcomes that are not yet well understood), and targets issues of primary importance and of known (or at least strongly suspected) major influence. Results of the stormwater monitoring and assessment activities should be linked to specific objectives related to the reduction of stormwater runoff through permits, modification of land use practices, retrofits, incentives, and other mechanisms.

Science can provide defensible and replicable insights regarding the ecological outcomes of management prescriptions, but it can not offer absolute certainty. Policy can be and should be informed by science but is ultimately based on a variety of considerations that are not always amenable to the limitations of the scientific process (Van Cleave *et al*. 2004), and the time frame needed to generate robust information may not be responsive to the much shorter timeline of social and political policy- and decision-making. These are uncomfortable truths for agency managers and elected officials to acknowledge, and they commonly result in funding decisions and public pronouncements using the "language" of science but not its substance. This overarching strategy seeks to avoid such a bifurcated outcome.

A Summary of "Lessons Learned"

From examples of monitoring and assessment programs (see Appendix B), some consistent themes emerge that show consistent success or, conversely, increase the likelihood of failing to meet program goals:

1. Clear and well-defined program goals must be articulated. Without this critical step, it is impossible to adequately frame the initial scope of investigations and the overall feasibility of the monitoring or restoration program.

2. Management or program goals must be translated into scientific and technical objectives that are measurable, and that define the means and mechanisms by which the ultimate goal will be realized. Once defined, the technical or scientific objectives are addressed through the application of scientific principals, including testable hypotheses.

3. Hypotheses can only be tested through the application of a robust scientific design. In examining 30 failed monitoring programs, Reid (2001) noted that 70% of the programs had problems in their fundamental scientific design that limited or precluded ultimate success.

4. Program goals must be phrased in ways that are meaningful to the public and directly address things that can be directly affected by management strategies (both current and alternative).

5. The application of science to a given set of resource objectives needs to be well integrated; that is, research, monitoring (in all of its forms), and modeling all need to work in harmony to address information needs and uncertainties.

6. Embrace uncertainty—defining what is not known is as important as what is known.

7. In a true adaptive management framework, the relationship between the policy sector and the science sector must be explicitly and formally defined. Science should inform policy, and vice versa, but neither should regulate the role of the other. Policy-makers must clearly define the program goals, their practical objectives and the nature of the decisions they have some control over; and the scientists in turn must define the application of scientific tools to address achievement of those objectives.

8. Both "bottom-up" science (*i.e.*, arising from the initiative of individual researchers) and "top-down" science (*i.e.*, directed by an oversight panel) need to be integrated into large-scale ecosystem protection and restoration programs. Large-scale ecosystem restoration cannot be strategic if left to bottom-up science alone, but top-down direction is stifling and may reflect only the limited views and interests of the oversight group.

9. Approach the issue from multiple scales—Systematically evaluating alternative strategies for protection and restoration across the landscape must be appropriately scaled to protect and restore ecosystem processes. This is difficult if not impossible with ad hoc deployment of opportunistic, small-scale protection and restoration activities.
10. Multiple layers of independent scientific review are needed to ensure rigor and accountability.
11. Science and Policy makers need to understand constraints and opportunities in terms of considering management alternatives. Then allow the science analyze the range of all possible management strategies (both protection and restoration) and promote scientific assessment of emerging alternatives.

An Overarching Strategy

The many groups interested in and responsible for collecting information about stormwater impacts in Puget Sound all agree that an overarching stormwater monitoring and assessment strategy is needed to ensure that the information is meaningful and useful for decision makers, to continue to prioritize the types of data to be collected, and to coordinate the efforts of the multiple parties involved.

The SWG intends to develop and carry out a stormwater monitoring and assessment strategy that improves how we manage stormwater and provides decision makers with critical information to help them make more informed, more successful decisions. In particular, we expect that:

- The Partnership will use information gained from this strategy to inform and improve future revisions to the *Action Agenda* and regional stormwater management policy,
- Ecology will use information gained from this strategy to refine the best management practices recommended in stormwater guidance manuals and required in permits, determine monitoring components of future NPDES stormwater permits, and improve regional stormwater management efforts, and
- Other entities will use information to inform relevant management programs associated with the improving health of Puget Sound basin.

Some of the actions needed to reduce the impacts of stormwater are currently addressed under the *Puget Sound Action Agenda* (Partnership 2008). The Partnership is using an Open Standards model (Conservation Measures Partnership 2007) approach to adaptive management to frame and support implementation of the *Action Agenda*, and the approach presented here is compatible with that model. Results from stormwater monitoring will be linked to specific objectives related to the reduction of stormwater runoff through permits, modification of land use practices, retrofits, incentives, and other mechanisms.

VOLUME 1. SCIENTIFIC FRAMEWORK

The *Stormwater Monitoring and Assessment Strategy for the Puget Sound Region* is intended to be comprehensive, or at least sufficiently broad-based that:

- Local, state, federal, and tribal governments; industries; agriculture; and others throughout the region are interested in joining and contributing to the effort;
- The diverse geography, biology, geology, climate, social/political ranges, and variations in land use combinations within the region are covered; and
- The results of the monitoring and assessment are meaningful and robust.

This scientific framework defines “the universe” of the stormwater problem and then narrows that universe to what we judge to be an achievable starting point, using a caucus-based stakeholder committee and broader public process (see Appendix A). This narrowing was challenging, and some conditions that are of great regional and local significance are not included as priorities. There are many land-use based management programs in place that are intended to improve water quality. While focusing on municipal NPDES permit-mandated stormwater programs is not a fully satisfying means of addressing the stormwater problems facing the region, it is the charge to the Stormwater Work Group and therefore our agreed-upon starting point. We also acknowledge the continuing need to focus on local and other watershed based problems while contributing to better understanding and solving regional stormwater-related problems.

1.1 Monitoring Priorities

In order to achieve our objectives we must set priorities. This section presents the monitoring priorities to be addressed by the proposed strategy. All water bodies and land uses need to tie in, eventually, and we recognize that local monitoring priorities may be driven by other issues. However, this document recommends the initial regional stormwater stormwater monitoring and assessment program focus on small streams, nearshore areas, and the full spectrum of urbanizing lands.

1.1.1 Identifying the Scientific Information Needs of Stormwater Managers

The development of the strategy depends on the ability to articulate the type of information that would be useful to help stormwater and resource managers make better decisions. These decisions may be related to small- or large-scale issues, and they may require small or large expenditures to implement. In the first half of 2009, the SWG in a series of meetings and workshops articulated a set of Assessment Questions (Appendix C) that captured the collective judgment of the most important types of information needed to help decision-makers.

These key assessment questions were the basis for developing this scientific framework. It is important to acknowledge that various monitoring efforts are already under way or completed that may partially answer some of the assessment questions. To date, however, no coordinated, integrated program has been developed to ensure these questions are answered in a rational, prioritized, and comparable fashion.

The key assessment questions can be summarized as follows:

1. Are management actions making progress in protecting or improving beneficial uses and biological resources from the impacts of stormwater runoff?
2. What is the effectiveness of specific stormwater management techniques, either individually or in combination, with regards to preventing harm from new development, retrofitting existing development, and controlling sources?
3. Where in the landscape are the sources of pollutants in stormwater and volumes of stormwater that impair beneficial uses?

1.1.2 Conceptual Model of Stormwater Impacts and Information Needs

The direct and indirect effects of stormwater on the ecosystem of Puget Sound, and the various pathways by which those effects are transmitted, are well studied (*e.g.*, Horner and May 1997, Booth *et al*. 2004, and NRC 2009). Figure 2 shows the types of stressors that should be considered, the pathways by which those stressors are transmitted, and how the outcomes of our management efforts should be assessed, using a Driver-Pressure-State-Impact-Response (DPSIR) conceptual model approach. The DPSIR approach, combined with a process to select appropriate indicators, is being applied by the Partnership to organize ecosystem recovery efforts and use monitoring information for adaptive management.

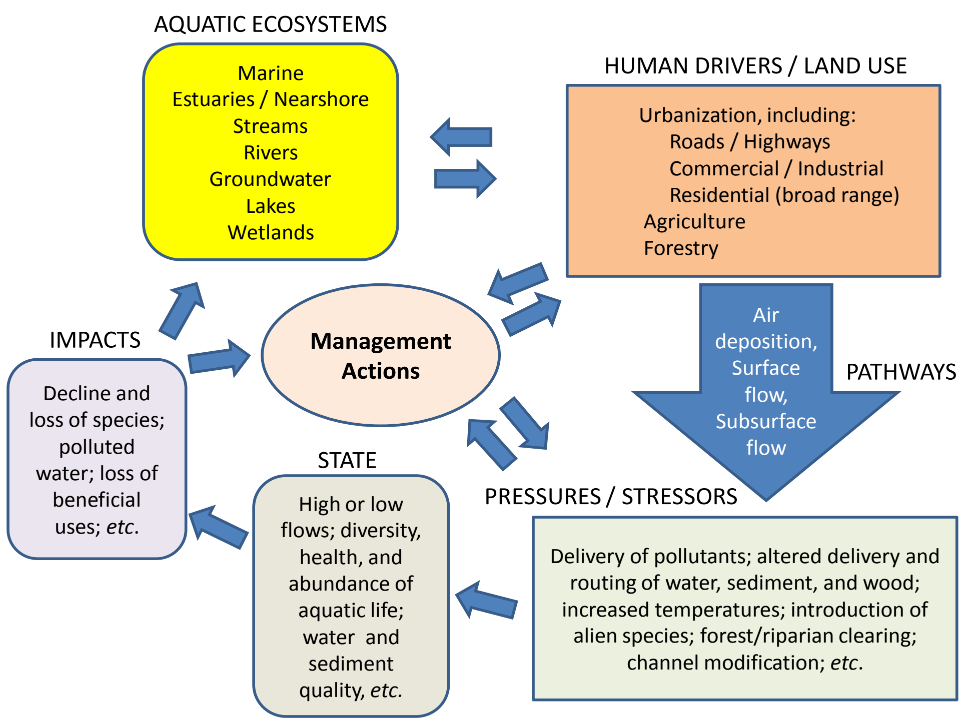


Figure 2. Conceptual Driver-Pressure-State-Impact-Response (DPSIR) model showing the complex interactions of land use and management actions on stressors impacting biological endpoints and beneficial uses in receiving waters and aquatic ecosystems.

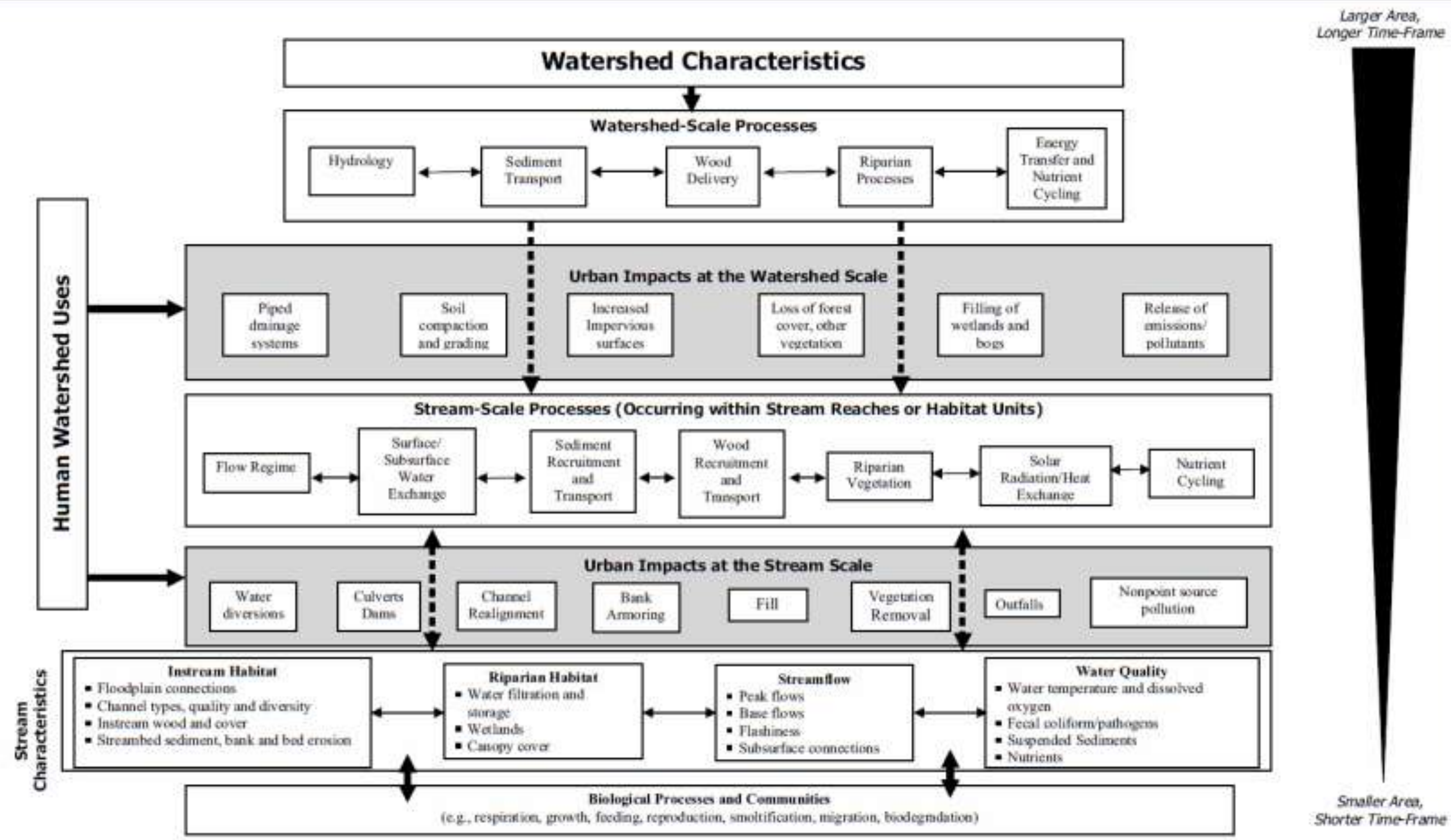
Management actions intended to minimize or eliminate the effects of stormwater on downstream systems are addressing (whether knowingly or implicitly) linkages between human drivers (particularly land alteration) and one or more of the "States" in the diagram. To be effective, those actions need to be applied in the right places in the landscape, and they need to "work." Whether stated explicitly or not, *what to do* and *where to do it* are both hypotheses, and so their accuracy should be tested and their guidance modified, if and as needed.

The integrated success of various efforts to avoid impacts to water features can only be determined by evaluating the condition of integrating attributes, best evidenced by biological responses or endpoints. Other such integrators relating to human health and well-being have been suggested in the course of developing the *Action Agenda*, the Partnership's plan for recovering the Puget Sound ecosystem by 2020 (Partnership 2008); they occupy the same conceptual position in this approach.

Within this broad conceptual approach, each element can be further deconstructed. Figure 3 shows an example of a more specific conceptual scientific model for comprehensively evaluating stormwater; we consider this to be a useful approach to inform our thinking and future development and refinement of monitoring efforts. Land conversion, or more specifically "urbanization" itself is multidimensional, and it has been defined in many different ways (McIntyre *et al.* 2000). It may constitute industrial, retail, housing developments, or farms; an urbanized watershed may contain polluting or nonpolluting industries, many roads or only a sparse road network. The topography, soils, vegetation, and channel networks in an urban basin may be altered in ways that vary within the same category of urban development. Across a single region, however, attributes of urbanization generally correlate with broad land-use categories, and so for purposes of outlining the overall scope of this adaptive management program we structured our discussion using common land-use categories: urban/urbanizing, including: roads and highways, the broad range of low- to high-density residential, commercial, and industrial uses; agriculture; and forestry.

Substantial differences exist even within each land-use category, however, that must be incorporated into the specifics of any stormwater-management approach (and the monitoring necessary to evaluate its effects). Most prominent of these differences is between disturbed land, structures, and roads: each of these landscape elements contribute to stormwater but in very different ways, suggesting an alternative organizational structure to that of land use. However, runoff from one such element (*e.g.*, a rooftop) may be conveyed by the road network even as it comingles with additional wash-off from the road surface itself, suggesting no simple method (or rationale) for discrimination. Roads therefore are considered primarily within the land uses that contain them, while also recognizing that they generate a particular set of stressors, may require targeted management alternatives, and pose specific monitoring needs. We differentiate between roads and major highways as well, because highways might act uniquely rather than within the land uses that contain them.

Just as land alteration has multiple facets, so "water features" comprise a variety of aquatic environments in the Puget Sound region. Not all of them are equally affected by urban stressors or stormwater runoff, and the pathways by which those stressors are expressed will vary with the nature of the receiving water (as well as with the nature of the stressor itself). Receiving waters for stormwater runoff in the Puget Sound region can be grouped into seven categories (marine, nearshore, small streams, large rivers, lakes, groundwater, and wetlands), recognizing that their location, potential impacts, and sensitivity to those impacts will vary across the landscape.



Note that there are many connections between elements within and among the boxes shown here. Only large arrows between categories are shown, individual arrows have been omitted for simplicity. See Spence et al. (1996) for a good discussion of physical, chemical and biological processes in stream systems.

Figure 3. Conceptual model of a stream ecosystem functioning in an urban environment (Seattle, 2007). The model includes many but not all areas targeted for investigation by the proposed regional stormwater monitoring and assessment strategy.

Thus, no single set of measured parameters or indicators should be expected to capture every potential combination of conditions expressed by even the (nominally) simple conceptual model of Figure 2. Tabulating the various combinations of land use and receiving water, and identifying some of the major potential impacts from stormwater that are known to occur, displays some of the complexities (and the commonalities) that emerge from this perspective into the universe of stormwater impacts.

Table 1 and Figure 4 depict the impacts of stressors, including those associated with stormwater, on receiving waters in the Puget Sound Basin. Washington State is required under the federal Clean Water Act, to determine the health of all water bodies, based on beneficial uses of those waters, every two years in a report called the *Water Quality Assessment*. Water body segments are evaluated using available water and sediment quality data, habitat assessments, or best professional judgment. Most of the stressors are related to stormwater flow or to contaminants carried in stormwater. Table 1 shows that, of nearly 15,000 segments of creeks and rivers that Ecology has assessed in the Puget Sound basin, about 28% are impaired; and about 14% of more than 3,000 lake segments are impaired. It is more difficult to infer as much about the extent of impaired marine and nearshore waters from Table 1 because so much of the Sound has not been assessed. To better understand these extent of impaired marine and nearshore conditions see the maps (Figure 4) showing results of marine and nearshore assessments.

The above review of existing *Water Quality Assessments* supports a focus on small streams and the nearshore as a starting point for our strategy. It also demonstrates that there are significant data gaps that need to be addressed by improved coordinated regional monitoring and assessment.

A truly comprehensive stormwater monitoring and assessment program would address every water body in every land use. However, our region lacks the resources and the time required to complete such a long list. Nor does the ecosystem have the luxury of waiting for so many studies to be completed before stormwater management policy and implementation improves. Starting with a smaller list of questions is also practical considering that launching the regional monitoring and assessment strategy is, itself, an experiment. As we gain experience with its implementation, we can refine and add additional questions. We anticipate that the strategy will be refined, expanded, and updated in an iterative process over a long period of time.

1.1.3 Identifying Categories of Monitoring to Include

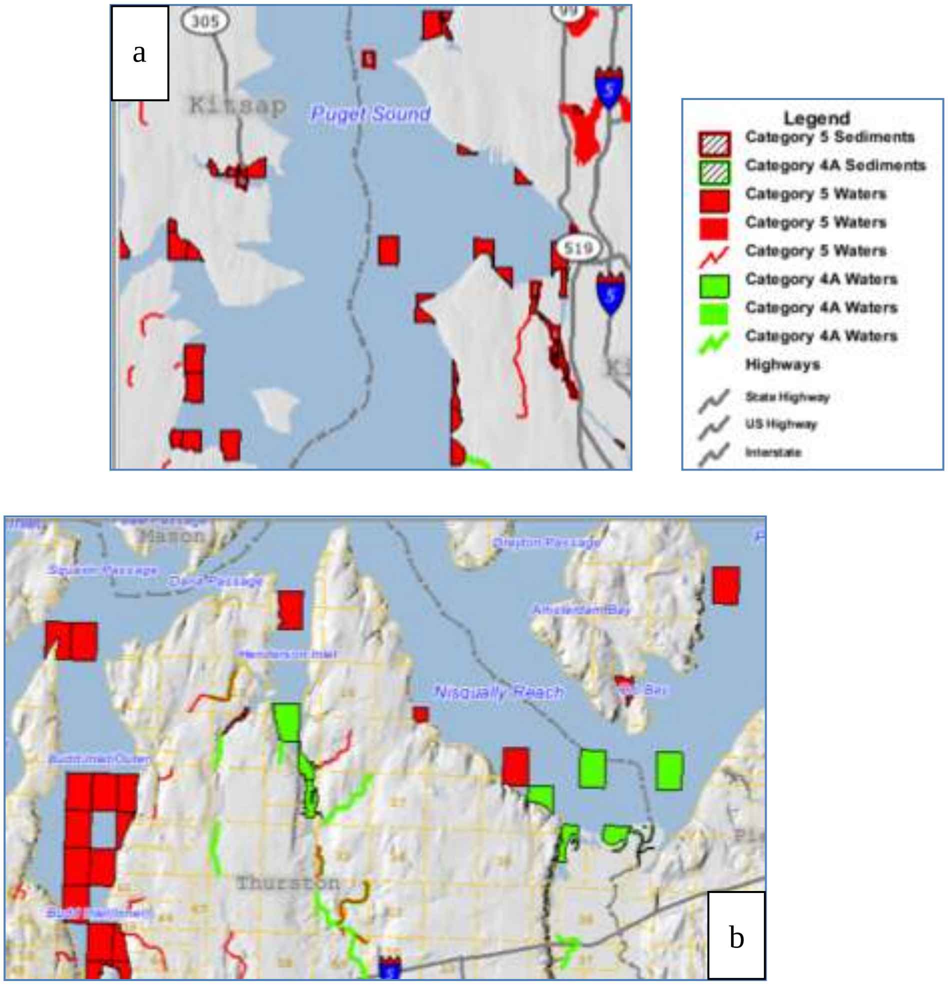
We decided to focus on major categories of monitoring that are somewhat interrelated but that use a division commonly expressed by other ecosystem monitoring programs, including the interests of both the Partnership and Ecology:

1. **Status-and-trends monitoring**: provides an integrative assessment of whether (biological or other) endpoint indicators are showing any consistent, statistically significant change over time. It provides the basis for assessing our overall progress in protecting and restoring water bodies impacted by stormwater. Even if the goals for each monitored water body are not the same, a measured observed improvement or decline in a key indicator will help target management actions across the region as well as locally. We recommend tying this monitoring to ongoing efforts in a way that fills gaps in knowledge and provides a more comprehensive regional understanding of the impacts of stormwater.

Table 1. Results of Washington Water Quality Assessment 2008 for segments of Lakes, Streams/Rivers and Marine Waters/Estuaries in the Puget Sound Basin, for specific stressors. (www.ecy.wa.gov/programs/wq/links/wq_assessments.html). The numbers in each column are *segments* (not miles) of water bodies. These assessments are based on existing data and so do not cover every mile/acre of every water body type. In addition, the data are limited by factors such as the level of sampling effort within a particular area and the willingness of entities to provide data to Ecology. Category 1 - Meets tested standards for clean waters; Category 2 - Waters of concern; Category 3 - Insufficient data; Category 4a - has a TMDL; Category 4b - has a pollution control program; Category 4c - is impaired by a non-pollutant; and Category 5 - Polluted waters that require a TMDL.

Stressor	Cat 5	Cat 4A	Cat 4B	Cat 4C	Cat 3	Cat 2	Cat 1	Total assessed	Total Impaired (4A & 5)	% Impaired of Segments Assessed
LAKES										
Bacteria	33				56	31	9	129	33	25.6%
Dissolved Oxygen	7				13	6		26	7	26.9%
Temperature	25				7	12	1	45	25	55.6%
Turbidity								0	0	
Tot. Dissolved Gas		24			5	2		31	24	77.4%
pH	4				13	11	9	37	4	10.8%
Fine Sediment								0	0	
Bioassessment								0	0	
Phosphorus	41	10			88	52	98	289	51	17.6%
Invasive Species				129		2		131	129	98.5%
Instream Flow								0	0	
Coarse Sediment								0	0	
Nitrogen	1							1	1	100.0%
Fish Habitat				1				1	1	100.0%
Bioassay	1				1			2	1	50.0%
Toxics	149	28			753	105	1557	2592	177	6.8%
Totals	**261**	**62**	**0**	**130**	**936**	**221**	**1674**	**3284**	**453**	**13.8%**
STREAMS / RIVERS										
Bacteria	595	617	44		509	364	325	2454	1256	51.2%
Dissolved Oxygen	574	106	11		1009	631	14	2345	691	29.5%
Temperature	924	367	21		927	556	409	3204	1312	40.9%
Turbidity	15	5			2	15		37	20	54.1%
Tot. Dissolved Gas	6	22			3	2		33	28	84.8%
pH	272	33	7		957	624	494	2387	312	13.1%
Fine Sediment	9	1						10	10	100.0%
Bioassessment	13			1	28	76	43	161	14	8.7%
Phosphorus	1	2						3	3	100.0%
Invasive Species				18				18	18	100.0%
Instream Flow				55		3	2	60	55	91.7%
Coarse Sediment		9						9	9	100.0%
Nitrogen								0	0	
Fish Habitat				53				53	53	100.0%
Bioassay	1				4	1		6	1	16.7%
Toxics	241	131			2183	333	1070	3958	372	9.4%
Totals	**2651**	**1293**	**83**	**127**	**5622**	**2605**	**2357**	**14738**	**4154**	**28.2%**
MARINE WATERS / ESTUARIES										
Bacteria	155	41			661	151	216	1224	196	16.0%
Dissolved Oxygen	138	12			101	93	42	386	150	38.9%
Temperature	5	1			38	114	83	241	6	2.5%
Turbidity								0	0	
Tot. Dissolved Gas								0	0	
pH	19	1			211	28	3	262	20	7.6%
Fine Sediment								0	0	
Bioassessment								0	0	
Phosphorus					1			1	0	0.0%
Invasive Species				93				93	93	100.0%
Instream Flow								0	0	
Coarse Sediment								0	0	
Nitrogen								0	0	
Fish Habitat				24				24	24	100.0%
Bioassay						2		2	0	0.0%
Toxics	53	4	1		179	49	846	1132	58	5.1%
Totals	**370**	**59**	**1**	**117**	**1191**	**437**	**1190**	**3365**	**547**	**16.3%**
Grand Totals	**3282**	**1414**	**84**	**374**	**7749**	**3263**	**5221**	**21387**		

Figure 4. Impaired waters with focus on nearshore areas (http://www.ecy.wa.gov/programs/wq/303d/2008/index.html). Views of (a) the Central Basin and (b) the South Sound. For category definitions, see Table 1.



2. **Source identification and diagnostic monitoring**: assist in determination of what specific physical, chemical, or biological stressors (see Figure 2), emanating from which locations or from which elements of what specific land use, in what quantities, and affecting what specific types of receiving waters, are causing significant impacts to beneficial uses. Source identification and diagnostic monitoring provides local governments with the necessary information to formulate active adaptive management strategies. We recommend that that the collective information gained from local source identification activities be routinely assessed to inform a regional perspective.
3. **Effectiveness studies:** provide an assessment of how well specific management actions or suites of actions reduce or eliminate the direct impacts of stormwater to receiving waters. We should be able to apply findings from each of these studies to management

activities across the region. We propose an initial set of studies to be undertaken to evaluate key practices associated with major land-use categories.

4. **Research**: targeted investigation into cause and effect relationships to provide improved understanding of basic ecosystem functions, and impacts of stressors on those functions. We propose that research activities be tracked and periodically synthesized to identify emerging issues and use this information to refine our other categories of monitoring. In the future, the regional stormwater monitoring and assessment program might establish priorities and target funds for conducting basic research.

To the extent practicable, a watershed approach will tie together the above categories of monitoring. However, monitoring will be conducted at various scales from local to regional to suit different purposes, and not always addressing the same stressors.

Another category that we considered was **characterization monitoring**. Characterization monitoring is typically conducted to understand the range of existing conditions. This information may used for a variety of purposes, including identifying and quantifying sources of pollution in stormwater so that we can target and assess actions intended to reduce pollutant concentrations and loadings. We decided that characterizing the condition of a water body or an outflow discharge at a particular time and place can be the product of the other kinds of monitoring. Future "characterization" monitoring efforts should be clearly articulated in either hypothesis-testing or systematic trend evaluation. As noted by NRC (2009, p. 508), "…monitoring under all three [NPDES municipal, industrial, and construction] stormwater permits is according to minimum requirements not founded in any particular objective or question. It therefore produces data that cannot be applied to any question that may be of importance to guide management programs, and it is entirely unrelated to the effects being produced in the receiving waters." We seek to proactively avoid this problem.

Still another category to be addressed is **compliance monitoring**. The value of this activity extends beyond "bean counting" and, in an approach similar to that proposed for characterization monitoring, we believe the most valuable compliance monitoring information will be that which provides environmentally meaningful metrics that are directly tied to improving our interpretation of monitoring results. Compliance monitoring recommendations will be made most obviously in developing effectiveness studies, but should also be made in future refinements of status-and-trends monitoring and source identification and diagnostic monitoring designs.

Our purpose is to understand what is causing negative impact to beneficial use and the extent to which management actions are reducing or preventing the impact. There are many cases in which indicators such as chemical pollutants apply across the categories of monitoring. However, in proposing initial activities for each category of monitoring we have not restricted ourselves to a single list of indicators. Instead, we recommend indicators that are most suitably and practicably applied to improving our understanding of stormwater impacts in various receiving waters, biota, or other conditions. We started with a long list of problems and stressors that have been identified in the region, prioritized them based on known impact and practicability of regional application. The rationale is given for selecting each indicator, whether the monitoring is biota-based or stressor-based.

Research can include any number of various types of studies and monitoring programs. Under most types of scientific frameworks, research is encouraged to highlight new and emerging issues and to explore essential unknown relationships between various environmental factors necessary to improve management actions. Research efforts have clearly been of use locally; for example, research to characterize Lake Washington's degraded water quality in the 1950s led to the formation of Metro to divert and treat sewage flowing into the lake. This type of monitoring is best described as essential basic research, where the results might indeed be used to improve management efforts or policy. But at the outset it is unknown how, or if, the results will be used, and no recommendations for this category are included here.

1.1.4 Monitoring Indicators

Indicator monitoring will be used differently for each category of monitoring. For status-and-trends, indicators measure the state of the system and track improvement or decline in a biological endpoint, or increase or reduction in a stressor. For source identification and diagnostic monitoring, indicators are used to track sources of problems. For effectiveness studies, indicators are used to determine whether stormwater management actions are protective of, or restoring, resources. Indicators from any category of monitoring may be useful to identify impaired water bodies; to provide data for modeling; or to provide data for mass loadings of pollutants to Puget Sound.

Stormwater indicators apply to a subset of environmental indicators that specifically address urban stormwater runoff impacts and the evaluation of stormwater programs and practices. Individual indicators can be used to assess different aspects of practices and programs. Some indicators are suited to problem identification, some are suited to assess particular techniques and best management practices (BMPs), while others are more appropriate for judging stormwater program management success.

"Indicators are a useful tool for evaluating stormwater pollution prevention programs if they are applied in the context of continuous improvement and are framed by a conceptual model that illustrates causal relationships between stormwater pollution, the prevention program, and other factors affecting beneficial uses of water."- Dan Cloak, Using Indicators to Improve Your Stormwater Program

It is difficult to write this strategy for a regional stormwater monitoring and assessment program in the absence of an overall ecosystem monitoring and assessment plan for Puget Sound. The complexity of an ecosystem monitoring plan is compounded by:

- the need to scale up from the sub-basin or catchment level to the regional level, and
- the necessity of having both short-term, spatially limited indicators as a measure of local effectiveness along with long-term biological indicators that can track changes to the health of the regional ecosystem over longer time periods.

A meaningful program will have nested indicators for multiple purposes at multiple levels; the challenge is to identify the appropriate indicators to answer specific questions.

Effectiveness indicators must operate in the context of two principles:

- a dedication to continually improving the program, whether it be finding more effective structural, non-structural, and treatment Best Management Practices (BMPs) or improving management and behavioral BMPs, and

- a clear understanding of the causes and effects the stormwater program is expected to address.

Prioritization is necessary. Status-and-trends monitoring will provide dynamic data about trends over time, but it is also possible to apply analytical methods to previously collected data to establish baselines and to identify areas of critical importance where damage has already occurred and that need priority treatment.

Stormwater indicators apply to a subset of environmental indicators that specifically address urban stormwater runoff impacts and the evaluation of stormwater programs and practices. Individual indicators can be used to assess different aspects of practices and programs. Some indicators are suited to problem identification, some are suited to assess particular techniques and BMPs, while others are more appropriate for judging stormwater program management success.

According to guidance from the Environmental Protection agency, evaluation of Stormwater Management Programs can proceed at three levels:

- Monitoring water quality
- Assessing program operations
- Evaluating social indicators

The Center for Watershed Protection has published a thorough review of watershed and stormwater management, including a recommended suite of indicators for tracking progress towards goals. These indicators are listed in Table 2.

1.1.5 Scales at Which to Conduct Monitoring

As with most other programs, an optimal approach will encompass multiple, nested scales of monitoring, and thus scales for any particular hypothesis that will guide their implementation. The broadest scale of monitoring is that of the integrated effect of stormwater impacts and stormwater management on receiving waters. *Status-and-trends monitoring* addresses these questions, and it also allows stormwater and resource managers to measure the broad benefits obtained from management investments. This follows the recognition that impacts will differ by water body and will reflect multiple stressors and the effect of multiple management actions. Individual conditions normally cannot be traced back to specific generators of pollution (NRC 2009), and so identifying conditions at this scale requires a larger spatial scale over longer time frames, the essence of status-and-trends monitoring. We propose complementary status-and-trends designs at both the watershed resource inventory area (WRIA) scale and the Puget Sound regional scale.

If status-and-trends monitoring (or other knowledge) indicates that there are impacts on beneficial uses in a specific water body, a second scale is invoked, that of *source identification and diagnostic monitoring*: "what are the specific stressors and sources causing these impacts, and how can we best plan for their removal?" These efforts are conducted at a local scale but they provide information that is applicable at a regional scale for ubiquitous stressors and sources of pollutants: "what regional source removal actions are necessary where local source removal actions are not sufficient to correct problems?" This category of monitoring also seeks to answer: "what specific locations and which parts of the landscape generate stormwater of sufficiently deleterious quantity and quality to cause impacts to beneficial uses, be they direct or

Table 2. Center for Watershed Protection Stormwater Indicators (CWP 2008).

- Water Quality Indicators
  - Water quality pollutant constituent monitoring
  - Toxicity testing
  - Non-point source loadings
  - Exceedance frequencies of water quality standards
  - Sediment contamination
  - Human health criteria
- Physical and Hydrological Indicators
  - Stream widening/downcutting
  - Physical habitat monitoring
  - Impacted dry weather flows
  - Increased flooding frequency
  - Stream temperature monitoring
- Biological Indicators Fish assemblage
  - Macro-invertebrate assemblage
  - Single species indicator
  - Composite indicators (*e.g.*, Index of Biotic Integrity (IBI))
  - Other biological indicators (*e.g.*, mussels)
- Social Indicators
  - Public attitude surveys
  - Industrial/commercial pollution prevention
  - Public involvement and monitoring
  - User perception
- Programmatic Indicators
  - Number of illicit connections identified/corrected
  - Number of practices installed, inspected, and maintained
  - Permitting and compliance
  - Growth and development metrics
- Site Indicators
  - BMP performance monitoring
  - Industrial site compliance monitoring

indirect?" This question is widely posed in stormwater management programs, and a number of existing monitoring programs seek to provide answers. The science of stormwater suggests where the greatest attention is probably warranted, namely a particular focus in all land uses on areas of well-connected (or "effective") impervious area (NRC 2009, p. 120, 231, 232), high vehicular traffic (NRC 2009, p. 232), and exposure to toxic chemicals (NRC 2009, p. 330).

We are attempting to broaden the finest scale at which our third category of monitoring, *effectiveness studies*, is typically conducted: we seek to move from, "are pollutant concentrations lower in the effluent" to, "which of our many stormwater-management actions achieve the greatest reduction in downstream impacts? On the whole, these stormwater control measures, both structural and nonstructural, vary by land use; the measures suitable for a residential neighborhood will likely be impractical or ineffective (or both) in an industrial setting. Most effectiveness studies will be stratified by land use, acknowledging that truly homogenous land uses are rare. Nonetheless, this organizational approach is used successfully by the Nationwide Stormwater Quality Database, which contains water-quality data from more than 8600 events and 100 municipalities throughout the country, of which 5800 events are associated with "homogeneous land uses." We see no basis to eschew the approach of this nationally recognized and funded effort in Puget Sound, and embrace the conceptual approach of land-use stratification for evaluating the effectiveness of stormwater control measures.

1.1.6 Attributes of Hypotheses for an Adaptive Management Program

A key element of any adaptive management approach is the set of hypotheses that guide both the management actions and their associated monitoring. Because these management actions are recognized as "experimental" (because in a complex system most outcome(s) cannot be predicted with absolute certainty), their selection must be guided by assumptions about what *might happen*, or what is *expected* to happen. This defines the first attribute of a useful hypothesis: it is **credible**, typically because it is based on prior knowledge or scientific understanding of the system. Indeed, some hypotheses may already be so well evaluated and understood (*e.g.*, "Stormwater runoff from freeways carries measurably elevated concentrations of toxic pollutants") that there is little point in going into detail about them in this scientific framework or to recommend that scarce monitoring resources be allocated to test hypotheses that are unlikely to result in new information or knowledge that would change management practices.

The second attribute of a useful hypothesis stems from the scientific reality that any experiment, whether conducted in the laboratory or across the landscape, provides value only insofar as its outcomes are measured and the effects are distinguishable from the influence of other, unrelated factors. Thus, the hypothesis that guides the experiment should not only be credible but also **testable**. Otherwise, why bother making measurements at all?

Lastly, these actions and measurements and analyses do not occur in a vacuum. In the present context, their purpose is to improve the management of stormwater and to reduce the associated impacts on the ecosystem of Puget Sound. Thus, the final guiding principle for any hypothesis in an adaptive management approach is that it be **actionable**, or that that different outcomes, as revealed by monitoring, can (and will) result in different management responses. If no difference occurs, then clearly there is no reason to have made the effort in the first place.

1.1.7 Translating our Assessment Questions into Hypotheses for Each Category of Monitoring

The information generated by the proposed regional stormwater monitoring and assessment program is designed explicitly to inform the ongoing implementation of the institutional framework for the full adaptive management cycle. We propose an initial set of questions to be answered for each of three monitoring categories and scales to provide different types of information useful for decision making: long-term regional status-and-trends monitoring, mid-scale targeted effectiveness studies, and local source identification and diagnostic monitoring efforts. A subset of these questions has been has been translated into hypotheses to be tested by specific experimental designs. These are not meant to define a comprehensive suite of stormwater monitoring actions, but rather to establish an overarching scientific framework for stormwater monitoring that will allow otherwise independent efforts or whole programs to contribute to our greater understanding and evaluation of progress. Concrete experimental designs must meet the necessary criteria for sensitivity, statistical power, and feasibility.

Existing data need to inform stormwater monitoring efforts. In particular, existing outfall information, including data from Phase 1 monitoring and other NPDES permit-related monitoring (industrial, construction, boatyard, *etc.*) should be integrated. Targeted literature reviews and ongoing analyses of monitoring data are necessary for refining our approach, and useful for early identification of problems and information gaps.

As described above, hypotheses used to guide the adaptive management approach must be credible, testable, and actionable. These criteria were applied to develop an initial set of priority hypotheses for more rigorous development. About 50 preliminary hypotheses were initially developed, used as the starting point, and narrowed to a list of priority hypotheses.

As hypotheses have been developed, we have aligned them with the three categories of monitoring listed above because these categories best reflect the underlying structure of the assessment questions and thus the broadly articulated stormwater-monitoring needs of the region. We also considered which land uses, which receiving waters, and which impact(s) to beneficial uses are most likely to be most problematic; and where is it most important to improve our understanding of the effectiveness of our management actions?

The Role, Utility, and Application of "Hypotheses" to Guide Monitoring

In order to meaningfully inform adaptive management, monitoring should be designed to test goals that can be measured and evaluated. We begin with a set of broadly vetted, overarching assessment questions (Appendix C) and drill them down to various levels – only some of which satisfy the criteria of testable hypotheses. For practical purposes, different types of hypotheses will guide the types of monitoring that will be conducted by the comprehensive regional stormwater monitoring and assessment program.

In this document we have not offered technically traditional statistical hypotheses with statements of a 'null' and one or more 'alternative' hypotheses associated with each. The practical application of hypotheses recognizes a continuum between "working hypotheses" and "experimental hypotheses" (Taylor 2009):

> "Working hypotheses are affirmative conjectures that propose a condition, affect, or outcome in the system being evaluated. Experimental hypotheses are the 'null' hypotheses posed in experimental studies that attempt to falsify the working hypothesis. Working hypotheses cannot be 'proved' *per se* by the collection of experimental data. Rather, working hypotheses are increasingly supported by the accumulation of observational or experimental tests of the working hypothesis. If these tests fail to show evidence contrary to the working hypothesis, the working hypothesis continues to be supported. This is the traditional use of working and experimental hypotheses in the scientific method."

We do favor hypotheses that indicate a measurable outcome, and there will be cases for some of our monitoring studies in which statistical tests can be performed on the data to determine if there is evidence to reject the 'null' and accept an 'alternative' (with various levels of confidence). But we are not convinced that policy makers require the experimental and statistical rigor involved in such scientific precision: they simply have questions that do not conform well to this approach. Taylor's definition of "working hypotheses" seems to best suit the desired management goals.

Each of our "hypotheses" should be sufficiently testable that an outcome can be measured and compared to some (preferably specified) alternative. This approach should meet the collective expectations of scientists, policy makers, and the public, provided we select indicators that help us separate out stormwater impacts. Therefore each "hypothesis" will need to include (either in this document or at some point in the near future) a clear statement of:

- What specific pollutant, stressor, or impairment is targeted for evaluation;
- What specific management action (or collection thereof) is expected to cause a change in the pollutant, stressor, or impairment;
- How to measure the change in the pollutant, stressor, or impairment;
- How to confirm and quantify implementation of the management action(s); and
- The level of confidence with which a change can be reported, over what time period.

The example "hypotheses" and hypothesis-driving questions presented in this document are provided as a starting point. More specific, detailed hypotheses will be decided after further discussions of issues among stakeholders.

"Hypotheses" for Each Category of Regional Monitoring

We recommend the following "hypotheses" and hypothesis-driving questions for prioritizing the initial efforts of the regional stormwater monitoring and assessment program:

For status-and-trends monitoring:

1. Salmon (focusing on appropriate life stages) in small streams show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.

2. Instream biological metrics (*e.g.*, B-IBI) show statistically significant improving trends in Puget Sound lowland streams in concert with increased and improved stormwater management efforts.

3. Bacteria levels limiting primary human contact show decreasing trends over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.

4. Bacteria levels in water and bacteria and/or toxics in shellfish along the nearshore limiting primary contact and harvest show decreasing trends over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.

5. Resident fish in nearshore areas show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts. – *Future Work*

6. Forage fish in nearshore areas show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts. – *Future Work*

For source identification and diagnostic monitoring:

7. Identification, prioritization, and removal of stormwater sources and stressors result in the improved targeted beneficial use.
8. Receiving-water status-and-trends monitoring in targeted watersheds results in early detection and prioritization for source removal.

For effectiveness studies:

We have identified the following "guiding questions" or focus areas for organizing future discussion, development, and selection of hypotheses to be tested by effectiveness studies:

9. What is the effectiveness of various low-impact development (LID) techniques in areas of new development and redevelopment?
10. What is the effectiveness of retrofitting existing development with various flow management and water quality treatment approaches?
11. What is the effectiveness of programmatic and non-structural best management practices, such as:
    a. Various provisions of the municipal stormwater NPDES permits, and
    b. Various agricultural best management practices.
12. What emerging technologies and treatment techniques show the most promise? – *Future Work*
    a. Examples include reducing fecal coliform and metals concentrations in stormwater runoff.

1.2 Scientific Framework for Each of the Categories of Regional Monitoring

In this section we propose an experimental approach for our highest priorities within three categories for regional stormwater monitoring in Puget Sound:

- Status-and-trends: Long-term regional monitoring focused on biological communities in small streams and nearshore areas to improve understanding of whether stormwater management programs are helping to achieve the larger goal of restoring the Puget Sound ecosystem.
- Source identification and diagnostic monitoring: prioritized based on local water body impairments, and collective assessments to identify regional issues.
- Effectiveness studies: evaluating whether best management practices in major land-use categories achieve intended outcomes of water quality improvements or stormwater volume reductions (or other protective or corrective measures).

The need to include and undertake sufficient monitoring and assessment actions in multiple locations around the Sound so variations are considered is balanced with the need to efficiently employ limited resources. Our intent is to create a comprehensive monitoring and assessment strategy by:

1) monitoring and assessing the most critical elements of stormwater;
2) conducting monitoring that helps answer the most important questions for decision makers;
3) collecting sufficient data to account for regional variations;
4) conducting a sufficient number of assessments to produce robust information;
5) ensuring data collection and assessments follow standardized protocols; and
6) compiling and sharing the results so that all interested parties can learn from the effort and regional decision makers can revise and improve stormwater management policy.

In describing this scientific framework and in our approach to creating the overall study designs, we have intended to be specific about how much effort is required, how often, and what information we expect to get given the indicated level of effort. To the extent that we had the capacity to do so for this document, we have tried to ensure that level of confidence provided has been clearly articulated and appropriate for decision makers. To address the range of uncertainty the concept of "power" of statistical tests should be applied and considered before studies are implemented, but it is too early in the development of our experimental designs, described below, to provide this level of detail. When experimental designs are more fully developed, the complete data needs for each hypothesis will be articulated, including the appropriate level of confidence and uncertainty of the outputs. Assumptions will be explicitly stated along with references to prevailing theories.

The following sections describe how the different types of monitoring designs would be used within an adaptive management structure. Information gathered under each category of monitoring can and should inform work under each of the other categories. The designs are given hierarchically, from the broadest and most general design to the most local site-specific designs. Some specific examples are presented in detail in Appendices D, E, and F.

1.2.1 Scientific Framework for Status-and-Trends Monitoring

Historically, the impacts of urbanization on receiving waters have been tested by comparing water quality to various sets of standards or guidelines. However, to truly assess cumulative impacts, "[b]iological monitoring of waterbodies is critical to better understanding the cumulative impacts of urbanization on stream condition" (NRC 2009, p. 233). To this end, hypotheses that address the integrated effects of stormwater-management actions on the biota of receiving waters are the recommended emphasis for status-and-trends monitoring. Our initial scope and focus for this work is on small streams and the nearshore marine environment. This monitoring is also intended as a starting point to support the recommended approach for source identification and diagnostic monitoring, and effectiveness studies (see sections 1.2.2 and 1.2.3 below). Two important definitions:

- Small streams are defined as wadeable, 2-3 order streams.
- As quoted from the Puget Sound Nearshore Ecosystem Restoration Project website (http://www.pugetsoundnearshore.org/what.htm):

> "The Puget Sound nearshore is defined as that area of marine and estuarine shoreline extending approximately 2,500 miles from the

> Canadian border, throughout Puget Sound and out the Strait of Juan de Fuca to Neah Bay. It generally extends from the top of shoreline bluffs to the depth offshore where light penetrating the Sound's water falls below a level supporting plant growth, and upstream in estuaries to the head of tidal influence. It includes bluffs, beaches, mudflats, kelp and eelgrass beds, salt marshes, gravel spits, and estuaries."

Biological communities and water quality are affected by more than just stormwater management activities. The information collected will integrate influences from various land uses, geologic and geomorphic conditions, and other factors outside the control of stormwater managers. As discussed in section 1.1.7, specific hypotheses should reflect the current understanding of stressors and the parameters being affected, and how those influences are likely to be expressed in the biota. Clearly, there are a vast number of unique combinations around which hypotheses could be constructed, and for which conditions could be monitored. The challenge at this level of hypothesis-generation is to identify a more limited, tractable number of such combinations. They must also each meet the test of being credible, testable, and actionable.

For the status-and-trends monitoring, the priority hypotheses that address those receiving-waters that are currently understood to be more directly associated with stormwater (Table 1 and Figure 3). *Small streams* (or "*creeks*") are an obvious choice, given the decades of research on them in the region, their recognized sensitivity to adjacent land-use activities, their critical role (both direct and indirect) in the life history of anadromous salmon and our corresponding lack of information about the effectiveness of proposed management actions to prevent these harms. We also focus on the *nearshore*, because of the importance and sensitivity of this interface between land-based activities and Puget Sound, and its importance to both natural and human (especially food- and recreation-based) resources.

Experimental designs for status-and-trends monitoring in small streams and nearshore areas are discussed in the section below and presented in more detail in Appendix D.

Sound-wide and Watershed Probabilistic Designs

The first three priority hypotheses for status-and-trends monitoring are designed to evaluate the status of water resources, *e.g.*, the percentage of stream miles supporting their beneficial uses, and to detect trends over time in water resources affected by stormwater and other land uses. The ultimate goal of this monitoring is to determine whether stormwater management is helping to protect the resource.

A probabilistic survey design starts with a complete master list of all possible sampling sites and selects a random subset for site visits to evaluate access and suitability prior to selection for monitoring. The Washington State Department of Ecology is charged with designing and implementing a statewide monitoring program to assess stream habitat and watershed health (Ecology 2006). We propose utilizing and building upon Ecology's probabilistic survey design for small streams in the Puget Sound region to assess status and measure trends over time. This probabilistic design allows for a quantitative understanding of the extent and magnitude of the impacts on beneficial uses across the multiple jurisdictions and watersheds of the Puget Sound region. Figure 5 shows an example of the sampling locations for probabilistic stream monitoring in the Puget Sound region. Similar probabilistic survey designs will be developed for nearshore monitoring of bacteria and toxic chemical accumulation in sediment and mussels.

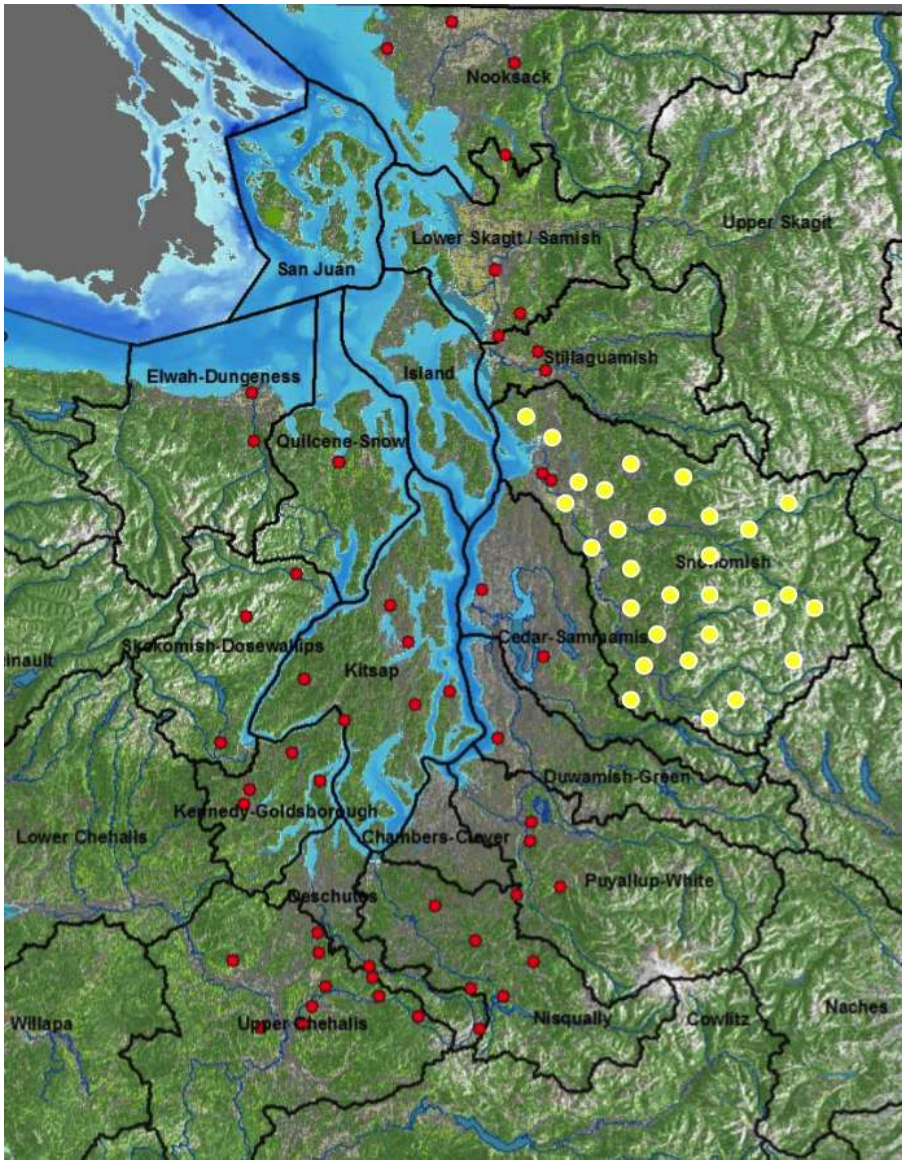


Figure 5. Probabilistic survey design for stream sampling in the Puget Sound watershed (red dots) and an example of high density stream sampling in the Snohomish watershed (yellow dots). Both sets of points are derived from the same master set of sampling sites.

The U.S. Environmental Protection Agency encourages states to adopt a probabilistic sampling design for the following reasons:

- A probabilistic survey design is, by definition, integrated [across land uses] because it includes all possible sites in the sampling frame (Larsen *et al*. 2001; Stevens and Olsen 1999).

- The design is flexible because the same design can be expanded to increase sampling densities based on geographic area, land use or some other factor (Ode and Rehn 2005).
- The magnitude of the problem can be evaluated, *e.g.*, "50% of stream miles are failing to support their designated uses" (Urquhart 1998; Stevens and Olsen 2003).
- The random nature of the design supports risk analysis to determine the most important drivers of degradation associated with stormwater (EPA 2006).

The potential exists for agencies to support each other's program by sharing the burden of data collection across projects (for example, all jurisdictions in one watershed may choose to pool resources to have one jurisdiction, consultant, university or other entity collect all the samples to reduce training, equipment, data management and other costs). To be truly comprehensive, a status-and-trends stormwater monitoring program would address all receiving waters: small streams, rivers, lakes, groundwater, nearshore areas, and the open marine system; and it would be regional in scale. As noted in *The Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery*, Vol. 2, p.8,

> "'Comprehensive' is not defined by the measurement all things, at all times, but rather is aimed at determining the most important things that need to be done to address key questions or objectives."

The intent of the status-and-trends monitoring is not to identify every variable or establish the loading or variability of each parameter. The intent of the monitoring effort is to produce sufficient information to inform stormwater management actions and to determine over time whether these actions are improving the beneficial uses of receiving waters. As noted above, we have initially focused status-and-trends stormwater monitoring in small streams and nearshore areas. Status-and-trends stormwater monitoring for other water bodies may be tied into programs designed by other work groups included in the overall ecosystem monitoring program for Puget Sound (see Introduction and section 2.1). The proposed stream monitoring includes sub-basin sampling at the WRIA-level for the water quality index, aquatic macroinvertebrates, fish diversity and abundance, stream physical features, and sediment chemistry for metals and petroleum. Additional sampling proposed at the Puget Sound scale includes sediment chemistry (phthalates, poly-aromatic hydrocarbons, and other toxics of concern), flow, temperature, and a pilot study for periphyton. The Puget Sound-scale sites (with the exception of the periphyton pilot study) will be a sub-set of the watershed-level sites that have the additional sampling (Figure 6 shows the watersheds (WRIAs and combinations of WRIAs) we propose for this focus). The approach will use current randomly selected sites, where available, to build upon historical data.

Marine nearshore sampling would focus at the Puget Sound scale on probabilistic sampling for fecal coliform, sediment chemistry, and caged mussel toxic accumulation. Because chemical data are not always reliable indicators of biological effects, direct biological testing (sediment toxicity tests) is often used in conjunction with sediment chemistry and infaunal community structure analysis (diversity and abundance of organisms living in the bottom substrate) to determine the biological significance of the chemicals measured in the sediments. This series of monitoring is known as the Sediment Quality Triad. However, as a tool for monitoring status and trends, using two (invertebrates sampling and sediment chemistry) of the three parts of the triad are recommended in this initial phase of the regional monitoring and assessment strategy.

Figure 6. Map showing the local salmon recovery areas in Puget Sound (Water Resource Inventory Areas (WRIAs) and combinations of WRIAs) proposed for probabilistic densified sampling. Island-based watersheds have few wadeable streams and therefore are not included in the proposed design.

The benefits of a WRIA-based Puget Sound-wide probabilistic survey design are that it:

- Summarizes the current condition of streams and nearshore with an estimated level of statistical precision at a watershed and Puget Sound levels;
- Makes regional comparisons of stream condition within and across WRIAs
- Prioritizes areas for protection and restoration in terms of physical, chemical and biological condition at the Puget Sound scale;
- Recognizes temporal and geographical variability and environmental response time to management practices.

- Provides regional estimates of water quality and flow conditions that support salmon recovery endpoints and other water resource issues,
- Answers at a spatial scale that often better matches the scale of decisions needed for stormwater management issues,
- Identifies common problems due to land use impacts or sources of pollutants that may need common solutions.
- Provides consistency over time and is not subject to changing jurisdictional boundaries.
- Considers entire watersheds without the constraints of jurisdictional boundaries.
- Provides a baseline for documenting longer-term and larger scale impacts, such as climate change.
- Recognizes that change of ownership may prohibit continued access for a site or reduction of flow may also preclude the ability to sample at a site. Sampling design will be robust enough to account for losing sites during the process.

The types of information not provided by a WRIA-based Puget Sound-wide probabilistic survey design include:

- Specific information about sites of interest, *e.g.*, sites with BMPs, cannot be addressed due to the random nature of the design. Some sites from specific locations would be needed to make comparisons and test for differences.
- Specific management practices or jurisdictional programs cannot be evaluated by this approach, though the information can be useful to support more localized monitoring efforts to evaluate individual programs.
- Trend information will not be available in the typical planning horizon for individual projects or permits. Trends require sufficient sampling to determine significant changes from natural variability, but also require the system has sufficient time to respond to actions or lack of action. More sampling does not necessarily mean a quicker detection of trends.
- Cause and effect relationships cannot be identified.

The probabilistic design allows for the nesting of monitoring programs of different densities in a comparable manner. Using the small streams example described above, the probabilistic survey design can be scaled to smaller watersheds, basins, and subbasins by increasing the density of sampling sites. The density can also be increased according to other factors, *e.g.*, stream size, land use, *etc.* Results from these areas of greater sampling effort should be rolled up in the regional reporting. In short, one probabilistic survey can be nested within another. (See the yellow dots in Figure 5 showing an example of additional sites for Snohomish watershed. Figure 6 shows the watersheds (WRIAs and combinations of WRIAs) we propose for this focus.)

The types of information provided by a watershed probabilistic survey design include:

- The change in percentage of the watershed supporting its beneficial uses after 5 years of sampling.
- How areas with different land uses, *e.g.*, urbanizing areas with LID construction vs. areas with predominantly existing residential, compare regarding their relationship to the supporting of beneficial uses.
- Identification of the greatest threats to water resources in the watershed and their relative risks.

The types of information not provided by a watershed probabilistic survey design include:

- Effectiveness of specific BMP treatments.
- Identification of sources of pollutants and diagnosis of stressors.

Non-probabilistic Sampling

In addition to the probabilistic sampling identified above, stream flow and temperature will be collected continuously at a series of sites across Puget Sound. These sites will be selected from existing U.S. Geological Survey and local government-operated stream gauge locations that represent a variety of stream sizes, geographic distribution and land uses. If necessary, additional gauges will be established to fill specific gaps in unrepresented areas. While flow and temperature vary substantially by location, they are responsive to land use impacts and stormwater management. The design of this effort will be determined after compilation of existing federal, state and local gauge information, anticipated in the second half of 2010.

Future Work

This effort is a starting point and recognizes there is still a need for monitoring stormwater impacts on other aquatic resources. Efforts are underway to develop marine nearshore monitoring protocols for aquatic habitat, various fish population health indicators, and other monitoring that could be effective measures of stormwater impacts on ecosystem and biological health. As these efforts and potentially others become more established and found to be reliable, they should be reviewed for inclusion in the strategy.

Small streams, while having the benefit of much more monitoring focus over the last few decades, also have a number of monitoring programs that look promising but do not yet have accepted reliability or clear response for stormwater-related impacts. These efforts, including caged or natural mussel/shellfish monitoring, biological or chemical parameters for salmonid pre-spawn mortality, or others, should also be reviewed for potential inclusion in the strategy.

1.2.2 Scientific Framework for Source Identification and Diagnostic Monitoring

Numerous studies have shown that urban development can adversely affect receiving water bodies. Stormwater conveyance systems in the built environment, and in particular in urbanized centers and agricultural areas located near shorelines, provide a rapid conveyance of pollutants where water quality treatment and flow reduction were not considered during the development of these areas.

The general “causal sequence” by which human activities can impair receiving-water health is shown in Figure 7. The potential impacts resulting from human activities can be assessed at each level in this causal sequence. Some monitoring programs focus on water quality metrics or physical metrics, which are receiving water exposure indicators. However, indicators at the “biological response” level are closer to the designated uses of the water bodies (NRC, 2001; Karr and Yoder, 2004; EPA, 2005) and reflect the combined influence of all of the receiving water body exposures, landscape exposures, and sources throughout the watershed. Source identification and diagnostic monitoring seek to interrupt this “causal sequence” in a targeted,

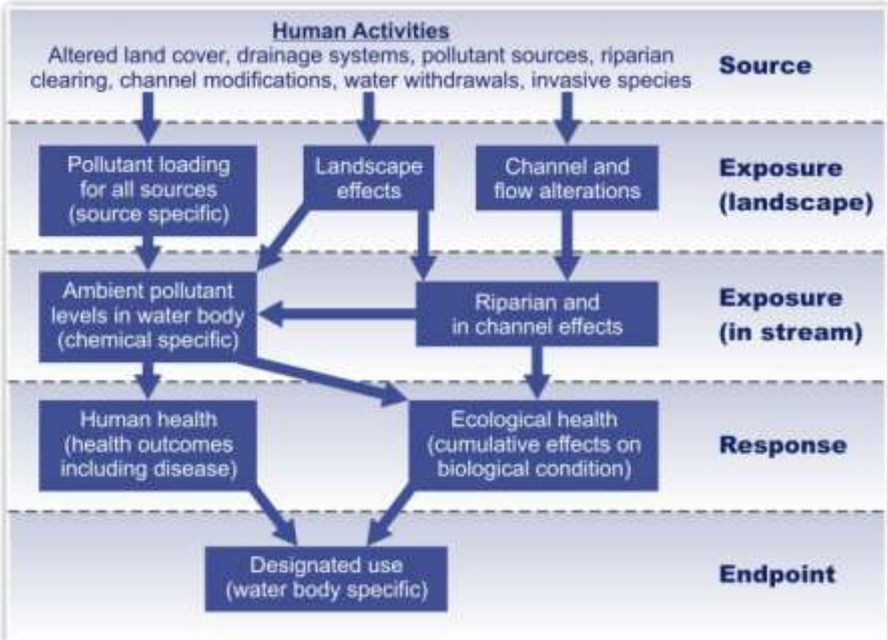


Figure 7. Causal sequence by which human activities affect receiving waters (EPA 2005, modified from Karr and Yoder, 2004)

planned series of actions that sufficiently reduce sources exposures to result in improved biological endpoints.

We recommend a comprehensive regional stormwater source monitoring framework for restoring failed receiving water biological endpoints or other impairments caused all or in part by stormwater. Implementation of this framework is preceded by prioritization of the known impairments that need to be addressed. This framework is a diagnostic tool to: determine the location and sources of stressors; identify the corrective action(s); and target monitoring to assess progress and achieve the targeted goal. Sources include toxic chemicals, nutrients, pathogens, flows and other stormwater indicators or parameters identified to be a stressor. Stormwater adaptive management strategies are an integral key to the Source identification and diagnostic monitoring framework.

The key components/steps of source identification and diagnostic monitoring are:

- Identify current problem sources/impairments (based on existing monitoring information)
- Prioritize problems (which problems to work on first)
- Set an initial target for source reduction
- Locate sources/causes (possibly more monitoring to further define the location)
- Plan the regulatory framework and actions to remove the source(s)
- Implement Source Removal Actions/Programs
- Monitor to provide feedback on the progress of Implementation
- Implement new source identification and diagnostic monitoring as needed to address sources/problems identified by research studies, effectiveness studies, status-and-trends monitoring and other programs and efforts.

A more detailed description of each of these key components is included in Appendix E. These activities occur in an iterative process to track improvements in the receiving waters and to identify needs for additional controls. Multiple entities need to cooperate in situations where the impairment is not confined within the boundaries of a single jurisdiction. The approach is connected to watershed-scale prioritization of specific impairments that have been identified, and provides tools and support for communities to participate in identifying and correcting their biggest pollution problems.

Source identification and diagnostic monitoring uses the existing framework of regulatory programs for Total Maximum Daily Loads (TMDLs), Clean Water Act 303(d) listings, Superfund sites, and more. The regional status-and-trends monitoring will serve as another tool to identify problem areas for focused source removal projects; it will provide data in areas where stormwater impacts are expected and serve as an "early" warning system. Source identification and diagnostic monitoring incorporates data from other sources including municipal NPDES permit-required Illicit Discharge Detection and Elimination (IDDE) programs, state watershed assessments, and stormwater outfall characterization monitoring.

The control, removal and prevention of sources can be accomplished through activities including behavior change, infrastructure repair, product substitution, regulatory prohibition, or retrofit with improved structural best management practices. The framework for source control efforts is to prioritize impairments at the WRIA level and subsequently implement monitoring and management actions at a scale that is sensible for the scope of the problem. Additional monitoring may better refine source locations and provide for a more efficient and effective plan that addresses the highest priority areas and sources contributing to the impairment. Some sources are so ubiquitous that removal or prevention is only cost-effective and practical by enacting legislation or other regional policy actions where the source is prevented from presence in the product (*e.g.*, phasing out copper from vehicle brake pads). However, other sources are most effectively controlled at the sub-watershed scale. Collective analyses of source identification and diagnostic monitoring efforts across Puget Sound will help target future regional source control initiatives.

Source identification and diagnostic monitoring is distinct from response to emergency water quality problems such as illicit connections, spills, and transient illicit discharges. Source identification and diagnostic monitoring can include: detailed monitoring to trace sources of pollutants or altered flow volumes upstream from the observed impacts on beneficial uses to their sources on the landscape; business inspections; on-site septic system inspections; illicit connection detection; and other programs. This approach is not focused on clean-up activities; but rather on removal of current stormwater sources. Two examples of successful source control programs initiated based upon high priority receiving water problem and controlled at the local jurisdictional level are: the City of Tacoma Thea Foss Source Control Program to control PAHs and DEHP in sediments, and the Kitsap County Health District Pollution Identification and Correction (PIC) Program to reduce fecal coliform in marine and fresh waters (see Appendix E for more information). The common denominator of these programs is that they are:

- performed on a site-by site basis by local entities,
- address an identified stormwater pollution impact or degraded beneficial use, and
- result in improved environmental quality.

Figure 8 demonstrates the stepwise process that may be necessary for a source identification and removal plan. The monitoring framework that is specified will be dependent upon the defined impairment, biological endpoint or exceedance: different approaches and steps are needed for approaching different types of impairments (see Appendix E). Not all sources will fit neatly into this recommended framework. However, our goal is to describe a framework that can be used not only locally at the WRIA or watershed level, but at the Puget Sound regional level.

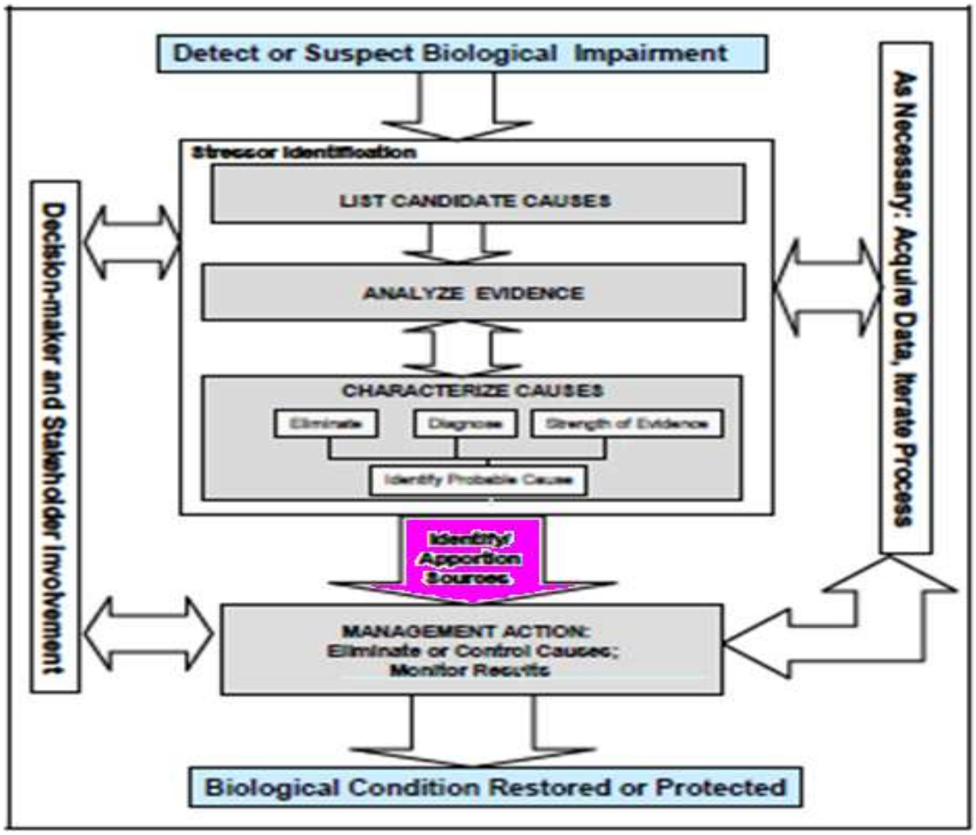


Figure 8. The stressor identification process (EPA, 2000).

Source identification and diagnostic monitoring provide an organized, step-wise approach to restore receiving-waters that have been identified as impaired by stormwater impacts. This approach provides tools to set priorities for investigation, determine the locations and sources of stressors causing impairments, identify the corrective action(s), monitor to assess progress, and achieve the targeted goal of improved receiving-water conditions. Stormwater adaptive management strategies are an integral key to the source identification and diagnostic monitoring framework.

All source identification and diagnostic monitoring projects should be required to follow all applicable regional protocols; and all data and findings should be submitted to a central monitoring data management system and readily available to the public.

Possible Roles of Outfall Characterization in Source Identification and Diagnostic Monitoring

Source identification and diagnostic monitoring will include stormwater outfall characterization when required in order to further identify the location, frequency and possibly the quantities of sources. Characterization is defined as measuring variation in relevant indicators across the landscape and through time. The need for characterization data is different for various types of studies, and to inform different diagnoses of impairments. Credible information is available in existing literature that can meet the needs of a particular study or problem. Where characterization is required, it should relate back to an identified problem and assist in determining the sources of problems and quantifying how much is coming from each source.

Calculation of loads is not of particular interest to source identification and diagnostic monitoring unless it directly informs corrective actions or policy changes. A characterization study design (not currently included in this strategy) would be required to calculate loads.

Outfall data are collected from sites covered under various stormwater NPDES permits including the Boatyard, Construction, Industrial, Municipal, Sand & Gravel, and Shipyard general permits, and sites with individual permits. With the exception of the current Phase I Municipal permit, the monitoring is currently conducted for compliance purposes only, but these monitoring programs could focus on providing information on specific activities to identify sources, contaminants or impairments.

1.2.3 Scientific Framework for Effectiveness Studies

Stormwater management effectiveness studies are intended to test our assumptions about whether or not stormwater management approaches are functioning as anticipated and result in improvements in beneficial uses. Some effectiveness studies of public domain structural BMP designs is already being performed through current municipal stormwater NPDES permit requirements and other efforts, and effectiveness studies of proprietary technologies are done through Ecology's program to evaluate emerging stormwater treatment technologies (the TAP-E protocol, see http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html).

Information collected through effectiveness studies will help quantify the costs and benefits of stormwater management approaches. Effectiveness studies are needed in the following five focus areas:

1. New development and redevelopment: testing the effectiveness of low-impact development (LID) and other techniques to minimize impacts from future new development and in areas of redevelopment,
2. Retrofit of existing development: testing the effectiveness of retrofitting urban areas with various flow management and water quality treatment approaches to decrease impacts from the built environment,
3. Non-structural, operational, programmatic approaches used in stormwater programs such as educational, source control and maintenance programs: testing the effectiveness of non-structural (*i.e.*, operational, behavior-change, planning) and programmatic approaches used in stormwater management programs, and in particular, of various provisions of NPDES stormwater permits and other regulatory programs.

4. New and emerging techniques: evaluating and assisting in the development of new technologies targeted at reducing specific stressors, and
5. Key knowledge gaps for existing technologies: fill key gaps in our current tools and practices to provide better tools for managing stormwater in the future.

These five focus areas are believed to encompass the complete range of types of information necessary for evaluating and improving stormwater management approaches. The first three focus areas are of approximate equal priority, relative to one another. We recommend that (apart from privately-funded TAP-E studies to gain regulatory approval for new proprietary technologies) studies related to the fourth and fifth effectiveness focus areas be delayed until satisfying information is being provided for the first three effectiveness focus areas.

All effectiveness studies should be designed to answer specific questions with clearly articulated hypotheses for testing (see sections 1.1.6 and 1.1.7). Effectiveness studies will likely occur at different spatial and temporal scales, depending on the intent of the study. (For example, studies may investigate the effectiveness of specific, parcel-scale approaches in individual storms, or the effectiveness of region-wide programs over the course of two to five years.) Typical methodologies to be used for evaluating stormwater management effectiveness include comparison of conditions:

- Upstream and downstream from management actions;
- In paired watersheds;
- Before and after management actions; and/or
- In runoff influent and effluent.

As part of each effectiveness study, the costs of various techniques and approaches should be quantified. Only with quality data on the cost of various management actions and approaches can a cost/benefit evaluation be conducted. We recognize that in this age of limited resources, smart investments in stormwater management are a priority, to ensure that maximum benefit is obtained. Use of this information would occur though an adaptive management approach for stormwater management.

All effectiveness studies should be required to follow all applicable and agreed upon regional protocols; and all data and findings should be submitted to a central monitoring data management system and readily available to the public.

A robust literature review is essential to effectively and efficiently address monitoring needs related to the effectiveness of stormwater management practices and programs. As appropriate within each of the five focus areas for effectiveness studies, the effectiveness of both individual practices and overall programs should be evaluated.

Table 3 shows a proposed outline for the literature review.

Initial Prioritization and Example Questions for Effectiveness Studies

The *initial focus* of effectiveness studies will be on the below-listed topics within each of the five focus areas. More work is needed to articulate working hypotheses that are suitable for designing studies (see sections 1.1.6 and 1.1.7). This focus of effectiveness studies should be re-evaluated on a routine basis, and after the initial focus, future investigation can consider the effectiveness studies for other stormwater permits and land-uses.

Table 3. Proposed Outline for Effectiveness Study Literature Review

I. New Development and Redevelopment

A. Effectiveness of various BMPs in managing peak flows and flows above forested conditions, using continuous runoff modeling
B. Effectiveness of various BMPs in removing various pollutants
C. Effectiveness of LID approach and techniques
D. Applications: Residential, Commercial, Municipal roads, State highways, Industrial, Agriculture
E. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions
F. Identification of what's known and well documented, and data gaps

II. Retrofitting existing development

A. Effectiveness of various BMPs in reducing surface runoff volumes and peaks
B. Effectiveness of LID techniques vs. more conventional BMPs
C. Applications: Residential, Commercial, Municipal roads, State highways, Industrial, Agriculture
D. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions
E. Identification of what's known and well documented, and data gaps

III. Non-structural, operational, programmatic approaches used in stormwater programs

A. Non-structural (Operational/Programmatic) BMPs
1. Effectiveness of various BMPs in reducing surface runoff volumes and peaks
2. Effectiveness of various BMPs in treating targeted pollutants
3. Applications: Municipal, Commercial, Agriculture, Industrial
4. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions
5. Identification of what's known and well documented, and data gaps

B. Effectiveness of Overall Municipal and Other Stormwater Management Programs
1. Effectiveness in not increasing, or in reducing, flow volumes and peaks to flow sensitive water bodies
2. Effectiveness in not increasing, or reducing, pollutant loadings and concentrations, and protecting beneficial uses
3. Applications: Municipalities (MS4's), Agriculture, Industrial, and other
4. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions, indicators
5. Areas/locations targeted for this type of monitoring

IV. New and emerging techniques and technologies

V. Identification of what is known and well documented, and data gaps

The following initial priority **topics**, questions, and/or hypotheses should be addressed within each focus area based on the results of the literature review, existing monitoring programs, and other information. Each hypothesis must be subjected to evaluation of whether it is in fact credible, testable, and actionable.

1. New Development and Redevelopment:
   Effectiveness of various LID techniques in new development.
2. Retrofit:
   Effectiveness and cost of retrofitting existing development with various flow management and water quality treatment approaches.
3. Programmatic and Non-Structural BMPs:
   Effectiveness and cost of various provisions of the municipal NPDES stormwater permit and effectiveness of various agricultural best management practices.
4. New Technologies:
   Fecal coliform and metals treatment techniques.
5. Fill Key Data Gaps for existing technologies:
   No topics prioritized at this time.

Collecting the Right Data: Data Quality Objectives for Effectiveness Studies

After a specific question has been selected and an appropriate monitoring design developed to answer the question, the next step is to identify the type and amount of data to be collected. Data Quality Objectives (DQOs) refer to the precision and accuracy of the data needed to answer the question. Too much data (oversampling) is unnecessarily expensive, too little data can doom a project to irrelevance.

DQOs can be interpreted in a strictly statistical sense, for example, in terms of the acceptable uncertainty associated with estimates (e.g., the error bars around estimates), or in terms of the probability of making a wrong decision (e.g., false positives or false negatives). DQOs may also be interpreted more broadly in the sense of an overall process to collect reliable data that will answer the question in a meaningful and complete way (EPA, 2006).

Law *et al*. (2008) provide a series of questions to guide the development of effectiveness studies. Several of their questions support thinking around what types of data to use and the quality of the expected data.

- *What factors should be considered when selecting study sites?*
  The study sites should be representative of conditions or situations that the study is designed to address. Alternatively the study sites should be representative of the most commonly found conditions; one way to insure this type of representativeness is to sample randomly. Other covariates that could affect the outcome should be considered, e.g., surrounding land use for a street sweeping study, age of structure for a retrofit study, or demographics for an education survey.

- *What minimum data are needed to characterize site conditions?*
  Often the preparatory work is equal to the amount of effort spent collecting the data. Desktop analysis may be extensive to locate appropriate study sites that are representative and safe to sample. This step focuses on the ancillary data needed to describe, select, and later evaluate the data collected from the sites. Only data that will contribute to the final analysis or

interpretation of the study question should be collected. At this step the indicator list is carefully pruned.

- *How much sampling effort is needed to get reliable data?*
  The most important outcome of this step is that the data collected are adequate to answer the study question with an acceptable level of precision; in other words, to avoid collecting data that are too imprecise to answer the study question in any definitive way.

  The number of site-visits and samples are easier to define for some studies than for others. To estimate the needed number of data points for a specified level of statistical confidence, the statistical model must be defined (*e.g.*, a paired design to compare toxic concentrations upstream and downstream of the LID development) and an estimate of variance must be available. National databases are available to obtain estimates of variance from similar projects.

  Statistical power analysis can be used to estimate the confidence associated with different outcomes and different sample sizes. Law *et al*. (2008) provide table values and other sources for calculating sample sizes for standard statistical tests. For projects that have no variance estimates available, the statistical test should still be specified and applied to some good guesses of what the data will be in order to evaluate whether the statistical approach will be appropriate.

  Although statistical texts often specify a p-value < 0.05 and a statistical power of 0.80, the acceptable confidence limits can vary widely depending on the study. Nonetheless, expectations should be specified for the type of difference that would be statistically significant or meaningful to the investigator before collecting the data. An assessment of the study design should be made to determine whether the data collected will meet the expectations.

- *What are the special data management and quality control considerations?*
  This step summarizes any unusual considerations for the type of data being collected. Examples might include chain of custody requirements, limited access to selected sites, or sample handling instructions. Any problems that are likely to occur and can negatively impact the value of the data should be emphasized during the data collection process.

Indicators to Track Effectiveness of Stormwater ManagementEffectiveness studies provide unbiased information about whether specific stormwater management actions and programs are reducing, preventing or mitigating stormwater impacts to beneficial uses in receiving waters. Its goals are:

- Providing data for adaptive management, and
- Demonstrating compliance.

Effectiveness indicators have constraints: They are meant to provide information about the success or failure of specific management actions. As such they must be of appropriate scale to screen out other possible causes of observed effects.

A proper effectiveness study assessment and prioritization scheme will be applied first to existing programs and data in the form of a comprehensive literature review and a review of findings from existing programs.

Indicators for effectiveness studies will be highly dependent on the practice, scale, and scope of the technique, program, or landscape being evaluated. The goals of effectiveness studies are to provide data for adaptive management and to demonstrate compliance with applicable regulations.

In this context several factors can be identified for assessment as hypotheses are defined and study designs are developed, finalized, and approved.

- Reference Conditions
  - Paired watershed approach- the paired watershed monitoring protocol compares the response of two watersheds, with a documented relationship, when subjected to different management strategies and/or development patterns. One watershed usually serves as the control, where no changes occur, while the other watershed receives some kind of treatment. (From Watershed Protection Techniques 2(2): 587-594)
  - Pre- and post-treatment
  - Upstream/Downstream treatment
- When to measure: consider intermittent nature of flows
- Spatial approach: to be successful, effectiveness studies must be highly aware of the spatial scale involved, and relatively small spatial scales (e.g., site or catchment) will be most effective in reducing influences from natural conditions or other actions.
- What to measure
  - Water quality (chemical and physical)
  - Biological indicators
  - Behavioral and attitudinal changes
- How to measure: standards and criteria
  - Human health criteria
  - Aquatic species criteria
    - Fish
    - Macroinvertebrates
    - Plankton and algae
  - Habitat criteria
  - Other

Summary of Scientific Framework for Effectiveness Studies

Effectiveness studies will test our assumptions about whether or not selected stormwater management approaches are functioning as anticipated and result in improvements in beneficial uses and help quantify the benefits of stormwater management approaches. These studies will provide unbiased information about whether specific management actions are preventing, reducing, or mitigating known stormwater impacts to beneficial uses in receiving waters. To be successful, effectiveness studies must be performed at sites selected within relatively small spatial scales (*e.g.*, site or catchment) to reduce influences from other actions or natural phenomena. Reducing influences not related to the management action itself is necessary for a robust experimental design. A final component of this monitoring is the linkage to specific "outcomes" as described in section 1.1.6.

Many effectiveness studies require a relatively small-scale focus and treatment locations where stormwater management actions are applied and their implementation is well documented. For each treatment location, the monitoring design may include upstream/downstream monitoring, before/after monitoring, or treatment/control monitoring. The selection of the appropriate approach is dependent on the specific hypotheses to be tested.

The types of information provided by effectiveness studies include:

- The amount of change in flow parameters or water quality parameters downstream relative to upstream of the stormwater management location, OR
- The amount of change in flow parameters or water quality parameters from before and after installation of the stormwater management action, OR
- The amount of difference in flow parameters or water quality parameters between a site receiving stormwater management action and a control site not receiving stormwater management action.

The types of information not provided by effectiveness studies include:

- Identification of sources of pollutants and stressor diagnosis.
- Cumulative impact of multiple stormwater management actions at the watershed or regional scale.

1.3 Other Tools and Data Needs

There are a good number of support structures, tools, and additional data needs to be included in establishing a regional stormwater monitoring and assessment program. The categories of greatest importance to our initial efforts are described in the following sections.

1.3.1 Inventory of Monitoring and Assessment Efforts in the Puget Sound Basin

An ongoing inventory of monitoring and assessment efforts in the Puget Sound region will inform the priorities of regional and local monitoring efforts and assist in their coordination and implementation. This early work will also help inform the next round of the Municipal General NPDES permits. The inventory will:

- Include all monitoring and assessment efforts, not just those directly associated with stormwater, because we need to conduct stormwater-associated monitoring and assessment within the context of the entire ecosystem.

- Cover a wide range of efforts from volunteer monitoring to wastewater discharge and sediment cleanup site monitoring to fisheries assessments and special studies on specific species, because we need to coordinate and partner with other efforts; and

- Be organized by Watershed Resource Inventory (WRIA) so that one can search for relevant projects on a watershed scale, but also searchable by other categories such as stressors.

The inventory (see section 2.1.8) is built upon inventories previously compiled by the Washington Forum on Monitoring Salmon and Watershed Health (Forum), the Partnership, the Environmental Information Management (EIM) system, Washington SeaGrant, and others.

1.3.2 Standard Operating Procedures and Data Reporting Requirements

To ensure data comparability across the multiple monitoring efforts, it is essential that a common set of standard operating procedures be developed and used throughout the region. The following necessary steps must be taken to ensure that credible data are collected in a quality manner for all monitoring and assessment conducted by the regional program (see Appendix G):

- data quality objectives must be identified;
- project plans must be approved and shared;
- standard field collection and data reporting protocols must be followed followed;
- appropriate analytical accuracy, precision, detection, and reporting limits must be used at accredited laboratories; and
- geographic information system (GIS) data must follow state guidelines.

Ecology has funded the development of an initial set of standard operating procedures for stormwater monitoring, though many more have been identified for future development. Future steps will make these and other tools widely available and accepted; and identify additional SOPs needed to successfully carry out this strategy.

1.3.3 Coordinated Information Management

Much of the information currently available on the status and health of Puget Sound has been collected by numerous agencies through preexisting monitoring programs; however, this information has generally not been coordinated or shared in a way that helps scientists, managers, and decision-makers answer key questions about the health of the Puget Sound ecosystem. Information management will likely require the tracking of multiple types of data, collected by multiple organizations and individuals, related to other data in complex ways, and sought after by many interested stakeholders. This complex set of relationships requires a holistic evaluation of data needs and approaches for assembling the data. However, an aim towards early delivery of some data management is likely to be of highest priority, to ensure that the largest and most commonly requested data are managed in a manner that maintains integrity and maximizes data sharing.

Information management is a field of specialized effort, where experts in database design and construction, website design and construction, and user interface design and construction must interact with experts in the various types of monitoring programs described, and policy experts in the use of the information generated by the monitoring programs. This multidisciplinary approach, and the time needed to create the information management systems, suggests that this task is never to be "completed", even as new and improved systems are developed. Instead, information management builds upon completed systems and operates, maintains, and builds new systems to improve the sharing and analysis of information gathered.

Other entities in Puget Sound, including the Washington Forum on Monitoring Watershed Health and Salmon Recovery and the Pacific Northwest Aquatic Monitoring Partnership, are addressing regional data management needs. We will benefit from these efforts. In addition, the coordinated information management system will likely build on existing efforts for managing stormwater-related data. Several examples of existing systems include, but are not limited to:

- Washington Department of Ecology's Environmental Information Management (EIM) system. This system includes water quality, sediment quality, stormwater quality, effluent quality, and tissue quality data collected by Ecology and multiple other organizations.
- Washington Department of Ecology's Hydrology system. This system includes continuous weather, flow, and water quality data collected by Washington State Department of Ecology.
- United States Geologic Survey's National Hydrology System. This system includes hydrology data collected by the USGS from throughout the United States.
- Puget Sound Stream Benthos. This system includes the majority of the stream benthos data collected in the Puget Sound region since 2002.
- King County's Hydrologic Information Center. This system includes continuous weather, flow, and water quality data collected by King County. Copies of this data management system are also used by Pierce County and Kitsap Public Utilities.
- Snohomish County Stormwater NPDES Data Management System. This system houses data collected by Snohomish County under their current stormwater NPDES permit.

None of these examples would serve as a complete information management system for a coordinated stormwater monitoring and assessment program, but each could be leveraged to manage certain aspects of the program.

All monitoring results data, QC data, meta data, and reports should be stored in data management system(s) where responsibility for providing QA/QC for data and for correcting, editing, and updating data lies with the data generators, and where all data are easily shared with all interested parties and the public.

1.3.4 Ancillary Data

Many additional types of data are useful and necessary to understand stormwater impacts and effectiveness of management activities in Puget Sound. An extensive body of knowledge is available for us to build upon, and this provides another area for literature review. Some examples include:

- Land use and land cover data and other watershed characterization metrics. To allow for the extrapolation of information to unmonitored areas and at different scales, it is necessary to have land use and land cover data for the region, particularly for impervious surfaces. We recommend a standardized means to routinely update and verify this information across the Puget Sound region and utilizing it to provide a screening and guiding mechanism for targeting and refining our monitoring efforts.
- Climate data. Many different state and federal agencies, local jurisdictions, tribes, individuals, and businesses operate climate modeling systems throughout the Puget Sound region. Some of these systems have been in operation continuously for many decades, while others are recently installed. To allow for coordinated analysis of stormwater impacts, an agreed-upon set of climate data is important.

- Stormwater infrastructure mapping: The region's stormwater infrastructure has been built over the past decades with varying understanding and consideration of stormwater impacts, and even more variation in requirements to address these impacts. Current municipal stormwater permittees are mapping their storm sewer systems, an invaluable tool for source identification and diagnostic monitoring. Widespread cataloging of structural treatment practices could be immensely helpful for effectiveness studies.
- Transportation corridor information. Numerous metrics are available including but not limited to stream crossings, vehicle miles traveled, and average daily trips. We need to continue discussing which of these are most helpful to our understanding of how management actions prevent and reduce impacts.

The regional stormwater monitoring and assessment program will identify what descriptive ancillary data about watershed conditions are required to help explain monitoring results. These details need to be articulated in each experimental design as QAPPs are developed. National GIS standards should be applied throughout the region.

1.3.5 Modeling Activities

There must be a strong connection between this regional stormwater monitoring program (our data) and ongoing modeling activities. The intent of this regional strategy is to collect data that supports modeling activities and can be used to verify past efforts, transfer results to un-monitored parts of the watershed, and better describe the water quality improvements and other benefits expected from various management activities. Data collection must be targeted to modeling efforts that will be useful in providing insight to help answer our questions.

Modeling might use and expand the usefulness of the data obtained by the strategy in one or more of the following ways:

- To extrapolate and credibly transfer information obtained from localized monitoring efforts to larger scales or areas where monitoring does not take place, thereby extending the utility of the data to unmonitored areas.
- To examine different future-oriented and hypothetical scenarios for stormwater management that cannot be directly monitored, and
- To improve estimates of the origin and fate of contaminants in streams, interpretations of water quality patterns based on nonpoint and point pollution sources, and predictions of biota responses to water quality improvements or degradations.

A process whereby the data collected by the regional stormwater monitoring program feeds into the modeling work that is needed, and vice versa, does not exist. A list of modeling needs should be generated and prioritized for stormwater science and management issues. See the implementation recommendations in chapter 2.1.9.

1.3.6 Other Assessment Activities

In addition to, or to follow up on, analyses described in Section 1.2, standardized approaches for analyzing the data collected for this strategy need to be proposed in sufficient detail that sufficient resources are reserved for these analyses to be performed and the results communicated to stormwater managers and other key decision makers in a timely fashion.

1.3.7 Literature Review and Gap Analysis

Existing data and programs must be a foundation for all later work done by the regional monitoring and assessment program. This strategy outlines initial steps to tie the monitoring recommended here to other existing short- and long-term monitoring in Puget Sound. We also recognize the need for a thorough analysis that would result in:

- A catalog of watershed land-use metrics,
- Identification of stressors,
- Prioritization of at-risk watersheds,
- Identification of what techniques are most effective in which watersheds, and
- Identification of data gaps and needed research.

1.3.8 Gaps in this Document

Compliance monitoring and tracking actions: Specific needs for compliance and implementation information should be identified in the course of developing more detailed study designs, but this issue was not addressed directly. The SWG sees this as a future work plan item.

Global pollutant levels: Global pollutant loading impacts impacts the goals and activities of the regional stormwater monitoring and assessment program, and this strategy needs to tie into a bigger picture addressing this issue over the long term. Air deposition may be addressed in source identification and diagnostic monitoring.

Climate change: Climate change is a priority for the overall framework but not included in the initial prioritization and focus. We recognize that climate change impacts the goals and activities of the regional stormwater monitoring and assessment program, and this strategy needs to tie into a bigger picture addressing this issue over the long term.

1.4 Response to Formal Peer Reviews on November 2009 Draft Scientific Framework

This volume is substantially revised from the November 2009 draft. Changes were based on discussions of the five formal peer reviews; consideration of the more than 800 stakeholder comments we received; and new work that was done to address some of the gaps identified by the reviewers, to clarify our purpose and scope, to hone our priorities, and to improve our experimental designs. Here is a summary of the SWG's response to the formal peer reviewers' comments. Appendix H includes the details of our discussions and decisions made to address these issues together with the issues raised in stakeholder comments.

Scientific peer reviews on the *Draft Stormwater Monitoring and Assessment Strategy for the Puget Sound Region Volume 1: Scientific Framework* were conducted by Rich Horner, Bob Pitt, Jean Spooner, Tom Schueler, and Steve Weisberg. Their complete written reports are posted at http://sites.google.com/site/pugetsoundstormwaterworkgroup/home/strategy-document-comments/formal-scientific-peer-reviews. Below are the major themes of their collective reports that the SWG discussed early in the process of revising the scientific framework. As a group, the SWG came to agreement as to whether and how to address each of these issues.

Gaps in the document, and thoughts on our approach and categories of monitoring:

- Need a more descriptive discussion of the problems caused by stormwater, their specific sources, and objectives of categories of management actions (i.e. to improve conditions or to prevent degradation). Do a gap analysis relating to specific sources/stressors/ controls prior to designing effectiveness studies, and focus on filling those gaps.
  Response: We do need the gap analysis, and have taken initial steps to do conduct one. However we do not need another white paper on stormwater.
- Biological focus is good, but be sure to measure indicators that have quicker and more direct responses to stormwater management actions, like pollutant loads, sediment contamination, and hydrology.
  Response: Agreed. We have included both types of indicators.
- Connect all three types of monitoring. Put more focus on status assessment and what specific stressors are being evaluated, and include baseline or reference conditions.
  Response: Agreed. Although the categories of monitoring serve very different purposes it was important that we think about and describe their relationships for our readers.
- Source identification approach is too limited: tie in compliance monitoring, characterization data, and illicit discharge survey information to help diagnose reasons water quality/beneficial use conditions are not met. Connect this to receiving water monitoring and do this prior to designing effectiveness studies to help define goals and get a better idea of how much control may be needed to achieve a biological response. Good idea to inform region-wide source control efforts.
  Response: Agreed. We have developed a new approach to this category of monitoring and described it in the revised scientific framework.
- Describe the analyses that will be performed.
  Response: We agree that all of the data that will be collected needs to serve a particular purpose, but we disagree that the specific analyses need to be described in this document. QAPPs are yet to be developed for all of the monitoring described herein and those documents will describe analyses that will be performed.
- Describe how the adaptive management framework will be used both to inform the monitoring and after reporting monitoring findings.
  Response: Agreed. We have intended to do this to the extent possible during development of the full institutional framework for adaptive management of ecosystem recovery efforts.
- Add a research category to help improve overall mechanistic understanding of stormwater effects and controls.
  Response: Agreed. We added the category but have neither identified priority topics for this category nor articulated a process by which those topics should be identified. This merits future work.
- Identify and include descriptive ancillary data about watershed conditions such as specific development land use/land cover metrics to help explain monitoring results.
  Response: Agreed. These details need to be articulated in each experimental design as QAPPs are developed.
- Explain the important role and application of various types of modeling to help managers use the data collected.
  Response: Agreed. We have added a brief section and next steps to address modeling needs.

<u>Conceptual model and priorities for monitoring</u>:

- Fix the mix of beneficial uses and stressors listed in the table summarizing current understanding of the most significant stormwater impacts to beneficial uses (categorized by receiving water and major land-use category). It is confusing to readers and if made more stressor-effect specific can be better used to inform monitoring priorities. A few specific cells in the table were of concern.
  <u>Response</u>: *The table served its purpose in helping the SWG articulate its priorities but was not sufficiently backed up by scientific references. We modified our approach to the conceptual model and offer a different table that we believe is less confusing.*
- Overall, reviewers support an initial emphasis on small streams and nearshore, and probably would add lakes next.
  <u>Response</u>: *Thank you. We have augmented our best professional judgment with a look at existing data that is presented in our revised section on monitoring priorities. We would like to address other water bodies besides small streams and nearshore areas in the future and also emphasize that water bodies of local concern still warrant local attention.*
- Need to look at mosaic pattern of land development, including changes in infrastructure and treatment over the past decades.
  <u>Response</u>: *We agree with this statement and are primarily addressing this issue within our proposed focus areas for effectiveness studies: retrofitting will take place in areas with older infrastructure and LID will take place in new development. The proposed inventory could be a useful tool and we will look into this further in future development of the source identification category of monitoring.*
- Definition of stormwater needs to include human activities.
  <u>Response</u>: *Agreed. We added non-precipitation-generated flows to our definition.*

<u>Hypotheses</u>:

- Reviewers made numerous specific comments about individual hypotheses. In general, they were concerned that the set of hypotheses in the November 2009 draft document oversimplified the situation and may not provide the best approach for designing a regional monitoring program. Some suggested fixes included rewriting in a way that: not all of the hypotheses should be assumed true unless otherwise proven; consider more neutral statements, and/or more quantitative, stressor-specific statements; and consider a rating or ranking system. Reviewers also suggested that we conduct a literature review and look at findings elsewhere.
  <u>Response</u>: *Agreed. We took a more thoughtful approach to translating our assessment questions into hypotheses for this version of the scientific framework. As a result we are at different places in articulating the hypotheses for each category of monitoring. We also include literature reviews as early implementation steps, most particularly to inform our selection of hypotheses for effectiveness studies.*
- Need more definition of "increased or improved stormwater management efforts."
  <u>Response</u>: *Agreed, particularly for effectiveness studies. For status-and-trends monitoring we are looking at broad, programmatic efforts and therefore can be more general. In selecting testable effectiveness hypotheses, we will describe: the specific type of actions targeted for evaluation, why we are targeting each action (the potential*

relevance of the actions to correct regional problems), and assumptions about its effectiveness.

- Effectiveness studies need more focus on specific beneficial use endpoints.
  Response*: Agreed in principle, however in practice we will initially focus on more proximate indicators and perhaps articulate research needs to tie reductions in stressors to improvements in beneficial uses.*
- Address construction phase impacts from which beneficial uses might not recover.
  Response*: We agree that these impacts are important to understand better, but beyond our highlighting impacts of hydrologic alterations these changes were not identified as a priority topic for investigation in the initial phase of the regional monitoring program.*

Experimental designs:

- Difficult to determine cause and effect for the chosen designs.
  Response*: We have substantially revised our experimental designs, and attempted to be more specific about what we can and cannot infer from findings of each type of monitoring.*
- Concerns about probabilistic design, analyses, and about parameters selected need to be addressed in evaluating and rewriting Experimental Design sections and appendices.
  Response*: This section has been revised and the concerns addressed to the extent that we were able. Future work will need to address unresolved issues.*

The reviewers also offered many comments about implementation planning, including the importance of having an overarching strategy to assign roles and responsibilities, establish standard methods, and coordinate/manage the information that is collected. The reviewers' input related to implementation planning was considered in developing the following chapter of this document and will continue to inform later work by the SWG.

VOLUME 2. IMPLEMENTATION PLAN

This implementation plan details our recommendations for implementing the scientific framework described in the previous volume. It recommends roles and responsibilities for local jurisdictions, state and federal agencies, businesses, and others who are directly or indirectly responsible for managing stormwater or affected resources, to participate in implementing the strategy and includes specific next steps and estimated costs. These recommendations also answer Ecology's request that we inform their allocation of required local government responsibilities in the next cycle of Clean Water Act National Pollutant Discharge and Elimination System (NPDES) municipal stormwater permits.

To successfully implement this strategy and support this new, integrated monitoring system, local jurisdictions, state and federal government agencies, and others will need to work together to develop and adopt new methods and infrastructure such as regional standardized operating protocols, data repositories, and regional conferences.

2.1 Regional Program Implementation Components

The Puget Sound Stormwater Work Group (SWG) was created by the Puget Sound Monitoring Consortium (Consortium) in 2008. The Consortium was a time-limited stakeholder group funded by the state legislature "facilitate the development of an ongoing monitoring consortium similar to Chesapeake Bay or San Francisco Bay to institute coordination between local, state, and regional monitoring agencies. The goal is to integrate ongoing monitoring efforts for stormwater, water quality, watershed health, and other state indicators and enhance monitoring efforts in Puget Sound.". The Consortium proposed a *Puget Sound Coordinated Regional Monitoring and Assessment Program* with authority to assure funding; ensure high-quality science, including adequate study design, QA/QC, and peer review; track projects; develop and maintain databases; conduct cross-topic synthesis and analysis; and more. The Consortium's proposal (http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/PSMC10Dec08ReportToLegislature.pdf) was taken on by the Partnership, which is in the early stages of implementing the first recommendations and establishing an ecosystem monitoring program to coordinate and manage this effort and connect it to other topic-driven monitoring coordination and prioritization efforts. The following sections describe steps toward providing the governance structures and financial arrangements for stormwater monitoring without presupposing or posing obstacles to making the necessary arrangements for ecosystem monitoring.

The activities recommended in the scientific framework for regional stormwater monitoring (volume 1 of this document) should ideally be conducted as part of the larger regional effort to monitor stressors, biota, and management activities, and other key aspects of the ecosystem critical to understanding its function and assessing progress toward its recovery. The Partnership, in advance of its efforts to create such a system, and in the absence of such a program, tasked the SWG with developing a component of the program to address stormwater and link to other program components. The effort underway by the Partnership will elaborate on how the full adaptive management framework will function to get corrective feedback to managers, make this monitoring program more useful, and help us communicate the information.

The SWG recommends that the following steps be taken to support regional implementation of a new regional stormwater monitoring and assessment program. In establishing our process, deciding upon a framework for the regional stormwater monitoring strategy, and making the recommendations, the SWG has relied heavily on the consensus recommendations of the Puget Sound Monitoring Consortium. The essential functions and characteristics of a successful regional monitoring program, as described in the Consortium's report to the Legislature, (http://www.ecy.wa.gov/programs/wq/psmonitoring/swworkgroup.html) apply to our recommendations, described in detail in the following sections.

2.1.1 Use Stormwater Work Group to Continue to Prioritize Stormwater Monitoring and Assessment Activities

The SWG is one of many topical work groups that will be coordinated, connected, and integrated by direct representation on the technical committee of the broader ecosystem monitoring program. The SWG has been formally established as the stakeholder group to oversee collective regional science needs for the topic of stormwater, and has been learning through applying this new process to collective prioritization. Several SWG members and staff also participate on other topical work groups, enhancing coordination and communication. The SWG represents a substantial investment in time and staff contributions from participating entities. The SWG has reached a level of group process and function that would take a long period of time to recreate. Ecology and the Partnership should evaluate the SWG and decide upon a permanent charter, composition, host agency, stable funding, and means to support long-term participation by stakeholders. They should also approve future SWG work plans.

We recommend that approach described in our bylaws and charter (http://www.ecy.wa.gov/programs/wq/psmonitoring/swworkgroup.html) be continued, with modifications as needed to improve our ability to perform and maintain these essential ongoing roles and functions:

- <u>Decision making and leadership</u>: Set priorities within broad scientific framework; get stakeholder buy-in on recommendations; and encourage broad participation.
- <u>Coordination and communication</u>: Establish and maintain connections to other topical work groups and to other existing efforts; recommend assigned roles and responsibilities.
- <u>Advising the regional stormwater control strategy</u>: Recommend stormwater management actions and provide a sounding board for ideas.

2.1.2 Secure Long-term, Sustainable Funding for Stormwater Monitoring and Assessment

Long-term, sustainable funding sources for the regional stormwater monitoring and assessment program will be identified and secured over time. The SWG is currently working to refine cost estimates and propose realistic funding mechanisms for Ecology and the Partnership to implement and advocate in the couple of years.

Funding and/or in-kind services should be contributed by all of the regional entities participating in the program. Entities conducting the regional monitoring and assessment component activities should partner to share resources and reduce costs.

Dear Readers: We understand that you want to know:

- What does the complete proposed stormwater monitoring and assessment program "package" look like, and how much will it cost?
- What are the funding sources and what is needed to maintain those sources over the long term to make the program sustainable?

We do not presently have complete answers to these questions, but we will share our progress at our public workshop on May 19, 2010 at the Renton Community Center. We will get feedback there, and include updated information in our final recommendations to Ecology, the Partnership, and others, at the end of June. Please consider joining us for the workshop. Pre-registration is required at http://swgworkshop3.eventbrite.com/ by 3:00 on Friday May 14th.

2.1.3 Determine Appropriate Cost-share Level for NPDES Permittees

Municipal stormwater NPDES permittees, particularly local governments, ports, and the Washington State Department of Transportation, will play a substantial role in funding and implementing regional stormwater monitoring. The mandated cost to, or level of effort contributed by, each local jurisdiction covered under the municipal stormwater NPDES permits should be based on equitable factors. Other municipal stormwater NPDES permittees should contribute equitably to the regional stormwater monitoring and assessment program.

As an example, if the local government cost share were based on population:

- If the total cost for local government NPDES permit components of the regional monitoring program was expected to be $15 million over five years and the cost were distributed evenly according to the estimated population for 2009, the smallest jurisdiction (population 2,760) would pay about $2,000 into the fund each year, the median-sized jurisdiction (population 16,710) would pay about $12,000, and the largest jurisdiction (population 602,000) would pay or otherwise contribute about $715,000.
- For a total cost of $50 million over five years, the smallest jurisdiction would contribute about $6,600 each year, the median jurisdiction about $40,000, and the largest jurisdiction about $1.4 million.

The total recommended level of effort for the combined regional stormwater monitoring program will be more clearly defined by June 2010. The SWG will then recommend an appropriate NPDES permittee cost-share to Ecology. The final cost-share will be formally established as part of the process of issuing the revised municipal stormwater NPDES permits for local governments. In order to be included in the permits, an administrative means to collect and manage cost-share contributions needs to be decided upon and established in the next six months.

Create a Fund Dedicated to Stormwater Monitoring and Assessment that Provides a Pay-in Option for NPDES Permittees

The SWG recommends that a fund be formally and permanently established and dedicated exclusively to implementing prioritized stormwater-related monitoring and assessment activities in the Puget Sound region. The fund will provide a technically and fiscally credible means of coordinating stormwater-related data collection and analyses, sharing data, and reporting findings. Collective pay-in to the fund will enable the fund to carry out regional stormwater science monitoring and assessment activities as articulated in other SWG recommendations.

The fund will serve as a cash flow tool to facilitate sustained long-term stormwater monitoring by accommodating annual payments by permittees and other participants. Expenditures by the fund cannot exceed the committed contributions; nor can funds be diverted to unapproved projects. Any and all interested parties can pay into the fund. The fund will enter into contracts for data collection, studies, and analyses. Its role and activities will begin with providing and/or supporting implementation of: regional status-and-trends monitoring, source identification investigations, effectiveness studies, data management and accessibility, and analysis and synthesis. Over time the activities will include: continued development of standard methods and procedures, cross-topic analyses and synthesis, and development of models to support extrapolation and extension of findings.

For NPDES permit-required monitoring activities in Puget Sound, a “pay or play” option needs to be adopted and approved by Ecology for 2012 and beyond. Other regulated entities should be able to meet part of their monitoring requirements through participation in the future, but we recommend beginning this program with a focus on municipal stormwater permittees. The SWG will make establishment of this fund a priority for fall 2010.

We recommend a “pay-in option” dedicated to stormwater-related monitoring and assessment with the following characteristics:

- It allows permittees flexibility to meet requirements by *either* paying into the fund, *or* conducting monitoring activities themselves,
- It ensures that permittees’ contributions are spent exclusively on monitoring activities that are related to municipal stormwater management, and have quality assurance project plans (QAPPs) that have been reviewed and approved by Ecology,
- It is independently managed by an entity, whose budget is permanently dedicated to monitoring and cannot be re-appropriated to other purposes by any legislative body,
- It allows and encourages all entities in the region to contribute to and participate in coordinated regional monitoring activities, and
- It provides businesses and other NPDES permittees with a future pay-in option.

We recommend that annual contributions from permittees be expected at the levels of effort recommended in each of the specific sections outlining the roles and responsibilities for status-and-trends, source identification, and effectiveness studies, plus a modest amount to support overall assessments and administration of the fund. The funding mechanism should maintain different accounts for specific science activities and for overall assessment. Adequate flexibility must remain to allow permittees to conduct some or all of their required status-and-trends, source identification, and effectiveness studies themselves. However, all permittees should be required to pay into the fund at a reasonable level to sustainably maintain the infrastructure of the regional monitoring program and its overarching responsibilities for contract oversight, data management, and synthesis activities.

Ecology and the local government caucus will help the SWG develop fiscal oversight and work planning arrangements that ensure the funds are dedicated to activities and products that meet needs of permitting authorities, permittees, and others who pay in. The structure and an initial, phased work plan should be developed in the coming six to nine months and finalized by March 2011 in time for the pay-in option to be included in the next round of municipal stormwater NPDES permits. The program should begin phased-in implementation in late 2012 or early 2013.

> Dear Readers: Fiscally and technically credible oversight of a pay-in option will be essential for the success of this program. We believe that the entity charged with this task should be separate from the SWG, from Ecology, and from the ecosystem monitoring program. Program start-up will be much more efficient if housed in an existing institution. Some plausible options to explore in the coming 6 months include but are not limited to: the new Stormwater Technical Resource Center; the new Puget Sound Institute; or a private entity. Do you have any preferences, or other recommendations, for selecting a "house" for the pay-in option?

2.1.4 Continue Key State and Federal Monitoring Programs

State and federal agencies, and in particular their ongoing monitoring programs, play an important ongoing role in the regional stormwater monitoring and assessment program and provide key information to answer important stormwater questions. In particular, we recommend the following monitoring activities that are currently funded and conducted by state and federal agencies should continue:

- Ecology's statewide status-and-trend monitoring program (State EMAP),
- Fish diversity and abundance monitoring for salmon recovery efforts,
- Shellfish bed monitoring by state and local health departments,
- Puget Sound Mussel Watch, and
- Sediment and other nearshore monitoring by the Puget Sound Assessment and Monitoring Program (PSAMP).

Memoranda of understanding may need to be adopted to implement components of these programs with shared responsibilities.

2.1.5 Conduct Targeted Literature Reviews

The literature reviews that are detailed in the scientific framework for each category of monitoring should be conducted in the coming six months to one year to further inform the development and finalization of initial study designs. Each will be targeted differently, but categories include: review of existing data; compilation of programs; review of specific types of effectiveness studies; identification of data gaps and research needs; identification of modeling activities and needs. These literatures should use other compilations from around the country (CASQWA, CWP). These reviews should cost somewhere between $15,000 and $40,000 depending primarily on the number and timing of reviews to be conducted to assist in selection and design of effectiveness studies.

2.1.6 Formalize a Process to Develop and Approve Standard Methods

The following necessary steps must be taken to ensure that credible data are collected in a quality manner for all monitoring and assessment conducted by the regional program:

- data quality objectives must be identified;
- project plans must be approved and shared;
- standard field collection and data reporting protocols must be followed followed;
- appropriate analytical accuracy, precision, detection, and reporting limits must be used at accredited laboratories; and
- geographic information system (GIS) data must follow state guidelines.

Among the pilot projects conducted by the Puget Sound Monitoring Consortium in 2008-09 was an effort to brainstorm and prioritize what standard methods needed to be adopted and used in order to be able to collectively analyze and interpret stormwater data collected in the region. We recommend that regional program participants contribute to and participate in ongoing efforts to develop and approve new standard methods.

We further recommend that an online a library be populated with an extensive set of approved standard operating procedures, methods, and protocols for stormwater-related data collection. Accompanying this library should be a prioritized list of methods that need to be standardized to improve our ability to perform regional science assessments with data collected by multiple entities. NPDES permittees doing their own monitoring would be required to follow (select from) these prescribed, web-accessible methods. Detailed recommendations for SOP elements are provided in Appendix G.

Recommended Process for Developing New SOPs

The 2008-09 SOP Pilot project was formed and funded by the Puget Sound Monitoring Consortium (http://www.ecy.wa.gov/programs/wq/psmonitoring/technical_advisory.html). This group developed a process for developing stormwater-related SOPs by partnering with multiple stakeholders to provide maximum information, research and resources and ensure clear interpretation. This collaborative SOP process is currently in place, but unfunded. Continuation of this group through the SWG can provide a means to develop SOPs for the regional stormwater monitoring projects. SOPs identified by the SWG can be developed and maintained to provide a comparable set of reliable data that can be used to confidently identify stormwater concerns and address them with an effective management strategy. For successful SOPs to be developed, strong leadership and funding are needed. In order to successfully develop SOPs the SWG should do the following:

- Identify specifically what type of SOPs will be needed in order to implement the design.
- Identify funding sources and costs associated with developing the necessary SOPs.
- Identify how SOPs will be managed, updated, and shared with the public.
- Identify the process for development, review and approval process, building upon the current the SOP group's process and lessons learned.

- Identify stakeholders and participants who should be involved with development, review and approval of SOPs.

Costs and Schedule

The SOP group demonstrated that four SOPs can be developed in one year at a cost between approximately $40,000 and $60,000.

2.1.7 Create and Maintain a Data Management System

The regional stormwater monitoring and assessment program needs a data repository, storage, and management structures that do not currently exist.

We believe that developing such a system will take the coordinated effort from a multidisciplinary team from multiple organizations. We recommend that such a team strive to leverage existing capacities, as described in section 1.3.3. We also recommend that all entities contribute funding and/or in-kind services to data management and data analysis activities.

There are multiple possible approaches that could be used to achieve the vision of the coordinated data management system. It is possible that different "modules" could be created to serve the different categories and components of the coordinated monitoring and assessment strategy. These modules would then feed data into a data mart, or be accessible via a single web portal, to allow for analysis across multiple data types. Also of critical importance is the standardization and automation of data analysis to track key indicators, such as the stream water quality index, and making these results available via the web.

The multidisciplinary, multi-entity data management team tasked with developing the data management framework will be need to assess all existing systems, understand the requirements of the new system, identify overlap, and identify a work plan for filling the gaps. This task is likely to be relatively time consuming, and it would be highly advantageous to complete this task, and begin constructing the new system, before additional data gets collected. The SWG should be responsible for reviewing and approving the data management approach. Examples of some key issues that need to be considered when designing a data management system are listed in Appendix I.

2.1.8 Create and Maintain an Inventory of Monitoring and Assessment Activities in the Puget Sound Basin

As part this effort to establish of a coordinated regional program, we have begun to assemble an inventory of existing and recently completed monitoring and assessment projects, studies and on-going programs in the Puget Sound Basin. The inventory is a work in progress and is not complete. It is being released concurrent with this draft comment period in order to solicit your help in filling in the gaps. We plan to continue to update and correct the inventory through at least fall 2010. It will ultimately be housed and maintained by the new ecosystem monitoring program that is presently being created by the Partnership, and will be turned over to them when they are ready for it. The inventory should be ongoing, with regular updates.

Dear Readers: The inventory was not available for posting at the time of this publication. Please check http://sites.google.com/site/pugetsoundstormwaterworkgroup/home/april-30-2010-public-comment-draft-strategy or contact Heather Trim directly at htrim@pugetsound.org if you would like to take a look at the Excel spreadsheet under development. She would appreciate your feedback as to whether programs are missing and to help her fill in the gaps. This is a large undertaking and she has only scratched the surface and will appreciate your help! Send additions/corrections to the inventory to Heather, not as comments on this strategy.

2.1.9 Identify and Prioritize Regional Stormwater Modeling Needs

The regional stormwater monitoring and assessment program intends to collect data that is needed and relevant for many stormwater-related models, and key relevant data gaps. In the coming year, the SWG will go through/identify the list of most relevant models that are in use or under development and identify their stormwater-related data needs. There are different types of models that 1) model problems and mechanisms; 2) extrapolate results from small scale studies to regional effects; and 3) infer or estimate the benefits associated with different management actions. The goal is to connect stormwater-related monitoring to the models that support actions to restore watershed health, but the specifics of all the possible connections is outside the scope of this document.

A process is needed to determine what data would support those efforts. What priorities have been identified by the Puget Sound Science Panel, Ecosystem Coordination Board, and Leadership Council? What focus do we need for stormwater management? How can we cross boundaries to see where our efforts inform other activities? Specifically, our objectives are to:

- Identify relevant regional efforts that are underway to predict the outcomes of various land-use or other stormwater management scenarios,
- Work with modeling experts to identify specific stormwater-related data needs for models, and
- Incorporate a modeling-specific data collection plan into the strategy.

2.2 Implementation Plan for Status-and-Trends Monitoring

Establishing a new, coordinated regional stormwater monitoring and assessment program with a watershed focus will be a fundamental change from current NPDES permit-required and other current monitoring efforts. Status-and-trends monitoring has two parts: 1) "status" is the assessment of current conditions and 2) "trends" is the ability to see changes over time. Status can be analyzed after each sampling period, whereas trends will require time for results of management actions to emerge and a level of monitoring rigor to accurately detect changes. As with any new venture, we strongly recommend that this program be flexible enough to respond to lessons learned during implementation.

Once the conceptual study recommendation is approved, there are many tasks to be completed before the monitoring program is ready to be implemented. The SWG, local governments, other permittees, Ecology, and others will need to work together to complete these tasks to a sufficient level to apply the recommendations in the next municipal stormwater NPDES permit. It is anticipated that tasks 1 through 5 would need to be completed by fall 2010 for inclusion into the 2012-2017 municipal stormwater NPDES permits.

In addition, many of the necessary tasks related to organizational structure, database development and management, and other aspects that will be common to multiple categories of monitoring are not explicitly described in this outline.

Task 1. Refine Hypotheses re. Stormwater Impacts on Aquatic Biota

- Revisit initial hypotheses and draft more specific questions to be answered through status-and-trends monitoring (*e.g.*, benthic scores remain stable or improve over time despite new development in catchment area; biological conditions at sites under new stormwater standards are closer to biological potential than sites developed under older standards).
- Discuss basin characterization data needed to interpret results (*e.g.*, key stressors in area draining to site)
- Statistical considerations

Task 2. Review Existing Programs for Potential Coordination Opportunities

- Review monitoring program inventory currently under development (see section 2.1.8).
- Compare salient data (*e.g.*, monitoring objectives, parameters, sites, frequency, duration, QA/QC level, reporting) to proposed SWG monitoring program.
- Identify potential coordination opportunities. Discuss with contacts. Develop appropriate formal agreements. Refine agreements if needed after final site selection (Task 6).
- Consult with PSAMP regarding coordination and opportunities for refining the study design for sediment sampling in the Puget Sound nearshore.

Task 3. Refine Sampling Design

- Develop initial statistical goal.
- Estimate number of observations needed to attain goal based on expected variability of key indicator parameters (*i.e.*, do not try to assess variability of each pesticide or endocrine disrupter).
- For random monitoring:
    - Define weighting criteria (different criteria for urban and rural WRIAs).
    - Identify marine outfalls to establish sampling frame for mussel watch and fecal coliform sites.
    - Apply EMAP procedures to develop candidate site list.
    - Evaluate randomly selected sites to identify any that are already being monitored.
    - Use GIS data to screen out sites that are likely to be unsuitable based on physical access or lack of desired channel conditions (e.g. too steep). Sort sites into physical access categories (e.g., easy, medium, hard) to allow estimation of level of effort (see Task 5). Identify sites that will require legal access requirements.
    - Continue until target # of sites is attained (or scale back on statistical goal).
- Freshwater flow and temperature sites:
    - Evaluate existing gages with respect to :
        - Proximity downstream of S&T sites,
        - Length of record,
        - Estimated accuracy, and

- Other considerations (*e.g.*, high flow access, power, vandalism).

Task 4. Document Monitoring Protocols

- Describe monitoring locations, frequency, field methods, health and safety, analytical methods, data quality objectives, QA/QC sample needs, data review and reporting.
- Incorporate EMAP and other existing protocols by reference.
- Identify responsibilities (*e.g.*, monitoring activities to be performed by volunteers or added to other on-going programs identified in Task 2, in-kind contributions).

Task 5. Refine Monitoring Cost Estimates

- Develop a more detailed cost estimate for each monitoring component (i.e., WQI, physical channel, sediment). Consider the following line items:
  - Site visits to finalize monitoring locations
  - Legal access negotiations
  - Site recon
  - Mobilization (acquisition of equipment and materials, monitoring team training)
  - Equipment installation
  - Monitoring procedures
  - Lab procedures
  - QA/QC
  - Data review and reporting
  - Data management

Task 6: Develop Implementation Agreements

- Develop formal interagency agreements as needed for NPDES monitoring at watershed scale.
- Identify cost-sharing arrangements that are equitable for NPDES permittees for both pay-in and in-kind contributions.
- Identify monitoring team members and specific assignments. Encourage volunteers where appropriate. Provide them with relevant monitoring documents from Task 4.

Task 7. Finalize Sites

- Obtain permission to inspect candidate sites on private property. If permission is not granted, remove site from pool of candidate sites.
- Visit candidate sites to evaluate suitability for monitoring (*e.g.*, riffles for BIBI, low velocity areas for sediment sampling, physical access). Prepare maps showing exact locations for monitoring, site access route, *etc*.
- Negotiate legal access for monitoring of suitable sites on private property. Coordinate with local jurisdictions if appropriate to facilitate negotiations.
- Coordinate with other jurisdictions (*e.g.*, tribes, federal agencies) where necessary to access sites.
- Eliminate sites with physical or long-term legal access problems.
- Prepare final site list.
- Update Task 4 monitoring documents and Task 5 cost estimates to reflect final site list.

Task 8. Mobilize (training, equipment, materials)

- Identify monitoring team members and specific assignments. Encourage volunteers where appropriate. Provide them with relevant monitoring documents from Task 4.

- Acquire equipment and materials if needed (e.g., stage and/or velocity sensors and data loggers for new flow gages). Get permits for electro-fishing.
- Install equipment.
- Train field crews to ensure they are familiar with monitoring procedures, site locations, etc.

Task 9. Implement Monitoring

- Freshwater
  - Water Quality Index, rotating – sample 390 sites twice per 5-yr permit term
  - Water Quality Index, permanent – sample 30 sites monthly
  - Benthic macroinvertebrates – sample 390 sites twice per 5-yr permit term.
  - Periphyton – two pilot studies during 5-yr permit term
  - Fish surveys – two surveys at 390 sites per 5-yr permit term
  - Stream physical features – two surveys at 390 sites per 5-yr permit term
  - Flow – continuous at 13 gages
  - Temperature – continuous at flow gages
  - Bottom sediment metals – annual grabs at 390 sites
  - Bottom sediment toxics – annual grabs at 30 sites
- Marine Nearshore
  - Fecal coliform – sample 50 sites monthly
  - Mussel watch bioaccumulation toxicity – annual at 30 sites
  - Bottom sediment metals and toxics – annual grabs at 30 sites

Task 10. Analyze Results

- Perform lab data quality review after each sampling round. Flag any results that did not meet data quality criteria. Work with lab and/or field crews to correct any problems.
- Screen qualified results to identify sites where rapid follow-up (*e.g.*, source identification) may be warranted.
- At end of each year, evaluate monitoring results to summarize current status and variability of each parameter. Evaluate sites with pre-existing data to discern potential trends.
- At end of year two, revisit monitoring results and identify monitoring components that may need to be adjusted (e.g., remove parameters that consistently met criteria). Discuss adjustments with SWG and Ecology. Refine monitoring protocols as needed. Train monitoring team members in new procedures.
- At end of year four, review the periphyton and mussel watch pilot study results. Identify potential improvements to monitoring procedures. Discuss potential changes with SWG and Ecology. Recommend revisions for next NPDES permit term.

Task 11. Prepare Reports

- In year five, prepare reports summarizing the status-and-trends monitoring results, tailored to the target audiences listed below.
  - SWG report: Summarize results and recommend changes in monitoring strategy as appropriate.
  - WRIA report: Summarize results to facilitate use by WRIA-based salmon restoration and shoreline management programs; identify areas where source identification appears warranted.

- Puget Sound report: Summarize key findings with respect to Puget Sound clean-up actions and priorities.
- Other reports as identified.

2.3 Implementation Plan for Source Identification and Diagnostic Monitoring

A comprehensive regional stormwater source identification and diagnostic monitoring framework is needed to help inform and prioritize both local and regional source control activities. This category of monitoring is focused on determining the highest priority impairments and subsequently implementing management actions to identify and correct the source of the impairment. This section outlines a diagnostic process to find causes of problems and fix them rapidly, with a feedback loop to confirm improvements in the receiving waters.

Such a framework will target limited resources in each WRIA on restoring the highest priority impairments (failed receiving water biological endpoints) related to stormwater impacts. Source identification and diagnostic monitoring are conducted to address long-term receiving-water impairments, as part of a broader effort to identify and eliminate pollution sources. Watershed-specific priorities should be set to target initial source identification and diagnostic monitoring efforts on the impairments of greatest local concern. Regional and local monitoring data should be reviewed at least every five years to help identify and prioritize which problems to address.

Most source identification activities are appropriately undertaken by local jurisdictions because they have detailed knowledge of their respective land uses, receiving waters, and potential pollutant sources. Unfortunately, while some local jurisdictions have in-house expertise and capacity to undertake these types of source identification and diagnostic monitoring efforts, many do not. In addition, many source identification efforts require working across departments (*e.g.*, the local health department and surface water management utility) within each jurisdiction and across multiple jurisdictions since the receiving water cross jurisdictional boundaries. Specifically, if the status-and-trends monitoring of small streams identifies stream segments that are more directly degraded by stormwater relative to others, this information will used to implement more intensive investigations within associated upstream tributaries and stormwater conveyance systems to identify the specific source of the degradation.

Conversely, more specific contaminants associated with particular land uses (or specific high-risk activities within particular land uses) identified through local source identification activities may be recognized as problems that should be addressed regionally. We need an established process for elevating those issues. The collective information gained from local source identification activities should be routinely assessed to identify such regional issues. SOPs and data reporting requirements need to be established to enable a collective regional assessment of the source identification and diagnostic monitoring information gathered locally.

2.3.1 Prioritize Problems/Impairments for Source Identification and Diagnostic Monitoring

Local entities have limited resources available for source identification, diagnostic monitoring, and water resources management. Many WRIAs may identify more problems than can be investigated at a particular time. Therefore, it will be necessary to prioritize the identified problems/impairments so that source identification is focused on the most important problems.

In the next six months, Ecology will lead a process, through the SWG, to recommend an approach to source identification monitoring for the municipal stormwater NPDES permits, including appropriate roles and responsibilities. Funding sources, roles, and responsibilities are not limited to NPDES permittees; however an appropriate level of effort for permittees needs to be determined, and responsibility for diagnosing and solving problems needs to be distributed equitably. This process will be informed by information about stormwater-related impairments around Puget Sound, particularly an analysis of water bodies where Total Maximum Daily Loads (TMDLs) might be avoided by implementation of early action plans.

A regional data base is needed to inform the prioritization effort, assist in developing plans to address problems, and share knowledge across watersheds and the region. The 5-year municipal stormwater NPDES permit term could provide a helpful and predictable framework for scheduling and implementing prioritization. Prioritization should consider local concerns as well as priorities for the Puget Sound region. For example, problems could be ranked based on:

- Potential to cause or contribute to shellfish closures
- Potential source of constituent(s) of concern for a TMDL or Category 5 water body
- Potential impact on existing or planned salmon habitat restoration project(s)
- Potential importance of municipal stormwater discharges
- Poor benthic macroinvertebrate health compared to other sites with similar levels of urban development (*e.g.*, based on Water Environment Research Foundation (WERF) bioassessment method). For example, sites with good biological potential but relatively poor current conditions could be classified as high priority for source identification.

2.3.2 Schedule and Sequencing

This timeline assumes that the prioritization cycle will be integrated with the five-year permit cycle beginning in February 2012.

Activity	Timeframe
Review existing data to identify & prioritize problems	2012
Perform source identification on top priority problems	2013-14
Implement early action plans	2013
Prepare scope & budgets for source control planning and CIP	2014-2015
Review S&T or other new data to identify & prioritize problems	2016

2.3.3 Roles and Responsibilities for Source Identification and Diagnostic Monitoring

Municipal stormwater NPDES permittees should lead source identification activities for stormwater-related problems that have been identified based on water quality constituent concentrations in their jurisdictions. Particularly where problems affect multiple jurisdictions, Dear Reader, We have a series of questions about implementing this overall approach to source identification and diagnostic monitoring:

- How many priority problem areas should be pursued for plans and implementation over a five year period? Should it be a fixed number per WRIA, with equal effort take place in each WRIA? Or should prioritization occur regionally?
- Should priority projects for each WRIA compete for regional funds in a grant program similar to the Centennial Clean Water Fund administered by Ecology? Who is the right entity to oversee such a process: Ecology? the SWG? Are different processes needed for local and regional efforts?
- What do you recommend for a prioritization cycle? Should it be integrated with the five-year cycle of the municipal stormwater NPDES permits?
- Realizing that not all jurisdictions have the expertise, staff and resources to perform monitoring to locate sources and track progress, should there be an option to draw upon a regional fund to pay in to, or perform the monitoring by the jurisdiction?
- Should source identification and diagnostic monitoring utilize the framework of 303(d) Category 4b? This provides a framework to implement a pollution control project under specified criteria, rather than a TMDL. It may be more cost effective and efficient. This framework is found in Ecology WQP Policy 1-11 pp. 12-15. Should this framework be within the NPDES permit system?

the permittees should coordinate and involve other entities as needed. Biological impairments can be more difficult to diagnose than water quality impairments because they could be related to a wide array of chemical, physical, and/or biological stressors. Some jurisdictions may not have the staff resources to evaluate the full range of potential stressors. Therefore, diagnostic monitoring for biological impairments should be led by the regional status-and-trends monitoring group, with support from the affected local jurisdiction(s).

2.3.4 Support Structure and Tools

The following processes/activities need to be established/conducted in coordination with the activities described in the timeline in section 2.3.2 above.

- Determine WRIA-based groups or lead entities to organize prioritization, or a municipal NPDES permit-based implementation scheme.
- At least every five years, review the status-and-trends monitoring data for small streams and the nearshore to identify additional problem areas that warrant source identification and diagnostic monitoring.

  - Also review additional information generated from other monitoring efforts. These data will be evaluated and incorporated into the prioritization process on regular intervals. This will require coordination with other monitoring programs.
- Create regional tools, where possible, and methods to remove sources including failing onsite sewage systems, agricultural manure practices, illicit connections, and enforcement.
- Develop source control program effectiveness evaluation methods regionally.
- Develop a feedback loop system for data to be used by local entities to determine effectiveness of source control activities.
- Establish a Puget Sound regional source control effectiveness evaluation monitoring program focused on quantifying source control activities. Determine Puget Sound-wide definitions for source control actions including enforcement, inspections, etc. The purpose is to inform assessment of effectiveness at the regional level.
- Implement data management structures and develop standard data collection and reporting methods for source identification and diagnostic monitoring.

2.3.5 Costs

The cost to develop a source identification and removal plan is dependent upon several factors including the size of the sub-basin, the source, the management actions and the extent of the impairment. Two cost estimate examples are provided below:

<u>Example 1</u>: City of Tacoma (De Leon and Thornburgh 2009)
Thea Foss Basin Source Control Program
Impairment: Metals, PAHs, DEHP in sediment
Implementation Activities: Source tracing investigations, business inspections, data analyis/reporting, program management, $260,000 annually 2007-2011
Monitoring: Stormwater outfall and storm system sediment trap 2007-2009 $5 million, 2009-2010 $6 million.

<u>Example 2</u>: Kitsap County Health District (Bazzell 2009)
North Dyes Inlet Restoration
Impairment: Fecal coliform bacteria, marine nearshore receiving water body and stream
Implementation activities: Septic system inspections, commercial property inspections, source control tracing and correction, cost-$350 per septic inspection, $160 per commercial property inspection, $1,000 per source control tracing, Total program cost for 250 properties $110,000. 2003-2006.
Monitoring: $10,000 annually for fecal coliform trend monitoring and tracing.

2.4 Implementation Plan for Effectiveness Studies

To implement stormwater management effectiveness studies, we recommend that a public and transparent process be developed and initiated to identify and prioritize effectiveness hypotheses (see below). Effectiveness studies should be conducted, as appropriate, at the site, watershed, and regional scales. Studies should include programmatic approaches as well as specific practices and activities, and should include the analysis of costs of the technique studied.

Additional specific questions to guide initial development of effectiveness studies are provided in Appendix G. For each hypotheses-driving question, the following information must inform refinement of the questions into working hypotheses: 1) who will be responsible for implementation; 2) when is implementation recommended; 3) what are the recommended methodologies for implementation; 4) where is the geographic scope for implementation; and 5) how will this be funded? And finally, each hypothesis must be subjected to evaluation of whether it is in fact credible, testable, and actionable.

The information derived from effectiveness studies should be used as part of an adaptive management approach. For example, when status-and-trends monitoring detects stormwater impacts, the source is identified and action is undertaken to minimize that impact. Effectiveness studies assure that the actions taken are sufficient and the results are used to direct the choices and development of future actions, and the techniques are used to address impacts elsewhere.

We recommend that effectiveness studies be implemented by all interested entities, potentially including:

- Local municipalities
- WSU research/evaluations
- Academic institutions
- Conservation Districts
- Tribes
- Federal and state agencies
- Ecology, EPA, and other grantors*
- National & international effectiveness studies (accessed through literature searches and other methods)
- Non-profits
- Consultants
- Others

*Current sources for Ecology's stormwater grants are limited and dwindling. It is our recommendation that the funding of these grant programs be stabilized and the funding pool increased.

2.4.1 Process for Selecting Topics for Effectiveness Studies

We recommend a public, transparent process to identify and prioritize future and more specific **topics**, questions, and hypotheses for effectiveness studies, applying the following criteria for evaluating and selecting effectiveness studies:

a. Meets the criteria for a sufficiently defined working hypothesis (see section 1._).
b. Addresses one of the most important stormwater-related threats or impacts in Puget Sound, based on prior assessments.
c. Diversity of studies across all of the prioritized topics within the new development / redevelopment, retrofit, and programmatic / non-structural BMP effectiveness study focus areas.
d. Likelihood of the practice to result in improvements to beneficial uses.
e. Likelihood of the study to result in increased cost-effectiveness of stormwater management actions mandated by the municipal NPDES permits with special focus on the costliest of the programs.

f. Likelihood to generate results within a two to four-year time frame.
g. Strength of link to the Partnership's Action Agenda and results chains.

We recommend that requests for proposals be issued for effectiveness studies, based on the guidance and priorities identified by the SWG, and that an open and transparent process be developed to evaluate the submitted proposals and select those for initial implementation. For effectiveness studies to be targeted for implementation through the municipal stormwater NPDES permits, this process needs to be expedited in fall 2010 in order to meet the timeline to inform the requirements for the coming permit cycle.

The SWG should re-evaluate the focus of effectiveness studies on a periodic basis.

For the new technologies evaluations, there are multiple possible technologies to test and evaluate. Possible methods for prioritization include the availability of private funding from technology proponents, interest among various stormwater managers in the new technologies, and whether the new technology addresses a high-priority stormwater management problem.

2.4.2 Recommendations for Municipal Stormwater NPDES Permit-Required Effectiveness Studies

The cities and counties covered under Phase I and Phase II municipal stormwater NPDES permits want to know whether their stormwater management programs are effective. There is also a real need to have more "tools in the toolbox" when it comes to additional techniques for flow control, preventing pollution, and treating stormwater discharges. With that in mind, and in anticipation of the next permit issuance in 2012, the permittees are willing to develop designs for five effectiveness studies to be started in the next permit term. The reasons these studies should be started at the beginning of the regional efforts are:

1. Permit compliance: permittees need monitoring to fulfill permit requirements.
2. Rigorous, directed monitoring that answers well-defined questions is extremely expensive, and beyond the ability (monetary and technical) of most Phase II jurisdictions. Phase I and II communities are poised to contribute to a pool of money to accomplish the monitoring proposed here.
3. Results from the initial proposed monitoring have a direct impact on future permits and requirements. For instance, a particular technique required in the Stormwater Manual may work marginally well, but by monitoring effectiveness under differing modifications, we may find simple retrofits that increase its efficiency significantly. These improved techniques could then become part of the subsequent updated Manual.

We do not recommend that these effectiveness studies all be undertaken simultaneously, but rather that an implementation cycle be set up whereby the initial set of priority hypotheses are identified and all are tested in the next decade. The SWG has a caucus-based, transparent decision-making process in place, and could act as the evaluation body to prioritize studies which studies will be done first. This prioritization should mesh with permit requirements and with regional needs. Local governments, Ecology, the Partnership, and others could weigh in on the priorities through their participation in this group.

As part of the next cycle of municipal stormwater NPDES permits, we recommend that the permits include requirements to conduct or contribute to effectiveness studies, and allow jurisdictions the flexibility to meet their requirements by either (1) paying into a fund for effectiveness study activities: *i.e.*, the "pay-in option" described in section 2.1.3; or (2) conducting effectiveness studies themselves: the "self-conducted study option." Funds generated by the "pay-in option" should be managed as described in section 2.1.3. The cost to each municipal stormwater NPDES permittee should be developed based on equitable factors.

2.4.3 Recommendations for Other Effectiveness Studies

The technology assessment program (TAP-E) should continue with funding from new technology proponents and other long-term, reliable funding sources.

Other entities beyond NPDES permittees should be encouraged to self-fund and/or conduct effectiveness studies following SWG priorities and guidance and regional protocols. Entities should partner to share resources.

Other entities beyond NPDES permittees should be encouraged to contribute to the "dedicated stormwater monitoring and assessment fund" to increase funding available for coordinated effectiveness studies.

2.4.4 Schedule, Sequencing, and Roles

a. Municipal permittees: Add a new permit requirement that provides flexibility for permittees to either pay into a fund to conduct effectiveness studies or do an approved study themselves.

b. Non-permitted municipalities: As part of future grants from Ecology for retrofits and non-structural BMPs, establish new policy of setting aside small amount for effectiveness studies.

c. WSU Puyallup: Ongoing testing and evaluation of LID techniques as part of grants from Ecology and match from Puyallup. Establishing Stormwater Technical Resource Center with UW Tacoma and may conduct additional effectiveness studies. Other entities may also conduct this work.

d. State and Federal Agencies: Assist in implementation of the stormwater strategy developed in this process.

e. Conservation Districts: Assist development and implementation of a robust monitoring strategy for evaluating effectiveness of various BMPs to reduce stormwater impacts from agricultural practices. Coordinate with this strategy.

f. Schedule and sequencing:

   2012: Stormwater effectiveness studies required as part of reissued municipal NPDES permits.

   2011 to 2012: Studies conducted as part of revisions to Ecology's grant programs.

   2010 and forward: Ongoing at WSU Puyallup and studies conducted by state and federal agencies and others.

g. Support structure and tools: A dedicated stormwater monitoring office/entity is needed, see section 2.1.3.

h. Implementation of priority monitoring

2.4.5 Costs

Costs for effectiveness studies can vary dramatically depending on the spatial and geographic scale and the type and scope of the study. Without definitive hypotheses chosen, and therefore no site distribution determined, it is not possible at this time to come up with specific cost estimates for the regional stormwater monitoring program's initial effectiveness studies. However, based on the work of others, we can give approximate costs for types of studies that fit into the categories of monitoring that are being proposed.

Cost tables from the Center for Watershed Protection document entitled *Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs, August 2008* are presented in Appendix F. The estimates shown are for studies that range from about $30,000 to $250,000. It is anticipated that this range of costs will encompass the majority of the stormwater effectiveness studies conducted in the Puget Sound region.

Dear Reader: The SWG has not recommended a specific funding level for effectiveness studies as part of the municipal NPDES stormwater permits. Cumulative funding levels (summed across all ~80 municipal stormwater NPDES permittees) discussed by the effectiveness subgroup of the SWG ranged from $250,000 to $1,000,000 per year. What do you think is a reasonable annual investment in effectiveness studies?

GUIDE TO APPENDICES

The appendices to this document, published separately, provide additional detailed information about: the stakeholder process, our connections to other efforts, adaptive management structure, assessment questions, hypotheses, and experimental designs. Here is a brief description of the contents of each appendix.

Appendix A. The Process to Develop a Regional Stormwater Monitoring and Assessment Strategy

The Stormwater Work Group was launched as a project of the Puget Sound Monitoring Consortium. The SWG includes 26 representatives of 7 caucus groups. We have a charter, bylaws, and work plan. We have sponsored workshops and are developing products to foster an integrated, strategic approach to monitoring and assessing stormwater.

Part of our charge is to act as a pilot model effort for creating the Partnership's regional ecosystem monitoring program. We will recommend to Ecology municipal NPDES stormwater permit monitoring components that are more relevant to regional needs. This is the most recent effort to develop an integrated approach to surface water management and builds on a long history of efforts.

Appendix B. Applying Lessons Learned from Adaptive Management at a Regional Scale

Many resource managers have recognized the need to integrate resource management and monitoring at a regional scale. A brief description and lessons learned from these efforts provide guidance for creating a regional stormwater monitoring and assessment program in Puget Sound.

Appendix C. Assessment Questions to Guide Regional Stormwater Monitoring

Starting with the request from the Partnership and Ecology, stakeholder workshops were convened to develop specific assessment questions that need to be answered for Puget Sound stormwater management. Under broad headings, we developed specific questions that were vetted by stakeholders, scientists, and managers.

Appendix D. Status-and-trends Monitoring Design

This appendix presents example description of probabilistic monitoring designs for small streams and nearshore areas. Included are descriptions of site selection methods, potential indicators, methods, and the sampling schedule.

Appendix E. Source Identification and Diagnostic Monitoring Design

This appendix presents a more complete description of the framework for prioritizing and conducting source identification and diagnostic monitoring. The framework represents a method of linking the status and trend monitoring and source control activities.

Appendix F. Initial Questions and Example Designs for Effectiveness Studies

The assessment questions presented in Appendix C related to effectiveness of stormwater management are refined and prioritized into an initial suite of questions to address. Example cost estimates for a range of possible effectiveness studies are presented to allow for estimating level of effort for an effectiveness monitoring program.

Appendix G. Data Collection and Data Management

A more detailed description of the variety of issues that need to be considered to ensure quality and comparable monitoring information.

Appendix H. Response to Formal Peer Review and Public Comments on November 2009 Draft Scientific Framework

We commissioned five formal peer review reports on the November 2009 Draft Scientific Framework, and also received over 800 public comments. We substantively modified our scientific framework in response to this feedback. This appendix presents a summary of the comments and feedback received, with discussion of the approach we used to address the input.

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