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Nutrient Projects Funded by the National Estuary Program Toxics and Nutrients Prevention, Reduction, and Control Cooperative Agreement

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Puget Sound Nutrient Synthesis Report, Part 1

Nutrient Projects Funded by the National Estuary Program Toxics and Nutrients Prevention, Reduction, and Control Cooperative Agreement

by

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Executive Summary

The United States Environmental Protection Agency (EPA) announced National Estuary Program (NEP) funding awards to support work to protect and restore Puget Sound, based on science and clear, measurable goals for recovery. Washington State Department of Ecology (Ecology) served as the lead organization for the NEP Cooperative Agreement for Toxics and Nutrients Prevention, Reduction, and Control (2011–2019). During this time, Ecology chaired the NEP Toxics and Nutrients Core Team, a committee that distributed $21 million of grant funds to toxics and nutrients projects.

The goal of the NEP Toxics and Nutrients grant program is to improve both human and environmental health by preventing, reducing, and controlling toxics and nutrients from entering Puget Sound. NEP grant funding was split between toxics and nutrients projects. NEP nutrient grant funds were allocated towards nutrient management projects (73%) and scientific application and research projects (27%) (Figure E-1).

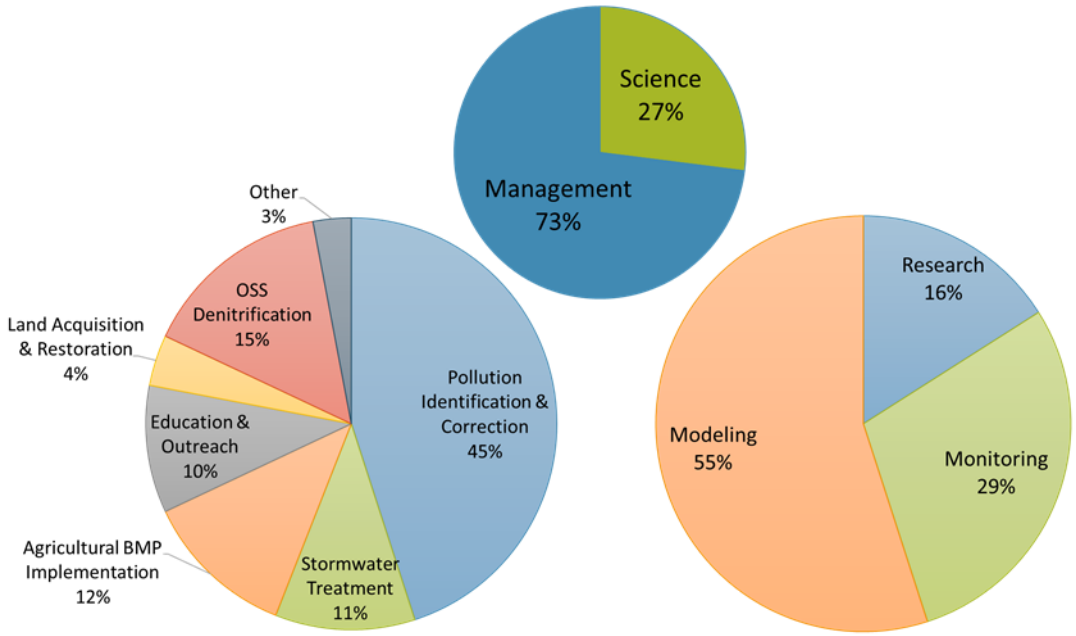

Figure E-1. NEP nutrient grant funding by project category and type.

This report identifies and summarizes the goals, objectives, and outcomes of each nutrient project based on available information. This report connects information and outcomes funded by the NEP grant and other related work to the overarching long-term goal of protecting and improving human and environmental health in the Puget Sound region. A similar report covering toxics projects was previously published (T. Roberts, 2017).

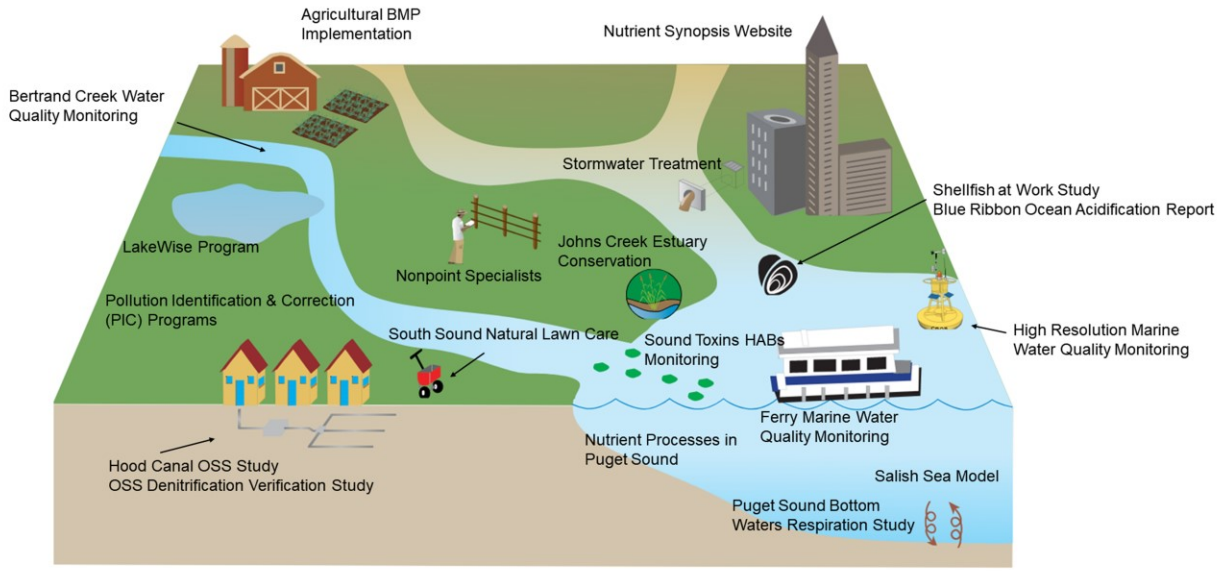

Figure E-2. Nutrient management projects and scientific studies. (Image developed with University of Maryland's Center for Environmental Science Integration & Application Network tools.)

Highlights from NEP nutrient management grant projects include the following:

- Kitsap County and Tacoma-Pierce County Health Department Pollution Identification and Correction programs identified and corrected failing on-site septic systems (OSS) and best management practices installations.
- Jointly funded nonpoint specialists from Ecology and Washington State Department of Health addressed nutrient and bacteria issues affecting shellfish harvesting areas and water quality throughout western Washington.
- The Johns Creek Estuary Conservation project acquired and restored habitat and estuary shoreline discharging into Oakland Bay.
- Snohomish County LakeWise Program and South Sound Natural Lawn Care implemented education and public outreach programs, including workshops and site visits for homeowners.
- The web-based Nitrogen in Puget Sound Story Map communicated scientific research on nutrients.
- The OSS denitrification verification study showed that both the vegetated recirculating gravel filter and the recirculating gravel filter with the woodchip bed systems are reliable and effective in removing nitrogen from wastewater.
- Other studies documented technological advances and implementation efforts to reduce nutrients, such as the mussel bioextraction study in Budd Inlet, stormwater treatment in Whatcom County, and the OSS denitrification study in Hood Canal.

Highlights from NEP scientific application and research projects include:

- Improvements and developments to the Salish Sea Model. This model helps guide nutrient management decisions in the Puget Sound region to improve dissolved oxygen conditions.
- High-resolution marine water quality monitoring data to help fill key data gaps in Puget Sound.
- State-of-the-science reports on ocean acidification and nutrient processes in Puget Sound.

General recommendations from this synthesis report include:

- Improving grant administration tasks and organization to ensure efficient, uniform tracking of nutrient management projects and final project outcomes and deliverables.
- Implementing effectiveness monitoring for nutrient management projects to quantify nutrient reductions as a result of management activities. Based on a review of project deliverables, there is a lack of quantitative information describing expected and actual nutrient reductions as a result of these projects.
- Developing a decision support tool that is specific to the Puget Sound region. This tool would provide guidance and support for nutrient management decisions and evaluate the effectiveness of nutrient management projects.

Background

Puget Sound is a large fjord estuary that is part of the larger Salish Sea. The greater Puget Sound region includes Puget Sound and its adjoining waterways and bays, and the United States watersheds that drain into its marine waters (Figure 1). The diverse lands draining into Puget Sound feature mountains, agricultural lands, cities, rivers, forests, and wetlands. Puget Sound provides vital environmental, cultural, and economic benefits.

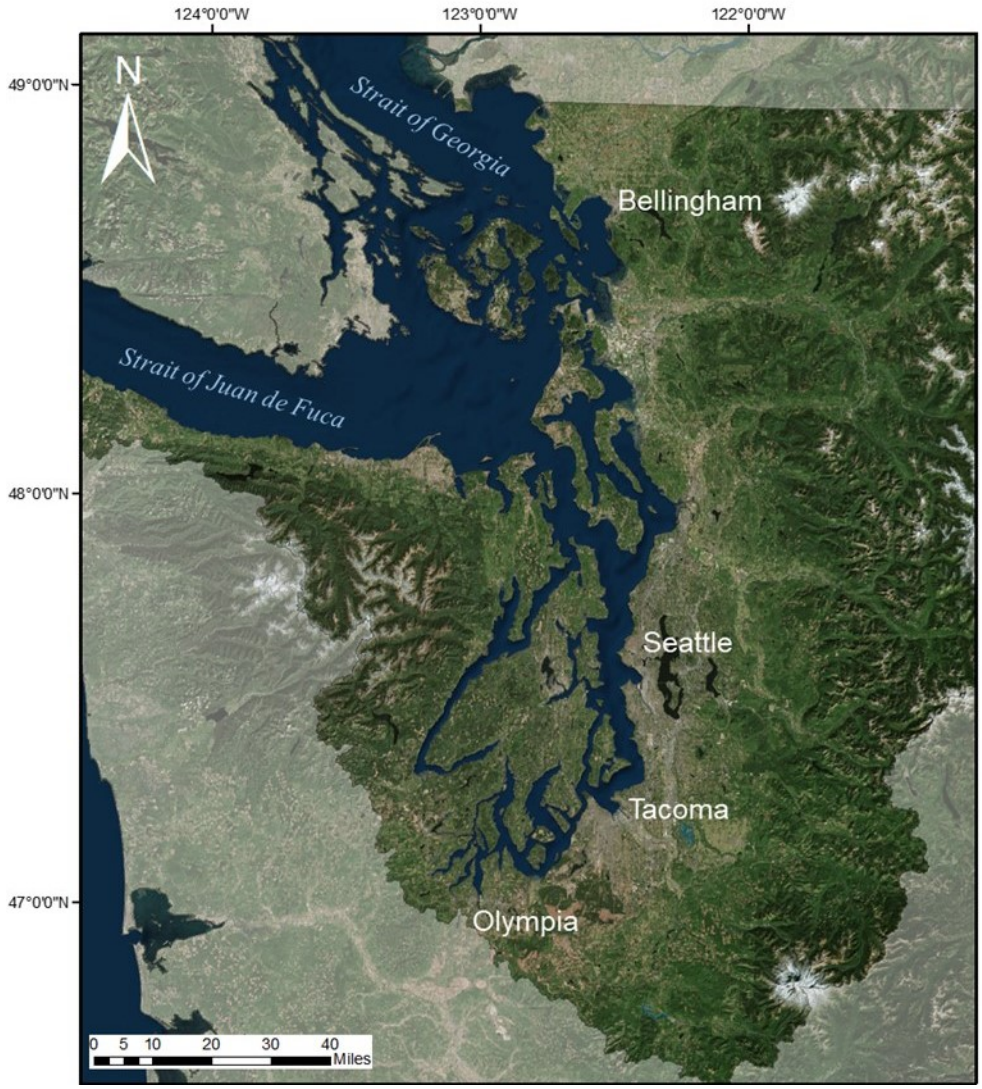

Figure 1. Greater Puget Sound region.

Nutrients play a critical role in the health of aquatic ecosystems in Puget Sound. While these nutrients are naturally present in the environment and are needed for a healthy ecosystem, excess nutrients can cause environmental issues. Nitrogen is the limiting nutrient in Puget Sound (Newton and Van Voorhis, 2002). Excess nitrogen can fuel algal growth, resulting in algal blooms. Algae are a source of organic carbon, as are terrestrial sources of detritus that are

delivered to marine waters. During the decomposition process of organic carbon, dissolved oxygen is consumed, resulting in a reduction of dissolved oxygen. This process is called *eutrophication* and can hinder the ability of an ecosystem to support aquatic life (Diaz and Rosenberg, 2008; Glibert et al., 2005).

Low levels of dissolved oxygen have been observed in Puget Sound, and recent studies show that excess nutrients from human activities have contributed to areas with low dissolved oxygen (Ahmed et al., 2019; Albertson et al., 2002; Mohamedali et al., 2011; M. Roberts et al., 2014). As population throughout the Puget Sound region continues to grow, increases in nutrients into Puget Sound are expected (M. Roberts et al., 2014). An over-enrichment of nutrients can cause human and environmental issues and may impact the following:

- Ocean acidification (Feely et al., 2010; Pelletier et al., 2017b).
- Changes to benthic (bottom-dwelling) community structure and diversity (Diaz and Rosenberg, 2008).
- Changes to micronutrient availability that can lead to increased occurrence and duration of harmful algal blooms (Howarth et al., 2011).
- Impairments to eelgrass beds, an important habitat for aquatic species in Puget Sound (Burkholder et al., 2007; Hessing-Lewis et al., 2011), and declines in eelgrass shoot density (Bittick et al., 2018; Nelson and Lee, 2001).

Figure 2. Aerial photograph of Puget Sound and an algal bloom captured by Ecology's Eyes Over Puget Sound (Krembs, 2016).

Phosphorus plays a critical role in freshwater systems. Local studies show the influence excess phosphorus has on dissolved oxygen levels and water quality in freshwater systems in the Puget

Sound region (Bell-McKinnon, 2010; Edmondson, 1970; Embrey and Inkpen, 1998). Additionally, excess phosphorus may contribute to eutrophication downstream as well (Howarth et al., 2011).

NEP Toxics and Nutrients Grant

The U.S. Environmental Protection Agency (EPA) announced National Estuary Program (NEP) funding awards (Grants PC00J20101 and PC00J89901) to support the Puget Sound Action Agenda, first developed in 2009 by the Puget Sound Partnership. The Puget Sound Action Agenda identifies work needed to protect and restore Puget Sound, based on science and with clear and measurable goals for recovery. The Puget Sound Partnership continues to update the Action Agenda routinely.

Specific Washington State agencies were selected from a 2010 competitive request for proposals issued by EPA Region 10, Seattle. They were selected as lead organizations to implement Puget Sound recovery efforts, including work related to toxics and nutrients prevention, reduction, and control.

The EPA awarded the NEP Lead Organization Cooperative Agreement for Toxics and Nutrients Prevention, Reduction, and Control to the Washington State Department of Ecology (Ecology) in 2011. Ecology chairs the NEP Toxics and Nutrients Core Team, a committee of partner agencies distributing the NEP Toxics and Nutrients grant funds ($21 million). Partner agencies on this committee include representatives from Ecology, EPA, the Puget Sound Partnership, and the Washington State Department of Health (DOH). EPA provided funds on an annual basis, called rounds, and also provided periodic awards for designated purposes.

The goal of the NEP Toxics and Nutrients grant is to improve both human and environmental health by preventing, reducing, and controlling toxics and nutrients from entering Puget Sound fresh and marine waters. The $21 million of funding was split between toxics and nutrients.

Identifying Projects for NEP Grant Funding

The NEP Toxics and Nutrients Core Team developed a process for selecting projects, reviewing project proposals, and awarding funds. The committee, consisting of representatives with experience in nutrients and toxics work from Ecology, the Puget Sound Partnership, and the Environmental Protection Agency, developed a 6-year strategy. The strategy used information from Puget Sound Action Agenda strategies, substrategies, near term actions, and recommendations of the science panel. NEP funding ($21 million) was split evenly between toxics and nutrients work, with some funding allocated for administration and quality assurance. The Core Team's goal was to allocate 50% of grant funding to nutrient projects with 10% of funds for science projects and 40% for implementation projects.

This process is detailed in a multiyear implementation plan presented to EPA in Amendment Three of the NEP Toxics and Nutrients Cooperative Agreement (Ecology, 2012). Project selection was informed based on the Nutrient Funding Strategy (NFS) and Nutrient Science Funding Strategy (NSFS) described within the implementation plan.

The NEP Nutrients grant was used to address both nitrogen (typically the nutrient of concern in marine waters) and phosphorus (typically the nutrient of concern in freshwater). Some projects focused primarily on one nutrient, while others addressed both.

Nutrient Funding Strategy

The Nutrient Funding Strategy (NFS) was created to guide and strategically allocate Puget Sound NEP Toxics and Nutrients grant to related projects from 2011 to 2019 (Ecology, 2012). Projects funded by the NEP grant were expected to address nutrients, along with helping to fill key data and programmatic gaps in ongoing activities in the Puget Sound region. The NEP activities were to be aligned with the broader toxics and nutrients strategies for Puget Sound, the state, and the larger region. The NFS established guidance to prioritize work that addressed the amount of nutrients released into the environment through implementation projects. Additionally, scientific investigations of nutrients were also funded at a smaller scale.

Within the nutrient management category, the top priorities for funding were informed by the Puget Sound Action Agenda (Puget Sound Partnership, 2012), Ecology's *Puget Sound Dissolved Oxygen Model Nutrient Load Summary* report (Mohamedali et al., 2011), and the *Toxics in Surface Runoff to Puget Sound* report (Herrera, 2011). Priority was given to projects that:

- Addressed nutrients from wastewater treatment plants within the context of a Total Maximum Daily Load (TMDL) or similar plan that allows for efficient investment in wastewater infrastructure to meet water quality standards.
- Addressed sources of nutrients on agricultural land. Key aspects of this work include:
  - Increasing inspection programs, with a primary focus on manure (livestock) to enhance shellfish bed openings and a secondary focus on chemical fertilizers in areas with known nutrient issues.
  - Increasing funding of best management practices (BMPs) in areas with Pollution Identification and Control (PIC) programs.
  - Ensuring BMPs being used are adequately addressing nutrients.
- Addressed sources of nutrients on residential land. Key aspects of this work include:
  - Residential fertilizer use.
  - On-site septic systems.

The NFS sought to identify projects that were primarily focused in areas with TMDLs in place or with other studies that have identified impairments related to nutrients. Figure 3 shows a map of dissolved oxygen TMDLs (influenced by excess nutrients) that are approved by EPA and those that are in development, along with the Puget Sound Action Areas (PSAA) as defined by the Puget Sound Action Agenda (Puget Sound Partnership, 2009). These PSAA represent seven geographic areas with similar physical and biological conditions, along with distinctive local characteristics and communities (Hood Canal, North Central Puget Sound, South Central Puget Sound, South Puget Sound, Strait of Juan de Fuca, Whatcom County/San Juan Islands, and Whidbey Island).

The NFS highlighted these key focus areas:

- Lynch Cove (Hood Canal).
- South Puget Sound, particularly Budd Inlet.
- Whidbey Basin.
- Watersheds with nutrient-related TMDLs, including Lake Whatcom, Deschutes River, and White River.

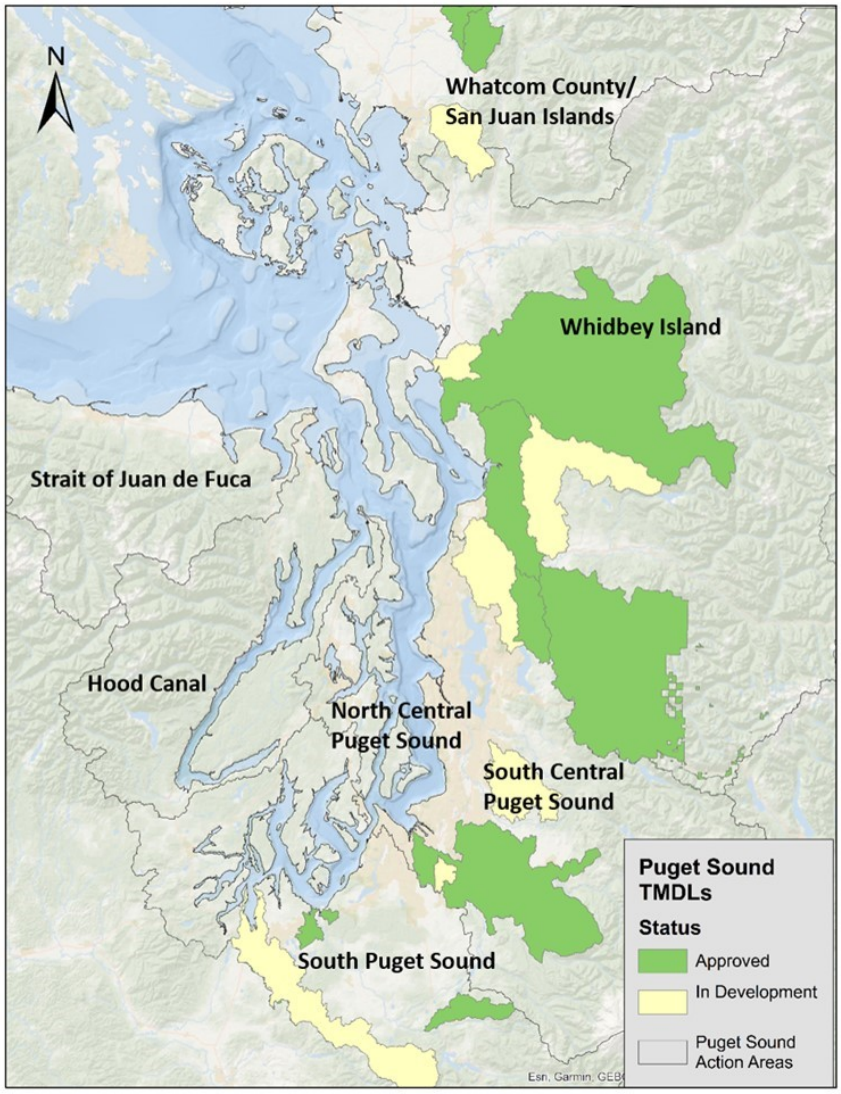

Figure 3. Puget Sound Action Areas and freshwater dissolved oxygen TMDL areas.

Nutrient Science Funding Strategy

The Nutrient Science Funding Strategy (NSFS) provided guidance for funding scientific investigations to improve understanding of the sources, transport, fate, and impact of human and natural nutrient inputs into Puget Sound and the greater Salish Sea ecosystem (Ecology, 2012). A leading question framing the NSFS was regarding the extent that human nutrient contributions are affecting the overall health of Puget Sound.

Priorities of the NSFS included:

- Developing modeling tools and applying them to management questions.
- Refining nutrient estimates from different sources.
- Quantifying transport, transformation, and fate of nutrients.
- Providing supplemental monitoring of key processes and locations.

Modeling was identified as a key priority for understanding the role of anthropogenic nutrient contributions to Puget Sound. This required continuing improvements to the Salish Sea Model (previously called the Puget Sound Dissolved Oxygen Model). The model has undergone development and refinement over the last decade to better simulate processes and understand low levels of dissolved oxygen in the Salish Sea. Results from this model are used to inform nutrient management and implementation strategies.

The Salish Sea Model (SSM) requires extensive data to represent complex physical, chemical, and biological processes of Puget Sound. Another priority for scientific investigations involved monitoring activities that would help fill key data gaps, such as high-resolution marine water quality monitoring.

Other efforts for the NSFS included monitoring the status and trends of nutrient-related parameters in Puget Sound. These strategic scientific investments can help identify the most beneficial management activities.

Overlap with NEP Pathogens Grant

This report addresses projects funded through the NEP Toxics and Nutrients grant focused on nutrients. However, there is overlap between projects funded under other NEP grants, particularly with the NEP Pathogens grant administered by DOH. Under both of these grants, projects were jointly funded to address BMPs on agricultural land. These BMPs address both nutrient and pathogen pollution. The pathogen-funded PIC grant may also address and resolve nutrient problems.

Some aspects of on-site septic systems (OSS) are addressed through the NEP Pathogens grant, such as inventorying septic systems and fixing failing systems. The Toxics and Nutrient grant does address part of the OSS issue, such as studies of lower-cost technologies for reducing nitrogen in septic systems.

The NEP Pathogen grant and the Toxics and Nutrients grant both funded nonpoint specialists at Ecology that worked on both pathogen and nutrient issues.

Projects that were predominantly funded and led by DOH (e.g., Snohomish PIC Program) will be described in a separate synthesis report that will include major project outcomes and deliverables (expected autumn 2019).

Puget Sound Nutrient Management

Activities and projects funded by the NEP Toxics and Nutrients grant complemented ongoing efforts to manage and reduce nutrients throughout the greater Puget Sound region. This includes supporting Ecology's Puget Sound Nutrient Source Reduction Project (PSNSRP), which will inform future regulatory and nonregulatory actions, and the Marine Water Quality (MWQ) Implementation Strategy, which will add implementation priorities to the Puget Sound Action Agenda. Both of these management efforts are described in more detail below.

Puget Sound Nutrient Source Reduction Project

Ecology's PSNSRP is a collaborative effort with communities and stakeholders to address human sources of nutrients. The PSNSRP focuses on using the latest science to find the right solutions for regional investments to control nutrients from point and nonpoint sources and help Puget Sound meet dissolved oxygen water quality criteria. The project objective is to improve Puget Sound water quality to support salmon and orca recovery and increase resiliency to climate impacts.

PSNSRP uses SSM results to inform nutrient management. Results from the first phase of PSNSRP model runs are documented in *Puget Sound Nutrient Source Reduction Project Volume 1: Model Updates and Bounding Scenarios* (Ahmed et al., 2019). The model scenarios show the range of Puget Sound water quality conditions from different nutrient loads. Model scenarios evaluated water quality conditions with (1) current levels of nutrient loading from marine point sources and watersheds into Puget Sound and (2) improvements in nutrient removal technologies applied to municipal wastewater treatment plants. PSNSRP will use results from the SSM as guidance for nutrient management decisions.

The funding allocations for NEP Nutrients and Toxics grant projects preceded the development of the PSNSRP. While NEP-funded nutrient projects were not developed specifically for PSNSRP, outcomes from these nutrient reductions in the greater Puget Sound region are inherently supportive of this ongoing work. These projects may serve as an example or template for future nutrient management projects in Puget Sound. Additionally, grant funding for SSM studies provides information to guide PSNSRP.

Marine Water Quality Implementation Strategy

An implementation strategy is currently being developed for the Marine Water Quality (MWQ) Vital Sign. Vital Signs are numerical indicators of ecosystem health. The MWQ Vital Sign will inform the Puget Sound Action Agenda, in collaboration with Ecology, the Puget Sound

Partnership, the Puget Sound Institute, and many volunteers from local government, tribes, state and federal agencies, conservation districts, and nongovernmental organizations.

The Action Agenda outlines the recovery strategy to reach the target for the MWQ Vital Sign: "By 2020, human-related contributions of nitrogen do not result in more than 0.2 mg/L reductions in dissolved oxygen levels anywhere in Puget Sound." However, the MWQ implementation strategy development was not initiated until 2018, after the modeling tools and other considerations were ready. The MWQ implementation strategy focuses on improving dissolved oxygen conditions in Puget Sound. It identifies approaches that remove barriers to reduce nutrients from human sources. A MWQ narrative, including key pathways for recovery, progress measures, and an adaptive management framework, will be ready in 2020 for inclusion in the Action Agenda to support and inform NEP funding decisions.

The Puget Sound Institute supports the implementation strategy development by compiling a starter package for each strategy. The starter package serves as a primer on the current state of research, regulations, and practices important to the Vital Sign. The MWQ starter package contains a collection of science, information, considerations, related programs, and ongoing work related to nutrients and dissolved oxygen in Puget Sound (T. Roberts et al., 2018). As the implementation strategy progresses, the starter package will evolve into a state-of-knowledge report that accompanies the final MWQ implementation strategy narrative product.

Nutrient Sources in Puget Sound Region

Figure 4 shows the different sources and pathways that deliver nutrients into Puget Sound. Sources of nutrients include the Pacific Ocean, wastewater treatment plants, urban sources, septic systems, agriculture, and natural sources. Pathways for nutrient transport include atmospheric deposition, rivers, stormwater, groundwater, and marine sediments.

Projects selected for NEP Nutrients grant funds were expected to reduce nutrients from sources influenced by human activities. Overall contributions of nutrient sources to Puget Sound have been quantified at varying levels in different studies. Information from the following sources was used to help guide the NFS, NSFS, and NEP grant project selection:

- 2012 Puget Sound Action Agenda (Puget Sound Partnership, 2012).
- South Puget Sound Dissolved Oxygen Study: Interim Nutrient Load Summary for 2006–2007 (Mohamedali et al., 2011a).
- Puget Sound Dissolved Oxygen Model Nutrient Load Summary for 1999–2008 (Mohamedali et al., 2011b).
- Toxics in Surface Runoff to Puget Sound: Phase 3 Data and Load Estimates (Herrera, 2011).
- Nutrient Funding Strategy from the NEP Toxics and Nutrients Cooperative Agreement (Ecology, 2012).

For a more detailed review of nutrient sources and pathways in Puget Sound, see Part 2 of this report, *Comparison of Watershed Nutrient Load Estimates* (McCarthy, 2019).

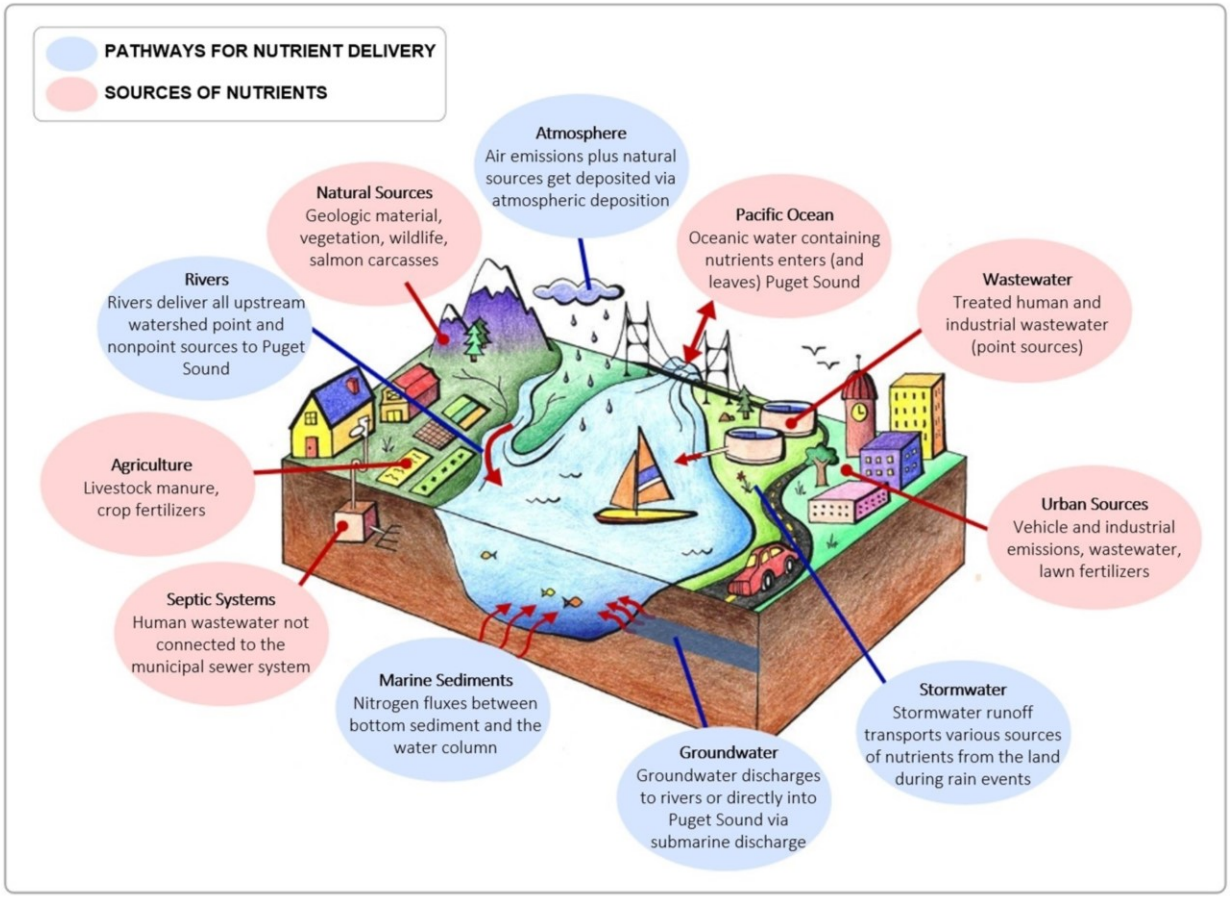

Figure 4. Nutrient sources and pathways. Figure adapted from Nitrogen in Puget Sound Story Map (Mohamedali and McCarthy, 2018).

Nutrient Synthesis Report (Part 1) Goals and Objectives

The NEP Toxics and Nutrients Prevention, Reduction, and Control agreement (2011–2019) funded projects to protect and improve human and environmental health in the Puget Sound region. This report is a synthesis of the funded nutrient projects, discussion and recommendations based on lessons learned from these projects, and connection with related nutrient management work in the region. Objectives of this report include:

- Review and summarize NEP-funded nutrient project outcomes, deliverables, and estimated nutrient reductions, based on available project information.
- Synthesize nutrient grant funding allocations in a general spatial analysis.
- Provide recommendations based on lessons learned throughout the NEP grant duration and information from nutrient projects.

Project Summaries

This section presents an overview of NEP-funded nutrient projects (Table 1).

Table 1. Overview of NEP Nutrients grant project list. Not all funds allocated were spent.

Project Title	Recipient	Funds Allocated*
Management Projects		
Kitsap County PIC	Kitsap Public Health District	$334,000
Tacoma-Pierce Penrose PIC	Tacoma-Pierce County Health Department	$248,000
Snohomish County PIC	Snohomish County	$100,000
Nonpoint Field Staff	Ecology	$2,278,000
Agricultural BMP Implementation	Conservation districts and nonprofit organizations	$773,000
Johns Creek Estuary Conservation	Capitol Land Trust	$251,000
Lake Whatcom Phosphorus Management	City of Bellingham, Whatcom County Public Works	$740,000
OSS Denitrification Verification Study	University of Washington, Department of Health	$630,000
Hood Canal OSS Study	Hood Canal Salmon Enhancement Group	$341,000
LakeWise Program	Snohomish Public Works	$296,000
South Sound Natural Lawn Care	City of Olympia	$219,000
Nutrient Synopsis Website	Ecology	$130,000
Shellfish at Work Study	Pacific Shellfish Institute	$179,000
Science Projects		
Modeling	Ecology	$1,313,000
Ferry-Based Marine Water Quality Monitoring	Ecology	$261,000
High Resolution Marine Water Quality Monitoring	University of Washington	$195,000
Bertrand Creek Water Quality Monitoring	Ecology	$150,000
SoundToxins HABs Monitoring	University of Washington	$87,000
Nutrient Processes in Puget Sound	USGS	$302,000
Puget Sound Bottom-Water Respiration	Ecology	$54,000
Blue Ribbon Panel on Ocean Acidification Report	University of Washington	$20,000
GRAND TOTAL		**$8,901,000**

* Funds allocated were not necessarily spent.

PIC = pollution identification and correction; BMP = best management practices; OSS= on-site septic system; HABs= harmful algal blooms.

Consistent with the NFS, the majority of funds were allocated for nutrient management projects (about $6.5 million), and the remainder were distributed to science and research projects (about $2.4 million).

The scope and geographic focus of nutrient projects ranged from local education and outreach programs (South Sound Natural Lawn Care and LakeWise Program), to countywide efforts (nonpoint staff and PIC programs), to science and research studies that covered the entire Puget Sound (Salish Sea Model and monitoring projects).

Figure 5 is a diagram that provides an overview of the different nutrient sources and pathways that the NEP-funded nutrient projects addressed. Some projects focused on specific nutrient sources, such as on-site septic systems (OSS) (Hood Canal OSS Study, OSS Denitrification Verification study), whereas others covered multiple potential nutrient sources (nonpoint specialists and PIC programs).

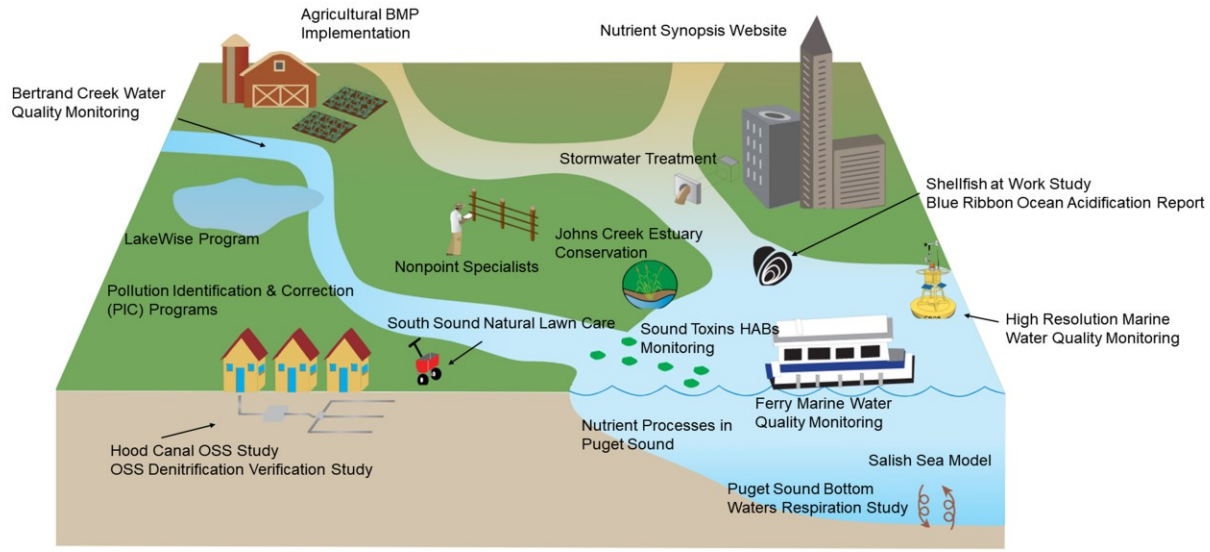

Figure 5. Diagram of nutrient sources addressed by nutrient projects. (Image developed with University of Maryland's Center for Environmental Science Integration & Application Network tools.)

Management Projects

The primary goal of the NEP Nutrients grant was to support efforts to manage or limit the amount of nutrients released into the environment. About $6.5 million (73% of grant funds) were devoted to projects focused on managing and reducing nutrients (Table 2). In addition to nutrients, many of these projects also addressed other pollutants commonly associated with nutrient sources, such as pathogens. Management projects focused on PIC programs, agricultural water quality BMP implementation, denitrifying septic systems, stormwater treatment, land acquisition, education and outreach, and other alternative nutrient reduction approaches.

Table 2. Overview of nutrient management projects.

Project Title	Recipient	Project Type	Funds Allocated*
Kitsap County PIC	Kitsap Public Health District	Pollution Identification and Correction	$334,000
Tacoma-Pierce Penrose PIC	Tacoma-Pierce County Health Department	Pollution Identification and Correction	$248,000
Snohomish County PIC Program	Snohomish County	Pollution Identification and Correction	$100,000
Nonpoint Field Staff	Ecology	Pollution Identification and Correction	$2,278,000
Agricultural BMP Implementation	Ecology and others	Agricultural BMP Implementation	$773,000
Johns Creek Estuary Conservation	Capitol Land Trust	Land Acquisition and Restoration	$251,000
Lake Whatcom Phosphorus Management	City of Bellingham, Whatcom County Public Works	Stormwater Treatment	$740,000
OSS Denitrification Verification Study	University of Washington, Department of Health	OSS Denitrification	$630,000
Hood Canal OSS Study	Hood Canal Salmon Enhancement Group	OSS Denitrification	$341,000
LakeWise Program	Snohomish Public Works	Education and Outreach	$296,000
South Sound Natural Lawn Care	City of Olympia	Education and Outreach	$219,000
Nutrient Synopsis Website	Ecology	Education and Outreach	$130,000
Shellfish at Work Study	Pacific Shellfish Institute	Other	$179,000
Total			**$6,519,000**

* Funds allocated were not necessarily spent.

PIC=pollution identification and correction; BMP=best management practices; OSS=on-site septic system.

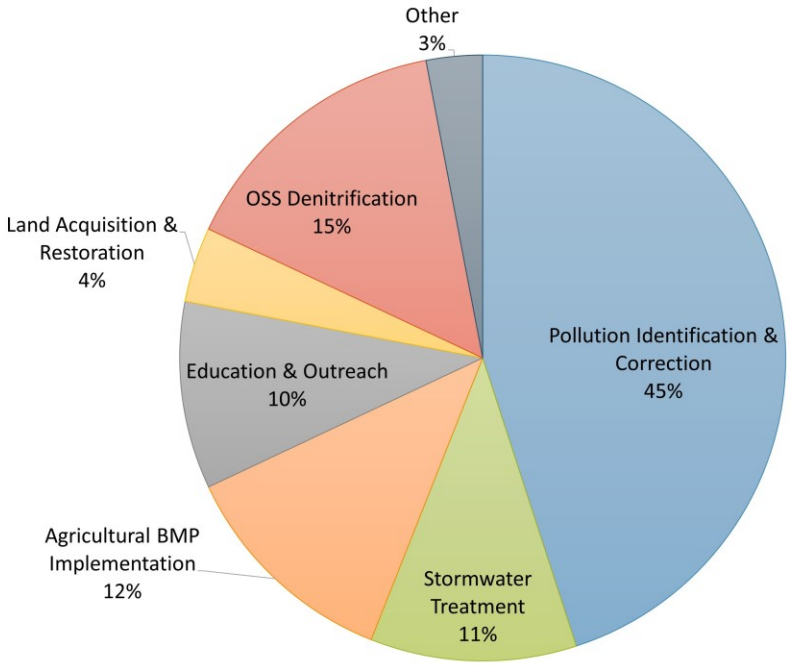

Figure 6. NEP grant funding allocations for nutrient management projects.

This section provides a brief summary of the goals, objectives, and outcomes for each project. Project-specific information, including updates since grant funding completion, was obtained through a review of project deliverables and correspondence with individuals involved with each project.

Appendix A provides a summary table for all projects and deliverables, including links to final reports and websites.

Pollution Identification and Correction Programs

One of the main priorities for the NEP Cooperative Agreement was the establishment of sustainable local nonpoint pollution identification and correction (PIC) programs in all Puget Sound counties. To support this goal, both Ecology and Department of Health funded multiple projects to develop and enhance local PIC programs.

The idea of PIC programs was modeled after Kitsap County's PIC program. The concept was for counties to lead efforts designed to address all sources of pollution. As part of their PIC program, counties would have ongoing monitoring and regulatory enforcement capability to identify and resolve pollution sources. Counties would also develop a financing plan that ensured sustainable funding for the future. Included in the regional PIC concept, state agencies would provide technical and regulatory compliance support using their respective authorities to help local governments successfully address pollution sources.

This project did not ultimately result in PIC programs in all Puget Sound counties, however, the following sections provide an overview of funding for PIC programs in Kitsap County, Tacoma-Pierce Health Department, and Snohomish County. Additionally, the NEP grant provided funding for Ecology to hire nonpoint specialists to support pollution identification and correction efforts throughout the Puget Sound region. This work is discussed in a later section.

Kitsap County PIC

The Kitsap Public Health District received funds for a nutrient reduction PIC project in Murden Cove and Fletcher Bay. The purpose of this project was to reduce nutrient loading and fecal bacteria to improve water quality to protect public health, shellfish, and aquatic habitat. This project assessed land use practices, conducted routine and investigative water quality monitoring, performed educational and outreach efforts with local residents and partners, and identified and corrected residential nonpoint pollution sources.

This PIC program involved door-to-door surveys for homes with older (more than 25 years) septic systems and within 200 feet of either the shoreline of major creeks that flow into Fletcher Bay. Surveys were used to identify four failing septic systems and provide educational information to homeowners about septic system maintenance and pumping. The educational and outreach component of the surveys will help to prevent future septic system problems from going undetected and encourage continuation of routine tank inspection and pumping. Based on a follow-up postcard survey, 89% of respondents found the door-to-door surveys and site visits beneficial (Table 3).

Kitsap Public Health District received funding in a later NEP grant round to assess Big Beef Creek and Lake Symington for fecal coliform bacteria and nutrients. They sampled water for nutrients and bacteria to identify failing septic systems and other potential sources of nutrients. This project also involved door-to-door property inspections within a 200-foot zone along the creek and lake. Enforcement of regulations occurred to ensure correction of pollution sources, as needed. Based on a follow-up survey, 97% of residents felt that the site visit was helpful (Table 3).

Public education and outreach were main components of this project. Outreach efforts included targeting owners of septic systems, education on fertilizer-maintained lawns, and proper pet waste disposal information. Additionally, two public meetings were held throughout the project, and property inspections included educational information.

Continuing efforts for this work include water quality monitoring in Big Beef Creek and providing public education and outreach with landowners to help address water quality issues in the watershed moving forward.

Table 3. Kitsap County PIC Program outcomes.

Project Aspects	Murden Cove and Fletcher Bay	Big Beef Creek and Lake Symington
Water Quality Samples	Yes	Yes
Property Inspections	275	180
Failing Septic Systems	4	5
Agriculture BMP Installation	1	-
Survey: % of residents reporting visits helpful	89%	97%

The Kitsap County PIC program[1] continues to address water quality issues in surface water, focusing on bacterial issues. They currently work on a watershed-by-watershed basis, identifying streams with high bacterial counts and investigating potential sources, monitoring 62 streams throughout the county, and sampling shorelines where freshwater flows into marine waters. They provide public education and outreach workshops for septic care, stormwater workshops for contractors, and education for school groups (Grant Holdcroft, pers. comm., 2019).

Tacoma-Pierce County Health Department Penrose PIC

The Tacoma-Pierce County Health Department developed a PIC program to address nutrient loading in Bay Lake and Mayo Cove. The goal was to reduce the frequency and magnitude of harmful algal bloom and beach closures for Penrose Point State Park. This PIC program included water quality sampling to identify pollution sources, a sanitary survey of shoreline properties to identify and correct facility septic systems, proper pet waste disposal, and implementing agricultural BMPs from 2015–2017.

Water quality samples were collected for fecal coliform and nutrient analysis from tributaries that discharge into Mayo Cove and stormwater outfalls. Bay Lake was sampled for nutrients and conventional parameters. Additionally, Bay Lake had 67 site visits that involved 43 observations of toxic algae, where 27 samples were examined to identify algal genera and 19 samples were analyzed for toxin concentrations by the King County Laboratory (Table 4).

[1] https://kitsappublichealth.org/environment/pic.php

Table 4. Penrose PIC Project outcomes (Tacoma-Pierce County Health Department).

	Mayo Cove and Surrounding Watersheds
Water quality samples	85
Bacteria samples	78
Toxic algae samples	27
Site visits	50
Manure bins installed	36
Other BMP projects	4
Soil samples	19
Sanitary surveys	31
Failing septic systems identified and corrected	3
Community events and workshops	7

In the Mayo Cove watershed, eight site visits were conducted at three different farms. Four manure bins were installed in the Mayo Cover watershed. Other BMP projects included one farm that had weed removal, manure removal, the planting of a pollinator hedgerow adjacent to a seasonal stream, and the installation of exclusion fencing to keep livestock out of the stream. In surrounding watersheds, 42 site visits were conducted, and 32 manure bins were installed. Three soil samples were also collected for nutrient analysis within the Mayo Cove watershed. The sanitary survey included 31 site visits, and three failing septic systems were identified and corrected. An additional septic system was identified as likely impacting water quality and will be monitored further to confirm and correct the issue. Total project outcomes for Mayo Cove and surrounding watersheds are shown in Table 4.

Community engagement and public outreach events were also included throughout this project duration. These included holding focus group sessions about improving water quality in the Mayo Cove watershed, hosting community events to encourage environmental stewardship, and conducting workshops regarding maintaining septic systems, manure management, and natural yard care. Feedback from the focus groups and public engagement was used to help guide regional water quality efforts.

Snohomish County PIC

Ecology and the DOH jointly funded a Snohomish County PIC program. DOH was the lead for this program due to its connection with pathogens and shellfish harvesting areas, while Ecology partially funded this project on a lesser scale given its overlap with nutrient work. Since this project was mainly funded by the NEP Pathogens grant with DOH serving as the lead organization, it will be discussed further in the Pathogens Synthesis report.

Department of Ecology Nonpoint Specialist Positions

The Department of Ecology used NEP funding to hire six nonpoint specialists. The purpose of these positions was to reduce nutrient and fecal bacteria pollution from nonpoint sources. The positions were field-oriented and focused primarily on identifying and correcting sources of nutrient and pathogen pollution from mainly agricultural sources.

Pollution identification and correction was conducted through a variety of approaches, including water quality monitoring, watershed windshield surveys, potential pollution source inventories, environmental complaint responses, site visits, technical assistance, BMP implementation, and regulatory enforcement. Nonpoint specialist efforts were typically conducted in coordination with local PIC programs and affiliated partners such as local conservation districts, local health jurisdictions, public works departments, and other state agencies, including the Department of Agriculture.

These specialists worked throughout the greater Puget Sound region and supported multiple local and Puget Sound–wide efforts and initiatives focused on nutrient and pathogen prevention, reduction, and control. Examples of efforts supported by the nonpoint positions include local PIC programs such as the Clean Samish Initiative (Skagit County) and Whatcom Clean Water Program, shellfish protection districts, the Washington Shellfish Initiative, and the Governor's Office Result WA 2020 goals for shellfish recovery. Efforts of the nonpoint positions funded by the NEP Toxics and Nutrients grant spanned approximately 8 years beginning in 2012 and ending in June 2019.

Nonpoint specialists worked out of Ecology's Northwest Regional Office, Southwest Regional Office, and Bellingham Field Office (Whatcom County). Cumulatively, these positions covered all Puget Sound counties. The following sections outline the activities within each region.

Bellingham Field Office (BFO)

Three nonpoint specialists and one agricultural BMP implementation specialist worked out of the Bellingham field office. These specialists worked to reduce nutrient and fecal coliform inputs into surface waters using the pollution identification and correction approaches described previously in this report.

The nonpoint specialists worked throughout Whatcom and Skagit Counties. They primarily focused on key watersheds where ongoing coordinated efforts addressed nutrient and bacteria pollution and recovery in commercial shellfish growing areas. Focus watersheds included the Lower Nooksack (Portage Bay), Drayton Harbor, Lummi Bay, Birch Bay, Padilla Bay, South Skagit Bay, and Samish Bay watersheds.

The agricultural BMP specialist position serviced the entire northwest region of the Puget Sound region. The BMP specialist supported the nonpoint specialist and other efforts, such as PIC programs, by providing technical and financial assistance to landowners to facilitate BMPs addressing nutrient and bacteria sources on their property.

From 2012–2019, these positions conducted approximately 900 site visits that led to the installation of over 500 structural and management agricultural practices. Many of the BMPs installed occurred on small-scale, noncommercial farms. These BMPs included:

- Planting riparian buffers.
- Installation of fencing to restrict livestock access to oversaturated fields and surface waters.
- Manure storage and application improvements.
- Off-stream livestock watering.
- Site-specific conservation plans.

During the grant period, nonpoint specialist efforts contributed to a shellfish harvest classification upgrade in Drayton Harbor, improved water quality in the Portage Bay shellfish growing area, and a significant reduction in the number of spring shellfish harvest closure days in Samish Bay.

Although these nonpoint specialists primarily addressed fecal coliform sources of pollution, their work also helped reduce nutrient pollution, because many of these bacteria sources were from agricultural activities or livestock manure.

Northwest Regional Office (NWRO)

The nonpoint specialist from the NWRO worked across King, Kitsap, Island, and Snohomish Counties and part of Skagit County in coordination with local conservation district staff and various code enforcement staff in Island, King, Snohomish, and Kitsap Counties. The specialist also provided regular support to the Snohomish County's Stillaguamish PIC program, with limited support to the Island County, Poverty Bay, and Vashon PIC programs.

Most of the specialist's time was in support of Ecology's South Skagit Bay Watershed Evaluation process. The South Skagit Bay work included windshield surveys, OSS mapping and analysis, water quality sampling, and data evaluation to better understand water quality conditions and identify potential pollution sources. Related efforts included uploading water quality data to the Washington State Department of Agriculture website and assistance updating the South Skagit Bay Watershed Evaluation Plan. Additionally, approximately 50 site evaluations were conducted, resulting in multiple referrals to local conservation districts and leading to four successful BMP installation projects.

Southwest Regional Office (SWRO)

At Ecology's SWRO, the nonpoint specialist focused efforts in Clallam, Jefferson, Mason, Thurston, and Pierce Counties within watersheds that directly drain into marine waters. Areas of emphasis included Henderson Inlet, Eld Inlet, and Key Peninsula. The nonpoint specialist worked to identify and correct nonpoint pollution sources and provided technical assistance to landowners to correct identified pollution sources. Other efforts included watershed windshield surveys and complaint responses. Many of these activities were conducted in coordination with partners such as local governments, local conservation districts, and other state agencies.

Approximately 25 on-site property evaluations were conducted as a result of these efforts, which led to the implementation of BMPs on five properties. Practices implemented included riparian buffers and exclusionary fencing for livestock to reduce suspended sediments, remove manure accumulations near surface water, and prevent nutrient and fecal bacteria pollution.

Agricultural BMP Implementation

Agricultural nonpoint source pollution has been identified as a source of water quality impacts to rivers, lakes, wetlands, groundwater, and estuaries in the Puget Sound region (Wong and Pickett, 2014). Understanding that a combination of incentive and regulatory approaches were needed to effectively address agricultural pollution, a dedicated cost-share funding source was established to support the implementation of agricultural BMPs. The program was specifically designed to accommodate small to midsize agricultural operations because these types of farms often times do not qualify for federal Farm Bill programs.

These funds, commonly referred to as Agricultural BMP Funds, were intended to complement and supplement the efforts of PIC programs and the Ecology nonpoint specialists. They provided a funding source that agricultural landowners could access to offset the cost of addressing pollution issues identified via PIC activities. The funds were also intended as an opportunity for PIC programs to proactively market and install agricultural BMPs to prevent pollution.

The Agricultural BMP Funds were provided to local entities via DOH (Pathogens grant) and the Department of Ecology (Toxics and Nutrients grant). The funding for BMP projects offered incentives to local landowners and reduced the financial burden of implementing costly BMPs to protect water quality and Puget Sound.

Ecology and DOH contracted with local governments, conservation districts, and a nonprofit group to implement agricultural BMP projects. Local governments worked to conduct PIC activities for OSS and agriculture, particularly focused on hobby farms.

Agricultural BMP Funds were collectively used to implement projects on over 30 properties, resulting in the installation of 60 BMP projects.

The Nutrients grant was used to fund the following entities and projects:

- San Juan Conservation District completed the installation of six BMP projects.
- A Rocha, a nonprofit organization in Whatcom County completed one BMP project.
- Snohomish Conservation District completed one BMP project.

The main types of BMPs installed included:

- Waste storage facilities to manage livestock manure.
- Exclusion fencing.
- Riparian restoration.

While the objective of these funds was to support PIC programs, not all counties that received NEP funding (Pathogen and Nutrients) to develop or enhance their PIC program elected to utilize

the funds. Some elected not to address corrections on agricultural lands and others relied on local conservation districts to identify projects rather than lead efforts to identify and correct agricultural nonpoint pollution sources.

Because of this, the Agricultural BMP Funds were not fully utilized, resulting in funds being reallocated to different projects. Instead, the majority of Agricultural BMP Funds provided to local governments through the NEP Pathogens grant were used to implement BMP projects, along with $314,000 of Nutrients grant funds, for implementing projects to protect and improve water quality.

Lessons learned from this project indicate the need for better approaches and protocols to identify and correct agricultural sources of pollution to effectively address pathogens and nutrient pollution. Future PIC programs need better-defined approaches for addressing agricultural pollution sources and the regulatory framework to ensure compliance.

Land Acquisition and Restoration

Johns Creek Estuary Conservation

The Johns Creek Estuary Conservation project was led by the Capitol Land Trust. This project worked to acquire, restore, and permanently protect 47 acres of land that was previously a golf course. The area acquired is a biologically sensitive and culturally significant estuary, nearshore, and riparian habitat on the alluvial fan and stream delta of Johns Creek. It includes a stretch of marine shoreline with remnant dendritic channels and emergent salt marsh, as well as the mouth and lower part of Johns Creek that discharges into Oakland Bay. This area serves as a key habitat for several species of salmon, marine mammals, and many waterfowl and bird species and is an important cultural resource for the Squaxin Island Tribe.

The Capitol Land Trust was able to leverage NEP funds ($251,000) to purchase the $2 million property. The land is now a preserve. Restoration included removal of buildings and a 1,400-foot tidal dike, and the creation of new tidal channels along the marine shoreline and new side channels on Johns Creek. In addition to NEP grant, the Capitol Land Trust received funding from other state and federal agencies, the Squaxin Island Tribe, and Taylor Shellfish Farms, along with help from the Mason Conservation District. Through this combined funding, a total of 74 acres were preserved on the Bayshore Peninsula, including the Johns Creek area, and surface water rights that were previously being used to irrigate the golf course were returned to instream flow for the benefit of salmon and other wildlife.

Long-term plans for the area include accessible trails, viewing platforms, and covered structures to support environmental education. Currently, the preserve is used as a field trip site where middle school students learn how to conduct environmental monitoring.

Pre- and post-restoration monitoring data are not currently available to determine the amount of nitrogen being reduced through this project. However, according to the Golf Course Environmental Profile Nutrient Management Report (Golf Course Superintendents Association of America, 2009), the nitrogen application rate to golf courses in western Washington is 3.2

pounds per 1,000 square feet. Based on the extent of golf course area being restored (47 acres) this results in an approximate removal of 6,500 pounds of nitrogen from fertilizer application.

Stormwater Treatment

Lake Whatcom Phosphorus Management

Two projects were funded to address phosphorus management in Lake Whatcom. For the first project, the City of Bellingham received funding to address water quality issues in response to changes in land use in the Huntington and Shepardson drainage area. This drainage area was previously forested land before being developed into a residential area. The city received funds to retrofit grassy ditches and an unpaved roadway section and install enhanced treatment and infiltration systems designed specifically for phosphorus removal. This project was expected to treat runoff from 18 acres of residential development, which currently adds an estimated 18 pounds of dissolved phosphorus to the lake annually.

The City of Bellingham conducted pre- and post-construction stormwater monitoring for effectiveness. Sampling occurred at inputs into the drainage area and stormwater at the end of the treatment facility. Samples were analyzed for phosphorus and other conventional parameters.

This study did not meet its sampling objectives within the project reporting period in part because of the inherent difficulty of stormwater sampling. Usable data were collected from only 56% of samples during the pre-construction monitoring period and 58% of samples during the post-construction monitoring period (Table 5). Data were either unable to be collected or discarded due to malfunctioning equipment and high volumes of unexpected stormwater inflow. During monitoring, an outside input to stormwater flow was observed, possibly originating from private land outside of the study area that flowed through the stormwater system during storm events.

The project was expected to remove 73% of phosphorus based on the project design loading and treatment rates (Wilson Engineering, 2015). Based on the post-construction monitoring data that was collected, the project achieved a 48% reduction in total phosphorus (Table 5). The City of Bellingham attributed the lower amount of phosphorus removed to the unexplained inflow of excess stormwater into the treatment area. The City of Bellingham plans to monitor this area and report on its performance as part of the Lake Whatcom TMDL Implementation Plan, in addition to including results for nutrient BMPs in 2020.

Whatcom County and the City of Bellingham also received funding to design and construct the Academy Road Stormwater Improvements project. This work will benefit Lake Whatcom water quality by treating and reducing phosphorus loading in stormwater runoff from the surrounding developed residential area. The new stormwater treatment system treats runoff from the 76-acre basin. The system primarily targets phosphorus removal generated by developed residential lots, streets, and grassy ditches.

The treatment system intercepts stormwater prior to discharging into the lake and provides enhanced treatment of phosphorus. This treatment process is expected to reduce phosphorus by

63% of its current load and be an innovative effort to treat stormwater through a cost-effective and easily maintained system (Table 5). The Academy Road Stormwater Improvements Project should also provide other benefits, including reducing heavy metals, fecal coliform bacteria, and total suspended solids entering Lake Whatcom. These reductions are expected to help improve habitat for fish and other aquatic organisms in the lake. Effectiveness monitoring of this treatment system will determine whether the system is working and meeting its design criteria.

Table 5. Lake Whatcom Phosphorus Management project outcomes (City of Bellingham and Whatcom County Public Works).

Phosphorus Reduction	Huntington/Shepardson Project	Academy Road Project
Expected reduction (%)	73%	63%
Actual reduction (%)	48%	–

OSS Denitrification

OSS Denitrification Verification Study

Washington State Department of Health and the University of Washington Department of Civil and Environmental Engineering collaborated on a project to design and evaluate cost-effective, reliable, and low-maintenance public domain treatment technologies that have high nitrogen removal efficiencies. The project evaluated three cost-effective and low-maintenance technologies that are used successfully in other parts of the United States to remove high levels of nitrogen from sewage. These systems were tested for use in Washington to assess design improvements and potential application. Systems were tested using a consistent source of domestic wastewater on the grounds of the Snoqualmie Wastewater Treatment Plant. The systems were removed at the end of the project.

The study tested three systems over a 1-year program using the EPA Environmental Technology Verification protocol for nutrient reduction. The systems were evaluated based on various stress tests, which were a series of simulated changes in wastewater flow due to various activities that may occur at single-home residences.

The first system is an enhanced recirculating gravel filter system. The 12-month testing period resulted in an average nitrogen removal of 82% and the average effluent total nitrogen concentration was 8.6 mg/L (lower than treatment objective of less than 20 mg/L) (Table 6). This system had high denitrification efficiency, showing low average effluent of nitrate/nitrite (0.6 mg/L). The nitrogen removal performance was impacted by changes in the influent total nitrogen concentrations and not by temperature or any of the stress tests. Average total phosphorus removal for this system was 40%.

The second system is a septic tank followed by a recirculating gravel filter and a vegetated denitrifying woodchip bed system. The average nitrogen removal for this treatment system was 92% and the average effluent concentration was 4.0 mg/L, which was well below the treatment objective of less than 20 mg/L (Table 6). Monitoring and assessment of the effluent nitrogen over the 12-month performance-testing period found that effluent total nitrogen concentrations

increased with lower temperatures. Stress tests showed few effects, with the exception of increased effluent nitrogen concentration during the low loading test. The average total phosphorus removal for the verification-testing period was 43%.

The third system in the study is a vegetated recirculating gravel filtering system. Final results showed that the average annual nitrogen removal was 69% and the average effluent concentration was 15.1 mg/L, less than the treatment objective (20 mg/L) (Table 6). The denitrification efficiency was lower than expected. The average annual total phosphorus removal was 40%.

Table 6. Summary of on-site septic system denitrification verification study results (UW and DOH).

On-site Septic System Technology	Total Nitrogen Removal	Total Phosphorus Removal
Enhanced recirculating gravel filter system	82%	40%
Recirculating gravel filter and vegetated denitrifying woodchip bed system	92%	43%
Vegetated recirculating gravel filter system	69%	40%

Hood Canal OSS Study

The Hood Canal OSS nitrogen reduction project was completed by the Hood Canal Salmon Enhancement Group. This study installed two nitrogen-reducing OSS on nearshore properties along lower Hood Canal. One system was installed at the offices of the Salmon Center in Belfair, while another was installed at a private residence (Woodcock) in Union. The septic systems were sampled monthly for 2 years at both the Salmon Center and Woodcock system in order to evaluate their performance.

The wastewater treatment technology utilizes two bacteriological treatment processes for the removal of nitrogen, known as nitrification and denitrification. The first step in the treatment process is a recirculating gravel filter, where the process of nitrification occurs when ammonium is converted to nitrite and then nitrate. The second step is a vegetated denitrifying woodchip bed, which provides conditions favorable for denitrification whereby nitrate is reduced by bacteria, resulting in nitrogen gas as an end product.

Both of the treatment study sites showed decreased nitrogen measured in effluent (Table 7). Denitrification in the vegetated denitrifying woodchip bed improved in the latter part of the study, where average nitrate/nitrite removal efficiency increased at both sites (from 45% at both sites to 84% and 90% at Salmon Center and Woodcock, respectively).

Table 7. Hood Canal OSS study outcomes (Hood Canal Salmon Enhancement Group).

	Salmon Center	Woodcock Residence
Nitrate/nitrite removed	45%–84%	45%–90%
Total nitrogen removed	46%	51%

The installation cost per system in this study is approximately $35,000. However, information from the review committee noted that a more economically friendly design is feasible. Maintenance required for these systems includes adjustments to pump settings and supplemental woodchips added to the vegetated denitrifying woodchip bed, and cleaning of the pump two to three times per year. Based on this study, the most significant issue relating to equipment performance was due to groundwater inflow during heavy precipitation at the Woodcock site that caused the system to be decommissioned. As of 2019, the system at the Salmon Center in Belfair is still in use.

Education and Outreach

LakeWise Program

The LakeWise program in Snohomish County works to reduce nutrients by building awareness of water quality impacts that residents have on their lakes. The program aims to influence behavioral changes through incentives, education, and technical assistance. The program is focused on nine specific BMPs landowners can take to reduce pollution. Landowners that adopt all BMPs on their property are considered LakeWise certified and receive a sign of acknowledgment. Shoreline landowners are also encouraged to maintain or restore shoreline vegetation to help filter nutrients and provide shoreline habitat.

NEP grant funding expanded and enhanced the existing LakeWise program. Over the grant period, the LakeWise program worked with several lake communities through various outreach activities. Comprehensive homeowner guides were developed to guide shoreline planting and stormwater infiltration. The program raised awareness of nutrient pollution, potential sources, and BMPs to reduce nutrients. Many of the target lake households adopted BMPs for septic system care, fertilizer use, infiltration of stormwater runoff, pet waste management, and bare soil and erosion control. Shoreline landowners also planted shoreline buffers.

The long-term goal of the program is to have sustained actions by landowners that improve water quality and aquatic habitat and change behaviors for shoreline development. Water quality conditions will continue to be assessed through a long-term volunteer lake monitoring program. The LakeWise program continues to work to improve nutrient pollution in Snohomish County and provides outreach information on the LakeWise webpage.[2]

Lessons learned in the LakeWise Program Evaluation 2017 indicated that (1) attending a workshop and participating in a site visit increased awareness of use of certain BMPs, and (2) financial incentives are a motivator for many activities, including septic system inspections, workshop participation, site visits, and shoreline restoration. Recommendations are to invest in community engagement, improve program marketing to new landowners, continue using mailers, workshops, and septic care incentives, maintain ongoing communication with landowners (particularly after site visits), and continue to increase interest in shoreline restoration with incentives and outreach. Since the grant funding period, the LakeWise program

[2] https://snohomishcountywa.gov/1125/LakeWise

has continued to develop a strategic communications plan, including improving communications to watershed landowners, better employing social media, developing and sending a regular email newsletter, working with new property owners, and improving website design.

LakeWise program outcomes from the NEP grant-funding period (2015–2017):

- Household participation: 320.
- Home site visits: 139.
- Workshops and community events: 16.
- LakeWise certifications: 61.
- Households with shoreline restoration projects: 35. This resulted in an estimated 2,271 feet of restored shoreline habitat and 1.2 acres of shoreline buffer plants.

Based on the project outcomes at the end of the grant-funding period (2017), nutrient reductions were estimated using an adapted nutrient model for Lake Loma developed by Ecology (M. Roberts, 2013). This project estimated annual 2,624 pounds of nitrogen removal and 147 pounds of phosphorus removal.

As of early 2019, 542 households had participated in the LakeWise program by attending a septic system care or natural lawn care workshop, 206 properties have had a LakeWise site visit and are working on completing the LakeWise checklist, and 84 properties have completed the checklist and become LakeWise certified (Marissa Burghdoff, pers. comm., 2019). For shoreline properties, 43 are LakeWise certified and 55 properties have a healthy shoreline as classified by the LakeWise program.

South Sound Natural Lawn Care

The City of Olympia developed the South Sound Natural Lawn Care program. It was created to reduce nutrient and pesticide loading into Budd Inlet and Puget Sound and targeted high-priority neighborhoods within the Deschutes watershed. The outreach and education program targets local residents doing their own lawn care and using quick-release fertilizers and weed-and-feed products. Key aspects of the program include intensive outreach with technical assistance and incentives that include a free soil test, two educational home visits by a lawn care professional, and demonstration workshops and incentives.

From 2014 to 2015, 220 households participated in the South Sound Lawn Care Program. Major outcomes by the end of the program included testing and analyzing soil samples, site visits by a lawn coach, program incentives for natural lawn care products, a natural lawn care video series designed for Puget Sound regional use, and communication of natural lawn care tips via email and demonstrations at outreach events and workshops.

Results from educational outreach efforts and a follow-up survey from the program showed that the program instigated behavioral changes. The largest changes in behavior were associated with lawn care practices and incentives supported by demonstrations and site visits. Survey results indicated that more than 75% of participants reported using natural lawn care practices (e.g., applying lime, using slow-release or organic fertilizer, aerating, and avoiding weed-and-feed,

which is quick-release fertilizer combined with pesticides). The second-largest reported behavior changes were avoiding broad application of weed killers, avoiding overapplication of fertilizer, and mulch mowing in dry months. Nearly all respondents (98%) indicated that their use of natural lawn care practices increased.

Survey results showed that at least 40% of participants were using all key lawn care practices, and more than 70% of participants were avoiding products that harm water quality. Additionally, natural or organic fertilizer use increased from 23% to 78%, with a 36% increase in the number of households calculating lawn area and application rate to determine fertilizer use. Results also showed that there was a large reduction in weed-and-feed use, decreasing from 73% to 16%.

Expected nitrogen reductions were calculated based on the baseline and post-outreach survey information about fertilizer and pesticide use and information gathered by lawn coaches during site visits. Expected reductions from the South Sound Natural Lawn Care projects are 1.55 pounds per 1,000 square feet of lawn, reduced from 3.36 pounds to 1.81 pounds of nitrogen per 1,000 square feet. This represents a 46% reduction in expected nitrogen use.

Outcomes for the City of Olympia South Sound Natural Lawn Care project are as follows:

- Number of households participating: 220.
- Number of home site visits: 386.
- Number of soil samples: 220.
- Expected nitrogen reduction: 1.55 pounds per 1,000 square feet (46%).

Project outcomes, assessed with lawn coach guidance and soil test recommendations, include the use of appropriate products and methods to improve overall soil and lawn health, resulting in long-term reductions in nutrient and pesticide loading to surface waters. The project also serves as a model for similar programs that could be implemented in other jurisdictions.

The City of Olympia continues to provide educational information on their Natural Yard Care webpage,[3] including natural lawn care instructional videos, lawn care guide, and other resources.

Nutrient Synopsis Website

Ecology received funding to bring together information about the state-of-the-science of nitrogen in Puget Sound into a website and an ArcGIS online story map targeting the general public, other agencies and local governments, and researchers. The purpose of this project was to highlight elements of various Ecology and other scientific publications that have quantified nitrogen sources and pathways to Puget Sound. Initially, Ecology nitrogen webpages displayed both qualitative and quantitative information on nitrogen in the Puget Sound ecosystem from 2015 to 2017 to improve communication to both technical and general audiences.

Ecology then developed a Nitrogen in Puget Sound Story Map[4] using ArcGIS Online in 2018. The story map communicates highly complex technical information about nitrogen in a more

[3] olympiawa.gov/city-utilities/water-resources/pollution-prevention/natural-yard-care.aspx
[4] https://waecy.maps.arcgis.com/apps/MapSeries/index.html?appid=907dd54271f44aa0b1f08efd7efc4e30

interactive style than a traditional website by using maps, graphs, and references to associated content and data. Topics covered within the story map include the effects of excess nitrogen on water quality conditions in Puget Sound, detailed descriptions of sources and pathways of nitrogen delivery, an overview of Ecology's marine and freshwater nutrient monitoring and how to access monitoring data, ongoing nutrient studies, and nitrogen trends in rivers and marine waters. It is updated periodically, as new data and studies become available.

Since the creation of the story map, Ecology has shared this scientific communication tool at multiple conferences throughout the Pacific Northwest to audiences comprised of scientists, policymakers, local governments, GIS developers, and others interested in learning more about the effects of nutrients in Puget Sound. The story map receives an average of 100 monthly views and regular inquiries from the public and researchers.

Other

Shellfish at Work Study

The Pacific Shellfish Institute received funds for a Shellfish at Work project to reduce nutrients in the Budd Inlet watershed. The goals of this project were to engage community members in the cultivation of a local species of bay mussel (*Mytilus trossulus*), quantify the nutrient sequestering abilities of this process, and demonstrate market-based mechanisms for cleaning South Puget Sound's Budd Inlet.

The pilot study (2012–2014) quantified actual and potential nutrient reduction based on the pounds of mussels harvested and biomass generated at the study sites (Table 8). Nutrient reductions were calculated by multiplying the amount of harvested mussels or potential biomass by the total percent nitrogen. Actual nutrient reductions from the mussels harvested from each site were 43 pounds of nitrogen and 3 pounds of phosphorus, based on approximately 4,200 pounds of mussels harvested. However, the potential for nutrient removal for these sites was 80 pounds of nitrogen and 6 pounds of phosphorus. Differences between the actual harvested biomass and potential biomass may be attributed to factors during the harvesting procedures and from sloughing off of mussel straps during the late season due to weight.

Following the pilot study, this project received additional NEP funding and continued to grow mussels and harvest them for nutrient removal and the generation of surf-to-turf mussel compost, where the nutrients are recycled by serving as compost used by local farmers. The project also continued to provide outreach and education opportunities to the general public and students and developed new partnerships with schools and local agencies.

The potential for nutrient reductions based on the potential pounds of biomass generated at the two sites in lower Budd Inlet during the 2015 study was 85 pounds of nitrogen and 5 pounds of phosphorus (Pacific Shellfish Institute, 2017). However, during the study, the actual amount of mussels harvested was lower (50 and 3 pounds for nitrogen and phosphorus, respectively), and therefore had a smaller amount of actual nutrients removed. Differences in potential versus actual nutrient reductions are attributed to (1) some of the straps of mussels were used for

education and outreach instead of biomass measurements, and (2) sloughing off from late-season weight. Table 8 shows nutrient reductions during both 2013 and 2015.

Table 8. Shellfish at Work nutrient reduction project outcomes (Pacific Shellfish Institute, 2017).

Nutrient Reductions	2013	2015
Nitrogen removed (lbs.)	43	50
Phosphorus removed (lbs.)	3	3

In addition to the nutrient removal by mussels, outreach and education activities were used to increase awareness and motivate citizens to make personal behavior choices to reduce nutrient and bacteria loading. Public outreach activities included public workshops, K–12 and college presentations, student mentoring, professional conferences, and meetings with key stakeholders.

The Pacific Shellfish Institute provides more information on this project on their Mussel Power webpage,[5] along with additional information and resources for other research projects and education and outreach.

[5] www.pacshell.org/mussel-power.asp

Science Projects

Scientific application and research projects were funded to a lesser extent (approximately $2.4 million or 27% of grant funds) than nutrient management projects (73%). These scientific studies were funded to help accomplish goals established by the NSFS. Priorities included refining estimates of nutrient sources, additional water quality monitoring, and developing modeling tools (Table 9).

Table 9. Scientific applications and research projects.

Project Title	Recipient	Project Type	Funds Allocated*
Modeling	Ecology	Modeling	$1,313,000
Ferry-Based Marine Water Quality Monitoring	Ecology	Monitoring	$261,000
High Resolution Marine Water Quality Monitoring	University of Washington	Monitoring	$195,000
Bertrand Creek Water Quality Monitoring	Ecology	Monitoring	$150,000
SoundToxins HABs Monitoring	University of Washington	Monitoring	$87,000
Nutrient Processes in Puget Sound	USGS	Research	$302,000
Puget Sound Bottom-Water Respiration	Ecology	Research	$54,000
Blue Ribbon Panel on Ocean Acidification: From Knowledge to Action Report	University of Washington	Research	$20,000
Total			$2,382,000

* Funds allocated were not necessarily spent.
HABs=harmful algal blooms.

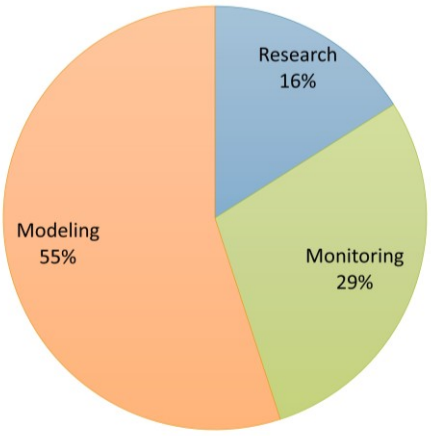

Figure 7. NEP grant funding allocations for scientific application and research projects.

Appendix A includes links to final project reports, project websites, and available data.

Modeling

The Salish Sea Model (previously called the Puget Sound Dissolved Oxygen Model) was developed by the Pacific Northwest National Laboratory (PNNL) in collaboration with Ecology. The Salish Sea Model (SSM) is a state-of-the-science computer modeling tool used to simulate the complex physical, chemical, and biological patterns inherent in this system. NEP grant funding allowed for continued updates to the model, including the development of an ocean acidification module, sediment diagenesis module, and dissolved oxygen modeling refinements. In addition, NEP funding allowed for development and updates of hydrologic and water quality regressions that are used as inputs to the model. Funds were also used for technical support and computational resources throughout model development.

Ecology's Salish Sea Model[6] webpage provides a list of publications relating to these model improvements.

Ocean Acidification Module

Ecology and PNNL developed a pH scoping document that identified approaches for a pH model as part of the existing Salish Sea Model (Long et al., 2014). The purpose of the scoping document was to describe approaches to expand the Salish Sea model to evaluate pH and aragonite saturation state and quantify the relative influences of regional and global sources. It identified critical information gaps that could be considered in acidification modeling programs. It provided recommendations to evaluate the relative impacts using available information as part of the Salish Sea Model and led to the addition of an ocean acidification module.

The addition of the ocean acidification module to the Salish Sea Model is described in two reports (Bianucci et al., 2018; Pelletier et al., 2017a). The module is used to model processes influencing ocean acidification by evaluating carbonate system variables, including aragonite saturation. It is used in assessing the ability for calcifying organisms to build shells. The module incorporates the additions of total dissolved inorganic carbon and alkalinity as state variables. Pelletier et al. (2017a) examined and quantified how regional freshwater and land-derived sources of nutrients generally impact acidification in Salish Sea. The ocean acidification module continues to be used within the Salish Sea Model, and its performance continues to be assessed and optimized based on the availability of new observational data and studies.

Sediment Diagenesis Module

Ecology and PNNL developed a Sediment Diagenesis Module for the Salish Sea Model. The overall modeling goal was to improve the performance of the model by incorporating sediment processes that influence dissolved oxygen. The sediment diagenesis module is described in its development document (M. Roberts et al., 2015) and final report (Pelletier et al., 2017b). The final calibrated model includes the sediment diagenesis module and is being used to evaluate the relative effect of anthropogenic nutrient sources.

[6] https://ecology.wa.gov/SalishSeaModel

Dissolved Oxygen Modeling Refinements

The SSM went through a series of other refinements to improve dissolve oxygen modeling. SSM improvements include:

- Expanded model domain with the open boundary extending around the northern end of Vancouver Island and seaward to the edge of the continental shelf, to improve SSM boundary condition predictions.
- Increased resolution and grid refinement for a portion of the domain to examine the influence of grid resolution on exchange through the Tacoma Narrows.
- Optimized computational efficiency (time step) of the model while it is run "off-line" (the hydrodynamic model is run first and then the output is directed as input to the water quality model).
- Updates to allow for distributed meteorological data, including wind speed and direction. Previous versions of the SSM used Weather Research Forecasting (WRF) model results generated by the University of Washington over a 12-km grid. Meteorological prediction results from the WRF model grid were used to describe uniform wind and heat load over the Salish Sea domain. The improvement allows for utilization of higher-resolution WRF Model results to a 4-km grid scale.
- Development of a complementary FV-COM (Finite Volume Community Ocean Model) plume model to allow plume particle tracking, and assessed the extent of a three-dimensional dilution zone so that both near-field and far-field impacts can be better understood.

Improvements to SSM are ongoing. The model is an important tool to identify the relative influences of climate effects, local anthropogenic nutrient sources, and the Pacific Ocean on dissolved oxygen. This effort helps inform the benefits of different nutrient management options considered in the Puget Sound Nutrient Source Reduction Project.

Technical Support and Computational Resources

NEP grant funds were also used to provide technical support and computational resources from PNNL, including computational core hours from PNNL and a pilot study to run the SSM on cloud computing resources.

Monitoring

Ferry-Based Marine Water Quality Monitoring

Ecology received funding for ferry-based marine water quality monitoring[7] that added Acoustic Doppler Current Profiling (ADCP) instruments to two ferries that regularly cross the entrance of Puget Sound. This type of monitoring provides fine-scaled spatial and temporal data for this location and provides information that can categorize intrusions and exchanges of ocean and Puget Sound water to improve characterization of oceanic inflow.

[7] https://ecology.wa.gov/Research-Data/Monitoring-assessment/Puget-Sound-and-marine-monitoring/Monitoring-Puget-Sound-from-ferries

Ecology worked with the Washington State Ferries to design a monitoring instrument to be placed at the lower hull of the ferries. Once installed, these ADCP instruments were connected to a networked data acquisition system to record measurements. Following data collection, the data were evaluated for quality using rigorous quality assurance procedures so that the final data set includes only data that meet standards.

This work resulted in a comprehensive, cloud-based data processing framework to automatically generate near real-time information products from the ferries. Data collection has continued since this program started in 2013. These data are key to mapping tidal currents and understanding the ocean–sound exchange flow. The project also resulted in a key data set of water current profiles.

High-Resolution Marine Water Quality Monitoring

The University of Washington received NEP grant funds to support continuous marine water quality monitoring at buoys throughout Puget Sound. The Oceanic Remote Chemical Analyzer (ORCA) autonomous moored profiling system provides real-time data streams of water and atmospheric conditions. These six profiling buoys are a key part of the overall monitoring strategy for Puget Sound Ecosystem Monitoring Program (PSEMP). The monitoring buoys are located in Admiralty Reach, South Puget Sound, Hood Canal, Main Basin, and Dabob Bay. These monitoring efforts are used for identifying water masses and increasing data representativeness of Puget Sound water quality conditions.

This project resulted in a collection of over 11,000 water column profiles measured by the buoys, 93 cruises to perform buoy maintenance and repair, and about 600 water samples (2012–2013) that were analyzed as described in the project's Quality Assurance Project Plan (Newton and Devol, 2012), found on the ORCA webpage.[8] Data are used to improve understanding of water quality in Puget Sound. Data are also made available to the public through the Northwest Association of Networked Ocean Observing Systems (NANOOS data explorer[9]).

Bertrand Creek Water Quality Monitoring Study

Ecology received funding for a 3-year pilot study in the Bertrand Creek watershed, a tributary that drains into the Nooksack River, which is primarily an agricultural watershed. This pilot study meant to assess BMPs with water quality improvements. However, given the complexity of the issues in the watershed, the short timeline for this study would have been insufficient to measure any appreciable change in water quality.

Study results describe water quality, habitat, and biological conditions in the watershed and measure changes in water quality indicators over the study period (Collyard, 2019). This study was not a comprehensive assessment of individual water cleanup activities. Rather, it provides a baseline for understanding watershed processes.

[8] https://nwem.apl.washington.edu/about_proj_ORCA.shtml
[9] http://nvs.nanoos.org/Explorer

The report concludes that water quality in Bertrand Creek is strongly influenced by groundwater contributions and many of the underlying water quality issues, other than bacteria, are driven by this dynamic (Collyard, 2019 *in review*). Actions to reduce bacteria inputs focused mainly on controlling overland contributions and would likely not have improve ground water quality in the watershed within the study period. Results from this study may be used as a general characterization of current conditions in the watershed and baseline data for future activities. It should be considered for future assessments of a larger set of cleanup actions. Study recommendations indicate that if a follow-up assessment is to occur, watershed managers should first consider if sufficient water cleanup or restoration actions have occurred over a great enough period of time before starting.

The published report is expected in autumn 2019.

SoundToxins HABs Monitoring

The SoundToxins Partnership monitors harmful algal blooms (HABs) in Puget Sound. Originally created in 2006 by NOAA's Oceans and Human Health Initiative, NEP grant funds supported this monitoring program after budget cuts in 2012.

The goal of the cooperative SoundToxins partnership is to establish a cost-effective monitoring program to provide an early warning of HAB events to Washington State Department of Health. SoundToxins HABs monitoring plays a critical role in the management of Puget Sound shellfisheries by helping to identify areas with toxic algae and alerting resource managers to direct additional monitoring efforts to the area. SoundToxins samples for phytoplankton focuses on identifying key HAB species. These data are used to pinpoint shellfish-growing areas for regulatory testing that monitors key environmental parameters indicative of potential HAB species. Monitoring data can then be used to provide early warning of harmful events.

SoundToxins uses a trained citizen science monitoring program that provides critical information to federal and state agencies, tribal harvesters, fish and shellfish farmers, community members, and academia for decision-making and resource allocation. An alert system to health officials shows the presence of harmful algae species that warrant additional review of shellfish products for unsafe biotoxin levels.

Sampling occurs at 16 sites from the San Juan Islands to Totten Inlet in South Puget Sound. Samples are collected weekly from March through October and monthly (or bimonthly) from November through February. Sampling parameters include salinity, temperature, and phytoplankton species diversity (*Pseudo-nitschia* species, *Alexandrium* species, *Dinophysis* species, and *Heterosigma akashiwo*), with some additional samples processed for nutrients, chlorophyll, and toxins.

The data collected by the SoundToxins program were summarized and presented as part of the PSEMP MWQ Working Group annual reports. Data are archived and preserved so that they can be used as a long-term data set for future analysis, as well as for incident review. All of these data sets are preserved for long-term forecasting and use by natural resource managers and researchers as harmful algae modeling advances.

Additional Science Projects

Nutrient Processes in Puget Sound

The United States Geological Survey (USGS) received NEP grant funding to study nutrient processes in Puget Sound and published two reports.

The first report is a literature review of existing approaches used to measure benthic nitrogen flux in Puget Sound and elsewhere. The report summarizes known benthic nitrogen fluxes in Puget Sound (Sheibley and Paulson, 2014). The report identified factors to consider for each approach used to measure benthic nitrogen fluxes.

The literature review included a compilation of 148 individual flux chamber measurements and 38 diffusive fluxes. Reviewing these data showed that fluxes beneath deep water (greater than 50 meters) tended to be lower than those beneath shallow water (less than 50 meters). There is a greater range of benthic fluxes at shallow depths than in deeper waters. The collection of additional study site information describing environmental factors (bottom temperature, depth, sediment porosity, sediment type, and sediment organic matter) will help to quantify benthic nitrogen flux in Puget Sound.

The second report addresses nutrient attenuation in rivers and streams throughout the Puget Sound region (Sheibley et al., 2015). This report is a review of scientific literature about physical, chemical, and biological factors related to nutrient attenuation. It identifies what factors are responsible for attenuating nutrients in freshwater systems and where these processes are expected to occur, to better understand and manage for the delivery of nutrients from rivers and streams to Puget Sound nearshore waters. Attenuation models were used to identify areas where high and low instream nutrient attenuation would be expected across different spatiotemporal scales.

Sheibley et al. (2015) recommend that nutrient management efforts focus on the preservation and improvement of instream nutrient attenuation by increasing travel time and contact time of water to sediment surfaces. Additionally, lowering nutrient concentrations will help to increase attenuation efficiency and avoid saturation of instream attenuation. Recommended activities to improve attenuation include maintaining and restoring channel floodplain connectivity and riparian zones, managing point and nonpoint nutrient loads, restoring woody debris, and maintaining pool-riffle morphologies to increase travel time. These activities are similar to those recommended to improve salmon habitat and can therefore serve a dual purpose to enhance the potential for nutrient attenuation.

Puget Sound Bottom-Water Respiration

The Padilla Bay National Estuarine Research Reserve received funding to measure Puget Sound bottom-water microbial restoration. This study conducted a survey of microbial respiration rates for near-bottom waters at Ecology's long-term marine water quality monitoring sites throughout Puget Sound.

Observations from this study will be used as a source for comparison with SSM output and potentially used for calibration purposes. This work will also be used to improve estimates of the temporal and spatial variability in rates of pelagic microbial respiration in marine waters, identify environmental parameters influencing pelagic microbial respiration, and determine the contribution of pelagic microbial respiration to oxygen and carbon cycling.

Sample collection and analysis occurred from fall 2018 through spring 2019 throughout Puget Sound. A report is expected in 2019 that will include the final data synthesis.

Blue Ribbon Panel on Ocean Acidification: From Knowledge to Action Report

Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response (2012) is a synthesis of scientific information and research to help address the issue of ocean acidification in the state. This report was completed in part to support the Washington State Blue Ribbon Panel on Ocean Acidification, which was formed in response to concerns about ocean acidification in Washington. Washington is particularly vulnerable to ocean acidification, which would have significant implications for Washington's marine environment, state and local economies, and tribes.

The report gave the Blue Ribbon Panel recommendations for Key Early Actions, including the following strategies and actions:

- Reduce emissions of carbon dioxide.
- Reduce local land-based contributions to ocean acidification.
- Increase our ability to adapt to and remediate the impacts of ocean acidification.
- Invest in Washington's ability to monitor and investigate the causes and effects of ocean acidification.
- Inform, educate, and engage stakeholders, the public, and decision-makers in responding to ocean acidification.
- Maintain a sustainable and coordinated focus on ocean acidification at all levels of government.

Discussion

Spatial Distribution of Nutrient Projects

This section presents a general spatial analysis of the NEP Toxics and Nutrients grant projects addressing nutrients. Puget Sound Action Areas (PSAAs) represent distinct geographic areas with similar physical and biological conditions as described in the Puget Sound Action Agenda (Puget Sound Partnership, 2009). These PSAAs are used in this report to spatially organize and synthesize localized nutrient-related projects and activities (Figure 8).

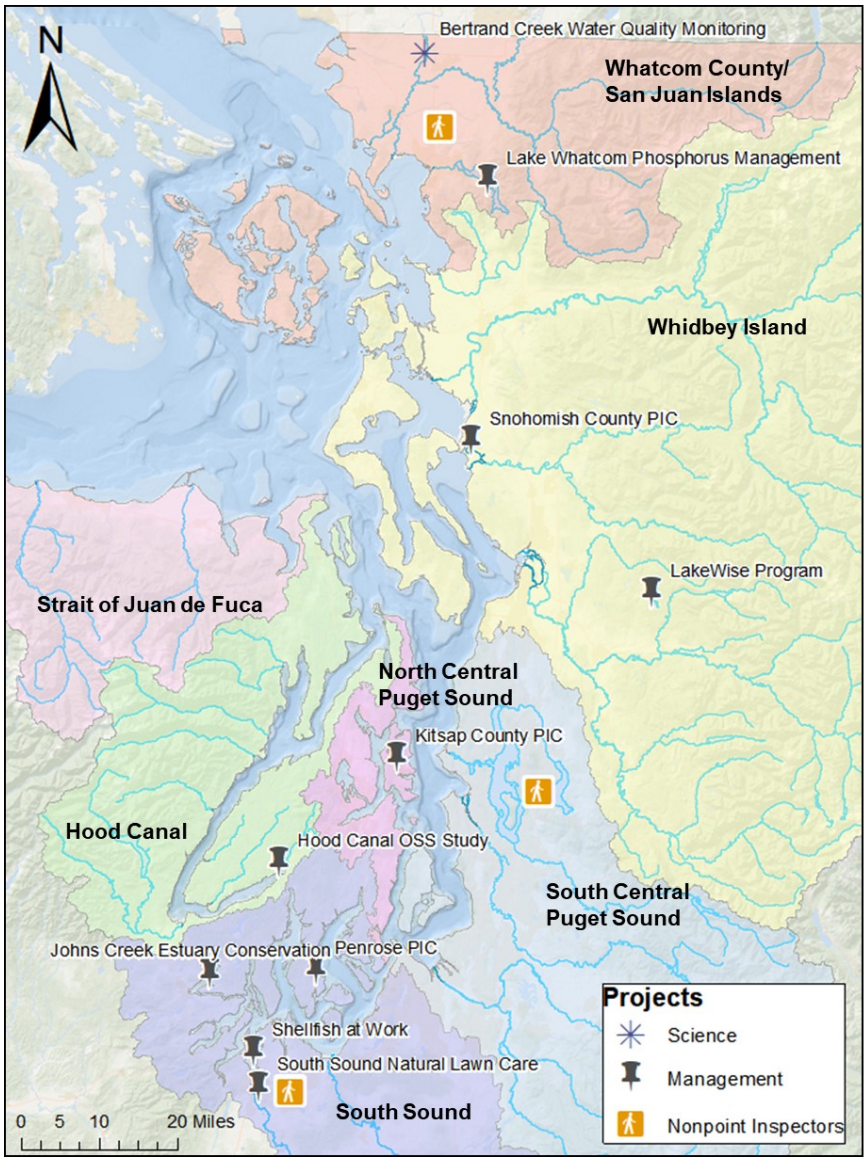

Figure 8. Map of nutrient projects and Puget Sound Action Areas.

Projects were identified with the PSAA in which they were primarily located. While some projects were clearly identifiable in a particular action area (e.g., South Sound Natural Lawn Care in South Puget Sound and Kitsap County PIC in North Central Puget Sound), other project locations were not as easily delineated. For example, nonpoint specialists are grouped by the office location that they were based from, however, their work crossed action area boundaries and serviced the greater Puget Sound region, with some specialists focusing in specific counties.

Priority Areas for Nutrient Management Work

Guidance from the NFS identified key areas to focus nutrient management activities on for marine waters (Lynch Cove in Hood Canal, Budd Inlet in South Puget Sound, and Whidbey Basin) and watersheds with nutrient-related TMDLs addressing dissolved oxygen impairments. Nutrient projects were summarized by PSAA, along with the number of TMDLs within the Action Area and funding allocations by project type (Table 12).

Table 10. Summary of TMDLs and nutrient projects and funding in each Puget Sound Action Area and broader regions.

Geographic Area	TMDLs	Management Projects	Management Funding	Science Projects	Science Funding	Total Funding
Puget Sound Action Areas						
Whatcom County/ San Juan Islands	0	1	$740,000	1	$150,000	$890,000
Whidbey Island	5	2	$396,000	0	$0	$396,000
South Puget Sound	2	4	$898,000	0	$0	$898,000
Hood Canal	0	1	$341,000	0	$0	$341,000
North Central Puget Sound	0	1	$334,000	0	$0	$334,000
South Central Puget Sound	5	0	$0*	0	$0	$0
Strait of Juan de Fuca	0	0	$0*	0	$0	$0
Region						
Puget Sound	--	0	$0	7	$2,231,000	$2,231,000
Greater Puget Sound	--	4	$3,811,000	0	$0	$3,811,000
Total	**12**	**13**	**$6,520,000**	**8**	**$2,381,000**	**$8,901,000**

*Funding allocations for projects within the Greater Puget Sound region (Nonpoint inspectors, agricultural BMP implementation) were distributed throughout various action areas.

The Hood Canal OSS Study was located in Belfair, near the Lynch Cove priority area in Hood Canal. The denitrification septic system from this study continues to work at the Belfair site (as of 2019).

Budd Inlet in South Sound was defined as a priority area and has a dissolved oxygen TMDL in development. Two nutrient projects were focused in this area: (1) South Sound Natural Lawn Care, an education and outreach program to reduce nutrients from lawn care practices, and (2) Shellfish at Work Study, an alternative approach to study the nutrient removal potential from

mussels in Budd Inlet. Additionally, nonpoint specialists were located at Ecology's headquarters and worked throughout South Sound.

Whidbey Island Action Area was also a priority area from the Action Agenda and has a high count of TMDLs (5 are either in development or approved). There were two nutrient management projects in this Action Area (Snohomish County PIC and LakeWise Program). The LakeWise Program provides education and outreach to communities with lakes throughout Snohomish County. The program focuses on private landowner efforts for reducing nutrient runoff and shoreline restoration. The Snohomish County PIC program, jointly funded between Ecology and DOH, received partial funding to help reduce nutrients throughout the Whidbey Island Action Area. Nonpoint specialists placed throughout the greater Puget Sound region worked in this priority area as well, particularly in Snohomish and Skagit counties.

The highest total of nutrient management grant funding ($3.8 million) was allocated for projects that crossed action area boundaries and were applied to the greater Puget Sound region. These projects include the nonpoint specialists, agricultural BMP implementation, the OSS denitrification verification study, and the nutrient synopsis website.

The majority of the grant funding for scientific application and research projects (94% or $2.3 million) was almost all focused on Puget Sound marine waters, with the exception of the Bertrand Creek water quality monitoring project in Whatcom County.

Quantifying Nutrient Reductions and Effectiveness Monitoring

The review of NEP Nutrients grant projects illustrated the gap in quantified information regarding the amount of nutrients reduced through these various management projects. Estimating the amount of nutrient removal may be accomplished through implementing effectiveness monitoring plan. Effectiveness monitoring allows for an assessment of how water quality improvement projects are working to reduce pollution and to evaluate if project goals are being achieved.

EPA provides extensive guidance on effectiveness monitoring in its *Monitoring and Evaluating Nonpoint Source Watershed Projects* report (Dressing et al., 2016). Ecology has also developed guidance for effectiveness monitoring for TMDLs and other water quality cleanup plans for the state (Collyard and Onwumere, 2013). Ecology's guidance document provides a strategy for effectiveness monitoring that is consistent with supporting watershed-based adaptive management efforts. Although developed for evaluating TMDL effectiveness, this guidance may be applied to other water quality improvement projects, such as the activities funded by the NEP Nutrients grant.

Ecology's effectiveness monitoring program measures the cumulative effect of all activities in the watershed. It is necessary as part of an adaptive management process because it allows for adjustments to restoration strategies if project goals are not being achieved. Major benefits of effectiveness monitoring include:

- More efficient allocation of funding.
- Optimization in planning and decision-making.
- Adaptive management or technical feedback to refine restoration treatment design and implementation.

Lessons learned from previous efforts have highlighted the need for a robust project planning process to optimize effectiveness monitoring projects. The development of an effectiveness monitoring project should consider the project scope and logistics, assess support from local partners, and have a clear understanding of the BMP implementation strategy within a watershed. For these types of projects, communication between project managers, local partners in the watershed, and those accomplishing on-the-ground fieldwork are critical to connect nutrient management and BMP activities with monitoring efforts.

NEP Nutrient Projects

While many of the NEP nutrient management projects provided estimates for expected nutrient reduction, many did not include post-project nutrient reduction measurements or an effectiveness monitoring program.

The Shellfish at Work study in Budd Inlet includes estimates of expected nutrient reductions and then reported actual, measured nutrient reductions. These results were helpful to determine differences between the expected and actual nutrient reductions and demonstrated areas for improvements in mussel harvesting techniques to optimize results in future efforts.

The City of Bellingham developed a stormwater treatment facility to reduce phosphorus inputs into Lake Whatcom from the Huntington and Shepardson drainage areas. While phosphorus reductions were estimated to result in 73% of phosphorus levels removed, monitoring post-construction showed that the actual phosphorus removed was 48%. This signified a need to re-evaluate the project design and effectiveness to correct issues occurring upstream of the project.

The original intent of the Bertrand Creek monitoring study was to evaluate the effectiveness of pollution control activities on agricultural land. Because BMP activities were not implemented within the study time frame, the results instead serve as a baseline data set for water quality conditions and may be used to evaluate cleanup activities in the future. Lessons learned from this project indicate the need for a clear project planning process to optimize water quality monitoring efforts with BMP implementation strategies and communication with local partners.

Lessons learned from these select projects indicate that there is a need for more post-project implementation monitoring and measurement of actual nutrient levels before and after management actions are taken, particularly in cases that are evaluating new technology or BMP implementation to evaluate effectiveness.

Henderson Inlet Effectiveness Monitoring Study

Although not funded by the NEP grant, a previous study for Henderson Inlet is an example of an effectiveness monitoring study that helped discern successful implementation and cleanup

activities (Collyard and Anderson, 2017). This study assessed the effectiveness of a post-TMDL implementation strategy to decrease fecal coliform bacteria loading into Puget Sound.

Approximately $22 million in state and federal grant funding went to 42 cleanup, restoration, and protection projects in the watershed. The study compared the relative ability of different restoration activities to reduce pollutant loading. Results from this study showed that stormwater retrofits, septic-to-sewer projects, and land acquisition and restoration projects were the most beneficial for decreasing bacteria levels in the watershed. This study also identified decreasing levels in nitrate at select sites that were attributed to stormwater retrofits and septic-to-sewer projects. Despite decreases in bacteria and nitrogen loading, results showed that some sites were unexpectedly showing increases in total phosphorus, signifying a need for further investigation to identify additional pollutant sources.

Ecology and Palouse Conservation District Paired-Watershed Monitoring Project

The Ecology and Palouse Conservation District Paired-Watershed Monitoring Project was also not funded by the NEP Toxics and Nutrients grant. However, it serves as an example of a type of study that evaluated land management practices and involved strong collaboration between local and state partners.

The Palouse River Watershed Regional Conservation Partnership Program, comprised of the Palouse Conservation District and many other partners, work with landowners in the watershed to help establish practices that reduce runoff and soil erosion. In 2016, the Palouse Conservation District and Ecology initiated a paired-watershed monitoring project to compare differences in water quality in two watersheds with different amounts of conventional and conservation tillage (till) (Collyard et al., 2019). Conventional till practices break down crop residue and can result in increased sediment entering adjacent streams. Conservation till practices leave crop residue on the soil surface and plant roots intact to serve as a filter, holding soil on the landscape, increasing infiltration rates, and reducing runoff.

The Kamiache Creek (treatment watershed with 80% conservation till and 20% conventional till) and Thorn Creek (control watershed with 75% conventional till and 25% conservation till) were the two study areas. The first year of monitoring showed that Kamiachie Creek, the conservation till watershed, had significantly lower sediment loading (220 tons/year) than Thorn Creek, which was mainly conventional till (2,447 tons of sediment/year). The second year of the monitoring data is not yet analyzed. However, the results from the first year of monitoring support the use of conservation till for reducing sediment runoff to adjacent streams.

Although this project was located in eastern Washington and measured sediment in the creeks, rather than nutrients, it is an example of a paired-watershed monitoring project that is being used to evaluate and compare BMPs in agricultural lands. This study exemplifies a successful approach for assessing land management techniques.

Additionally, this project demonstrates a collaborative effort between Ecology and Palouse Conservation District. Ecology developed the monitoring plan, trained Conservation District

staff, and provided water quality monitoring support throughout the duration of the project. Alternatively, the Palouse Conservation District was the leader for building local landowner relationships, fundraising and managing the project, and conducting the on-the-ground sampling. The Water Quality and Tillage Practices in the Palouse Story Map[10] communicates background information, study methods, and results of the project. The framework and lessons learned from this collaborative project can serve as a model for future effectiveness monitoring projects with Ecology and local watershed partners.

These effectiveness monitoring studies are critical when evaluating not only the benefits of cleanup activities, but also to identify projects that are not working as expected. Incorporating more effectiveness monitoring into nutrient management projects will improve the ability to measure benefits of cleanup and BMP activities, optimize distribution of grant funds, and review effectiveness of projects for future work.

[10] https://waecy.maps.arcgis.com/apps/Cascade/index.html?appid=e1296b1942894c10a056905609187b93

Conclusions

The NEP Toxics and Nutrients grant allocated funds to improve both human and environmental health by preventing, reducing, and controlling toxics and nutrients from entering Puget Sound fresh and marine waters. This synthesis report provides a summary of these nutrient projects and connects them within the broader framework of ongoing Puget Sound nutrient management efforts.

- The NEP grant funded 21 nutrient management and science projects. The majority of grant funds (73%) were focused on nutrient management.
- Nutrient management projects received $6.5 million. Highlights from these projects include:
  - Kitsap County and Tacoma-Pierce County Health Department PIC programs that identified and corrected failing OSS and BMP installations.
  - Jointly funded nonpoint specialists by Ecology and DOH to address nutrients and bacteria affecting shellfish harvesting areas and water quality throughout western Washington.
  - Land acquisition and restoration of habitat and estuary shoreline discharging into Oakland Bay as part of the Johns Creek Estuary Conservation project.
  - Education and public outreach, including workshops and site visits for homeowners as part of the Snohomish County LakeWise Program and South Sound Natural Lawn Care.
  - Communication of scientific research on nutrients through the web-based Nitrogen in Puget Sound Story Map.
  - The OSS denitrification verification study, showing that both the vegetated recirculating gravel filter and the recirculating gravel filter with the woodchip bed systems are reliable and effective in removing nitrogen from wastewater.
  - Other technology and implementation efforts to reduce nutrients, such as the mussel bioextraction study in Budd Inlet, stormwater treatment in Whatcom County, and the OSS denitrification study in Hood Canal.
- Many of the nutrient management projects were unable to be evaluated for effectiveness due to a lack of quantitative information describing nutrient reductions. This type of information is needed to evaluate project effectiveness and identify areas for improvement.
- Scientific application and research studies received $2.4 million in grant funding. Highlights include:
  - Development of and improvements to the Salish Sea Model (sediment diagenesis module, ocean acidification module, other dissolved oxygen modeling refinements). This model guides nutrient management decisions in the Puget Sound region to improve dissolved oxygen conditions.
  - High-resolution marine water quality monitoring data throughout Puget Sound to help fill key data gaps that will improve understanding of the interplay of nutrients and water quality, including monitoring of harmful algal blooms.
  - State-of-the-science reports on ocean acidification and nutrient processes in Puget Sound.

Lessons Learned

Grant Administration

Similar to those lessons learned stated in the Puget Sound Toxics Control report (T. Roberts, 2017), this synthesis report identified difficulties due to staff changes and other variables throughout the funding period (2011–2019). Shifts in project organization over the period of grant administration highlighted the need for the following items:

- Consistent project-tracking system throughout the entire duration of the funding period. This will include an organization and file management system with relevant information (e.g., points of contact, funds allocated, funds spent, project status reports, etc.).
- Clearly identified changes in projects (e.g., funding reallocation), particularly for projects that are jointly funded.
- Consistent assignment of all final project deliverables to a single designated location.

Nutrient Projects

The following are lessons learned from NEP-funded nutrient management projects:

- Community engagement is key. Outreach may differ based on the goals of each project and community, but it may utilize social media, websites with interactive materials and resources, mailers and newsletters, and connections with key community members for word-of-mouth communication.
- Follow-up surveys are useful to evaluate feedback when working with homeowners. These surveys (e.g., online surveys or mail-in postcards) are used to determine project effectiveness and identify areas for improvement.
- Incentives are helpful to encourage participation among homeowners and reduce costs associated with nutrient management activities (e.g., septic system pump vouchers or native plants for shoreline restoration).
- Effectiveness monitoring helps to measure nutrient reductions from implementation projects or identify areas that are not meeting expected results.

The following are lessons learned from NEP-funded nutrient scientific application and research studies:

- When administering effectiveness monitoring projects, working with local partners is critical to ensure the study design coordinates with on-the-ground activities.
- To improve access to data and results from monitoring and research studies, upload data to a public database and post publications to a related webpage.

Recommendations

Grant Administration

NEP Nutrients projects varied in terms of scale, funding rounds, locations, duration, points of contact, and final deliverables. Because of this, having a project tracking system in place for recordkeeping is key when trying to identify, assess, and summarize major highlights for these projects.

Since the NEP Toxics and Nutrients grant funding period, Puget Sound Partnership recently released the following resources to help in tracking and synthesizing grant funding in the region:

- Action Agenda Tracker[11] organizes tracking and reporting on Action Agenda Regional Priorities, Near Term Action (NTA) status and accomplishments, and investments in recovery activities.
- National Estuary Program (NEP) Atlas[12] summarizes Puget Sound NEP investments.
- Data Center[13] provides detailed information about activities, progress measures, and organizations that contribute data and reports.

By using a central location for summarizing key project components, these web resources will help organize, synthesize, and review current and future NEP activities.

Effectiveness Monitoring for Nutrient Management Projects

Effectiveness monitoring programs are recommended to evaluate the actual nutrient reductions from large nutrient management activities and validate expected reductions proposed by a project.

- Plan projects to include monitoring both pre- and post-project implementation to measure nutrient reductions by a specific action in an area.
- Evaluate project effectiveness at different stages post-implementation to assess relative effectiveness and make adaptations, as needed.

Incorporating effectiveness monitoring into project management will help to optimize investments toward projects that are proven to be successful in removing nutrients in watersheds throughout the greater Puget Sound region.

Developing Watershed Tools to Guide Nutrient Management

Ecology recommends adapting and implementing a predictive decision support system (DSS) tool to optimize funding for nutrient projects in the greater Puget Sound region. DSS tools are adapted for specific watersheds or sub-watersheds and typically incorporate land use

[11] https://actionagenda.pugetsoundinfo.wa.gov/
[12] https://psp.wa.gov/gis/NEPAtlas/Home
[13] https://www.pugetsoundinfo.wa.gov/DataCenter

characteristics and geospatial data. They are used to evaluate BMPs throughout specific watersheds that will reduce nutrients and improve water quality.

Once developed for select watersheds within the Puget Sound region, local watershed planning groups and local governments may use the DSS tool to evaluate the predicted effectiveness of BMP implementation and guide nutrient management decisions. For example, the DSS tool could be applied to determine optimal investments in nutrient reduction projects, such as those funded through the NEP Toxics and Nutrients grant. Part 2 of this report provides further discussion on developing a DSS tool for the Puget Sound region (McCarthy, 2019).

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Glossary, Acronyms, and Abbreviations

Glossary

Anthropogenic: Human-caused.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

Greater Puget Sound: Includes Samish, Padilla, and Bellingham Bays, as well as South Sound, Main Basin, Whidbey Basin, Admiralty Inlet, and Hood Canal (see also Puget Sound) (Figure 1).

NEP Toxics and Nutrients Core Team (committee): The Department of Ecology and partner agencies that distribute Toxics and Nutrients grant funds. Partner agencies include the U.S. Environmental Protection Agency, Puget Sound Partnership, and Washington State Department of Health.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare; (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses; or (3) livestock, wild animals, birds, fish, or other aquatic life.

Puget Sound: Includes South Sound, Main Basin, Whidbey Basin, Admiralty Inlet, and Hood Canal (see also greater Puget Sound).

Salish Sea: Puget Sound, Strait of Georgia, and Strait of Juan de Fuca, including their connecting channels and adjoining waters.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from not meeting water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Toxics: Toxic chemicals.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector, such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiling
BFO	Ecology's Bellingham Field Office
BMP	Best management practice
DOH	Washington State Department of Health
DSS	Decision support system
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
HABs	Harmful algal blooms
MWQ	Marine water quality
NEP	National Estuarine Program
NFS	Nutrient funding strategy
NHD	National Hydrography Dataset Plus
NLCD	National Land Cover Database
NSFS	Nutrient science funding strategy
NWRO	Ecology's Northwest Regional Office
ORCA	Oceanic Remote Chemical Analyzer
OSS	On-site septic system
PIC	Pollution Identification and Correction program
PNNL	Pacific Northwest National Laboratory
PSAA	Puget Sound Action Area
PSEMP	Puget Sound Ecosystem Monitoring Program
PSNSRP	Puget Sound Nutrient Source Reduction Project
QAPP	Quality Assurance Project Plan
SSM	Salish Sea Model
SWRO	Ecology's Southwest Regional Office
TMDL	Total Maximum Daily Load (see glossary)
USGS	U.S. Geological Survey

Units of Measurement

ft	feet
ha	hectare
kg	kilograms, a unit of mass equal to 1,000 grams
kg/yr	kilograms per year
km	kilometer, a unit of length equal to 1,000 meters
lbs.	pounds
m	meter
mg/L	milligrams per liter (parts per million)
yr	year

Appendices

Appendix A. Nutrient Project Summary Table

Table A-1. Summary of nutrient projects funded by the National Estuary Program, 2011–2019.

Project Title	Recipient	Funding Category	Nutrient Data Collected?	Links to Project Webpage/Report
Agricultural BMP Implementation	Ecology and others	Management	No	N.A.
Bertrand Creek Water Quality Effectiveness Monitoring	Ecology	Science	Yes	*Report expected 2019*
Blue Ribbon Panel on Ocean Acidification: From Knowledge to Action Report	University of Washington	Science	N.A.	https://fortress.wa.gov/ecy/publications/documents/1201015.pdf
Ferry-Based Marine Water Quality Monitoring	Ecology	Science	Yes	http://www.apl.washington.edu/project/project.php?id=ferries_for_science
High Resolution Marine Water Quality Monitoring	University of Washington	Science	Yes	http://orca.ocean.washington.edu/about_proj_ORCA.shtml
Hood Canal OSS Study	Hood Canal Salmon Enhancement Group	Management	Yes	https://pnwsalmoncenter.org/hcseg-testing-new-septic-technology/
Johns Creek Estuary Conservation	Capitol Land Trust	Management	No	http://www.pugetsoundnearshore.org/factsheets/JohnsCreek.pdf
Kitsap County PIC	Kitsap Public Health District	Management	Yes	• https://kitsappublichealth.org/environment/pic.php • https://www.bainbridgewa.gov/DocumentCenter/View/8230/KPHD-NEP-Grant-Final-Report?bidId

Project Title	Recipient	Funding Category	Nutrient Data Collected?	Links to Project Webpage/Report
LakeWise Program	Snohomish Public Works	Management	No	https://snohomishcountywa.gov/1125/LakeWise
Lake Whatcom Phosphorus Management	City of Bellingham, Whatcom County Public Works	Management	Yes	http://www.lakewhatcom.whatcomcounty.org/lake-threats/nutrients
Modeling	Ecology	Science	N.A.	https://ecology.wa.gov/Research-Data/Data-resources/Models-spreadsheets/Modeling-the-environment/Salish-Sea-modeling
Nonpoint Specialists	Ecology	Management	No	N.A.
Nutrient Processes in Puget Sound	USGS	Science	N.A.	https://pubs.usgs.gov/sir/2014/5033/ https://pubs.er.usgs.gov/publication/sir20155074
Nutrient Synopsis Website	Ecology	Management	N.A.	https://waecy.maps.arcgis.com/apps/MapSeries/index.html?appid=907dd54271f44aa0b1f08efd7efc4e30
OSS Denitrification Verification Study	University of Washington, Department of Health	Management	Yes	https://www.doh.wa.gov/Portals/1/Documents/4400/337-139-VRGF-WB-Final-ETV-Report.pdf
Shellfish at Work Study	Pacific Shellfish Institute	Management	Yes	http://pacshell.org/pdf/ShellfishAtWorkFinalReport.pdf http://www.pacshell.org/pdf/PSI_NEP_G1500057_FinalReport.pdf

Project Title	Recipient	Funding Category	Nutrient Data Collected?	Links to Project Webpage/Report
Snohomish County PIC	Ecology, Department of Health	Management	N.A.	N.A.
SoundToxins HABs Monitoring	University of Washington	Science	Yes	https://soundtoxins.org/
South Sound Natural Lawn Care	City of Olympia	Management	Yes	http://olympiawa.gov/city-utilities/water-resources/pollution-prevention/natural-yard-care.aspx
Puget Sound Bottom-Water Respiration	Ecology	Science	Yes	*Report expected 2019*
Tacoma-Pierce Penrose PIC	Tacoma-Pierce County Health Department	Management	Yes	https://www.tpchd.org/healthy-places/surface-water-quality/beach-information

Appendix B. Spatial Comparison of Nutrient Projects with Nutrient Loading into Puget Sound

The USGS SPARROW (Spatially Referenced Regressions On Watershed attributes) model estimates total nitrogen loads in a Pacific Northwest application (Wise and Johnson, 2013). Part 2 of this report (*Comparison of Watershed Nutrient Load Estimates* [McCarthy, 2019]) includes background information on this model and a discussion of nutrient loading in the Puget Sound region. These load estimates from SPARROW were not considered as part of the project selection process for NEP-funded projects. Instead, they are used to visually compare areas with high total nitrogen loads with the locations of NEP nutrient projects (Figure B-1).

Figure B-1. NEP grant-funded nutrient project locations compared with SPARROW total nitrogen load estimates (2002).

Localized projects for nutrient management projects and studies are primarily located in South Puget Sound (South Sound Natural Lawn Care, Shellfish at Work Study, Johns Creek Estuary Conservation). These locations do not correlate with rivers and areas with the highest total nitrogen loading.

Whidbey Island Action Area has rivers with some of the highest total nitrogen loads (Snohomish and Skagit Rivers). There were two projects (Snohomish County PIC and LakeWise Program) in this action area.

SPARROW model results were not used to identify and select NEP Toxics and Nutrients grant projects. However, these results are useful in combination with the Salish Sea Model results to

identify priority areas for nutrient management activities and allocating funding with the Puget Sound Action Agenda and Ecology's Puget Sound Nutrient Source Reduction Project.

References for Appendix B

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