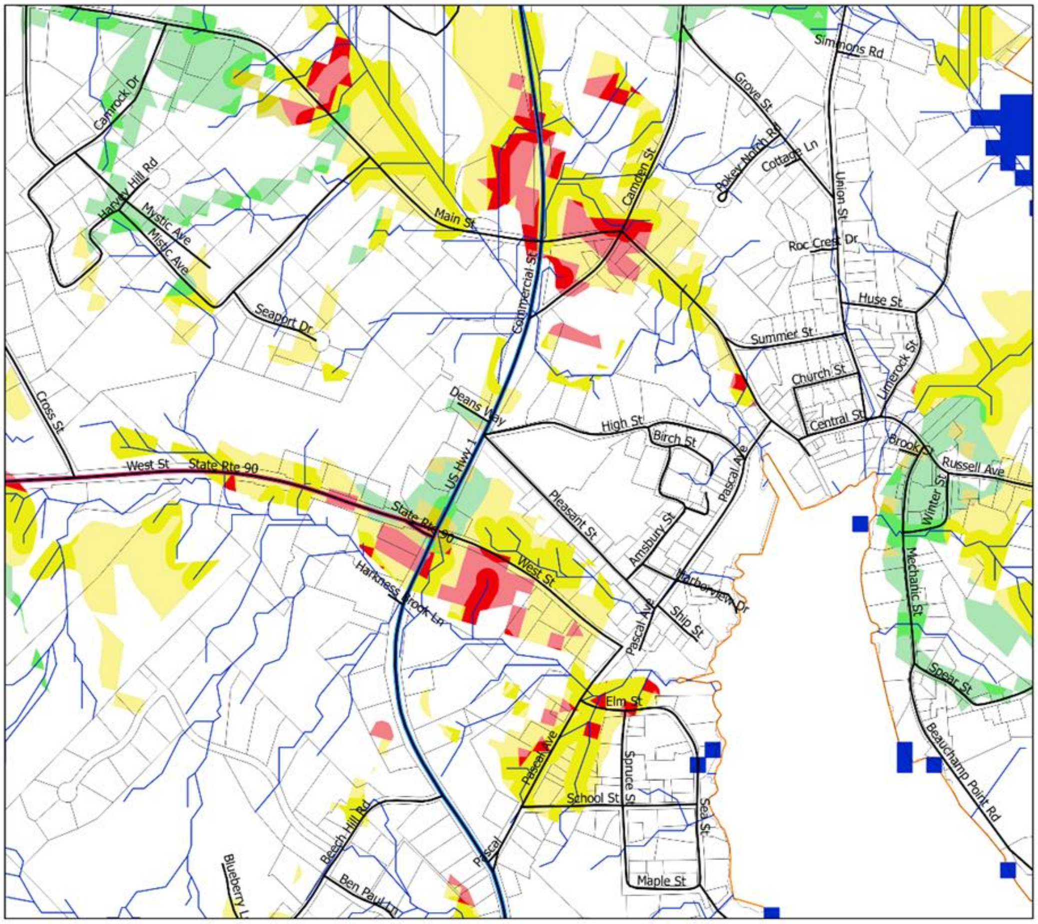
A Watershed Approach to Managing Land Use Impacts to Coastal Waters



Final Report

Submitted to Coastal Community Grant Program
Maine Department of Agriculture, Conservation and Forestry

December 2016

ROCKPORT, MAINE
1891

Maine Coastal Program

EMERGENCY MANAGEMENT AGENCY
KNOX COUNTY

A Watershed Approach to Managing Land Use Impacts to Coastal Waters

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Preface

The Maine Coastal Program, established in 1978 and administered by the Maine Department of Agriculture, Conservation and Forestry (DACF), provides funding from Federal, state and local sources to enable projects that benefit Maine's coastal communities. Funds for this project were provided through a Coastal Community Grant awarded by the DACF's Municipal Planning Assistance Program. Partners in the implementation of this project were the Town of Rockport, Office of Planning and Development; the Rockport Conservation Commission; and the Knox County Emergency Management Agency.

Acknowledgements

Rockport Conservation Commission volunteers Kim Kimball, Lynn Bannister, George Forristall and Jim Chalfant assisted with the collection of field observations and water samples for both stream and harbor sampling locations. Harbor sampling locations were accessed using the Rockport Harbor Master's boat, operated by Rockport Harbor Master Abbie Leonard and Assistant Caleb Lincoln.

The Knox County Emergency Management Agency provided computer resources and GIS expertise as part of its ongoing support to Knox County municipalities.

A Stakeholders Advisory Group (SAG) composed of project area residents, business persons, members of civic groups, and town officials and employees whose responsibilities include aspects of Rockport's environmental management and conservation efforts, met on three occasions and provided useful comments and suggestions to the project team. The SAG included the following individuals – Lynn Bannister, Owen Casas, Jim Chalfant, Chris Holden, Ron Howard, Ken McKinley, Doug Posson, Ann Robison, Ian Stewart, Bruce Kapp, Mario Turi, Abbie Leonard and Mike Young.

The Maine Water Company provided access to their Mirror Lake Water Quality Laboratory in West Rockport, ME for sample preparation. The laboratory also performed bacterial analyses. Nutrient and pigment analyses were performed by the Chesapeake Biological Laboratory, University of Maryland, Solomons, MD.

Town of Rockport Select Board members Ken McKinley and Brandan Riordan served as Select Board liaisons to the Rockport Conservation Commission and provided useful comments throughout the project.

Dr. Patrick Deliman (Environmental Laboratory, US Army Engineer Research and Development Center) provided technical review of this report.

A Watershed Approach to Managing Land Use Impacts to Coastal Waters

1. Introduction

The quality of marine coastal waters is markedly influenced by inputs of materials derived from non-point sources (NPS) in coastal watersheds and transported to the coastal margin by rivers and streams (e.g., Nixon et al. 1996, Howarth et al. 2002, Kelly 2008). These materials, which include sediment, nutrients, organic matter, bacteria, and natural and man-made contaminants, can have marked deleterious effects. Excessive inputs and subsequent deposition of sediment reduce water clarity, degrade the quality of benthic habitats thereby impacting shellfish and sea grass communities, and in extreme cases, can require removal by dredging. Increases in nutrient availability, especially of nitrogen and phosphorus, have a fertilizing effect on phytoplankton, often increasing the potential for harmful algal blooms (Backer and McGillicuddy 2006). Decomposition of both dissolved and particulate organic material, especially when introduced to coastal waters experiencing reduced mixing, can exceed the ability of natural processes responsible for reaeration thereby leading to reduced dissolved oxygen concentrations or hypoxia and consequent impacts to biota. Bacteria, especially those of fecal origin, introduced to coastal areas, including shellfish habitats and swimming areas, are clear threats to public health (Colford et al. 2007).

Marine and freshwater resources are integral to Rockport's natural heritage (Town of Rockport 2004). Portions of five drainage basins are located within its boundaries. These include those of the Goose River, the Oyster River, Quiggle Brook and Meadow Brook, as well as of the coastal drainage with its numerus first-order streams draining directly to coastal waters. The Goose River drains to Rockport Harbor on West Penobscot Bay, while the Oyster River, Quiggle Brook and Meadow Brook are confluent with the Saint George River and estuary, which discharges to Muscongus Bay to the south. Despite their relatively rural nature, there are notable examples that water resources in these drainage basins, and the coastal waters with which they are confluent, are and have been impacted by NPS pollution.

Chickawaukie Lake **-** This 142.4-ha (352-acre) impoundment of Meadow Brook exhibited eutrophic conditions during the 1980s related, in part, to NPS nutrient loadings from the watershed (Walker 1988). The resulting excessive algal growth reduced water clarity and negatively impacted water uses during summer months. Dissolved oxygen concentrations in bottom waters were reduced during the summer stratified period, often resulting in the release of sediment-stored phosphorus. In response, the Maine Department of Environmental Protection recommended implementation of best management practices (BMPs) in portions of the lake's watershed as a means to curtail the influx of nutrients and sediment

(MDEP 1994). In addition, nutrient-rich bottom sediments were treated with aluminum salts to reduce the internal cycling of phosphorus.

Lily Pond – Lily Pond, long noted for its pristine condition and the clarity of ice harvested and shipped to Boston and New York in the early 1900s, began to exhibit impaired water quality in the 1980s (MDEP 2005). Nutrients in leachate from a nearby landfill and runoff from shoreline areas, including cattle grazing areas, led to excessive phytoplankton growth and associated eutrophication-related symptoms. Studies conducted by Maine Department of Environmental Protection documented deteriorating water quality conditions, estimated NPS phosphorus contributions from shoreline and non-shoreline land uses, and developed a phosphorus control plan (MDEP 2005). Engineered improvements to the landfill and better gazing practices have resulted in markedly improved water quality in recent years (Kennedy, unpublished data).

***Figure 1.1**. Ulva sp. growing on rocks in the intertidal reach of the Goose River*

Rockport Harbor – The Town of Rockport's Conservation Commission (RCC) initiated a study in 2012 as a means to assess water quality in Rockport Harbor, as well as the Goose River and selected streams that potentially transport NPS pollutants to the harbor. Results for the period 2012-2016 indicate that nutrient and chlorophyll concentrations and water clarity are similar to other locations across Maine's Mid Coast Region (Thornton and Mayer 2015, Volunteer River Monitoring Annual Reports for 2013-2015[1]). However, episodic loadings of nutrients, especially nitrogen, and suspended material exported from sites in the watershed and transported by the Goose River during periods of elevated flow adversely impact water quality and water clarity in the harbor. Elevated levels of enterococcus, a fecal indicator bacterium, have been observed in surface waters from the head of the harbor to its opening to Penobscot Bay. Excessive growths of *Ulva*, a macro-alga that proliferates in shallow, nitrogen-rich environments, are present in the inter-tidal reaches of the Goose River and near inflowing streams and the outfalls of storm drains suggesting high nitrogen loading rates (Figure 1.1).

***Figure 1.2.** Goodie's Beach*

Goodie's Beach - The Maine Healthy Beaches (MHB) Program, administered by the University of Maine Cooperative Extension, began sampling for enterococcus at Goodie's Beach

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[1] https://www1.maine.gov/dep/water/monitoring/rivers_and_streams/vrmp/reports.html

near the head of Rockport Harbor (Figure 1.2) in 2009. Samples were collected weekly from late May to early September, and public health advisories are posted when enterococcus levels exceed the standard for marine waters (104 MPN/100ml)[2]. During the period 2009-2014, public health advisories were posted on 5 to 11 occasions each season (Figure 1.3).

The RCC identified a 25-acre area draining to the beach as the primary source of elevated bacteria levels (Kennedy 2011). Land uses in this area include residential (39 homes, all of which are on sewers), lawns, impervious surfaces (roads and sidewalks) and natural areas, including a 5-acre wetland. Inspections of selected homes, sewer lines and storm drains failed to identify illicit connections, breaks or engineering failures that could result in the discharge of domestic waste water to surface waters. While efforts continue to locate potential sources of domestic waste water, runoff from NPS sites (e.g., poorly managed pet waste on walking routes frequented by visitors and residents, and run-off from lawns and impervious surfaces) will likely continue to result in elevated bacteria and nutrient levels in storm water discharged near the beach. As an interim BMP, health advisories are posted based on historical information relating precipitation and bacteria contamination, and daily observations of precipitation amounts.

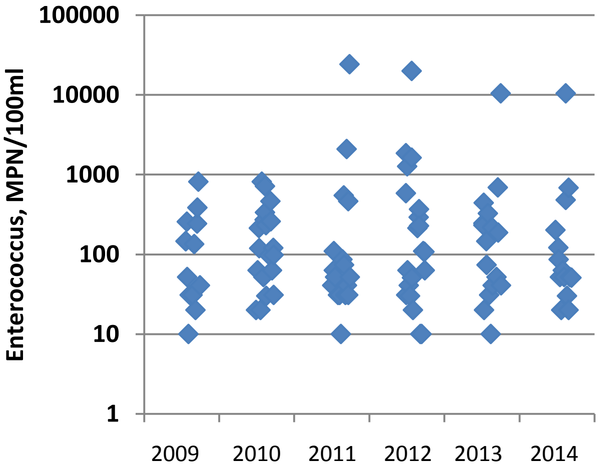

Figure 1.3. *Enterococcus levels at Goodie's Beach for 2009-2014. The criterion for marine waters is 104 MPN/100ml*

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[2] Most Probable Number

2. Objectives and Approach

Because of their diffuse origins, NPS pollutant exports from watersheds are difficult to quantify and manage effectively, especially for small communities such as Rockport that often have limited resources and expertise. Needed are decision-making tools that are relatively easy for non-technical managers to apply, require a minimal amount of input data, and produce results that are easily understood by managers and the public. Such tools would ideally also be scalable within watersheds and transferable between watersheds. Described here are the results of efforts to identify and demonstrate such decision-making tools; characterize NPS loadings of nutrients and their potential impacts on the quality of Rockport's water resources; and assess potential best management practices (BMPs) for reducing NPS loadings.

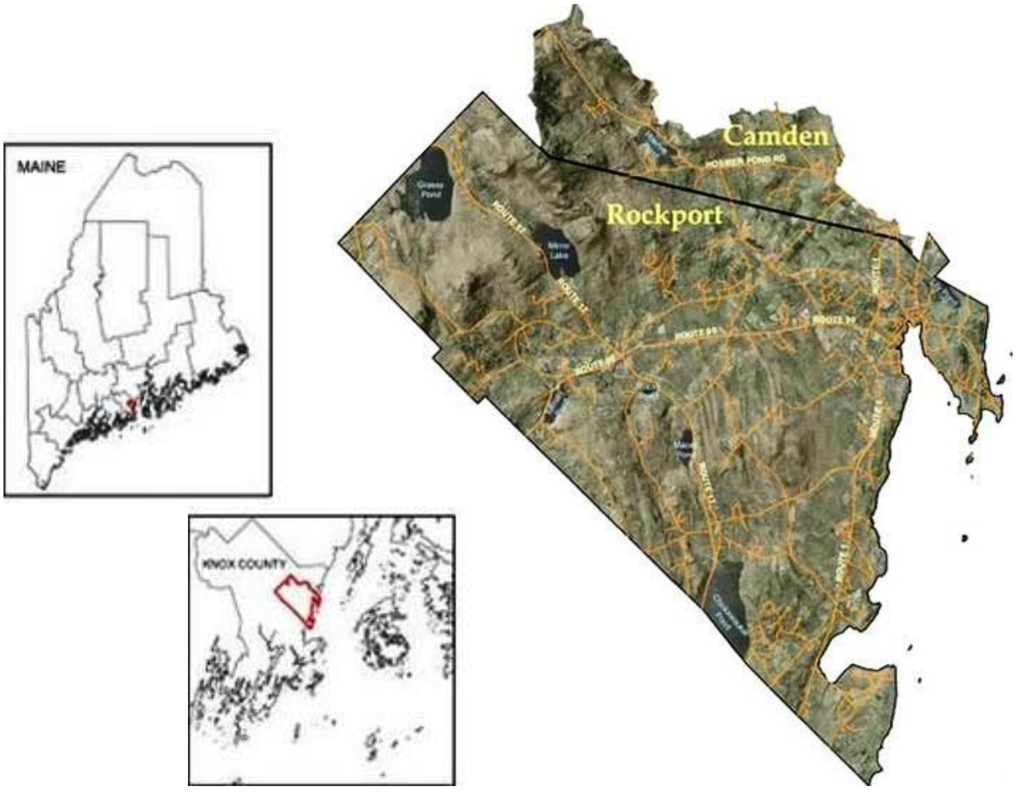
The approach followed is based on current understanding of hydrologic processes involved in the generation of runoff from land surfaces coupled with knowledge of relationships between runoff, soils, land use and land cover that lead to the export of contaminants (nutrients, sediment and organic matter in this case) from watersheds. Watershed characteristics are first evaluated using existing geospatial data and GIS tools as a means to assess, rank and map the potential for selected watershed areas to generate NPS loadings. Much of these data are then employed in the application and evaluation of a spreadsheet tool for quantifying runoff-related exports and potential reductions associated with the application of BMPs. The results can be presented in the form of maps, tables and simple graphical displays that can be easily interpreted and understood by managers and stakeholders.

3. Project Area

The Town of Rockport is located on West Penobscot Bay in the Mid-coast Region of Maine and is bordered by the towns of Warren, Hope, Camden and the City of Rockland. Portions of five watersheds basins are located in Rockport, three of which drain south to the St. George River and Muscongous Bay. The fourth, as well as the narrow coastal watershed, drain to Penobscot Bay. Quiggle Brook drains west from Grassy Pond through Crawford Pond and is confluent with the St. George River. The Oyster River arises north of Mirror Lake, the discharge from which flows south through Tolman Pond to its confluence with the St. George River Estuary near Thomaston. Meadow Brook flows south from Mace's Pond to Chickawaukie Pond, a large shallow impoundment that straddles the boundary between Rockport and Rockland, and then south to its confluence with the St. George River. The Goose River arises as the discharge from Hosmer Pond in Camden and is confluent with Penobscot Bay at the head of Rockport Harbor.

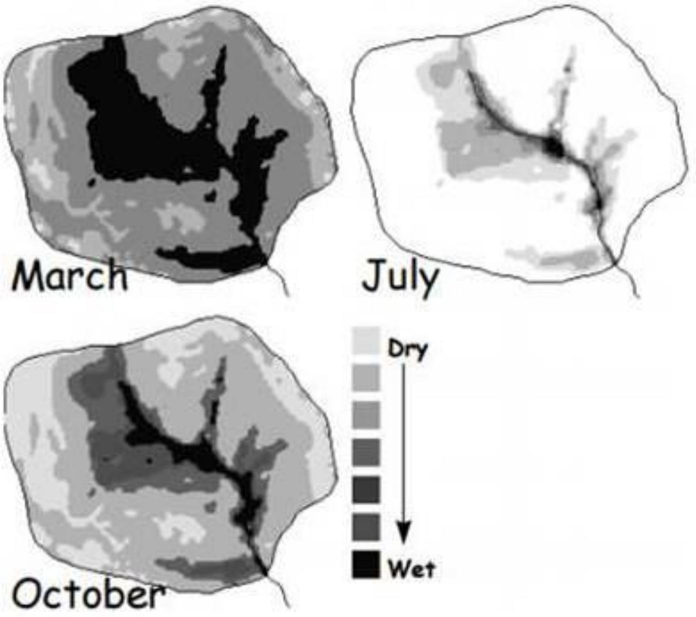
For the purposes here, the project area was defined as being bounded by the limits of the Town of Rockport to the south and west; the watershed boundary of the Goose River, which extends into portions of Camden, to the north; and the coastal margin to the east (Figure 3.1). The total area included is 26.3 mi^2. The entirety of the Goose River watershed (8.6 mi^2) was included since it is the primary source of freshwater to Rockport Harbor and was the site selected for demonstrating tools to estimate NPS loadings and the potential effectiveness of best management practices (BMPs) during this effort.

Figure 3.1. *Maps of the location and extent of the project area.*



4. Hydrology and NPS Pollution

Figure 4.1. *Variable Source Area (VSA) hydrology is the concept that runoff-generating areas in the landscape will vary in size over time. From Walter et al. 2000.*



Nonpoint source pollution is difficult to deal with both conceptually and methodically. The very name, nonpoint source, suggests the diffuse, transient nature to this source of resource degradation. However, in recent years, research in small watershed hydrology and nutrient fate and transport has shown that the loading of nutrients to streams and waterways is most often due to precipitation and subsequent runoff events, and that such loadings are derived from rather restricted areas of the landscape adjacent to drainage ways and stream channels rather than being equally distributed across all parts the landscape. The latter phenomenon forms the basis for what is referred to as variable source area (VSA) hydrology (Hewlett and Hibbert 1967). VSAs are those portions of the landscape that contribute most heavily to surface runoff. VSAs vary both spatially and temporally, expanding and contracting seasonally and with changes in rainfall intensity and duration during a precipitation event (Figure 4.1). While there have been calls to reconsider aspects of the VSA concept (McDonnell 2003), the recognition that primary sources of runoff are near stream channels continues to be important in the context of NPS management.

Surface runoff and shallow subsurface "return flow" (both considered to be surface runoff in this discussion) are primarily responsible for transporting NPS pollutants in or on the soil to the stream network and eventually to a receiving water body such as a lake, stream or coastal water. Surface runoff (R) is a component of the soil water balance equation:

$$P = E + T + S + D + R \qquad \text{Eq. 1}$$

Where:

P = precipitation (rainfall + the water equivalent of snow)
E = evaporation
T = transpiration
S = change in soil water content (i.e. storage)
D = deep percolation (i.e. below the bottom of the root zone)
R = runoff

Rearranging this equation, the amount of water available for surface runoff from a hillslope segment is then:

$$R = P - (E + T + S + D) \qquad \text{Eq. 2}$$

The term ‘available’ reflects the fact that during a typical daily storm event not all of the water in excess of the sum of E + T + S + D runs off immediately. Some is temporarily detained as surface storage in small depressions and irregularities in the soil surface, including living or dead vegetation and any other natural or anthropogenic materials on the soil surface that could impede flow. Some of this detained water eventually ends up infiltrating the soil or evaporating after the storm event rather than occurring as runoff. For this reason, the actual amount of infiltration of incoming precipitation is very dependent upon the cover characteristics of the soil surface, as well as soil properties that influence percolation. Intimately associated with the runoff process is the process of extraction and transport of soluble or finely divided material on or in the soil by the surface runoff. Saturation excess flow (see Box 4.1) is also more effective at extracting nutrients and other dissolved and finely divided material from the soil and into the surface runoff plane.

Box 4.1. Surface Runoff Mechanisms

Surface runoff can occur by either of two mechanisms. When rainfall rate is greater than the rate at which water can infiltrate into the soil and exceeds depression storage capacity, water flows across the soil surface - a process known as Hortonian Flow in recognition of the early work of Horton (1933). Dunnian Flow, after the work of Dunne (1990), occurs after the soil saturates in a thin layer at the soil surface during a storm event and that any further rainfall runs off rather than infiltrates into the soil. Both mechanisms are known to occur, but most recent research suggests that Hortonian Flow, when it occurs, happens early in a rainfall event before the soil surface becomes saturated, but that Dunnian or “saturation excess” Flow dominates most of the rainfall event and subsequent storm hydrograph.

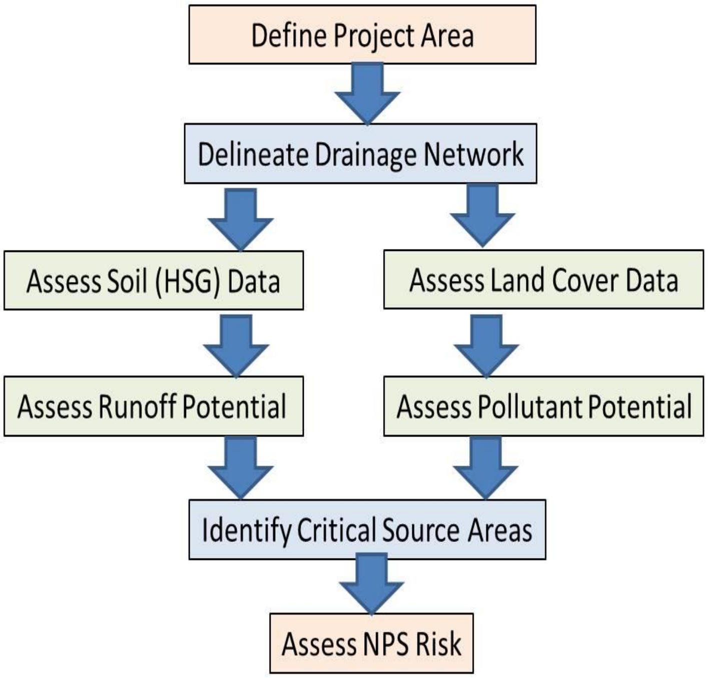
Knowledge that areas likely to generate surface runoff are located proximal to the stream (i.e., VSAs) when coupled with information about nutrient availability, as related to land use and land cover, is useful in identifying and managing nonpoint sources of pollution. Gburek and Sharpley (1998) defined as “critical source areas” (CSAs) as those areas occurring at the intersection of portions of the landscape where surface runoff is most likely to occur and portions of the landscape containing exportable nutrients or contaminants. A number of subsequent studies of nutrient export (e.g., Pionke et al. 2000, Kleinman et al. 2006) affirm the applicability of the critical source area concept.

The assessment approach developed and employed here aims to identify the potential for NPS pollutant loading and to locate areas within a watershed most likely to be the source of such loads based on VSA hydrology and the CSA concept. This is intended as a ‘first tier’ resource assessment (Joyce 2000) and not the primary tool of a regulatory process. It is also not the sole basis for the development of a plan for dealing with a specific resource degradation problem. It is, instead, a risk-based assessment of the soil and water resources in a watershed with regard to general NPS concerns. It gives landowners and managers, local units of government, and practicing professionals an overview of the potential sources of NPS pollution in an area, a general idea of the extent and location of these source areas, and some indication of the types of solutions that might be used to mitigate associated problems. While it can be used in both a curative and a preventative mode, it is probably more useful in the latter, as it can be incorporated into a planner’s or manager’s toolbox when applying problem solving principles to particular water resource planning issues.

5. Assessing the Potential for NPS Pollution

The assessment process employed is adapted from that developed by Coplin et al. (2013) and is based on the CSA concept (Gburek and Sharpley 1998). As previously described, CSAs occur at the intersection of portions of the landscape where surface runoff is most likely to occur and portions of the landscape containing exportable nutrients or contaminants. However, the approach taken here enhances that of Coplin et al. (2013) by assigning subjective measures of risk to the potential for various combinations of soil and land cover/use to generate NPS loads.

Figure 5.1. *Flow chart showing the major steps in applying the assessment process.*



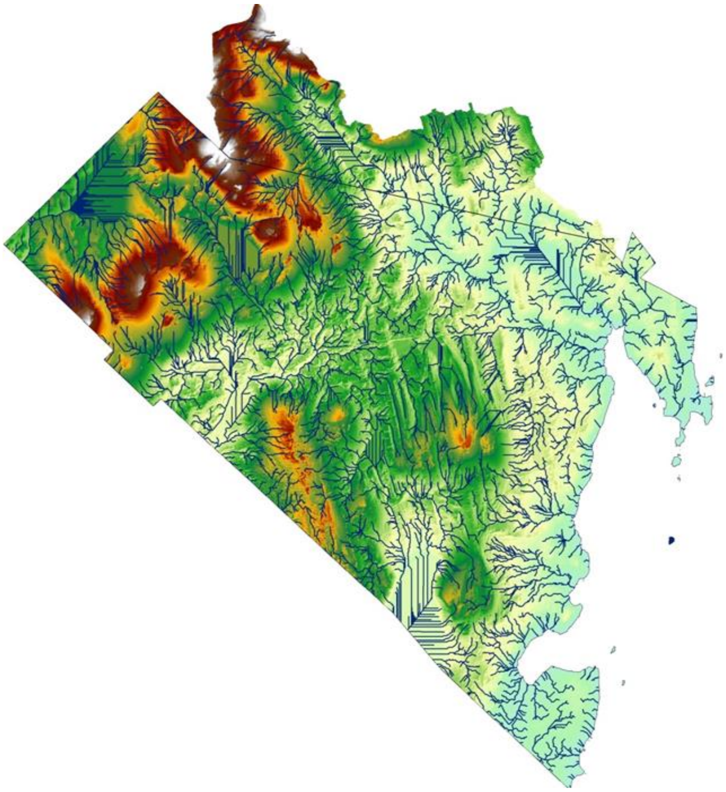
The method is designed to use readily available information and not require special field or laboratory investigations, or other forms of specialized site-specific information that cannot be gleaned from online sources or otherwise accessible data and documents. It is GIS-based and relies on national and in some cases, regional geospatial datasets that are publically available and typically free of charge. The GIS procedures involved are not overly complex and can be readily applied by land and resource managers and their staff if they have GIS and spatial analysis capabilities. Because it is platform independent, it can be applied using commercially available or open source GIS software, and typical desktop computing facilities. The main products are maps identifying the extent and distribution of contributing soil and land cover/use factors, and resulting risk measures. Figure 5.1 is a flow chart showing the major steps in applying this assessment procedure.

Delineating the Drainage Network

Coplin et. al. (2013) used the National Hydrography Dataset (NHG; Simley and Carswell 2009), which represents perennial water courses (i.e., permanently flowing streams and rivers) to develop the drainage network and map CSAs. We used instead a base map derived from a 1/3 arc second (30-m resolution) digital elevation model (DEM; Carswell 2014) and GIS-based flow routing to delineate the drainage network. This resulted in finer drainage network delineation in the project area than would have been possible with the NHD (Figure 5.2). [Note that a drainage network developed from a 1 arc second (90-m resolution) DEM would have also provided a finer resolution than would the NHD. By selecting a particular DEM for delineating the drainage network users can tailor the assessment to their particular project's objectives, size of the project area, and level of detail desired.]

This finer delineation of the drainage network was chosen for this study since the project focus was at the parcel and local-area level. It is also important to note that this finer drainage network includes not only perennial streams, as with the NHD, but also many of the smaller low-order intermittent drainage ways that are ephemeral or flowing only during storm events, as well as some landscape features that may contain surface flowing water but only during storm events of particular intensities or durations. All of these landscape features can act as runoff collection points that channel runoff to the perennial stream network.

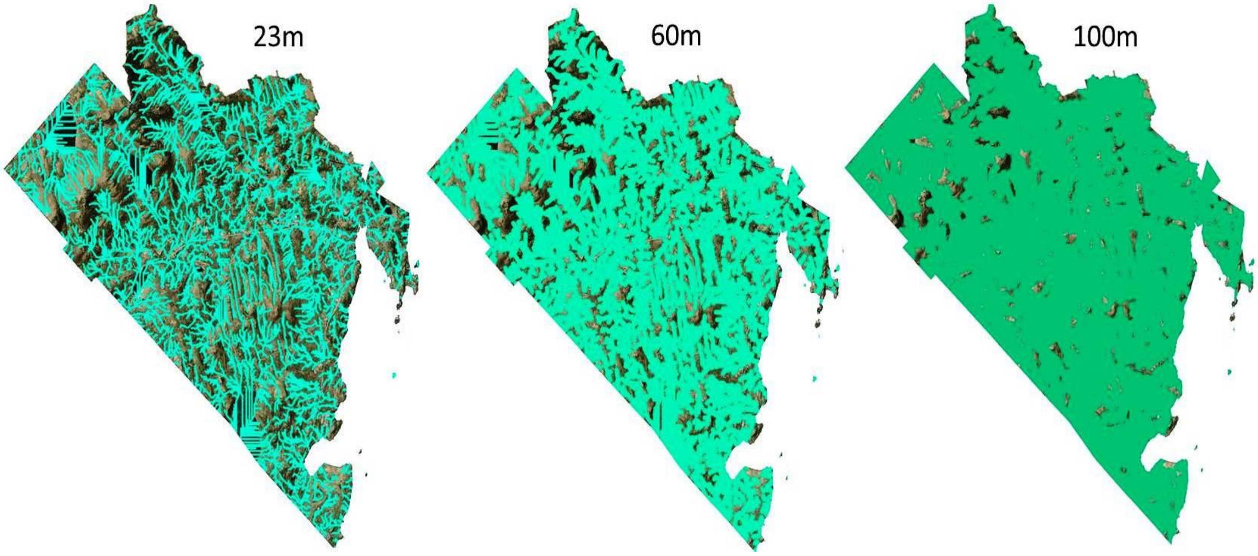
Figure 5.2. *Map of the project area indicating elevations (darker shades with increasing elevation) and the drainage network based on a 1/3 arc-second DEM*.



Variable Source Areas

As described earlier, VSA hydrology provides the conceptual basis for the assessment approach developed here. However, since the assessment does not explicitly consider temporal and spatial variability in precipitation or soil moisture, VSAs would be considered as 'static' and not 'variable.' To overcome this limitation, three buffers or zones of increasing perpendicular distance from elements in the drainage network were established. A 23-m buffer corresponds to the existing 75-ft setback requirement as regards development activities in the vicinity of low-order streams (MDEP, 1990). A 60-m buffer was chosen to be compatible with distances typically associated with runoff-borne input of nutrients to the stream networks in small watersheds (Gburek et al. 2000). A 100-m buffer was established as a means to address the potential extreme variability in runoff source areas, as during more intense storm events. When applied to the Rockport project area, the 23-m, 60-m and 100-m buffer areas (Figure 5.3) totaled 5,789, 11,785 and 14,812 acres, respectively.

Figure 5.3*. Drainage network and associated land areas for the 23-m, 60-m and 100-m buffer distances***.



Runoff Potential

Runoff potential was based on hydrologic soil group (HSG) designations and the infiltration properties associated with each group. This information was obtained from the Soil Survey Geographic (SSURGO) Database available online from the US Department of Agriculture[3]. The four soil groups are designated as A through D based on expected relative rates of infiltration ranging from high to low, respectively. Conversely, relative runoff rates range from low to high, respectively.

There are also three dual HSGs (A/D, B/D, and C/D). Dual groups are assigned to certain wet soils that could be adequately drained through management efforts.

Table 5.1. *Descriptions of hydrologic soil groups (HSG) and their assigned runoff potential*

HSG	Runoff Potential	Description*
A	Low	Low runoff potential when thoroughly wet. Water is transmitted freely through the soil.
B	Low	Moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded.
C	Medium	Moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted.
D	High	High runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted.

* From USDA (2007)

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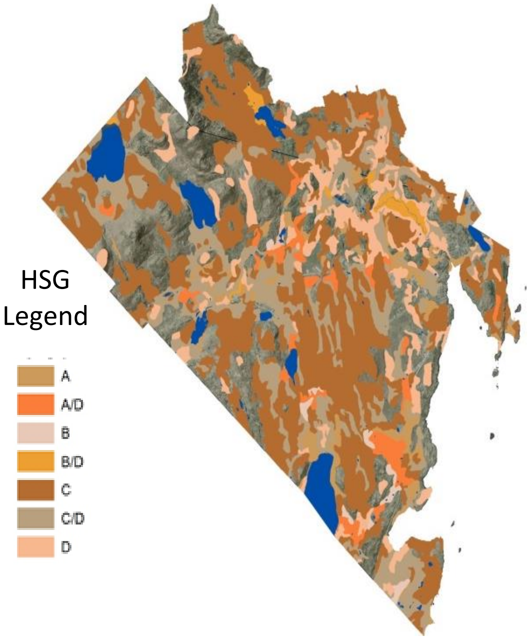
[3] Soil Survey Staff, Natural Resources Conservation Service, USDA. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/.

Figure 5.4. *Hydrologic soil groups (HSG) for the project area. (Lakes and ponds are in blue.)*



The first HSG letter applies to the drained condition and the second to the undrained condition. In general, soils are assigned to dual groups if the depth to a permanent water table is the sole criterion for assigning a soil to HSG D (Nielsen and Hjelmfelt, 1998). Dual HSGs were identified in the project area (Figure 5.4). As a conservative application for this project, all dual-classed soils were reclassified as HSG D, and therefore rated as having a high runoff potential. Table 5.1 lists the four soil groups, descriptions of their properties relative to infiltration and runoff, and the assigned relative runoff potential (low, medium and high).

Relative runoff potential classes from the HSG data were clipped to each of the three buffers as displayed in Figure 5.5. Table 5.2 lists resultant areas associated with each runoff potential class and buffer distance. This distribution is skewed towards the medium and high runoff potential classes as a result of the natural surficial geology of the project area. Many of the soils have formed over either competent crystalline granitic bedrock, or over dense glacial till deposits that cause impermeable layers within the soil profile that may restrict water transmission through the soil to varying degrees (Figure 5.4 and Table 5.1).

Figure 5.5. *Distribution of low (green), medium (yellow) and high (red) runoff potential for the 23-m, 60-m and 100-m buffer*

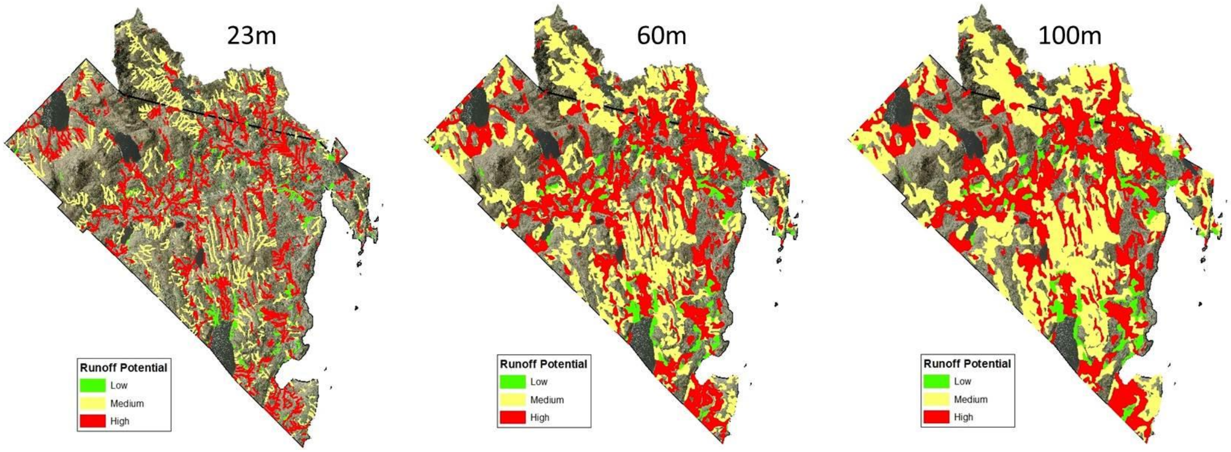


Table 5.2. *Area of runoff potential classes associated with each buffer distance.*

Runoff Potential	Area, ac		
	23-m	**60-m**	**100-m**
Low	242.0	509.3	654.6
Medium	1823.7	4118.2	5427.4
High	2291.4	4088.2	4528.1

Pollutant Potential

The potential for landscape areas to export pollutants (pollutant potential) was based on an interpretation of land cover data contained in the 2011 National Land Cover Database (NLCD) available from the US Geologic Survey (Homer et al. 2015) The NLCD provides national coverage of Landsat-based, 30-m resolution, georeferenced land cover data. Land cover classes for the project area are displayed in Figure 5.6.

The 14 NLCD land cover classes identified in the project area were reclassified as low, medium or high pollutant potential based on best professional judgement (Table 5.3). Land cover/use classes considered to have a low pollutant potential are undisturbed or minimally disturbed, well-vegetated areas with limited anthropogenic nutrient additions, which includes most of the forested areas and ungrazed grass lands.

Land cover classes assigned a medium pollutant potential included developed lands and open space with natural buffering against pollutant export; pastures and hayfields that, while often offering natural buffering, may be subject to nutrient additions and animal waste; and woody and herbaceous wetlands, which as natural areas are generally nutrient-rich and often receive additional nutrients associated with runoff from surrounding areas that are available for subsequent export. Land cover classes indicating possible anthropogenic nutrient additions or high erosion rates were deemed to have a high pollutant potential. These included developed land experiencing medium or high intensity human activity, fertilized crop lands and barren land.

Pollutant potential classes and the NLCD land cover classes from which they were derived, as well as the rationale for their assignment to pollutant potential class are presented in Table 5.3. These data were then clipped to each of the three buffers, as was done for the runoff potential classes, and are displayed in Figure 5.7. Table 5.4 lists areas associated with each pollutant potential class and buffer distance. In contrast to the runoff potential classes (Table 5.2), the pollutant potential classes were skewed to lower potential (Figure 5.7 and Table 5.4), reflecting the relatively undeveloped and low intensity land use that characterizes much of the project area.

Risk Metrics

A five-class NPS metric was developed to rank the risk or potential for the export of pollutants from watershed areas based on the intersection of runoff potential and pollutant potential as developed above (Table 5.5). A risk score of 1 was assigned to the low risk class as they were considered to represent post-cultural natural background conditions (i.e. the “natural” background after European settlement of the area but not pristine pre-colonization conditions). Risk score 2 was considered a low-to-moderate risk class because of good natural vegetative ground cover and little development in combination with an HSG of C. However, it has a medium land cover factor that increases the potential for anthropogenic nutrient additions and losses unlike those areas with a risk score of 1.

Table 5.3. *Reclassification of the NLCD 2011 land cover classes to pollutant potential classes.*

Map Unit Symbol	NLCD Land Cover Class Name	Pollutant Potential	Comments
23	Developed, Medium Intensity	High	Anthropogenic nutrient additions; other contaminants; high BOD in runoff.
24	Developed, High Intensity		
31	Barren Land (Rock/Sand/Clay)	High	Potential for sediment export that would contribute to nutrient loading
82	Cultivated Crops	High	Anthropogenic nutrient additions via fertilization
21	Developed, Open Space	Medium	Similar to 23 and 24, but significant natural buffering offsets higher probability of contaminated runoff
22	Developed, Low Intensity		
81	Pasture/Hay/Turf	Medium	As with 21 above; considerable opportunity for buffering before any nutrients leave the area, but management for hayland and turf requires anthropogenic nutrient additions and grazing generates animal waste
90	Woody Wetlands	Medium	Though natural areas, wetlands are generally nutrient-rich and often receive additional nutrients via runoff from surrounding areas that is available for export with significant storm events
95	Emergent Herbaceous Wetlands	Medium	As above for map unit 90
41	Deciduous	Low	Undisturbed or minimally managed areas that consist typically of native or introduced vegetation with good ground cover that receives little if any anthropogenic nutrient additions
42	Evergreen		
43	Mixed		
52	Shrub/Scrub		
71	Grassland/Herbaceous		

***Table 5.4**. Area of pollutant potential classes associated with each buffer distance.*

Pollutant Potential	Area, ac		
	23-m	**60-m**	**100-m**
Low	4005.0	8316.5	10616.1
Medium	1551.8	2934.0	3484.4
High	232.5	534.1	711.7

The moderate risk class consists of two components: risk score 3L is due to land cover, a use-dependent temporal characteristic of the land, while score 3S has an inherent, stable-static limiting soil characteristic (i.e., a HSG of D) and high runoff potential. An area with a score of 3L could revert to a lower class with a score of 2 or even 1 depending on use and management, while an area scored 3S could not change risk class unless the soil type was one that was amenable to drainage that lowers a naturally high water table thus increasing the depth to a saturated soil zone (essentially changing the soil hydrologic group from D to C). Conversely, a 3L area could not rise to a higher risk class because of the HSG of C (barring paving or other major alteration of the surface of the soil). However, depending on use and management, a 3S area could change to the high risk class. The 3L areas have more 'resiliency' or more land use management options, as compared to 3S. It thus seemed beneficial to separate these two conditions while keeping a moderate risk class for both.

***Figure 5.6.** NLCD land cover classification for the project area*

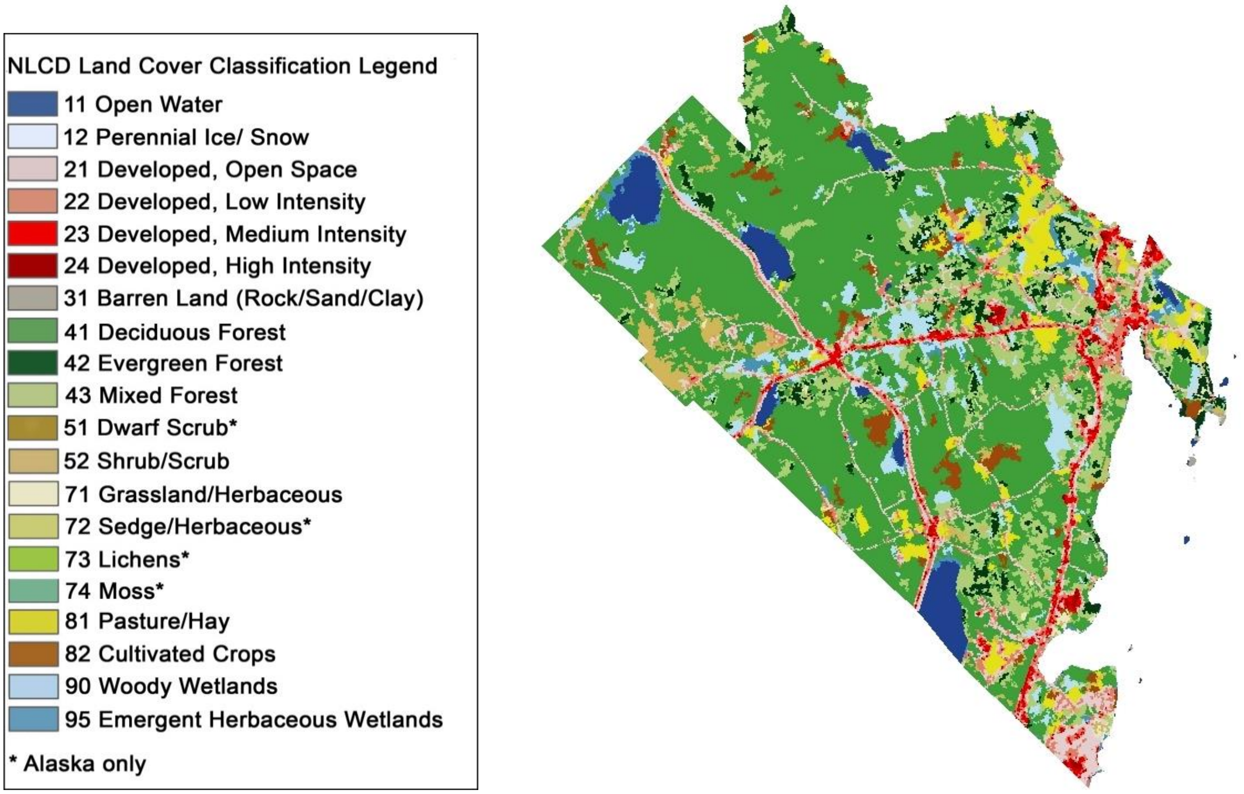


Figure 5.7. *Distribution of low (green), medium (yellow) and high (red) pollutant potential for the 23-m, 60-m and 100-m buffer*

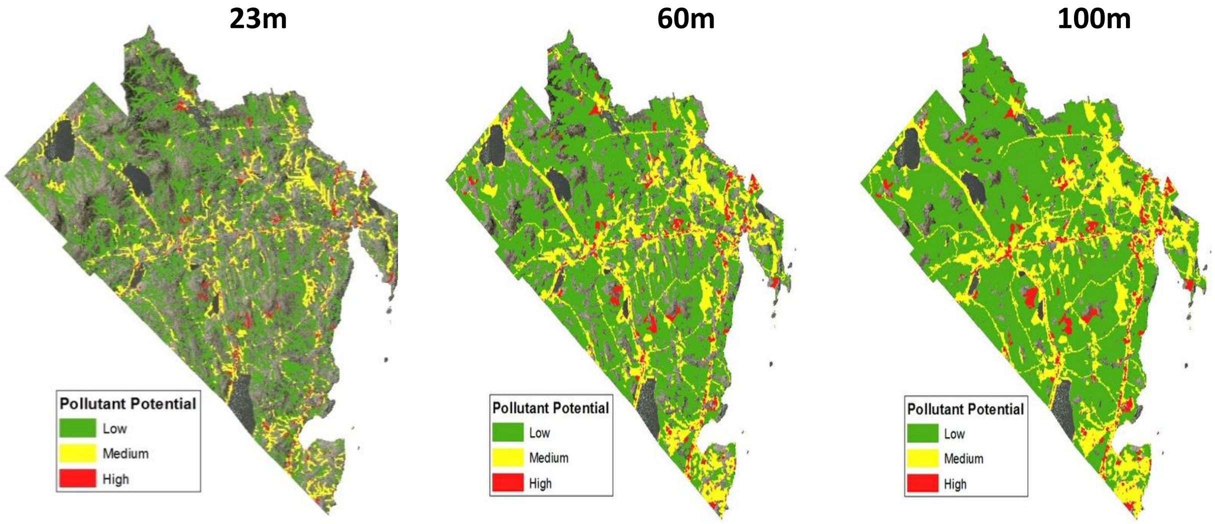


Table 5.5. *Risk metrics based on HSG and land cover risk factors*

Risk Class	**Numerical Risk Score**	**Risk Factors**		**Explanation**
		HSG	**Land Cover Class**	
High	4	D	H	Soil type D; Barren land, medium to high intensity development, constructed wetlands for waste & runoff treatment, aquaculture wetlands/ponds, cultivated crop land
Moderate (Soil)	3S	D	M	Soil type D; developed open space, low intensity development, hay meadows, turf, pastureland, natural woody and herbaceous wetland
Moderate (Landcover)	3L	C	H	Soil type C; Barren land, medium to high intensity development, constructed wetlands for waste & runoff treatment, aquaculture wetlands/ponds, cultivated crop land
Low-Moderate	2	C	M	Soil type C; developed open space, low intensity development, hay meadows, turf, pastureland, natural woody and herbaceous wetland
Low	1	D	L	Type D; Forest (all), shrub land and grassland
		C	L	Type C; Forest (all), shrub land and grassland

Should land cover and/or use and management practices change, the low risk class areas could move into the moderate risk class (score 3L or 3S). Areas scored as 3L have an intermediate runoff potential due primarily to a land cover factor of medium but the HSG remains C. Even with changes to a barren land cover or intensively managed and fertilized cropland, these areas would remain in the moderate risk class. Areas scored as 3S have an intermediate runoff potential due to a land cover and a soil factor.

The high risk class (risk score of 4) was assigned to areas in which land cover factors suggest a high probability for application of large amounts of nutrients as part of normal use and management or have less natural ground cover or more impervious area, as well as the highest potential for generating surface runoff (i.e., HSG D).

Assessing NPS Risk for the Project Area

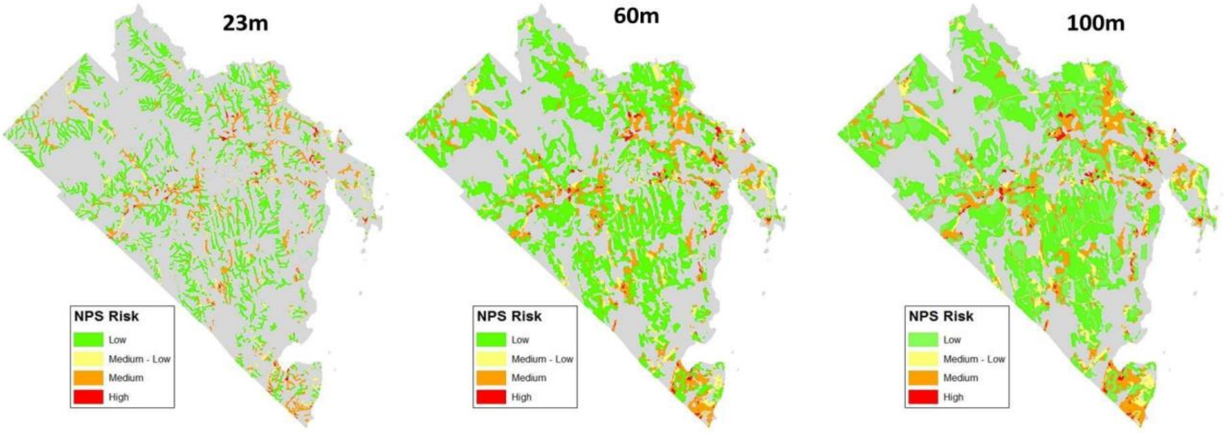
Runoff potential and pollutant potential datasets, as described above, were intersected as a means to generate a spatial depiction of the risk metrics. The resulting data layer was clipped first to the project area, and then to the 23-, 60- and 100-m buffers. The resulting spatial distribution of risk scores are displayed in Figure 5.8. Areas associated with each risk score and buffer distance are listed in Table 5.6.

Table 5.6. *Total areas for each NPS risk class and each buffer distance for the project area.*

NPS Risk	Area, ac		
	23-m	60-m	100-m
Low	1465.1	3235.4	4211.9
Low/Moderate	1421.4	2757.7	3324.9
Moderate	743.3	1345.6	1567.3
High	63.0	129.5	146.0

While much of the project area is identified as exhibiting low and low-moderate NPS risk potential (Table 5.6; approximately 78-81% depending on buffer distance), there are several areas classified as moderate and high risk. Areas classified as posing moderate NPS risk accounted for 17-20% of the project area. Noteworthy are areas along the lower and middle reaches of the Goose River, and on Brewster Point at the southeastern-most portion of the project area. Moderate risk areas along the middle reaches of the Goose River coincide with the location of a golf course, while runoff from moderate risk areas on Brewster Point would discharge to Glen Cove where high levels of fecal indicator bacteria have been documented (Town of Rockport, unpublished data). Areas potentially posing a high NPS risk, which account for less than 2% of the project area, were identified for the middle and lower reaches of the Goose River, Harkness Brook and several parcels along Route 17 in the west-central portion of the project area.

Figure 5.8. *Distribution of low (green), moderate/low (yellow), moderate (orange) and high (red) NPS risk classes for the project area at the 23-m, 60-m and 100-m buffer distances*



6. Estimating NPS Loads and Evaluating BMPs

The assessment process described above identifies areas on the landscape which, based on soil and land cover properties, have varying potential to export NPS pollutants. It does not provide an estimate of the relative amount of NPS pollutants exported from these areas to receiving waters. These amounts, which are often referred to as pollutant loads, are a function of pollutant concentrations and volume of runoff entering a receiving water body (i.e. stream, lake, ocean, etc.). Loads are quantified as the rate of pollutant mass exported to or received by the receiving water body for a specified period of time. Knowledge of pollutant loading rates is important in understanding the potential impacts to receiving water bodies. For planners and managers, this is a starting point for discussions about how much to reduce loads deemed unacceptably high.

The most direct means for quantifying loading rates involves collecting coincidental data describing pollutant concentration and instantaneous flow rate. Given a sufficient number of such observations, the relationship between concentration and flow can be assessed and applied to the complete stream flow record to estimate loading over the period of interest. This approach is well-accepted and widely used (Quilbé et al. 2006) but requires considerable time, effort and expense to collect data, and assumes analytical expertise and capabilities that may not be available to local managers, including the services of a laboratory capable of performing necessary chemical analyses.

Alternatively, there are now a number of sophisticated computer models based on detailed understanding of the basic processes governing water movement, and pollutant fate and transport which could be used for estimating loading rates. However, applying these models requires extensive field data for calibrating and evaluating model performance and requires a high level of expertise and experience, again unlikely to be available to local practitioners and managers. Needed is a means for estimating loading rates and assessing BMPs that allows local managers to engage in meaningful dialog with constituents and stakeholders, and to evaluate alternative ameliorative plans without an overreliance on external expertise or excessive cost.

The Spreadsheet Tool for the Estimation of Pollutant Load (STEPL; Tetra Tech 2006), which was developed for the US Environmental Protection Agency for reporting and tracking State and Tribal efforts under the Section 319 Nonpoint Source Management Program, is a spreadsheet-based, user-friendly calculator that incorporates simple algorithms to estimate annual loads of nutrients, sediment and biological oxygen demand (BOD). Estimates of sediment loads from sheet and rill erosion are based on the Universal Soil Loss Equation (USLE; Wischmeier and Smith 1978) and a sediment delivery ratio[4]; nutrient loading estimates are based on computed runoff volume and assumed nutrient concentrations, and may be over or under estimated depending on land use type (Frink 1991). Load reductions due to the implementation of BMPs are estimated based on known BMP efficiencies. Basic STEPL components, including required user inputs, processes employed and outputs, are presented in Figure 6.1.

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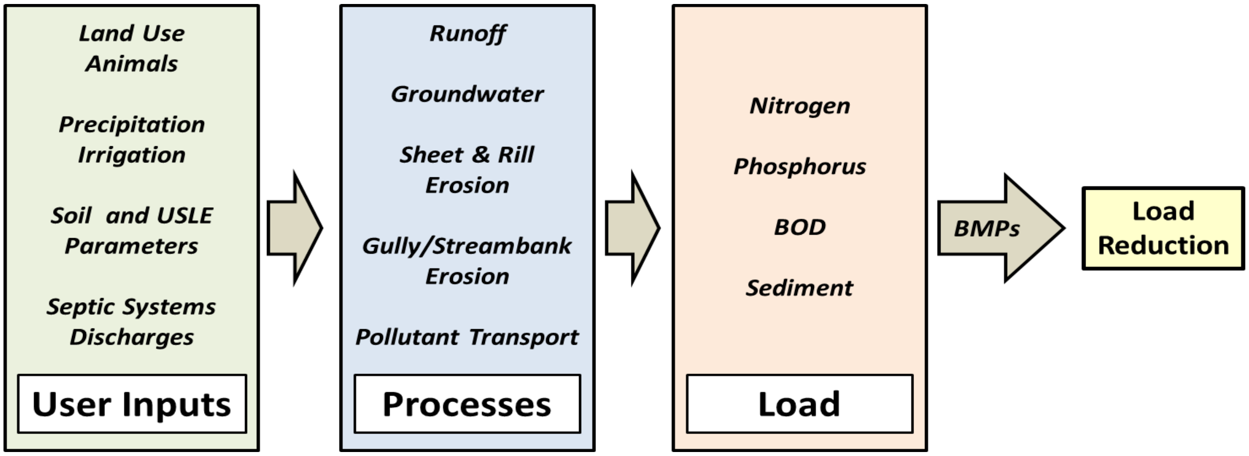
[4] The empirically determined proportion of the total eroded sediment that is actually discharged from the drainage area.

***Figure 6.1**. STEPL application flow diagram*



Much of the required input data for STEPL is relatively easy to obtain from local sources or available online. STEPL also includes linked resources with suggested values for precipitation (including average number of rain days and anticipated runoff) by state and county, soil nitrogen and phosphorus concentrations, and USLE parameters by state and county. The full list of user specified inputs for STEPL includes the following:

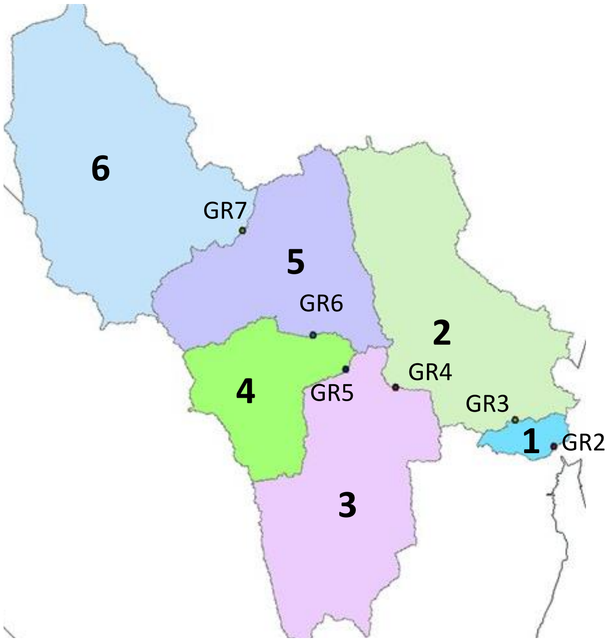
- Watershed land use area (ac)
- Annual precipitation (in)
- Number and type of agricultural animals
- Number of septic systems and average number individuals in households services by septic systems
- Number of illegal direct wastewater discharge
- Universal Soil Loss Equation (USLE) parameters to reflect the watershed under study
- Runoff curve numbers for different land use types and associated hydrologic soil group
- Runoff curve number specific to urban areas
- Nutrient concentration in runoff (mg/l)
- Nutrient concentration in shallow groundwater (mg/l)
- Urban land use distribution
- Irrigation area (ac) and irrigation amount (in)

During initial STEPL setup, the user can specify a number of sub-watersheds, as may be appropriate for larger watersheds or watersheds with marked spatial differences in land use and/or soils, and specify that all sub-watersheds are to be treated as one watershed. Comparisons across multiple watersheds is also possible by establishing multiple ‘sub-watersheds’ but not indicating that they are part of the same watershed. For this application to the Goose River watershed, six sub-watersheds (subsequently referred to as W1 through W6) were defined based on a number of considerations, including general land use patterns and stream branching, as well as ease of access to the main channel for collecting water quality samples (Figure 6.2).

STEPL Application and Assessment

STEPL was initialized using input data reflecting characteristics of each sub-watershed as delineated by the three buffer distances (23m, 60m and 100m), as well as the unbuffered areas for a total of four evaluative applications. In general, input values were obtained from SSURGO and NLCD data assessments as described earlier, lookup resources provided with STEPL, easily available online sources and local knowledge bases. (Complete details of the initial setup and application of STEPL to the unbuffered areas are presented in Appendix D.)

***Figure 6.2**. Sub-watersheds of the Goose River watershed and the location of six water quality sampling locations on the Goose River.*

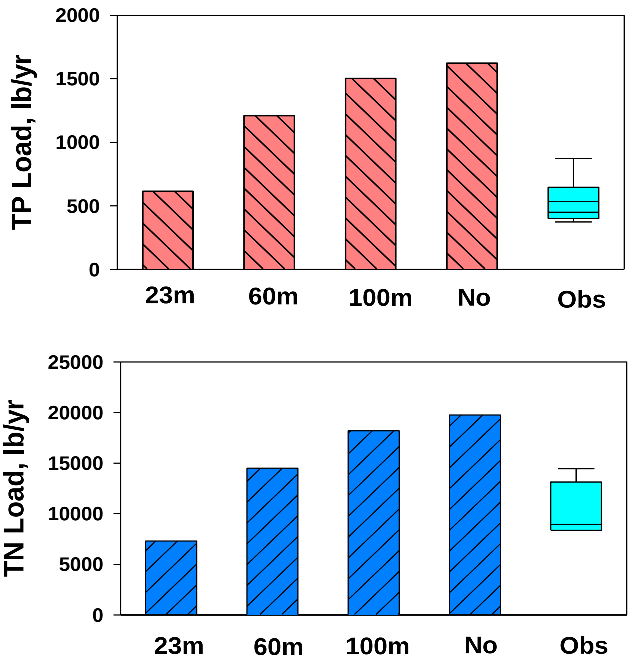


Loads of TP and TN, as estimated by STEPL for the entire watershed with no BMPs applied, were in reasonable agreement with those based on observed data for the water quality sampling site (GR2) located at the downstream boundary of the watershed (Figure 6.3; see Appendix E for a description of how loading was estimated from observed data). As would be expected, TP and TN loads increased with increasing buffer distance. Increases between the 23-m and 60-m buffer were markedly greater than those between the 60-m, 100-m and unbuffered areas. STEPL loading estimates for TP and TN ranged from 615 to 1,622 lb/yr and 7,305 to 19,751 lb/yr, respectively, for the entire watershed. Corresponding estimates based on observed data were 373 to 873 lb/yr for TP and 8,334 to 14,453 lb/yr for TN. Differences between estimates provided by STEPL and those based on observed data are likely due to differences in estimation method and associated uncertainties, and instream processes known to affect the fate and transport of nutrients (Minshall et al. 1985).

TN, TP, BOD and sediment loads were estimated for each sub-watershed and buffer distance using STEPL. The results varied longitudinally and by buffer distance within sub-watersheds (Figure 6.4). In general, loads were reflective of differences in sub-watershed area. Sub-watershed W-2 and W-3 (21.6 and 21.3% of the Goose River watershed, respectively) produced the largest loads while loads for sub-watershed W1 were the lowest.

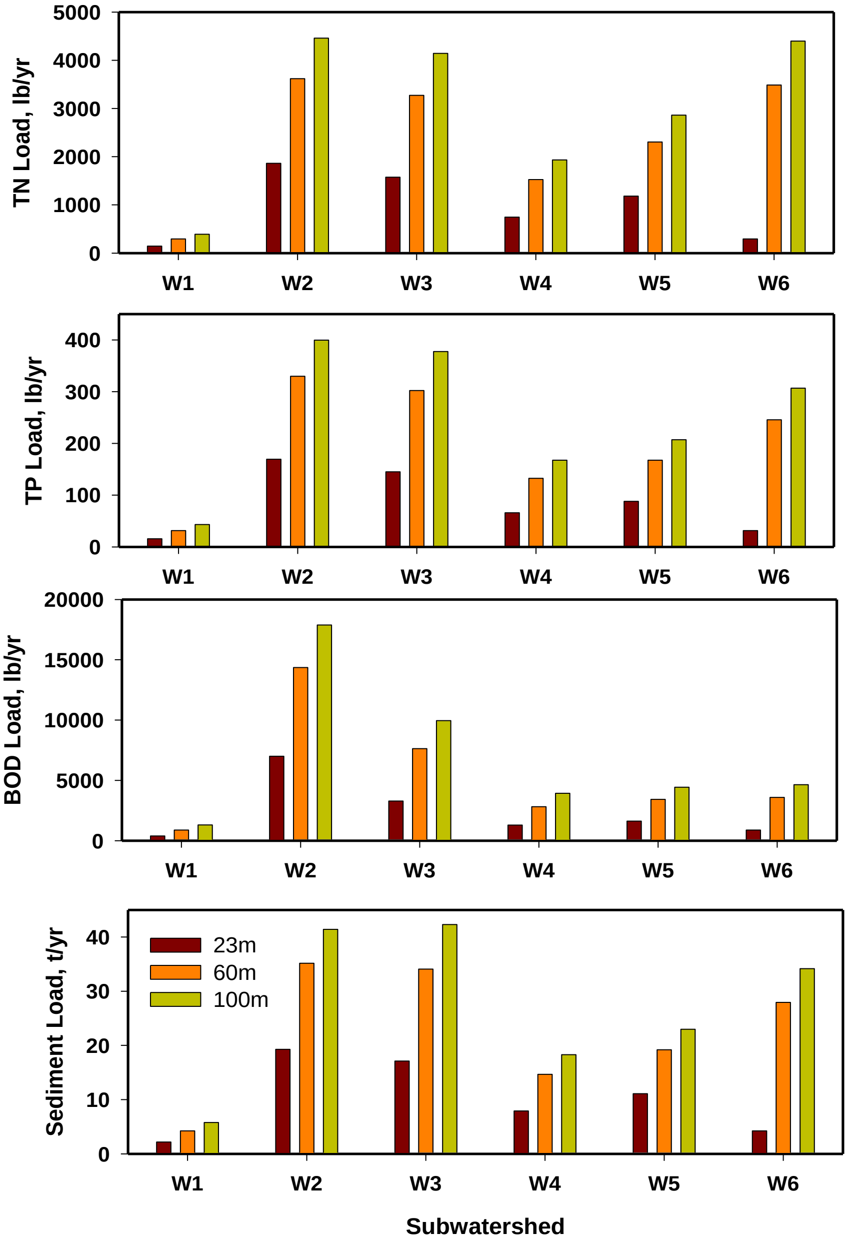
Sub-watershed W6, which accounts for 27.2% of the watershed, had low TN, TP and sediment loads for the 23-m buffer. These increased, however, as the buffer distance increased to 60m and 100m. STEPL load estimates for W-6 are likely inappropriate since this sub-watershed includes Hosmer Pond, which would act to reduce loads to downstream areas due to sedimentation of particulates and/or algal uptake and subsequent settling.

***Figure 6.3**. Comparison of estimated annual total phosphorus (TP; upper) and total nitrogen (TN; lower) loads for the Goose River based on STEPL with 23-, 60- and 100-m buffer distances., as well as with the total drainage area (i.e., no buffer) and loading rates based on observed data computed by multiple methods (Obs).*



Loading rates (mass per year) expressed as areal export rates (mass per unit area per year) provide a somewhat different accounting of NPS sources (Table 6.1). Sub-watersheds W3, W4 and W5 (47.5% of the Goose River watershed) had similar export rates for the 23-m buffer distance of 3.45-3.99 lb/acre/year for TN, 0.26-0.37 lb/acre/yr for TP, and 0.032-0.43 t/acre/yr for sediment. BOD rates did differ, increasing from W5 (4.74 lb/acre/yr) to W3 (8.34 lb/acre/yr). Highest estimated TN, TP and sediment export rates were associated with sub-watershed W1, which accounts for only 3.7% of the

Figure 6.4. *STEPL loading estimates by buffer distance for total nitrogen (TN), total phosphorus (TP), biological oxygen demand (BOD) and sediment for the six Goose River sub-watersheds.*



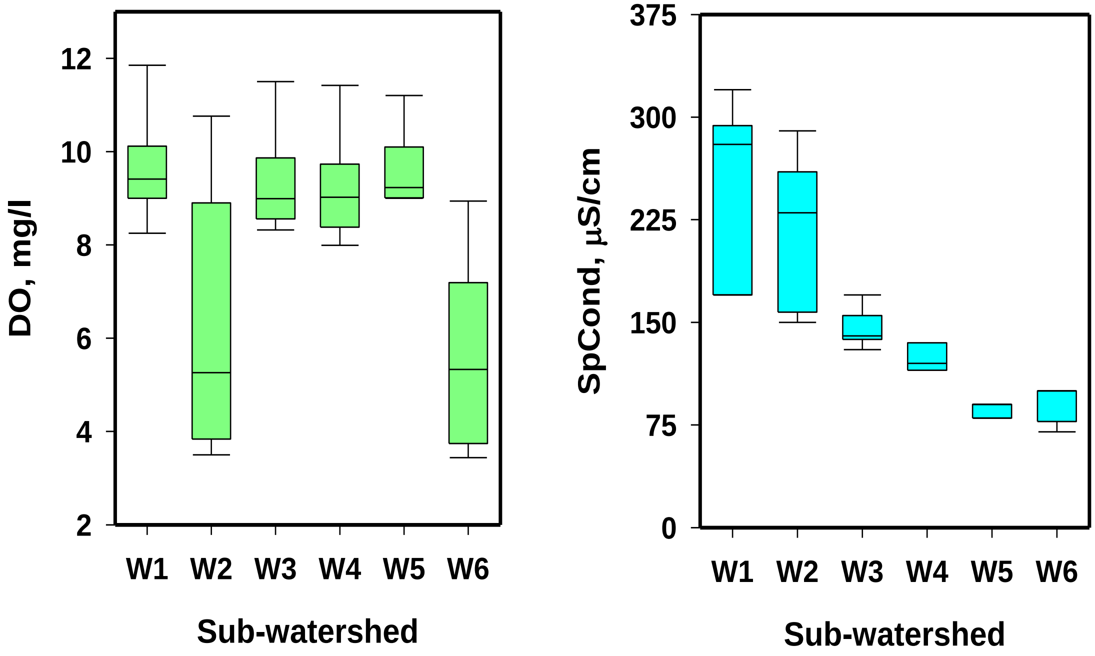
watershed.

Table 6.1. *Export rates for TN, TP, BOD and sediment for each sub-watershed with a 23-m buffer.*

Sub-watershed	**Export Rates**			
	TN lb/ac/yr	**TP lb/ac/yr**	**BOD lb/ac/yr**	**Sed t/ac/yr**
W1	4.84	0.53	13.36	0.073
W2	4.02	0.37	15.11	0.042
W3	3.99	0.37	8.34	0.043
W4	3.98	0.35	6.95	0.042
W5	3.45	0.26	4.74	0.032
W6	0.55	0.06	1.65	0.008

Patterns in observed Goose River water quality provide useful evaluative information. Values for specific conductance, a measure of the ionic strength of natural waters as influenced by geology, evaporation and precipitation and associated interactions (e.g., Gibbs 1970), were, on average, within the range observed for streams in the region (Griffith 2014). Marked longitudinal increases in specific conductance were observed from discharge from W-6 to the downstream boundary of W-1 (Figure 6.5). Average values for W-5 and W-6 discharges were 85.0 and 87.5 µS/cm, respectively, but increased to 126.7 µS/cm at the W-4

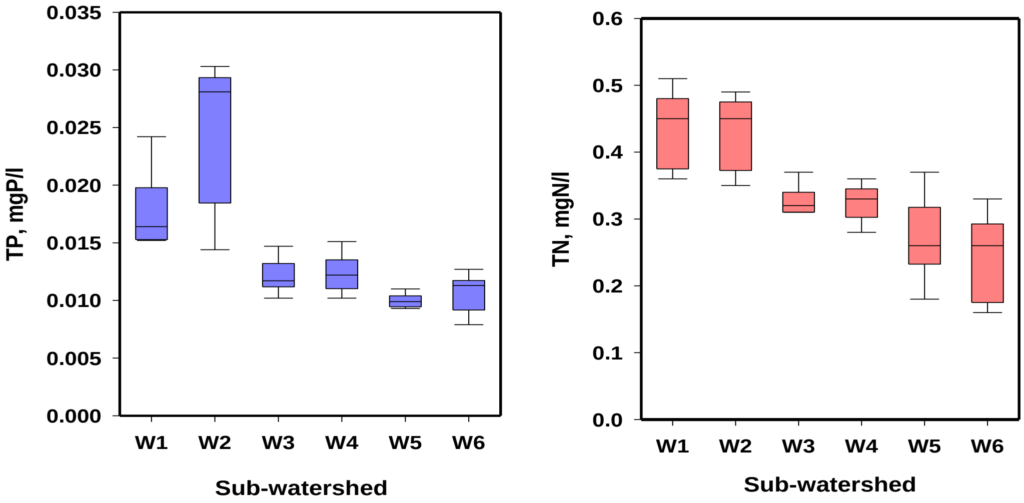
Figure 6.5. *Dissolved oxygen (DO; left) concentration and specific conductance (SpCond; right) observed at Goose River sites located at the downstream boundary of each of the six sub-watersheds.*



downstream boundary and to 147.5 µS/cm at W-3. The largest average increase (65 µS/cm) occurred between W-3 and W-2; the average value remained high at the discharge from W-1.

Dissolved oxygen levels were at or near saturation (average 92-98%) at the downstream boundaries of W1, W-3, W-4 and W-5, but were markedly depressed at those for W-2 and W-6 (Figure 6.5). Averages for the latter sites were 64% and 59% saturation. Lowest concentrations at these sites (3.95 mg/l for W-2 and 3.44 mg/l for W-6) occurred in late summer coincident with low flow conditions. TP and TN concentrations also exhibited longitudinal increases, the largest of which were observed at the downstream boundary of W-2. Here average TP and TN concentrations increased by 100% and 30%, respectively.

Figure 6.6. *Total phosphorus (TP; left) and total nitrogen (TN; right) concentrations observed at Goose River sites located at the downstream boundary of each of the six sub-watersheds.*



The distribution of land use classes and resultant longitudinal differences in STEPL loading values for TN, TP and BOD are, in general, consistent with observed patterns in water quality. Dissolved oxygen declines at the outflow from W-6 were unexpected since flow here is primarily from the outflow of surface water from Hosmer Pond. However, the Goose River flows through a wetland located between Hosmer Pond and the sampling site, which may exert an oxygen demand, especially during the summer low-flow period. Declines in dissolved oxygen across W-2 are likely related to the fact that the river meanders through a golf course and large wetland. Land cover and land use activities in W-2 suggest the potential for moderate to high pollutant risk.

Increases in the concentration of TN, and especially TP, at the discharge from W2 are also consistent with land uses described above. While TN concentrations were similar in W1 and W2, TP declined in W1, due possibly to particulate settling in a small impoundment along Route 1. The lack of decline in TN concentration here may indicate a predominance of soluble forms of nitrogen, which would be less likely to be removed by sedimentation.

Evaluating BMPs

STEPL provides analytical routines that allow the user to evaluate various BMP implementation strategies. In general, removal efficiencies for nitrogen, phosphorus, BOD and sediment for selected BMPs are applied to user-defined portions (percentage) of land use classes across the watershed or su-watershed. Percent reductions in resultant load calculations can then be used to compare BMP strategies.

For purposes here, this capability was evaluated using the six Goose River sub-watersheds. Previous evaluative applications of STEPL involved separate applications based on areas associated with the entire sub-watershed and on areas defined by each of the three buffer distances. Given that BMPs would most efficaciously target watershed areas determined to have moderate or high NPS risk, potential BMP application areas were defined by the NPS risk assessment process developed in Section 5. NPS risk was first assessed for the Goose River watershed for each of the buffer distances (Figure 6.7) and for each sub-watershed. Areas

Figure 6.7. *NPS risk for the Goose River sub-watersheds for the 23-m, 60-m and 100-m buffer distance.*

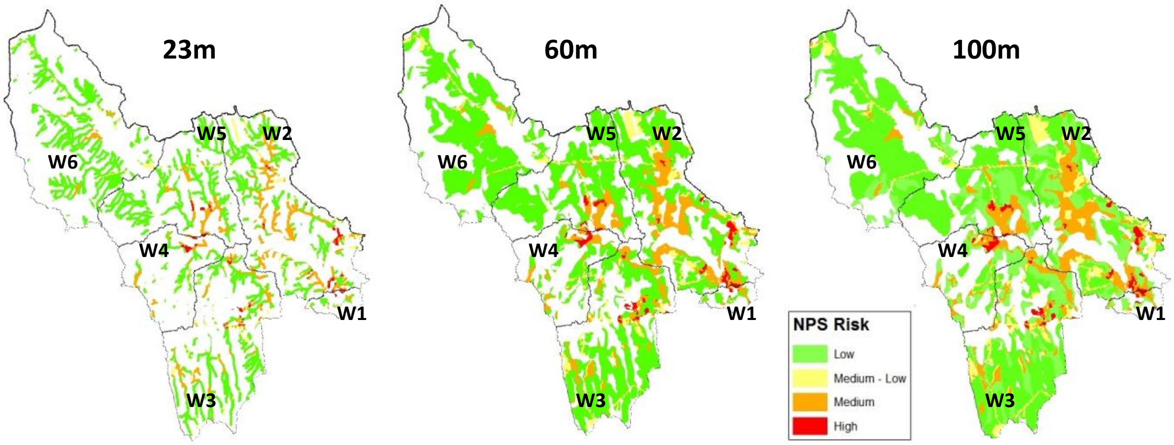
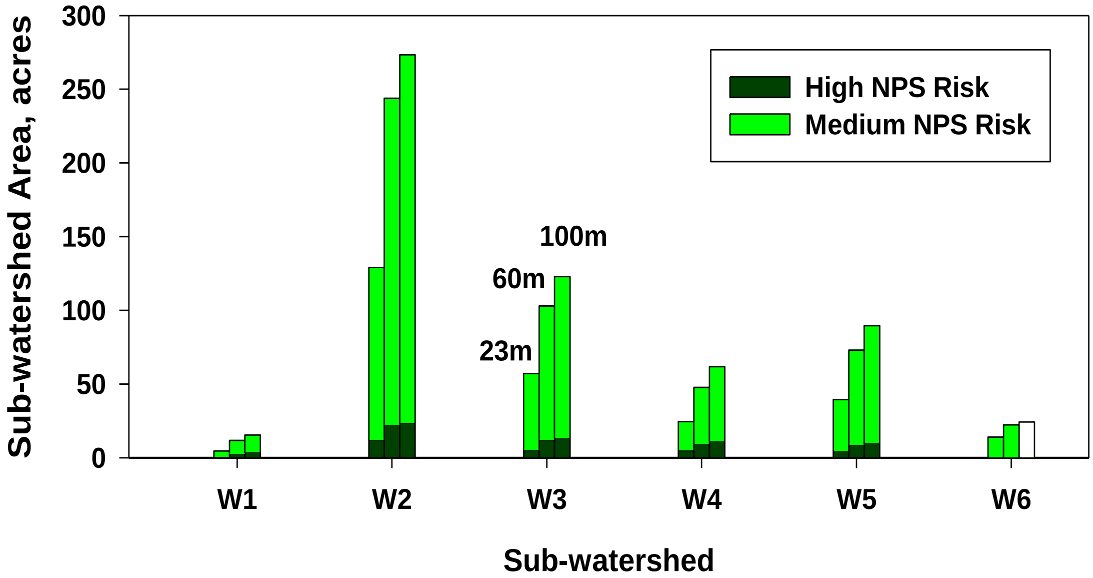


Table 6.2. *Sub-watershed, 60-m buffer acreage by STEPL land use class for high and moderate NPS risk scores*

Sub-watershed	Urban	Cropland	Pasture	Forest	Wetland
W1	3.3	0.0	1.2	6.4	0.8
W2	24.3	0.9	69.0	121.0	28.7
W3	12.0	0.2	10.2	72.2	8.3
W4	2.6	1.7	3.9	31.1	8.4
W5	1.2	1.6	4.7	61.0	4.4
W6	0.1	0.5	1.0	20.0	0.7

Figure 6.8. *Areas (acres) of high (dark green) and moderate (light green) NPS risk for each buffer distance for the sub-watersheds of the Goose River.*



ranked as having moderate and high NPS risk were then summed by sub-watershed (Figure 6.8). The example STEPL application described below is based on areas associated with the 60-m buffer distance. Combined moderate/high NPS risk areas for this buffer distance were 11.8, 243.9, 102.9, 47.6, 73.1 and 22.3 acres for sub-watersheds W1 through W6, respectively. Moderate/high NPS risk areas were further differentiated by STEPL land use class (urban, cropland, pastureland, forest and wetland) and used as input for this STEPL application. The resulting areas of moderate and high risk for each land use class are presented in Table 6.2.

Table 6.3. *Land use specific BMPs applied to the six Goose River sub-watersheds.*

STEPL Land Use Class	Evaluated BMP
Urban (W1)	Weekly street sweeping
Urban (W2-6)	Vegetated swale*
Cropland	Filter strip
Pastureland	Filter strip
Forest	Grass and legume seeding
Wetland	Extended wet detention

** No BMP for NPS risk areas less than 0.33 acres*

The selection of BMPs for this evaluative application of STEPL was based on local knowledge of the watershed and was not intended to be an iterative process designed to maximize NPS load reduction (Table 6.3).

STEPL allows the user to enter a separate BMP for each of nine urban sub-categories (commercial, industrial, institutional, transportation, multi-family, single-family, urban-cultivated, vacant-developed and open space), and provides a simple tool for selecting these. BMPs were applied to 50% of the NPS risk areas in land use classes cropland, pastureland and forest; the BMP for wetland NPS risk areas was applied to 100% of these areas. For this application, filter strips were applied to cropland and pastureland NPS risk areas; grass and legume seeding for forest areas and extended wet detention for wetland areas (Table 6.3). Weekly street sweeping was selected for urban land use areas in sub-watershed W1 since many of these areas are located in the Village of Rockport where other BMPs might be impractical. Vegetated swales were applied to all other urban risk areas greater than 0.33 acres in sub-watersheds W2-W6; no BMP was applied to risk areas less than 0.33 acres in area.

As would be expected, resultant loads were markedly lower than those based on total subwatershed areas delimited by the 60-m buffer distance. Estimated watershed-wide loads of TP, TN, BOD and sediment were 1,971 lb/yr, 186 lb/yr, 5,806 lb/yr and 25 t/yr, respectively.

Table 6.4. *STEPL estimated TN, TP, BOD and sediment annual loads and export rates for the Goose River sub-watersheds without BMPs applied. Estimates limited to watershed areas within the 60-m buffer, and assigned moderate or high NPS risk scores.*

Sub-Watershed	Annual Load				Export Rate			
	TN, lb/yr	TP, lb/yr	BOD, lb/yr	Sediment, t/yr	TN, lb/ac/yr	TP, lb/ac/yr	BOD, lb/ac/yr	Sediment, t/ac/yr
W1	55.5	6.2	165.8	0.9	4.71	0.52	14.09	0.08
W2	981.3	94.7	3865.8	12.0	4.02	0.39	15.85	0.05
W3	414.2	40.4	964.5	5.3	4.03	0.39	9.37	0.05
W4	188.7	17.8	348.8	2.5	3.96	0.37	7.32	0.05
W5	254.9	20.6	381.2	3.0	3.49	0.28	5.22	0.04
W6	75.8	6.0	79.7	0.9	3.40	0.27	3.58	0.04

TN, TP, sediment, and especially, BOD loads were highest for sub-watershed W2 and lowest for sub-watershed W1 (Table 6.4). Expressing annual loads as an export rate provides a somewhat different accounting of NPS influences in the Goose River watershed (Table 6.4). There is a downstream increase in export rates for all four loading variables, with the largest increase in BOD export rate occurring for sub-watershed W2. Highest TP, TN and sediment export rates were associated with sub-watershed W1.

Table 6.5. *Predicted load reductions due to BMP implementation*

Sub-Watershed	Load Reduction (%) with Selected BMPs			
	Nitrogen	Phosphorus	BOD	Sediment
W1	4.7	10.6	4.6	23.3
W2	22.7	27.3	1.2	50.3
W3	12.5	20.5	1.7	45.7
W4	17.6	23.7	3.1	41.5
W5	10.4	20.1	3.4	38.5
W6	6.7	17.2	4.8	37.3
Average	17.4	23.8	1.7	45.5

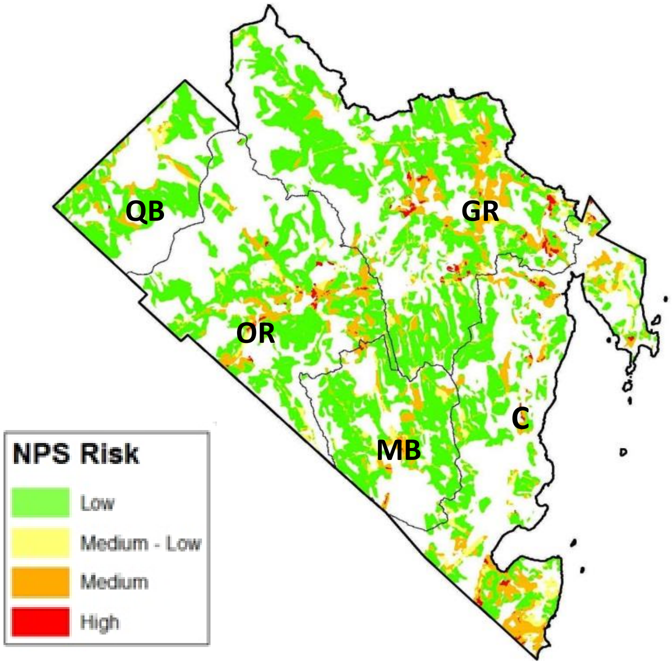
The application of selected BMPs led to reductions in annual loads (Table 6.5). Sediment load exhibited the highest reductions with an area-weighted average of 45.5% watershed-wide; reductions in BOD were minimal (<2% on average). Nitrogen reductions averaged 17.4% with highest reduction rates associated with W2 and W4. Rates of phosphorus reduction averaged 23.8% and were fairly uniform for W2-W5.

7. Summary

Local and regional managers and planners must navigate the often conflicting interests of private stakeholders, and publically-held interests and regulatory requirements for protecting or enhancing environmental quality. For smaller communities with limited fiscal and technical resources, this can be especially difficult. Difficult too is the task of effectively engaging local stakeholders. In this regard, simple analyses early in the planning process may be more effective than those that are complex and not easily understood by stakeholders (Nejadhashemi and Mankin 2007).

The two analytical approaches demonstrated here are of potential utility to local managers and planners. The risk-based assessment is conceptually consistent with VSA hydrology and the concept of CSAs. Despite suggestions that its tenets be reconsidered (MacDonnell 2003), VSA hydrology offers a useful concept for identifying near-stream areas likely to generate runoff. Although not captured mechanistically with this assessment approach, the temporal variability in the spatial distribution of VSAs (seasonally and in response to rain events) can be bracketed by performing the assessment at multiple distances (i.e., buffer widths) from elements of the drainage network.

Figure 7.1. *Project area NPS risk for the 60-m buffer for the five major watersheds located in the project area: Coastal (C), Goose River (GR), Meadow Brook (MB), Oyster River (OR) and Quiggle Brook (QB).*



Identification of runoff potential derives from readily available data on spatial distribution of hydrologic soil groups, and a well-established understanding of soil properties as they relate to infiltration and runoff. Pollutant potential, a somewhat less rigorous treatment of geospatial data describing the distribution of land cover and land use, is also derived from readily available data. The intersection of these two data layers provides the basis for assigning estimates of NPS risk across the landscape.

Identifying general patterns in the distribution of NPS risk, as was done for the project area and its five watersheds (Figure 7.1), provides managers and planners with information upon which to begin to develop management strategies and assign implementation priorities (White et al. 2009). Also, these information products are visual and easily understood thus facilitating effective stakeholder

Figure 7.2. *Risks scores for the 23-m and 100-m buffers projected on parcel data for a portion of the project area. Risk scores common to the 23-m and 100-m buffer are indicated by a difference in shading.*

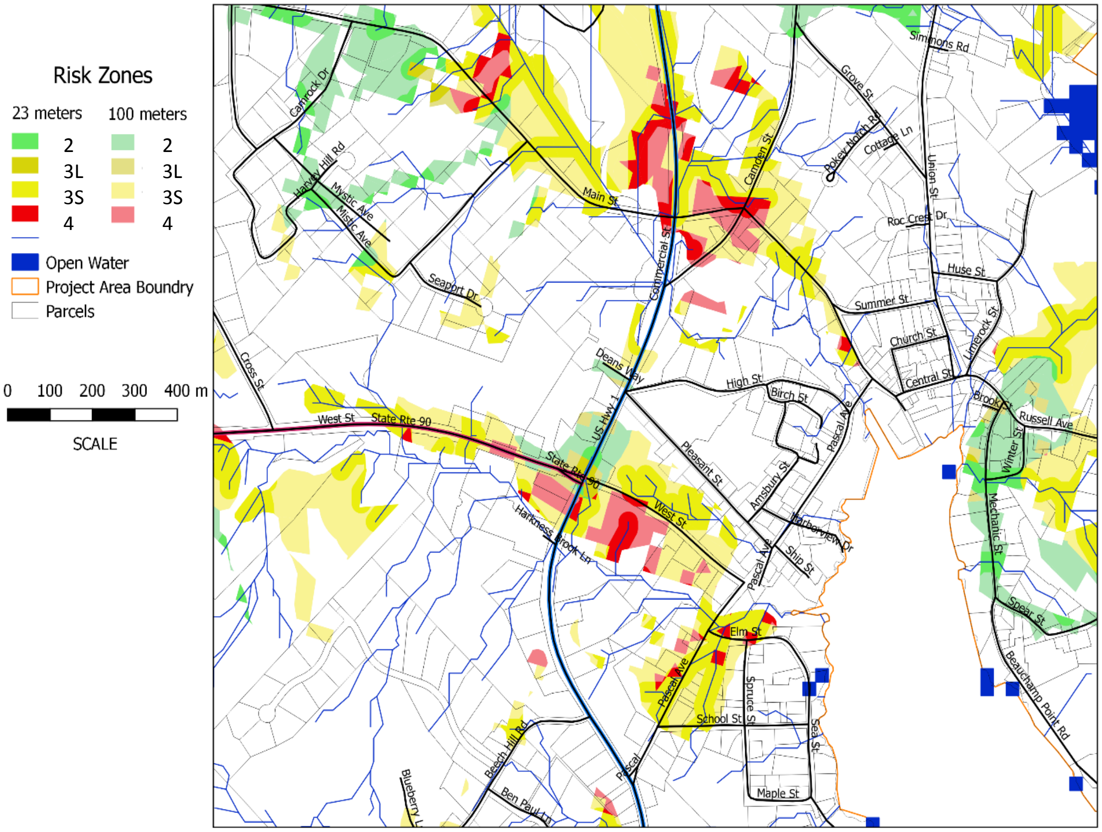
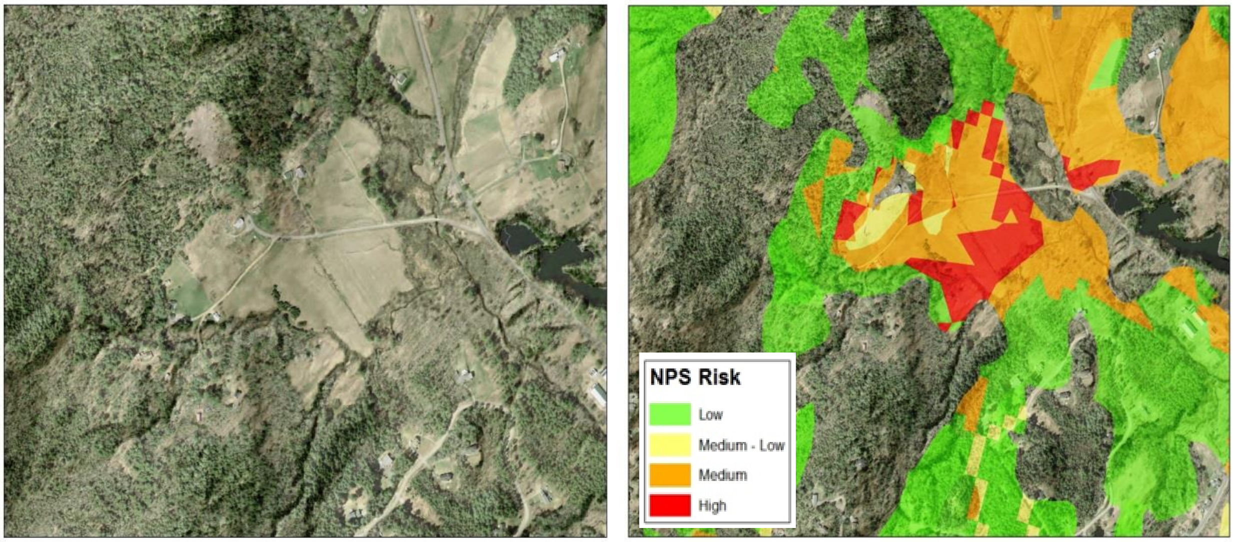


Figure 7.3. *Ortho-imagery of a farm plot located adjacent to the Goose River in sub-watershed W4 (left) and the same image overlain with the 60-m NPS risk map (right).*



involvement. This can be important since such involvement can provide a useful reality check (Nejadhashemi and Mankin 2007).

Projecting NPS risk on various base maps, such as those constructed using parcel data (Figure 7.2) or ortho imagery (Figure 7.3) offers the opportunity to 'drill-down' to finer scale allowing an initial check or ground-truth evaluation of particular locations of concern. Managers would logically conduct on-site inspections of those areas about which they continue to have concerns.

STEPL allows estimation of material (TN, TP, BOD and sediment) loads by those with limited modeling expertise using data that are relatively easy to obtain. Much of the information required, including watershed areas and land uses, is easily obtained from readily available sources. Locally-collected water quality data, while useful, are not required. Nejadhashemi et al. (2011) compared the performance of STEPL, PLOAD, L-THIA and SWAT in predicting long term average nutrient and sediment loads for a mixed land use watershed, and found STEPL to predict higher nutrients loads but lower sediment loads. However, they also observe that while using STEPL can produce uncertain results, it can be applied effectively to estimate the relative contribution of differing land uses.

STEPL estimates of TP and TN loadings for the project area were in reasonable agreement with those based on limited field data. The absence of field data precluded a similar comparison for sediment and BOD loads. Patterns in the spatial distribution of nutrient loads among the six sub-watersheds of the Goose River are also reasonable based on longitudinal differences in observed water quality and the locations of landscape areas ranked as high and moderate NPS risk.

These two assessment tools are useful in the early stages of efforts to mitigate the effects of NPS pollution on fresh and coastal waters. The tools allow a first order estimation of the magnitude and spatial extent of areas likely to generate NPS loads. Neither of the methods enables source accounting, or the attribution of particular pollutant loadings or loading events to specific parcels or tracts of land, which is needed to design and implement specific BMPs and track their effectiveness over time. They do allow managers and planners to rank NPS sites relative to their potential impact and to assess potential benefits of alternative mitigation strategies. Products from these assessment tools, as well as the data upon which they are based, are useful in the broad context of watershed management planning (USEPA 2008).

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APPENDIX A: Stakeholder Advisory Group

A Stakeholder Advisory Group (SAG) was established as a means to solicit input from the local community. The membership included area residents, business persons, members of civic groups, and town officials and employees whose responsibilities include aspects of Rockport's environmental management and conservation efforts.

Lynn Bannister (resident)
Jim Chalfant (real estate agent)
Ken McKinley (Selectman)
Ann Robison (Rockport Garden Club)
Mario Turi (Rockport Harbor Committee)
Mike Young (Department of Public Works)
Ian Stewart (Coastal Mountains Land Trust)
Owen Casas (building contractor)
Chris Holden (resident)
Doug Posson (resident)
Bruce Kapp (resident)
Abbie Leonard (Rockport Harbor Master)
Ron Howard (Maine Coast Heritage Trust)

The project team met formally with the SAG on three occasions during the conduct of the project. Guiding questions throughout these meetings were:

- Do the tools demonstrated in this project provide useful NPS management information?
- How can such information best be turned into local NPS management action?
- How can the community be engaged in this process?

The first meeting of the SAG was October 15, 2015 at Rockport Town Office and was intended as a means to acquaint SAG members with the project, describe their role, and solicit their comments and suggestions at this early stage of the project. The project's development, approach and expected outcomes were described in a visual presentation, and ample time was allotted for questions and discussion.

The second meeting, which occurred on 14 July, 2016, was an opportunity for the project team to share progress at mid-project with the SAG, respond to questions, and receive comments. The final scheduled SAG meeting was held on 17 October, 2016, and included the full Board of Selectmen.

APPENDIX B: Water Quality Sampling and Analytical Methods

Introduction

The Rockport Conservation Commission (RCC) initiated a water quality monitoring program in 2010 to assess ambient conditions and detect trends in water quality in Rockport Harbor, the Goose River and selected streams discharging to the harbor. Sample Analysis Plan (SAP) was submitted to and subsequently approved by the Maine Department of Environmental Protection's (MDEP) Volunteer River Monitoring Program (VRMP) in April 2013. Sample collection and analysis for the current Coastal Communities grant effort adhere, in general, to the SAP, but have been modified and expanded to more appropriately meet that effort. Resultant sample collection and analysis methodologies are described below.

Sample Design

__Figure B.1.__ Harbor and stream sample sites.

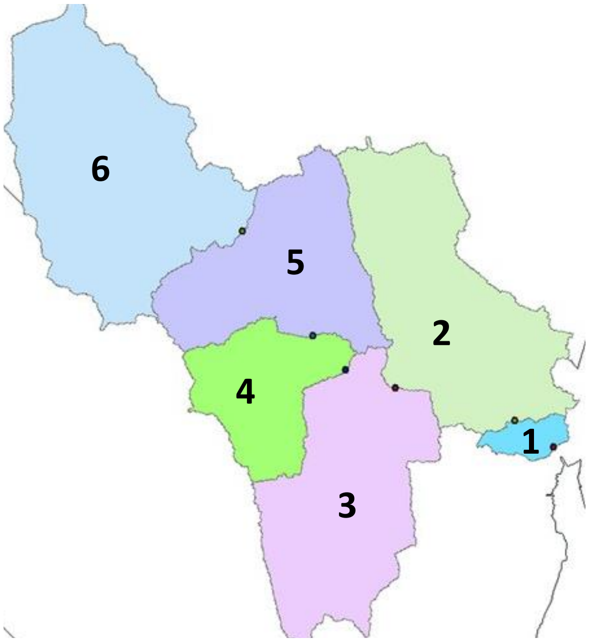
In-situ data and water samples were collected at 4 harbor sites (RH1-3), including a site in Penobscot Bay (RO), a site on the Goose River just above head of tide (GR-2), and at downstream sites on Ott Brook (OT-1), Harkness Brook (HB-1), Lily Pond Stream (LPS-1) and Winter Street Stream (WS-1; Figure B.1). Sampling was at approximately monthly intervals from May through October.

An additional five sample locations were established on the Goose River as a means to assess longitudinal patterns in water quality (Figure B.2). Locations extended from the downstream boundary of the watershed (GR-2) upstream to the discharge from Hosmer Pond (GR-7) and corresponded to the boundary between six sub-watersheds established for STEPL (see Section 6). Samples were collected at 2-week intervals during the period 4 June to 3 August, 2015.

Field Data and Sample Collection/Handling

Stream Sites – Temperature and dissolved oxygen (concentration and percent saturation) were determined in the field using a YSI 550A DO meter (Yellow Springs Instruments, Yellow Springs, OH). Conductivity was determined using a Sper Model 850037 Large Display Conductivity Pen (Sper Scientifc, Scottsdale, AZ). Water samples for bacteria will be collected in 125-ml sterile poly-bottles. Water samples for nutrient analyses were collected in acid-washed, 125-ml plastic bottles. Sampling occurred in the center half of the stream width. Samples for total phosphorus and total nitrogen were frozen within 2 hours of collection. Analyses for enterococcus bacteria were initiated within 2 hours of sample collection.

Figure B.2. *Sub-watersheds and the location of six water quality sampling locations on the Goose River.*



Harbor/Bay Sites - Transparency was determined in the field using a standard (20-cm) Secchi disk and calibrated line. Temperature, dissolved oxygen (concentration and percent saturation), pH, salinity were determined at 1- to 2-m depth intervals from surface (0.1-0.2m) to near bottom using a Eureka Manta 2 Sub 3 multi-parameter water quality probe (Eureka Water Probes, Austin, TX). Samples for total phosphorus and total nitrogen were collected from just below the surface (0.1 m) and stored in plastic, screw-capped bottles. One-liter samples for chlorophyll/phaeophytin analyses were collected from just below the surface in plastic bottles and stored on ice in the dark. Sample bottles for nutrients and chlorophyll/phaeophytin were triple rinsed with sample water prior to sample collection. Water samples for Enterococcus bacteria were collected from just below the surface (0.1 m) in 125-ml sterile poly-bottles and stored on ice. Samples for chlorophyll/phaeophytin were filtered using 0.45µ glass fiber filters; filters and retained material were sealed in aluminum foil and immediately frozen. Samples for total phosphorus and total nitrogen were frozen within 2 hours of collection. Analyses for enterococcus bacteria were initiated within 2 hours of sample collection.

Analytical Methods

Enteroccocus bacteria – *Enterococcus* bacteria levels were determined using Enterolert® (IDEXX Laboratories), which uses a Defined Substrate Technology® (DST®) as a nutrient indicator and the Quanti-Tray® System. Enterolert provides quantitative results in 24 hours. Samples were diluted 1:10 or

1:100 when levels are expected to be high (above 2400 MPN/100ml). This analysis were performed by the Mirror Lake Laboratory, Maine Water Company, Rockport, ME.

E. coli bacteria – *E. coli* bacteria levels were determined using Colilert® (IDEXX Laboratories), which uses a Defined Substrate Technology® (DST®) as a nutrient indicator and the Quanti-Tray® System. Colilert provides quantitative results in 24 hours. Samples were diluted 1:10 or 1:100 when levels are expected to be high (above 2,419 MPN/100ml). This analysis was performed by the Mirror Lake Laboratory, Maine Water Company, Rockport, ME.

Chlorophyll - Chlorophyll α was extracted from cells using a 90% solution of acetone. The samples were refrigerated in the dark from 2 to 24 hours. Samples were centrifuged to separate the sample material from the extract. The extract was analyzed fluorometrically. To determine phaeophytin and active chlorophyll α, the extract was then acidified using 5% HCl, and reread. The Method Detection Limits (MDL) are 0.68 µg/L for total chlorophyll α, 0.29 µg/L for phaeophytin, 0.56 µg/L for active chlorophyll α, and 0.87 µg/L for non-acid chlorophyll α. This procedure conforms to EPA Method 445. and was performed by the Nutrient Analytical Services Laboratory, University of Maryland, Solomons, MD (http://www.nasl.cbl.umces.edu).

Total phosphorus - Potassium persulfate was used to oxidize organic and inorganic phosphorus in unfiltered samples to orthophosphate under heated acidic conditions. Ammonium molybdate and potassium antimony tartrate react in an acid medium with dilute solutions of orthophosphate to form an antimonyphosphomolybdate complex which was reduced to an intensely blue-colored complex by ascorbic acid. Color is proportional to orthophosphate concentration. The Method Detection Limit (MDL) is 0.0015 mg TP as PO_4-P/L. This procedure conforms to Standard Methods #4500-P.B.5, #4500 P.E, and EPA Method 365.1 (USEPA 1993) and was performed by the Nutrient Analytical Services Laboratory, University of Maryland, Solomons, MD (http://www.nasl.cbl.umces.edu).

Total nitrogen - Potassium persulfate is used to oxidize organic and inorganic nitrogen in unfiltered samples to nitrate under heated alkaline conditions. Enzyme catalyzed reduction is used to quantitatively reduce dissolved nitrate to nitrite which is then measured by colorimetrically. The Method Detection Limit (MDL) is 0.05 mg TN as NO_3-N/L. This procedure conforms to Standard Methods #4500-N C, 4500-NO3 F and EPA Method 353.2 (USEPA 1993) and will be performed by the Nutrient Analytical Services Laboratory, University of Maryland, Solomons, MD (http://www.nasl.cbl.umces.edu).

APPENDIX C: Geospatial Data – Sources and Software

Data Sources

Data	Source	Description
National Elevation Dataset (NED)	US Geological Survey http://nationalmap.gov/	Bare earth digital elevation models (DEM) available in geographic coordinates at 1/3, 1, and 2 arc-seconds.
Soil Survey Geographic Database (SSURGO)	US Department of Agriculture Natural Resources Conservation Service https://gdg.sc.egov.usda.gov/	National database of soil information collected by the National Cooperative Soil Survey at scales ranging from 1:12,000 to 1:63,360.
National Land Cover Dataset 2011 (NLCD 2011)	Multi-Resolution Land Characteristics Consortium (MRLC) http://www.mrlc.gov/nlcd2011.php	Spatially explicit, national land cover data with 16 land cover classes. Based on a decision-tree classification of circa 2011 Landsat satellite data.
Orthoimagery (2013), 2-m Hillshade	Maine Office of GIS (MEGIS) Hillshade (2013) - http://www.maine.gov/megis/catalog Orthoimagery 6-in resolution - obtained raster files from MEGIS and hosted locally	Orthoimagery - Geo-referenced image data of the Earth's surface, collected from airborne sensors Hillshade - a grayscale 3D representation of the surface, with the sun's relative position taken into account for shading the image.
National Wetlands Inventory (NWI)	US Fish & Wildlife Service https://www.fws.gov/wetlands/	Geospatial wetland survey data collected nationally since the mid-1970s. Data can be downloaded by HUC 8 watershed boundary or by State.
Stream Stats (Version 3)	US Geological Survey http://water.usgs.gov/osw/streamstats	A Web application that provides access to an assortment of analytical tools useful for a variety of water-resources planning and management purposes, including delineation of drainage-basin boundaries and export of associated shape files.
E911 Road Data	Maine Office of GIS (MEGIS)	Road data produced by the Maine Emergency Services Communication Bureau and published through Maine Office of GIS
Parcel Data	Tax Assessor Office, Town of Rockport and Town of Camden	Geospatial data indicating parcel boundaries and assessed use categories

Software

GIS software used in this project included Esri's ArcGIS for Desktop application and Spatial Analyst extension, utilizing the Standard License level and desktop versions 10.2.2 and 10.4.1.

APPENDIX D: Spreadsheet Tool for the Estimation of Pollutant Load (STEPL)

STEPL is public domain software developed for the USEPA by Tetra Tech, Inc. (Pasadena, CA). STEPL is an Excel® spreadsheet application that estimates material (nitrogen, phosphorus, BOD and sediment) loads and allows the user to evaluate the potential effectiveness of various best management practices (BMPs). STEPL version 4.3, documentation and associated support files were downloaded from http://it.tetratech-ffx.com/steplweb/models$docs.htm.

STEPL requires a number of user input variables. Values for selected variables are provided in the supporting files and are loaded to the spreadsheet using a lookup function. Others are entered by the user. In all cases, the user has the option to use locally-derived values. Below is specific information related to the application of STEPL to the entire Goose River watershed (i.e., without buffer distances applied).

Input Table 1 - Input watershed land use area (ac) and precipitation (in)

Watershed Area – The Goose River watershed and its sub-watersheds were delineated using Stream Stats (Ries et al., 2004). Stream Stats is an online application that allows delineation of watershed boundaries and selected watershed characteristics, including area upstream of user-selected locations using an interactive map. Users can also download shapefiles for use in other applications.

Sub-watersheds for the Goose River watershed were established by first delineating areas upstream of points corresponding to the locations of six water quality sampling sites distributed longitudinally from the head of tide to the discharge from Hosmer Pond. While originally selected based primarily on logistical considerations, these sites provide a reasonable segmenting of the watershed based on broad land use and land cover characteristics, and major stream confluences (see Appendix B for a discussion of sample locations and methods). Areas of each of the resulting six sub-watersheds, which were denoted as W1 to W6 in upstream order, were then determined as the difference between areas estimated from each successive downstream and upstream site (Table D.1).

***Table D.1**. Sub-watershed areas (acres). Areas of open water are excluded.*

Sub-watershed	W1	W2	W3	W4	W5	W6
Area (acres)	198.8	1153.5	1139.3	527.9	867.47	1454.4

Table D.2. Reclassification of NLCD land cover classes

NLCD Code	NLCD Description	STEPL Reclassification
21	Developed, Open Space	Pastureland
22	Developed, Low Intensity	Urban
23	Developed, Medium Intensity	Urban
24	Developed, High Intensity	Urban
31	Barren Land (Rock/Sand/Clay)	Urban
41	Deciduous	Forest
42	Evergreen	Forest
43	Mixed	Forest
51	Dwarf Scrub	Forest
52	Shrub/Scrub	Forest
71	Grassland/Herbaceous	Pastureland
72	Sedge/Herbaceous	Pastureland
81	Pasture/Hay	Pastureland
82	Cultivated Crops	Cropland
90	Woody Wetlands	Wetland
95	Emergent Herbaceous Wetlands	Wetland

STEPL requires that users specify areas associated with each of five land use classes. These include urban, cropland, pastureland, forest, user defined and feedlot. For this application, the user defined class was defined as wetland; no feedlots are located in the Goose River watershed, so this land use class was not included in the application. Land cover class polygons available in the 2011 National Land Cover Database (NLCD) were retrieved for the project area. The 16 NLCD land cover classes associated with these polygons were reclassified for use in STEPL according to Table D.2.

Reclassified STEPL polygons were clipped to the six sub-watersheds. The resulting land use areas for each sub-watershed (Table D.3) were used as input for this application.

Table D.3. Sub-watershed areas (acres) by STEPL land use class

Sub Watershed	Urban	Cropland	Pastureland	Forest	Wetland
W1	26.9	0.0	11.8	46.9	4.2
W2	119.9	3.5	339.3	668.1	114.2
W3	119.8	10.5	120.3	795.6	78.7
W4	29.6	21.6	61.2	358.6	72.1
W5	17.8	17.9	61.2	765.0	41.5
W6	8.1	48.6	66.1	1349.6	31.7

Rainfall - The Knox County weather station nearest to the project area and available through STEPL is 'ME Rockland 1W.' Since annual precipitation data were available for the National Weather Service gage in West Rockport, these data were averaged over the period of record (1976-2015) and used as annual rainfall in this application. However, values derived from the ME Rockland 1W were used for rain correction factors, rain days and average rain per event (Table D.4).

Table D.4. *Rainfall and rainfall correction factors for the Goose River sub-watersheds*

Rain correction factors		
0.870*	0.530**	
Annual Rainfall	**Rain Days**	**Avg. Rain/Event**
55.66	112.5	0.812
* percentage of rainfall events that exceed 5mm per event **percentage of rain days that generate runoff		

Input Table 2. Input agricultural animals

<u>*Agricultural animals*</u> – Since there are no known areas in the Goose River watershed that support agricultural animal husbandry or the spreading of animal manure, values for this input table were set to zero.

Input Table 3. Input septic system and illegal direct wastewater discharge data

<u>*Septic systems*</u> - Parcel descriptions, available as geo-referenced data for both Rockport and Camden, were used for estimating the number of septic systems. Parcel descriptions indicating the potential existence of a septic system included “two unit,” “single family,” “mobile home,” “multiple family” “multi houses” and “single family waterfront.” It was assumed that parcels indicated as multiple residences were serviced by two septic systems and that all others were serviced by a single septic system. Parcels located in sub-watershed W1 were assumed to be on municipal sewers. Population per septic system (2.43) and failure rate (2%) were set to defaults values (Table D.5).

<u>*Illegal direct wastewater discharges*</u> – Illegal wastewater discharges were assumed to be nonexistent (Table D.5).

***Table D.5**. Septic system and illegal direct wastewater discharge data*

Sub-Watershed	No. of Septic Systems	Population per Septic System	Septic Failure Rate, %	Wastewater Direct Discharge, # of People	Direct Discharge Reduction, %
W1	0	2.43	2	0	0
W2	218	2.43	2	0	0
W3	150	2.43	2	0	0
W4	103	2.43	2	0	0
W5	51	2.43	2	0	0
W6	120	2.43	2	0	0

Input Table 4 - Modify the Universal Soil Loss Equation (USLE) parameters

The Universal Soil Loss Equation (USLE) is widely used to estimate average annual soil loss due to rill and sheet erosion, especially for agricultural landscapes (Wischmeier and Smith 1978). The average annual soil loss is estimated in STEPL as the product six contributing factors:

$$A = R*K*LS*C*P \qquad \text{Eq. D.1}$$

where

A = average annual soil loss
R = rainfall erosivity factor
K = soil erodibility factor
LS = slope length (L) and slope (S) factor
C = cropping factor
P = conservation practice factor

STEPL requires inputs for four land cover/use classes - urban, cropland, forest land and pasture land, as well as thr user defined class, which in this application is wetland. Many of the required USLE factor values are available for Knox County, ME in the resource file provided with STEPL. Two cropland types (cultivated and uncultivated) are included in that file. Based on knowledge of the project area, values for cropland-uncultivated were used for this application. All required factor values were available for pasture land. Not included in the resource file were values for LS and C for forest land, and all factor values for wetlands. The value for factor LS for forest land was set equal to the average of that for pasture land and cropland-uncultivated while the value for factor C was set equal to the value suggested by Wischmeier and Smith (1978) for forest with 45-70% canopy.

***Table D.6**. USLE parameter values for each STEPL land use class*

Land Use	R	K	LS	C	P
Cropland-noncultivated	100	0.240	1.389	0.026	1.0
Forest land	100	0.224	1.348*	0.003**	1.0
Pastureland	100	0.280	1.307	0.003	1.0
Wetland	100	0.090+	1.000	0.007++	1.0

** Average of values for cropland and pastureland*

*** Based on Wischmeier and Smith (1978) for forest with 45-70% canopy*

+ Based on Essien 2013

++Based on OEPD (2002)

Determining factor values for wetlands, a mix of both woody and herbaceous systems, was more problematic. Given that both wetland types are vegetated, and located in landscape depressions that accumulate fine sediments and store organic detritus, the value for K was set to 0.09 (Essien 2013). Factor C was set to a value of 0.007 based on values reported OEPD (2002). LS was set to a value of 1.0. Factor values for all land use types are listed in Table D.6.

Input Table 5 - Select average soil hydrologic group (SHG), SHG A = highest infiltration and SHG D = lowest infiltration

Soil hydrologic group – A single HSG is required for each sub-watershed and land use class combination. The predominant (>75%) HSG based on an accounting of all HSG areas in each watershed was used for this application. When HSGs had similar %, lowest infiltration HSG used.

Soil nutrient and BOD concentrations - Soil phosphorus and nitrogen values for all watershed areas were set to the midpoint values for ranges depicted in the national maps provided with STEPL reference files.

Input Table 6 - Reference runoff curve number

Curve numbers (CNs), empirically-derived relationships for estimating runoff amounts, are available for a variety of HSG and land use combinations from the USDA's Technical Release 55 or TR-55 (USDA 1986). CNs for wetland areas, which are not available in TR-55, were adopted from those for paddy fields (Sumarauw and Ohgushi 2012). Table D.7 lists NLCD and appropriate corresponding TR-55 descriptions, and associated CNs for each HSG. Since NLCD land cover/use descriptions do not correspond to the four STEPL land use classes, CNs were area-weighted by HSG and NLCD class for each STEPL class (Table D.8).

***Table D.7**. Curve numbers for NCLD component classes of each STEPL class for each hydrologic soil group. Based on USADA's Technical Release 55 (USDA, 1986) and Sumarauw and Ohgushi (2012).*

STEPL Class	**NLCD Class**	**NLCD Description**	**TR-55 Description**	**TR-55 Curve Number by Soil Group**			
				A	**B**	**C**	**D**
Pastureland	21	Developed, Open Space	Open spaces; Good condition (grass cover > 75%)	39	61	74	80
Urban	22	Developed, Low Intensity	Residential districts by average lot size of 2 acres	46	65	77	82
Urban	23	Developed, Medium Intensity	Residential districts by average lot size of 1/2 acres	54	70	80	85
Urban	24	Developed, High Intensity	Residential districts by average lot size of 1/8 acres	77	85	90	92
Urban	31	Barren Land (Rock/Sand/Clay)	Streets and roads; Paved; open ditches (including right-of-way)	83	89	92	93
Forest	41	Deciduous	Woods; Fair condition	36	60	73	79
Forest	42	Evergreen	Woods; Fair condition	36	60	73	79
Forest	43	Mixed	Woods; Fair condition	36	60	73	79
Forest	51	Dwarf Scrub	Brush-weed-grass mixture with brush the major element; Fair condition	35	56	70	77
Forest	52	Shrub/Scrub	Brush-weed-grass mixture with brush the major element; Fair condition	35	56	70	77
Pastureland	71	Grassland/Herbaceous	Meadow—continuous grass, protected from grazing and generally mowed for hay	30	58	71	78
Pastureland	72	Sedge/Herbaceous	Meadow—continuous grass, protected from grazing and generally mowed for hay	30	58	71	78
Pastureland	81	Pasture/Hay	Meadow—continuous grass, protected from grazing and generally mowed for hay	30	58	71	78
Cropland	82	Cultivated Crops	Small grain; Straight rows	63	75	83	87
Wetland	90	Woody Wetlands	Paddy field *	67	78	85	89
Wetland	95	Emergent Herbaceous Wetlands	Paddy field *	67	78	85	89

* Sumarauw and Ohgushi, 2012

Table D.8. *Area-weighted CNs for each HSG and sub-watershed****.***

STEPL Class	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
Urban	54.7	na	79.2	83.2
Cropland	63	na	83	80.3
Pastureland	37.5	61	73	78.9
Forest	36	60	73	79
Wetland	67	na	85	88.8

Input Table 6a - Detailed urban reference runoff curve number

Urban curve numbers – Since there was insufficient information to clearly distinguish between urban land use types, each was assigned the same CN as established for the overall STEPL urban class (Table D.9).

Table D.9*. CNs for each urban land use type by HSG*

Urban Land Use Type	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
Commercial	54.7	na	79.2	83.2
Industrial	54.7	na	79.2	83.2
Institutional	54.7	na	79.2	83.2
Transportation	54.7	na	79.2	83.2
Multi-Family	54.7	na	79.2	83.2
Single-Family	54.7	na	79.2	83.2
Urban-Cultivated	54.7	na	79.2	83.2
Vacant-Developed	54.7	na	79.2	83.2
Open Space	54.7	na	79.2	83.2

Input Table 7 - Nutrient concentration in runoff (mg/l)

Phosphorus and nitrogen runoff values (0.041 mg/l and 0.83 mg/l, respectively) are the average 75th percentile values for the distributions for data for stream sites HB, OT, LPS and WS for 2012 through 2015. This approach to determining runoff concentrations assumes that such concentrations increase with flow rate. Data availability was insufficient to evaluate this assumption. (See Appendix B for descriptions of sample locations and analyses.)

Input Table 7a - Nutrient concentration in shallow groundwater (mg/l)

Phosphorus and nitrogen concentrations for shallow groundwater were set as the averages of intercepts when plotting concentration versus 7-day antecedent precipitation for OT, HB, WS and LPS (Table D.9). This approach is based on the assumption that base flow or flow during periods of little or no surface runoff, is derived primarily from groundwater infiltration

Table D.9. *Intercept values for the relationship between TP and TN concentration, and 7-day antecedent precipitation stream sites.*

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Stream	Intercept	
	TP, mg/l	TN, mg/l
Harkness Brook (HB)	0.030	0.63
Ott Brook (OT)	0.016	0.68
Winter Street Stream (WS)	0.022	0.83
Lily Pond Stream (LPS)	0.031	0.47
Average	**0.025**	**0.65**

Input Table 8 - Input or modify urban land use distribution

Urban land use distributions – The percent distributions of various urban land uses were approximated following review of the parcel data for the watershed (Table D.10). Urban land uses in the Goose River watersheds account for only 2.1% of the watershed area. For applications involving larger proportions of urban land use, greater effort in determining these distributions would be appropriate.

Table D.10. *Urban land use distributions*

Watershed	Urban Area (ac.)	Commercial %	Industrial %	Institutional %	Transportation %	Multi-Family %	Single-Family %	Urban-Cultivated %	Vacant (developed) %	Open Space %
W1	8.8	15	10	10	10	10	30	5	5	5
W2	44.1	15	10	10	10	10	30	5	5	5
W3	42.8	15	10	10	10	10	30	5	5	5
W4	9.9	15	10	10	10	10	30	5	5	5
W5	5.3	15	10	10	10	10	30	5	5	5
W6	2.9	15	10	10	10	10	30	5	5	5

Input Table 9 - Input irrigation area (ac) and irrigation amount (in)

Irrigation area – There is no significant crop irrigation in the watershed and all values set to zero (Table D.11).

Irrigation amount – There is no significant crop irrigation in the watershed and all values set to zero (Table D.11).

Table D.11. *Irrigation area (ac) and irrigation amount (in)*

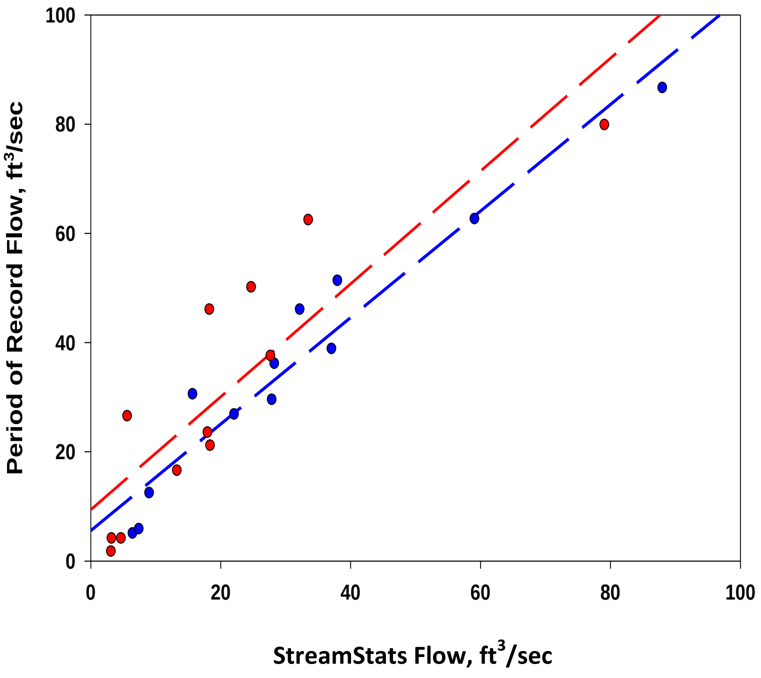
Watershed	Total Cropland (ac)	Cropland: Acres Irrigated	Water Depth (in) per Irrigation - Before BMP	Water Depth (in) per Irrigation - After BMP	Irrigation Frequency (#/Year)
W1	0	0	0	0	0
W2	3.3	0	0	0	0
W3	10.6	0	0	0	0
W4	21.4	0	0	0	0
W5	17.2	0	0	0	0
W6	48.1	0	0	0	0

APPENDIX E: Estimating Nutrient (N & P) Loading Rates for the Goose River

Loading rate, or the rate at which materials are transported from watersheds to receiving waterbodies, is commonly estimated by establishing a relationship between paired observations of material concentration and instantaneous flow, and applying that relationship to the complete flow record. While total phosphorus (TP) and total nitrogen (TN) concentrations are available for 2012-2016, there are no measured flow data for the Goose River requiring a somewhat different approach.

Goose River monthly flows were estimated based on statistical relationships between gaged and ungaged streams in Maine (Dudley 2004) as incorporated in the online resource StreamStats[5] (Ries et al. *2004).* To assess the applicability of the StreamStats approach for the Goose River, observed mean and median monthly flows and those estimated using StreamStats were compared for the nearby Ducktrap River, the watershed of which has a similar size (14.9 versus 8.6 mi^2) and similar land uses (Figure E.1). The relatively strong correlation for both mean and median flows (r=0.97 and r=0.88, respectively) suggests that such flow measures for the Goose River would be reasonably estimated using StreamStats.

Figure E.1. *Comparison of mean (blue) and median (red) monthly flows for the Ducktrap River as estimated by Stream Stats and as observed for the published period of record (1998-2015).*



Goose River flows were also estimated based on Ducktrap River observed flows using a watershed-area ratio (8.6/14.9 or 0.58). This approach seems reasonable since the slope of the relationship between mean monthly flows for the Goose River and the Ducktrap River, as determined based on StreamStats, is 0.59. More tenuous is the use of this approach for estimating mean daily flows for the Goose River since the short-term temporal distribution of flows for the two rivers would likely differ to some undeterminable degree. However, the approach could offer an approximate means to flow-weight observed nutrient concentration data.

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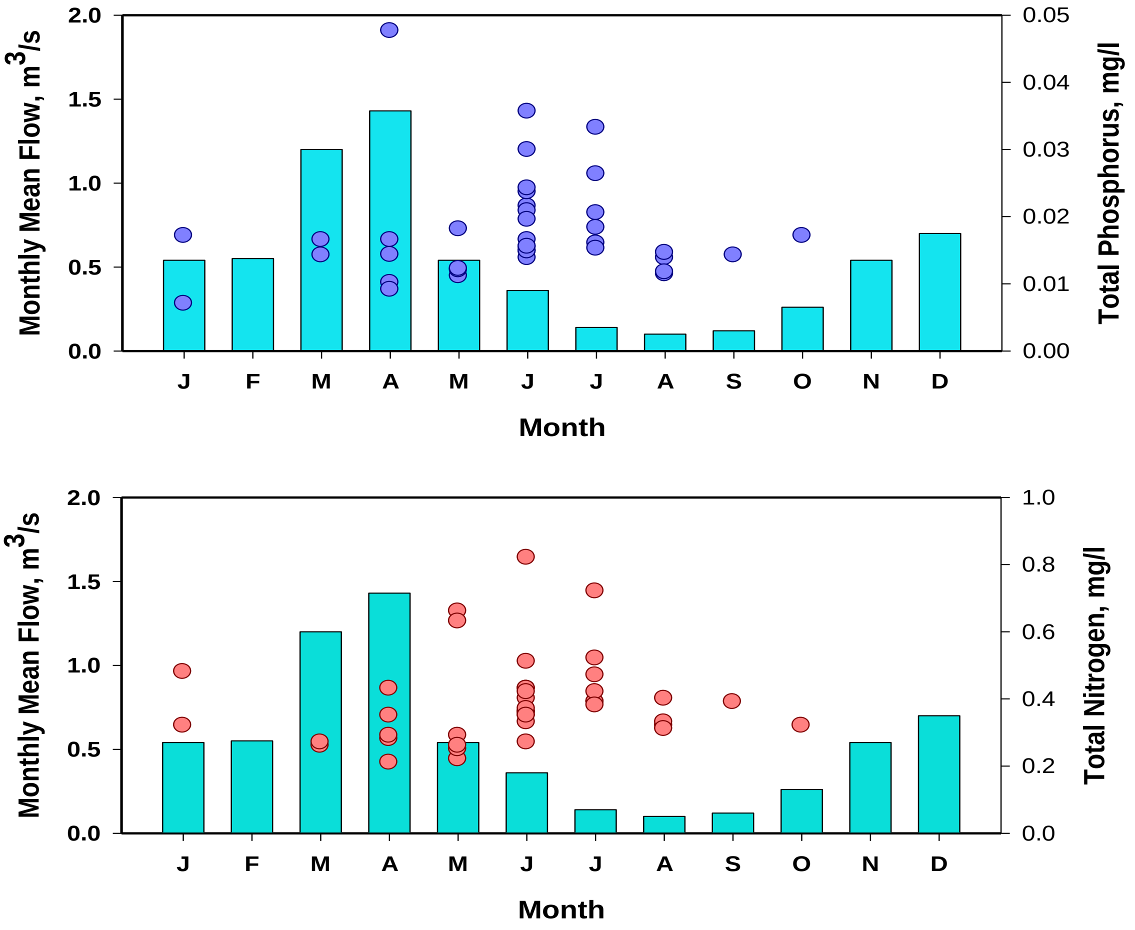
[5] Available at http://water.usgs.gov/osw/streamstats/maine.html

Figure E.2. *Mean monthly flow for the Goose River (vertical bar), as estimated using Stream Stats, and observed (2012-2016) total phosphorus (upper) and total nitrogen (lower) concentrations.*



TN and TP concentrations observed at site GR-2 on the Goose River for the period 2012-2016 (see Appendix B for sample site location, and sample collection and analysis methods) varied seasonally (Figure E.2). In general, concentrations were highest during late spring and early summer following elevated mean flows that occur in March, April and May. However, program objectives during 2012 to early 2015 focused sampling effort on the summer recreation season, and concentration data for winter and late fall are limited or nonexistent thus precluding any definitive seasonal assessment.

Five methodological approaches were applied in estimating nutrient loading from the Goose River watershed. Each employs summaries of observed concentrations and estimates of flow based on either Goose River StreamStats data or the application of a watershed-area ratio to observed flows for the Ducktrap River. Method A is an approximate means for flow-weighting concentrations using estimated mean daily flows based on flows for the Ducktrap River and the watershed area ratio. The geometric mean of the products of paired observations of concentration and estimated daily flow (0.6 and 10.4 kg/day for TP and TN, respectively) were then expressed on an annual basis.

Method B and C both use concentration data summarized (averaged) by month and either mean (B) or median (C) monthly flows based on StreamStats. Problematic with this method is the fact that limited data were available for fall and winter months (two months had single observations and three had no observations). Therefore, data for September through March were pooled and the resulting average applied to each of these months.

Method D uses mean annual concentration and mean annual flow from StreamStats to compute loading, while Method E uses median annual concentration and median annual flow from StreamStats. Results from applying each of the five methods are presented in Table E.1.

Table E.1*. Annual loads of TP and TN estimated by each of five methods.*

Estimation Method	TP Load lb/yr	TN Load lb/yr
A. Mean daily load	449	8,334
B. Average monthly concentration and mean StreamStats monthly flow	571	12,690
C. Average monthly concentration and median StreamStats monthly flow	373	8,368
D. Average annual concentration and mean StreamStats monthly flow	873	14,453
E. Median annual concentration and median StreamStats monthly flow	410	8,947