Appendix A:

EPA Water Quality Trading and Case Study Fact Sheets

Southern Minnesota Beet Sugar Cooperative Permit
Minnesota

Overview

The Southern Minnesota Beet Sugar Cooperative (SMBSC) is a farmer-owned cooperative with a beet-processing facility located in southern Minnesota (MPCA 1999). The processing facility treated process wastewater by storing it in lagoons during the processing season and spray-irrigating it over 500 acres of alfalfa and grassland during the growing season; however, the SMBSC wanted to build a wastewater treatment plant (WWTP) to serve the facility. This would allow SMBSC to expand sugar production and resolve odor problems.

A carbonaceous biochemical oxygen demand ($CBOD_5$) wasteload allocation (WLA) had been developed and approved on the lower Minnesota River in 1988, however, which prohibited the additional loading (MPCA 1997). The Minnesota Pollution Control Agency (MPCA) allowed SMBSC to obtain a permit for the proposed WWTP provided they offset all of the additional loading through nonpoint source projects that reduced total phosphorus. The permit required SMBSC to establish a $300,000 trust fund to finance the projects, which was overseen by a trade board made up of a processing plant official, SMBSC's consultant, a Soil and Water Conservation District official, the Hawk Creek watershed coordinator, and an environmental advocacy representative (Breetz et al. 2004).

SMBSC's permit requires that the needed nonpoint source reduction be based on the actual discharge. To accomplish this, the actual discharge is grouped into categories that create thresholds for the actual nonpoint source reduction needed and that requirement reflects the 2.6 to 1 trade ratio. The largest category or tier of nonpoint source trade offsets requires 13,000 lbs total phosphorus/yr. To date, the facility is achieving nearly 2.5 times the permit's required nonpoint source reductions (Klang 2006b).

Type of Trading

Point Source–Nonpoint Source

Pollutant(s) Traded

Total phosphorus

Number of Trades to Date

SMBSC contracts for spring sugar beet cover cropping best management practices (BMPs). In 2005 SMBSC had contracts on 579 sites totaling 58,832 acres yielding 14,292.5 lbs total phosphorus reduction/yr. One contract was established for cattle exclusion and bluff/channel stabilization BMPs yielding 1,475 lbs total phosphorus reduction/yr. SMBSC also has one surface tile intake credit as part of a contract with a watershed district; however, because of to problems with the agreement the contract was broken off and the credit was not included in their total. SMBSC's total approved credit count is 15,767.5 lbs total phosphorus/yr (Klang 2006b).

Who Is Eligible to Participate?

SMBSC is the sole point source covered by the permit. Landowners, including sugar beet farmers and cattle ranchers, in the lower two-thirds of the Minnesota River Basin are eligible nonpoint sources. Landowners do not have to be members of SMBSC. There are 600 beet growers in this region (Breetz et al. 2004).

What Generated the Need for Trading?

Before 1999, SMBSC disposed of its sugar beet process wastewater by storing it in lagoons during the processing season and spray-irrigating it over 500 acres of alfalfa and grassland during the growing season. This process resulted in unpleasant hydrogen sulfide odors that brought complaints from neighboring areas. To resolve this problem and accommodate a 40 percent production expansion, in 1999 SMBSC proposed building a WWTP to treat the wastewater and discharge into a tributary of the Minnesota River. However, in 1985 a $CBOD_5$ WLA was developed and approved, which prohibited new $CBOD_5$ loading. A permit was issued by MPCA, which required SMBSC to offset all of the WWTP's $CBOD_5$ loading by funding the installation of nonpoint source BMPs (Breetz et al. 2004).

What Serves as the Basis for Trading?

In 1985 EPA, MPCA and the Metropolitan Council (the regional planning agency for the Twin Cities area, negotiated a wasteload allocation) described in the Lower Minnesota River Wasteload Allocation Study, for the lower 26 miles of the Minnesota River. The wasteload allocation required a 40 percent reduction of upstream and sediment $CBOD_5$ concentrations. Most of the $CBOD_5$ came from loading from wastewater treatment plants and manure from feedlots. The Minnesota River Assessment Project (MRAP), completed in 1992, identified that eutrophication in the river supplied a significant amount of $CBOD_5$ load as dead algae. SMBSC's WWTP would have discharged into Beaver Creek, a tributary to the Minnesota River and so SMBSC's permit was developed using knowledge gained from these projects (Klang 2006a). SMBSC was located far enough upstream that its $CBOD_5$ loading was not of concern; however, since 70 percent of the upstream $CBOD_5$ loading was caused by dead algae decaying and phosphorus is the limiting nutrient for algal growth in the basin, SMBSC was required to limit phosphorus (Klang 2006d).

What Types of Data and Methodologies Were Used to Calculate the Basis for Trading?

A RMA-12 model was used in the development of the 1985 Wasteload Allocation Study for point sources on the Minnesota River. This is a version of the QUAL-II model, which is a one-dimension model for stream quality. The RMA-12 model differs from the QUAL-II model by changing the growth equation for algal biomass and redefining the nitrogen cycle. While the QUAL-II model considers nitrogen as Kjeldahl nitrogen, the RMA-12 model allows for organic- and ammonia-nitrogen to be considered separately. The RMA-12 also allows for uptake of ammonia-nitrogen by algae as opposed to only allowing nitrate-nitrogen uptake by algae as in the QUAL-II model (MPCA 1985).

The RMA-12 model is a one-dimensional model and simulates the effects of wasteloads, nitrification, sediment oxygen demand, and algal photosynthesis (USEPA 1992). It uses an advective-dispersive equation to solve for eleven water quality constituents numerically (MPCA 1985). The constituents include

1. Phytoplankton algae
2. Chlorophyll *a*
3. CBOD
4. Dissolved Oxygen
5. Benthic oxygen demand
6. Atmospheric reaeration
7. Organic nitrogen
8. Ammonia nitrogen
9. Nitrite nitrogen
10. Nitrate nitrogen
11. Orthophosphate

The model considers 30 different transformation pathways for the above constituents including sources/sinks for $CBOD_5$ by settling or resuspension, loss of ammonia nitrogen to the atmosphere, and uptake of phosphorus into phytoplankton biomass. It also used a finite-difference technique to solve the mass balance equations taking into account various stream effects. Since the critical period of concern for low dissolved oxygen was the summer low-flow period, the RMA-12 model was used in steady-state mode for the study (MPCA 1985).

While water quality calibration data existed from an intensive river survey in 1965 and summer low-flow survey in 1974, the existing data lacked sufficient measurements of algal productivity and benthic demands. Therefore another intensive river survey was conducted during a seasonally warm and low-flow period in August 1980 and the resulting data was used to calibrate the RMA-12 model (MPCA 1985). Though data existed for 9 days, only 4 days were used for calibration because unsteady flow and rainfall conditions prevailed during the latter part of the study period. A period of 4 days was sufficient because it captured one complete flow through of the study reach. The model was verified by simulating water quality responses observed in the 1974 survey (MPCA 1985).

The Wasteload Allocation Study assumed that no additional load would be added to the Minnesota River. The two existing WWTPs, Blue Lake and Seneca, operated at secondary treatment requirements which resulted in effluent averaging 25 mg/L $CBOD_5$. In the spring and fall, the WWTPs did not need additional treatment to ensure the river met the 5 mg/L dissolved oxygen minimum requirement (MPCA 1985). In the summer, additional treatment as well as a reduction in the headwater and sediment oxygen demand was required to maintain the 5 mg/L dissolved oxygen minimum requirement. The model predicted that additional treatment to 10 mg/L $CBOD_5$ by the WWTPs and a 40 percent reduction in headwater and sediment $CBOD_5$ concentrations would be required to meet the dissolved oxygen requirement during critical summer conditions (MPCA 1985). The model also predicted that additional treatment may also be required in the winter because of limited atmospheric reaeration caused by ice cover; however, it is difficult to quantify the amount of ice cover on the river. Under complete ice cover, a reduction to 10 mg/L $CBOD_5$ would be required by the WWTPs. If a 6 percent reduction in ice cover was possible, no additional treatment (beyond 25 mg/L $CBOD_5$) would be necessary to maintain the dissolved oxygen requirement (MPCA 1985).

Are Permits Used to Facilitate Trades?

SMBSC's permit specifies that the new WWTP must meet effluent limitations and offset its load through nonpoint source projects. Treated process wastewater and non-contact cooling water can be discharged to County Ditch (CD) 45 via Surface Discharge Station (SD) 005 at a rate of 3.5 cfs between September and March. Between April and August, no discharge is allowed to CD 45. During this time and when the flow effluent limitations cannot be met between September and March, treated process wastewater is diverted to wastewater storage ponds. The pond water is land applied over 11 parcels for treatment. The permit contains effluent limits for the relevant outfalls. SD 001 and SD 005 must meet a 15-mg/L monthly average and a 34-mg/L monthly maximum $CBOD_5$ concentration. SD 005 also has a total phosphorus yearly average limit of 0.75-mg/L year-round and a yearly total of 1,135- kg/yr (approximately 2,500-lbs/yr) between September and March. Outfalls SD 003 and 004 must meet a 25-mg/L daily maximum concentration of $CBOD_5$ year-round.

Chapter 12.1 of SMBSC's NPDES permit describes the provisions for trading under its *Phosphorus Management Plan*. The permit specifies that Soil Erosion Best Management Practices, Cattle Exclusion, Rotational Grazing with Cattle Exclusion, Critical Area Set Aside, Constructed Wetland Treatment Systems, Alternative Surface Tile Inlets, and Cover Cropping are acceptable nonpoint source practices that can be used to generate credits. Other BMPs must be approved by MPCA. The formulas used to calculate phosphorus credits from each BMP are detailed in the document *Phosphorus Trade Crediting Calculations* that is incorporated into the permit (MPCA 2004b). The permit goes on to describe the project eligibility criteria, the membership and role of the phosphorus trade board, the schedule for granting credits, the project and credit approval processes, and requirements for annual reporting.

Also according to the permit, SMBSC is liable for ensuring nonpoint source phosphorus reductions take place (Breetz et al. 2004). SMBSC is responsible for retaining an independent auditor to certify project completion as described in section 12.1.22 of the permit (MPCA 2004a). If BMPs are not properly implemented or maintained, the SMBSC will be responsible for identifying another project (Breetz et al. 2004).

The permit includes a document entitled *Phosphorus Trade Crediting Calculations* which provides a brief explanation of the trade ratios and expands upon the requirements for the approved BMPs. The document largely focuses on how to calculate the number of phosphorus credits that each BMP generates; however, it also provides some information on the purpose of the BMP and how it should be implemented (MPCA 2004b). The entire document is attached to the end of the permit fact sheet.

How Are Credits Generated for Trading?

MPCA specified that acceptable BMPs to reduce phosphorus included cattle exclusions, buffer strips, constructed wetlands, set-asides, alternative surface tile inlets and cover cropping, all of which are designed to reduce the runoff of phosphorus to surface waters.

According to the discharge permit, SMBSC must propose a BMP site to MPCA for approval. Some specifics the proposal must include are documentation of the use and condition of the site over the previous 5 years, the BMP(s) to be implemented and specifics on the implementation process, operation and maintenance, and the detailed calculations justifying the phosphorus credits applied for. The permit specifies the formulas used to calculate phosphorus credits generated by the phosphorus loading reduction assumed for each type of BMP. After the project is implemented, SMBSC must submit an implementation report to MPCA and a third-party auditor. The auditor will inspect and certify the project implementation. If the project is implemented according to MPCA's approval, the auditor will recommend the issuance of credits. MPCA will then approve or deny the credits (MPCA 2004a).

What Are the Trading Mechanisms?

A nonpoint source BMP must first be approved by the trade board and then by MPCA. SMBSC's permit prescribes how to document BMPs in order to submit for approval. SMBSC has annual contracts for cover crops with the sugar beet farms that are participating and a 9-year contract for cattle exclusion and bluff/channel stabilization site (Klang 2006a). The land managers are paid through these contracts based on annual credits.

For each project, SMBSC will receive credits on the basis of the ratio of its financial contributions to that of public sources. It will not receive credits for the portion funded by public sources (MPCA 2004a). The credits are granted in a schedule to give the point source greater flexibility in meeting the permit requirements: 45 percent are granted when the contractual agreements are reached, 45 percent when the nonpoint source controls have been implemented, and 10 percent when vegetation establishment criteria are reached (Breetz et al. 2004). SMBSC is required to obtain credits amounting to 2.6 times its annual phosphorus mass discharge limit.

What Is the Pollutant Trading Ratio?

The trade ratio specified in the SMBSC permit is 2.6:1. This means that for every 2.6 pounds of total phosphorus reduced through nonpoint source BMPs, one pound is reduced at the wastewater treatment plant. Therefore, one credit is given for every 2.6 pounds of total phosphorus reduced by a nonpoint source BMP.

The trade ratio includes three different components: a base of 1:1 to offset the discharge, +0.6 as an explicit *engineering safety factor* which, in addition to conservative assumptions implicit in the calculations, accounts for variations among sites, and +1 to allow for water quality improvement which takes into account MPCA's existing plans to improve water quality including the MPCA water quality interim target for the Minnesota River Basin, the MPCA dissolved oxygen TMDL on the lower Minnesota River, and the MPCA Phosphorus Strategy (MPCA 2004b).

What Type of Monitoring is Performed?

SMBSC monitors its wastewater outfall but does not conduct water quality monitoring at the BMPs. The reductions from the BMPs are estimated by using calculations described in the permit. Some data were collected on initial phosphorus concentrations in the soil and used in the reduction calculations (Klang 2006a). SMBSC is responsible for submitting technical and engineering reports, including structural specification, operation plans, and detailed photographs, to MPCA before and after each trade (Breetz et al. 2004). The permit also requires annual reports accounting for nonpoint source credits. SMBSC is responsible for submitting an implementation report to MPCA and its third-party auditor for comparison with the auditor's findings. If the auditor finds the project was completed as approved, he or she can recommend the issuance of credits, which MPCA can then grant or deny (MPCA 2004a). Previously, MPCA fulfilled the auditors role (Breetz et al. 2004); however, since December 2004 (when the permit was reissued) MPCA now requires SMBSC to retain an auditor to certify implementation. The auditor can be a professional engineer, certified crop advisor, or a representative of a local watershed interest (Klang 2006a; MPCA 2004a). The auditor must certify that the project was completed and recommend issuance of credits the first time the BMP is implemented. For each year following, SMBSC must certify in the *Phosphorus Trading*

Site Annual Report that the BMP sites remain active. The report is to include photographs of each site taken during the previous year or the landowner's written certification that the project remains in-place and effective (MPCA 2004a).

What Are the Incentives for Trading?

The trading program allowed SMBSC to construct and operate its own WWTP which alleviated the land application problems and allowed it to expand the processing operation. In addition, SMBSC pays members to plant cover crop BMPs, and they also receive the ancillary benefit of protecting young sugar beet plants (Klang 2006a).

What Water Quality Improvements Have Been Achieved?

SMBSC has exceeded its offset requirements by implementing sugar beet spring cover crops, cattle exclusion, and bluff/channel stabilization. Because SMBSC's total phosphorus limit is 2,500 lbs/yr, the permit requires that the wastewater treatment plant offset 6,500 lbs of total phosphorus/year and to date, the nonpoint source BMPs generated reduction credits for 15,767.5 lbs total phosphorus/year (Klang 2006b). In addition, the new WWTP has solved the land application odor problem that was a significant community nuisance.

What Are the Potential Challenges in Using This Trading Approach?

The environmental community was initially hesitant to support the trading arrangement due to past permit compliance issues at SMBSC. To remedy these concerns, MPCA required SMBSC to develop a plan and compliance schedule before the permit was issued (Breetz et al. 2004).

Another concern of the environmental community was that not enough documentation was required by the previously issued Rahr Malting Co. trading permit. SMBSC's permit contains many more detailed documentation requirements such as a site-proposal package with specific components detailed in the permit, an implementation report and certification by a third-party auditor, as well as the specifics regarding what should be included in the *Phosphorus Trading Site Annual Report* (Breetz et al. 2004; MPCA 2004a). A remaining concern from some of the local conservationists is that the permit is not restrictive enough regarding the crediting program set up for sugar beet spring cover crop nonpoint source reductions even though the NRCS standard equations are used for the erosion estimates.

A concern of the SMBSC representatives is the equity issue of offering one shareholder a cost incentive that the other shareholders may not have available to them because they live outside of the watershed. SMBSC was able to resolve this issue after the 2004 Summer Low Flow Dissolved Oxygen TMDL, which manages the upstream requirements of the 1985 Wasteload Allocation Study, was completed. The TMDL required no discharge during the summer critical flow months. SMBSC accepted this by spray irrigating its wastewater during this time. Even though SMBSC was no longer required to trade because it did not directly discharge during the critical flow months, it chose to continue trading and negotiated an agreement in the permit to require 80 percent of the trades to take place inside the Minnesota River basin and allow the other 20 percent to be in the adjacent Crow River watershed, resolving the equity issue.

Historically there have been tensions between some ranchers and sugar beet farmers which have made it difficult for SMBSC to obtain ranchers as trading partners (Breetz et al. 2004; Klang 2006c).

The permit required approximately 0.25–0.50 full-time equivalency of MPCA staff for permit trade calculation development. Immediately after permit completion, some critical time, on the order of weeks, was spent setting up the trades. Now MPCA spends only a few days a year managing the program (Klang 2006c).

What Are the Potential Benefits?

This approach allowed SMBSC to expand its processing operation and alleviate the problems associated with land application by building a wastewater treatment plant.

Fang and Easter (2003) found that in 2000–2001, it cost farmers $18.65/lb phosphorus reduction, which is comparable to the cost for a 1–2 mgd WWTP to treat its effluent to meet a 1 mg/L phosphorus limit. However, SMBSC was required to completely offset its discharge, meaning that in the absence of trading, it would have to meet a 0.0 mg/L phosphorus limit. Therefore, SMBSC believes that trading provided cost savings over treatment (Breetz et al. 2004). The representatives from SMBSC also believe the cost estimate does not include the production costs saved by avoiding the occasional replanting that may be necessary if the young sugar beet plants are not protected by cover crop BMPs.

The trading program raised watershed awareness and provides a good example of both community cooperation and allowing for growth on impaired waters (Klang 2006c).

Applicable NPDES Permit Language

Permit MN0040665

Chapter 12. Total Facility Requirements

1. Phosphorus Management Plan

General Requirements for Phosphorus Trading

1.1 The Permittee shall achieve the phosphorus trade reduction credits by implementing projects subject to contractual arrangements. Projects shall be Soil Erosion Best Management Practices (BMPs), Cattle Exclusion, Rotational Grazing With Cattle Exclusion, Critical Area Set Aside, Constructed Wetland Treatment Systems, Alternative Surface Tile Inlets, or Cover Cropping. The Permittee shall calculate the proposed trade credits for these projects according to the terms of this permit and the "Phosphorus Trade Crediting Calculations" appended to and incorporated into this permit. The MPCA is responsible for approving the number of phosphorus trade credits for the proposed projects.

1.2 BMPs, other than those specified above, cannot be employed without MPCA approval.

1.3 A contractual arrangement that the Permittee enters into for trade sites shall require the performance of what the MPCA has approved for the sites. However, the Permittee retains responsibility for the proper construction, installation, operation and maintenance of the projects the MPCA has approved for phosphorus trade credits under this permit notwithstanding the contractual arrangements that the Permittee may have entered into regarding the projects.

1.4 Credits generated from this program, in excess of those required by this permit, can be transferred to other Permittees, if approved in writing by the MPCA.

1.5 It is the intent of this permit that the Permittee shall achieve and maintain MPCA-approved phosphorus trade reduction active credits for the life of the wastewater treatment plant discharge to surface waters.

General Project Eligibility Criteria

1.6 The Permittee shall achieve and maintain MPCA-approved phosphorus trade reduction credits in the amount of 2.6 times the annual phosphorus mass discharge limit (1,130 kg/yr or 2,500 lbs/yr) for SD009 (2.6 × 2,500 lbs P per year = 6,500 credits).

1.7 Phosphorus trade credit projects shall not include activities required to be permitted by the MPCA and/or by other entities according to MPCA rules.

1.8 Phosphorus trade credits shall not be proposed or approved for sites which simultaneously track benefits for other environmental programs, including but not limited to wetland mitigation under the Wetland Conservation Act. If a site for which trade credits already have been approved or granted under this permit is entered into another environmental program, the Permittee shall immediately inform the MPCA to revoke the trade credits for that site.

1.9 Phosphorus trade credit project best management practices shall be additional to those occurring prior to1999 for existing trade projects and for cover crop BMP in general and during at least the previous five years for new sites proposed for trade credits.

1.10 At least eighty percent (80%) of the required credits shall be located in the Minnesota River drainage basin, excluding landlocked areas, lakes, or reservoirs with significant phosphorous assimilative capacity.

Phosphorus Trade Board

1.11 The Permittee shall establish and maintain a Phosphorus Trading Board. The Board shall consist of no more than seven members. At least one of these members shall be a local, watershed manager, at least one shall be a non-MPCA government representative knowledgeable in the field of agriculture, and at least one shall be the leader of a locally based water resources organization. The Phosphorus Trading Board shall review and approve the sites proposed by the Permittee before these sites are proposed for approval to the MPCA. The MPCA shall provide copies to the Phosphorus Trading Board of its correspondence regarding its review of these proposed sites, including MPCA approval and denial decisions on these sites.

Granting Phosphorus Trade Credits

1.12 Forty-five percent of the project's potential phosphorus credits for a site shall be granted when the MPCA approves a proposed project

1.13 Forty-five percent of the project's potential phosphorus credits for a site shall be granted when construction is complete, according to the MPCA-approved plans and specifications, and the MPCA's requirement for review has been satisfied.

1.14 Ten percent of the project's potential phosphorus credits for a site shall be granted when vegetation establishment criteria have been achieved at the site, the Permittee submits required documentation, and the MPCA's requirement for review has been satisfied.

1.15 Credits shall not be considered active until they have been granted as described above.

1.16 The MPCA may at any time revoke previously approved phosphorus trade credits. In order to revoke credits, the MPCA shall make the following findings:

1. The project as credited by the MPCA was not constructed or installed as approved; or
2. The project as credited by the MPCA was not operated or maintained as approved; or
3. The project contractual arrangement(s) have not been honored.

Project Submittal and Review

1.17 To propose a site for phosphorus trade credit approval by the MPCA, the Permittee shall provide to the MPCA, at least 90 days before the Permittee expects to receive an approval response from the MPCA, the following information for the site:

1. Site name and location, as detailed on a USGS 7.5-minute quad map with lat/long location identified to the nearest second. Identification of the major and minor watersheds, and HUC reach codes, in which the site is located. The extent to which lakes or reservoirs are downstream of the site.
2. Landowner name and mailing address.
3. Documentation, including photos as needed, of the vegetation species, land use and specific drainage practices at the site over the previous 5 years.
4. Type of BMPs proposed to be implemented at the site.
5. Copy of the signed contractual arrangement that stipulates future management requirements and length of term and that stipulates that the construction will not begin until MPCA approves the project.
6. Plan view of the project, and engineering plans, specifications and, for structural practices, the professional engineer's certification, for the project, if needed. Operation and maintenance plans.
7. Vegetation establishment and maintenance criteria and plans to achieve 100 pct active crediting for the project.
8. The total annual pounds (kg) of phosphorus credit applied for, and the basis for this value, including the detailed calculations.
9. Those projects with vegetative components shall include establishment and maintenance criteria and plans to ensure a dense stand, including the dates of seeding.

1.18 Those projects that treat sediment by filtering or settling shall include operation and maintenance plans that include, but are not limited to, procedures to:

1. Ensure sheet flow conditions are maintained in upland flow areas;
2. Remove accumulated sediment that may hinder the operation of the BMP;
3. Inspect and, if needed, reestablish a structure or vegetation after major storm events or fire; and

4. Remove harmful infestations, including carp from treatment wetlands, destructive insects from vegetation, and beavers from bioengineering sites.

1.19 The MPCA shall in writing approve, or deny with comments, the proposed project. The MPCA shall, in its approval of proposed project, certify that appropriate contractual arrangements are in place for the site, confirm the project's potential trade credits, and shall specify the information required to document construction completion and clarify the auditor's responsibilities.

1.20 The credit value for a project shall be based upon the ratio of the Permittee's financial contributions to the contributions from public sources. The Permittee shall not receive credits for those portions of a project financed by public funding sources.

Project Construction/Implementation, Documentation, Auditing, and Credit Approval

1.21 Project Construction shall not begin until MPCA written approval for the project is received.

1.22 The Permittee shall retain an independent auditor to certify project completion:

1. For engineered projects designed by a registered professional engineer, the auditor shall be a registered professional engineer. The professional engineer shall provide a construction documentation report for the project and the engineer shall certify that the project was completed in substantial conformance with the approved plans and specifications. The MPCA may require that photographs and/or record drawings be included in the report, depending upon the project complexity.
2. For cover crop, the auditor can be a registered professional engineer, a certified crop advisor, or a representative of a local watershed interest. The Permittee shall provide the list of MPCA approved cover crop contracts and the auditor shall select10% at random for a site inspection. The Permittee shall submit its implementation report to the MPCA and the auditor. The auditor will compare audit site information to Permittee's report, noting any inconsistencies in the auditors report submitted.
3. For other projects, or for portions of projects not designed by the registered professional engineer, the auditor can be a registered professional engineer, a certified crop advisor, or a representative of a local watershed interest. The auditor shall inspect the construction site as needed to confirm and document that the project was completed in accordance with the approved project.
4. For projects where vegetation establishment is required, the auditor shall provide written verification that the vegetation establishment criteria have been achieved.
5. The auditor will prepare a report to submit to the MPCA and the Permittee, the report will provide documentation required for that project. If the project was completed as approved, the report will recommend issuance of construction credits.

1.23 The MPCA shall respond to the Permittee's documentation reports and auditor's certification reports and either issue or deny construction credits or vegetation establishment credits.

Annual Reporting

1.24 The Permittee shall submit a Phosphorus Trading Site Annual Report: due on November 30 of each year following permit issuance.

1.25 The Permittee shall certify in the Phosphorus Trading Site Annual Report that the active sites approved by the MPCA for phosphorus trade credits, remain active according to the plans and specifications approved by the MPCA

1.26 The Report covering a site shall include photographs of each site taken during the previous year (these photographs shall correspond in view and detail to the initial photographs provided to the MPCA for that site) or landowner's written certification that the project remains in-place and effective.

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Red Cedar River Nutrient Trading Pilot Program
Wisconsin

Overview

Facing stringent phosphorus discharge limits, the city of Cumberland participated in a trading pilot project that involves paying farmers in the Red Cedar River watershed to install nonpoint source best management practices (BMPs). The nonpoint source BMPs reduce phosphorus discharges to the Red Cedar watershed and offset the phosphorus discharge from the City of Cumberland's publicly owned treatment works (POTW), helping the city to avoid costly upgrades.

Type of Trading

Point Source–Nonpoint Source

Pollutant(s) Traded

Phosphorus

Number of Trades to Date

More than 60 BMPs purchased

Who Is Eligible to Participate?

Eligible participants include the city of Cumberland's POTW and farmers in the Red Cedar River watershed.

What Generated the Need for Trading?

Eutrophication and algal blooms in Tainter Lake in the Red Cedar River watershed catalyzed watershed-wide management (Breetz et al. 2004). The mandated 1 mg/L phosphorus discharge limit for municipal wastewater treatment plants, and the challenge to achieve this limit, generated the need for trading. The 1 mg/L phosphorus discharge limit required of Cumberland's POTW caused the city to pursue water quality trading as a means of reducing compliance costs. The city believed that reducing phosphorus through nonpoint source discharges rather than removing chemical phosphorus at the POTW would benefit the watershed (Breetz et al. 2004).

What Serves as the Basis for Trading?

The primary regulatory driver for point sources is Chapter NR 217 of the Wisconsin Administrative Code. Chapter NR 217 mandated 1 mg/L phosphorus discharge limits for municipal treatment plants with a monthly discharge exceeding 150 pounds of phosphorus and industrial sources with a monthly discharge exceeding 60 pounds of phosphorus (Breetz et al. 2004).

What Types of Data and Methodologies Were Used to Calculate the Basis for Trading?

Cumberland was required to purchase 4,400 pounds of phosphorus credits to offset the phosphorus discharge from its POTW (Breetz et al. 2004). To determine the amount of phosphorus credits that the city had to purchase, calculations traditionally used in nonpoint source management programs that quantify soil delivery reductions and associated reductions in phosphorus loading were used (Prusak 2004).

Two computer models have been used to facilitate development of the trading pilot program in the Red Cedar River watershed. The first model was the Simulator for Water Resources in Rural Basins, used to help establish loading rates and make allocations to various land uses. The SWAT model is now being used for other impoundments in the watershed. Results from both models will help to establish goals and reduction rates (WDNR 2002).

Are Permits Used to Facilitate Trades?

The NPDES permit for the city of Cumberland's POTW states that the city must commit to trading or take actions to meet the 1 mg/L standard; the permit does not contain language that specifies the details of the trading program (Environomics 1999). An agreement between the Wisconsin Department of Natural Resources (WDNR) and the city contains the details of the trading program, including implementation milestones (Environomics 1999).

How Are Credits Generated for Trading?

The phosphorus reduction credits associated with a BMP were estimated using phosphorus loading models developed for and used by many Priority Watershed projects. All the trades have involved nutrient management planning or no-tillage, which are well-established and well-understood practices. Dischargers may trade only to meet phosphorus requirements and farmers may receive payment for a BMP for 3 years (Breetz et al. 2004).

What Are the Trading Mechanisms?

The Barren County Land Conservation Department serves as a third-party facilitator, negotiating with farmers and establishing contracts between participating farmers and Cumberland (Breetz et al. 2004).

What Is the Pollutant Trading Ratio?

Initially, the WDNR proposed a trading ratio of 20:1, expecting the city of Cumberland to negotiate for a smaller ratio. Eventually a trading ratio of 2:1 was agreed upon by WDNR and the city (Prusak 2004).

What Type of Monitoring Is Performed?

The Barron County Land Conservation Department and Cumberland evaluated landowners according to the trading area criteria. Soil testing of each field was done to calculate the phosphorus delivery to the stream from the field where the BMP was used (Breetz et al. 2004). Additional monitoring is taking place to help calibrate the SWAT model (WDNR 2002).

What Are the Incentives for Trading?

The city of Cumberland believed that participating in a trading program to promote nonpoint source phosphorus reductions would be beneficial to the watershed and would not require an investment for phosphorus controls at the POTW. However, the WDNR's fourth progress report on the trading of water pollution credits stated that the effluent limit of 1 mg/L was not an adequate driver for a trading program; a total maximum daily load (TMDL) is needed to generate interest (WDNR 2002).

What Water Quality Improvements Have Been Achieved?

Water quality improvements are unknown. However, in 2001 the city of Cumberland paid 22 landowners a total of $14,526, primarily for reduced tillage on lands showing excessive phosphorus in soil tests. These trades resulted in 5,000 pounds of phosphorus credits, although Cumberland was required to reduce phosphorus by only 4,400 pounds. Approximately the same number of farmers participated in 2002, 2003, and 2004. The number of acres enrolled in the program increased from 720 in 2003 to 891 in 2004. In 2004 Cumberland paid 21 landowners a total of $17,659.45 for no-till planting and reduced conservation tillage that resulted in 9,584 lbs of phosphorus saved. As of 2004, Cumberland has paid a total of $58,000 to remove a total of 31,500 lbs of phosphorus (WDNR 2006). It is anticipated that the city will continue trading until it becomes impossible to secure enough nonpoint source credits (Breetz et al. 2004).

What Are the Potential Challenges in Using This Trading Approach?

One challenge associated with the Red Cedar River Trading Pilot Program is determining a precise phosphorus credit for BMPs. Other challenges cited by the WDNR include developing an agreed-upon set of tools for quantifying phosphorus reduction loads from BMPs and generating an incentive for participation without a TMDL in place (WDNR 2002).

What Are the Potential Benefits?

Through the Red Cedar River Trading Pilot Program, the watershed could benefit in the long term from the installation of BMPs. The city of Cumberland will pay for only one BMP for 3 years, and after that will find different landowners to generate credits through new BMPs. The hope is that the original BMPs will remain up and running in the watershed after the 3-year, credit-generating period (WDNR 2002). The BMPs installed through the program reduce phosphorus loads in part by reducing sediment loads to the watershed; therefore, the Red Cedar River watershed is receiving an additional water quality benefit (Prusak 2004).

Applicable NPDES Permit Language

4.0 Schedules of Compliance

4.1 Phosphorus

> Pursuant to s. 283.84, Stats., the 1.0 mg/L phosphorus limitation is held in abeyance as long as the permittee is active in the Red Cedar River Watershed Pilot Project. If the permittee stops participating or the pilot terminates, the permittee shall take steps to achieve total phosphorus limits.

Required Action

Letter of Intent: The permittee must submit a letter of intent to the Department regarding pollutant trading. The letter of intent shall indicate whether the permittee intends to continue the Red Cedar River Watershed Pilot Project or proceed with adjustments/modifications to the facility to achieve compliance with the phosphorus limitation. If the letter of intent states that the permittee does not intend to continue trading, then the permittee shall proceed with modifications to the plant (or adjust plant operations) to achieve compliance with phosphorus limitation by a deadline established by the Department.

Contact Information

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Resources and References

Breetz, H., K. Fisher-Vanden, L. Garzon, H. Jacobs, K. Kroetz, and R. Terry. 2004. *Water Quality Trading and Offset Initiatives in the U.S.: A Comprehensive Survey*. Dartmouth College, Hanover, NH.

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Tualatin River Watershed, Oregon

Clean Water Services Integrated Municipal Permit

Permitting Authority Contact:
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Permittee Point of Contact:
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Regulatory Affairs Department Director
Clean Water Services
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Permit Type:
Integrated municipal permit (integration of NPDES permits for four advanced wastewater treatment facilities, two industrial storm water permits, and permit for Municipal Separate Storm Sewer System)

Permit Information:
www.deq.state.or.us/wq/wqpermit/cwspermit.htm

Pollutants of Concern in Watershed:
Temperature, bacteria, low dissolved oxygen (DO), chlorophyll a, toxics (arsenic, iron, and manganese), biological criteria, and low pH

Pollutants Addressed in Permit:
Temperature, bacteria, DO, ammonia, and phosphorus

Permit Issued: February 26, 2004
Modified: July 27. 2005

Watershed: Tualatin River, Oregon

Key Water Quality Concerns: Temperature, bacteria, low DO, chlorophyll a, arsenic, iron, manganese, low pH, and biological criteria

Stakeholder Involvement Techniques:

- Permittee and permitting authority motivated by opportunities to protect the river while streamlining requirements through integrated permitting
- Public notice and public meetings
- General public outreach on water quality trading
- Outreach to stakeholders regarding participation in water quality trading

Case Study Issues of Interest

Type of Point Sources	POTW Discharges	✔
	Industrial Process/Nonprocess Wastewater Discharges	
	Concentrated Animal Feeding Operations	
	Municipal Separate Storm Sewer System Discharges	✔
	Construction Site Stormwater Discharges	
	Industrial Facility Stormwater Discharges	✔
	Combined Sewer Overflows	
Highlighted Approach(es)	Statewide Watershed Approach	
	Implementation of Water Quality Standards	✔
	Implementation of Total Maximum Daily Loads or Other Watershed Pollutant Reduction Goals	✔
	Permit Coordination/Synchronization	✔
	Integrated Municipal Requirements	✔
	Point Source – Point Source Water Quality Trading	✔
	Point Source – Nonpoint Source Water Quality Trading	✔
	Discharger Association	
	Coordinated Watershed Monitoring	

Overview

Clean Water Services (CWS) is a public utility (special services district) that operates four municipal wastewater treatment facilities, each with its own permit under the National Pollutant Discharge Elimination System (NPDES). CWS also has two industrial stormwater permits and is a co-permittee on a Municipal Separate Storm Sewer System (MS4) permit. The Tualatin River is the receiving stream for each of these permitted discharges. Oregon's Department of Environmental Quality (OR DEQ) issued total maximum daily loads (TMDLs) for the Tualatin River for ammonia, phosphorus, temperature, bacteria, and tributary dissolved oxygen (DO). In February 2004, OR DEQ issued a single watershed-based, integrated municipal permit to CWS. This permit incorporates the NPDES requirements for all four of CWS's advanced wastewater treatment facilities, its two industrial storm water permits, and its MS4 permit. A significant feature of the integrated permit is its inclusion of provisions for water quality credit trading involving temperature (thermal load), biochemical oxygen demand (BOD), and ammonia.

The watershed-based permit has resulted in various benefits to CWS, the permitting authority (OR DEQ), and the environment. For both CWS and OR DEQ, one permit is easier to administer and implement. The integrated permit provides economies of scale for both CWS and OR DEQ in terms of resource use. Both organizations are now better able to focus their resources on the most critical resource problems, and the integrated permit provides greater protections for the environment than what might have been realized under the previous array of permits. Since the integrated watershed based permit was issued, CWS has planted nearly 10 miles of riparian shading, preventing 101 million kilocalories (Kcal) per day of thermal energy from impacting the Tualatin River.

This case study focuses on the components of the watershed-based permit issued to CWS. It also summarizes key components of CWS's thermal load trading program.

Permitting Background

CWS operates four municipal wastewater treatment facilities that provide advanced wastewater treatment for the cities of Banks, Beaverton, Cornelius, Forest Grove, Gaston, Hillsboro, North Plains, Tigard, Sherwood and Tualatin, the communities of Durham and King City, and some unincorporated areas of Clackamas, Multnomah, and Washington Counties. Prior to issuance of the integrated watershed-based permit, CWS had four individual NPDES permits for these facilities. It also had two general industrial NPDES stormwater permits for its Durham and Rock Creek advanced wastewater treatment facilities (AWTF) and was a co-permittee on an NPDES permit for a MS4 with Washington County Department of Land Use and Transportation (DLUT) and the Oregon Department of Transportation (ODOT) covering the urbanized area of Washington County.

The Tualatin River subbasin has stream segments listed on Oregon's 1998 Clean Water Act section 303(d) list for temperature, bacteria, dissolved oxygen, chlorophyll a, arsenic, iron, manganese, biological criteria, and low pH. The state established TMDLs in 1988 for ammonia and phosphorus to address low dissolved oxygen and elevated pH and chlorophyll a in the mainstem. OR DEQ later revised the TMDLs for ammonia and phosphorus and established new TMDLs for temperature, bacteria and tributary dissolved oxygen. EPA approved the state's TMDL Water Quality Management Plan for the Tualatin River in August 2001.

Permit Strategy

For years, CWS had been very interested in implementing a watershed-based approach to managing the water resources within the Tualatin River basin. Beginning in 2000, several events occurred that allowed CWS to pursue development of a single integrated municipal NPDES permit. The individual NPDES permits for its four wastewater facilities expired in 1995 and were administratively extended pending the development of the revised Tualatin TMDL, the original of which was issued in 1988. CWS's MS4 permit, under which it was a co-permittee, expired in early 2001. These circumstances, along with the release of guidance documents and encouragement from EPA regarding the watershed-based permitting approach, allowed CWS to propose the development of an integrated municipal permit to OR DEQ. At the time, OR DEQ had a large permit reissuance backlog. Therefore, the state was open to the approach of consolidating permits for CWS's five discharges (four wastewater treatment plants, including its stormwater discharges, and the MS4) into a single permit.

CWS was in a position to benefit from an integrated water resources management approach. It is the only major discharger in the Tualatin River watershed; it owns one quarter of the stored water in the basin, which is released for instream flow management; it has a significant amount of facility and ambient data; and it has long been responsible for managing surface water and stormwater in the basin.

CWS was issued a Clean Water Act section 104(b)(3) grant to begin developing the framework for an integrated municipal NPDES permit and a stakeholder outreach and education program. The intent of the outreach program was to build stakeholder support and understanding of CWS's integrated water resources management approach. CWS viewed the outreach as critical, especially because the Tualatin basin is home to a number of organisms that are listed as species of concern under the Endangered Species Act (ESA).

OR DEQ revised and expanded the TMDL for the Tualatin River to include temperature and bacteria in August 2001. In February 2004, OR DEQ issued a single watershed-based, integrated municipal permit to CWS covering all four advanced wastewater treatment facilities, the two industrial storm water permits for the Rock Creek and Durham AWTFs, and the MS4 for the urbanized areas of Washington County. OR DEQ included a unique feature in the permit. It included provisions for CWS to engage in water quality credit trading involving temperature (thermal load), biochemical oxygen demand (BOD), and ammonia.

OR DEQ noted in the permit fact sheet that the single watershed-based, integrated municipal permit does not reduce any of the requirements that had previously been contained in the separate permits. Instead, it provides a number of advantages and efficiencies for both the OR DEQ and CWS, including:

- Enhanced opportunities for environmental results
- Targeted and maximized use of resources to achieve greatest environmental results
- Administrative efficiencies
- Opportunities for more effective watershed-wide monitoring programs
- Opportunities for water quality trading programs

- Achieving water quality goals in a more cost-effective and efficient manner.

In addition, an Intergovernmental Cooperative Agreement was drafted between CWS and the OR DEQ in order to "provide for the continuation of the development and implementation of a watershed based regulatory framework in the Tualatin River watershed." The agreement outlines pending issues and commits the parties to continue to work on them.

Permit Highlights

The TMDL temperature standard states that no measurable increase in water temperature is allowed from dischargers. (See highlight box below for further details.) Using methods outlined in the TMDL, the permit (Provision 10 of Schedule D) includes the thermal load each of CWS's two AWTFs must offset. The loads specified are as follows: 2.0×10^8 kcal/day (Durham AWTF) and 7.2×10^8 kcal/day (Rock Creek AWTF). The permit authorizes CWS to implement mitigation measures from its Temperature Management Plan (TMP) and engage in riparian shade trading (i.e., planting vegetation to shade stream) to meet these offsets. The offset period is May 1–October 31 each year; however, the critical period for the offsets is July–August. The flow CWS releases during this latter time period defines the shade goals CWS must meet during the offset season (May 1–October 31). The permit states that if CWS achieves the thermal load offset goals for July–August (the critical period), OR DEQ will deem CWS to be in compliance with its thermal load requirements for the entire season (May 1–October 31).

Temperature Management Plan (TMP)

CWS submitted a revised Temperature Management Plan to OR DEQ on February 25, 2005. In the plan, CWS proposes three methods for reducing stream temperatures. These include wastewater reuse, flow augmentation, and the creation of stream shade. CWS is currently developing a Reclaimed Water Master Plan, which will address future reuse needs and opportunities for expansion.

Augmenting flow and increasing stream shading will allow CWS to obtain tradable thermal load credits. CWS notes in its TMP that augmenting flow and providing stream shading will eliminate the need for the organization to employ more burdensome alternatives, such as the installation of refrigeration equipment at its wastewater treatment facilities or piping treatment facility effluent to another river basin. CWS estimated that it would cost the organization \$60–\$150 million to install the necessary refrigeration equipment at both AWTFs , and the electricity necessary would increase air pollution and contribute to global warming. CWS further estimated that its yearly costs to operate the refrigeration equipment or pipe treated effluent to another river basin would be between \$2.5 and \$6 million.

Tualatin TMDL Temperature Standard (2001)

The applicable temperature standard for the Tualatin River and tributaries, set to protect salmonid fish rearing, is "no measurable surface water temperature increase resulting from anthropogenic activities." The treatment facilities wasteload allocations are based on achieving "no measurable increase" in stream temperature at the edge of the mixing zones. OR DEQ defines a measurable increase as greater than a 0.25 degrees Fahrenheit (°F) increase at the edge of the mixing zone using the applicable stream temperature standard. Additionally, the discharges may not cause the receiving water within the mixing zone to exceed 77 °F at any time. Temperatures above 77 °F are considered acutely harmful to salmonids. Based on this standard, the CWS wastewater treatment plants were given wasteload allocations that are less than 10% of their current heat load. The magnitude of the difference between their current heat load and the waste load allocation in the TMDL report provides significant impetus for trading. This allocation, modified as allowed by the TMDL document has been included in the watershed-based permit as a thermal load to be offset (www.deq.state.or.us/WQ/tmdls/docs/willamettebasin/tualatin/tmdlwqmp.pdf). The integrated permit also requires CWS to develop a Temperature Management Plan. The plan is to indicate how CWS will address temperature concerns at its wastewater treatment facilities.

Riparian Shading Trading

According to the TMP, solar radiation (sunlight) accounts for about 40 percent of the thermal energy input to the Tualatin River during the summer months. Since sunlight is easily blocked by vegetation, CWS argued in its TMP that if the watershed's streams were better shaded, total thermal energy inputs would be smaller and the streams would be cooler.

The number of thermal credits that CWS is required to achieve via stream shading is based on the amount of thermal reductions CWS could achieve via other means (e.g., with refrigeration equipment). OR DEQ has limited the duration of each credit to 20 years, which is approximately equal to the useful life of mechanical refrigeration equipment. The magnitude of each credit will depend on the amount of shaded stream surface that CWS is able to achieve. The amount of energy that is blocked by shade along a particular stream is a function of stream width, tree height, and vegetation density.

CWS took all of these factors for determining shade credit into consideration when developing its TMP. To account for the fact that shade can take a significant amount of time to establish, CWS proposed that a trading ratio of 0.5 be applied when determining the shade credit associated with a particular project. Using this trading ratio means that, in

20 years, CWS will have offset twice as much heat through shading as the excess thermal load its treatment plants add to the Tualatin. This reduction is significantly larger than what would be accomplished using other methods, such as refrigeration equipment. In other words, OR DEQ is allowing CWS to not entirely offset its excess heat load within 5 years, in exchange for the fact that over 20 years it will offset twice its excess heat load.

Vegetation planted during a single permit term (5 years) will not by itself be of a sufficient height or maturity to offset CWS's excess thermal load. The integrated watershed-based permit allows CWS to undertake other activities to offset its thermal load. In order to determine CWS's energy inputs and credits from thermal load offset activities, the TMP includes a process for developing a thermal energy budget. The procedures to create the thermal energy budget, which accounts for all thermal inputs to the river from CWS activities, and how to determine the thermal credits generated via flow augmentation and riparian restoration/protection projects are detailed in Appendix B of the TMP.

The thermal energy budget submitted in Appendix B estimates that CWS's annual thermal load after flow augmentation is about 330 million kcal/day. To offset this load, about 35 miles of riparian restoration/protection is required over the five-year permit period This is the Shade Credit Goal.

The integrated permit requires CWS to annually calculate and report a thermal energy budget (using flow augmentation, shade credits, and other OR DEQ projects) to the state. The permit also requires CWS to annually report on its progress toward achieving the thermal offset requirements. OR DEQ will use the thermal load budget calculated in the fifth year of the permit term to determine CWS's compliance with the permit's temperature requirements. If flow augmentation, the cumulative total of shade created, and all other DEQ-approved temperature management measures combine to offset the excess thermal load, CWS will have met its permitted temperature requirements. Prior to the five-year mark, OR DEQ will determine CWS compliance on the basis of the milestones CWS achieves in its approved TMP.

To remain consistent with the basic principles of trading, credits for creating shade will be generated only for those activities that go beyond regulatory requirements, such as the Forest Practices Act, local water quality management rules developed by the Oregon Department of Agriculture (also known as SB 1010), and CWS's own Design and Construction Standards. Therefore, re-vegetation projects implemented for creating shade credits will need to exceed the minimum requirements established in these regulations.

CWS will develop and implement "shade programs" aimed at increasing riparian shade. Programs intended primarily for use on private lands will be incentive based. Most projects on public lands will be conducted under CWS's Urban Stream Enhancement Program. CWS will rely on various stream restoration partners—the U.S. Department of Agriculture (USDA), Oregon Department of Forestry (ODF), and Soil and Water Conservation Districts (SWCDs)—in order to meet the temperature requirements in its permit. CWS will set up the planting programs, help with the funding, and make sure that its partners perform in accordance with individual project contract requirements. The TMP includes a detailed "shade implementation plan," which describes how planting, maintenance, and monitoring will be accomplished for each project undertaken.

CWS will calculate shade credit for each project using a computer model developed by OR DEQ. To run the model, site-specific data must first be collected, including the size of the site, width of the stream, orientation of the site to the sun, and the estimated canopy height and density 20 years after planting. The model uses these data to determine the effective shade produced by the project. "Effective shade" is a measure of the amount of sunlight blocked by shade. The blocked sunlight is then converted to kilocalories per square foot of stream surface.

More information on the Clean Water Services and water quality trading in Oregon may be found at:

www.deq.state.or.us/WQ/trading/faqs.htm

Permit Components

Effluent Limits

Schedule A of the CWS watershed-based permit contains all effluent limitations for the facilities covered under the permit for the following parameters: carbonaceous biochemical oxygen demand (CBOD), pH, total suspended solids (TSS), bacteria, residual chlorine, temperature, ammonia, and phosphorus. The outfall-specific limits are based on the approved TMDLs for the Tualatin River basin, technology-based effluent limitations (TBELs), the maximum extent practicable (MEP) standard for the MS4 covered, and pollutant benchmarks for industrial storm water discharged under the permit. Schedule A also contains a methodology for CWS to use for trading oxygen- demanding parameters (CBOD and ammonia) between the Durham and Rock Creek advanced wastewater treatment facilities. OR DEQ based the methodology on a combined Rock Creek and Durham oxygen demand load limitation expressed at Oswego Dam.

The effluent temperature limitations, the temperature monitoring requirements (in Schedule B), CWS's Temperature Management Plan (TMP), including a Thermal Load Credit Trading Plan (TLCTP), (in Schedule C), and the thermal load to offset and water quality trading provisions (in Schedule D) constitute the primary elements of the approved surface water TMP. The permittee is deemed to be in compliance with in-stream water quality standards and is not deemed to be causing or contributing to a violation of the Tualatin Basin temperature TMDL or water quality standards for temperature if the permittee is in compliance with this approved surface water temperature management plan.

Monitoring and Reporting Requirements

Schedule B of the permit includes a requirement for CWS to develop a watershed monitoring plan. The plan is to be designed as "a comprehensive and integrated approach to watershed assessment, to address CWS's long-term progress towards achieving the goals of the Clean Water Act and, where appropriate, the Endangered Species Act." CWS is responsible for all end-of-pipe monitoring activities covering the wastewater treatment facilities, the MS4, and industrial storm water facilities. CWS is also responsible for evaluating and assessing the MS4 stormwater management plan (SWMP). Schedule B also includes a schedule and description of the various reports and deadlines for all facilities covered under the watershed-based permit.

Special Conditions

The permit contains special conditions under Schedules C and D. Schedule C contains compliance conditions and schedules, while Schedule D contains trading and other special conditions.

Compliance Conditions and Schedules

This section includes the requirements for the MS4 SWMP, facility-specific stormwater pollution control plans (SWPCPs), and the required components of the TMP and the Thermal Load Credit Trading Plan.

Schedule C.1 outlines the elements required in the TMP. The TMP is to describe and explain how CWS will manage and implement measures to offset the thermal load from its various wastewater treatment facilities to the Tualatin River. The required elements of the TMP include the following:

(1) A description of the cooling benefits of flow augmentation.

(2) A description of CWS's long range plans for increasing in-stream water supply within the watershed.

(3) An explanation of how an increase in stream shade that will result from riparian revegetation will offset thermal load discharges from CWS's facilities.

(4) A description of how CWS will protect and use stream shade in existing high quality riparian areas to offset thermal load discharges from its facilities.

(5) An explanation of how and when CWS will accomplish stream surface area shading via riparian revegetation. OR DEQ will use this information to form the basis for compliance with the permit during the time it takes for shade to become established.

(6) A methodology for prioritizing areas throughout the Tualatin Basin where riparian revegetation/protection could take place in order to maximize the benefits of the proposed projects for the protection of the most sensitive beneficial uses. OR DEQ notes that the *receipt of credit for riparian re-vegetation/protection will not be affected by whether these actions occur in priority areas.*

(7) CWS's criteria for plant selection and a copy of the plant list. The plants on the list must be appropriate given the native plant communities found in the Tualatin Basin.

(8) CWS's approach for working with potential growers and contractors involved in riparian restoration so that adequate plant materials will be available and that contractors will have adequate time to mobilize resources.

(9) A description of the kinds of approaches CWS will use to reach the target increase in stream shade.

(10) A copy of CWS's planting plan. The plan should include expected plant survival rates and justification for planting densities, and should reflect natural succession.

(11) A monitoring plan to assess plant survival.

(12) A monitoring plan to assess the amount of shade that is created.

(13) A maintenance plan that will promote plant survival and reduce the impact of invasive species.

Schedule C.2. of the permit outlines the requirements of the TLCTP, which are to be included in the TMP. The TLCTP is to describe the mechanisms through which CWS will use water quality trading to offset the thermal loads from the treatment facilities. In particular, this plan is to include details of how CWS will create thermal credits through river flow augmentation and stream surface shading and include the methodologies CWS will use for calculating these credits. The elements to be included in the TLCTP include the following:

(1) A description of the thermal load to be offset based on Schedule D.10 of the permit. Any reuse of reclaimed water will directly reduce the thermal load discharged by the facilities. The TLCTP will specify a baseline for thermal credit trading.

(2) A discussion of how CWS will create, purchase, or otherwise arrange for thermal credits generated by the following types of actions, activities, and projects:

(a) Thermal loadings relative to applicable baselines

(b) Flow augmentation resulting from CWS's voluntary purchase and release of stored water to the Tualatin Basin

(c) Stream surface area shading.

(3) The methodology for calculating the amount of thermal credits generated by flow augmentation that can be applied to offset the thermal load.

(4) The methodology for calculating the amount of thermal credit that will be generated by stream surface water shading through riparian re-vegetation and high quality area protection that can be applied to offset the thermal load.

(5) Other thermal credit trading options proposed by CWS for consideration by OR DEQ, along with a technical justification for how much thermal credit should be granted for such actions.

(6) Reporting requirements for thermal load trading credits.

Trading and other special conditions

Schedule D outlines all of the additional special conditions included in the watershed-based permit. Provision 7 describes the fundamental requirements of any water quality trading plans implemented under the watershed-based permit, such as:

- General authority.
- Authorized parameters for trading (oxygen demanding parameters such as CBOD5 and ammonia-nitrogen, temperature, and other parameters approved by OR DEQ)
- Trading baselines for both authorized parameters (temperature and oxygen-demanding materials)
- Definition of a *water quality credit* and how to apply credits for compliance purposes
- Requirements for Thermal Credit Trading Agreements between CWS and a conservation entity (defined as a "reputable land or water conservation organization or governmental entity") charged with implementing a component of the TMP to include:
    - A commitment by the Conservation Entity to fully implement the Trading Agreement in accordance with its terms, including terms for initial planting and long-term maintenance, monitoring, and reporting
    - A provision that the Credit Trading Agreement is enforceable by CWS and the OR DEQ and any successor agency. A breach of the Credit Trading Agreement by the Conservation Entity is not deemed a violation of the permit by CWS. In the event of a breach, CWS will be required to update its Clean Water Services Temperature Management Plan to demonstrate it still will be able to offset the thermal load.
- Conditions of compliance and enforcement provisions.
- Reporting and evaluation requirements.

Permit Effectiveness

Environmental Benefits

The TMP establishes benchmarks against which CWS will demonstrate its progress toward meeting the Shade Credit Goal. Each benchmark will apply to the collective group of shade programs, rather than individually. This approach will allow CWS to meet the benchmark using whatever combination of shade programs is optimal. The TMP describes a benchmark as the annual increase in the percentage of the average excess thermal load that is offset by shade after accounting for flow augmentation and any other OR DEQ-approved temperature management measure. OR DEQ will evaluate CWS's progress toward achieving the benchmarks annually. Benchmarks are a means of measuring progress but are not requirements.

In the event the shade credit created in any year is less than 50 percent of the benchmark for that year, CWS must prepare and submit to OR DEQ a written memorandum that contains a list of measures that will be undertaken to meet benchmarks in subsequent years.

As of March 2006, CWS has met Year Two's goals by having planted more than 9.5 miles of streams. CWS has a contract in place with the Natural Resource Conservation Service (NRCS) to register landowners for incentive programs developed by CWS. According to project contact, Charles Logue, the permit, with its provision for water quality trading, has significantly increased the pace and quantity of riparian area restoration in the Tualatin Basin. The additional miles of stream planted will result in the prevention of 101 million/Kcal/day from reaching the Tualatin River tributaries that would otherwise result in additional increases in water temperature. Also, CWS has adjusted the release of stored water to develop temperature credits in the July-August time frame while continuing to release stored water in the fall to ensure assimilative capacity for oxygen demand in that time period.

Mr. Logue believes that the integration of the stormwater permits into the watershed-based wastewater discharge permit, has increased the public's awareness of stormwater related impacts and activities on the overall water quality in the basin.

No trades of oxygen-demanding parameters have occurred to date. CWS's Operations staff is continuing to evaluate operating scenarios that would take advantage of this element of the permit. CWS currently is updating its Facilities Plan. A key element of this update is to make use of a "systems" approach to future operations of the CWS facilities to take full advantage of the water quality trading elements for biochemical oxygen demand and ammonia to optimize the wastewater treatment facilities.

Benefits to the Permittee

CWS' Mr. Logue believes that one of the primary benefits of the watershed-based permit is that is has allowed CWS to spend resources where the greatest environmental benefit is realized. CWS has restored riparian areas and improved channel morphology, through utilizing "sanitary user fees" in areas outside the service boundaries, through the nexus created in an integrated watershed-based permit. The new watershed-based permit extends the purview of CWS to stormwater discharges that occur outside of the service area but that are within the urban growth boundary of Washington County. Also, the integrated permit has enabled CWS to redirect capital funds from traditional concrete and steel engineered solutions to more natural solutions (stream plantings), which provide significantly greater environmental benefit without increasing the sewer or stormwater user fee rate structure. By applying the capital savings from averting a construction-based solution to thermal load reduction, CWS has directed its capital funding towards stream restoration projects, which results in far greater benefits to the basic ecosystem services of the basin.

Since issuance of the integrated permit, CWS has reorganized to centralize its various regulatory affairs related activities into one department. According to the CWS contact, Mr. Logue, this action was a direct result of the integrated, watershed-based approach and heightened awareness of watershed issues within the District. The single watershed-based permit has also streamlined CWS's annual reporting requirements, thereby saving staff time and resources.

The success of the CWS water quality trading program has led to the formation of other watershed based approaches in Oregon. For example, the Willamette Partnership, a coalition of conservation, city, county, business, farm, and scientific leaders formed to protect the Willamette Basin. The goal of the Willamette Partnership is to accelerate and expand restoration of the Willamette River Basin through water quality and conservation trading. EPA is helping fund this effort with a matching grant of nearly $800,000. By using conservation credits as a form of environmental currency, the Willamette Partnership intends to create an Ecosystem Marketplace that will focus public and private ecological investments across the entire Willamette River Basin to improve water quality, restore fish and wildlife habitat, and protect endangered species (www.willamettepartnership.org).

Benefits to the Permitting Authority

Sonja Biorn-Hansen, OR DEQ Environmental Engineer, stated that this permitting effort "was truly about achieving environmental gain instead of just dotting I's and crossing T's." Issuing the watershed-based permit to CWS was very time and resource intensive for the permitting authority, however. The permit writer, Lyle Christensen, believes that future iterations will be much easier to issue in a timely manner and that working with one permit, rather than multiple permits, will save time and resources as well.

> After the permit with Clean Water Services was negotiated, Oregon DEQ used the experience gained to develop an Internal Management Directive to guide future trading efforts in the state. This document may be found at: www.deq.state.or.us/wq/pubs/imds/wqtrading.pdf

Lessons Learned

The project contact, Mr. Charles Logue, was asked a number of questions to ascertain "lessons learned" from the CWS's watershed-based permitting project. The questions asked and Mr. Logue's responses to them are reported below.

- What has been the most challenging part of the project?

  The most challenging part of the project has been the lack of other similar work to build upon. At the same time, this has been the greatest asset of the project in that the development was not impeded or restricted by work precedents done elsewhere. CWS continues to advocate this approach across the country so as to gain from others' experience. An issue that continues is the development of the permitting accounting and tracking systems which were not designed to accommodate integrated NPDES permits. While issued as a "single" permit, the permit numbers are still administratively being tracked individually in the OR DEQ system. An additional problematic issue is the traditional enforcement response matrix accounting mechanism for permit violations. Many potential candidates for an integrated permit are concerned with the potential for accelerated movement through a regulatory agency enforcement response matrix with multiple facilities/outfalls covered under a single permit. In the CWS case, the individual facilities are still treated as individual discharges from an enforcement response perspective.

Another challenge is combining the different individual permit approaches, language, requirements, reporting elements and schedules into a more comprehensive single format. In the CWS permit, there was not time to fully develop true "integrated" permit language and schedules. This is the major work to be accomplished in the renewal process.

- What could have been done differently to resolve the challenges more easily?

  I am not sure that the process could have moved any faster. For an innovative permitting action, the process went very fast. Both the state and federal agencies were highly supportive and willing to make this happen.

- Would this approach be applicable to other watersheds? What characteristics would define other candidate watersheds?

  Absolutely, this approach is applicable to other watersheds. There are numerous other instances where one jurisdiction or utility with multiple facilities are the major dischargers to a stream or river segment. These are the obvious candidates for an integrated permit.

- If the approach were to be applied in another area, what changes should be made?

  I am not sure that there need to be any changes, if the same situation occurs elsewhere. If you have the same level of system understanding, same degree of data available, same willingness by the parties, the approach should work anywhere.

Resources

Clean Water Services. 2005. *Revised Temperature Management Plan*. February 18, 2005.
www.deq.state.or.us/wq/wqpermit/cwspermit.htm

Oregon Department of Environmental Quality. Clean Water Services NPDES Watershed-based Discharge Permit (ORS108014) Evaluation Report and Fact Sheet. Modified on July 27, 2005.
www.deq.state.or.us/wq/wqpermit/cwspermit.htm

Oregon Department of Environmental Quality. 2005. *Water Quality Trading Internal Management Directive.* January 13, 2005.
www.deq.state.or.us/wq/pubs/imds/wqtrading.pdf

Oregon Department of Environmental Quality. "Water Quality Credit Trading in Oregon: A Case Study Report". Report submitted to USEPA Region 10 documenting results of the OPEI grant project entitled: Effluent Trading in Oregon - #CP-970211-01.
www.deq.state.or.us/wq/trading/docs/wqtradingcasestudy.pdf

Note: All Web references current as of July 6, 2007.

Appendix B:

Draft 2013 Interim Water Quality Monitoring Reports (UNH WRRC and WQAG)

NITROGEN ASSESSMENT FOR THE OYSTER RIVER WATERSHED

DRAFT INTERIM REPORT

December 24, 2013

New Hampshire Water Resources Research Center (NH WRRC)

UNH Water Quality Analysis Laboratory (WQAL)

Department of Natural Resources

114 James Hall

56 College Rd.

Durham, NH 03824

Report Prepared for:

The University of New Hampshire

TABLE OF CONTENTS

1.0 Spatial trends of Nitrogen

- **Spatial relationships between nitrogen and watershed characteristics and watershed N inputs**
- **Longitudinal sampling in College Brook and Pettee Brook**

Spatial relationships between nitrogen and watershed characteristics and watershed N inputs

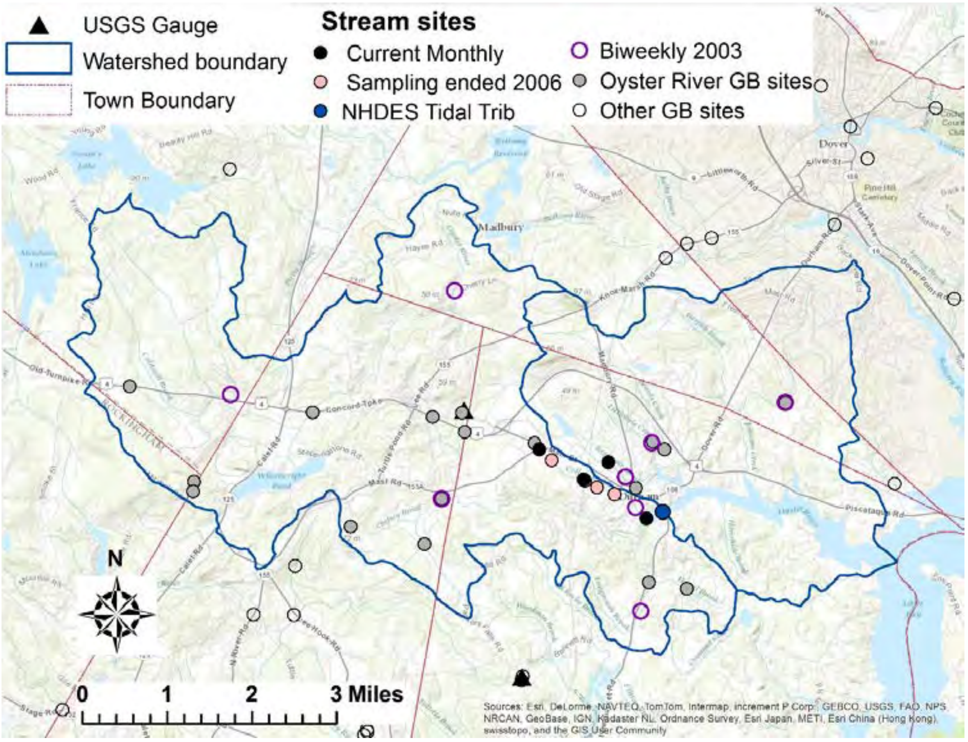

Figure 1. Stream sites in the Oyster River watershed sampled by the NH WRRC for various frequencies and durations. A few samples were collected from College Brook and Pettee brook in 1991 and approximately monthly samples have been collected since 2000 (black filled circles). Sampling of some College Brook sites ended in 2006 (pink filled circles). PREP supports monthly sampling (March-December) of the Oyster River at the head of tide dam for total and dissolved N species (blue filled circle). A graduate student (Tracey O'Donnell) sampled 8 streams in the Oyster watershed (including College Brook and Pettee Brook) every other week during 2003 (purple open circles). Additionally, several sites in the Oyster River watershed were sampled 3-5 times as part of the current NOAA NERRS Science Collaborative project "Great Bay Nitrogen Sources and Transport Pathways". Other sites from this project that are located outside of the Oyster River watershed are also shown (black open circles).

Samples from all sites have been analyzed for dissolved N fractions and some other water quality parameters.

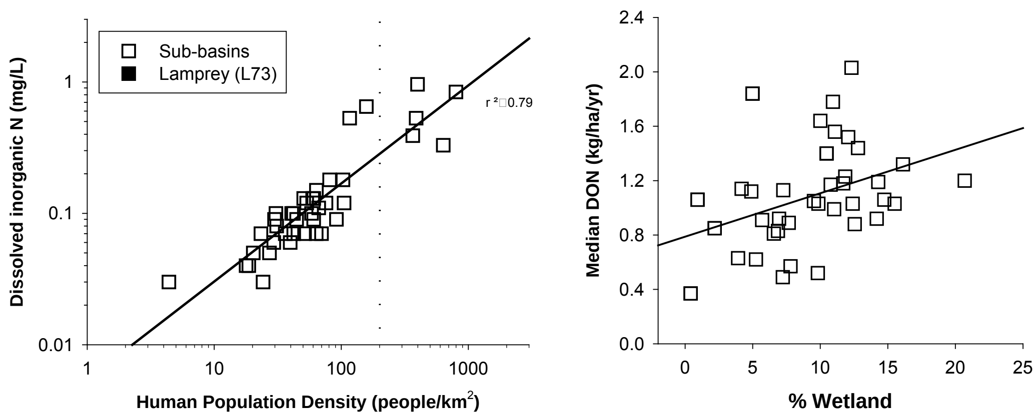

Figure 2. Lamprey and Oyster dissolved inorganic N (DIN) and dissolved organic N (DON) landscape models (based on discharge weighted mean concentrations and median annual runoff from 2000-2009).

Among Lamprey and Oyster River sub-basins, DIN is strongly related to measures of human activity in the landscape (Figure 2) and to non-point N inputs (Daley et al. 2010). Because spatial variability in DON flux is primarily related to natural landscape features (wetlands) and does not relate to measures of human activity in the landscape (e.g. human population density or impervious surfaces) or to the spatial variability in non-point N inputs or (Daley et al. 2010), we recommend that management efforts to reduce non-point sources of N in the Oyster River watershed focus on reducing DIN.

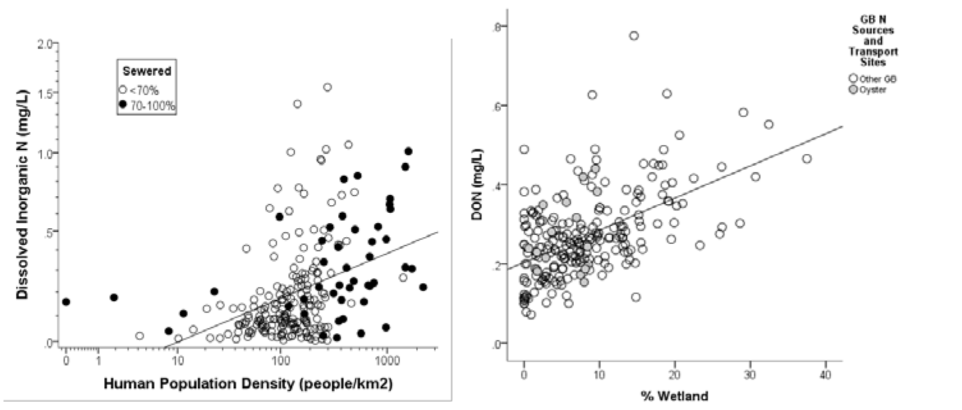

Figure 3. Preliminary Great Bay DIN and DON landscape models from the current Great Bay N Sources and Transport project. Sites were sampled 3-5 times from 2010-2012 and median N concentrations are presented. For the DIN landscape model, filled black circles represent sites where $\geq$ 70% of the population relies on WWTFs (<30% rely on septic systems). For the DON landscape model, filled gray circles represent sites in the Oyster River watershed.

NH WRRC Comments on Figure 3

- Population density is a significant predictor of DIN among Great Bay sites; developed area is also significant predictor, but explains less variance than population density (agriculture alone is not significant)
- Wetland cover is a significant predictor of DON among Great Bay sites; DON is not related to population density or developed area (weak positive correlation with agriculture)

NH WRRC Comments on Figure 2 and 3

- In both Lamprey and Oyster and preliminary Great Bay landscape models, measures of human activity in the landscape were good predictors of DIN, but not DON. DON was primarily related to the amount of wetlands in the watershed.
- Additional multivariate statistics will be performed to determine if agriculture can explain any additional variance in DIN or DON among the Great Bay sites as part of the additional Great Bay N Sources and Transport project (ends August 31, 2014)
- These results suggest that DIN is amenable to management and this is where we can "move the needle" in terms of reducing N loads or concentrations. DON will not be very amenable to management and it will be difficult to "move the needle" when it comes to reducing DON loads or concentrations.
- These landscape models do not include PN (17% of TN in Lamprey) because we do not have sufficient data on how PN varies with land use among Lamprey, Oyster or Great Bay sites. PN is attached to sediment and increases with flow; therefore, frequent sampling during storms is necessary to accurately quantify PN. Currently, the NH WRRC only supports PN sampling in the main stem of the Lamprey (at Packers Falls).

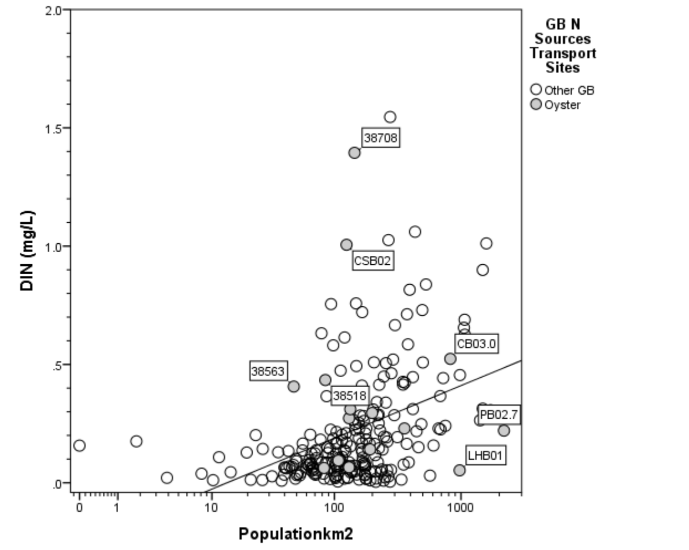

Figure 4. Preliminary median DIN vs. human population density from the current Great Bay N Sources and Transport project with sites in the Oyster River watershed shown as filled gray circles. Sites were sampled 3-5 times from 2010-2012.

NH WRRC Comments on Figure 4

Potential hot spots (higher than other sites with the same population density):

- 38707 – Hamel Brook Ffrost Drive
- CSB02 – Chelsey Brook at Packers Falls Rd. – Durham has flow measurements here

Other somewhat high N Sites

- CB03.0 – College Brook at Mill Pond Rd.
- 38563 – small tributary to Wheelwright Pond on Stepping Stone Rd
- 38518 – small stream draining Lee 5 corners at rt 4 crossing east of traffic circle

2.0 Temporal trends of nitrogen in College Brook Pettee Brook and the Oyster River

Available Datasets

- Monthly samples at various College Brook stations and Pettee Brook (Table X). Dissolved N fractions available.
- Monthly samples (March-Dec) collected from the Oyster River (OR) just above the tidal dam. All N fractions available since Sept 2007, TN available on previous samples. Analysis supported by NHDES and PREP.

Table X. Data collection periods from College Brook (CB) and Pettee Brook (PB) sites.

Sample Name	SiteID	Min Date	Max Date	Location
CB0	CB00.5	5/17/2000	4/16/2013	CB @ Mast Rd
CB1	**CB00.8**	5/17/2000	9/22/2006	CB @ end of Boulder Field, just before access road
CB2	**CB01.5**	5/17/2000	4/16/2013	CB @ Waterworks Rd. (below athletic fields)
CB3A	**CBT01.5**	5/17/2000	6/20/2006	CB Trib near CB2
CB4	**CB01.8**	5/17/2000	8/8/2006	CB @ Spaulding culvert just downstream of building
CB5	CB02.2	5/17/2000	9/22/2006	CB @ Underneath MUB bridge
CB6	CB03.0	10/31/2006	4/16/2013	CB @ Right before the Oyster
PB1	**PB02.0**	5/17/2000	4/16/2013	PB near NE Center at emergence from Edgewood Rd

Bold sites have data from 1991

Highlighted sites currently sampled

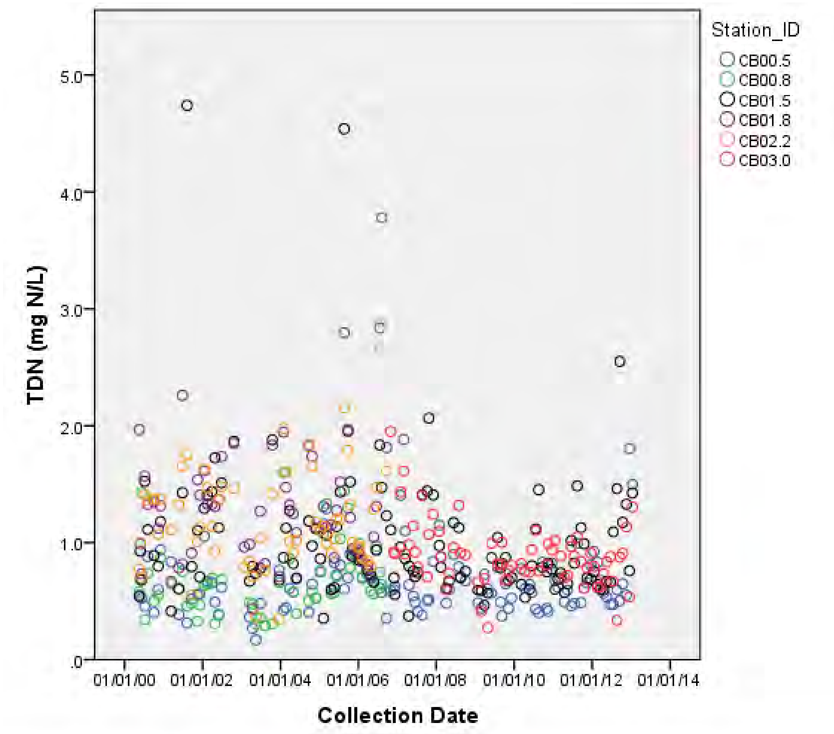

Figure X. Total dissolved nitrogen (TDN) concentrations over time among College Brook sampling stations.

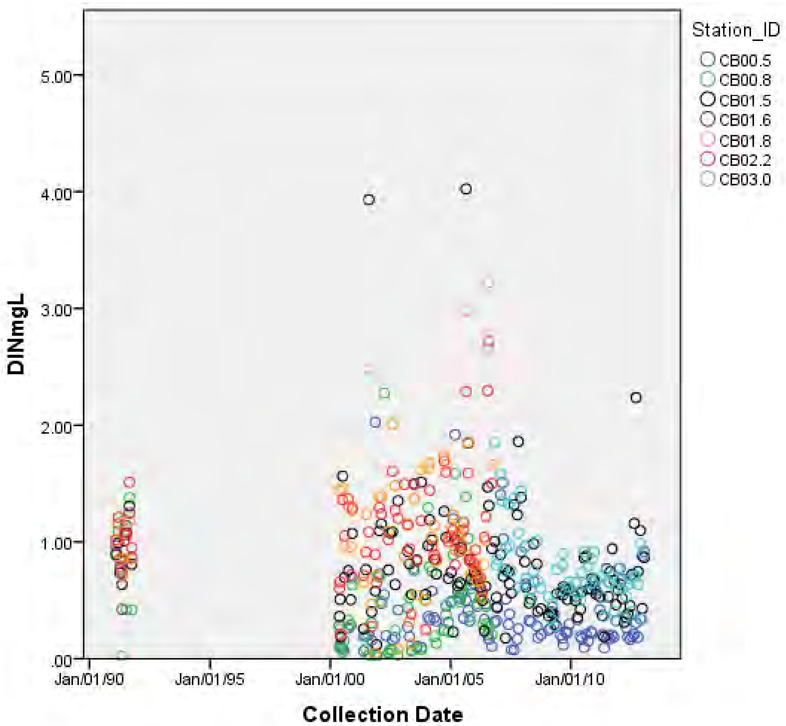

Figure X. Dissolved inorganic nitrogen (DIN) concentrations over time among College Brook sampling stations.

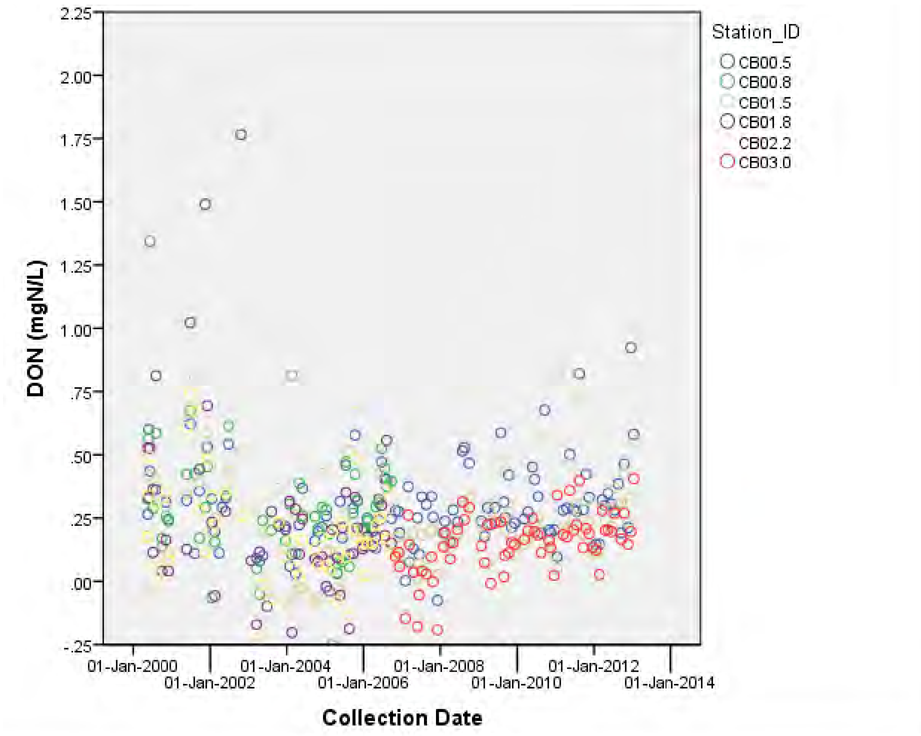

Figure X. Dissolved organic nitrogen (DON) concentrations over time among College Brook sampling stations.

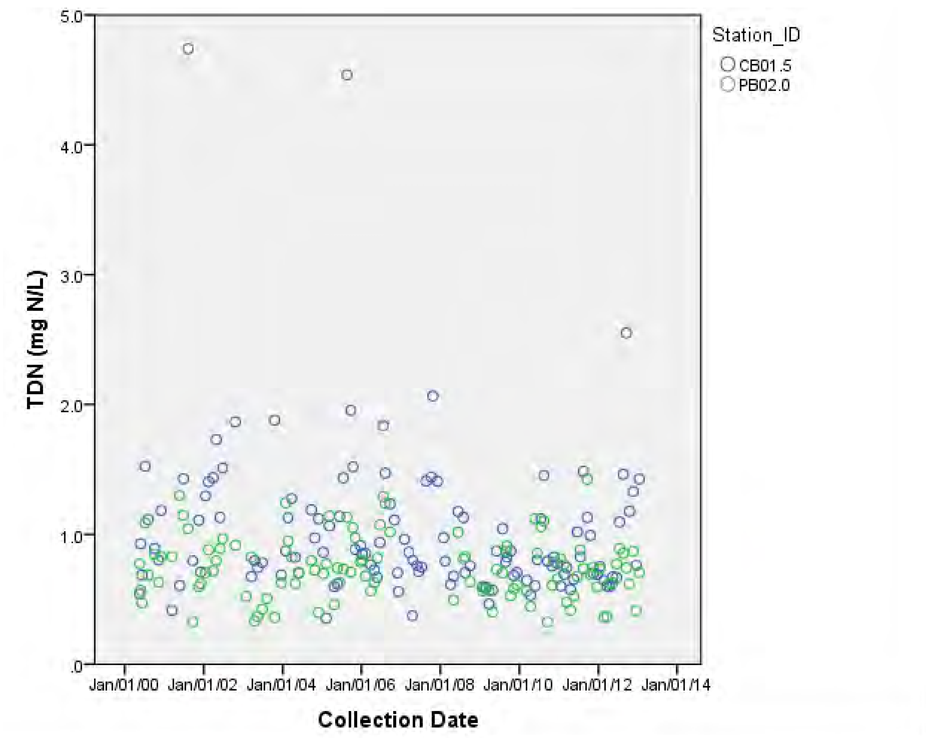

Figure X. Total dissolved nitrogen (TDN) concentrations over time among College Brook and Pettee Brook sampling stations with the longest record.

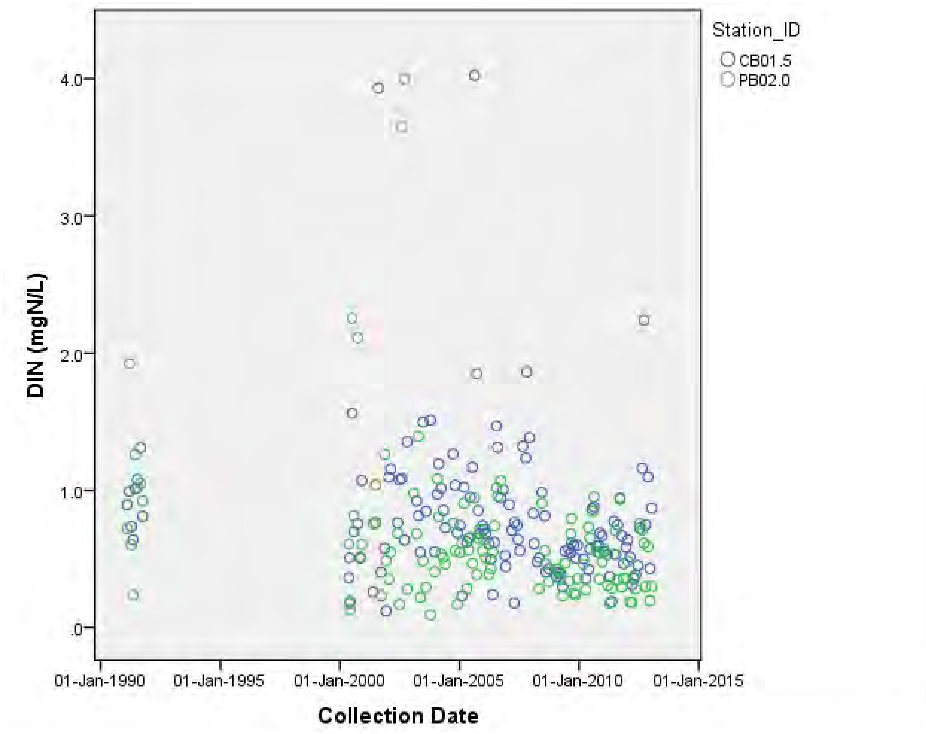

Figure X. Dissolved inorganic nitrogen (DIN) concentrations over time among College Brook and Pettee Brook sampling stations with the longest record.

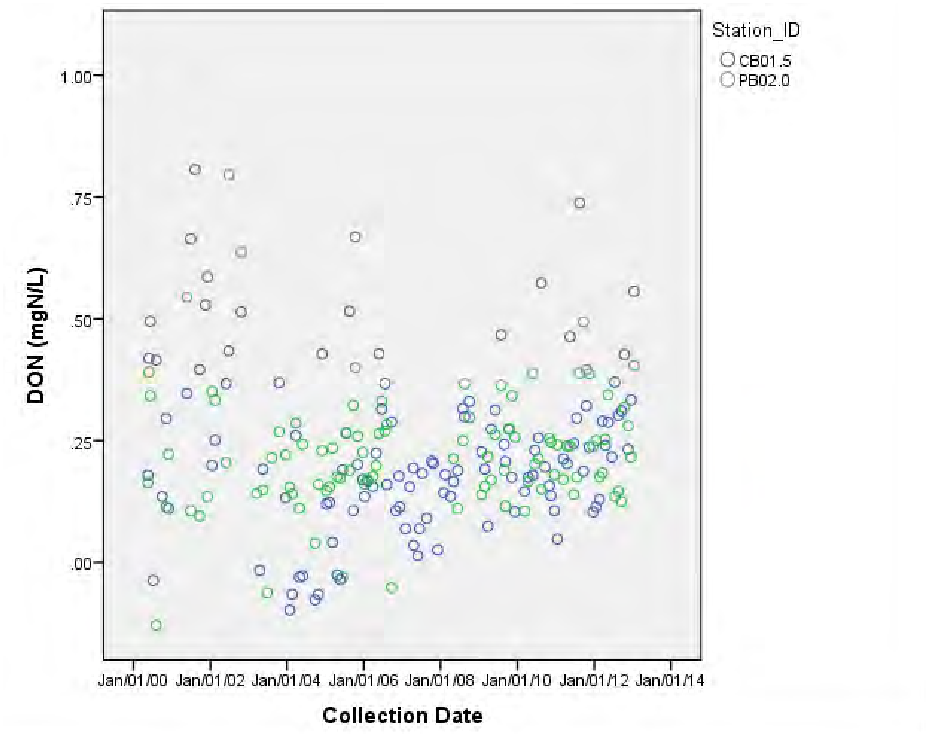

Figure X. Dissolved organic nitrogen (DON) concentrations over time among College Brook Brook and Pettee Brook sampling stations with the longest record.

We used the Seasonal-Kendall Test (SKT) to detect possible changes in monthly DIN and DON concentrations from WY 2000 through WY 2009 at stations CB02.2 and PB02.0 (seasons set to 12; Helsel et al. 2006). If more than one sample was collected in a given month, we calculated the monthly median concentration. There was no long-term change in DIN or DON concentrations at CB02.2 or PB02.0 based on this analysis.

Comment [DM1]: Need to update this through 2013 once all 2013 data is analyzed.

3.0 Relationships between N concentration and Oyster River runoff in College Brook, Pettee Brook and Oyster River

- **Long-term trends**
- **Seasonal trends**

4.0 Median Annual delivery of nitrogen from the Oyster River, College Brook, Pettee Brook and 6 other Oyster River sub-basins (2000-2009)

Figure X. Oyster River sub-basin sites for comparing with VHB nitrogen model.

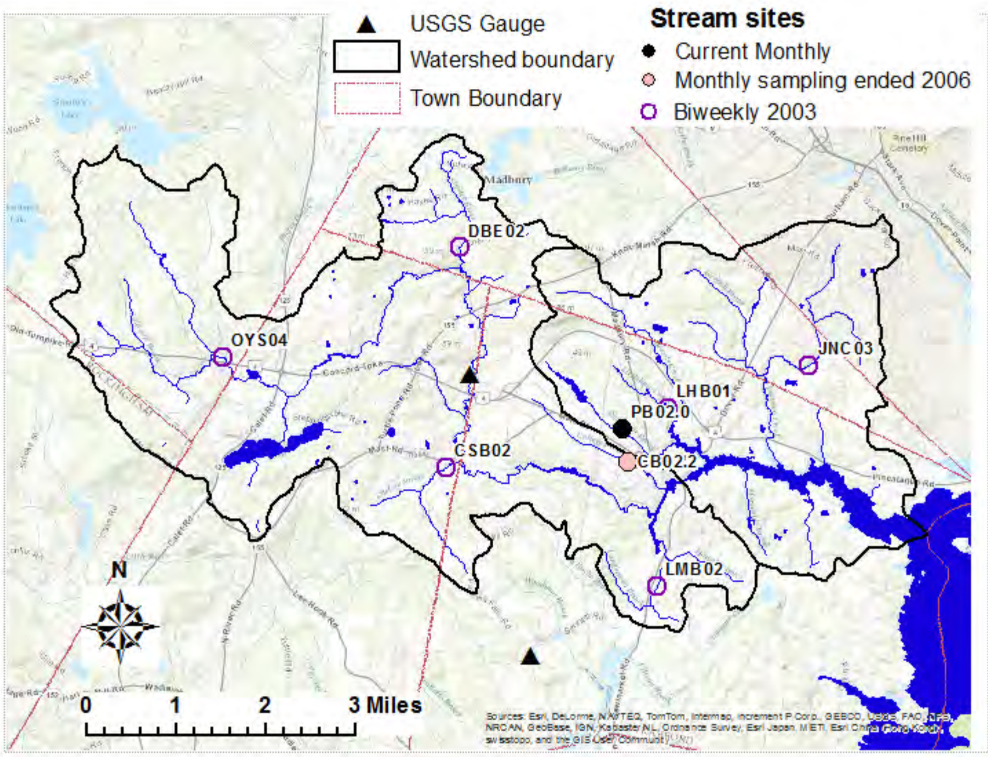

Table X. Sample collection time period and frequency for Oyster River sub-basins used to determine medina annual nitrogen delivery.

Station_ID	Min Date	Max Date	Sampling Regime	km²	acres
CB02.2	5/17/2000	9/22/2006	Monthly	2.028	501.06
CB02.2 with Ave CB01.5 CB03.0	5/17/2000	9/30/2009	Monthly; Combined station CB02.2 data (5/17/2000-9/22/2006) with the average of stations CB01.5 and CB03.0 (10/31/2006-9/30/2009)	2.028	501.06
CSB02	8/18/2001	8/15/2009	Bi-weekly 2003 with a few additional ORWA samples	3.979	983.26

DBE02	6/29/2002	8/15/2009	Bi-weekly 2003 with a few additional ORWA samples	3.417	844.25
JNC03	8/18/2001	8/12/2009	Bi-weekly 2003 with a few additional ORWA samples	5.414	1337.72
LHB01	1/14/2003	12/19/2003	Bi-weekly 2003	0.907	224.25
LMB02	3/3/2003	12/19/2003	Bi-weekly 2003	1.271	314.00
OYS04	1/14/2003	12/19/2003	Bi-weekly 2003	11.747	2902.63
PB02.0	5/17/2000	9/30/2009	Monthly	2.542	628.04

Table X. Discharge weighted mean (DWM) nitrogen concentrations for Oyster River sub-basins. Daily discharge was estimated at each site by using the Oyster River USGS gauging station data and by assuming that runoff was evenly distributed throughout the watershed.

Comment [DM2]: Need to add mean, median, min and max concentrations.

Station_ID	**DWM TDN mg/L**	**DWM DON mg/L**	**DWM NO_3 mgN/L**	**DWM NH_4 mgNL**	**DWM DIN mg/L**
CB02.2	1.04	0.16	0.85	0.05	0.90
CB02.2 with Ave CB01.5 CB03.0	0.94	0.17	0.74	0.06	0.78
CSB02	0.76	0.28	0.46	0.03	0.48
DBE02	0.37	0.30	0.05	0.02	0.07
JNC03	0.63	0.30	0.31	0.03	0.34
LHB01	0.47	0.14	0.29	0.04	0.33
LMB02	0.35	0.25	0.07	0.03	0.10
OYS04	0.29	0.20	0.05	0.04	0.09
PB02.0	0.68	0.23	0.40	0.08	0.48

Table X. Median annual N delivery from Oyster River sub-basins in metric units. Nitrogen delivery was calculated by multiplying discharge weighted mean nitrogen concentrations by the median annual runoff for the Oyster River watershed from 2000-2009 (609.6 mm/yr; determined from Oyster River USGS gauging station data).

Station_ID	**TDN kg/ha/yr**	**DON kg/ha/yr**	**NO_3 kgN/ha/yr**	**NH_4 kgN/ha/yr**	**DIN kg/ha/yr**	**DIN + DON kg/ha/yr**
CB02.2	6.340	0.998	5.191	0.310	5.469	6.466
CB02.2 with Ave CB01.5 CB03.0	5.701	1.058	4.484	0.342	4.779	5.838
CSB02	4.634	1.707	2.775	0.160	2.935	4.641
DBE02	2.250	1.831	0.301	0.118	0.419	2.250
JNC03	3.842	1.818	1.868	0.198	2.066	3.884
LHB01	2.879	0.865	1.792	0.222	2.015	2.879

LMB02	2.156	1.524	0.436	0.196	0.632	2.156
OYS04	1.774	1.248	0.300	0.226	0.526	1.774
PB02.0	4.172	1.408	2.442	0.483	2.946	4.354

Table X. Median annual N delivery from Oyster River sub-basins in US units. Nitrogen delivery was calculated by multiplying discharge weighted mean nitrogen concentrations by the median annual runoff for the Oyster River watershed from 2000-2009 (609.6 mm/yr; determined from Oyster River USGS gauging station data).

Station_ID	TDN lb/ac/yr	DON lb/ac/yr	DIN lb/ac/yr	DIN + DON lb/ac/yr
CB02.2	5.656	0.890	4.879	5.769
CB02.2 with Ave CB01.5 CB03.0	5.086	0.944	4.264	5.208
CSB02	4.135	1.523	2.618	4.141
DBE02	2.007	1.633	0.374	2.007
JNC03	3.428	1.622	1.844	3.465
LHB01	2.569	0.772	1.797	2.569
LMB02	1.924	1.360	0.564	1.924
OYS04	1.583	1.113	0.469	1.583
PB02.0	3.722	1.256	2.629	3.885

5.0 Moore Fields (To be compiled by Katie Swan Spring 2014)

- N loading from Moore Fields to the Oyster River
- Temporal changes in N concentration and loading from 2002-2013
    - Did switch from traditional fertilizer to organic fertilizer impact N?
- Comparison between Moore Fields and Burley-Demeritt Farm

Moore fields data available – 4 sites sampled some months during 2001-2003, 2005-2008 and 2011-now. Dissolved N fractions available

Draft Report For: "Baseline quantification of the magnitude and timing of non-point nitrogen fluxes in the Oyster River and its impacted tributaries."

Principle Investigator: Wilfred Wollheim
Co-Investigators: Gopal Mulukutla and Richard Carey

UNH Water Systems Analysis Group

2013-12-23

1. Summary of Major Results

A. Flow-weighted mean nitrate concentrations are lower for the April to December 2013 deployment period than the long term annual flow weighted nitrate concentrations (WRRC summary, Daley et al. 2013), while relative values among watersheds are similar.

B. Lower nitrate concentrations during the 2013 deployment compared the long term mean may be due to the differing time periods over which samples were collected (April-October vs. Annual), or a greater weighting of sampling during storm events in 2013. We recommend looking at the distribution of sample collection vs. season and discharge during the 2000-2009 period to understand the differences.

C. More intensive sampling of site-specific discharge and frequent measurement of nitrate likely result in similar but slightly lower flux estimates than when using other less intensive sampling approaches, with greater differences in flashy systems such as highly impacted headwater sites (e.g. College Br.).

   - Flow-weighted mean concentrations and areal fluxes are lower when using site-specific discharge measurements than when using discharge derived from the USGS gage data.

   - Flow-weighted mean concentrations and fluxes are higher when using high frequency nitrate measurements than using infrequent grab measurements, but remain slightly lower than the least intensive approaches.

D. Infrequent grab samples are especially inadequate at capturing short-term storm responses during storm events when most flows occur, especially in impervious dominated watersheds.

E. The results from our high intensity measurements (both site-specific discharge and high frequency nitrate measurements), though somewhat lower, are very similar to those previously summarized for the 2000-2009 period (Daley et al. 2013).

F. Although flow-weighted concentrations and areal flux estimates are similar across the different methods, the high temporal resolution results provides a picture of actual dynamics that may offer potential to identify mitigation strategies.

G. Uncertainties remain in our areal flux estimates due to site-specific discharge rating curves that currently need to be extrapolated to higher flows. Rating curves will continue to be improved over the coming months as storm event opportunities present themselves. A second lesser source of error is uncertainty in exact watershed areas (important for estimating areal fluxes).

2. Introduction

This report presents preliminary estimates of non-point nitrate fluxes in the Oyster River watershed between April and December 2013, using new sensor technology that improves characterization of nitrate concentrations during storms. Our goal in this report is to compare flux estimates using novel in situ sensor technology of continuous nitrogen measurements with the classic approach of developing estimates using infrequent grab sampling techniques. An assessment of flux estimates using these different calculation methods is important because observed fluxes over annual time scales are being used to calibrate/validate a non-point source watershed model that will be used to develop permits and management strategies. We assume that the in situ sensor approach, with high frequency measurements, provides a better estimate of actual fluxes. Biases in flux estimates are possible using infrequent grab sampling approaches because concentrations are highly dynamic especially during storms, when most flows occur and the probability of grab sampling is relatively low. The results presented here should be considered preliminary estimates, as various aspects of the project are still being completed. We expect feedback and dialogue with interested stakeholders. The report covers mainly nitrate, but we also offer some preliminary estimates for DON.

3. Context

Coastal New Hampshire is experiencing significant environmental problems associated with excess nitrogen (N). The Great Bay, NH, has been classified as N impaired by the US Environmental Protection Agency due to increases in both point and non-point sources (NH-PREP 2009). Thus far, mitigation options have focused on reduction of point sources, which can be very costly. However, a significant proportion of elevated N fluxes are due to non-point sources (NH-PREP 2009). A complementary strategy is reduction of non-point sources as part of an integrated watershed management plan.

Management of non-point sources is challenging because it requires adequate quantification of non-point fluxes which are highly dynamic over time and because monitoring is rarely at sufficient temporal resolution to account for variability within and across storms when most fluxes occur (Kirchner et al. 2004; Doyle, 2005). Accurate and relatively precise measurements will be needed in order to evaluate the effectiveness of non-point management activities. Existing approaches for scaling infrequent point samples over time using statistical interpolation (e.g. using the USGS LOADEST approach) are inadequate, particularly in smaller watersheds that may be targeted for management actions and for which baseline non-point flux amounts and patterns are of interest. However, new *in situ* sensor technology now available has the potential to quantify fluxes continuously, avoiding the uncertainties in extrapolation of infrequent grab samples (Heffernan and Cohen 2010; Pellerin et al. 2012).

The overall goal of the Oyster River Non-Point Source study was to:

Quantify the amount and temporal variation of N fluxes from Oyster River sub-watersheds using continuous and high frequency *in situ* measurements in order to establish a baseline of non-point export flux patterns.

4. Study Design and Methods

Our approach is to provide nitrate flow-weighted mean concentration and areal flux estimates using a variety of approaches of increasing effort and cost (Table 1). The simplest approach for calculating fluxes, which has been commonly used throughout the SeaCoast region, is to use periodic nutrient grab samples (weekly to monthly) combined with flow estimates at the sample site derived based on area-weighted discharge (i.e. runoff, mm/yr) from the nearest USGS gage at the same point in time. Fluxes are then estimated using flow-weighted concentrations, annual runoff from the USGS gage, and watershed area of the sample site. The major assumption is that runoff at the sample site is identical to that at the USGS gage site.

Table 1. Comparison of methods to estimate NO3-N flux during the April to December deployment period. We compare these estimates to those from the long term synthesis of annual flow-weighted mean concentrations and fluxes over the 2000 to 2009 period developed by the UNH Water Resources Research Center (Daley et al. 2013)

Method	Discharge	Concentration	Calculation	Assumptions
Grab*USGS.Q	USGS Oyster R. gage	Weekly to bi-weekly grabs	Flow weighted concentrations * total flow	Assume runoff at measurement site identical to runoff at USGS gage; scale by watershed area
Grab*Local.Q	Local stage with rating curve	Weekly to b-weekly grabs	Flow weighted concentrations * total flow	Rating curve at local site is sufficient
SUNA*Local.Q	Local stage with rating curve	15minute concentrations from sensors, validated	15-minute Concentration * 15-minute flow	Rating curve at local site is sufficient, Instrument calibrated

We have organized the report into various sections so that the reader can understand how we came up with these flux estimates, and can evaluate uncertainties in each component. The components include: estimates of continuous discharge (Local.Q in Table 1) and estimates of continuous nitrate (SUNA in Table 1).

4.1. Site Descriptions and Sensors

We monitored seven sites (three intensive and four non-intensive) in non-tidal locations across a range of land uses (agriculture to residential) and river size (headwaters vs. mainstem) (Figure 1, Table 2). Suites of continuously monitoring in situ sensors were deployed at the three intensive monitoring sites between April and December 2013 (Table 3). Continuous measurements are most useful in flashy, impacted systems due to dynamic nutrient responses that are difficult to characterize with grab samples alone. Weekly site visits at the intensive sites were used to maintain and clean the sensors in order to minimize the effect of biofouling. Although the sensors were equipped with wipers that minimize biofouling, regular cleaning was needed.

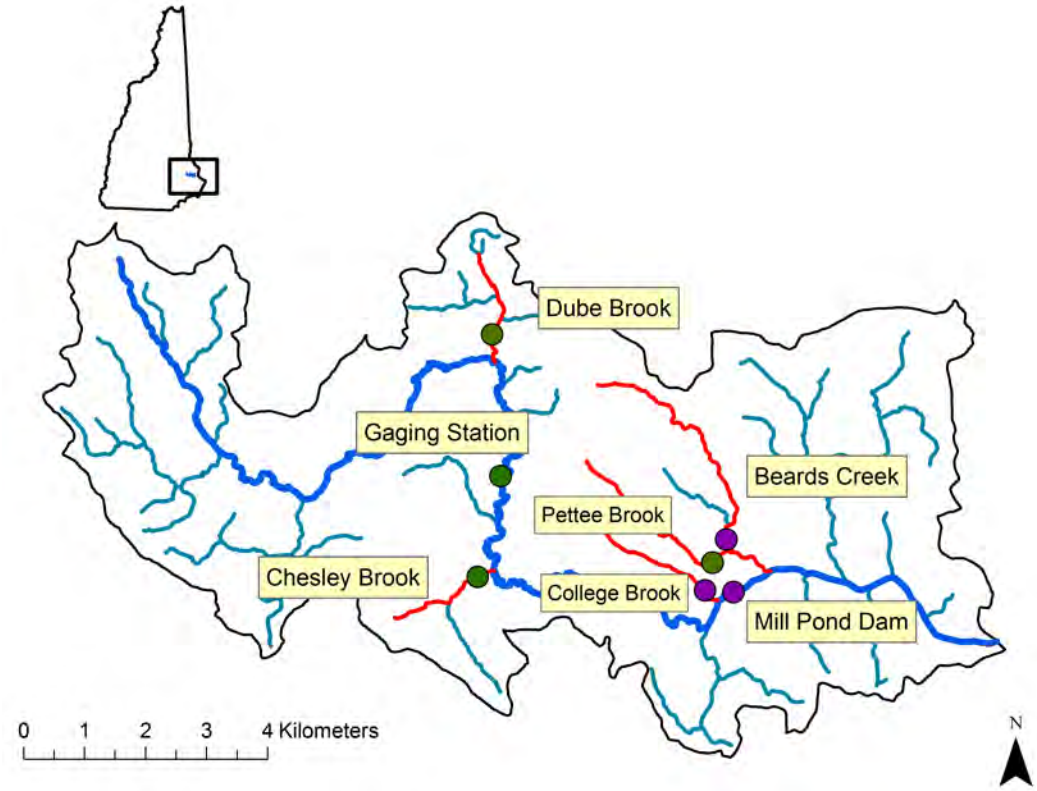

Figure 1. Map of Oyster River Watershed study area. Intensive sites are shown in purple, less intensive sites in green.

Name	Code	WSAG/UNH Estimate (km^2)	VHB estimate (km^2)	WRRC Estimate (km^2)	USGS Estimate Km^2
Oyster River at Mill Pond Dam	OMPD	49.118	50.05		
Oyster River at USGS Gaging Station	OGS	30.982	31.58		31.33
College Brook	CLGB	3.688	3.27	1.9	
Pettee Brook	PTEB	0.812	1.58	1.03	
Chesley Brook	CHSB	3.862	4.18	3.95	
Dube Brook	DBB	2.062	1.85	3.41	
Beards Creek	BRDS	4.501	5.58*		

Table 2. Watersheds used in this study, and their watershed area estimated by various entitities.

Description including name of equipment:	Measurements	Location
SUNA (Submersible Ultraviolet Nitrate Analyzer)	Nitrate concentration and dissolved organic carbon quality in the UV (200-400 nm) range	Mill Pond dam College Br. Beards Cr.
Turner Designs : C6 Multisensor Platform	Flluorescent Dissolved Organic Matter (fDOM) Chlorophyll, Turbidity	College Br. Beards Cr.
HydroLab MS5 – Multiparameter Sonde	pH, dissolved oxygen, water temperature	College Br. Beards Cr
YSI EXO2	fDOM, turbidity, pH, conductivity, dissolved oxygen,	Mill Pond dam
Onset Inc. Hobo water level and conductivity loggers	Stage height, water temperature and specific conductivity.	Mill Pond dam College Br. Beards Cr. Dube Br. Chesley Br. Pette Br. Gaging Station

Table 3. Sensors deployed at the three intensive and four less intensive monitoring sites.

The intensive monitoring sites were located on the Oyster River main stem (Mill Pond dam near Rt. 108 in Durham) and two smaller tributaries with varying degrees of urban/agricultural land use (College Brook and Beards Creek). The smaller tributary sites were of contrasting urban intensity: College Br. (at Durham marketplace) was more urban, while Beards Cr. (at Stolworthy Preserve) was more suburban. Water level and conductivity loggers were deployed at the four non-intensive sites on the main stem of the river (USGS gaging station) and selected tributaries (Dube Brook, Chesley Brook, and Pettee Brook). Dube Br. was included as a forested reference site; both Chesley Br. and Pettee Br. are impacted tributaries with Pettee similar to College Br (urban) and Chesley being agricultural.

4.2. Grab Samples

Weekly grab samples were collected at the intensive monitoring sites to validate nitrate sensor measurements and to develop proxies for dissolved and particulate organic N. We also targeted sampling during several storm events to capture concentrations during high flows. There is potential to develop proxies for DON from fluourescent Dissolved Organic Matter (fDOM) sensors, and PON from turbidity sensors. We include here preliminary results for DON. PON may be an important component of total N fluxes in smaller tributaries. Conductivity can function as proxies for water quality including chloride and potentially NO3. At the non-intensive sites, monthly grab samples were collected. All grab samples were analyzed for nitrate (NO3), ammonium (NH4), total dissolved N (TDN; DON = TDN –NO3 – NH4), particulate organic N (PON), dissolved organic carbon (DOC), total suspended solids (TSS), phosphate (PO4), total dissolved phosphorous (TDP), chloride (Cl) and other anions. Lab analysis was conducted by the UNH Water Resources Research Center (WRRC).

__4.3. Discharge__

Continuous stage height was measured (5 minute intervals) at each of the seven sites using HOBO stage loggers deployed in deeper pools within the channel. Discharge was estimated in each of the headwater sites (College Br., Beards Cr., Pettee Br., Chesley Br. and Dube Br.) by developing rating curves using periodic discharge measurements and stage height data (Figures 2 and 3). Both the area-velocity method (using Flow tracker velocity meters) and salt dilution methods were used. Regressions (power functions) developed at each site were used to convert continuous stage height data to continuous discharge (Figures 2 and 3). We were unable to measure discharge across the entire range of measured stage heights. As a result, the hydrographs used for this report include discharge estimated by extrapolating the rating curves to higher stage heights. This leads to considerable uncertainty during high flux periods. The rating curves in figure 3 and 4 show the distribution of measurement points and the range of extrapolation (regression lines extended to highest measured stage). Currently, rating curves at all the sites require additional high flow measurements, but particularly in the less intensively monitored sites. Water level loggers remain at all sites except the USGS gaging station; both rating curves and uncertainties in flux estimates will be improved with additional discharge measurements. All discharge in volumetric units was converted to runoff in depth units by dividing by watershed area. Runoff as used here refers simply to area-weighted discharge as opposed to storm surface runoff. This allows comparison of flows at all sites, regardless of watershed area.

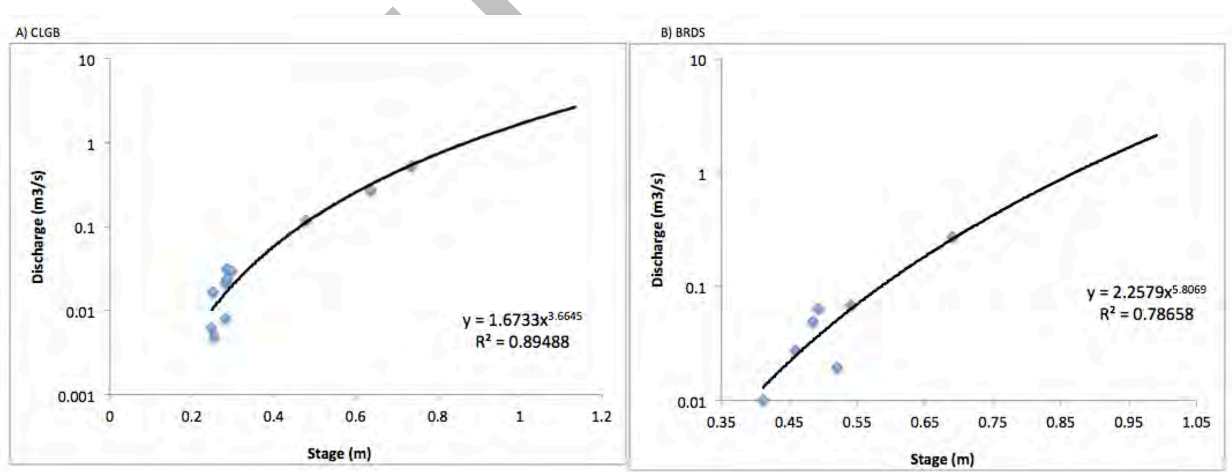

Figure 2. Rating curves for (a) College Brook and (b) Beards Creek for 2013, including all measurements through December 20th, 2013. The rating curves are extrapolated to the highest stage height recorded during the deployment. The difference between the stage of the highest measured discharge and the maximum stage indicates a region of greater uncertainty in discharge estimates.

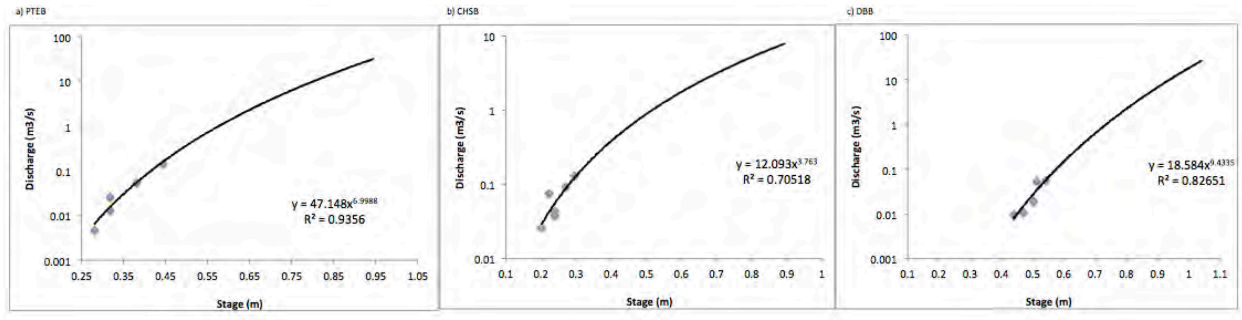

Figure 3. Rating curves for less intensive sites: a) Pettee Br., b) Chesley Br., and c) Dube Br. The points indicate measurements and the fitted line the rating curve, extrapolated to the highest stage. These sites have more uncertain discharge estimates than the two intensive sites because we have not been able to measure discharge across most of the high flow stage heights. We therefore do not include estimates of flux from local discharge.

Oyster Mill Pond gage

The Oyster River at Mill Pond dam required a different method to calculate continuous discharge since we could not measure discharge directly. We estimated discharge at the Oyster River Mill Pond dam using dam geometry combined with stage height measured with a depth logger (Hobo water level logger, Onset Inc., Falmouth MA). The dam has an "Ambursen –type" structure constructed in the early 1900's (Figure 4). Discharge over the dam was estimated as Q = AV where Q is discharge, A is cross sectional area of the flow, and V is velocity. A is given by width of the dam and depth above the crest, derived from the stage logger. V is estimated as $V_{theoretical} = 2/3\sqrt{2g}H^{3/2}$, where H is the height above the crest and g is the constant for gravity. An empirical correction factor, Cd was included to account for losses at the edges of the dam and contractions in area of flow that modify velocity from the theoretical estimate. We used the discharge coefficient (Cd) for a paved embankment, such as the Oyster R. dam, that was determined by Hulsing (1967). The resulting equation for Q then was $Q = C_d A V_{theoretical} = 2/3\, C_d W\sqrt{2g}H^{3/2}$, where W is width. For details see the appendix 1.

Deployment of the stage logger at the Oyster dam began 4/18 2013 and continues to present. Initial deployment of the logger was done on a temporary basis between 4/18/2013 and 6/19/2013, when it was moved to its current permanent and fixed location. Data from the temporary deployment between 4/18 and 6/19 was influenced by the sway of the pipe that contained the logger, especially during storms. As a result, a regression of stage height at the USGS gage and OMPD for the period 6/20-9/30 was used to construct a stage height record for 4/18/2013- 6/19/2013 (see Appendix).

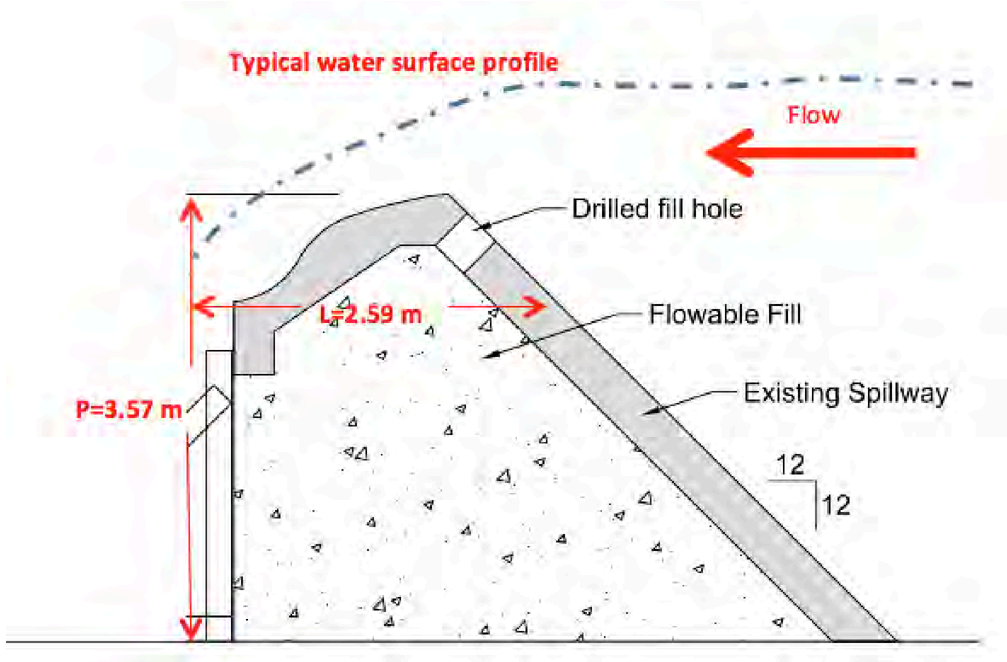

Figure 4. Cross section of the dam is shown. The sloped upstream face significantly lowers the velocity of approach, as opposed to an upstream vertical faced dam. (figure modified from : "Oyster River Dam Restoration, report of a 2012 Senior Project , Brian Paula, Mathew Bogle, Neal Drake, Alexander Klink, Maxwell Murray, UNH Civil Engineering)

<u>*5. Results*</u>

We focus here on providing preliminary flow-weighted mean concentrations and areal flux for nitrate using the different approaches summarized in Table 1. We only present results for sites/methods for which we have some level of confidence in the flux estimates. We do not here present or attempt to understand finer scale patterns, though this is something we will actively pursue in the coming months. Understanding the patterns will potentially identify management options for mitigating N fluxes.

5.1. Runoff.

Comparison of runoff (in units of mm/d) shows the greater flashiness of the headwater sites than in the mainstem, with the greatest flashiness in College Br. (CLGB) (Figure 5). This is consistent with our expectations based on impervious surface percentages in the different basins. Estimates from the Oyster River at the Mill Pond dam are similar to those upstream at the USGS gage. However we continue to have considerable uncertainty in these estimates due to the assumptions required to make a flow estimate at the dam (see Appendix 1). Summed over the entire deployment period covered in this report (4/18 – 9/30) runoff was: USGS gage = 204 mm; Oyster River at Mill Pond = 225mm (range of 131 to 319 mm); College Br. = 78 mm; and Beards Cr. = 69 mm. The much lower runoff estimates in the headwaters are inconsistent, and may result from methodological issues (e.g. inadequate rating curve, Figure 2). We are planning to evaluate this potential source of error with additional high flow measurements. Errors in stage depth may also occur due to infrastructure issues, which we are also currently evaluating. The rating curves at the less intensive sites required even more extrapolation, so we do not include a hydrograph at this point.

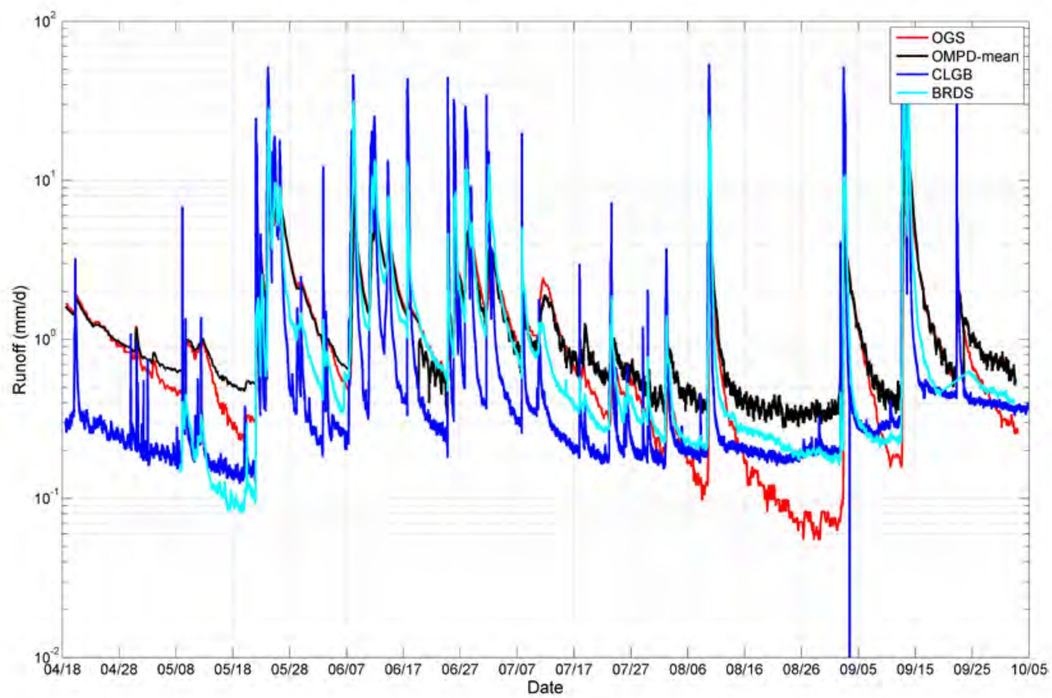

Figure 5. Runoff (in units of mm/d) at intensive sites compared to USGS gage runoff. The runoff estimates at each site have considerable uncertainty due to incomplete rating curves and the assumed parameters at the dam.

5.2. *Nitrate Grab Samples*

Nitrate grab samples at the intensively monitored sites were highest in College Br, followed by Beards Cr. and then the Oyster River at Mill Pond (Figure 6). Greater variability in nitrate is evident in College Br and Beards Cr., indicating storm responses. However, DON increases during storms, resulting in relatively stable TDN concentrations.

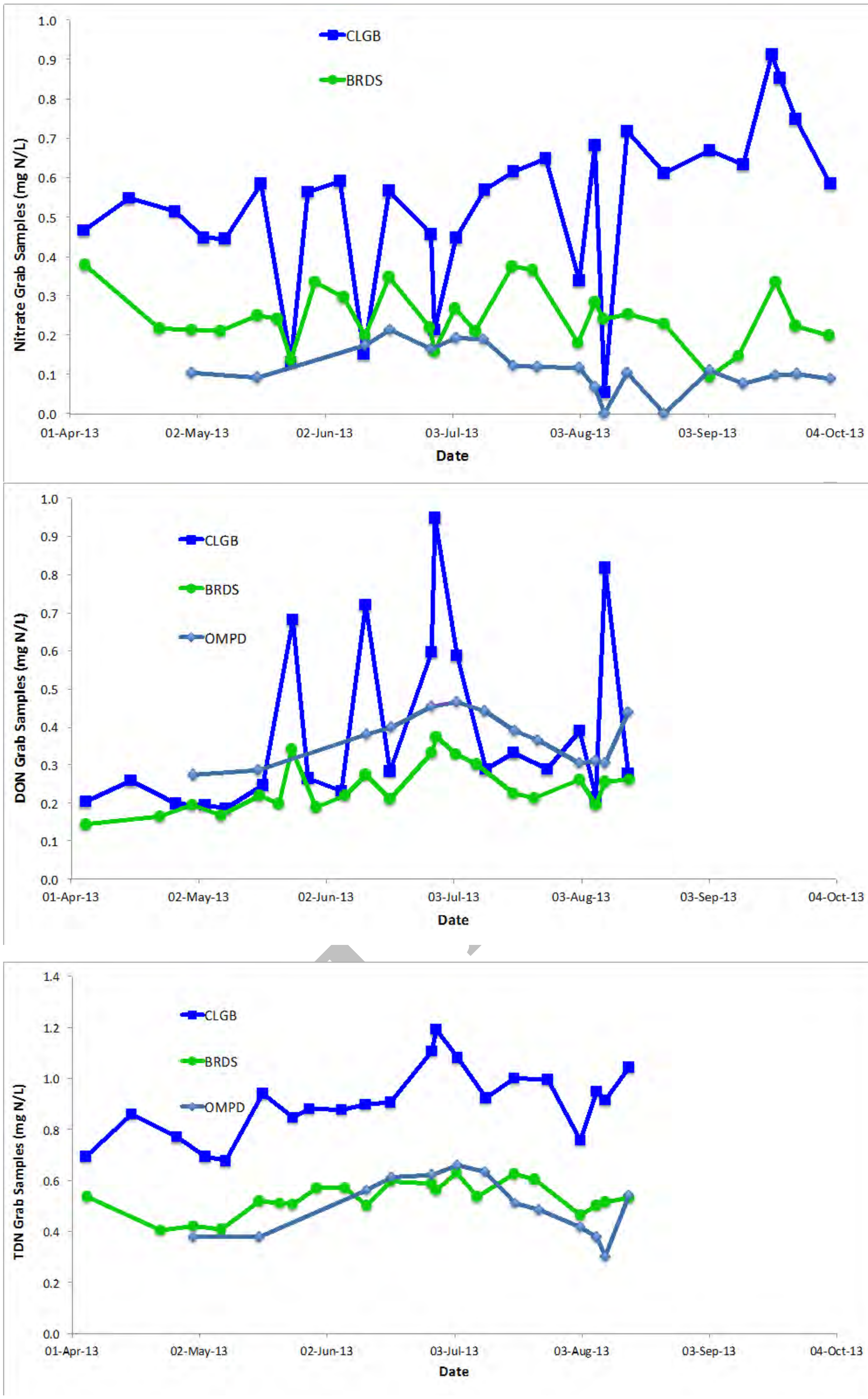

Figure 6. Grab sample data for the deployment period for a) NO3, b) DON, c) TDN. The large dips in nitrate occur during storm events, and coincide with increased DON, resulting in relatively stable TDN over time.

5.3. SUNA Nitrate concentration Validation

SUNA nitrate concentrations were highly correlated with nitrate in grab samples analyzed in the lab (Figure 7). In both College Br. and Beards, the slopes were nearly 1, but showed slight offsets of 0.07 to 0.1 mg N / L. In the Oyster River at Mill Pond, there is also a high correlation, though there is more scatter and the slope appears to differ from one. SUNA results were corrected for these offsets, so that they matched lab-estimated concentrations. There is some indication that residuals in these relationships are related to DOC. We are further exploring this issue to determine how it affects our flux estimates.

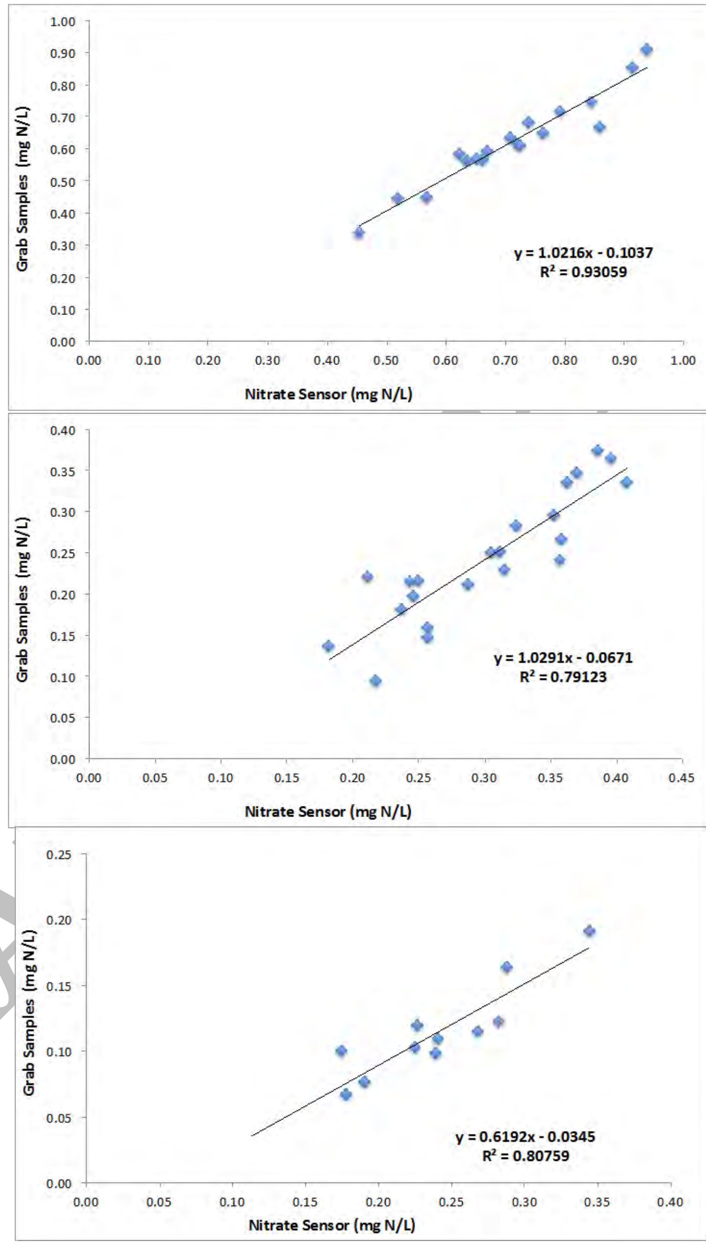

Figure 7. Relationship between grab sample nitrate and sensor nitrate in a) College Br., b) Beards Cr. and c) Oyster River at Mill Pond.

5.4. Nitrate Sensor Time Series

The nitrate time series from the insitu sensors indicates considerable flashiness, especially in College Br. , but also during storms at Beards, and the Oyster at Mill Pond (Figure 8). The spikes are mostly associated with storms. Short term nitrate spikes occur at the beginning of most storms in College and Beards, before diluting. In the Oyster, storms tend to flush nitrate, without much sign of dilution.

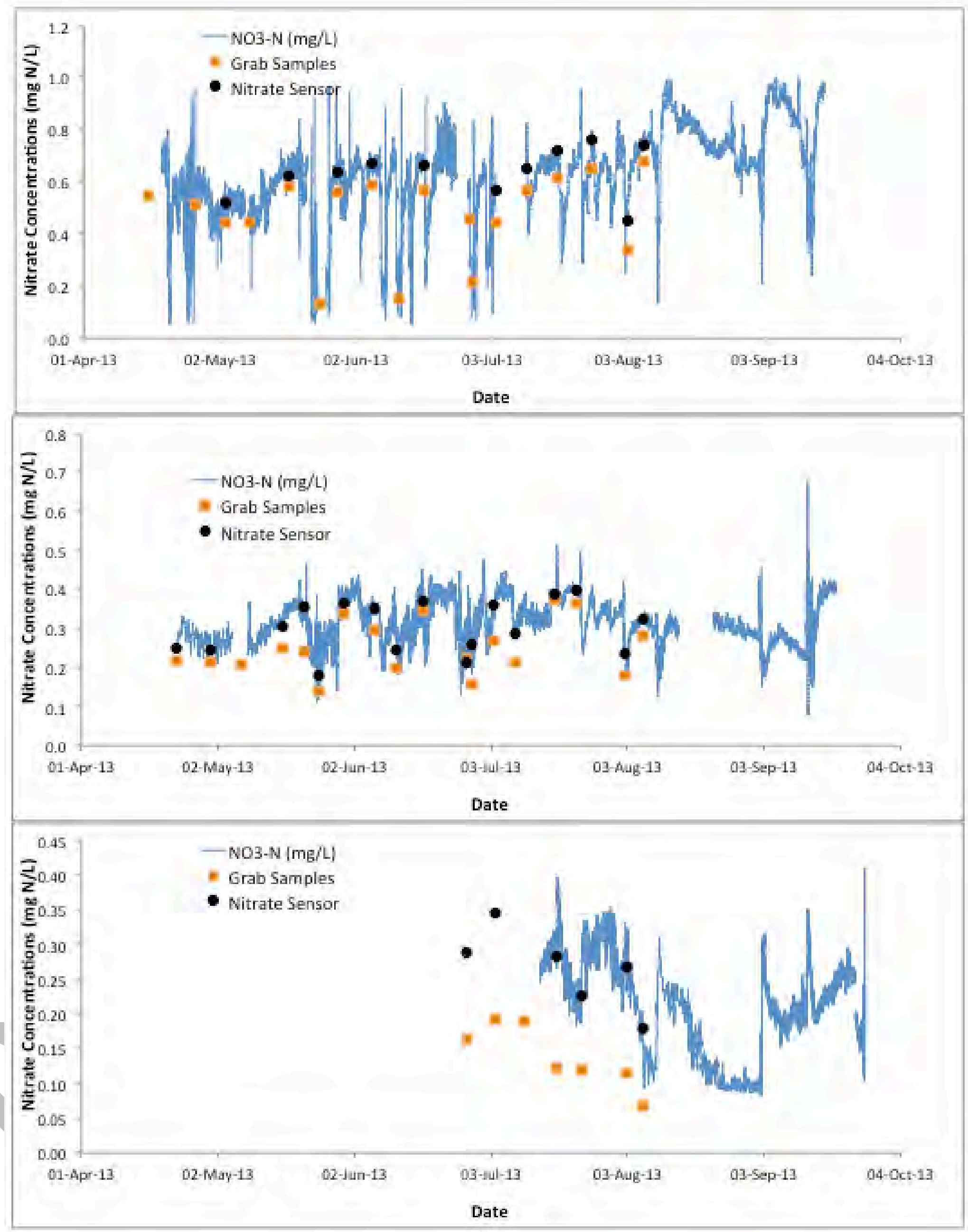

Figure 8. Nitrate time series as measured by the insitu sensors (blue line) at a) College, b) Beards, and c) Oyster at Mill Pond. Grab sample values are shown in orange squares, while black circles indicate the sensor reading at the time of grab sample collection

5.5. Nitrate Flow-weighted Concentrations and Fluxes

Nitrate flow-weighted mean concentration and flux estimates using the different approaches (Grab*USGS.Q, Grab*Local.Q, and SUNA*Local.Q) are reported in Table 4. The table also compares flow weighted mean concentrations with those reported by the Water Resources Research Center (WRRC) from 2000-2009 (Daley et al. 2013).

Comparison of 2013 Concentrations with Long Term Average. In general, flow weighted mean concentrations we determined for the 2013 study period are lower than those reported by the WRRC (2000-2009) when using the identical method (i.e. Grab*USGS.Q). However, the relative concentrations among watersheds were similar (CLGB>CHSB>PTEB> DBB). The difference is least for our most pristine site, Dube Br, which had nearly identical concentrations. Differences may be due grab sample collection time frames (i.e., WRRC includes samples collected over the whole year, while 2013 results are from April to October). They may also result from more frequent grab sampling at high flows in 2013 that we targeted in order to validate the sensors. Flow weighted nitrate concentrations at Dube Br. are similar for both the long term average and 2013 deployment period, suggesting that concentrations at this site are generally less variable than other sites.

Because of uncertainty in the discharge rating curves developed at the less intensive sites (Figure 3), we cannot yet develop reasonable flow weighted estimates using our own discharge measurements at these sites. This is something we will be continuing to improve in coming months. Our rating curves are more reasonable at the intensively monitored sites (Figure 2), although some extrapolation was still required. We are confident enough to provide preliminary flow weighted concentrations at these sites. However, these estimates may also change as we improve the rating curve.

	WRRC Data		**WSAG Data**		
	Grab Samples (2000-2009) and USGS Runoff (2000-2009)	**Grab Samples (2000-2009) and USGS Runoff (2013)**	Grab Samples (2013) and USGS Runoff (2013)	Grab Samples (2013) and Local Runoff (2013)	Nitrate Sensor (2013) and Local Runoff (2013)
CLGB					
Flow Weighted Concentrations (mg/L)	0.85	0.85	0.41	0.26	0.38
Nitrate Areal Fluxes (kg/km^2/period)	519.12	215.79	104.48	57.38	84.25
BRDS					
Flow Weighted Concentrations (mg/L)			0.21	0.14	0.17
Nitrate Areal Fluxes (kg/km^2/period)			53.09	37.85	46.14
OMPD					
Flow Weighted Concentrations (mg/L)			0.15	0.12	0.12
Nitrate Areal Fluxes (kg/km^2/period)			37.73	31.29	30.88
DBB					
Flow Weighted Concentrations (mg/L)	0.05	0.05	0.07	TBD	NA
Nitrate Areal Fluxes (kg/km^2/period)	30.12	12.52	16.97	TBD	NA
OGS					
Flow Weighted Concentrations (mg/L)			0.07	TBD	NA
Nitrate Areal Fluxes (kg/km^2/period)			18.79	TBD	NA
CHSB					
Flow Weighted Concentrations (mg/L)	0.46	0.46	0.31	TBD	NA
Nitrate Areal Fluxes (kg/km^2/period)	277.46	115.34	78.87	TBD	NA
PTEB					
Flow Weighted Concentrations (mg/L)	0.40	0.40	0.22	TBD	NA
Nitrate Areal Fluxes (kg/km^2/period)	244.15	101.50	54.52	TBD	NA

Table 4 Estimates of nitrate flow-weighted concentration and areal fluxes for each site as determined by the Water Resources Research Center archival data (2000-2009), and by WSAG measurements during 2013 using in situ sensors. TBD is To Be Determined. NA is Not Applicable (no in situ sensors were deployed.)

Comparison Using USGS gage vs. Site Specific Q Measurements from 2013 data. Flow weighted concentrations (FWC) and fluxes were lower using locally estimated discharge than when using the USGS discharge at all three intensive sites (Table 4). The difference was greatest in the most urban, flashy, watershed (College Br.) and lowest in the larger, least flashy, Oyster River at Mill Pond. We would expect a lower difference in OMPD, as it is located downstream of the USGS gage in the same river. In College Br. FWC was 0.26 mg N / L using local Q and 0.41 mg N/ L using USGS Q, while flux was 57kg/km2/period using local Q vs. 104 kg/km2/period using USGS Q. In Beards, FWC was 0.14 mg N / L vs. 0.21 mg N / L, while flux was 38 kg/km/period vs. 53 kg/km2/period.

The lower flux estimates when using site specific Q measurements are in part the result of lower runoff estimates in the headwater sites than at the USGS gage. The runoffs resulting from our rating curve and hydrograph indicate that areal runoff was lower in the headwaters than at the USGS gage. Total runoff over the 6 month period was 78 mm/period in CB and 69 mm/period in Beards, while it was 204 mm/period at the USGS gage. We estimate rainfall of 554 mm/period (measured at the UNH, Thompson Farm), which may not reflect precipitation over the Oyster R watershed as a whole. We are investigating the reasons for these large differences in runoff, whether they are real or some methodological artifact. Some of this may be due to extrapolation of our rating curve. However, lower areal discharges also occur during baseflows (Figure 5). Lower runoffs during this deployment period may occur if storm runoff was captured by storm drains and diverted from the catchment, or if precipitation patterns varied over the watershed. We will need to discuss these results with other project team members, which we have not done yet. An additional source of error may be our estimates of watershed size, which also influence the runoff estimate (Table 2). For now, we have more confidence in the Flow Weighted Concentrations than the areal flux estimates, as we believe those will be more robust to errors in the rating curve.

At the Oyster River Mill Pond site, FWC and areal fluxes were only slightly lower using the site-specific discharge. The similar estimates indicate that in larger catchments where flows and nitrate concentrations are less flashy, the simpler method is robust. We are uncertain of the discharge and runoff estimates at OMPD. Flow estimates at dams are not commonly done, and we are still refining the method for estimate discharge at this site.

Comparison Using Grabs vs. High Temporal Frequency NO3. Flow weighted concentrations (FWC) and fluxes were higher using high temporal frequency nitrate measurements from the sensors than when using infrequent grab samples in the headwater sites, but not the Oyster River mainstem (Table 4). The difference was again greatest in the most urban, flashy, watershed (College Br.) and lowest in the larger, least flashy, Oyster River at Mill Pond. Beards Cr. was intermediate. We believe these estimates provided the truest estimate of FWC and areal flux in the headwaters.

The high frequency concentration measurements resulted in FWC and flux estimates very similar to the simpler approach (grab*USGS runoff) (Table 4). This result suggests that errors in flow and concentration timing using the simpler approach nearly offset one another. However, we point out that these sensors get the answer right for the right reason, which will be beneficial when developing mitigation strategies. The higher FWC using the sensors occurs because the sensors are able to measure the higher nitrate concentrations that occur at times during high flow events (i.e. first flushes) (Figure 9). In College Br., our grab samples are infrequent during the high flow events, and completely miss periods of high nitrate that occurs at high flows

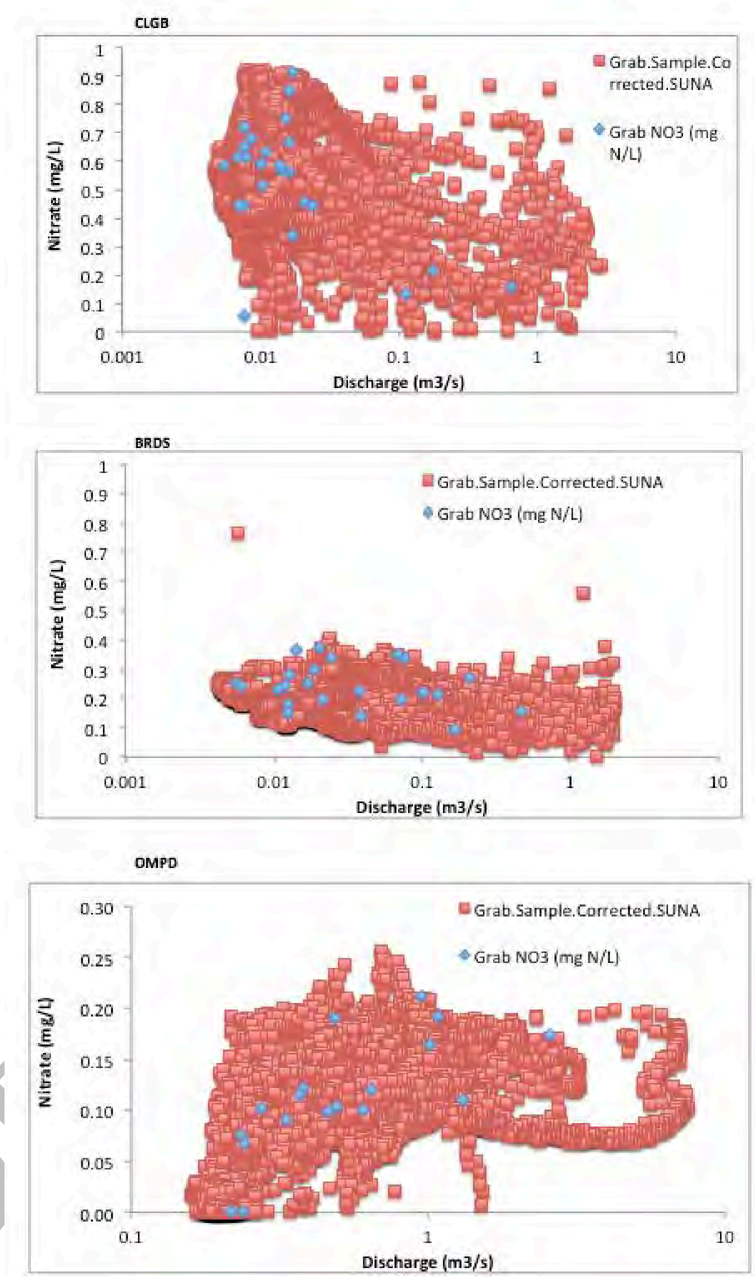

Figure 9. Comparison of SUNA nitrate and grab sample nitrate vs. discharge during the 2013 deployment at a) College Br. b) Beards Cr. , and c) Oyster River at Mill Pond. Grab samples at College Br. completely miss the periods of high nitrate that occurs at times during high flows.

5.6. Preliminary Dissolved Organic Nitrogen Flow-weighted Concentration and Flux Estimates

DON flux estimates using the different approaches (Grab*USGS.Q, Grab*Local.Q, and Sensor*Local.Q) are reported in Table 5. The table includes flow weighted mean concentrations from periodic grab samples (all sites) and continuous DON concentrations estimated using continuous (15-minute) FDOM measurements (Turner Designs C6 Multisensor Platform and YSI EXO2) and grab samples (intensive sites). There was not a strong relationship between FDOM and DON concentrations at College Br. ($R^2 = 0.15$; n=13); additional data is therefore needed at this site to develop continuous DON estimates. However, there were strong relationships at both Beards Cr. ($R^2 = 0.80$; n=17) and Mill Pond dam ($R^2 = 0.85$; n=5). There were fewer data points at Mill Pond dam than College Br. and Beards Cr. because the FDOM sensor at Mill Pond dam was deployed later in the study period. Additional grab samples at the Mill Pond dam will be used to validate the relationship between FDOM and DON concentrations.

At each site except College Br., flow weighted mean DON concentrations were similar for the different approaches. The flow-weighted mean DON using grab samples in 2013 were higher than the long term average for unknown reason (Table 5). The high resolution sensor data did not improve DON FWC or areal flux estimates in Beards or Oyster R, indicating that less frequent grab samples can be adequate to monitor DON concentrations at these sites.

	WRRC Data		WSAG Data		
	Grab Samples (2000-2009) and USGS Runoff (2000-2009)	Grab Samples (2000-2009) and USGS Runoff (2013)	Grab Samples (2013) and USGS Runoff (2013)	Grab Samples (2013) and Local Runoff (2013)	FDOM Proxy (2013) and Local Runoff (2013)
CLGB					
Flow Weighted Concentrations (mg/L)	0.16	0.16	0.46	0.69	TBD
DON Areal Fluxes (kg/km^2/period)	99.78	41.48	117.81	153.38	TBD
BRDS					
Flow Weighted Concentrations (mg/L)			0.26	0.26	0.28
DON Areal Fluxes (kg/km^2/period)			64.85	69.05	73.84
OMPD					
Flow Weighted Concentrations (mg/L)			0.40	0.39	0.40
DON Areal Fluxes (kg/km^2/period)			101.66	97.44	100.28
DBB					
Flow Weighted Concentrations (mg/L)	0.30	0.30	0.34	TBD	NA
DON Areal Fluxes (kg/km^2/period)	183.06	76.09	86.08	TBD	NA
OGS					
Flow Weighted Concentrations (mg/L)			0.29	TBD	NA
DON Areal Fluxes (kg/km^2/period)			73.67	TBD	NA
CHSB					
Flow Weighted Concentrations (mg/L)	0.28	0.28	0.34	TBD	NA
DON Areal Fluxes (kg/km^2/period)	170.69	70.95	85.51	TBD	NA
PTEB					
Flow Weighted Concentrations (mg/L)	0.23	0.23	0.41	TBD	NA
DON Areal Fluxes (kg/km^2/period)	140.79	58.52	103.95	TBD	NA

Table 5. Estimates of DON flow-weighted concentration and areal fluxes for each site as determined by the Water Resources Research Center archival data (2000-2009), and by WSAG measurements during 2013 using in situ sensors. TBD is To Be Determined. NA is Not Applicable (no in situ sensors were deployed.)

6. Future Work

Additional work is ongoing to refine and improve the estimates provided in this report. The site specific Q measurements all require additional points at high flows to better constraint actual discharge. In addition to additional Q measurements, we hope to use the ADCP deployed at Chesley Br. to provide better discharge estimates there, and will explore whether we could deploy a similar system at other sites. Once improved rating curves are available, we will provide similar FWC and flux estimates at the four less intensive sites. We have found strong relationships between nitrate, discharge, and conductivity at several of the more impacted stream locations, offering the potential to improve flux estimates at less intensively monitored locations. We will also refine our estimates of DON and PON fluxes, but require additional time to understand the relationships between fDOM and turbidity and DON and PON concentrations. Finally, we expect to delve into an understanding of the storm event patterns and their variability to better inform potential management options. We are maintaining stage, conductivity, and periodic grab sampling at all the sites through the winter in order to develop robust annual budgets.

7. Preliminary Conclusions

We tentatively conclude that more intensive sampling of site-specific discharge and frequent nitrate are likely to result in lower flux estimates than when using other sampling approaches, particularly in flashy systems such as highly impacted headwater sites. Storm periods are less common, and thus less frequently sampled by grab samples, especially when not targeted. The greater the degree of flashiness/urbanization, the greater the likelihood infrequent grab samples will overestimate actual fluxes. Since most drainage water (and thus potentially non-point sources) in a basin enters through smaller headwater streams, this impacts our understanding of loading to river systems and what reaches the coastal zone. High flow periods generally result in overall dilution, though complex patterns also occur (e.g. short term flushing), which further affects flux estimates. In this study, flow-weighted mean concentrations and flux estimates using the highest intensity measurements (Sensors, Site Specific Q) were very similar to estimates using the simplest approach (Grabs, USGS Q). However, this may be fortuitous, as clearly with the simpler approach, we were getting it right for the wrong reason. It remains to be seen if this occurs in other systems. Further, the specific timing may be off. If we wish to develop management strategies, we will need to understand the underlying temporal patterns. However, for longer-term flux estimates, (e.g. for models) our results suggest that the simpler method may average out the errors, though actual fluxes may be somewhat lower than estimates made using less frequent grab sampling. The errors will be greatest in watersheds that are flashier, while estimates for larger watersheds will likely be robust.

Appendix 1. **Estimation of Discharge from Stage Height Measurements at Oyster River's Head of Tide at Mill Pond**

Start of Deployment : 4/18/2013
End date of Data discussed here : 10/02/2013
A stage height logger was deployed at Mill Pond dam (Hobo water level logger, Onset Inc. Woodshole MA) to provide an estimate of discharge at the head of tide. Deployment began 4/18 2013 and continues till present day. Initial deployment of the logger was done between 4/18/2013 and 6/19/2013 on a temporary basis and moved to its current location on the sensor cage. The pressure data obtained from the water level logger was corrected for barometric pressure using data from a sensor located at Wednesday Hill Brook in Lee, NH
Data from the initial deployment between 4/18 and 6/19 was found to be influenced by the sway of the pipe that contained the logger, especially during storms. As a result, a regression of stage height at the USGS gage and OMPD for the period 6/20-9/30 was used to construct a stage height record for 4/18/2013- 6/19/2013. Figure A.1 shows the regression used to develop the stage height.

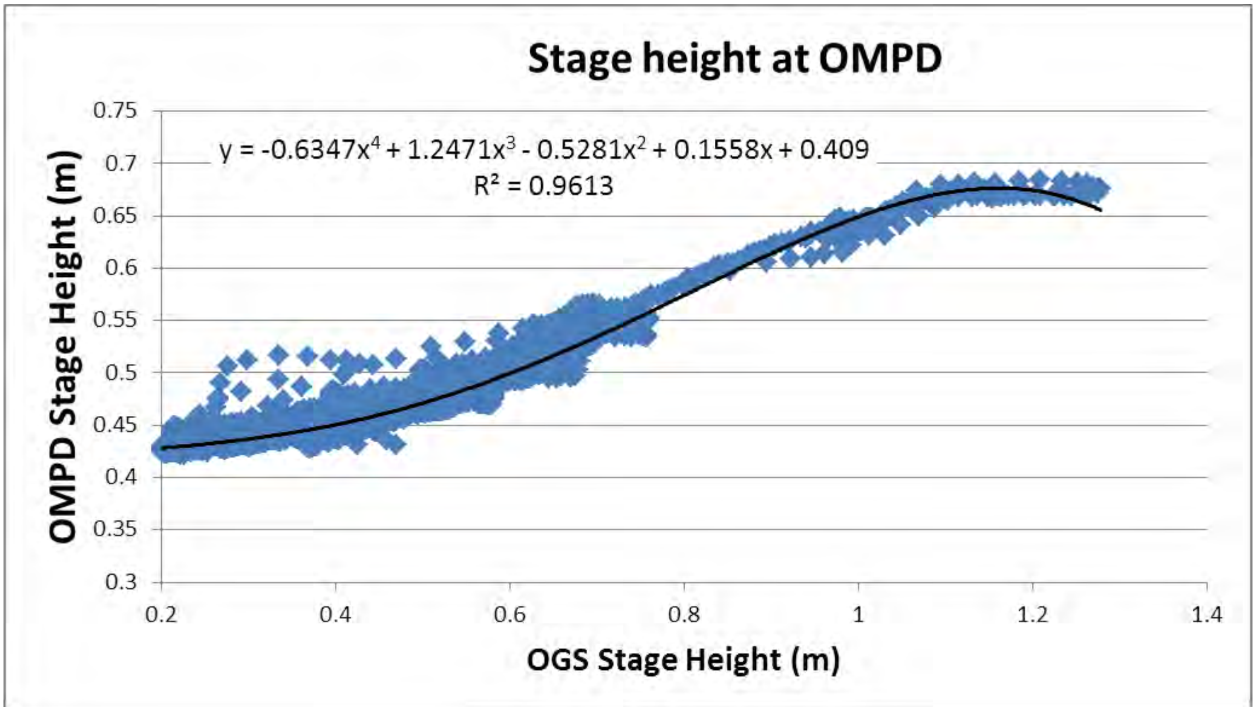

Figure A.1 A regression of stage height at OMPD with the stage height observed at OGS (recorded by USGS). Stage height here describes the height of water above the crest of the dam. The period of measurement is 6/20 to 9/30/2013. The non-linear regression (R^2=0.9613) is used to develop the stage height for the period 4/18 to 6/19.

Furthermore, in the month of August two short periods of no flow were observed at the dam. A correction factor of 0.039 m(3.9 cm) (a value to be subtracted from the stage height record) was estimated that would correct for the no-flow period. Applying this correction to the complete stage height record seemed to significantly underestimate the flow. As a result we developed an upper bound and lower bound estimate of discharge did not correct (upper bound) for and correct for the no-flow period (lower bound). A mean discharge record was developed based on these estimates. Figure A.2 shows the upper and lower bound of the stage height record.

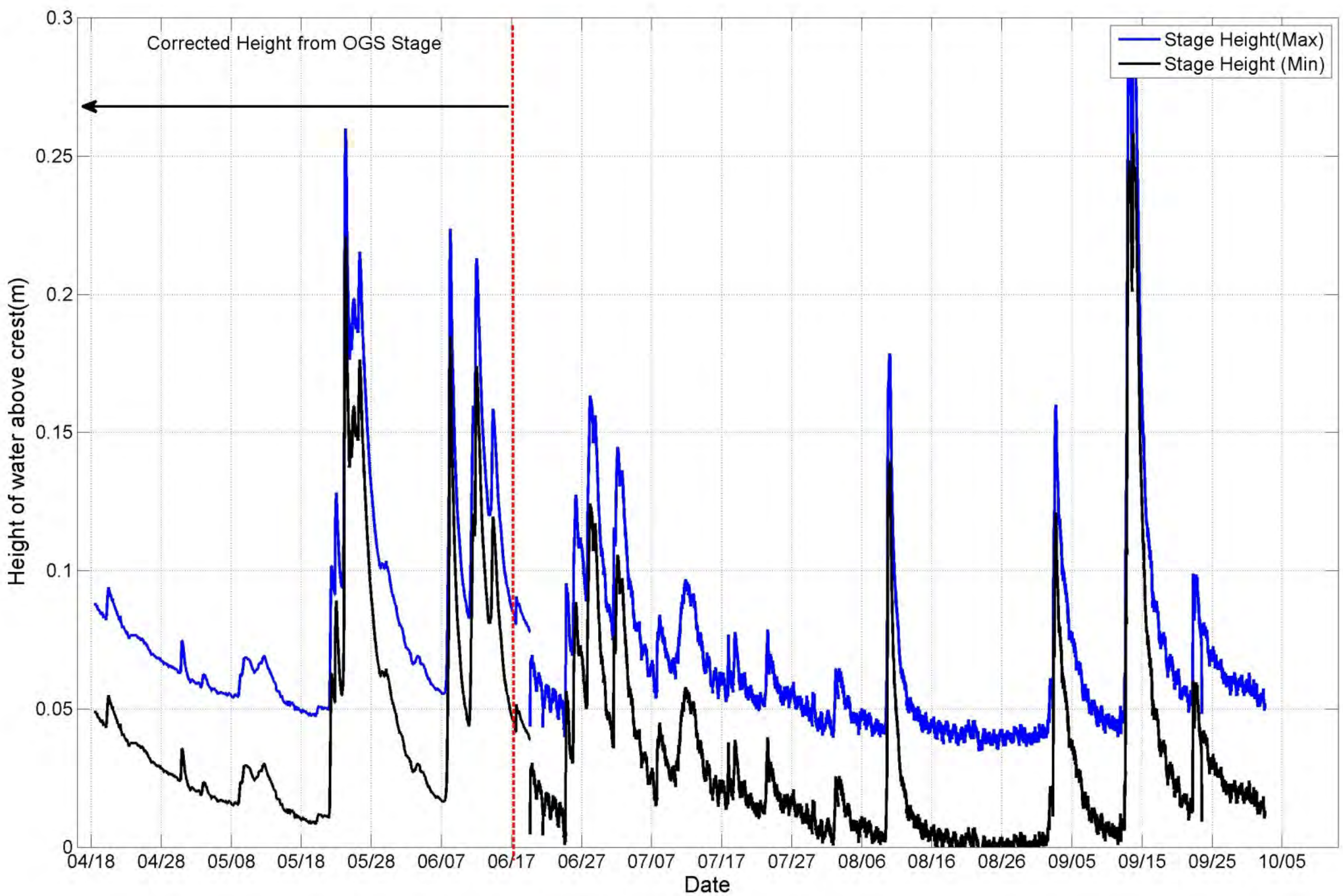

Figure A.2: Height of water above crest of dam. An upper bound and lower bound was determined by considering a correction for no-flow period. Figure shows the complete record of deployment between 4/18 and 9/30.

Discharge Estimation Methodology

The dam was determined to be a "Ambursen –type" structure constructed in the early 1900's. A schematic of the dam's cross section is shown in Figure A.3**.** The geometrical characteristics of the dam are an important consideration in estimating discharge from stage height.

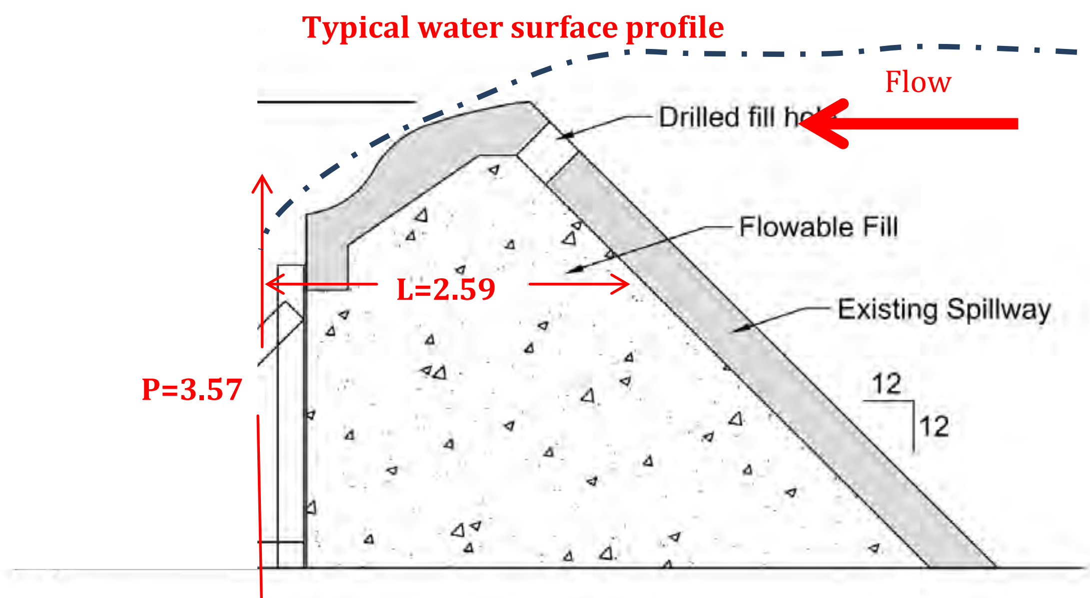

Figure A.3. Cross section of the dam is shown. The sloped upstream face significantly lowers the velocity of approach, as opposed to an upstream vertical faced dam. (figure modified from : "Oyster River Dam Restoration, report of a 2012 Senior Project , Brian Paula, Mathew Bogle, Neal Drake, Alexander Klink, Maxwell Murray, UNH Civil Engineering)

Discharge over a weir is commonly given by the following

Q= AV

Where A is the cross section of flow over the crest and V is the velocity of approach. Since V is difficult to measure, the (theoretical) velocity at any height h above the crest is given by

$V_{theoretical} = \sqrt{2gh}$

When H is the head of water above the crest, the theoretical approach velocity is determined by integrating over the entire head to get

$V_{theoretical} = \int_0^H \sqrt{2gh}\, dh$ or $V_{theoretical} = 2/3\sqrt{2g}H^{3/2}$

The actual velocity of approach is determined by the geometry of the weir, and also for losses at the edges of the weir and contractions in area of flow that combine to provide a velocity of approach that is lower than the theoretical estimate. In order to account for this an empirical coefficient C_d is introduced.

$Q = C_d\, A\, V_{theoretical} = 2/3\, C_d\, W\sqrt{2g}H^{3/2}$

Determining the most appropriate value of C_d for OMPD is complicated by the fact that the weir is not of a standard shape. It has a a mix of features of a "broad crested weir" with the structure of a "sharp crested weir". An exhaustive survey of literature did not provide a definitive value of C_d that was appropriate. Moreover C_d is a function of H. As a result a more elaborate method is used to estimate the bounds of discharge at OMPD

The maximum height of water above the crest was recorded to be 0.2985 m (=h). The ratio, max height over width of dam h/L = 0.11. This shows that the velocity of approach will be considerably small (as described in the report "Measurement of peak discharge. at dams by indirect method"- Techniques of Water-Resources Investigations to the United States Geologica Survey, Harry Hulsing , 1967). Moreover the sloped upstream surface also slows down the velocity. So after a considerable study **it was decided that the most appropriate approach to determining Cd is to treat the dam as a paved embankment.**

The discharge coefficient (Cd) for a paved embankment for very low values of h/L was determined by Hulsing (1967). **Figures A.4 and A.5** show the original plot (metric units) and its digitized version for a paved embankment (SI units).

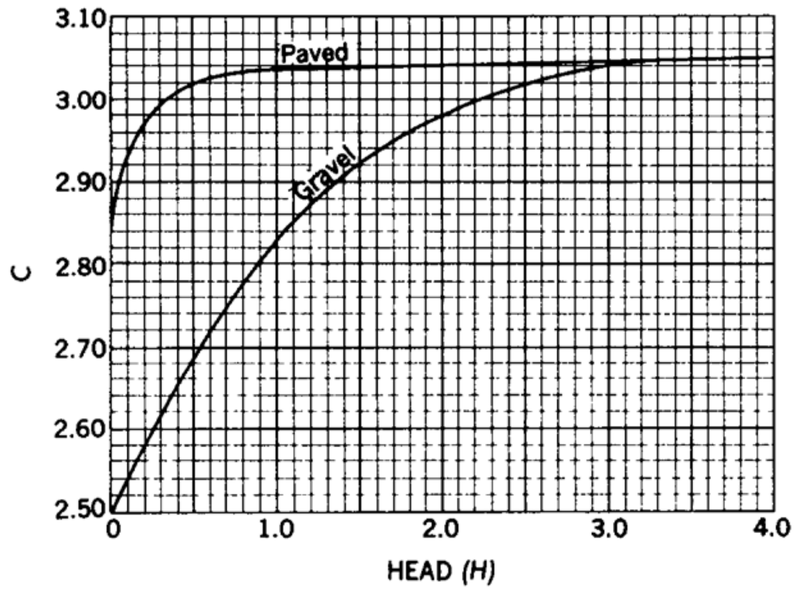

Figure A.4 Plot showing the variation of discharge coffiecient (C) as a functionf of head (in ft) . (for H/L <0.15) (source: Hulsing, 1967)

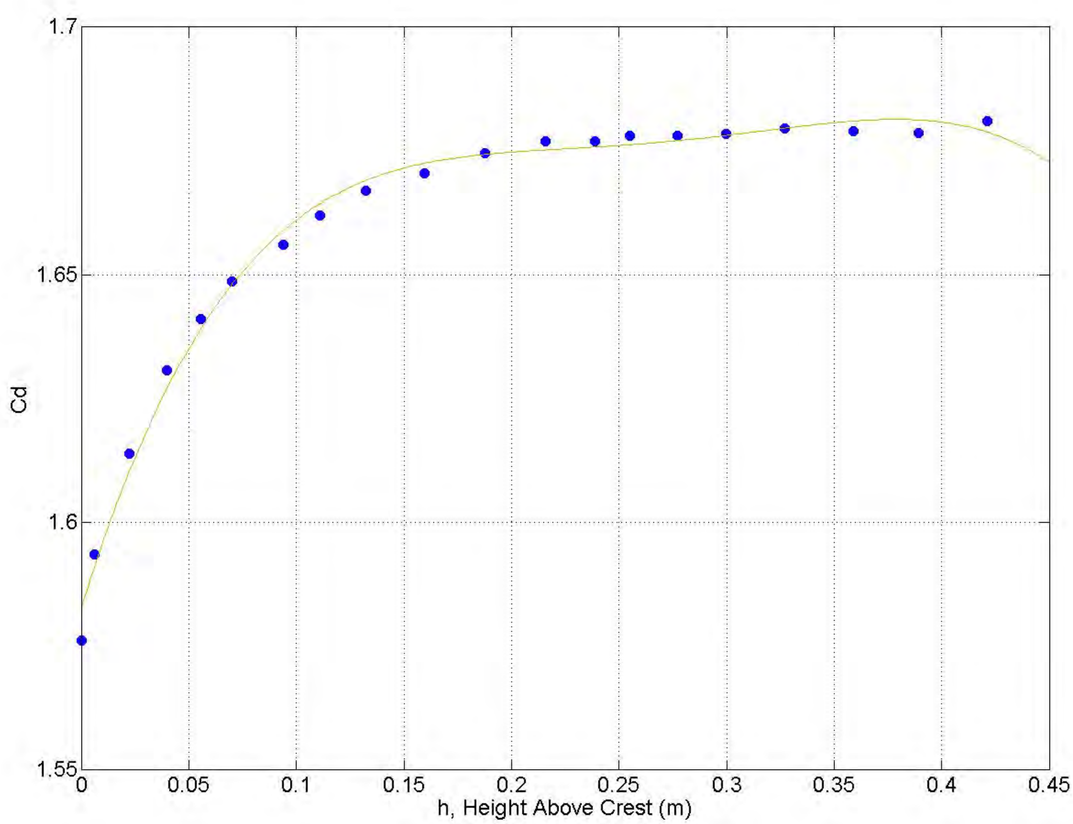

Figure A.5 SI unit plot of discharge coefficient for a paved embankment.

The value of Cd is also affected by metric units. It was transformed by determining the ratio of Cd (metric)/Cd(SI). Cd is actually a product of - 2/3 *Ec* $\sqrt{2g}$, where Ec is an empirical coefficient between 0 and 1.

For Ec=1

Cd (SI units)= 2/3$\sqrt{2 * 9.80665}$ = 2.95

Cd(metric units)= (2/3)* $\sqrt{2 * 32.174}$)= 5.34

The ratio (Cd (metric)/Cd(SI)= 1.81 This value was used to transform the metric unit plot to SI units . The equation of flow over a weir was used

Q = 2/3 C_d W$\sqrt{2g}H^{3/2}$

Where W= spillway length of 30.47 m (from report"Mill Pond Bathymetric Survey and Sediment Sampling Study ', prepared for Town of Durham by VHB and Hydroterra Environmental Services LLC. 2009-2010)

Figure A.6 provides the estimate of flow (mean, upper bound and lower bound estimates) and its comparison with the flow recorded at the upstream USGS gage.

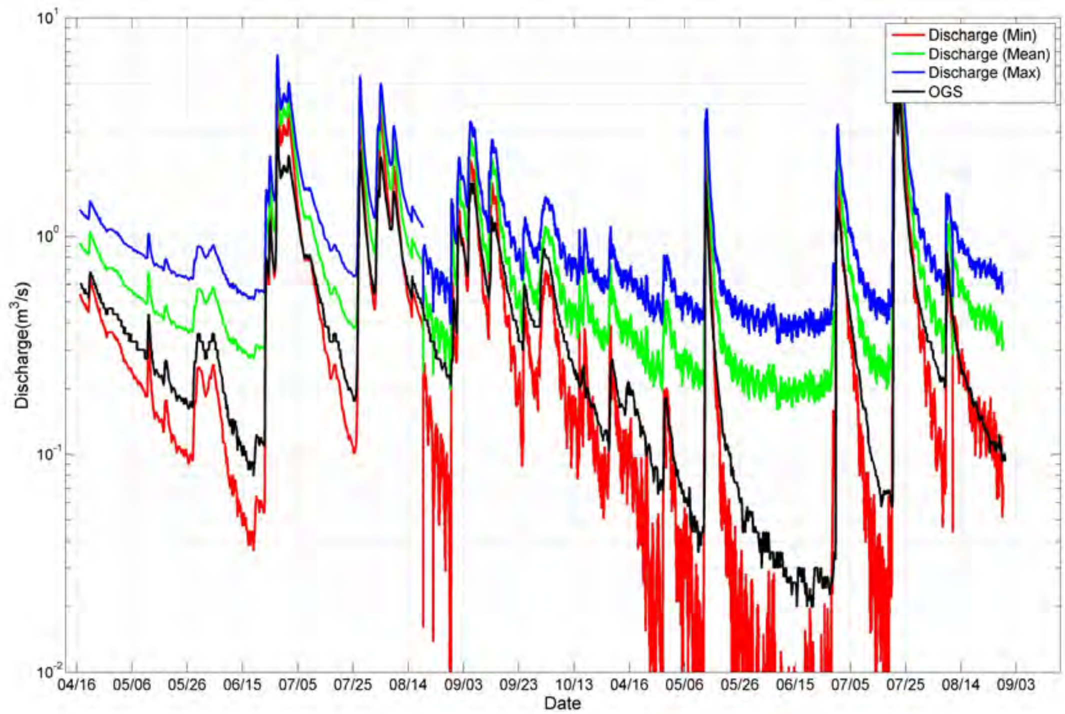

Figure A.6 The estimated flow at the Oyster River at Mill Pond dam is given along with flow at the upstream USGS gage. The upper lower bound estimates , and mean flow provide an approach to bracket the flow, and thus nutrient fluxes exported at the head of tide.

Appendix C:

Durham Residential Survey Results on Fertilizer Usage

DRAFT

Durham Lawn Care Attitude Survey

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The Survey Center

University of New Hampshire

November, 2013

The University of New Hampshire
Survey Center

The UNH Survey Center is an independent, non-partisan academic survey research organization and a division of the UNH College of Liberal Arts.

The Survey Center conducts telephone, mail, e-mail, Internet, and intercept surveys, as well as focus groups and other qualitative research for university researchers, government agencies, public non-profit organizations, private businesses, and media clients.

Our senior staff have over 40 years experience in designing and conducting custom research on a broad range of political, social, health care, and other public policy issues.

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Table of Contents

Executive Summary

The University of New Hampshire Survey Center conducted a survey for Woodard & Curran in conjunction with the Town of Durham Department of Public Works and VHB, designed to understand the lawn care practices and fertilizer use of Durham households. A random sample of four hundred seventy (470) Durham households was interviewed by telephone between October 24 and November 1, 2013. In each household the person with the most knowledge about how the property is taken care of was selected to be interviewed. The margin of sampling error for the survey is +/- 4.5%. (See Technical Report below for a more detailed description of survey methods.) The questionnaire used in the survey was developed jointly by the UNH Survey Center and Woodard & Curran with input from VHB and Town of Durham Department of Public Works. The following report highlights survey findings and displays survey results. Detailed tabular results can be found in Appendix A, Appendix B contains open-ended responses and Appendix C contains the survey instrument.

Major Findings

- Nearly one in four Durham households hires a lawn care service. The large majority of these households would be more likely to hire a service that is certified as "environmentally friendly."
- Fertilizer Use: Less than half of Durham households use fertilizer on their lawn (43%). Those who hire a lawn care service are more likely to have fertilizer applied. The amount of fertilizer used varies greatly among households with the most saying they apply fertilizer to their lawn twice a year (30%), use one bag each time they apply (37%), and typically buy 10 to 15 pound bags (30%).
- Fertilizer Behavior: Most determine how much fertilizer to use either by following the instructions on the bag or allowing the lawn care service to decide. More than two thirds (69%) of those who personally administer fertilizer to their lawn either always or usually apply it at the recommended rate. Very few throw away the fertilizer that is left over; nine in ten either use the whole fertilizer bag or store the rest for later use.
- Fertilizer Understanding: Only half of Durham households who use fertilizer know the current square footage of their lawn. But nearly all of those who do use this information to decide how much fertilizer to use. Three in five understand what the three numbers on the fertilizer bag mean.
- When considering whether to adopt environmentally friendly health care practices, households consider protecting the Great Bay and protecting the health of their pets and children to be the most important. Whether these new practices would result in their lawn looking the same as it does now and the practices fitting in easily with what they currently do are also moderately important. Over half of households (51%) are interested in acquiring more information on these practices.
- Friends and neighbors are the most used source for lawn care information while a University extension is considered the most trustworthy source by Durham households. The town newsletter or website is considered to be the most useful way to learn about issues in the community.
- The sample demographics vary somewhat from Durham's census totals. This is largely because the respondent was not a randomly selected member of the household. Instead, the household member with the most knowledge of how the property is cared for was selected to take the survey. This explains the larger amount of older and more educated respondents in the sample.

Sample Demographics

Age of Respondent	
18 to 34	5%
35 to 49	25%
50 to 64	35%
65 and Over	35%

Sex	
Male	48%
Female	52%

Children in Household	
No Children	66%
One Child	12%
Two Or More Children	22%

Highest Level of Education	
High School Or Less	5%
Technical School/Some College	9%
College Graduate	31%
Postgraduate	55%

Years Lived in Durham	
2 Years or Less	8%
3 to 5 Years	9%
6 to 10 Years	19%
11 to 20 Years	27%
20 or More Years	37%

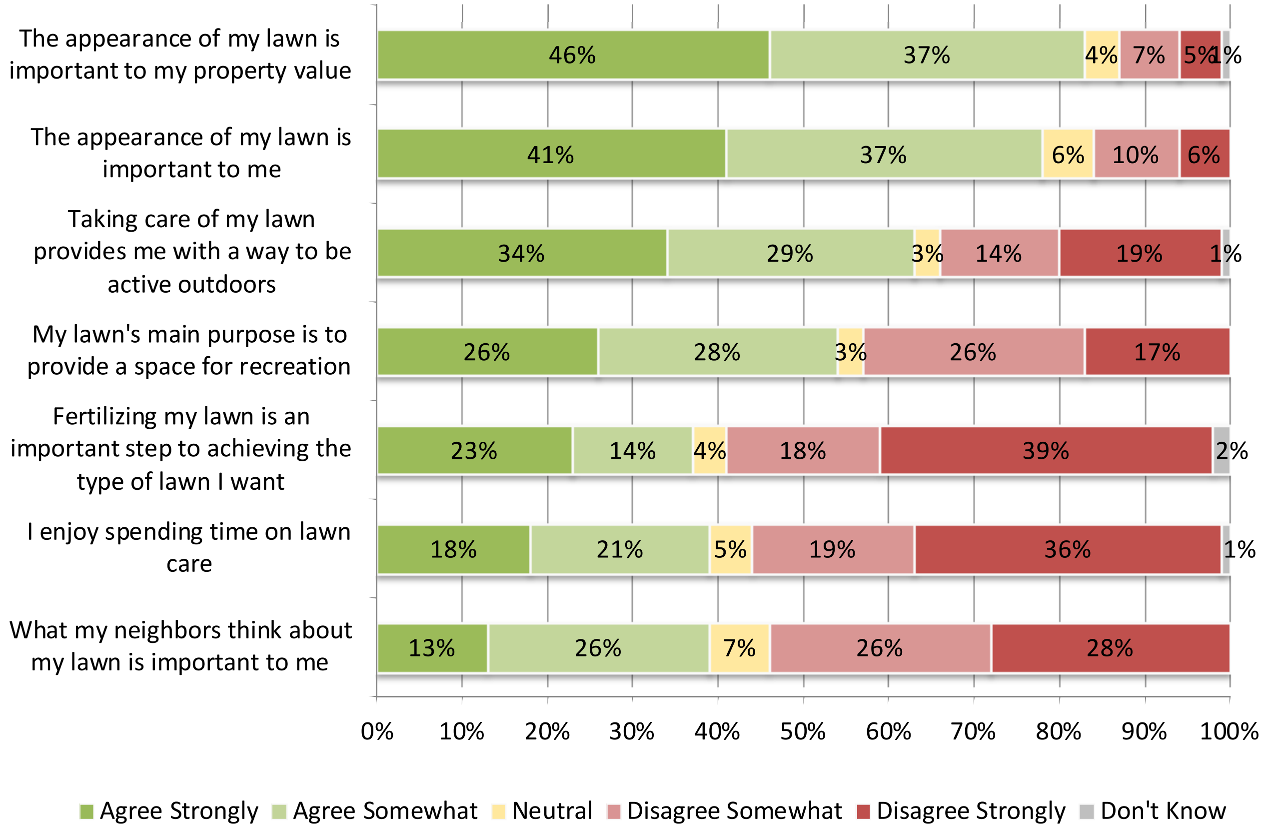
Perception About Lawn Care

Durham residents believe the appearance of their lawn is important to the value of their home and the appearance of their lawn is important to them personally. Residents to not especially enjoy taking care of their lawn nor do they think the use of fertilizer is important.

Almost half of Durham households (46%) strongly agree the appearance of their lawn is important to their property value, 41% strongly agree the appearance of their lawn is important to them, 34% strongly agree their lawn provides them with a way to be active outdoors and 26% strongly agree their lawn's main purpose is to provide a space for recreation. Less than a quarter of households strongly agree that fertilizing their lawn is an important step to achieving the type of lawn they want (23%), they enjoy spending time on lawn care (18%), and what their neighbors think about their lawn is important to them (13%).

- Non-college graduates are *more likely* to strongly agree <u>their lawn is important to their property value</u>.
- Non-college graduates and households who use a lawn care service are *more likely* to agree that <u>fertilizing their lawn is an important step in achieving the type of lawn they want</u>.
- Younger respondents (18 to 49) and households with children are *more likely* to agree <u>their lawn's main purpose is to provide space for recreation</u>.

Figure 1: Statements About Your Lawn

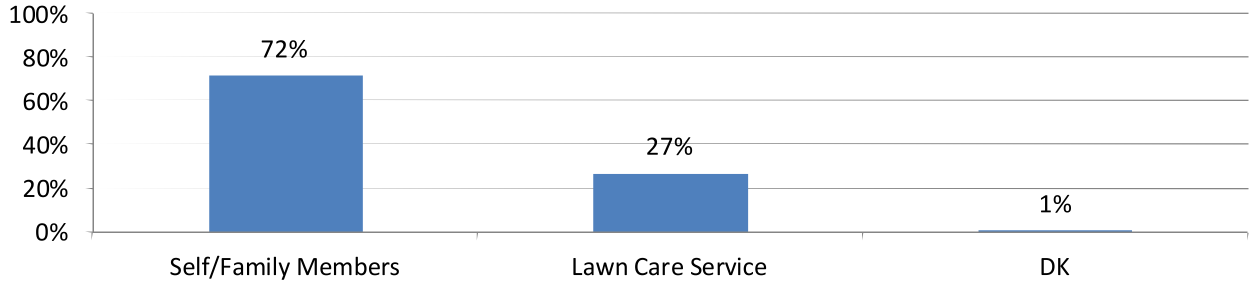


Lawn Care Services

Nearly three in four Durham households (72%) say someone in their household is responsible for taking care of their lawn, 27% hire a lawn care service and 1% are unsure.

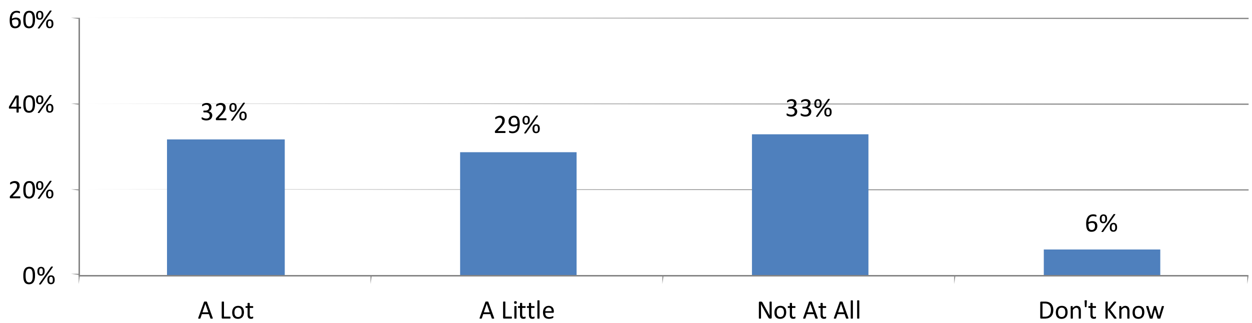
- Older respondents (65 and older) are *more likely* to hire a lawn care service to maintain their yard.

Figure 2: Who Maintains Your Lawn?



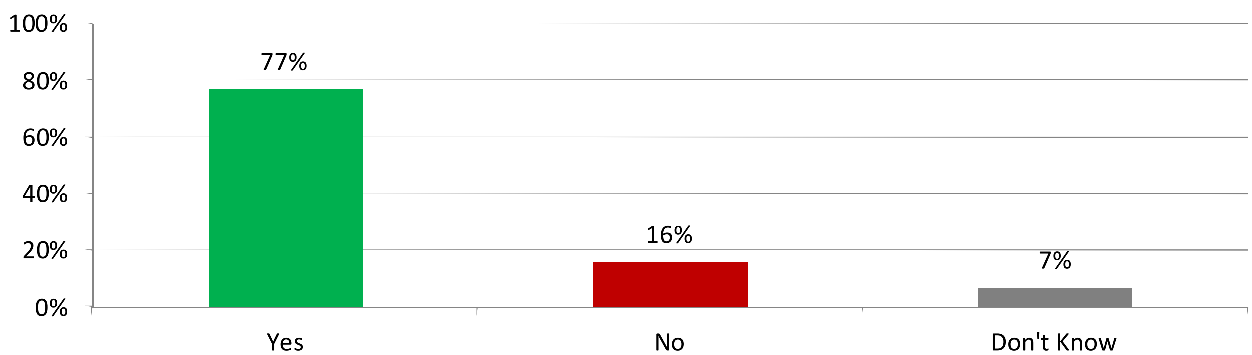
Of households who use a lawn care service, 32% say they direct the practices of the lawn care company a lot, 29% direct them a little, 33% don't direct them at all and 6% are unsure.

Figure 3: To what extent do you direct the lawn care company?



Of households who use a lawn care service, 77% say that they would be more likely to hire a lawn service company that was certified as environmentally friendly, 16% would not be more likely to hire them and 7% are unsure.

Figure 4: More likely to use an environmentally friendly lawn care service?

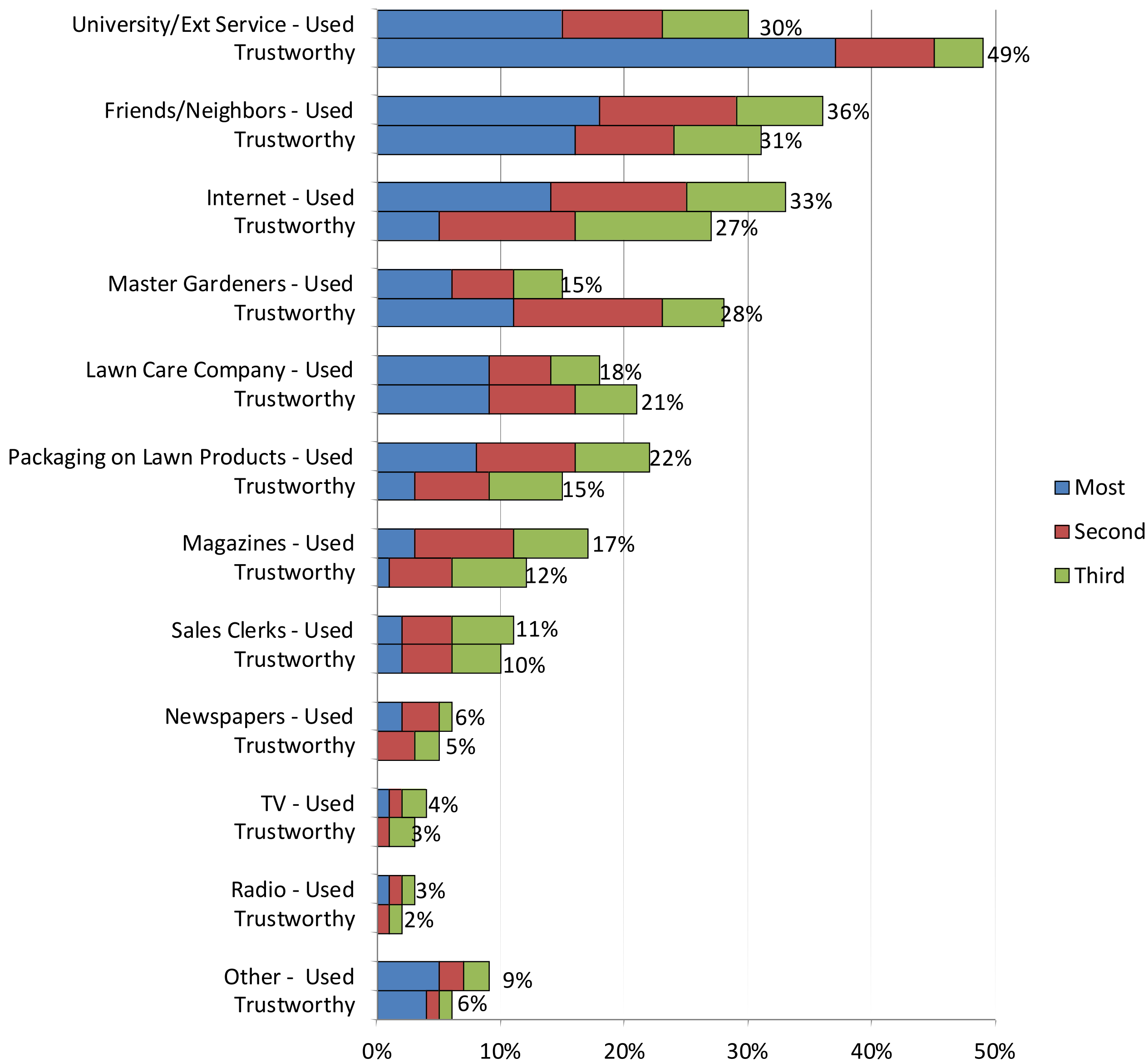


Information About Lawn Care

When asked what top three sources they get lawn care information from, 36% of households named their friends and neighbors, followed by the internet (33%), a university extension service (30%), the packaging on lawn care products (22%), the lawn care company (18%), magazines (17%), master gardeners (15%), sales clerks (11%), newspapers (6%), TV (4%), and radio (3%). There were also 9% who cited an "other" source.

When asked what sources are the most trustworthy, responses changed significantly as 49% said a university extension service, followed by friends and neighbors (31%), master gardeners (28%), the internet (27%), the lawn care company (21%), packaging on lawn care products (15%), magazines (12%), sales clerks (10%), newspapers (5%), TV (3%) and radio (2%). There were also 6% who cited an "other" source.

Figure 5: Most used/Trustworthy sources for lawn care information

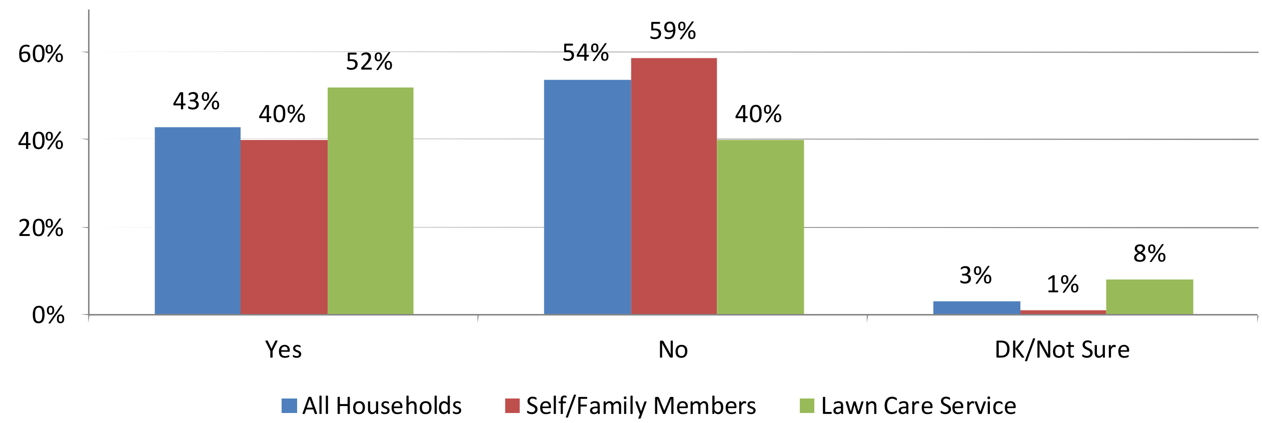


Fertilizer Use

Fertilizer usage in Durham is fairly widespread. Just under half of Durham households (43%) say fertilizer is used on their lawn, 54% don't use fertilizer and 3% were unsure.

- Households who use a lawn care service are *more likely* to use fertilizer on their lawn.

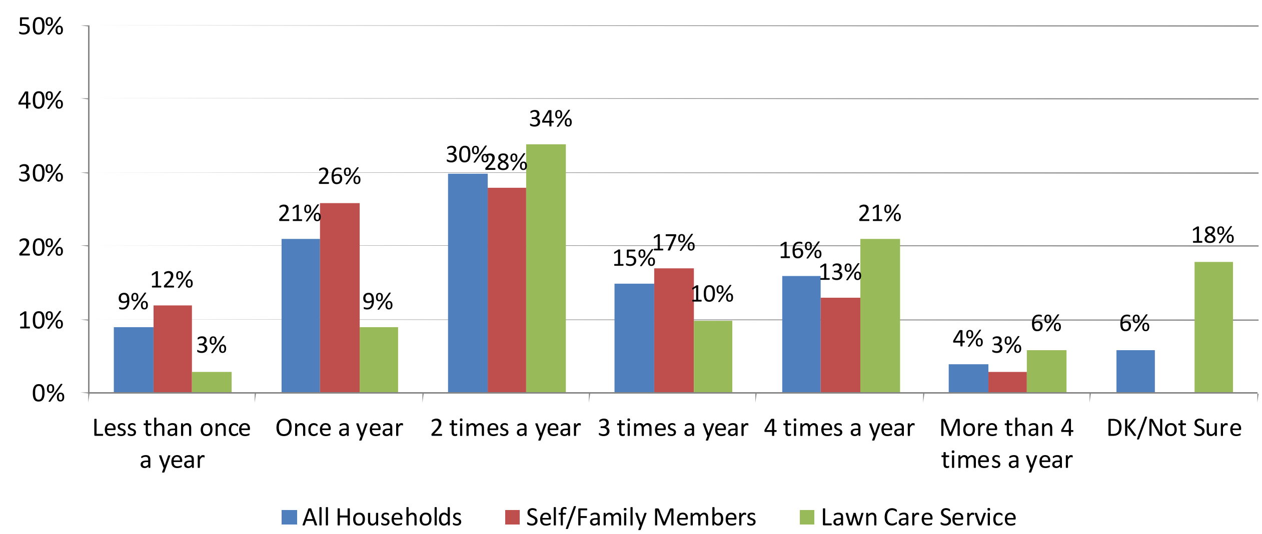
Figure 6: Is fertilizer put on your lawn?



Of households who use fertilizer on their lawn, 9% apply it less than once a year, 21% apply it once a year, 31% apply it twice a year, 15% apply it 3 times a year, 16% apply it 4 times a year, 3% apply it more than 4 times a year, and 6% are unsure.

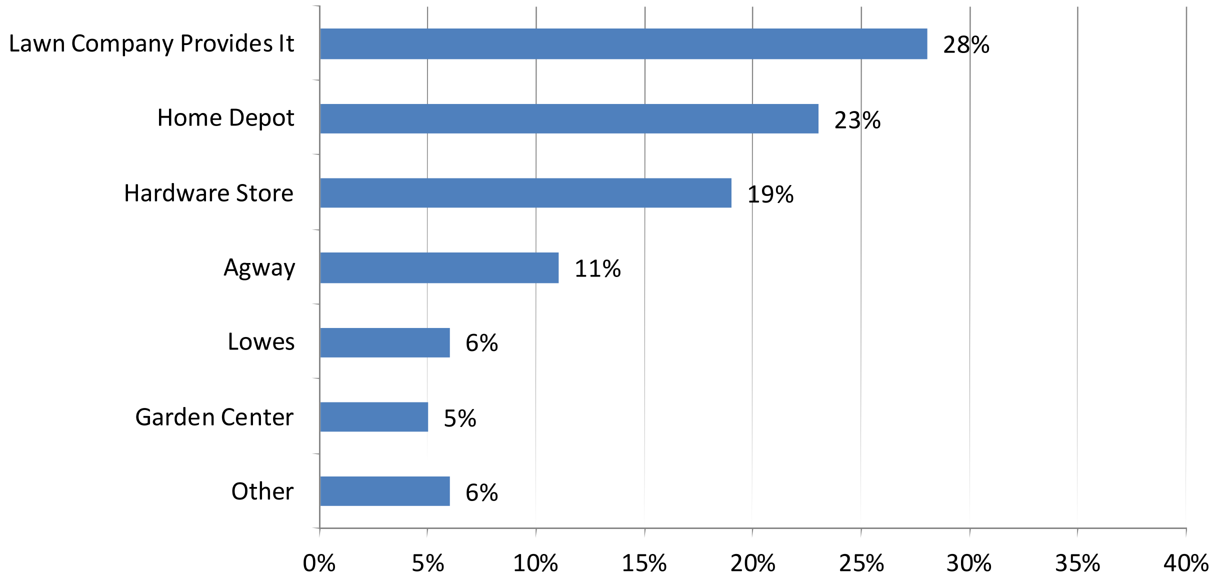
- Households who use a lawn care service are *more likely* to be unsure about how often fertilizer is put on their lawn.

Figure 7: How many times is fertilizer put on your lawn?



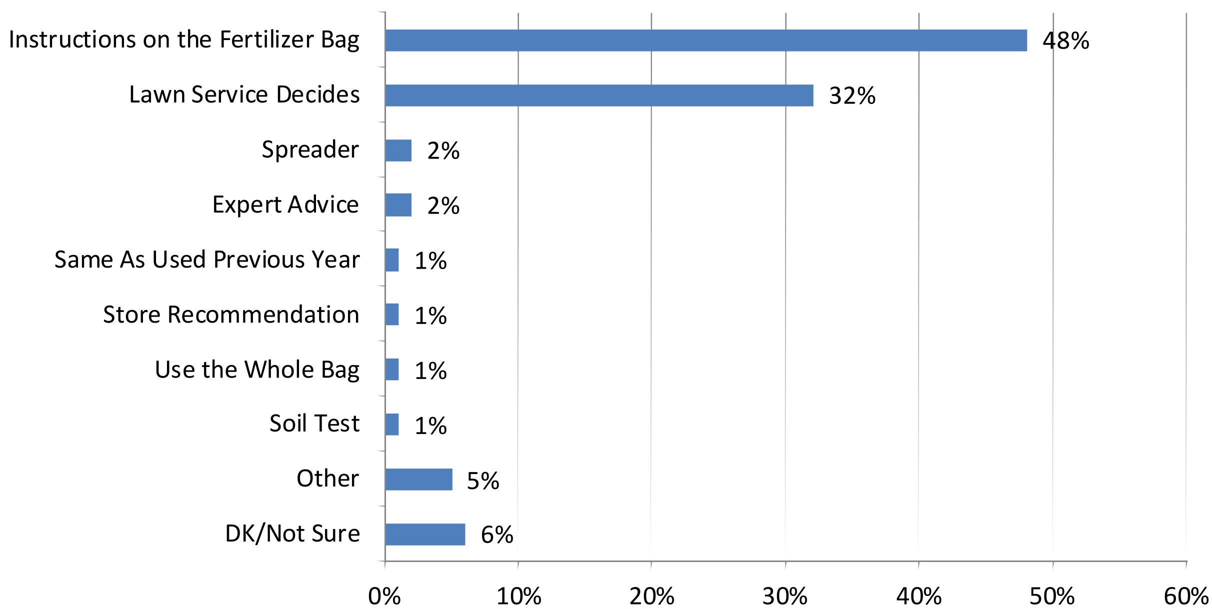
Of households who put fertilizer on their lawn, 28% say that their lawn company provides the fertilizer, 23% buy it at Home Depot, 19% at a hardware store, 11% at Agway, 6% at Lowe's and 5% at a garden store or center. There were also 6% who bought fertilizer at an "other" location.

Figure 8: Where do you typically buy fertilizer?



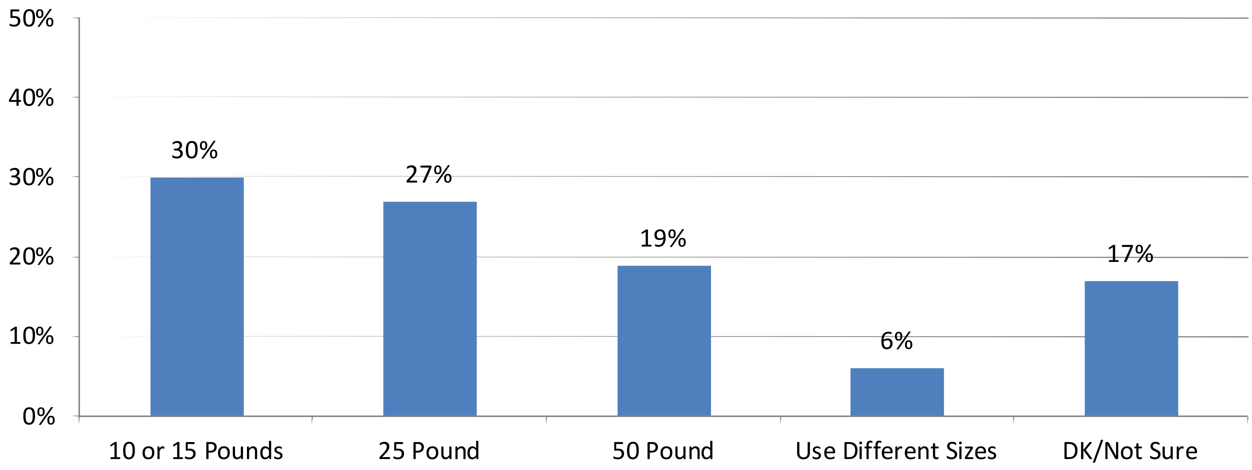
Of households who put fertilizer on their lawn, nearly half (48%) say that they decide how much from the instructions on the bag, 32% say the lawn service decides, 2% use expert advice, 2% use instructions from a spreader, 1% apply the same amount as the previous year, 1% use a store recommendation, 1% use the whole bag, 1% use a soil test, 5% use something else and 6% are unsure.

Figure 9: How do you decide how much fertilizer to apply to your lawn?



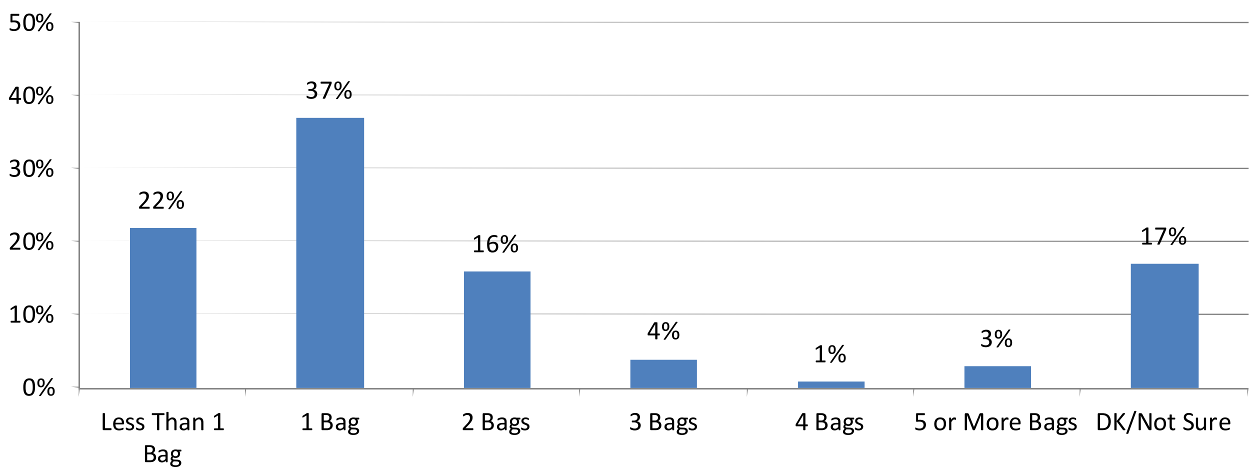
Three in ten (30%) households who put fertilizer on their lawn say that they typically buy 10-15 pound bags, 27% buy 25 pound bags, 19% buy 50 pound bags, 6% use different sizes and 17% are unsure.

Figure 10: What size bags of fertilizer do you typically buy?



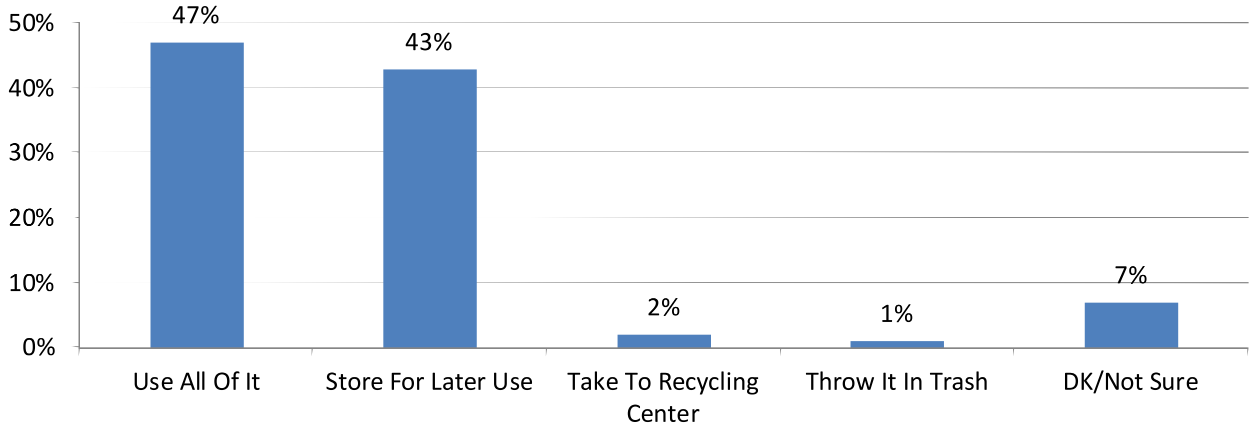
Most households who use fertilizer generally use a small amount– 22% use less than 1 bag, 37% use 1 bag, 16% use 2 bags, 4% use 3 bags, 1% use 4 bags, 3% use 5 or more bags and 17% are unsure.

Figure 11: How many bags of fertilizers do you typically use each time you fertilize your lawn?



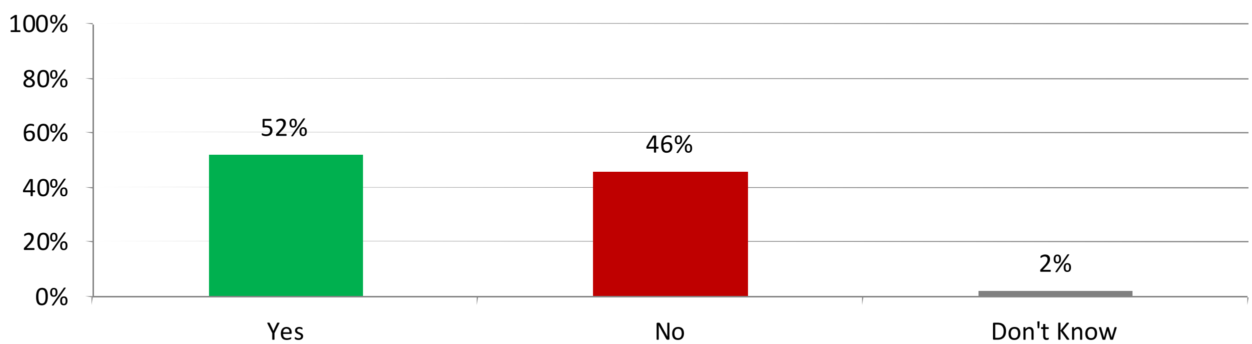
A plurality of households (47%) say they don't have left-over fertilizer because they use it all, 43% store it for later use, 2% take it to the recycling center, 1% throw it in the trash and 7% are unsure.

Figure 12: What do you do with the left-over fertilizer?



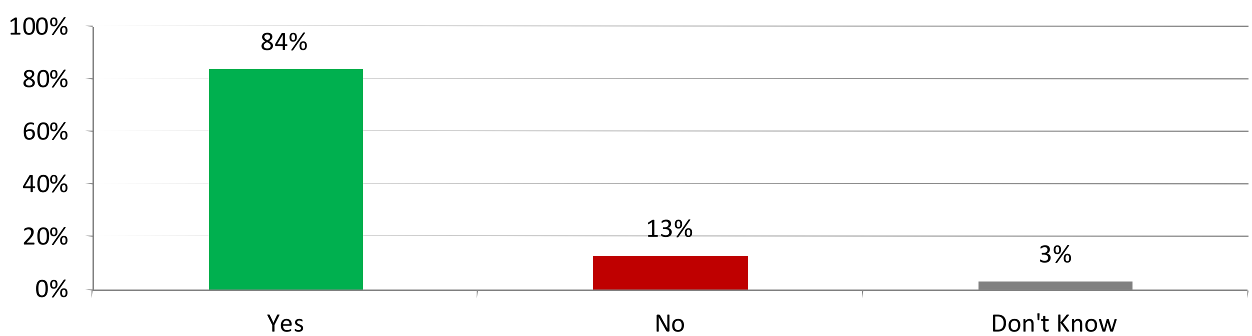
More than half of Durham households (52%) who fertilize their lawn say that they know the square footage of their lawn, 46% don't know it and 2% are unsure.

Figure 13: Do you know the square footage of your lawn?



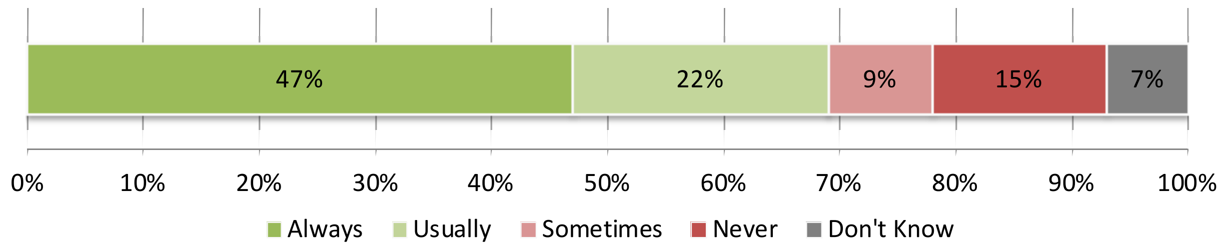
The large majority (84%) of those who know the square footage of their lawn use this information to account for the fertilizer application rate, 13% don't and 3% are unsure.

Figure 14: Do you use this information to account for fertilizer application rate?



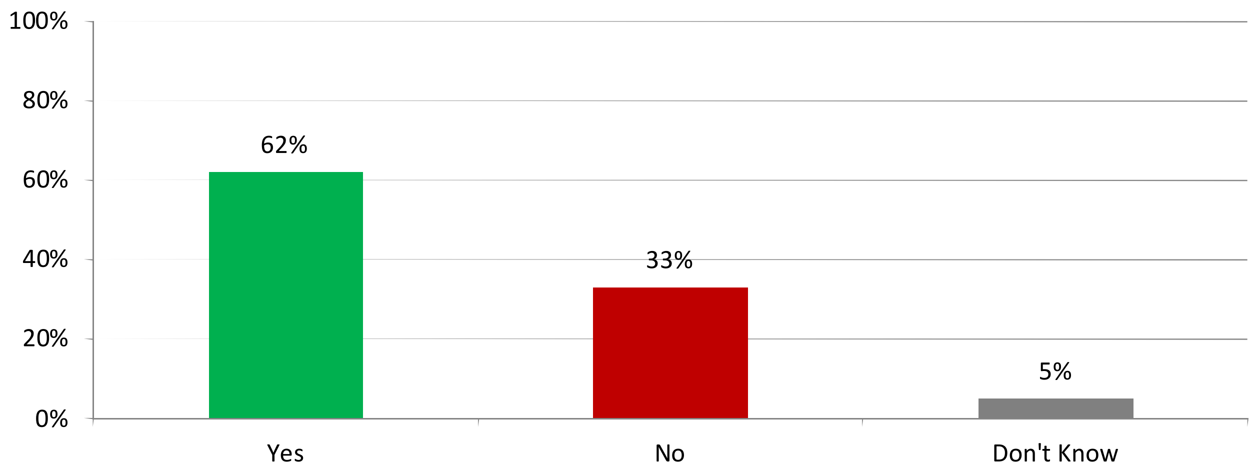
Most households who use fertilizer apply it at the recommended application rate – 47% say they always do, 22% usually do, 9% sometimes do, 15% never do and 7% are unsure.

Figure 15: How often do you apply fertilizer at the recommended application rate?



Three in five (62%) say they understand what the numbers on the fertilizer bag mean, 33% don't and 5% are unsure.

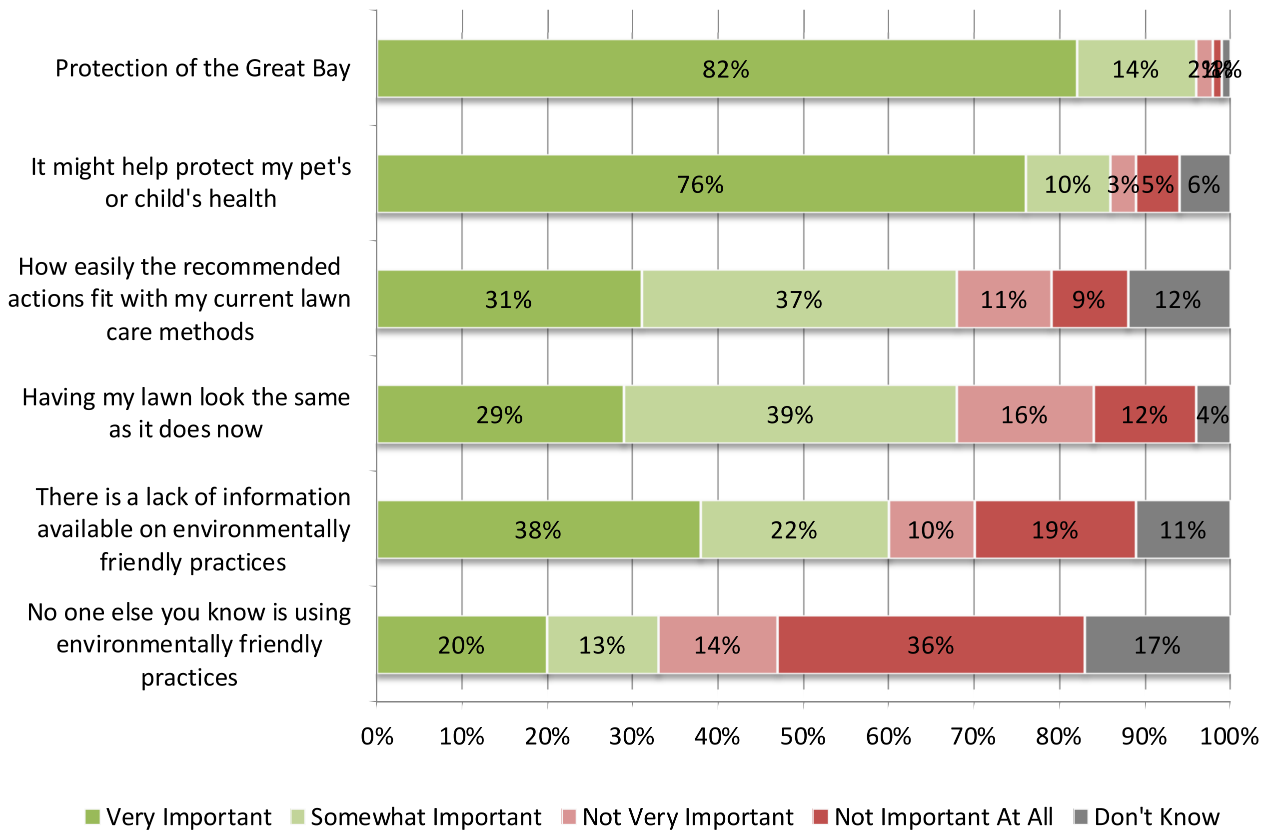
Figure 16: Do you understand what numbers on the fertilizer bag mean?



Choosing Environmentally Friendly Lawn Practices

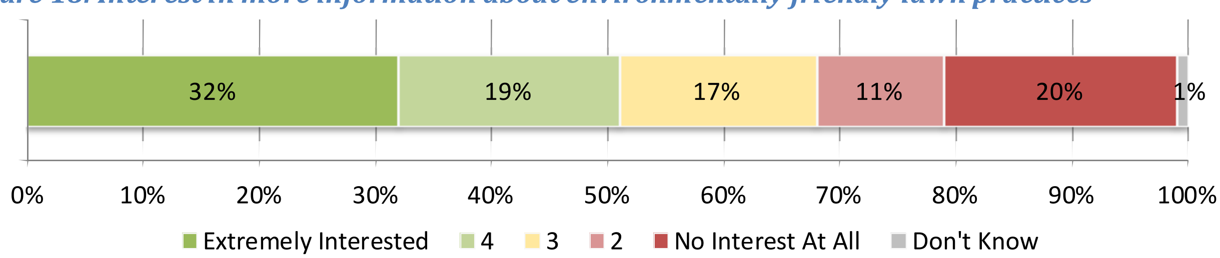
Almost all Durham households (96%) say that protecting the Great Bay is important (82% "very", 14% "somewhat") in choosing whether or not to adopt environmentally friendly lawn care practices. This was followed by potentially protecting the health of their pet or child (86%), how easily the recommended actions fit with their current lawn care methods (68%), having their lawn look the same as it does now (68%), and that there is a lack of information available on environmentally friendly practices (60%). Few Durham households (33%) find that no one they know is using environmentally friendly practices to be important in their consideration.

Figure 17: What is important in choosing to adopt environmentally friendly lawn care practices?



Over half of Durham households (51%) would be interested in acquiring more information about environmentally friendly lawn practices, 31% would not be interested and 18% are neutral or unsure.

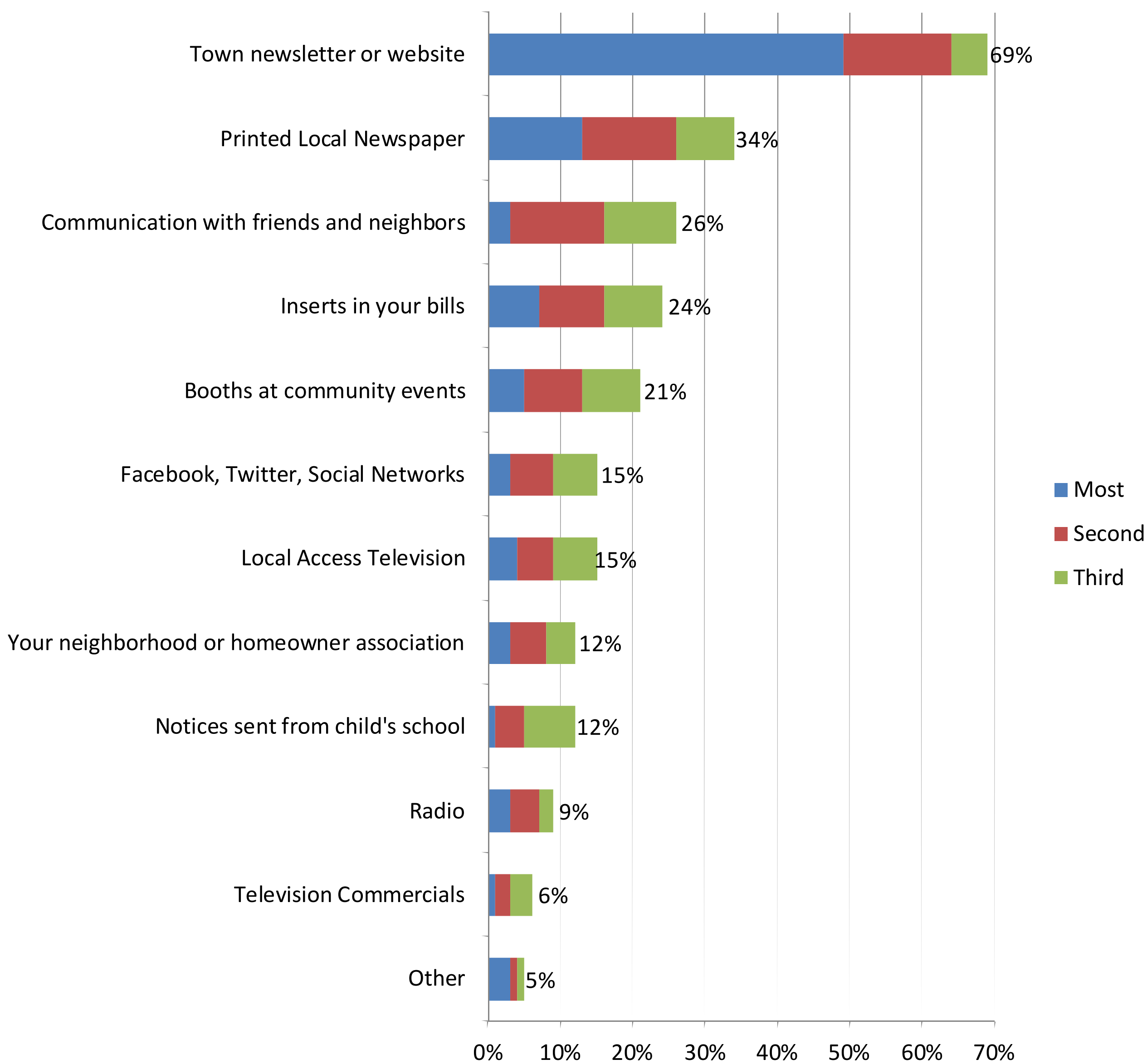
Figure 18: Interest in more information about environmentally friendly lawn practices



Ways To Receive Local Information

When asked the top three ways to learn about current issues in town, over two thirds (69%) of Durham households cite the town newsletter or website, followed by the newspaper (34%), communication with friends and neighbors (26%), inserts in their bills (24%), booths at community events (21%), Facebook, Twitter or other social networks (15%), local access television (15%), their neighborhood or homeowner association (12%), notices sent from their child's school (12%), radio (9%), and television commercials (6%). There were also 5% who cited another way.

Figure 19: Most useful ways to learn about issues in town



Technical Report

How the Sample Was Selected

The 2013 Durham Lawn Care Attitude Survey was a telephone survey of randomly selected households in the town of Durham. This survey was conducted using a procedure called Random Digit Dialing (RDD), of both landline and cellular telephone.

A sample of households in the area was selected by a procedure known as random digit dialing. The way this works is as follows. First, with the aid of a computer, one of the three digit telephone exchanges that are currently used in the town (e.g., 772) is randomly selected. The computer then randomly selects one of the "working blocks"--the first two of the last four numbers in a telephone number (e.g., 64)--and attaches it to the randomly selected exchange. Finally, the computer program then generates a two digit random number between 00 and 99 (e.g., 57) which is attached to the previously selected prefix (772), and the previously selected working block (64) resulting in a complete telephone number, i.e., 772 6457. This procedure is then repeated numerous times by the computer to generate more random numbers, so that we have a sufficient quantity to conduct the survey. The end result is that each household in the area in which there is a telephone has an equally likely chance of being selected into the sample. This procedure is done for both land line and cellular exchanges.

The random sample used in the survey was purchased from Scientific Telephone Samples (STS), Foothill Ranch, CA. STS screens each selected telephone number to eliminate non-working numbers, disconnected numbers, and business numbers to improve the efficiency of the sample, reducing the amount of time interviewers spend calling non-usable numbers.

Each of these randomly generated telephone numbers is called by one of our interviewers from a centrally supervised facility at the UNH Survey Center. If the number called is found not to be a residential one, it is discarded and another random number is called. If the person reached is found not to be a full-time resident of Durham, the number is also discarded. If it is a residential number in Durham, the interviewer then asks to speak with the adult currently living in the household who has the most knowledge about lawn care on the property. No substitutions are allowed. If, for example, the selected adult is not at home when the household is first contacted, the interviewer cannot substitute by selecting someone else who just happens to be there at the time. Instead, he or she must make an appointment to call back when the selected adult is at home. In this way, respondent selection bias is minimized.

When the Interviewing Was Done

Durham adults were interviewed between October 24 and November 1, 2013. Each selected respondent was called by a professional UNH Survey Center interviewer from a centrally supervised facility at the UNH Survey Center. Telephone calls during the field period were made between 9:00 AM and 9:00 PM.

Response Rates

Interviews were completed with 470 randomly selected adults in Durham from a sample of 3650 randomly selected telephone numbers. Using American Association for Public Opinion (AAPOR) Response Rate 4, the response rate for the 2013 Durham Lawn Survey was 44% percent. The formula to calculate standard AAPOR response rate is:

$$\frac{I}{(I+P)+(R+NC+O)+e(UH+UO)}$$

I=Complete Interviews, **P**=Partial Interviews, **R**=Refusal and break off, **NC**=Non-Contact, **O**=Other, **e**=estimated portion of cases of unknown eligibility that are eligible, **UH**=Unknown household, **UO**=Unknown other.

Weighting of Data

The data in the Durham Lawn Survey are weighted by the number of telephone numbers a household can be reached at in order to equalize the odds of any household being included in the survey.

Sampling Error

The Durham Lawn Survey, like all surveys, is subject to sampling error due to the fact that all households in the area were not interviewed. For those questions asked of five hundred (450) or so respondents, the error is +/-4.6%. For those questions where fewer than 450 persons responded, the sampling error can be calculated as follows:

$$Sampling\ Error = \pm 1.96\sqrt{\frac{P(1-P)}{N}}$$

Where P is the percentage of responses in the answer category being evaluated and N is the total number of persons answering the particular question.

For example, suppose you had the following distribution of answers to the question, "Should the state spend more money on road repair even if that means higher taxes?” Assume 1,000 respondents answered the question as follows:

YES	47%
NO	48%
DON'T KNOW	5%

The sampling error for the "YES" percentage of 47% would be

$$\pm 1.96\sqrt{\frac{47(53)}{1000}} = \pm 3.1\%$$

for the "NO" percentage of 48% it would be

$$\pm 1.96\sqrt{\frac{48(52)}{1000}} = \pm 3.1\%$$

and for the "DON'T KNOW" percentage of 5% it would be

$$\pm 1.96\sqrt{\frac{5(95)}{1000}} = \pm 1.4\%$$

In this case we would expect the true population figures to be within the following ranges:

YES	43.9% - 50.1% (i.e., 47% ±3.1%)
NO	44.9% - 51.1% (i.e., 48% ±3.1%)
DON'T KNOW	3.6% - 6.4% (i.e., 5% ±1.4%)

Appendix A: Detailed Tabular Results

Q1A: "Please tell me if you agree or disagree with the following statements:" "I enjoy spending time on lawn care."

	Agree Strongly	Agree Somewhat	Neutral	Disagree Somewhat	Disagree Strongly	DK/Not Sure	Number Responding
Durham Households	**18%**	**21%**	**5%**	**19%**	**36%**	**2%**	**462**
Age							
18 to 34	21%	28%	4%	17%	30%	0%	22
35 to 49	13%	26%	6%	21%	34%	1%	113
50 to 64	18%	23%	3%	18%	38%	1%	154
65 and over	20%	16%	6%	18%	37%	3%	155
Sex							
Male	19%	23%	5%	20%	32%	1%	226
Female	16%	20%	5%	18%	40%	2%	236
Lawn Caretaker							
Self/Family Members	20%	23%	5%	18%	33%	1%	339
Lawn Care Service	10%	18%	4%	20%	45%	3%	119
Education							
High school or less	18%	22%	4%	26%	16%	13%	21
Some college	33%	14%	5%	14%	34%	0%	38
College graduate	15%	24%	3%	20%	36%	2%	143
Post-graduate	17%	21%	6%	17%	38%	0%	252
Children in Household							
No children	19%	20%	4%	17%	37%	1%	298
One	21%	21%	0%	16%	41%	2%	53
Two or more	13%	26%	7%	19%	32%	2%	103
Years Lived in Durham							
2 years or less	8%	31%	5%	30%	27%	0%	37
3 to 5 years	23%	13%	7%	20%	36%	0%	40
6 to 10 years	17%	22%	1%	14%	40%	4%	84
11 to 20 years	19%	20%	5%	22%	34%	0%	125
20 or more years	18%	22%	6%	15%	38%	2%	170

Q1B: "The appearance of my lawn is important to me."

	Agree Strongly	Agree Somewhat	Neutral	Disagree Somewhat	Disagree Strongly	Number Responding
Durham Households	**41%**	**37%**	**6%**	**10%**	**6%**	**466**
Age						
18 to 34	55%	41%	0%	4%	0%	22
35 to 49	42%	42%	4%	7%	4%	113
50 to 64	32%	41%	6%	13%	9%	154
65 and over	45%	29%	8%	11%	7%	160
Sex						
Male	40%	39%	6%	9%	6%	225
Female	42%	35%	6%	10%	6%	241
Lawn Caretaker						
Self/Family Members	37%	38%	7%	10%	8%	338
Lawn Care Service	52%	33%	3%	9%	3%	126
Education						
High school or less	55%	30%	8%	4%	3%	22
Some college	55%	33%	5%	5%	2%	39
College graduate	45%	38%	4%	6%	7%	145
Post-graduate	36%	38%	6%	14%	7%	254
Children in Household						
No children	41%	34%	6%	12%	7%	304
One	40%	38%	7%	2%	14%	52
Two or more	40%	44%	5%	8%	3%	103
Years Lived in Durham						
2 years or less	28%	58%	9%	5%	0%	38
3 to 5 years	37%	44%	5%	5%	11%	41
6 to 10 years	43%	42%	2%	9%	4%	86
11 to 20 years	44%	34%	4%	11%	7%	127
20 or more years	41%	31%	8%	12%	7%	170

Q1C: "The appearance of my lawn is important to my property value."

	Agree Strongly	Agree Somewhat	Neutral	Disagree Somewhat	Disagree Strongly	DK/Not Sure	Number Responding
Durham Households	**46%**	**37%**	**4%**	**7%**	**5%**	**1%**	**466**
Age							
18 to 34	51%	46%	0%	0%	3%	0%	22
35 to 49	46%	41%	5%	5%	3%	0%	114
50 to 64	41%	39%	4%	8%	6%	2%	155
65 and over	53%	29%	3%	8%	6%	1%	158
Sex							
Male	49%	33%	5%	7%	5%	1%	226
Female	44%	40%	3%	6%	5%	1%	241
Lawn Caretaker							
Self/Family Members	42%	38%	5%	7%	7%	1%	340
Lawn Care Service	58%	33%	2%	6%	0%	2%	124
Education							
High school or less	71%	25%	4%	0%	0%	0%	21
Some college	71%	23%	0%	2%	4%	0%	39
College graduate	49%	33%	5%	7%	5%	1%	144
Post-graduate	38%	42%	4%	8%	5%	1%	255
Children in Household							
No children	47%	35%	4%	7%	5%	2%	302
One	48%	33%	3%	7%	9%	0%	54
Two or more	44%	44%	5%	5%	3%	0%	103
Years Lived in Durham							
2 years or less	30%	52%	7%	5%	6%	0%	39
3 to 5 years	53%	40%	2%	0%	5%	0%	40
6 to 10 years	53%	33%	4%	8%	3%	0%	86
11 to 20 years	40%	42%	5%	6%	5%	2%	127
20 or more years	50%	32%	3%	9%	6%	1%	170

Q1D: "Fertilizing my lawn is an important step to achieving the type of lawn I want."

	Agree Strongly	Agree Somewhat	Neutral	Disagree Somewhat	Disagree Strongly	DK/Not Sure	Number Responding
Durham Households	**23%**	**14%**	**4%**	**18%**	**39%**	**2%**	**462**
Age							
18 to 34	21%	25%	4%	20%	30%	0%	22
35 to 49	23%	14%	7%	13%	43%	1%	114
50 to 64	19%	16%	2%	22%	39%	1%	154
65 and over	26%	11%	4%	16%	40%	3%	155
Sex							
Male	24%	13%	3%	19%	39%	2%	225
Female	22%	16%	5%	16%	40%	1%	237
Lawn Caretaker							
Self/Family Members	20%	10%	4%	19%	45%	1%	338
Lawn Care Service	31%	26%	4%	15%	22%	3%	122
Education							
High school or less	38%	17%	0%	4%	24%	17%	22
Some college	36%	21%	2%	20%	21%	0%	39
College graduate	23%	13%	4%	23%	36%	2%	141
Post-graduate	20%	14%	5%	16%	45%	0%	253
Children in Household							
No children	24%	14%	3%	18%	39%	1%	298
One	24%	17%	0%	14%	42%	3%	54
Two or more	22%	14%	8%	16%	39%	1%	103
Years Lived in Durham							
2 years or less	20%	12%	5%	29%	35%	0%	39
3 to 5 years	21%	22%	2%	15%	40%	0%	41
6 to 10 years	20%	13%	10%	18%	38%	1%	85
11 to 20 years	26%	14%	1%	16%	41%	1%	125
20 or more years	24%	14%	3%	17%	39%	3%	167

Q1E: "What my neighbors think about my lawn is important to me."

	Agree Strongly	Agree Somewhat	Neutral	Disagree Somewhat	Disagree Strongly	DK/Not Sure	Number Responding
Durham Households	**13%**	**26%**	**7%**	**26%**	**28%**	**0%**	**465**
Age							
18 to 34	34%	21%	13%	25%	7%	0%	22
35 to 49	10%	33%	6%	22%	30%	0%	113
50 to 64	10%	25%	5%	28%	32%	0%	155
65 and over	15%	21%	7%	28%	28%	1%	158
Sex							
Male	11%	27%	6%	25%	30%	0%	225
Female	14%	25%	8%	26%	27%	1%	241
Lawn Caretaker							
Self/Family Members	11%	26%	7%	25%	30%	1%	339
Lawn Care Service	17%	27%	6%	28%	23%	0%	123
Education							
High school or less	37%	21%	0%	21%	21%	0%	22
Some college	17%	25%	10%	35%	9%	5%	39
College graduate	14%	25%	5%	28%	28%	0%	144
Post-graduate	9%	27%	8%	24%	32%	0%	254
Children in Household							
No children	13%	24%	7%	29%	28%	1%	302
One	6%	29%	14%	16%	35%	0%	53
Two or more	16%	33%	4%	23%	24%	0%	103
Years Lived in Durham							
2 years or less	11%	29%	5%	18%	37%	0%	38
3 to 5 years	22%	26%	11%	25%	16%	0%	41
6 to 10 years	11%	33%	3%	22%	31%	0%	85
11 to 20 years	10%	24%	7%	23%	34%	1%	127
20 or more years	14%	23%	8%	32%	24%	0%	170

Q1F: "My lawn's main purpose is to provide a space for recreation."

	Agree Strongly	Agree Somewhat	Neutral	Disagree Somewhat	Disagree Strongly	Number Responding
Durham Households	**26%**	**28%**	**3%**	**26%**	**16%**	**464**
Age						
18 to 34	49%	30%	0%	17%	4%	22
35 to 49	48%	36%	2%	6%	8%	114
50 to 64	23%	34%	6%	25%	12%	154
65 and over	12%	18%	2%	42%	26%	158
Sex						
Male	23%	29%	4%	30%	14%	225
Female	29%	27%	2%	23%	18%	240
Lawn Caretaker						
Self/Family Members	29%	28%	3%	24%	16%	338
Lawn Care Service	18%	29%	3%	33%	17%	124
Education						
High school or less	22%	22%	0%	47%	9%	21
Some college	37%	25%	2%	17%	18%	39
College graduate	32%	32%	5%	21%	10%	142
Post-graduate	21%	27%	3%	29%	20%	255
Children in Household						
No children	16%	25%	4%	35%	20%	300
One	28%	40%	2%	16%	14%	54
Two or more	56%	31%	3%	5%	5%	103
Years Lived in Durham						
2 years or less	25%	37%	7%	16%	14%	39
3 to 5 years	47%	24%	2%	11%	16%	40
6 to 10 years	28%	31%	5%	22%	14%	86
11 to 20 years	30%	29%	2%	28%	11%	125
20 or more years	18%	24%	3%	33%	22%	170

Q1G: "Taking care of my lawn provides me with a way to be active outdoors."

	Agree Strongly	Agree Somewhat	Neutral	Disagree Somewhat	Disagree Strongly	DK/Not Sure	Number Responding
Durham Households	**34%**	**29%**	**3%**	**14%**	**19%**	**1%**	**458**
Age							
18 to 34	38%	34%	0%	17%	11%	0%	22
35 to 49	29%	33%	4%	15%	18%	0%	113
50 to 64	33%	31%	3%	13%	19%	0%	153
65 and over	40%	24%	3%	12%	19%	2%	153
Sex							
Male	37%	28%	4%	12%	18%	1%	224
Female	32%	29%	3%	16%	20%	1%	234
Lawn Caretaker							
Self/Family Members	38%	31%	4%	13%	14%	0%	339
Lawn Care Service	24%	21%	1%	19%	32%	3%	116
Education							
High school or less	35%	26%	4%	9%	16%	9%	21
Some college	52%	31%	0%	2%	12%	2%	38
College graduate	31%	31%	5%	16%	16%	1%	143
Post-graduate	33%	28%	3%	15%	21%	0%	249
Children in Household							
No children	35%	29%	2%	13%	19%	1%	295
One	34%	25%	9%	12%	21%	0%	53
Two or more	35%	30%	5%	14%	17%	0%	103
Years Lived in Durham							
2 years or less	34%	28%	8%	17%	13%	0%	36
3 to 5 years	30%	23%	5%	25%	18%	0%	40
6 to 10 years	30%	33%	3%	11%	24%	0%	83
11 to 20 years	35%	29%	4%	16%	15%	0%	125
20 or more years	37%	29%	1%	10%	20%	2%	169

Q2: "Do you maintain your yard or does a hired lawn care service maintain your yard?"

	Self/Family Members	Lawn Care Service	DK/Not Sure	Number Responding
Durham Households	**73%**	**27%**	**1%**	**469**
Age				
18 to 34	66%	34%	0%	22
35 to 49	83%	17%	0%	114
50 to 64	78%	20%	1%	155
65 and over	62%	37%	1%	160
Sex				
Male	77%	22%	0%	226
Female	68%	31%	1%	243
Education				
High school or less	58%	42%	0%	22
Some college	64%	36%	0%	39
College graduate	76%	22%	2%	145
Post-graduate	73%	27%	0%	256
Children in Household				
No children	68%	31%	1%	305
One	85%	15%	0%	54
Two or more	80%	20%	0%	103
Years Lived in Durham				
2 years or less	65%	35%	0%	39
3 to 5 years	71%	29%	0%	41
6 to 10 years	71%	29%	0%	86
11 to 20 years	82%	18%	0%	127
20 or more years	70%	28%	2%	171

Q2B: “To what extent do you direct the practices of the landscape maintenance company, that is, how often they mow and what fertilizers or weed killers they use?”

	Not At All	A Little	A Lot	DK/Not Sure	Number Responding
Durham Households	**33%**	**29%**	**32%**	**6%**	**124**
Age					
18 to 34	25%	50%	25%	0%	7
35 to 49	24%	27%	34%	15%	19
50 to 64	24%	32%	38%	6%	32
65 and over	36%	28%	31%	5%	58
Sex					
Male	30%	31%	34%	6%	50
Female	35%	28%	32%	6%	74
Education					
High school or less	80%	20%	0%	0%	9
Some college	40%	27%	27%	7%	14
College graduate	34%	24%	35%	6%	32
Post-graduate	24%	34%	35%	7%	66
Children in Household					
No children	36%	29%	31%	4%	95
One	15%	55%	15%	15%	6
Two or more	23%	23%	41%	14%	21
Years Lived in Durham					
2 years or less	32%	20%	34%	14%	14
3 to 5 years	32%	53%	16%	0%	12
6 to 10 years	37%	19%	33%	11%	25
11 to 20 years	36%	36%	20%	8%	23
20 or more years	29%	29%	40%	2%	47

Q2C: "If a lawn service company was certified as 'environmentally friendly,' would you be more likely to hire them?"

	Yes	No	DK/Not Sure	Number Responding
Durham Households	**77%**	**16%**	**7%**	**124**
Age				
18 to 34	88%	0%	13%	7
35 to 49	80%	15%	5%	18
50 to 64	89%	11%	0%	32
65 and over	70%	19%	11%	59
Sex				
Male	65%	28%	8%	50
Female	85%	9%	6%	74
Education				
High school or less	67%	11%	22%	8
Some college	87%	13%	0%	14
College graduate	85%	9%	6%	31
Post-graduate	73%	20%	7%	68
Children in Household				
No children	79%	16%	6%	94
One	61%	13%	26%	7
Two or more	77%	18%	5%	21
Years Lived in Durham				
2 years or less	86%	14%	0%	14
3 to 5 years	91%	0%	9%	11
6 to 10 years	81%	19%	0%	24
11 to 20 years	85%	7%	8%	23
20 or more years	65%	23%	12%	49

Q3_1: Most used source for lawn care information

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**18%**	**2%**	**6%**	**1%**	**1%**	**9%**	**8%**	**3%**
Age								
18 to 34	34%	0%	4%	0%	0%	13%	3%	8%
35 to 49	18%	3%	3%	0%	0%	15%	8%	2%
50 to 64	18%	2%	7%	2%	2%	4%	13%	2%
65 and over	14%	1%	9%	1%	0%	10%	4%	4%
Sex								
Male	14%	3%	7%	1%	1%	9%	8%	2%
Female	21%	1%	5%	1%	0%	10%	8%	4%
Lawn Caretaker								
Self/Family Members	15%	2%	5%	1%	1%	6%	10%	4%
Lawn Care Service	25%	2%	9%	2%	0%	20%	2%	1%
Education								
High school or less	9%	9%	18%	4%	4%	9%	3%	9%
Some college	17%	0%	5%	5%	0%	5%	5%	5%
College graduate	15%	3%	5%	0%	1%	10%	10%	2%
Post-graduate	20%	1%	6%	1%	1%	10%	8%	2%
Children in Household								
No children	15%	2%	8%	1%	0%	9%	8%	4%
One	21%	0%	2%	0%	5%	4%	12%	4%
Two or more	22%	2%	4%	2%	0%	16%	5%	0%
Years Lived in Durham								
2 years or less	24%	0%	12%	0%	0%	5%	0%	0%
3 to 5 years	25%	0%	2%	0%	0%	7%	8%	5%
6 to 10 years	15%	2%	8%	2%	0%	17%	8%	0%
11 to 20 years	20%	2%	3%	2%	3%	7%	10%	2%
20 or more years	14%	2%	8%	1%	0%	10%	8%	5%

Q3_1: Most used source for lawn care information

	Newspapers	Internet	University or extension service	Other	None	DK/Not Sure	Number Responding
Durham Households	**2%**	**14%**	**15%**	**5%**	**13%**	**3%**	**454**
Age							
18 to 34	0%	21%	17%	0%	0%	0%	22
35 to 49	0%	23%	10%	7%	10%	3%	112
50 to 64	3%	13%	15%	5%	13%	2%	151
65 and over	3%	7%	18%	6%	16%	5%	153
Sex							
Male	3%	16%	14%	6%	15%	3%	222
Female	1%	12%	15%	5%	12%	3%	232
Lawn Caretaker							
Self/Family Members	3%	15%	13%	6%	17%	3%	332
Lawn Care Service	1%	9%	18%	4%	4%	3%	122
Education							
High school or less	0%	0%	13%	4%	18%	0%	21
Some college	5%	25%	18%	2%	7%	2%	39
College graduate	1%	12%	18%	6%	14%	3%	137
Post-graduate	2%	14%	13%	5%	13%	3%	250
Children in Household							
No children	3%	9%	16%	6%	15%	4%	292
One	2%	9%	21%	3%	16%	2%	52
Two or more	0%	28%	10%	5%	6%	1%	103
Years Lived in Durham							
2 years or less	4%	20%	14%	5%	15%	2%	38
3 to 5 years	0%	28%	16%	5%	5%	0%	40
6 to 10 years	0%	13%	15%	3%	13%	2%	83
11 to 20 years	3%	15%	14%	6%	9%	2%	123
20 or more years	3%	7%	14%	5%	18%	5%	165

Q3_2: Second most used source for lawn care information

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**11%**	**4%**	**5%**	**1%**	**0%**	**5%**	**8%**	**8%**
Age								
18 to 34	8%	8%	4%	0%	0%	4%	17%	0%
35 to 49	15%	6%	3%	2%	0%	4%	8%	10%
50 to 64	10%	5%	6%	1%	1%	7%	9%	11%
65 and over	9%	3%	7%	0%	0%	4%	6%	5%
Sex								
Male	7%	2%	4%	1%	0%	4%	10%	11%
Female	14%	6%	6%	1%	1%	6%	7%	5%
Lawn Caretaker								
Self/Family Members	9%	5%	3%	1%	1%	3%	10%	8%
Lawn Care Service	16%	2%	9%	1%	0%	10%	5%	6%
Education								
High school or less	9%	0%	4%	0%	0%	4%	0%	18%
Some college	14%	10%	5%	2%	0%	2%	17%	4%
College graduate	13%	7%	6%	1%	0%	7%	7%	4%
Post-graduate	8%	2%	4%	1%	1%	4%	8%	10%
Children in Household								
No children	9%	4%	6%	1%	0%	5%	7%	6%
One	13%	4%	2%	0%	2%	7%	9%	11%
Two or more	14%	6%	3%	2%	0%	4%	12%	11%
Years Lived in Durham								
2 years or less	2%	2%	7%	2%	0%	7%	10%	5%
3 to 5 years	14%	10%	0%	0%	0%	5%	12%	5%
6 to 10 years	16%	2%	4%	1%	0%	7%	11%	3%
11 to 20 years	9%	5%	5%	1%	1%	5%	9%	12%
20 or more years	10%	4%	6%	1%	0%	3%	6%	8%

Q3_2: Second most used source for lawn care information

	Newspapers	Internet	University or extension service	Other	None	DK/Not Sure	Number Responding
Durham Households	**3%**	**11%**	**8%**	**2%**	**34%**	**0%**	**454**
Age							
18 to 34	0%	28%	17%	4%	8%	0%	22
35 to 49	0%	13%	10%	0%	29%	1%	112
50 to 64	2%	13%	3%	1%	33%	0%	151
65 and over	7%	7%	9%	3%	41%	0%	153
Sex							
Male	3%	13%	5%	2%	37%	0%	222
Female	3%	10%	10%	1%	32%	0%	232
Lawn Caretaker							
Self/Family Members	2%	13%	7%	2%	36%	0%	332
Lawn Care Service	5%	7%	9%	1%	29%	0%	122
Education							
High school or less	4%	7%	4%	0%	49%	0%	21
Some college	2%	10%	5%	0%	29%	0%	39
College graduate	3%	12%	7%	1%	29%	1%	137
Post-graduate	3%	12%	9%	2%	36%	0%	250
Children in Household							
No children	4%	11%	7%	2%	37%	0%	292
One	0%	17%	1%	2%	34%	0%	52
Two or more	1%	9%	14%	0%	25%	1%	103
Years Lived in Durham							
2 years or less	5%	9%	14%	2%	34%	0%	38
3 to 5 years	2%	20%	12%	2%	18%	0%	40
6 to 10 years	2%	9%	9%	1%	33%	1%	83
11 to 20 years	2%	14%	6%	2%	30%	0%	123
20 or more years	4%	9%	6%	2%	41%	0%	165

Q3_3: Third most used source for lawn care information

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**7%**	**5%**	**4%**	**2%**	**1%**	**4%**	**6%**	**6%**
Age								
18 to 34	24%	0%	0%	4%	4%	0%	8%	8%
35 to 49	9%	3%	5%	2%	1%	6%	6%	10%
50 to 64	6%	5%	2%	3%	1%	3%	9%	4%
65 and over	5%	6%	5%	1%	0%	4%	5%	4%
Sex								
Male	8%	5%	1%	3%	1%	4%	5%	4%
Female	6%	4%	6%	2%	0%	4%	8%	7%
Lawn Caretaker								
Self/Family Members	7%	6%	2%	2%	0%	3%	8%	7%
Lawn Care Service	7%	2%	8%	3%	2%	6%	3%	3%
Education								
High school or less	9%	3%	0%	4%	0%	9%	4%	0%
Some college	17%	7%	6%	2%	0%	5%	5%	7%
College graduate	6%	3%	5%	4%	1%	3%	9%	9%
Post-graduate	7%	5%	2%	1%	1%	4%	5%	4%
Children in Household								
No children	7%	4%	4%	2%	1%	3%	6%	4%
One	2%	7%	7%	4%	0%	4%	4%	4%
Two or more	10%	4%	2%	3%	1%	6%	9%	10%
Years Lived in Durham								
2 years or less	7%	4%	7%	2%	0%	5%	7%	2%
3 to 5 years	16%	9%	5%	2%	2%	7%	5%	5%
6 to 10 years	5%	1%	2%	5%	0%	5%	8%	6%
11 to 20 years	6%	5%	6%	1%	1%	3%	7%	10%
20 or more years	7%	5%	1%	2%	1%	3%	6%	4%

Q3_3: Third most used source for lawn care information

	Newspapers	Internet	University or extension service	Other	None	DK/Not Sure	Number Responding
Durham Households	**1%**	**8%**	**7%**	**2%**	**47%**	**0%**	**457**
Age							
18 to 34	0%	4%	17%	0%	30%	0%	22
35 to 49	1%	8%	5%	2%	43%	0%	111
50 to 64	2%	10%	10%	3%	42%	0%	153
65 and over	1%	5%	5%	2%	56%	0%	154
Sex							
Male	1%	6%	8%	3%	51%	0%	222
Female	1%	9%	6%	2%	44%	0%	235
Lawn Caretaker							
Self/Family Members	1%	9%	8%	2%	47%	0%	331
Lawn Care Service	1%	7%	6%	4%	47%	1%	122
Education							
High school or less	0%	13%	0%	0%	57%	0%	21
Some college	0%	2%	0%	0%	48%	0%	39
College graduate	1%	10%	6%	2%	41%	1%	139
Post-graduate	1%	7%	9%	3%	49%	0%	250
Children in Household							
No children	1%	7%	7%	3%	50%	0%	295
One	0%	9%	14%	2%	46%	0%	52
Two or more	1%	10%	4%	2%	38%	0%	102
Years Lived in Durham							
2 years or less	0%	2%	9%	0%	51%	2%	38
3 to 5 years	0%	10%	14%	2%	23%	0%	40
6 to 10 years	1%	12%	4%	0%	52%	0%	82
11 to 20 years	2%	6%	8%	5%	41%	0%	123
20 or more years	1%	8%	6%	2%	54%	0%	168

Q3: Most used sources for lawn care information – combined

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**35%**	**11%**	**15%**	**4%**	**2%**	**18%**	**23%**	**16%**
Age								
18 to 34	66%	8%	8%	4%	4%	17%	28%	17%
35 to 49	42%	11%	10%	3%	1%	25%	23%	21%
50 to 64	34%	12%	14%	6%	4%	14%	30%	16%
65 and over	28%	10%	20%	2%	0%	18%	15%	14%
Sex								
Male	30%	10%	12%	4%	3%	17%	23%	16%
Female	41%	12%	17%	4%	1%	19%	23%	16%
Lawn Caretaker								
Self/Family Members	31%	13%	11%	3%	2%	12%	28%	19%
Lawn Care Service	48%	6%	26%	7%	2%	36%	10%	9%
Education								
High school or less	26%	12%	22%	9%	4%	22%	7%	26%
Some college	48%	17%	16%	10%	0%	12%	26%	16%
College graduate	34%	13%	16%	4%	2%	20%	26%	15%
Post-graduate	35%	8%	13%	3%	2%	18%	21%	16%
Children in Household								
No children	32%	11%	18%	3%	1%	17%	21%	14%
One	35%	10%	10%	4%	7%	14%	25%	18%
Two or more	45%	12%	9%	6%	1%	26%	26%	21%
Years Lived in Durham								
2 years or less	33%	7%	25%	5%	0%	17%	17%	7%
3 to 5 years	55%	19%	6%	2%	2%	19%	24%	14%
6 to 10 years	35%	6%	15%	8%	0%	28%	26%	9%
11 to 20 years	36%	13%	13%	3%	5%	15%	25%	24%
20 or more years	31%	11%	15%	3%	1%	16%	20%	17%

Q3: Most used sources for lawn care information – combined

	Newspapers	Internet	University or extension service	Other	None	DK/Not Sure	Number Responding
Durham Households	**6%**	**33%**	**29%**	**9%**	**94%**	**3%**	**458**
Age							
18 to 34	0%	54%	51%	4%	38%	0%	22
35 to 49	1%	45%	25%	8%	81%	3%	112
50 to 64	7%	35%	28%	9%	87%	2%	153
65 and over	11%	19%	33%	11%	113%	5%	154
Sex							
Male	7%	35%	27%	11%	102%	3%	223
Female	5%	31%	31%	8%	87%	3%	235
Lawn Caretaker							
Self/Family Members	6%	37%	28%	10%	99%	3%	332
Lawn Care Service	7%	22%	34%	8%	80%	4%	122
Education							
High school or less	4%	21%	18%	4%	124%	0%	21
Some college	7%	37%	23%	2%	85%	2%	39
College graduate	5%	32%	31%	9%	83%	4%	140
Post-graduate	7%	33%	31%	11%	98%	3%	250
Children in Household							
No children	8%	27%	29%	11%	101%	4%	295
One	2%	35%	37%	7%	95%	2%	52
Two or more	2%	47%	28%	6%	68%	2%	103
Years Lived in Durham							
2 years or less	9%	31%	37%	7%	100%	5%	38
3 to 5 years	2%	59%	42%	9%	45%	0%	40
6 to 10 years	3%	35%	28%	4%	98%	3%	83
11 to 20 years	7%	36%	28%	12%	80%	2%	123
20 or more years	7%	24%	26%	9%	113%	4%	168

Q4_1: Most trustworthy source for lawn care information

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**16%**	**2%**	**11%**	**0%**	**0%**	**9%**	**3%**	**1%**
Age								
18 to 34	17%	0%	13%	0%	0%	13%	8%	0%
35 to 49	20%	4%	8%	0%	0%	12%	2%	0%
50 to 64	16%	3%	14%	1%	1%	8%	4%	1%
65 and over	12%	1%	9%	0%	0%	6%	3%	3%
Sex								
Male	15%	3%	8%	1%	0%	10%	3%	1%
Female	17%	2%	13%	0%	0%	8%	3%	2%
Lawn Caretaker								
Self/Family Members	14%	3%	9%	0%	0%	6%	4%	2%
Lawn Care Service	22%	0%	15%	0%	0%	17%	2%	1%
Education								
High school or less	4%	3%	17%	0%	0%	17%	0%	4%
Some college	21%	0%	13%	0%	0%	7%	6%	5%
College graduate	17%	5%	11%	0%	0%	11%	5%	0%
Post-graduate	16%	2%	9%	0%	0%	7%	2%	1%
Children in Household								
No children	15%	2%	11%	0%	1%	9%	4%	2%
One	19%	5%	5%	0%	0%	2%	0%	2%
Two or more	15%	4%	12%	1%	0%	12%	2%	0%
Years Lived in Durham								
2 years or less	28%	0%	21%	0%	0%	0%	2%	2%
3 to 5 years	15%	2%	8%	0%	0%	0%	7%	0%
6 to 10 years	13%	5%	8%	0%	0%	19%	1%	0%
11 to 20 years	19%	3%	10%	0%	1%	8%	2%	2%
20 or more years	13%	2%	10%	1%	0%	8%	4%	1%

Q4_1: Most trustworthy source for lawn care information

	Newspapers	Internet	University or extension service	Other	None	DK/Not Sure	Number Responding
Durham Households	**0%**	**5%**	**37%**	**4%**	**6%**	**5%**	**450**
Age							
18 to 34	0%	3%	46%	0%	0%	0%	22
35 to 49	0%	8%	38%	4%	2%	3%	112
50 to 64	1%	4%	34%	5%	5%	4%	150
65 and over	0%	4%	38%	3%	11%	8%	151
Sex							
Male	1%	5%	38%	3%	6%	5%	219
Female	0%	5%	36%	4%	7%	5%	231
Lawn Caretaker							
Self/Family Members	1%	6%	39%	4%	8%	5%	330
Lawn Care Service	0%	2%	31%	3%	2%	5%	119
Education							
High school or less	0%	0%	25%	0%	21%	8%	22
Some college	0%	2%	37%	0%	2%	5%	39
College graduate	0%	5%	33%	3%	5%	5%	137
Post-graduate	1%	6%	41%	5%	6%	4%	245
Children in Household							
No children	1%	4%	35%	4%	8%	6%	288
One	0%	5%	48%	5%	7%	2%	52
Two or more	0%	9%	39%	4%	1%	2%	103
Years Lived in Durham							
2 years or less	0%	5%	35%	2%	5%	0%	39
3 to 5 years	0%	8%	50%	2%	5%	2%	41
6 to 10 years	0%	7%	37%	2%	6%	2%	80
11 to 20 years	2%	3%	34%	6%	5%	4%	122
20 or more years	0%	5%	36%	3%	9%	8%	163

Q4_2: Second most trustworthy source for lawn care information

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**8%**	**4%**	**12%**	**1%**	**1%**	**7%**	**6%**	**5%**
Age								
18 to 34	17%	13%	8%	0%	0%	4%	17%	8%
35 to 49	10%	4%	12%	2%	0%	10%	6%	2%
50 to 64	6%	4%	12%	2%	2%	6%	8%	6%
65 and over	8%	2%	14%	1%	0%	6%	3%	5%
Sex								
Male	7%	5%	13%	1%	1%	7%	5%	4%
Female	10%	3%	12%	2%	1%	7%	7%	5%
Lawn Caretaker								
Self/Family Members	8%	4%	11%	1%	1%	6%	8%	5%
Lawn Care Service	9%	5%	15%	2%	0%	8%	3%	3%
Education								
High school or less	30%	0%	0%	4%	4%	8%	4%	0%
Some college	5%	7%	17%	0%	0%	2%	7%	9%
College graduate	7%	5%	8%	2%	0%	8%	10%	5%
Post-graduate	8%	3%	15%	1%	1%	7%	5%	5%
Children in Household								
No children	7%	4%	15%	1%	0%	5%	5%	5%
One	8%	2%	6%	2%	4%	11%	4%	7%
Two or more	12%	5%	7%	3%	1%	10%	11%	3%
Years Lived in Durham								
2 years or less	0%	7%	2%	0%	0%	14%	5%	2%
3 to 5 years	9%	14%	15%	0%	0%	4%	2%	5%
6 to 10 years	14%	0%	13%	4%	0%	8%	12%	0%
11 to 20 years	8%	2%	15%	2%	2%	4%	7%	5%
20 or more years	7%	4%	11%	1%	1%	7%	5%	7%

Q4_2: Second most trustworthy source for lawn care information

	Newspapers	Internet	University or extension service	Other	None	Number Responding
Durham Households	**3%**	**11%**	**8%**	**1%**	**33%**	**450**
Age						
18 to 34	0%	4%	13%	4%	11%	22
35 to 49	1%	13%	8%	1%	33%	112
50 to 64	1%	14%	10%	0%	30%	150
65 and over	6%	7%	6%	1%	40%	151
Sex						
Male	2%	11%	7%	1%	36%	219
Female	3%	10%	9%	1%	31%	231
Lawn Caretaker						
Self/Family Members	2%	12%	7%	1%	34%	330
Lawn Care Service	4%	9%	11%	0%	32%	119
Education						
High school or less	0%	4%	4%	0%	41%	22
Some college	5%	12%	7%	0%	29%	39
College graduate	3%	11%	8%	1%	33%	137
Post-graduate	3%	10%	9%	1%	34%	245
Children in Household						
No children	4%	9%	9%	1%	35%	288
One	2%	14%	7%	2%	32%	52
Two or more	1%	12%	7%	0%	28%	103
Years Lived in Durham						
2 years or less	5%	9%	15%	5%	36%	39
3 to 5 years	0%	18%	5%	2%	26%	41
6 to 10 years	2%	11%	6%	0%	31%	80
11 to 20 years	2%	10%	9%	0%	33%	122
20 or more years	3%	9%	8%	0%	36%	163

Q4_3: Third most trustworthy source for lawn care information

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**7%**	**4%**	**5%**	**2%**	**1%**	**5%**	**6%**	**6%**
Age								
18 to 34	13%	0%	13%	4%	0%	0%	0%	17%
35 to 49	12%	3%	6%	0%	0%	5%	4%	8%
50 to 64	7%	4%	2%	3%	2%	4%	8%	5%
65 and over	3%	4%	7%	1%	1%	6%	4%	5%
Sex								
Male	5%	3%	6%	3%	1%	5%	6%	7%
Female	9%	4%	5%	1%	0%	5%	5%	5%
Lawn Caretaker								
Self/Family Members	6%	4%	5%	1%	1%	4%	6%	7%
Lawn Care Service	9%	3%	5%	4%	1%	7%	4%	5%
Education								
High school or less	4%	0%	13%	4%	0%	0%	0%	4%
Some college	7%	2%	5%	5%	0%	0%	2%	5%
College graduate	9%	4%	5%	2%	0%	5%	5%	5%
Post-graduate	6%	4%	5%	1%	2%	6%	7%	7%
Children in Household								
No children	4%	4%	5%	1%	1%	5%	6%	6%
One	10%	0%	4%	4%	0%	4%	7%	7%
Two or more	13%	5%	8%	2%	0%	5%	5%	5%
Years Lived in Durham								
2 years or less	7%	2%	10%	2%	0%	7%	5%	0%
3 to 5 years	18%	5%	5%	0%	0%	0%	4%	11%
6 to 10 years	8%	1%	8%	4%	0%	4%	6%	4%
11 to 20 years	4%	4%	4%	2%	2%	8%	5%	9%
20 or more years	5%	5%	4%	1%	1%	3%	6%	5%

Q4_3: Third most trustworthy source for lawn care information

	Newspapers	Internet	University or extension service	Other	None	DK/Not Sure	Number Responding
Durham Households	**2%**	**11%**	**4%**	**1%**	**48%**	**0%**	**453**
Age							
18 to 34	0%	25%	4%	0%	24%	0%	22
35 to 49	1%	9%	3%	0%	51%	0%	112
50 to 64	2%	13%	4%	1%	43%	0%	152
65 and over	3%	7%	4%	1%	54%	0%	152
Sex							
Male	3%	8%	2%	1%	50%	0%	220
Female	2%	13%	5%	0%	46%	0%	233
Lawn Caretaker							
Self/Family Members	3%	12%	3%	0%	48%	0%	330
Lawn Care Service	1%	7%	5%	2%	46%	1%	119
Education							
High school or less	0%	13%	4%	0%	58%	0%	22
Some college	2%	21%	5%	0%	46%	0%	39
College graduate	2%	9%	4%	1%	48%	1%	139
Post-graduate	3%	10%	3%	0%	48%	0%	245
Children in Household							
No children	3%	11%	4%	1%	49%	0%	290
One	0%	14%	0%	0%	50%	0%	52
Two or more	1%	8%	5%	0%	44%	0%	103
Years Lived in Durham							
2 years or less	2%	2%	5%	2%	52%	2%	39
3 to 5 years	0%	15%	2%	0%	40%	0%	41
6 to 10 years	2%	12%	5%	0%	47%	0%	80
11 to 20 years	1%	12%	2%	0%	48%	0%	122
20 or more years	4%	10%	5%	1%	49%	0%	166

Q4: Most trustworthy sources for lawn care information - combined

	Friends or neighbors	Sales Clerks	Certified Master Gardeners	TV	Radio	Lawn care company	Packaging on lawn care products	Magazines
Durham Households	**31%**	**10%**	**28%**	**3%**	**2%**	**20%**	**15%**	**12%**
Age								
18 to 34	46%	13%	34%	4%	0%	17%	25%	25%
35 to 49	41%	11%	26%	2%	0%	27%	12%	10%
50 to 64	29%	12%	27%	6%	5%	18%	20%	11%
65 and over	23%	8%	30%	2%	1%	17%	10%	13%
Sex								
Male	27%	11%	27%	4%	3%	21%	15%	13%
Female	35%	9%	29%	2%	1%	19%	15%	12%
Lawn Caretaker								
Self/Family Members	28%	11%	25%	2%	3%	16%	17%	14%
Lawn Care Service	41%	8%	35%	5%	1%	32%	9%	8%
Education								
High school or less	38%	3%	30%	8%	4%	25%	4%	8%
Some college	33%	10%	35%	5%	0%	10%	16%	18%
College graduate	33%	13%	24%	4%	0%	22%	19%	10%
Post-graduate	29%	9%	29%	2%	3%	20%	13%	13%
Children in Household								
No children	26%	10%	31%	2%	2%	18%	15%	13%
One	38%	7%	15%	5%	4%	16%	11%	16%
Two or more	40%	13%	27%	5%	1%	27%	17%	9%
Years Lived in Durham								
2 years or less	35%	10%	33%	2%	0%	21%	12%	5%
3 to 5 years	43%	20%	28%	0%	0%	4%	13%	16%
6 to 10 years	35%	6%	29%	7%	0%	31%	19%	4%
11 to 20 years	31%	9%	30%	3%	4%	21%	15%	17%
20 or more years	25%	11%	25%	2%	3%	18%	15%	13%

Q4: Most trustworthy sources for lawn care information - combined

	Newspapers	Internet	University or extension service	Other	None	DK/Not Sure	Number Responding
Durham Households	**5%**	**26%**	**48%**	**5%**	**88%**	**5%**	**453**
Age							
18 to 34	0%	32%	63%	4%	35%	0%	22
35 to 49	2%	30%	48%	5%	85%	3%	112
50 to 64	5%	31%	46%	6%	78%	4%	152
65 and over	10%	18%	49%	5%	105%	8%	152
Sex							
Male	6%	25%	47%	5%	92%	6%	220
Female	5%	28%	49%	5%	84%	5%	233
Lawn Caretaker							
Self/Family Members	5%	30%	49%	5%	90%	5%	330
Lawn Care Service	5%	18%	47%	5%	80%	6%	119
Education							
High school or less	0%	17%	34%	0%	120%	8%	22
Some college	7%	35%	49%	0%	78%	5%	39
College graduate	5%	25%	44%	6%	84%	6%	139
Post-graduate	6%	26%	53%	6%	88%	4%	245
Children in Household							
No children	7%	24%	47%	5%	92%	7%	290
One	2%	34%	55%	7%	89%	2%	52
Two or more	2%	29%	51%	4%	73%	2%	103
Years Lived in Durham							
2 years or less	6%	16%	55%	10%	93%	2%	39
3 to 5 years	0%	42%	57%	5%	70%	2%	41
6 to 10 years	5%	29%	47%	2%	84%	2%	80
11 to 20 years	5%	25%	45%	6%	86%	4%	122
20 or more years	7%	24%	48%	5%	94%	8%	166

Q5: "Do you (DOES YOUR LAWN CARE COMPANY) put fertilizer on your lawn?"

	Yes	No	DK/Not Sure	Number Responding
Durham Households	**43%**	**54%**	**3%**	**466**
Age				
18 to 34	20%	76%	4%	22
35 to 49	47%	52%	1%	114
50 to 64	44%	54%	1%	154
65 and over	41%	53%	6%	159
Sex				
Male	44%	54%	2%	225
Female	43%	54%	3%	241
Lawn Caretaker				
Self/Family Members	40%	59%	1%	340
Lawn Care Service	52%	40%	8%	126
Education				
High school or less	68%	32%	0%	22
Some college	39%	56%	5%	39
College graduate	42%	56%	2%	142
Post-graduate	43%	54%	3%	256
Children in Household				
No children	44%	52%	4%	302
One	42%	58%	0%	54
Two or more	45%	53%	2%	103
Years Lived in Durham				
2 years or less	40%	55%	5%	39
3 to 5 years	31%	66%	2%	41
6 to 10 years	47%	51%	2%	86
11 to 20 years	45%	51%	4%	127
20 or more years	44%	54%	2%	169

Q6: "About how many times a year do you (does your lawn care company) put fertilizer on your lawn?"

	Less than once a year	Once a year	Twice a year	Three times a year	Four times a year	More than four times a year	Depends	DK/Not Sure	Number Responding
Durham Households	**9%**	**21%**	**30%**	**15%**	**16%**	**4%**	**0%**	**6%**	**202**
Age									
18 to 34	0%	36%	0%	0%	21%	0%	0%	43%	4
35 to 49	10%	12%	36%	23%	16%	2%	0%	2%	54
50 to 64	12%	24%	28%	15%	11%	7%	0%	4%	68
65 and over	6%	26%	32%	11%	17%	3%	0%	5%	65
Sex									
Male	8%	18%	26%	19%	18%	6%	0%	5%	99
Female	10%	23%	33%	10%	13%	3%	1%	7%	103
Lawn Caretaker									
Self/Family Members	12%	26%	28%	17%	13%	3%	1%	0%	137
Lawn Care Service	3%	9%	34%	10%	21%	6%	0%	18%	65
Education									
High school or less	13%	31%	6%	6%	19%	0%	0%	25%	15
Some college	6%	27%	37%	6%	12%	12%	0%	0%	15
College graduate	9%	19%	24%	11%	22%	3%	0%	11%	59
Post-graduate	8%	19%	36%	19%	12%	4%	0%	1%	111
Children in Household									
No children	9%	24%	25%	13%	17%	4%	1%	7%	133
One	4%	17%	46%	13%	8%	8%	0%	4%	22
Two or more	10%	14%	38%	20%	12%	2%	0%	4%	46
Years Lived in Durham									
2 years or less	0%	12%	43%	18%	12%	0%	0%	16%	16
3 to 5 years	0%	22%	22%	20%	22%	7%	0%	7%	13
6 to 10 years	12%	12%	42%	16%	9%	2%	0%	7%	40
11 to 20 years	8%	23%	23%	13%	19%	7%	0%	7%	57
20 or more years	11%	26%	28%	14%	15%	4%	0%	3%	74

Q7: "Where do you typically buy fertilizer?"

	Home Depot	Agway	Lowes	Hardware Store	Garden Center	Lawn Company Provides It	Other	DK/ Refused	Number Responding
Durham Households	**23%**	**11%**	**6%**	**19%**	**5%**	**28%**	**6%**	**14%**	**203**
Age									
18 to 34	0%	0%	0%	36%	0%	43%	21%	0%	4
35 to 49	24%	16%	7%	17%	3%	31%	3%	9%	54
50 to 64	25%	5%	6%	22%	7%	22%	8%	14%	68
65 and over	20%	16%	6%	18%	4%	27%	7%	17%	65
Sex									
Male	27%	13%	8%	19%	2%	26%	7%	11%	99
Female	20%	9%	4%	18%	8%	29%	6%	16%	104
Education									
High school or less	0%	13%	0%	6%	6%	31%	19%	25%	15
Some college	29%	6%	0%	20%	6%	31%	12%	6%	15
College graduate	26%	14%	8%	21%	3%	33%	5%	7%	59
Post-graduate	25%	10%	6%	20%	5%	25%	5%	15%	111
Children in Household									
No children	23%	11%	5%	18%	5%	27%	8%	14%	133
One	29%	21%	8%	25%	8%	17%	0%	8%	22
Two or more	21%	8%	7%	19%	4%	35%	6%	10%	46
Years Lived in Durham									
2 years or less	20%	0%	6%	16%	16%	29%	0%	24%	16
3 to 5 years	27%	15%	12%	0%	0%	29%	7%	15%	13
6 to 10 years	19%	9%	2%	5%	5%	42%	7%	14%	40
11 to 20 years	26%	11%	5%	26%	2%	25%	8%	11%	57
20 or more years	25%	14%	8%	26%	5%	23%	6%	11%	74

Q8: "How do you typically decide how much fertilizer to use when you apply it to your lawn?"

	Lawn Service Decides	Same As Used Last Year	Store Recommendation	Instructions On Bag	Use The Whole Bag	Expert Advice	Soil Test	Other	Spreader	DK/Not Sure	Number Responding
Durham Households	**32%**	**1%**	**1%**	**48%**	**1%**	**2%**	**1%**	**5%**	**2%**	**6%**	**200**
Age											
18 to 34	43%	0%	0%	14%	0%	21%	0%	0%	0%	21%	4
35 to 49	28%	2%	2%	53%	2%	0%	2%	8%	0%	4%	53
50 to 64	30%	0%	0%	51%	0%	3%	3%	7%	3%	4%	68
65 and over	35%	1%	3%	44%	2%	1%	0%	3%	1%	9%	65
Sex											
Male	28%	1%	3%	52%	1%	2%	3%	5%	2%	4%	99
Female	35%	1%	0%	44%	2%	2%	0%	6%	3%	8%	101
Lawn Caretaker											
Self/Family Members	12%	1%	2%	65%	2%	2%	1%	8%	3%	3%	137
Lawn Care Service	74%	0%	0%	11%	0%	1%	1%	0%	0%	12%	63
Education											
High school or less	38%	0%	0%	13%	0%	0%	0%	19%	6%	25%	15
Some college	31%	0%	0%	47%	0%	0%	0%	10%	0%	12%	15
College graduate	37%	3%	5%	43%	2%	2%	0%	3%	3%	3%	59
Post-graduate	28%	0%	0%	55%	1%	3%	3%	4%	2%	4%	109
Children in Household											
No children	34%	1%	1%	43%	2%	2%	1%	6%	4%	7%	132
One	21%	0%	0%	58%	0%	4%	8%	4%	0%	4%	22
Two or more	31%	2%	2%	55%	0%	0%	0%	6%	0%	4%	45
Years Lived in Durham											
2 years or less	53%	0%	0%	29%	0%	0%	6%	0%	6%	6%	16
3 to 5 years	29%	0%	0%	49%	0%	0%	7%	15%	0%	0%	13
6 to 10 years	50%	2%	2%	31%	2%	0%	0%	7%	0%	5%	39
11 to 20 years	22%	0%	0%	52%	2%	7%	2%	6%	5%	5%	56
20 or more years	26%	1%	3%	56%	1%	0%	0%	4%	1%	9%	74

Q9: "What size bags do you typically buy … 10-15 pound bags … 25 pound bags … or 50 pound bags?"

	10 or 15 Pounds	25 Pound	50 Pound	Use Different Sizes	DK/Not Sure	Number Responding
Durham Households	**30%**	**27%**	**19%**	**6%**	**17%**	**135**
Age						
18 to 34	0%	40%	0%	0%	60%	2
35 to 49	29%	38%	18%	0%	15%	42
50 to 64	34%	21%	20%	6%	18%	46
65 and over	26%	25%	16%	14%	18%	41
Sex						
Male	26%	23%	27%	8%	16%	71
Female	34%	32%	11%	4%	19%	64
Education						
High school or less	29%	14%	14%	29%	14%	7
Some college	32%	7%	32%	11%	18%	9
College graduate	20%	33%	23%	5%	18%	41
Post-graduate	34%	28%	16%	5%	17%	78
Children in Household						
No children	32%	22%	19%	9%	18%	84
One	32%	37%	16%	5%	11%	18
Two or more	24%	36%	21%	0%	19%	34
Years Lived in Durham						
2 years or less	36%	41%	9%	0%	14%	7
3 to 5 years	52%	26%	9%	13%	0%	7
6 to 10 years	24%	40%	20%	0%	16%	23
11 to 20 years	27%	26%	20%	5%	22%	41
20 or more years	30%	21%	21%	10%	17%	55

Appendix B: Open-Ended Responses

Q2A: What is the name of the landscape company or lawn care service that takes care of your yard?

- Landcare (12)
- Elfs Landscaping (9)
- Neighbor/Friend (8)
- John's Landscaping of Madbury (6)
- Rivet Landscaping (6)
- Lawn Dogs (5)
- Allegro Lawn (4)
- Crown Point Landscaping (4)
- J & D Enterprises (3)
- True Green (3)
- Great Cove Landscaping (2)
- John Crooks (2)
- Juniper Hill (2)
- Mainly Grass (2)
- Make a Difference landscaping (2)
- O'Malley Landscaping (2)
- Rick Fritsch Landscaping (2)
- Simply Green (2)
- T & T (2)
- Waitt's Landscaping (2)
- Chemlawn
- LJH landscape
- Long Marsh Lawn Care
- Mike Mandu
- Moe's
- Organics
- Richard Frederickson
- Rick Orcatt
- Scott Seegal
- Toms Landscaping
- Vachon Landscaping

Q3: Please tell me which sources you use to get information about lawn care the most often? (Other responses)

- My Experience (8)
- Books (4)
- Family (3)
- Garden Centers (2)
- I just do it myself (2)
- Is a plant scientist, has own knowledge (2)
- Self-knowledge (2)
- All the information I get is from the condo meetings
- Blue bell nursery

- Common sense
- Daughter who is landscape architect
- Father
- Father in law is a landscaper
- Getting numbers in community
- His own research
- I don’t go looking for it
- Mail
- Many years of information sought by myself
- Mother earth
- My husband brings most of the stuff home
- Personal observation throughout the neighborhood
- She reads a lot, she says she just "knows"
- Self-informed - trial and error
- Traditional of how it’s been passed down from generation
- We don’t really do much as far as the lawn itself
- Worked at a nursery for 15 years

Q4: Which do you think are the most trustworthy sources? (Other responses)

- My experience (2)
- family (4)
- Myself (4)
- Blue bell nursery
- Books
- Don't use them so can't answer
- Father in law
- Garden center nursery
- Her own brain
- Mother earth
- Scientific sources
- Worked at a nursery

Q7: Where do you typically buy fertilizer?

- Lawn service provides it (58)
- Home Depot (49)
- Local hardware store (32)
- Agway (18)
- Lowes (13)
- At the garden store/center (10)
- Ace hardware (3)
- Aubuchon Hardware (3)
- Box store (3)
- Bjs (2)

- Houghton’s Hardware (2)
- Walmart (2)
- We make our own (2)
- Cheapest place I can find
- Greenhouses
- John Dear Seed distributor
- Lessco
- Patuckaway

Q8: How do you typically decide how much fertilizer to use when you apply it to your lawn? (Other responses)

- Husband figures it out (2)
- Depends on how it looks
- Depends on how much the lawn needs
- Experience
- He wing's it
- My own knowledge
- Random guess
- Wherever it needs it the most

Q17: Please tell me which of the following ways would you find most useful to learn about issues in your town? (Other Responses)

- Agriculture commission and garden clubs
- Belongs to Durham garden club
- Family
- Go right down the town office and ask
- Library
- Mailing
- Marine protection
- My wife
- Online Newspaper
- Portsmouth Square
- Professional lawn care person
- Seasonal, timely mail reminders from a reliable source.
- The local government
- Town Council
- Town Meeting
- Town Office
- Transfer Station Flyers
- University Extension

Appendix C: Survey Instrument

DURHAM NH LAWN CARE Survey
FINAL

INTRO:
"Good evening / afternoon. My name is ____________________ and I'm calling from the University of New Hampshire Survey Center. This month, the Town of Durham and the University is conducting a study with Durham residents about some important decisions the town needs to make regarding protecting the Great Bay and saving tax dollars. The survey will only take about five minutes and we'd really appreciate your help and cooperation."

TOWN
"And just to confirm, do you live in Durham or some other town?"

1 DURHAM
2 OTHER TOWN → TERMINATE

99 REFUSED → TERMINATE

CELL1
"First, to confirm, have I reached you on your cell phone or a land line?"

1 CELL PHONE
2 LAND LINE→ SKIP TO RSEL

99 REFUSED → TERMINATE

CELL2
"Are you currently driving a car or doing any activity that requires your full attention?"

1 YES → APPOINTMENT
2 NO

99 REFUSED → TERMINATE

AGE18
"And are you 18 years old or older?"

1 YES→ SKIP TO SEX
2 NO

99 REFUSED → TERMINATE

AGETERM
"Thank you very much, we are only interviewing adults 18 years or older."

RSEL
"In order to determine who to interview, could you tell me, of the adults aged 18 or older who currently live in your household, who would have the most knowledge about how you take care of your property, that is, who takes care of the lawn, buys lawn fertilizer, or handles recycling?"

1 INFORMANT → SKIP TO SEX
2 SOMEONE ELSE (SPECIFY): _______________ → SKIP TO INT2
3 LIVE IN APARTMENT, ISN'T RESPONSIBLE FOR LAWN CARE → TERMINATE
4 NO ADULTS IN HOUSEHOLD

* 99 REFUSED -- ENTER NON-RESPONSE INFORMATION

INT2
ASK TO SPEAK TO THAT PERSON

"Hello, this is ____________________ calling from the University of New Hampshire Survey Center. This month, the University is conducting a study with Durham residents about how you take care of your lawn and property. You have been identified as the adult in your household who had the most knowledge about taking care of your lawn and who buys things like weed killer and fertilizer. Is this correct?"

1 YES → SKIPTO SEX
2 APPOINTMENT
3 LIVE IN APARTMENT, ISN'T RESPONSIBLE FOR LAWN CARE → TERMINATE

* 99 REFUSAL → TERMINATE

SEX
"Thank you very much for helping us with this important study. Before we begin I want to tell you that your telephone number was randomly selected from all families in Durham and that this call may be monitored for quality assurance. Participation is voluntary. If you decide to participate, you may decline to answer any question or end the interview at any time."

IF ASKED: "This survey will take about 5 minutes to complete."

RECORD SEX OF RESPONDENT

1 MALE
2 FEMALE

* 99 NA

Q1
"I'd like to start by asking some questions about your lawn. Please tell me if you agree or disagree with the following statements." ROTATE Q1A TO Q1G

Q1A
"I enjoy spending time on lawn care."

IF AGREE OR DISAGREE: "Is that strongly or just somewhat?"

1 AGREE STRONGLY
2 AGREE SOMEWHAT
3 NEUTRAL / NEITHER AGREE NOR DISAGREE
4 DISAGREE SOMEWHAT
5 DISAGREE STRONGLY

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q1B
"The appearance of my lawn is important to me."

Q1C
"The appearance of my lawn is important to my property value."

Q1D
"Fertilizing my lawn is an important step to achieving the type of lawn I want."

Q1E
"What my neighbors think about my lawn is important to me."

Q1F
"My lawn's main purpose is to provide a space for recreation."

Q1G
"Taking care of my lawn provides me with a way to be active outdoors."

Q2
Do you maintain your yard or does a hired lawn care service maintain your yard?

1 SELF / FAMILY MEMBERS → SKIPTO Q3
2 LAWN CARE SERVICE

98 DON'T KNOW → SKIPTO Q15
99 NA/REFUSED → SKIPTO Q15

Q2A
"What is the name of the landscape company or lawn care service that takes care of your yard?"

RECORD VERBATIM RESPONSE

Q2B
"To what extent do you direct the practices of the landscape maintenance company, that is, how often they mow and what fertilizers or weed killers they use? Would you say not at all … a little … or a lot?"

1 NOT AT ALL
2 A LITTLE
3 A LOT

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q2C
"If a lawn service company was certified as 'environmentally friendly,' would you be more likely to hire them?"

1 YES
2 NO

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q3
"I'm going to read several sources that people use to get information about lawn care. Please tell me which of these you use most often."

READ LIST AND RECORD MOST OFTEN USED

"Which do you use next?"

"And which is your third most used source?"

1	friends or neighbors;
2	sales clerks;
3	certified master gardeners;
4	from TV;
5	from radio;
6	from a lawn care company;
7	from the packaging on lawn care products;
8	from magazines;
9	from newspapers;
10	from the internet;
11	from a university or extension service?"
12	OTHER – SPECIFY ______________________________
13	NONE, NO SECOND OR THIRD CHOICE
14	DON'T KNOW / NOT SURE
15	NA / REFUSED

Q4
"Now think about the same sources of information I just read, which do you think is the most trustworthy source?"

READ LIST AND RECORD MOST TRUSTWORTHY

"Which is the second most trustworthy source?"

"And which is the third most trustworthy source?"

1	friends or neighbors;
2	sales clerks;
3	certified master gardeners;
4	from TV;
5	from radio;
6	from a lawn care company;
7	from the packaging on lawn care products;
8	from magazines;
9	from newspapers;
10	from the internet;
11	from a university or extension service?"
12	OTHER – SPECIFY ______________________________
13	NONE, NO SECOND OR THIRD CHOICE
14	DON'T KNOW / NOT SURE
15	NA / REFUSED

Q5
"Do you (DOES YOUR LAWN CARE COMPANY) put fertilizer on your lawn?"

1 YES
2 NO → SKIPTO Q15

98 DON'T KNOW / NOT SURE → SKIPTO Q15
99 NA / REFUSED → SKIPTO Q15

Q6
About how many times a year is do you (DOES YOUR LAWN CARE COMPANY) put fertilizer on your lawn?"

1 LESS THAN ONCE A YEAR
2 ONCE A YEAR
3 TWICE A YEAR
4 THREE TIMES A YEAR
5 FOUR TIMES A YEAR
6 MORE THAN FOUR TIMES A YEAR

97 DEPENDS → PROBE: "In a typical year …"
98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q7
"Where do you typically buy fertilizer?"

RECORD VERBATIM RESPONSE. PROBE FOR SPECIFIC STOR AND LOCATION.

Q8
"How do you typically decide how much fertilizer to use when you apply it to your lawn?"

DO NOT READ RESPONSES

1 LAWN SERVICE DECIDES
2 SAME AS USED PREVIOUS YEAR
3 STORE RECOMMENDATION
4 INSTRUCTIONS ON THE FERTILIZER BAG
5 USE THE WHOLE BAG
6 EXPERT ADVICE
7 SOIL TEST
8 OTHER - SPECIFY

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

IF (Q2 = 2) (USE LAWN CARE SERVICE) → SKIPTO Q15

Q9

"What size bags do you typically buy … 10-15 pound bags … 25 pound bags … or 50 pound bags?"

1 10 OR 15 POUNDS
2 25 POUND
3 50 POUND
4 USE DIFFERENT SIZES

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q10

"How many bags of fertilizer do you typically use each time you fertilize your lawn?"

1 LESS THAN 1 BAG
2 ONE BAG
3 TWO BAGS
4 THREE BAGS
5 FOUR BAGS
6 FIVE OR MORE BAGS

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q11

"What do you do with the left-over fertilizer? Do you throw it away in your trash … store it for later use … or do you use all of it so there is none left over?"

1 THROW IT IN TRASH
2 STORE FOR LATER USE
3 USE ALL OF IT
4 TAKE TO RECYCLING CENTER - VOLUNTEERED

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q12

"Would you say that you currently know the square footage of your lawn?"

1 YES
2 NO

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q12A If Yes: Do you use this information to account for fertilizer application rate?

1 YES
2 NO

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q13
"Fertilizer bags often provide recommended application rate for how much you should put on your lawn. How often would you say you apply fertilizer at the recommended application rate? Would you say you always apply fertilizer at the recommended rate … usually … sometimes … or never?"

1 ALWAYS
2 USUALLY
3 SOMETIMES
4 NEVER

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q14
"Bags of fertilizer have three numbers on them, like 20 – 20 – 20. Would you say that you understand what these three numbers mean?"

1 YES
2 NO

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q15
"Let's change to environmentally friendly lawn care practices."
"How important are each of the following when making decisions whether or not to adopt more environmentally friendly lawn care practices?... Very Important… Somewhat Important … Not Very Important or Not Important At All." ROTATE Q15A TO Q15F

Q15A
"Having my lawn look the same as it does now. "

IF Necessary "Is this very important … somewhat important … not very important … or not important at all in your decisions about adopting more environmentally friendly lawn practices?"

1 VERY IMPORTANT
2 SOMEWHAT IMPORTANT
3 NOT VERY IMPORTANT
4 NOT IMPORTANT AT ALL

98 DON'T KNOW / NOT SURE
99 NA / REFUSED

Q15B
"How easily the recommended actions fit with my current lawn care methods."

Q15C
"There is a lack of information available about environmentally friendly practices."

Q15D
"No one else you know is using environmentally friendly lawn care practices. "

Q15E
"It might help protect my pet's or child's health. "

Q15F
"Protection of the Great Bay?"

Q16
"On a scale from 1 to 5 where "1" means 'no interest at all' and 5 means 'extremely interested,' how much interest would you have in acquiring more information on environmentally-friendly lawn care practices?"

1	NO INTEREST AT ALL
2	
3	
4	
5	EXTREMELY INTERESTED
98	DON'T KNOW / NOT SURE
99	NA / REFUSED

Q17
"I am going to read a list of ways that you may learn about issues, information, events and trends taking place in your community. Please tell me which of the following ways would you find MOST useful to learn about issues in your town?" What is the second most useful way? What is the third most useful way?" READ LIST. RECORD TOP THREE IN ORDER.

1	Local Access Television
2	Television Commercials
3	Radio
4	Printed Local Newspaper
5	Facebook, Twitter or other internet social network
6	Town Newsletter or Website
7	Your neighborhood, homeowner or condo association
8	Communication with friends and neighbors
9	Notices sent home from your child's school
10	Inserts in your tax, water or other utility bills
11	Booths at farmers' markets, festivals or other community events
12	OTHER –SPECIFY
13	NONE OF THE ABOVE
14	DON'T KNOW / NOT SURE
15	NA / REFUSED

"D1
"Now, a few final questions ..."
"What is your current age?"

___ ___
: : : : (RECORD EXACT NUMBER OF YEARS OLD -- E.G., 45)
:____: :____:

96 NINETY-SIX YEARS OF AGE OR OLDER
97 REFUSED
98 DK
* 99 NA

D2
"How many years have you lived in Durham?"

IF "ALL MY LIFE": "And how many years is that?"

___ ___
: : : : (RECORD EXACT NUMBER OF YEARS - E.G., 45)
:____: :____:

96 NINETY-SIX YEARS OF AGE OR LONGER
97 REFUSED
98 DK
* 99 NA

D3
"What is the highest grade in school, or level of education that you've completed and got credit for ..." [READ RESPONSES]

1 "Eighth grade or less,
2 Some high school,
3 High school graduate, (INCLUDES G.E.D.)
4 Technical school,
5 Some college,
6 College graduate,
7 Or postgraduate work?"

98 DK (DO NOT PROBE)
* 99 NA / REFUSED

D4
"Including yourself, how many adults CURRENTLY live in your household?"

	1	ONE
	2	TWO
	3	THREE
	4	FOUR
	5	FIVE
	6	SIX
	7	SEVEN OR MORE
	98	DK
*	99	NA / REFUSED

D5
"And how many children under 18 currently live in your household?"

	0	NONE
	1	ONE
	2	TWO
	3	THREE
	4	FOUR
	5	FIVE
	6	SIX
	7	SEVEN OR MORE
	98	DK
*	99	NA / REFUSED

D6
"Not counting business lines, extension phones, or cellular phones -- on how many different telephone NUMBERS can your household be reached?"

	0	NO LANDLINE
	1	ONE
	2	TWO
	3	THREE
	4	FOUR
	5	FIVE
	6	SIX
	7	SEVEN OR MORE
	98	DK
*	99	NA / REFUSED

D7
"And on how many different cellphone NUMBERS can your household be reached?"

0	NO CELL PHONE
1	ONE
2	TWO
3	THREE
4	FOUR
5	FIVE
6	SIX
7	SEVEN OR MORE
98	DK
99	NA / REFUSED

"Those are all the questions I have. Thank you again for your time. Goodbye."

Appendix D:

Data Inputs& Assumptions Used in the Oyster River Watershed Modeling

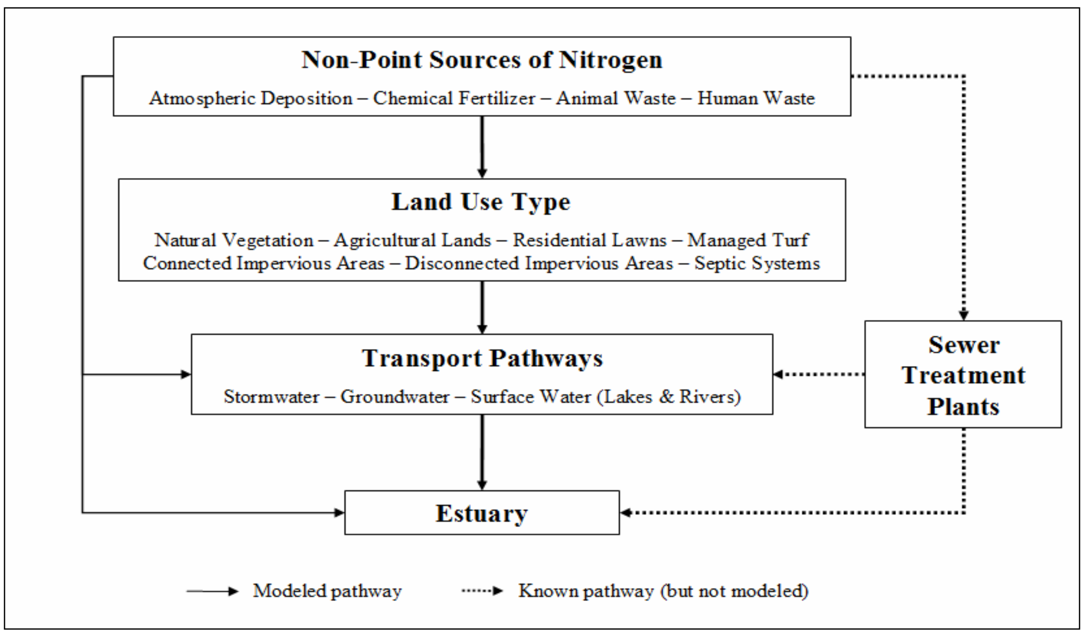
1.0 Model Background

The NLM estimates nitrogen inputs from four major sources including atmospheric deposition, chemical fertilizers, animal waste and human waste discharged through septic systems. How much nitrogen is generated and ultimately delivered to an estuary largely depends on the amount of development, human activity and the extent of various land uses within the watershed. Atmospheric deposited nitrogen contributed to natural or developed areas as well as that delivered directly to surface water bodies are included.

Figure 1 illustrates how the NLM model accounts for the primary nitrogen sources, land use types and transport pathways that contribute to the nitrogen load estimation processes and ultimately affect the amount of nitrogen estimated to be delivered to estuary. The NLM model does not include loads from wastewater treatment facilities (WWTF) but this transport pathway is included in the diagram to reflect the significance of WWTF contributions to the total nitrogen load relative to nonpoint sources.

DES noted that the model is most appropriate for larger watershed scale analyses and model accuracy will likely diminish for smaller watershed areas. A limited sensitivity analysis was conducted as part of this Oyster River modeling study to assess the relative influence of key assumptions and factors have on the model results. The sensitivity analysis showed that the model is more sensitive to the model coefficients and parameters associated with attenuation/delivery factors and stormwater/groundwater partitioning than many of the model inputs (e.g. areas of land use types).

Figure 1 - Simplified Watershed Nitrogen Loading Model Diagram



1.1 Model Advantages and Limitations

NLM's key advantage, relative to other loading models, is its ability to track nitrogen loads by specific sources, such as fertilizer use, septic systems, atmospheric deposition and animal waste while accounting for the effects of land use and attenuation losses along the delivery pathway. Where most models rely on lumped, loading coefficients for various land use types to estimate nitrogen inputs, the NLM tracks and estimates nitrogen loads by each individual source within each land use category, analysis unit or area of interest. This helps to identify and assess how certain source control measures and especially non-structural measures, such as public education and outreach campaigns or regulations on fertilizer usage or manure management practices, might affect future nitrogen loads rather than rely strictly on structural controls such as end-of-pipe, stormwater treatment measures.

Within the NLM model, land use and land cover conditions (e.g., lawn areas, agriculture, connected and disconnected impervious surfaces, etc.) not only influence source inputs but affect the transport pathway (i.e., stormwater/surface water and groundwater) and delivery factors used to estimate how much nitrogen is likely to be delivered to the downstream estuary. For each transport pathway, specific attenuation loss factors are included in the model to estimate how much nitrogen moves by surface water or through the saturated or unsaturated groundwater zones and is delivered to the downstream estuary. These assumed pathway and attenuation (i.e., delivery) factors greatly influence the modeled load estimates. Understanding the principal travel pathways will be critical to the future evaluation of management alternatives and determining which measures are best suited to affect the initial source inputs and pathways involved with the delivery of nitrogen to the estuary.

Potential management measures can be evaluated by modifying the model inputs and parameters as follows:

Model Modification	Scenario Evaluated
Land use breakdown and septic system quantities	- Disconnecting impervious cover through stormwater control practices or BMPs - Extending sewer connections to high density septic system areas in the watershed - Estimating future loads associated with future development
Source loading rates	- Ordinances that will limit the fertilizer application rates - Reducing fertilizer application rates or areas treated - Revising agricultural fertilizer practices - Future reductions in atmospheric loading
Pathways partition coefficients	- Increase of structural stormwater control practices that increase infiltration

The principal NLM model limitations are summarized below:

- Does not fully account for any seasonal, temporal or spatial variations in loading inputs, pathway partitioning or delivery rates.
- Does not account for the effects of certain hydrologic factors such as wet weather effects and how varying flow conditions may change loading rates during the course of a year.
- Limited ability to account for natural transformation processes along the flow path within the watershed.
- Does not account for seasonal variations in biological activity which might affect nitrogen transformations and variations in the delivered load during the course of an annual cycle.
- Does not calculate in-stream concentrations

To compensate for these limitations, VHB performed additional model refinement and alternative model comparisons, as discussed in subsequent sections of this report. The NLM model results are considered sufficient for initial planning purposes to evaluate the relative source contributions for the various sources.

2.0 Model Development

This section describes the various steps involved in the development of Oyster River NLM including data inputs and assumptions within the model framework.

2.1 Model Framework

NLM calculations consist of an accounting of total nitrogen inputs and outputs from the source to the estuary based on source input type (i.e., atmosphere, fertilizer, septic or animal) and assumed delivery and attenuation factors. VHB developed a model framework to:

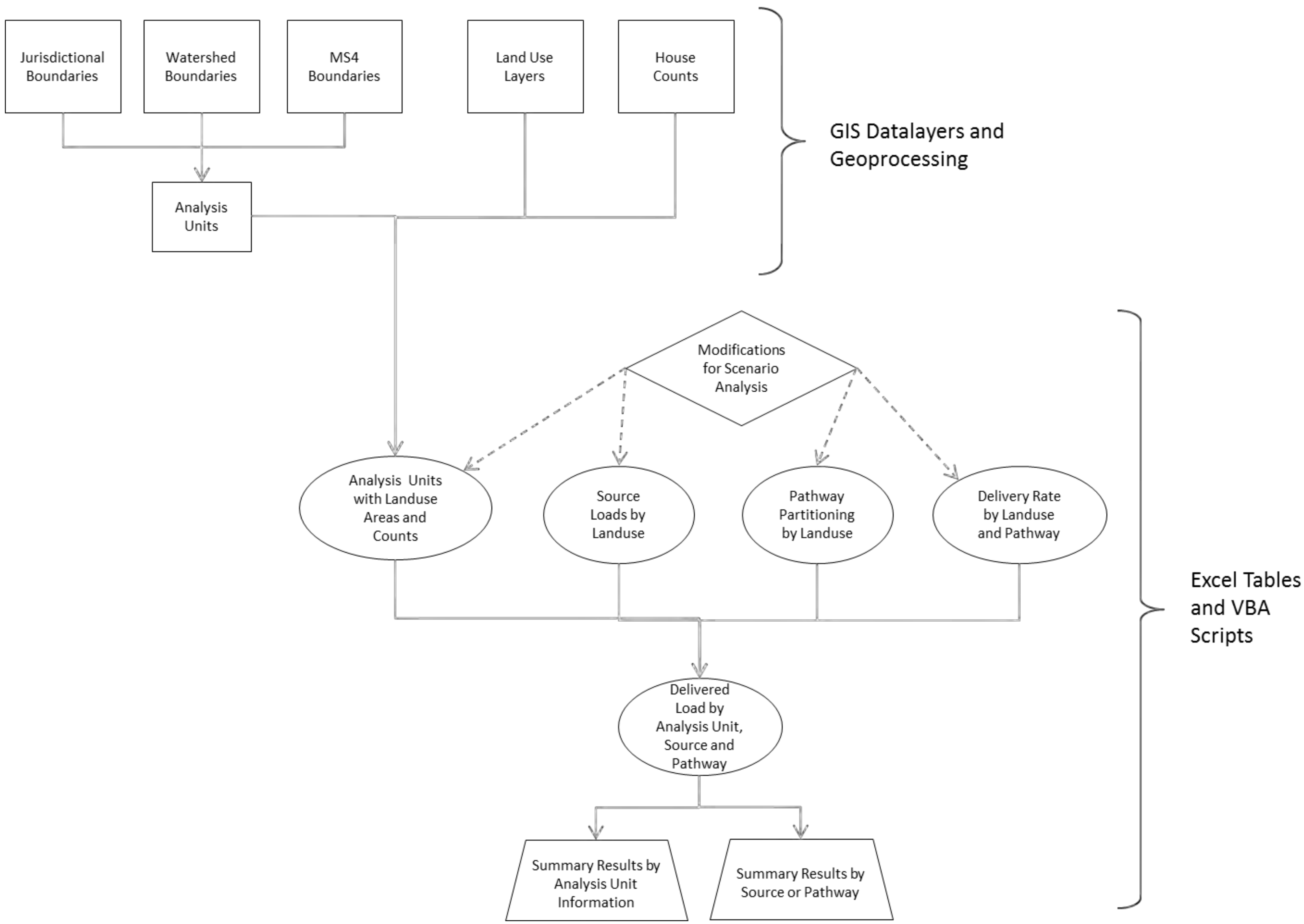
- Develop the required input data for the model in a way that provides flexibility to incorporate new or more accurate input data as available,
- Perform the loading calculations,
- Run scenarios, and tabulate and compare results to facilitate the use of the model as a tool to inform management practices.

Figure 2 shows the modeling framework which includes the use of a Geographic Information System (ArcGIS) for spatial dataset input manipulation and the use of a spreadsheet (Microsoft Excel) for loading calculations, running scenarios, and tabulating results. For this analysis, we have tracked the model "inputs" within each of the principal analysis units (e.g., jurisdictional watershed and MS4 boundaries) including land uses and number of homes utilizing septic systems. Model "parameters" are defined as the source loading rates, pathway partitions, and delivery factors used in the load calculations.

VHB developed scripts within the ArcGIS program to automate and preserve the geospatial and mathematical equations used to manipulate existing datasets to produce the required input data for the model (described more in the following section). The resulting GIS processed, model input data was then imported into the spreadsheet. VHB developed additional model scripts within the spreadsheet using Visual Basic for Applications (VBA) to perform the loading calculations while preserving the analysis unit base information (jurisdiction, sub-watershed, regulated MS4 areas) land use, source and pathway. These raw results were then summarized by each of the primary categories to help define the loads within the overall watershed.

The scripts allow for an efficient means to include updated input data and to perform iterative model scenarios, including a sensitivity analysis to assess how different model assumptions affect the model output.

Figure 2 - Oyster River NLM Framework



2.2 Model Input

As described further below, the model inputs were accounted and tracked by jurisdictional areas, sub-watersheds and regulated MS4 boundaries that make up the analysis units.

Analysis Units

An important first step in the model development involved determining key areas of interest or points of analysis in the watershed to summarize nitrogen load estimates. These include locations where relevant ambient water quality data exists to allow comparisons to model predictions. Anticipated future water quality monitoring locations were also considered as well as political or jurisdictional boundaries that define limits of regulatory responsibility and where potential source control measures may be implemented. The following Oyster River NLM analysis units were included:

- Sub-watershed areas of major tributaries,
- Watershed area draining to head of tide (Mill Pond dam) and mouth of Oyster River,
- Town Boundaries and UNH Campus area,
- Regulated MS4 areas.

Intersecting the boundaries of these areas resulted in 240 analysis units within the Oyster River watershed. An additional overlay with the hydrologic soil groups (HSG), grouped into two categories A/B and C/D, was performed to track soil type for pathway portioning, resulting in approximately 660 analysis units. Using the NLM model, average annual nitrogen load estimates were developed for each analysis unit, which were then aggregated to larger areas of interest to present total loads by subwatershed, political boundary, and MS4 entity.

Model Land Uses and Input Data

Table 1 summarizes the source inputs and land uses categories used in the model to develop nitrogen load estimates for each analysis unit. VHB used the available spatial datasets along with geo-processing tools in ArcGIS to calculate the land use areas and source inputs counts for each analysis unit.

Table 1 – Listing of Oyster River NLM Sources and Land Use Input

Source / Land Use Inputs	Sub-Unit
Lawn	Residential Lawns UNH Lawns
Agriculture	Corn, Apples, Hay, UNH Corn, UNH Hay, Other
No. of Septic Systems	Septic within 200 meter buffer of tidal estuary
	Septic outside 200 meter from tidal estuary but drains to tidal waters Septic outside 200 meters of tidal estuary and in freshwater portion of watershed
Natural Vegetation Area	Natural Vegetation Area UNH Grasslands (not fertilized)
Impervious Cover	Connected Impervious Cover Disconnected Impervious Cover- Medium Density Residential Disconnected Impervious Cover- High Density Residential Disconnected Impervious Cover- UNH Campus Disconnected Impervious Cover- Commercial
Open Water Area	Estuary, Lakes and Ponds
Managed Turf	Golf Courses Athletic Fields / UNH Athletic Fields Parks /School Recreational Fields
Animals	No. of Cows, Horses and Dogs

Table 2 lists differences between the GIS data layers and assumptions used in the Oyster River NLM and those used in the GBNNPS Study. The Oyster River NLM used high resolution (1-meter resolution), impervious cover data that was available for the Towns of Durham, Lee and Madbury and UNH campus, which allowed a more accurate delineation of impervious cover and lawn area in these key areas. This same high resolution impervious cover data was not available for other towns in the Oyster River watershed, but is expected to become available in the next few months.

Table 2 – Comparison of Data Inputs and Model Assumptions used in Oyster River Model vs. GBNNPSS

Oyster River NLM Approach	GBNNPSS Approach
Land use based on UNH campus base-mapping and 2010 Community Technical Assistance Program (CTAP) data including detailed digitized land use areas (Strafford Regional Planning Commission).	Land use based on 2006 NOAA Coastal Change Analysis Program (C-CAP) Landsat™ Imagery for Land Use Delineation (30-meter resolution.
Impervious cover (IC) for Durham, Lee, Madbury and UNH Campus based on 2010 high-resolution (1-meter) impervious cover data layer supplemented with UNH's Campus GIS data. IC data for other watershed Towns was based on the 2010 30-meter resolution GIS data.	Impervious cover based on 2010 30-meter resolution impervious cover data
Used Town and UNH storm drain mapping data to estimate directly connected and disconnected impervious surfaces in Durham area.	Used Sutherland Equation (1995) to estimate the amount of connected and disconnected impervious area.
Sub-watershed areas based on NH DES Geologic Survey Piscataqua Region Stressed Basin Mapping to delineate major tributaries in the Oyster River watershed.	USGS Hydrologic Unit Code (HUC) 12 watersheds.
Digitized house/buildings located outside the sewered area to determine the number of septic systems in the watershed/sub-watersheds that are within or outside of 200 meters from a surface water body.	Use of 2010 census-block population data and sewer line data to estimate proportion of population that are serviced by septic systems.
Use pathway partitioning coefficients based on land cover and hydrologic soil group and varying groups of disconnected impervious cover.	Used consistent pathway partitioning by land use across watershed.
Use higher source loading rate for impervious cover based on EPA research other reported values.	Assume impervious cover loading is solely from atmospheric deposition (consistent throughout watershed) and pet waste.
Actual lawn area within Durham was delineated based on, high-resolution land use, impervious cover mapping, and LiDAR datasets (see more information in Appendix B) Lawn area within the UNH campus were based on UNH Campus base mapping.	Lawn area was estimated based on use of 2006 NOAA C-CAP "developed" land use categories with estimated percentage of lawns for each category.

2.3 Model Parameters

The NLM model generates estimates of average nitrogen load delivered to the estuary by combining initial source loading rates with partitioning coefficients and attenuation loss factors associated with each pathway. The model "parameters" for the Oyster River NLM are defined as the following:

- Source loading rates by land use/input,
- Load pathway portioning rates by land use/input,
- Load delivery/attenuation factors by pathway and land use/input.

Source Loadings

Table 3 presents the source loading rates used in the Oyster River Watershed model. The loading rates are provided the various sources (atmosphere, fertilizer, animals or septic/people) and applicable land use or activity.

VHB essentially used much of the same loading rates used by NHDES in the GBNNPS model with some exceptions as noted below. DES used local data, where available, to develop loading rates for atmospheric deposition and land application sources, as described below. The basis for these load input values are discussed in greater detail in the Draft GBNNPSS Report (Trowbridge and Wood, 2013).

The following describes the principal data sources used by DES to develop their loading rates which are the same as those used in the Oyster River NLM:

- Atmospheric loading rate: measured wet and dry deposition data collected in 2009 within the study area, supplemented by DES' regional dispersion model to quantify relative contributions from various sources in the eastern United States.
- Agriculture fertilizer rates: 2011 USDA National Agricultural Statistics Service Cropland Data Layer to determine agricultural areas and fertilizer application rates based on USDA data for New York for corn, apples and other crops and consultation with UNH Cooperative Extension for typical fertilizer application rates on hay fields and pasture areas.
- Residential lawn fertilization rates: Based on published reports and the percentage of lawns fertilized based on a Durham Residential Fertilizer survey.
- Managed turf fertilizer rates: calculated average of application rates reported by surveyed parties within the Great Bay watershed.
- Nitrogen load estimates from septic systems were based on a per capita input rate of 10.6 lbs/person/year (4.8 kg/person/year) and an estimate of the population served by septic systems.

VHB modified or replaced loading rate information for UNH lawns and agricultural fields based on the following information provided by UNH.

- UNH Agriculture fertilizer application rates were based on UNH's reported liquid manure application rates. As such, UNH's cow and horse counts were not included in the model to avoid double-counting.
- UNH lawn fertilizers rates based on actual fertilizer usage (number of bags and nitrogen content) applied in 2012 and 2013 as provided by UNH Facilities.
- Grassy areas on campus that are not maintained as lawn or as an agricultural field were classified as UNH grasslands and no fertilizer application was assumed.

VHB modified the loading rate for residential lawn fertilizer use based on a telephone survey conducted by the UNH Survey Center, which provided a better understanding of the lawn care practices and fertilizer use by Durham households. Individuals from a random sample of 470 Durham households were interviewed by telephone between October 24 and November 1, 2013. Based on the survey results, it appears that only 45 percent of the households in Durham apply fertilizer to their homes which differs from DES's previous assumption of 64 percent homes use lawn fertilizer. VHB accounted for this by multiplying 45 percent to the original previously assumed application rate of 2 pounds of nitrogen per 1,000 square feet (based on extensive literature review conducted by DES) resulting in a application rate of 39 lbs/ac/yr instead of the original 87 lbs/ac/yr. in addition, recognizing that not all grass areas identified on the landscaped is fertilized, it was assumed that only 50 % of the identified lawn area was fertilized.

VHB also reduced the amount of hay field assumed to be fertilized from 50 % to 25% of the total hay field area based on review and information provided by Dan Wright, who serves as the local agricultural specialist for the Natural

Resource Conservation Service. This adjustment was made by re-classifying identified hay fields into a category of "Agriculture Other", which is assumed to not receive chemical fertilizer inputs.

VHB also estimated the amount of nitrogen from dog waste a little differently by calculating an average aerial loading rate using DES' estimate of number of dogs in the watershed divided by the total land area in which the waste is assumed to be deposited (impervious cover & lawn area). Since DES' model indicated that dog waste was a relatively small portion of the overall load, VHB did not spend additional time to update the number of dogs in the watershed.

Table 3 - Oyster River NLM Source Loading Rates

	Source						
Land Use / Input	**Atmosphere[1] (lb/ac/yr)**	**Chemical Fertilizer[2] (lb/ac/yr)**	**UNH Manure Fertilizer (lb/ac/yr)**	**Dogs[3] (lb/ac/yr)**	**Cows[4] (lb/ animal/yr)**	**Horses[5] (lb/ animal/yr)**	**People[6] (lb/ person/yr)**
Natural Vegetation	5.2						
Agriculture – Corn	5.2	57					
Agriculture – Apples	5.2	32					
Agriculture – Hay	5.2	25					
Agriculture – Other	5.2	0					
UNH Agriculture – Corn	5.2		204[7]				
UNH Agriculture – Grass	5.2		80[7]				
Residential Lawns	5.2	39		1.1			
UNH Lawns	5.2	26[8]		1.1			
UNH Grasslands	5.2	0					
Managed Turf – Golf	5.2	41					
Managed Turf – Athletic Field	5.2	71					
Managed Turf – Park	5.2	33					
Managed Turf – UNH Athletic Field	5.2	133[8]					
Open Water	5.2						
Estuary	5.2						
Impervious Cover - Connected	13.0			1.1			
Impervious Cover - Disconnected (all categories)	13.0			1.1			
Cows					197		
Horses						88	
Septic: W/in 200 m of tidal waters				0.03			10.6
Septic: outside 200 m of tidal waters but w/in tidal drainage area				0.03			10.6
Septic: outside 200 m of tidal buffer and in upper watershed				0.03			10.6

Notes: 1 From Tables 5 and 6 of Appendix A of GBNPPS. DES estimates of dry deposition plus wet deposition for all sources, all locations. Includes additional local sources for impervious cover land uses.

2 Unless otherwise noted, agriculture values from Table 2 from Appendix C of GBNPPS. Agriculture – Other land use represents non-fertilized agricultural areas based on communication with regional NRCS representative. Residential lawn values from Table 5 Appendix E of GBNPPSS. Managed Turf values from Table 3 Appendix D of GBNPPS.

3 From DES results: 1,321 dogs resulting in 5,811 lbs/yr in Oyster River Watershed. Assumed 55% non-scoop rate distributed the overall load by watershed areas and residential lawn and impervious cover (2,900 acres total) to calculate a lb/ac from dog waste. It was then assumed 9% scooped and flushed rate and watershed population to calculate lb/person from dog waste.

4 From Table 1 Appendix F of GBNPPS - average excretion rate of dairy and beef cows.

5 From Table 1 Appendix F of GBNPPS - excretion rate of horses

6 From Page 9 Appendix G of GBNPPS – per capita nitrogen output per person per year.

7 Based on UNH application rates and analytical testing on N content indicating approximately 20 lb N /1000 gal liquid fertilizer

8 Based on UNH fertilizer usage divided over the UNH lawn areas and managed turf areas

Pathway Partitioning

The stormwater/groundwater partitioning coefficients used for the various vegetated land cover surfaces and disconnected impervious cover was significantly changed from DES' GBNNPS approach. DES originally utilized the same assumptions in the Cape Cod region approach which was a generic ratio of 12% of the land applied nitrogen load traveled via storm water runoff and the remaining 88 % of the land applied nitrogen traveled via groundwater. This partitioning approach did not account for the varying effects that soil types and percent imperviousness have on the rainfall/runoff relationship and the related nitrogen transport pathway.

To account for soil type and percent impervious cover for disconnected IC, VHB performed a long-term hydrologic simulation using EPA's SWMM model and a 10-year daily rainfall record to estimate the proportion of precipitation converted to runoff on an annual average basis for different land use/IC combinations and soils groups identified within the watershed. VHB assumed that the proportion of precipitation converted to runoff is the same proportion of nitrogen source load that is delivered via storm and surface water. The remainder is assumed to be delivered via the groundwater pathways. Table 4 presents the refined pathway partitioning coefficients used to estimate the portion of the nitrogen source load traveling via stormwater runoff or groundwater flow in the watershed.

Table 4 - Oyster River Watershed NLM Pathway Partitioning Coefficients

Land Use / Source Input	Estimated Pathway Partitioning (Percent)				
	Stormwater		Groundwater		Direct
	HSG A/B	HSG C/D	HSG A/B	HSG C/D	
Natural Vegetation	3	13	97	87	0
Agriculture - Corn	3	13	97	87	0
Agriculture - Apples	3	13	97	87	0
Agriculture - Hay	3	13	97	87	0
Agriculture - Other	3	13	97	87	0
UNH Agriculture - Corn	3	13	97	87	0
UNH Agriculture - Grass	3	13	97	87	0
Residential Lawns	4	15	96	85	0
UNH Lawns	4	15	96	85	0
UNH Grasslands	4	15	96	85	0
Managed Turf - Golf	4	15	96	85	0
Managed Turf – Athletic Field	4	15	96	85	0
Managed Turf - Park	4	15	96	85	0
Managed Turf – UNH Athletic Field	4	15	96	85	0
Open Water	100	100	0	0	0
Estuary	0	0	0	0	100
Impervious Cover - Connected	100	100	0	0	0
Med Density Residential Disconnected IC	54	65	46	35	0
High Density Residential Disconnected IC	64	71	36	29	0
Impervious Cover - Disconnected UNH	69	74	31	26	0
Impervious Cover - Disconnected Commercial	73	76	27	24	0
Cows and Horses	3	13	97	87	0
Septic Systems:	0	0	100	100	0

Note: Pathway partitioning based on long-term hydrologic analysis.

Soils in the watershed are predominantly Hydrologic Group C/D soils with limited areas of A and B soils. For most vegetated surfaces, the revised partitioning coefficient did not change too dramatically from the original 12%/88% stormwater/groundwater ratio. For disconnected IC areas, however, the revised approach resulted in a considerable change in the partitioning coefficients and nearly tripled the estimated nitrogen load from disconnected IC areas.

For atmospheric deposition directly falling on connected impervious areas, 100 percent of the nitrogen was assumed to be delivered via stormwater runoff. Nitrogen derived from septic systems was assumed to travel entirely by groundwater. Nitrogen that falls directly on surface water bodies from atmospheric deposition was assumed to enter directly into water body. For both the stormwater and groundwater pathways, specific delivery or attenuation factors were applied to reflect expected losses due to vegetative uptake, volatilization or de-nitrification along the flow path as discussed below.

Delivery Factors

Table 5 presents the inherent model delivery factors that were originally developed by Valiela et al. (1997) based on various research findings. Delivery factors represent the percentage of nitrogen assumed to be delivered to the estuary while accounting for attenuation losses along the flow path. The delivery factors used in the Oyster River Watershed NLM were the same as those used in the GBNNPSS model. For nitrogen assumed to be transported by stormwater, it was generally assumed that 13 percent of the initial load would be attenuated due to vegetative uptake and denitrification as the stormwater entered adjacent freshwater streams and the remaining 87 percent was assumed to be delivered downstream to the estuary.

For nitrogen assumed to be transported via groundwater (based on the transport partitioning coefficient) had much lower delivery factors ranging from 8.9 percent for atmospheric derived nitrogen falling on natural vegetation to 15.5 percent for nitrogen derived from land applied chemical fertilizer and animal waste (see Table 5). The lower delivery factors reflect the combined effect of various estimated attenuation losses in three different travel zones as nitrogen moves from the land surface to the unsaturated vadose zone, from the vadose zone to the groundwater table and then within the horizontal flow of the saturated zone to the estuary.

In Appendix H of the Draft GBNNPSS Report, DES describes how the NLM delivery factors are consistent with other research findings. In terms of overall delivery, Daley et al. (2010) reported that 16 percent of all nitrogen imported into the Lamprey River Watershed was found to be exported downstream based on data collected from 2000 to 2009. Other studies cited by DES include Boyer et al., (2002) which reported that 25 percent of nitrogen inputs, on average, were delivered downstream in large watersheds in northeastern United States. Galloway et al., (2003) reported 30 to 70 percent of nitrogen being delivered once it enters wetland-stream-river continuum. This general range of delivery factors based on measured data is consistent with model results, however, additional research and analyses may be warranted as part of a future study phase to evaluate whether adjustments to these delivery factors are warranted.

The delivery rates for nitrogen released from septic systems were based on studies as cited in Appendix H of the GBNNPS Study. Studies researched by DES and by Valiela et al. (1997) indicated that reported nitrogen delivery rates for septic systems ranged from a low of 20 percent to as high as 80 percent. Septic systems located closer surface water bodies tended to have higher delivery factors and less attenuation. For the GBNNPS Study, DES used a delivery factor of 60 percent, for near-shore septic systems within 200 meters of the tidal estuary and a delivery factor of 26 percent for septic systems outside the 200 meter buffer but within the direct watershed of the tidal estuary.

VHB included one modification for the delivery rates for septic systems located in the upper portions of the watershed and not within the direct watershed of the tidal estuary. Similar to all other source inputs expected to travel via stormwater/stream pathway to the estuary, a 13 percent attenuation factor was applied to septic systems located in the upper part of the watershed and outside the 200 meter zone, resulting in a 22 percent delivery rate. The rational was based on the assumption that any nitrogen released from septic systems in the upper watershed was likely to travel in shallow groundwater flow to the nearest tributary stream and be subject to attenuation processes and vegetative uptake along the stream riparian corridor prior to enter the downstream estuary below the tidal dam. This was a relatively minor change in the delivery factor.

Table 5 - Oyster River NLM Delivery Factors for Sources and Transport Pathways

Land use / Input	Delivery Factors (percent)					
	Stormwater/ Surface Water (all sources)	Groundwater: Atmospheric	Groundwater: Chemical Fertilizer	Groundwater: Dogs	Groundwater: Cows / Horses	Groundwater: People
Natural Vegetation	87	8.9				
Agriculture – Corn, Apples, Hay, Other	87	9.6	15.5			
UNH Agriculture – Corn, Grass	87	9.6	15.5			
Residential Lawns	87	9.6	15.5	15.5		
UNH Lawns	87	9.6	15.5	15.5		
UNH Grasslands	87	9.6	15.5			
Managed Turf – Golf	87	9.6	15.5			
Managed Turf – Athletic Field	87	9.6	15.5			
Managed Turf – Park	87	9.6	15.5			
Managed Turf – UNH Athletic Field	87	9.6	15.5			
Open Water	87					
Estuary	100					
Impervious Cover - Connected	87					
Impervious Cover - Disconnected (all categories)	87	9.6		15.5		
Cows and Horses	87				15.5	
Septic: W/in 200 m of tidal water body						60.0
Septic: outside 200 m buffer of tidal water but within tidal watershed						25.7
Septic: Outside 200 m of a tidal water body and in freshwater portion watershed						22.4

Source/Land use via Groundwater: Appendix H Table 1 Delivery Factors =ground surface to vadose x vadose to aquifer x aquifer to estuary
Source/Land use via Stormwater: Appendix H Table 3 Delivery Factor =surface water to estuary
Septic via Groundwater: Appendix H Table 2 Delivery Factors = septic/leach field attenuation x plume attenuation x groundwater transport

3.0 COMPARISON OF OYSTER RIVER MODEL RESULTS TO DES MODEL RESULTS AND ESTIMATED NITROGEN LOADS BASED ON MEASURED DATA

The Oyster River model load estimates were compared to other relevant load estimates based on the following sources:

- DES GBNNPSS Model results
- Water quality monitoring data from:
  - DES Environmental Monitoring Data Base
  - UNH Water Resources Center

Comparison with GBNNPSS Results

The predicted annual nitrogen loads from the Oyster River NLM were compared to the GBNNPSS results developed by DES for the Oyster River watershed. Tables 12 and 13 provide a comparison of the Oyster River NLM and GBNNPSS model estimates for both land use/source input and source type, respectively. Overall, the Oyster River NLM predicted delivered nitrogen load of 73,440 pounds (36.7 tons), which is fairly close to the GBNNPSS estimated load of 71,960 pounds (36.0 tons) but the distribution of estimated loads for the various sources and land uses are quite different. The estimated loads for impervious cover, natural vegetation and agriculture differ by as much as 150, 80 and 45 percent, respectively, between the two approaches. The differences are largely due to revisions in the stormwater/groundwater pathway coefficient is derived by accounting for soil types. The NLM also includes a higher source load rate for impervious surfaces to account for the local atmospheric sources (i.e., 14.1 lbs/ac vs. 7.0 lbs/ac). The higher load rate is consistent with the guidance included in the Draft 2013 MS4 Stormwater Permit. The adjusted load rate was estimated to account for nearly half of the overall load difference while the remaining difference is due to the adjustments in the stormwater/groundwater partitioning coefficients.

The Oyster River NLM approach also produced a considerably lower septic system load (i.e., -25 %) primarily due to the difference in methods used to estimate the number of people served by septic systems where the NLM approach was based on an actual count using high resolution aerial photos and DES based it on indirect method using Census block data.

A much larger amount of lawn area (i.e., additional 600 ac or +71%) was estimated using the data and methods used to estimate lawn area based on higher resolution GIS and LiDAR data as compared to DES's indirect method of using general ratios depending on land use classifications. As noted earlier, the fertilizer application rate was also lowered, however, to account for the lower percentage of Durham residents assumed to be applying fertilizer to lawns (i.e., 45% instead of 64%) based on the results of the recent fertilizer survey. Consistent with DES' approach, this adjustment was added to the original assumption of only 50 percent of the lawn area is considered to be treated.

The estimated agricultural load of 13,590 pounds for the Oyster River watershed was considerable lower than the 24,780 lbs DES had estimated with the GBNNPSS model, primarily due to 140 fewer acres of agricultural lands included in the NLM model and fewer hay fields identified as being fertilized as part of this study.

The relatively close comparison in the overall load estimates between the GBNNPSS results and the Oyster River NLM indicates the model setup and processes were properly developed and are likely to have in a similar estimated margin of error (+/- 13 percent as reported by DES).

Table 12 - Comparison of Oyster River NLM Results with GBNPSS Results by Land-use

Land Use / Source Input	Oyster River NLM Delivered Load (lb/yr)	GBNPSS Delivered Load (lb/yr)	Percent Difference in Load Estimate	Oyster River Area (ac) or Count[1]	DES Area (ac) or Count[1]	Percent Difference Area/Count
Lawn	15,020	12,580	19%	1,470	860	71%
Impervious Cover	14,420	5,770	150%	1,540	2,150	-28%
Septic (people)	13,950	18,630	-25%	5,350	6,500	-18%
Agriculture	13,590	24,780	-45%	1,590	1,710	-8%
Natural Vegetation	12,100	6,720	80%	14,300	14,500	-1%
Open Water	3,640	3,070	19%	740	620	19%
Managed Turf	710	410	73%	30	40	-25%
Total	**73,440**	**71,950**	**2%**	**19,660**	**19,880**	**-1%**

Notes: [1] Septic Count refers to the estimated number of people served by septic systems in the watershed.

Table 13- Comparison Oyster River NLM Results with GBNNPSS Results by Source

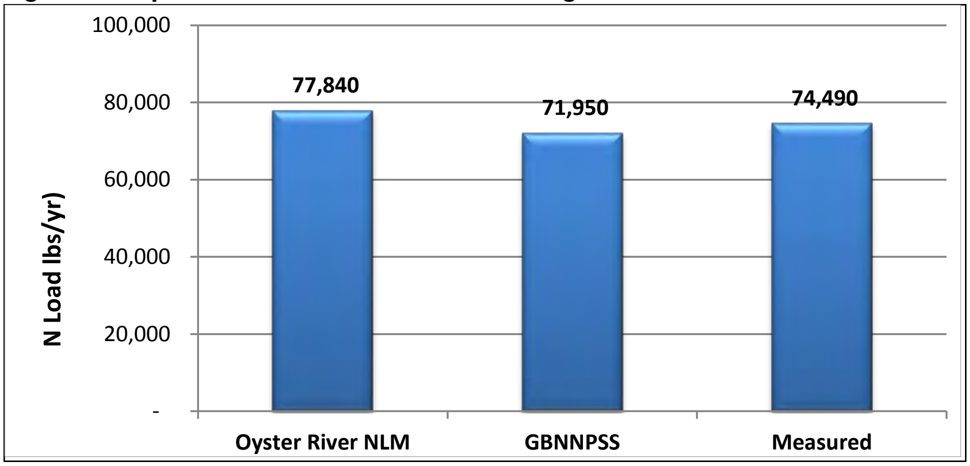
Source	VHB Delivered Load (lb/yr)	DES Delivered Load (lb/yr)	Difference (pounds)	Percent Difference
Chemical Fertilizer	18,860	22,590	-3,730	-17%
Septic	13,950	18,550	-4,600	-25%
Atmosphere	31,950	17,160	14,790	86%
Animals	8,670	13,650	-4,980	-36%
Total	**73,440**	**71,950**	**1,490**	**2%**

Comparison of Model Load Estimates to Measured Water Quality Data

VHB compared the estimated watershed loads produced by the model with estimated nitrogen loads based on measured nitrogen water quality data as a check of model accuracy. DES had developed estimates of the nonpoint source nitrogen load for the watershed at the head of tide using monthly nitrogen sampling data multiplied by the average annual flow rate using gauging data. The median total dissolved nitrogen concentration measured in the Oyster River was 0.40 mg/L based on 43 monthly grab samples collected at the head of tide dam during the summer months between the years 2008 to 2011. VHB used the same median concentration estimated from the water quality data with an area-weighted estimated average flow to the mouth of the Oyster River to estimate the total annual load for the entire Oyster River watershed. This method produced an average annual nonpoint source nitrogen load of approximately 74,490 pounds for the entire watershed. Figure 9 shows a comparison of the measured load estimate to the Oyster River NLM model estimate of 77,840 pounds and DES's model results of 71,950 pounds. The Oyster River NLM load estimate is within 5 percent of the measured load estimate, which is reasonably close to DES' previous load estimate despite the number of data inputs and related margins of error.

The UNH Water Resources Research Center (WRRC) is currently collecting additional water quality data at several locations within the Oyster River watershed. As this data becomes available, additional comparisons and analysis of modeled load estimates to measured load estimates can be conducted for select Oyster River tributaries.

Figure 9: Comparison of Modeled and Measured Nitrogen Loads



Since 2000, the UNH WRRC has also collected extensive nitrogen data in the nearby Lamprey River watershed. The monitoring data was used to develop annual nitrogen budgets (i.e., inputs and outputs) for several sub-basins in the larger watershed (Daley et al., 2010). The estimated nitrogen inputs ranged from 7.2 to 22.2 lbs/ac/yr while the estimated nitrogen outputs for the same sub-basins ranged from 0.8 to 5.9 lbs/ac/yr. Their study concludes that as much as 61 to 92 percent of the nitrogen input is attenuated in the watershed with highest attenuation rates occurring in the less developed, highly forested sub-basins. As shown in Table 14, the Oyster River modeled nitrogen input and output estimates are similar to the data reported for more urbanized and developed sub-basins of the Lamprey River watershed. These similarities to nitrogen budget estimates developed for other watersheds in the region using measured data suggests that the initial Oyster River model results are reasonably close to that observed in terms of overall watershed loads.

Table 14 - Comparison of Oyster River NLM Loads to Lamprey River Load Estimates

Watershed	Estimated % Forested Cover	Estimated % Impervious	Source Load (lbs/ac/yr)	Delivered Load (lbs/ac/yr)	Percent Delivered
Oyster River NLM	68 %	9.3%	16.3	4.0	24%
Lamprey River	80 %	< 5%	11.8	2.2	19%
Wednesday Hill Brook[1]	60 %	12 - 15 %	17.8	4.3	24%
Moonlight Brook[1]	< 50 %	30 - 40 %	12.5[2]	5.0	40%

Notes: [1]Data for these two watersheds was based on data presented by Dr. Wiliam McDowell, PhD at the Nitrogen Loading Workshop held May 11, 2013 at the DES-Pease office. [2]This watershed is primarily sewered, which may explain relatively lower source load input value.

Attachment A - Summary Table of Model Input Data Sources

Model Input		Town Boundaries	USGS Piscataqua River Catchment Areas	Urbanized Area	NH DOT Roadways	NHD Streams and Water bodies	UNH and Durham Sewer Infrastructure	VHB Building Datalayer (VHB)	UNH Coop Extension Agriculture	2010 CTAP Land Use (SRPC)	Tree Canopy (VHB)	NASS agriculture/livestock	Durham 2010 IC	UNH and Durham Stormwater Infrastructure	IC 2005 PREP	Managed Turf (DES and VHB)	UNH Base Mapping	Process
Analysis Units	Town/University Boundaries	x																Intersect towns with UNH boundary
	Watershed Boundaries		x															Group watersheds by tributary and design point
	MS4 Boundaries			x	x								x					Use urban layer to identify MS4 Boundaries. Isolate NH DOT roadways as a separate MS4.
Land Use Inputs	Connected / Disconnected IC within Durham	x											x	x			x	Split IC polygons into connected/disconnected using buffer from drainage system infrastructure.
	Connected / Disconnected IC Outside Durham	x													x			Partition IC area into connected/disconnected using Sutherland Equations (DES approach)
	Managed Turf															x		Use DES layer and add additional managed turf areas based on review/input from UNH and towns
	Residential Lawns within Durham	x								x	x				x		x	Subtract impervious cover and tree canopy (derived from LiDAR processing) from residential/developed land uses classes. Assumes remaining pervious land is lawn. Classify UNH Grasslands (not fertilized) based on direct knowledge.
	Residential Lawns outside of Durham	x								x								Use 2010 LU to get polygons for residential/developed land use cover. Categorized residential/developed land use classifications into low, medium, high density, residential open). Use DES percent of lawn per land use classification.
	Agricultural Lands									x		x					x	Use 2010 land cover and UNH base mapping to develop agriculture polygons. Tag generic agriculture areas with type using NASS and/or direct knowledge
	Natural Vegetation									x								Use 2010 LU classifications to ID natural vegetation areas.
Quantity Inputs	Septic within/out 200 meters of water body (number of people on septic systems)					x	x	x	x									Use VHB-developed building data layer and stream buffers to count number of buildings outside of sewered areas (determined by sewer infrastructure mapping). Assume number of people per home based on averages by town.
	Cows and Horses																	Livestock count per area using DES counts minus UNH counts based on manure application data.

Appendix E:

Preliminary Alternative Analysis Memos on Potential Management Measure

DURHAM/OYSTER RIVER NITROGEN POLLUTION ABATEMENT MANAGEMENT ALTERNATIVES

This memorandum presents a high-level overview of stormwater and non-point source management options that **MAY** be viable to reduce nutrient pollution in the Oyster River subestuary. It provides a basis for continuing discussions with regulators and for preparing cost-benefit analyses of management actions most applicable to Durham and Oyster River communities once a thorough understanding of non-point sources has been vetted and accepted. The following memo has been developed to provide a starting place for evaluation of various nutrient pollution removal, management or abatement techniques and are not necessarily preferred or recommended management options. Future evaluation of management options will also need to include wastewater treatment plan optimization as another critical option in abatement of pollution sources from the Town of Durham. Final selection of the preferred management actions will be based on pollutant loading model results, discussions with regulators and the Project Team (UNH/Durham) and interviews and analysis of staff and Town/University to determine management and administrative capabilities.

For the purposes of this memorandum, stormwater and non-point source pollution abatement are treated similarly and can be generally categorized into treatment technologies, conservation practices or operations that reduce pollutant generation or transport. The treatment technologies, conservation practices and operations, as described herein, represent the current "state of the practice" and are widely accepted for the abatement of nutrient pollution and will also address many non-nutrient pollutants.

NITROGEN IN THE ENVIRONMENT

Nitrogen can take many chemical forms, which readily change and cycle in the environment depending on ambient biogeochemical conditions, temperature, water body hydrodynamics and other factors. The forms of most concern for management because of their suitability for biological uptake by plants as a nutrient are ammonia (primarily as ammonium), nitrate, and nitrite, which comprise the dissolved inorganic nitrogen (DIN) pool. Because they are soluble in water and are preferred plant nutrients, they can drive plant and algae growth in coastal waters to levels that are harmful to the aquatic environment, accelerating the process called eutrophication.

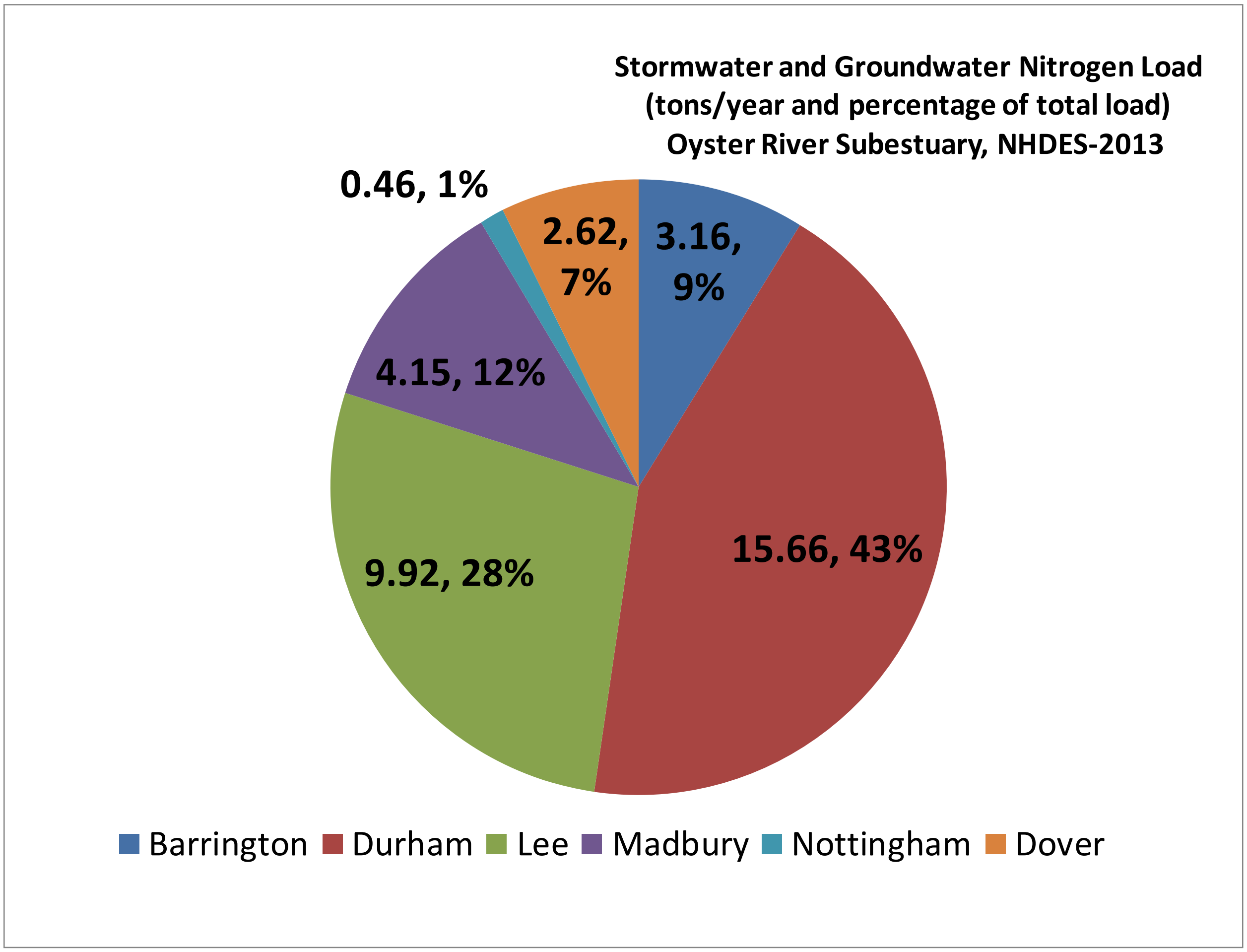
Not all nitrogen pollution is delivered to enriched waters as DIN. Loads of organic nitrogen, both in particulate and dissolved forms, may also be quickly oxidized into the more available nutrient DIN forms. Thus, the nitrogen may cycle in the environment from both organic and inorganic forms to become readily available ammonium and nitrate that fosters plant growth. The generated plant growth ultimately dies and is recycled as organic nitrogen which breaks down and is again oxidized into DIN, fueling another round of plant growth. The sources of nitrogen, both organic and DIN are many, and include:

- Airborne from agriculture (livestock and fertilizer), industrial processes, and burning of fossil fuels (primarily nitrate, but also volatized ammonia and particulate organic nitrogen);
- Waterborne surface runoff (potentially all forms of nitrogen); and
- Underground waterborne sources (primarily nitrate) which can lead to elevated nitrate levels in groundwater, which then migrates to drinking wells, streams or bays.

These forms of nitrogen can be found in elevated levels in runoff or groundwater throughout the year, including meltwater (Burton and Pitt 2002). When these untreated sources migrate into estuarine and coastal areas, elevated levels of nitrogen can contribute to oxygen depletion directly as organic forms and ammonium are oxidized, and DIN can stimulate excessive unsightly and potentially hazardous algal blooms, deplete dissolved oxygen causing fish kills, and reduce light penetration causing declines in native estuary plant species.

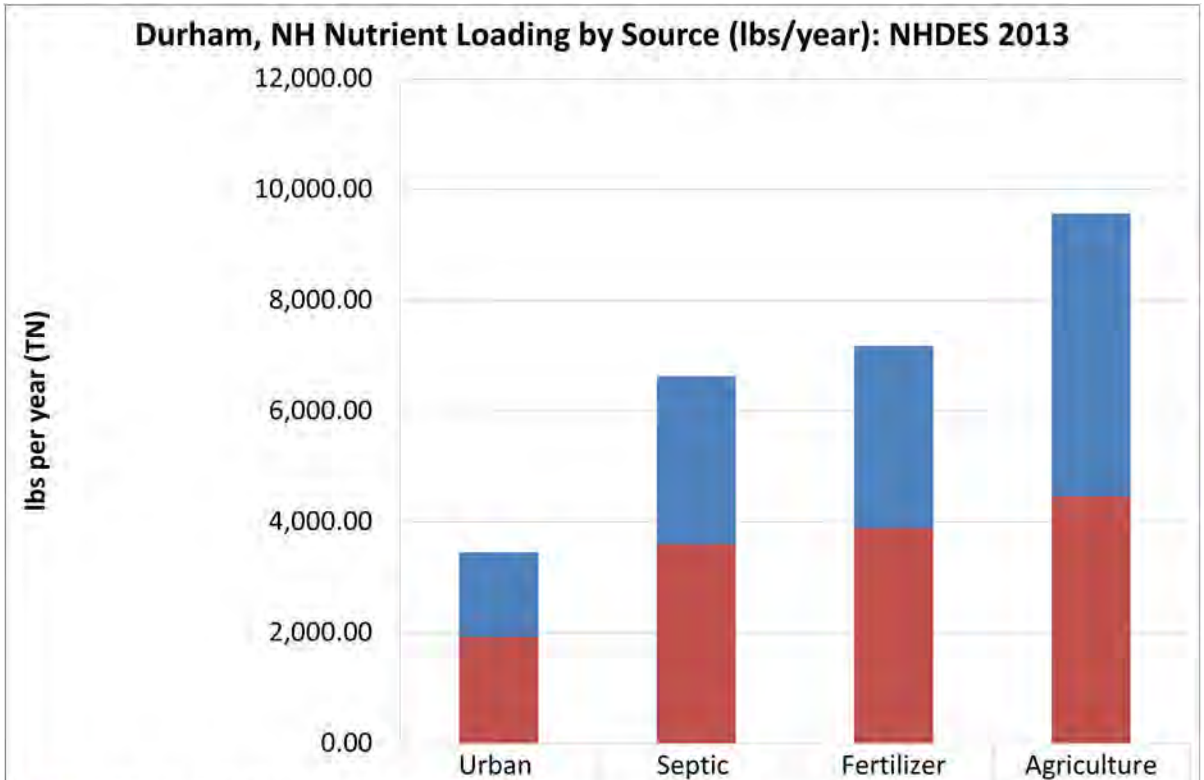
DURHAM AND OYSTER RIVER LOADS AND POLLUTION SOURCES

Figure 1: Total Nitrogen pollutant loading (excluding WWTF) into the Oyster River waters as defined by the Draft Great Bay Nitrogen Non-point Source Study (NHDES, 2013).



Additionally, total nitrogen loads from individual sources within Durham and across the entire Oyster River watershed are summarized in Figure 2 and Figure 3. The loads are expressed in pounds per year.

Figure 2: Total Nitrogen pollutant loading (excluding WWTF and natural sources) into the Oyster River waters from Durham grouped according to general land use category. Source: Draft Great Bay Nitrogen Non-point Source Study (NHDES, 2013).



	Urban	Septic	Fertilizer	Agriculture
Non-Tidal Load (lbs per year)	1,533.72	3,032.11	3,286.65	5,100.99
Tidal Load (lbs per year)	1,921.90	3,593.29	3,889.26	4,464.46

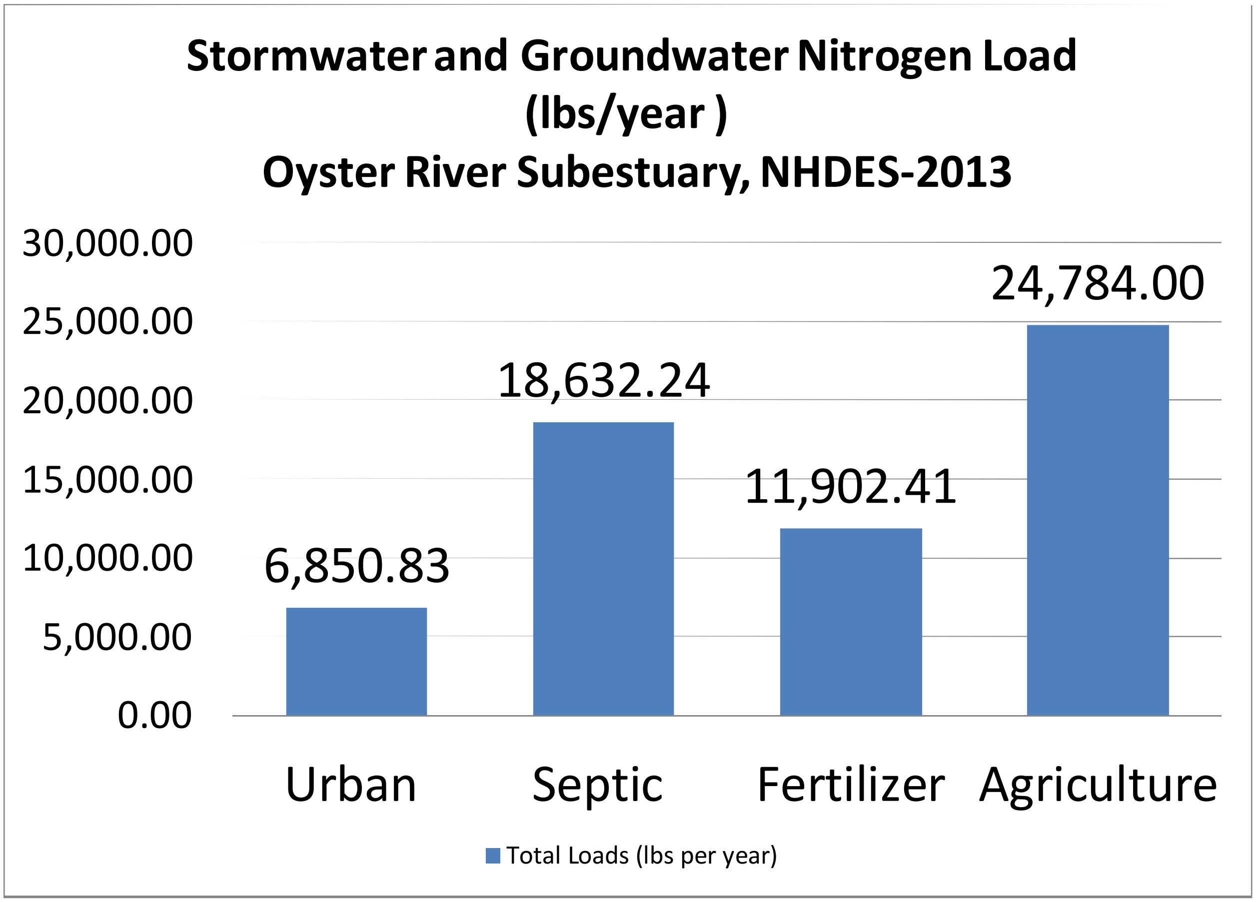
Note: Nonpoint source groupings have been defined by W&C for this memo.
Urban inputs include the following:

- Impervious Landcover Inputs
- Atmospheric Inputs delivered through developed lands (i.e. managed turf, lawn, etc)

Septic Inputs include septic sources.
Fertilizer inputs include all chemical fertilizer with exception of agricultural fertilizer.
Agriculture includes the following:

- Manure
- Agricultural chemical fertilizers
- Agricultural lands runoff

Figure 3: Total Nitrogen pollutant loading (excluding WWTF and natural sources) into the Oyster River waters from all communities grouped according to general land use category. Source: Draft Great Bay Nitrogen Non-point Source Study (NHDES, 2013).



Note: Nonpoint source groupings have been defined by W&C for this memo.
Urban inputs include the following:

- Impervious Landcover Inputs
- Atmospheric Inputs delivered through developed lands (i.e. managed turf, lawn, etc)

Septic Inputs include septic sources.
Fertilizer inputs include all chemical fertilizer with exception of agricultural fertilizer.
Agriculture includes the following:

- Manure
- Agricultural chemical fertilizers
- Agricultural lands runoff

URBAN LAND CONSERVATION AND OPERATIONS MANAGEMENT ACTIONS

Non-structural urban land conservation, management and operations prevent or reduce nutrient pollution migration into surface waters by reducing the exposure and generation of pollutants, preservation of un-built landscapes and/or providing a regulatory framework that minimizes the likelihood that built areas will increase nutrient migration into water bodies. Non-structural approaches to pollution prevention and management can be the most cost-effective and holistic practices within a watershed management framework. There are several components of non-structural management actions, each of which requires a sufficient management and tracking program to ensure implementation and effectiveness:

- Planning, design and construction that minimizes or eliminates adverse impacts;
- Pollution prevention measures aimed at minimizing exposure and release of pollutants;
- Education and training to promote awareness regarding the previous two components; and
- Conservation practices that ensure landscapes retain their hydrologic integrity which reduces flow volumes and pollutant export.

The following conservation practices and operations have been selected primarily for water quality improvements and are based on proven performance and the potential to reduce Nitrogen in stormwater and groundwater. Costs for non-structural management are highly variable and have not been included at this time. Cost estimates for these types of management actions will be developed in future phases of work and will be based on Durham/UNH policies, equipment and administration.

The following list of practices and operations includes references on effectiveness and general comments on the technology.

<u>Urban Nutrient Management:</u> Urban nutrient management plans address nutrient uptake by turf and landscape plants on urban pervious land. The management of turf or fertilizer application can be voluntarily implemented or included in a set of local or state laws. Urban nutrient management can result in significant reductions (according to established credit programs) but can be difficult to enforce or track. An expert panel in the Chesapeake Bay defined a core set of urban nutrient management practices based on research and current legislation and has been used herein as defined load reductions have been utilized in the Chesapeake Bay as a result of this management guidance. Local urban nutrient management guidelines may be utilized if load reduction percentages are agreed upon in later phases of work.

1. Consult with the local extension service, master gardener or certified applicator to get technical assistance to develop an effective urban nutrient management plan for the property.
2. Maintain a dense vegetative cover of turf grass to reduce runoff, prevent erosion, and retain nutrients.
3. Choose not to fertilize, or adopt a reduce rate/monitor approach or a small fertilizer dose approach.
4. Retain clippings and mulched leaves on the yard and keep them out of streets and storm drains.
5. Do not apply fertilizers before spring green up or after grass becomes dormant.
6. Maximize use of slow-release N fertilizer during the active growing season.
7. Set mower height at 3 inches or taller.
8. Immediately sweep off any fertilizer that lands on a paved surface.
9. Do not apply fertilizer within 15 to 20 feet of a water feature (depending on applicable state regulations) and manage this zone as a perennial planting, meadow, grass buffer, or a forested buffer.

10. Employ lawn practices to increase soil porosity and infiltration capability, especially along portions of the lawn that convey or treat stormwater runoff.

The expert panel developed a watershed model that assumed an average annual nitrogen fertilizer input on urban land of 43 lbs N/acre/year. The fertilizer application period was assumed to be 80 days in the spring and the fall. According to the model, there is a 3% reduction in delivered nitrogen load from pervious land for each 10% increment reduction of the current fertilizer input of 43 lbs/acre/year. The value of 43 lbs/acre/year (1 lbs per 1000 ft^2) of input on urban land and lawns is consistent with input loads used by NHDES in their Great Bay Non-Point Source Study. They used a prorated value of 1.28 lbs/1000ft^2 based on average fertilizer application rate and likely percent of lawns fertilized each year.

Implementation of urban nutrient management plans involve public education geared towards residence owners and businesses. One approach to public outreach is the retail method, which provides training and direct technical assistance to individual property owners as well as certification of commercial fertilizer applicators on appropriate management practices. This retail method is shown to be more effective than wholesale methods, which relies on passive outreach through social media. For example, one study conducted in four New England communities revealed that after having received extension service training, 55% of residents reported a reduction in fertilizer application (Aveni et al. 2013).

Appendix B provides an overview of regulatory and non-regulatory fertilizer control programs in New England.

Street Sweeping: The ability of street sweeping to reduce nutrient loads depends on factors such as equipment type, frequency of cleaning, conditions of roadways and catchments, and street sweeping methods. For example, higher nutrient removal efficiencies can be achieved through weekly sweeping using high efficiency regenerative air-vacuum sweeper technology, while the low end of nutrient reduction would be accomplished using a mechanical broom twice per year. Street sweeping can also be used to support leaf litter collection programs and catch basin cleaning practices. Removal efficiencies are based on acres of impervious surface swept using the street sweeping practice.

Catch Basin Cleaning: Catch basin cleaning involves removing material that has accumulated in catch basins to reduce the potential migration of these materials into downstream water bodies. Removal efficiencies are based on the acres of impervious drainage area that contributes to catch basins.

Organic Waste and Leaf Litter Collection Program: This practice involves management of leaf litter and organic waste through regular removal and disposal of these materials from impervious surfaces that contribute runoff to surface water bodies. The Draft NH MS4 Permit recommends a gathering and removal frequency of once per week from September to December for a phosphorous reduction credit, which may be applicable to nitrogen reduction as well. Removal efficiencies are based on acres of impervious surfaces that were managed under this program.

Elimination of Illicit Discharge Connections and Discharges: This practice involves the removal of illicit connections that contain untreated wastewater that are being discharged to surface water bodies. Removing illicit cross connections and relining sanitary sewer lines may be a cost effective method in comparison to structural stormwater treatment technologies. Removal efficiency is based on discharge flow (based on metered household water use) and nitrogen concentration in sewerage. The Draft NH MS4 Permit, Appendix H uses a nitrogen concentration of 40 mg/L, and also assumes 90% of water used goes to the sanitary sewer. The amount of nitrogen load reduction for elimination of illicit discharge can be calculated using the following equation:

TN Reduction (lbs/yr) = Discharge Flow (gal/day) x Water Use Factor (0.9) x TN (40 mg/L) x Conversion Factor (0.00304)

Land Retirement/Conservation: Land retirement practices improve water quality through long-term management of resource areas that generate minimal pollutants when compared to surrounding built areas. Agricultural land retirement may also involve planting permanent vegetation on erosive agricultural cropland or pastureland. Conservation plans are used to protect and improve water quality by protecting and restoring undeveloped lands. Removal efficiencies are based on the number of acres retired/conserved and the extent to which the land was previously used.

Riparian Buffers: Riparian buffers are areas of permanent vegetation adjacent to a water body. Pollutants in runoff can be removed through plant uptake, as well as infiltration and temporary storage in the underlying soils. The riparian area is generally managed to maintain the integrity of stream channels and shorelines. A buffer should have a width of 100 feet and a minimum width of 35 feet and nitrogen removal can be 13-46% effective for grass buffers, and up to 65% effective for forest buffers. Higher removal efficiencies can be achieved depending on program management (Mayer *et al*. 2005). Removal efficiencies are based on the number of acres of buffer.

Rooftop Disconnection Programs: Rooftop disconnection practices utilize interception, infiltration, and filtration mechanisms to manage runoff. Simple disconnection systems direct runoff from rooftops to pervious areas, such as vegetated filter strips. Other disconnection systems include an alternative method to reduce runoff, such as bioretention and storage in vessels. Removal efficiencies are based on acres of vegetated filter strips since they are similar in practice to rooftop disconnection programs.

Erosion and Sediment Control: Erosion and sediment control practices are implemented during land development activities. These practices are designed to prevent sediment pollution and increases in runoff by retaining sediments on-site. Examples of erosion and sediment control include mulching, riprap, seeding, filter berms, sediment traps, and hay bales. Removal efficiencies are based on the acres of construction activity providing managed erosion and sediment control.

Forest Harvesting Practices: Forest harvesting best practices involve reducing the release of sediments and nutrients resulting from forest operations, which include road building, log removal, site preparation, and forest management. Removal efficiencies are based on forest harvest acres managed under best practices.

Public Education: Public education programs can increase awareness regarding nitrogen loading among the general public as well as municipalities, and can include informational brochures, public service announcements, and school programs. The programs should cover topics such as proper pet waste disposal, rooftop disconnections, impervious surface disconnections, and low-impact development.

Planning for Growth Control: Planning for growth control involves developing ordinances that can address low-impact development, stormwater runoff pollution, and land conservation.

Table 1: Urban Land Conservation and Operations Management Actions and Removal Efficiencies

System Category	Nitrogen Removal Efficiency
Urban Nutrient Management	17%(1)
Street Sweeping	3%(1) – 10%(3)
Catch Basin Cleaning	2%(3)
Organic Waste and Leaf Litter Collection Program	5%(3)
Elimination of Illicit Discharge Connections and Discharges	TBD
Land Retirement/Conservation	3-8%(1)
Riparian Buffers	13-65%(1)
Rooftop Disconnection Programs	25-50%(2)
Erosion and Sediment Control	25%(1) – 33%(4)
Forest Harvesting Practices	50%(1)
Public Education	TBD
Planning for Growth Control	TBD

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010
(2) Virginia DCR Stormwater Design Specification No. 1, Rooftop (Impervious Surface) Disconnection, March 2011.
(3) Draft NH MS4 Permit, Appendix F. The 10% reduction refers to phosphorous removal; however, this should be applicable to nitrogen removal as well.
(4) CBP Watershed Model: Appendix H

AGRICULTURAL LAND CONSERVATION AND OPERATIONS MANAGEMENT ACTIONS

Proper agricultural management practices can prevent non-point source pollution originating from sources such as chemical fertilizer and manure. Implementation of these practices must take economic impacts into consideration while maintaining environmental quality. The following agricultural practices and operations have been selected primarily for water quality improvements and are based on proven performance and the potential to address Nitrogen in agricultural runoff. The following list of practices and operations includes references on effectiveness and general comments on the technology.

Cropland Nutrient Management: Cropland nutrient management plans detail the optimum use of nutrients that can both minimize nutrient loss and maintain crop yield. Nutrient management plans will depend on soil type, expected crop yield, and nutrient availability, and should include guidelines for the amount, placement, and timing of nutrient application for each crop. It is recommended that management plans include a minimum reduction of 10% in nutrient application rates, and management plans are updated every two to three years. Removal efficiencies are based on percentage of acres under nutrient management.

Enhanced Nutrient Management: According to research conducted by the American Farmland Trust, nitrogen application rates are set approximately 35% higher than necessary for optimal crop growing conditions. A 15% reduction in nitrogen application rates to cropland would result in a 7% nitrogen removal efficiency. Included in this plan would be an incentive or crop insurance in case of crop yield loss.

Conservation Plans: Conservation plans are used to protect and improve water quality by protecting and restoring undeveloped lands. Removal efficiencies are based on the number of acres conserved and the extent to which the land was previously used.

Horse Pasture Management: This practice involves stabilizing small pasture animal containment areas, as well as maintaining a 50% pasture cover in order to reduce erosion and nutrient loss. Horse pasture management should be used in conjunction with stream protection with fencing when appropriate. Removal efficiencies are based on acres of horse pasture being managed. Although there is currently no established nitrogen removal efficiency for this practice, it may be comparable to the phosphorous removal efficiency of 20%.

Animal Waste Management Systems: This practice accounts for the proper handling, storage, and utilization of waste generated from confined animal operations. Liquid wastes are treated or stored in lagoons, ponds, or tanks, while solid wastes are stored in sheds or pits. Runoff should be controlled from roofs, feedlots, and loafing lots. Removal efficiencies are based on manure acres reduced. A manure acre is defined by the Chesapeake Bay Watershed Model as 145 Animal Units in an area which is susceptible to runoff and where high concentrations of confined animals are contained. (CBP Watershed Model: Appendix H)

Barnyard Runoff Control: Practices installed to control barnyard runoff includes roof runoff control, diversion of clean water from entering the barnyard, and control of runoff from barnyard areas. Nitrogen removal efficiency may vary depending on the presence of manure storage on-site.

Cover Crops: This practice involves planting and growing cover crops (i.e. rye, barley, wheat) on cropland, maintaining a vegetative cover with minimal disturbance of the surface soil. The cover crops capture and maintain nutrients within the root zone or in the plant matter directly, reducing erosion and nutrient leaching to groundwater. Captured nitrogen can be released and re-used for the next crop when cover crops are plowed in the spring. Factors that can influence nitrogen removal efficiencies include crop species, planting times, and fertilizer applications. Removal efficiencies are based on acres of land converted to grow cover crops.

Continuous No-Till: Continuous no-till practices involve eliminating soil disturbance by tillage equipment, such as plows and disks. This practice applies to multi-crop, multi-year rotation systems that retain crop residue on the field, and is recommended to be maintained for at least five years. Removal efficiencies can vary by geography. Removal efficiencies are based on acres of cropland planted using continuous no-till practices.

Loafing Lot Management: This practice involves stabilizing areas that are frequently and intensively used by people, animals, or vehicles. Stabilization will prevent manure and sediment runoff due to ground cover destruction. Stabilization methods include establishing a vegetative cover, surfacing the area with materials, or installing necessary structures such as concrete walkways. Removal efficiencies are based on acres of loafing lots being managed under this practice.

Water Control Structures: Water control structures include controlling runoff from surface drainage ditches by installing and maintaining boarded gate systems. Removal efficiencies are based on acres of drainage area being controlled with water control structures.

Stream Protection with Fencing: This practice involves fencing strips of land along streams to prevent streambank erosion and direct animal contact with surface waters. Removal efficiencies are based on linear feet of fencing along the streambank.

Table 2: Agricultural Land Conservation and Operations Management Actions and Removal Efficiencies

System Category	Nitrogen Removal Efficiency
Cropland Nutrient Management	5-39%[4]
Enhanced Nutrient Management	7%[1]
Conservation Plans	3-8%[1]
Animal Waste Management Systems	80%[1]
Barnyard Runoff	20%[1]
Cover Crops	30-45%[2]
Continuous No-Till	10-15%[1]
Loafing Lot Management	20%[1]
Water Control Structures	33%[1] - 40%[3]
Stream Protection with Fencing	60%[2] – 75%[4]

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010
(2) Tracking Restoration Efforts in Maryland's Tributaries (http://dnrweb.dnr.state.md.us/watersheds/surf/bmp/swbmp.asp)
(3) Neuse River Basin (North Carolina).
(4) CBP Watershed Model: Appendix H.

SEPTIC MANAGEMENT ACTIONS

Improper installation and maintenance of on-site septic systems can lead to migration of nitrogen and other pollutants in surface runoff and groundwater. Regulatory mechanisms have the potential to address non-point source pollution originating from individual sewage disposal systems (ISDS) but are primarily focused on new construction. Currently, New Hampshire regulates ISDS through state-wide policies on baseline minimum design and capacity requirements.

The DES has passed rules regulating the design of septic systems or, more broadly, ISDS. Env-wq 1000 requires that all plans for all newly installed ISDSes are sent for approval to the DES Subsurface Systems Bureau. Id. § 1003.02. Specifically, septic tanks are addressed beginning at § 1010, providing for capacity and design requirements. The regulations are highly technical and are overseen by the DES in its rulemaking and oversight capacity. Significantly, however, DES provides only briefly for mandatory inspection and pumping. See id. § 1023.01 ("Septic tanks shall be inspected for accumulation of sludge and surface scum at a frequency sufficient to allow the tank to be pumped by a licensed septage hauler when the combined thinness of the sludge and surface scum equal 1/3 or more of the tank depth."). The DES also provides for the minimum septic tank setbacks from varying bodies of waters, property lines, wells and other features. See id. § 1008.04. Notably, the mandatory setbacks are 75' from surface water and very poorly drained jurisdictional wetland and 50' from poorly drained jurisdictional wetland.

Municipal regulation of septic systems also exists through local ordinances; however, each town implements differing requirements with various levels of enforcement. The Town of Durham currently includes provisions in its Zoning Ordinance concerning septic design, installation, and zoning (Town of Durham, Zoning Ordinance 2006, Article XXIV). The Town's Septic System Code not only supports DES state-wide regulations, but also strives to enforce more rigorous septic design and zoning standards. Specifically, section 175-139 states that the location of the leaching field cannot be within 125' from any water body or very poorly/poorly drained soils, which is much more stringent than the DES standard of 75’ for minimum septic tank setbacks. Enforcement involves an inspection of the system installation by the Town’s Code Enforcement Officer (section 175-140); beyond this, however, there is no provision for regularly scheduled mandatory inspections or pumping.

Municipal and regional on-site wastewater management districts are a common alternative to state agency wastewater regulation. Such districts are generally established pursuant to three forms of legal authority. First, many states have existing legislation authorizing the voluntary formation of districts to assume responsibility for establishing standards, ensuring enforcement, and procuring funding for local and regional wastewater regulation. Second, municipalities can use their home rule authority to enact bylaws and regulations to be enforced by municipal officials in addition to state laws. Lastly, a legislature can enact special legislation enabling the formation of a particular regional district. States such as Massachusetts and Rhode Island have demonstrated that regional management districts can be more effective in regulating on-site sewage disposal, especially in enforcing mandatory inspections and maintenance. Currently, New Hampshire has no comparable law authorizing the general creation of management districts anywhere in the state. Without such enabling legislation, regional entities, other than individual municipalities, have no legal authority to impose or enforce more stringent regulations.

The following list of practices and management strategies include references on effectiveness and general comments on the technology.

Waste Water Management Districts: These districts are legal entities independent of the state which have the authority to enforce state or local laws and to provide a management entity responsible for effective ISDS management. One such district created pursuant to the Rhode Island law is the South Kingstown Onsite Wastewater Management Program (see “South Kingston, RI example” in Appendix A). The program has instituted an inspection schedule requiring compliance with stringent local standards established pursuant to town ordinances. In its first five years, the inspection program completed over 4500 inspections, discovering over 150 substandard ISDS and repairing almost 90 systems. The burden of paying for mandatory inspections and repairing substandard wastewater systems is left to the homeowner, but loan programs are available in RI to help residents with replacements and costly repairs.

Septic Pumping: Septic pumping is a management practice that increases the system’s capacity to remove solids from wastewater and reduce nutrient leaching. It is recommended that septic tanks be pumped once every three to five years depending on ISDS loading. Waste water management districts provide a means to enforce mandatory septic pumping on a regular basis.

Septic Denitrification: Traditional septic systems typically include a holding tank to settle solids from the wastewater and a drain field to allow the wastewater to infiltrate through the ground. Septic denitrification involves replacing the traditional septic systems with advanced technology that can further treat and remove nitrogen through denitrification.

Table 3: Septic Management Actions and Removal Efficiencies

System Category	Nitrogen Removal Efficiency
Establishment of ISDS Wastewater District	TBD
Septic Pumping	5%(1)
Septic Denitrification	50%(1)

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010

STORMWATER RUNOFF TREATMENT TECHNOLOGIES

Denitrification

The natural microbial process of denitrification is a primary treatment method for removing excess nitrogen in runoff. Denitrification converts the water-soluble nitrogen compounds, especially nitrate, into nitrogen gas. These microbial processes are promoted in structural stormwater management systems by creating an anaerobic (oxygen-free) water-saturated zone that contains a carbon source such as wood chips. Management practices may also take advantage of naturally carbon-rich, anaerobic conditions that exist in wetlands and riverine corridors by infiltrating water into those soils.

Specific Approaches for Denitrification

When nitrogen removal from stormwater is desired, a water-saturated, anaerobic zone with a carbon donor can promote the natural process of denitrification to provide an effective solution (Hinman 2009, Kim *et al*. 2003), with bioretention cells specifically cited (Brown *et al*. 2009, Davis *et al*. 2001). Many existing stormwater treatment system designs may need modification to ensure denitrification. In addition, care must be taken to limit the anaerobic zone to only the zone where denitrification occurs, in order to avoid release of sequestered pollutants from other zones designed for aerobic filtration. Some studies show denitrification can occur in grass buffer strips (Cors and Tychon 2007) or in soil (Dietz and Clausen 2005, Elliott 2010), though the results suggest soil denitrification may not occur in all situations.

Reducing Runoff – Infiltration

Limiting “directly-connected” impervious surfaces is a sound strategy to treat nitrogen in storm water. Although it does not eliminate all DIN from the watershed, it does reduce the likelihood of direct transport to surface waters and affords opportunities for physical nitrogen removal in soils, vegetative uptake and denitrification, natural processes in surface soils that attenuate nitrogen species in runoff. Additionally, disconnection of runoff from low-nitrogen sources, such as rooftops, reduces the potential for transporting pollutants via concentrated flow in road ditches and pipes.

Infiltration Concerns near Drinking Water Wells or Sensitive Coastal Areas

Infiltrating large amounts of nitrogen-rich runoff into groundwater in certain sensitive locations should be avoided. Without attention to nitrogen removal before infiltration, DIN can accumulate in groundwater and pollute drinking water drawn from wells. Soluble forms of nitrogen can travel undiminished through groundwater into coastal waters, causing the same problems as stormwater runoff. Because groundwater transport can be slow and gradual, nitrogen eutrophication may only become apparent years after the loading begins (e.g., following neighborhood septic systems installations), at which point the problem will likely persist for decades even after sources are controlled.

Despite its limitations, infiltration of stormwater remains a viable option for reducing many harmful stormwater effects and system designs can be tailored to reduce the potential migration of nutrient species into groundwater.

Structural System Treatment Technologies

Stormwater management technologies that promote infiltration, denitrification and other pollutant removal features can be implemented as modifications to existing stormwater management facilities or as new stormwater management facilities to be incorporated into an existing storm drain system or built area.

There are three typical management goals considered for stormwater management retrofit facilities. These include:

- Stormwater quantity control (i.e. reducing peak rate of runoff) to prevent downstream flooding using systems typically designed to manage 2, 10, or 100-year recurrence storm events;
- Stormwater quality or Water Quality Volume (WQV) treatment typically associated with the 1-inch, 24-hour storm event; and
- Peak runoff rate attenuation for the Channel Protection Volume (CPV) typically associated with the 1-year recurrence storm event. The CPV helps to minimize erosion and other such impacts to downstream natural stream systems.

Selected stormwater technologies with potential to address nitrogen in stormwater can provide nutrient "credits" towards attainment of water quality management goals that can be quantified and tracked. . The structural stormwater management systems identified below are based on proven performance but feasibility and effectiveness in any location is highly dependent upon characteristics of the site (e.g., soil drainage, site dimensions, existing cover, available hydraulic head and elevations of existing infrastructure, etc.). A range of installation costs for these systems as retrofits has been provided for reference.

<u>Urban Filtering Practices (Rain Gardens, Bioretention):</u> Urban filter systems are usually designed as vertical flow media filters vegetated or vegetated/soil media systems, but may also include subsurface filtration processes. Surface systems are typically vegetated with grass and/or landscape plantings. Subsurface vertical flow systems usually designed with an inert subsurface filtration media (e.g. sand, gravel). In poorly draining subsoils, infiltration may be limited but volumetric losses via evapotranspiration can be enhanced and infiltration below the underdrain promoted, if appropriate. Filter systems have the potential to reduce overall stormwater volumes and peak flows and have been shown to be effective in reducing loads of certain pollutants, including nitrogen. As described previously, these systems can be designed to provide an anaerobic zone within the cross section of the filter bed to enhance Total Nitrogen removal and/or can include specific filter media designed for nutrient sequestration.

<u>Vegetated Open Channels or Dry Swales:</u> Vegetated open channels can provide water quality improvement via infiltration or filtration while conveying stormwater runoff and are typically utilized along linear transportation features. Surface systems involve filtering runoff through soil media and vegetation, while subsurface systems allow water to infiltrate into the subsoils. Vegetated open channels or dry swales can be designed and function as a subcategory of filtering practices and treatment processes can be similar.

<u>Urban Infiltration Practices:</u> Urban infiltration practices involve basins that are designed to provide storage and promote infiltration into the soil. These infiltration basins and trenches are constructed when soils meet specific infiltration design criteria, and can be vegetated or non-vegetated. Because these systems can provide complete infiltration, no underdrains are typically utilized with these systems. Permeable pavements are also associated with urban infiltration practices, and can utilize both infiltration and filtration mechanism to improve water quality. Infiltration practices can provide significant pollutant removal if designed appropriately and also have the potential to reduce runoff volume and attenuate peak flows. These systems should be carefully designed when nutrient pollutants are the target as infiltration of nitrogen species may result in the movement of pollutants in groundwater.

<u>Wet ponds:</u> Wet ponds are retention structures that store stormwater runoff, promoting the settlement of sediments and pollutants. Wet ponds can contain anaerobic zones and therefore provide some degree of denitrification depending on design. This technology is an older style of stormwater treatment and may have limited pollutant removal or contribute to increases in runoff temperature.

Dry Detention Basins and Extended Detention Basins: Dry detention ponds are primarily designed to reduce stormwater runoff volume and reduce peak flow by providing temporary storage. The water is released via surface discharge through an outlet control structure. An increased residence time can improve water quality via sedimentation and vegetative pollutant uptake but the primary design criteria for dry detention basins was historically peak rate reduction and therefore they offer minimal pollution control.

Gravel Wet Vegetated Treatment System (GWVTS): GWVTS are horizontal flow retention and filter systems. The GWVTS utilizes temporary storage and solids settling, filtration and biogeochemical processes as the mechanisms for pollutant removal. These systems can also provide peak flow attenuation and, through evapotranspiration, can reduce runoff volumes. These systems are especially well-suited on poorly draining soils or in locations with limited hydraulic head. This is one of the University of New Hampshire Stormwater Center's most successful systems for overall pollutant removal and particularly Nitrogen removal.

Below-Grade Treatment Train: Proprietary below grade treatment trains are diverse but typically include a physical settling and filtration component. These systems are well suited to stormwater treatment on parcels with limited available surface area. The system considered for project costs is the Contech® Hydrodynamic Separation and Filtration unit, but there are numerous other proprietary systems that may vary in cost. The below grade treatment train is typically an off-line, flow through system with a defined maximum flow through rate based on filter limitations. The below grade treatment train can provide modest pollutant removals but does not provide peak flow attenuation or overall volume reductions unless designed with upstream storage. For this exercise, this system type is assumed to only provide filtration.

Structural System Effectiveness and Cost

The following table provides reported treatment capabilities of each of the categories of treatment systems as described above. We acknowledge that removal efficiency can vary widely but many of the identified pollutant removal efficiencies have been established by EPA for nutrient reduction in the Chesapeake Bay TMDL (Cheseapeake Bay Program 2010).

Table 4: Stormwater Treatment Technology Nitrogen Removal Efficiency and Opinion of Cost

System Category	Nitrogen Removal Efficiency	Cost per acre of impervious area treated[4]
Urban Filtering	40%[1]	$57,000-131,000
Urban Infiltration	80-85%[1]	$32,000-$744,000[5]
Wet ponds	33%[2]	$46,000
Vegetated Open Channels	10-45%[1]	$83,000
Dry Detention Basins	25%[2]	$35,000
GWVTS	55-75%[2]	$80,000
Below-Grade Treatment Train	18-38%[3]	$270,000

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010

(2) UNH Stormwater Center 2012 Biennial Report

(3) Evaluation of the Stormwater Management StormFilter® system for the removal of total nitrogen, 2006.

(4) Costs may vary significantly based on installation location and relative size of system to size of drainage area. These opinions of cost reflect costs per unit impervious area treated based on delivered and placed material costs and include engineering, survey, construction bonds and contingency. These costs reflect treatment options for non-residential properties. Residential treatment options are typically lower cost per unit than non-residential options. Operating costs are often considered as an annual percentage (3-5%) of overall project costs but have not been included in this cost summary.

(5) High end cost estimate reflects cost of full depth reconstruction of existing surface asphalt pavement with porous asphalt pavement.

NITROGEN HARVESTING

The following non-traditional practices and operations have been selected primarily for water quality improvements and are based on their potential to address Nitrogen. The following list of practices and operations includes references on effectiveness and general comments on the technology.

Oyster Restoration: Oyster reefs provide a number of important ecological benefits to the Great Bay ecosystem, including nutrient removal through their filter-feeding mechanisms. It is estimated that one acre of live oyster reef can filter up to one ton of nitrogen each year (McKeton *et al*. 2012). However, the oyster population in the Great Bay has declined significantly over the past century due to overharvesting, pollution, and disease. Oyster restoration effort examples include the Cheseapeake Bay Oyster Management Plan adopted in 2004 and the Oyster Conservationist Program organized by the Nature Conservancy and University of New Hampshire. Oyster reefs are constructed using hard surfaces such as oyster shells on which hatchery-raised larval oysters can grow.

Urine Segregation: Urine segregation is a practice that can reduce nitrogen loads in domestic wastewater, potentially reducing costs and improving influent water quality for wastewater treatment facilities. The recovered nutrients can be treated or reused for applications such as agricultural fertilizer. It is estimated that 80% of the nitrogen found in sewage is from urine; therefore, urine segregation could potentially reduce 50-75% of nitrogen loads in wastewater (Hazen & Sawyer, 2009). Urine separation systems include toilets with separate collection bowls and effluent lines, which will convey urine to a small storage tank. Urine treatment options to remove and recover nitrogen include evaporation, precipitation, and electrochemical treatment.

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APPENDIX A: EXAMPLE ONSITE WASTEWATER MANAGEMENT PROGRAM: SOUTH KINGSTOWN, RI

BACKGROUND

The Town of South Kingstown, Rhode Island (Town) obtained the services of Woodard & Curran to review the scientific basis and implementation guidance of several Total Maximum Daily Load studies in order to develop a cost effective strategy for compliance with the Town's Municipal Separate Storm Sewer System (MS4) RIPDES permit and to initiate water quality improvement in the TMDL waterbodies. The following is a summary of the Town's Onsite Wastewater Management Program, presented herein, to provide an example of a septic management program utilized in a community similar to Durham, NH.

South Kingstown is a town in Washington County, Rhode Island. The population was 30,639 at the 2010 census. South Kingstown includes the villages of Kingston, West Kingston, Wakefield, Peace Dale, Snug Harbor, Tuckertown, East Matunuck, Matunuck, Green Hill, and Perryville. The University of Rhode Island is located in the village of Kingston.

A central portion of South Kingstown, including the villages of Wakefield, Peace Dale, Kingstown, West Kingstown, and the URI campus, is served by a sanitary sewer system that conveys wastewater to a treatment plant located in Narragansett. Outside these sewer service areas, all other areas of South Kingstown rely on private onsite wastewater treatment systems (commonly referred to as septic systems) for wastewater treatment and dispersal.

REGULATORY FRAMEWORK

In Rhode Island, Onsite Wastewater Treatment Systems (OWTS) traditionally referred to as Individual Sewage Disposal Systems (ISDS), fall under the regulatory authority of RIDEM, which issues administrative regulations governing their approval, design, installation, inspection, and management. Each municipality is authorized to adopt local ordinances which meet or exceed standards set forth in the state regulations and allow for local incentives and penalties to compliment state oversight. South Kingstown has created a local Onsite Wastewater Management Program, allowing the town to implement local OWTS ordinances and policies. In addition, the Rhode Island Coastal Resources Management Council has developed the Salt Pond Region Special Area Management Plan (SAMP), with OWTS requirements and recommendations focused specifically on the long-range preservation of sensitive salt pond and watershed resources.

RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

The General Laws of the State of Rhode Island grant authority to the Department of Environmental Management Office of Water Resources to regulate new, existing and replacement onsite wastewater treatment systems. On January 1, 2008 the "Rules Establishing Minimum Standards Relating to Location, Design, Construction and Maintenance of On-Site Wastewater Treatment Systems (OWTS)" became effective. These rules specify design flows and minimum setback distances, and designate certain critical resources within the State. The South Shore Coastal Ponds are among those areas identified as critical resources. In those areas identified as critical resources, all new sites, as well as those systems being rehabilitated, are required to install OWTS that are capable of nitrogen reduction.

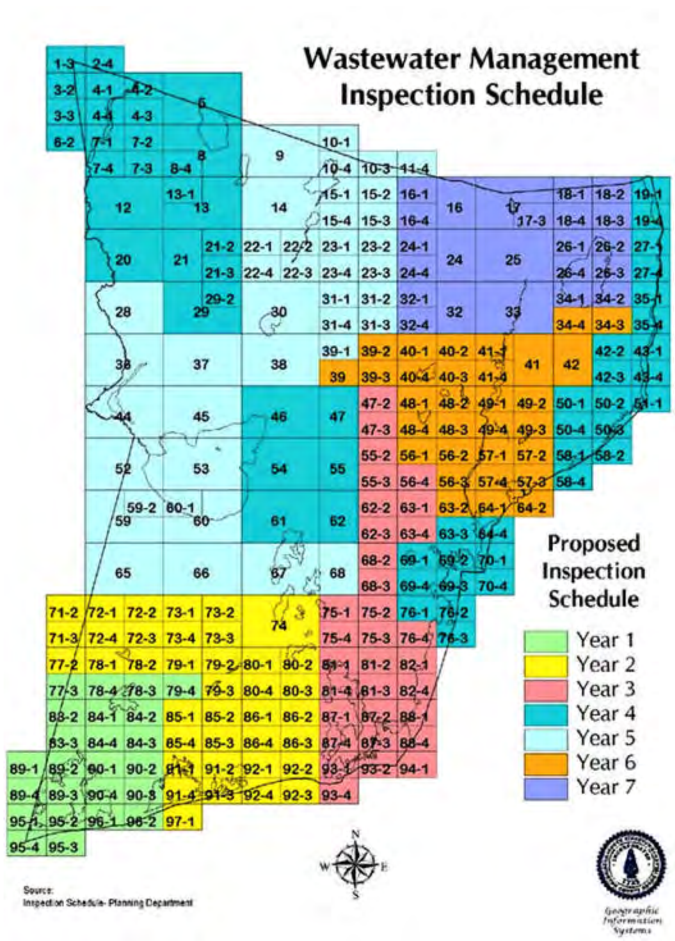
SOUTH KINGSTOWN ONSITE WASTEWATER MANAGEMENT PROGRAM

South Kingstown has adopted an ordinance and regulations creating a local Wastewater Management District (WWMD) under the authority of the State of Rhode Island General Laws, Title 45, Chapter 24.5:

§ 45-24.5-3 Declaration of purpose. – The purpose of this chapter is to authorize the cities and towns of the state to adopt ordinances creating waste water management districts (WWMD), the boundaries of which may include all or a part of a city or town, as specified by the ordinance. These ordinances must be designated to eliminate and prevent the contamination of state waters, caused by malfunctioning individual subsurface disposal systems (ISDS), through the implementation of ISDS inspection and maintenance programs. The waste water management district ordinance programs shall be designed to operate as both an alternative to municipal sewer systems and as a method to protect surface and ground waters from contamination.

The Town of South Kingstown adopted an Onsite Wastewater Management Ordinance in October 2001 which established a mandatory maintenance inspection of all OWTSs and cesspools. As set forth in the ordinance, this program is being implemented in seven phases based on the perceived environmental sensitivity of each geographic area. The inspection schedule is included as Figure 1.

Figure 1: South Kingstown Onsite Wastewater Management Inspection Schedule



- Provisions of the program include:
- Establishing an entity with the authority to manage local individual sewage disposal systems
- Making regular inspection and maintenance of septic systems mandatory
- Emphasizing the problem of cesspools as a sub-standard form of sewage treatment

- Instituting local penalties for non-compliance of up to $500 per day
- An initial Town notice to owners to inspect their systems (45-day compliance limit to schedule an inspection with a Town-approved Inspector)
- All cesspools and any system installed prior to 1970 must be pumped at the initial inspection
- Town-issued violation notice if repairs or upgrades are needed (proof must be submitted to Town within 30 days that actions have been taken)
- All septic tanks must be proven to be watertight
- All cesspools must be replaced within 5 years of the initial inspection or within 12 months of a property sale
- Remediation plans developed by owners of a lot containing more than one detached dwelling unit – these plans may include gray-water and shared systems
- A schedule for future pump-outs and inspections is determined by site-specific factors such as system age, household occupancy, tank size, sludge and scum measurements and date of last pump-out
- Reminder notices for next inspection and pump-out (pump-outs must be completed within 30 days and receipt submitted to Town) based on site-specific conditions
- Education and technical assistance.

As of March 2010, inspection notices had been mailed to property owners in District 1 through 5 and notifications of property owners in District 6 had begun. In the first five years of the program, over 5,000 notices were sent to property owners (Table 20). Most of these notices (87%) have resulted in a completed inspection. 153 individual septic systems were reported as failing, and at least 88 of these have been repaired. 408 cesspools have been identified through the program and 86 of these have been replaced.

Table 20: Number of Notified Properties, Inspections Completed, and Results by District

District	Properties	Inspections Completed	Number Passed	Number of Cesspools	Cesspools Replaced	Failed ISDS	ISDS Repaired	Deferred	Under Review	Not Inspected
Year 1	1269	1237	1212	65	11	25	13	6	0	25
Year 2	875	825	806	105	27	19	14	18	9	22
Year 3	1312	1222	1169	142	38	53	33	55	0	36
Year 4	966	857	824	76	10	33	20	59	0	50
Year 5	947	531	508	20	0	23	8	107	0	307
Totals Year 1-5	5369	4672	4519	408	86	153	88	245	9	440

To complement the enforcement of the ordinance mandates, the Town of South Kingstown has established a Community Septic System Loan Program (CSSLP) for property owners with failed onsite disposal systems or cesspools. The program is open to owner occupied and non-owner occupied property owners (up to a four unit property). Current features of the program include:

- 2% Fixed Rate
- Loan amounts to $25,000
- Loan terms to 10 years
- No income restrictions (with a maximum 45% debt to income ratio)
- Goals established for the continuing operation of the Onsite Wastewater Management Program include:
- Complete mailing of mandatory inspection notices to District 7 property owners
- Follow-up with property owners who have not met their inspection deadline
- Send out “Notice of Violation” letters to property owners with failed septic systems or cesspools
- Update and refine septic system tracking software as needed
- Prepare Wastewater Management Ordinance amendments as needed
- Mail mandatory inspection and pumping notices in accordance with initial inspection report

APPENDIX B: EXAMPLE FERTILIZER MANAGEMENT PROGRAMS IN NEW ENGLAND

BACKGROUND

Nutrient runoff pollution from improper fertilizer use is a major concern for the northeast region, especially given the increase in residential and commercial development in coastal areas. Recently, several New England states have made efforts to legislate nutrient content and application of turf and lawn fertilizers. There are also opportunities to regulate fertilizers on a local scale, including municipal ordinances and regional initiatives that push for more vigorous fertilizer standards and educational outreach.

The following is a summary of fertilizer regulations and programs implemented in the New England region to provide examples of fertilizer management in communities similar to Durham, NH.

REGULATORY FRAMEWORK

New Hampshire: The state of New Hampshire currently regulates the labeling, registration, and transportation of fertilizers and liming material (RSA 431). Under the Shoreland Protection Act (RSA 483), state law prohibits the use of fertilizers within 25 feet of the reference line of any public water, with the exception of limestone; beyond 25 feet, slow or controlled release fertilizer may be used (483-B:9, II(d)). The regulation also prohibits the application of any fertilizers within 50 feet of surface waters to maintain a waterfront buffer, with the exceptions of limestone, slow-release nitrogen, and low-phosphorus products (483-B:9, V(a)).

A bill was recently signed into law amending RSA 431 to regulate nitrogen and phosphorus content of fertilizers available for retail purchase. Specifically, the amendment includes the following nitrogen fertilizer provisions (431:4-a):

- No turf fertilizer sold at retail shall exceed 0.7 lbs per 1000 square feet of soluble nitrogen per application when applied according to the instructions on the label;
- No turf fertilizer sold at retail shall exceed 0.9 lbs per 1000 square feet of total nitrogen per application when applied according to the instructions on the label ;
- No turf fertilizer sold at retail shall exceed an annual application rate of 3.25 lbs per 1000 square feet of total nitrogen when applied according to the instructions on the label; and
- No enhanced efficiency fertilizer shall exceed a single application rate of 2.5 lbs per 1000 square feet of total nitrogen and an annual application rate of 3.25 lbs per 1000 square feet, nor release at greater than 0.7 lbs per 1000 square feet per month when applied according to the instructions on the label.

The bill also includes a provision that prohibits local government from regulating the registration, sale, formulation, or transportation of fertilizer (431:4-d). The bill will go into effect on January 1st, 2014.

Massachusetts: The Commonwealth of Massachusetts currently regulates the shipping, handling, and labeling of fertilizers (300 CMR 15.00) under the authority of M.G.L. c. 128, § 64 through 83. In 2012, a bill was signed to amend M.G.L. c. 128, § 65 with the following regulations pertaining to fertilizer application:

- No fertilizer shall be applied on lawn or non-agricultural turf between December 1 and April 1;
- No fertilizer shall be applied to any impervious surfaces. If application does occur, the fertilizer must be immediately cleaned and contained or disposed of legally; and
- No fertilizer shall be applied to areas within 20 feet of any surface water subject to the jurisdiction of the Wetlands Protection Act. The setback may be reduced to 15 feet where a drop spreader, rotary spreader with a deflector, or targeted spray liquid is used for fertilizer application.

Although the bill does not specifically regulate the application rate of nitrogen-containing fertilizers, it does include restrictions on the use of phosphorus-containing fertilizers. The act will take effect on January 1st, 2014.

There are also state regulations that allow the opportunity for more localized programs. For example, waterbodies listed in the Massachusetts List of Impaired Waters (303(d)) will require a Total Maximum Daily Load (TMDL) analysis that will determine the reduction of specific pollutants, such as nitrogen. Towns can implement fertilizer regulations in order to meet their local TMDL requirement.

The Massachusetts Department of Environmental Protection (MassDEP) also has a model Groundwater Protection Bylaw/Ordinance that provides protection of groundwater reserves. Communities could adopt this provision and expand it to allow for monitoring of excessive fertilizer use in large scale development using groundwater monitoring wells (Horsley Witten Group 2007).

NANTUCKET LOCAL REGULATION

The Town of Nantucket, Massachusetts is an example of a municipality that has successfully passed an ordinance regulating fertilizer content and application on a local level. The following is a summary of the Town's fertilizer regulation program.

The Massachusetts Estuaries Program (MEP) completed a report in 2006 on excessive nutrient loading of Nantucket's waterbodies, and considered fertilizers as a significant and controllable nutrient source. As a result, MassDEP issued three TMDLs in Nantucket's waters. The development of a local fertilizer ordinance became imperative in order to reduce nitrogen loading and achieve compliance with the TMDLs.

In 2010, the Town enacted the Home-Rule Petition process in order to authorize the Board of Selectmen (BOS) to introduce legislature regulating fertilizer application in the Town and County of Nantucket. The BOS appointed the Article 68 Work Group comprised of local stakeholders to assist in developing the legislation, which created a Best Management Practices (2010-2012) document that forms the basis of the fertilizer ordinance. The Nantucket BMP provides science-based guidelines on fertilizer management and nitrogen reduction, and serves as an educational document for fertilizer applicators.

The Board of Health (BOH) passed Local Regulation 75.00 on fertilizer content and application, effective January 1st, 2013, under the authority of M.G.L. c. 111, § 31. The Regulation serves to protect and improve the Town's water quality and aid in compliance with the embayment TMDLs through reduction in nitrogen and phosphorous loading. The Regulation includes performance standards for non-licensed and licensed fertilizer applicators. Specifically, the Regulation includes the following provisions for non-licensed applicators regarding fertilizer application rates on turf, other plants, or soil:

- The annual application rate for turf should not exceed 3.0 pounds of actual Nitrogen per 1000 square feet;
- The annual application rate for trees, shrubs, herbs, and other ornamental plantings should not exceed 2.0 pounds of actual Nitrogen per 1000 square feet;
- A single application rate for turf or other plants should not exceed 0.5 pounds of actual Nitrogen per 1000 square feet; and
- A single application rate using fast-release nitrogen fertilizer should not exceed 0.25 pounds N per 1000 square feet.

The Regulation also mandates that the Town's Board of Health maintain an education program that is based on the Nantucket BMP. The BOH is in the early stages of implementing such a program, with potential collaboration with the Department of Natural Resources (DNR). The program will target retailers and homeowners to promote awareness and encourage compliance. There are currently many existing non-regulated education programs in various Massachusetts communities that can be used as a model program for Nantucket. For example, the Town of Dennis has developed a "Clean-Green" Lawn Program in order to implement fertilizer education and management. The voluntary program consists of distributing flyers to the public on proper fertilizer application, aimed to reduce over-fertilization and prevent nitrogen leaching into the groundwater. Greenscapes Massachusetts Coalition is another program aimed to promote awareness on proper landscaping practices, with participants such as the North and South Rivers Watershed and the Connecticut River Watershed.

Enforcement of the Regulation will involve an appointed enforcement officer from the BOH or the DNR. Violators of this Regulation will be subject to noncriminal disposition, and the BOH may also suspend or revoke any license pursuant to the Regulation. Implementation of the fertilizer program may also require a water quality specialist to perform seasonal sampling.

REGIONAL FERTILIZER MANAGEMENT PROGRAMS

The Pleasant Bay Alliance developed a fertilizer management plan for the Pleasant Bay watershed, which includes the towns of Brewster, Chatham, Orleans, and Harwich. The plan recommends the implementation of best management practices for municipal turf management. The Alliance plans to work with each watershed town to adopt and implement the recommended municipal policy over the next five years. The plan also calls for coordination with golf courses to reduce nitrogen loads and public education efforts to reduce residential fertilizer use. A number of regional groups have already begun to implement fertilizer education programs, including Chatham and Orleans Conservation Commissions, Orleans Ponds Coalition, Friends of Pleasant Bay and Friends of Chatham Waterways, and regional garden clubs. According to the Pleasant Bay Resource Management Plan, these measures have the potential to reduce existing nitrogen load from fertilizers by approximately 5%. The plan also suggests limiting the size of lawns for future lots created in order to reduce future nitrogen load. This bylaw is currently being discussed by the Orleans Planning Board and is present in draft regulations for the Brewster Natural Resource Protection District (Pleasant Bay 2013).

The Cape Cod Commission developed a Regional Policy Plan (RPP), effective August 17, 2012, which presents policies and guidelines for development throughout Barnstable County. The RPP issued a maximum nitrogen load of five parts per million to the local aquifer and embayments. This provides indirect fertilizer application rate control on a regional level for new development and redevelopments. Building on this requirement, the Town of Mashpee in Cape Cod decided to include nitrogen loading regulations in its zoning bylaw, which requires subdivision plan applications to submit a water quality report with nitrogen loading calculations. The bylaw provides a standard lawn fertilizer rate of 1.08 lbs N per 1000 square feet.

The New England Interstate Water Pollution Control Commission (NEIWPCC) formed the Northeast Voluntary Turf Fertilizer Initiative in 2011, a regional effort that focuses on the impact turf fertilizers have on water quality. The initiative's goal is to develop guidelines for New York and New England states on proper fertilizer application and formulation, with the intent of unifying various state and local fertilizer regulations. These regional, voluntary guidelines will make it easier to manufacture and purchase fertilizer products that minimize impact to the environment, as well as provide a clear public outreach message for New England. Several stakeholder meetings will be held to discuss mutually agreeable fertilizer guidelines, and will include participants such as manufacturers, retailers, state environmental agencies, municipalities, and the general community (NEIWPCC).

In 2010, the New Hampshire Coastal Protection Partnership (NH Coast) implemented a fertilizer and stormwater runoff education and outreach program in the Town of New Castle, NH. The program was a year-long pilot study aimed to promote awareness on proper lawn fertilizer techniques and the impacts of nitrogen pollution on estuaries among New Castle landowners. Education included the distribution of lawn care brochures to landowners, public events and workshops, and social media outreach via Facebook, Twitter, and monthly e-newsletters. The program also included a pledge to either not use lawn fertilizers or to only use low phosphorus, slow-release nitrogen fertilizers. By the end of the year, 77 homeowners in New Castle and the surrounding area had signed the pledge, and more than 1,500 had received hard copies of outreach materials. Based on the program's success in New Castle, NH Coast developed a "community action toolkit" that will allow other coastal communities in New Hampshire to implement similar programs (NH Coast 2010).

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Appendix E:

Preliminary Alternative Analysis Memos on Potential Management Measure

DURHAM/OYSTER RIVER NITROGEN POLLUTION ABATEMENT MANAGEMENT ALTERNATIVES

This memorandum presents a high-level overview of stormwater and non-point source management options that **MAY** be viable to reduce nutrient pollution in the Oyster River subestuary. It provides a basis for continuing discussions with regulators and for preparing cost-benefit analyses of management actions most applicable to Durham and Oyster River communities once a thorough understanding of non-point sources has been vetted and accepted. The following memo has been developed to provide a starting place for evaluation of various nutrient pollution removal, management or abatement techniques and are not necessarily preferred or recommended management options. Future evaluation of management options will also need to include wastewater treatment plan optimization as another critical option in abatement of pollution sources from the Town of Durham. Final selection of the preferred management actions will be based on pollutant loading model results, discussions with regulators and the Project Team (UNH/Durham) and interviews and analysis of staff and Town/University to determine management and administrative capabilities.

For the purposes of this memorandum, stormwater and non-point source pollution abatement are treated similarly and can be generally categorized into treatment technologies, conservation practices or operations that reduce pollutant generation or transport. The treatment technologies, conservation practices and operations, as described herein, represent the current "state of the practice" and are widely accepted for the abatement of nutrient pollution and will also address many non-nutrient pollutants.

NITROGEN IN THE ENVIRONMENT

Nitrogen can take many chemical forms, which readily change and cycle in the environment depending on ambient biogeochemical conditions, temperature, water body hydrodynamics and other factors. The forms of most concern for management because of their suitability for biological uptake by plants as a nutrient are ammonia (primarily as ammonium), nitrate, and nitrite, which comprise the dissolved inorganic nitrogen (DIN) pool. Because they are soluble in water and are preferred plant nutrients, they can drive plant and algae growth in coastal waters to levels that are harmful to the aquatic environment, accelerating the process called eutrophication.

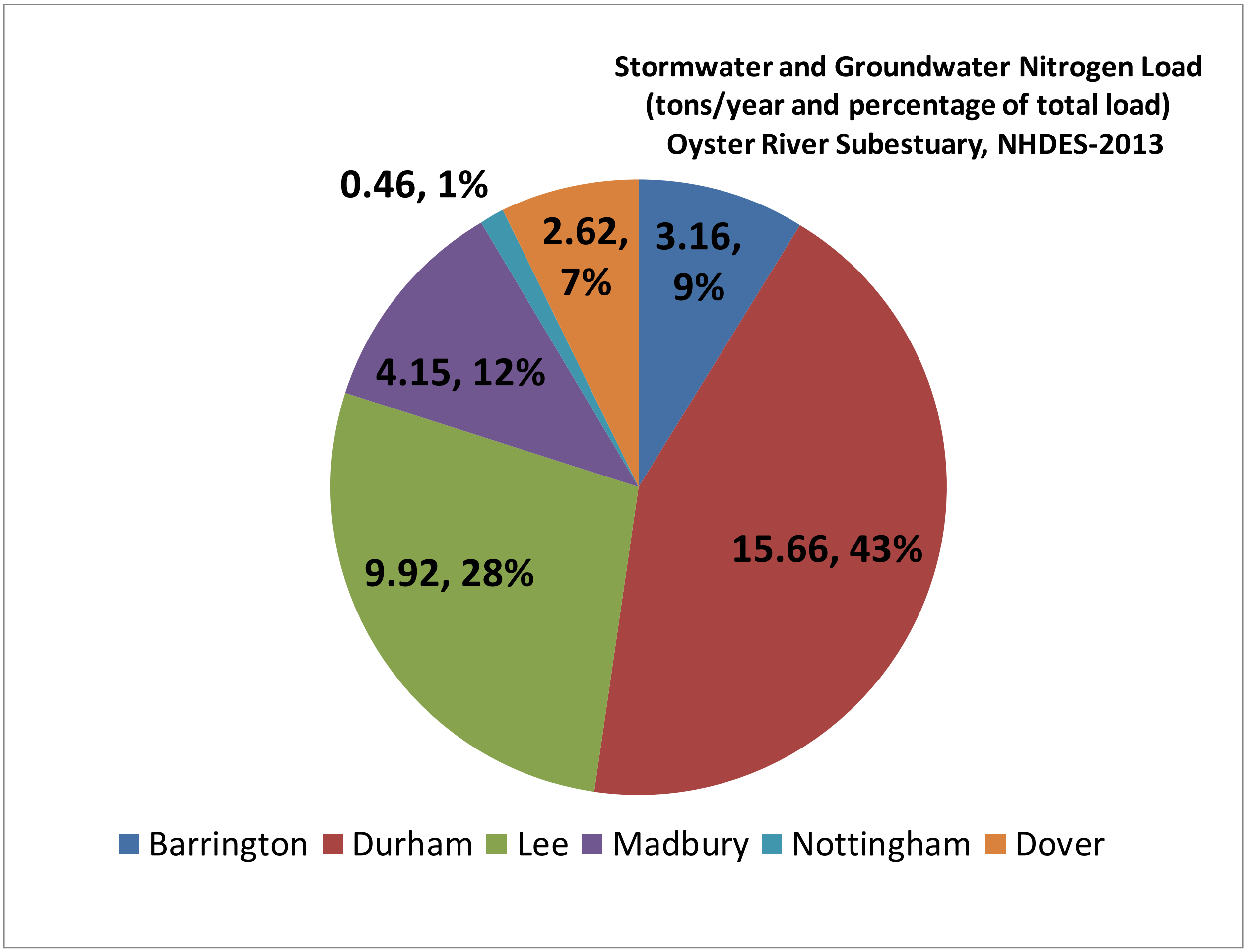
Not all nitrogen pollution is delivered to enriched waters as DIN. Loads of organic nitrogen, both in particulate and dissolved forms, may also be quickly oxidized into the more available nutrient DIN forms. Thus, the nitrogen may cycle in the environment from both organic and inorganic forms to become readily available ammonium and nitrate that fosters plant growth. The generated plant growth ultimately dies and is recycled as organic nitrogen which breaks down and is again oxidized into DIN, fueling another round of plant growth. The sources of nitrogen, both organic and DIN are many, and include:

- Airborne from agriculture (livestock and fertilizer), industrial processes, and burning of fossil fuels (primarily nitrate, but also volatized ammonia and particulate organic nitrogen);
- Waterborne surface runoff (potentially all forms of nitrogen); and
- Underground waterborne sources (primarily nitrate) which can lead to elevated nitrate levels in groundwater, which then migrates to drinking wells, streams or bays.

These forms of nitrogen can be found in elevated levels in runoff or groundwater throughout the year, including meltwater (Burton and Pitt 2002). When these untreated sources migrate into estuarine and coastal areas, elevated levels of nitrogen can contribute to oxygen depletion directly as organic forms and ammonium are oxidized, and DIN can stimulate excessive unsightly and potentially hazardous algal blooms, deplete dissolved oxygen causing fish kills, and reduce light penetration causing declines in native estuary plant species.

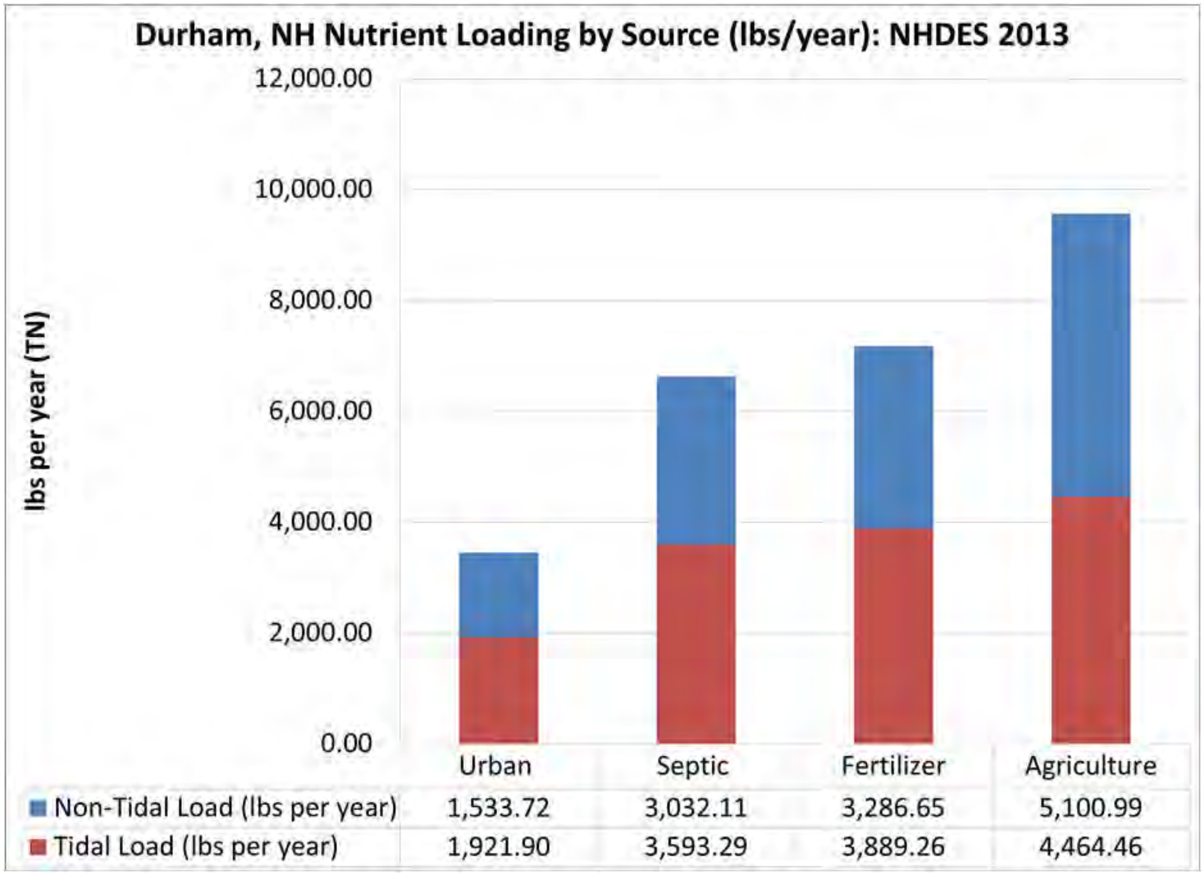
DURHAM AND OYSTER RIVER LOADS AND POLLUTION SOURCES

Figure 1: Total Nitrogen pollutant loading (excluding WWTF) into the Oyster River waters as defined by the Draft Great Bay Nitrogen Non-point Source Study (NHDES, 2013).



Additionally, total nitrogen loads from individual sources within Durham and across the entire Oyster River watershed are summarized in Figure 2 and Figure 3. The loads are expressed in pounds per year.

Figure 2: Total Nitrogen pollutant loading (excluding WWTF and natural sources) into the Oyster River waters from Durham grouped according to general land use category. Source: Draft Great Bay Nitrogen Non-point Source Study (NHDES, 2013).



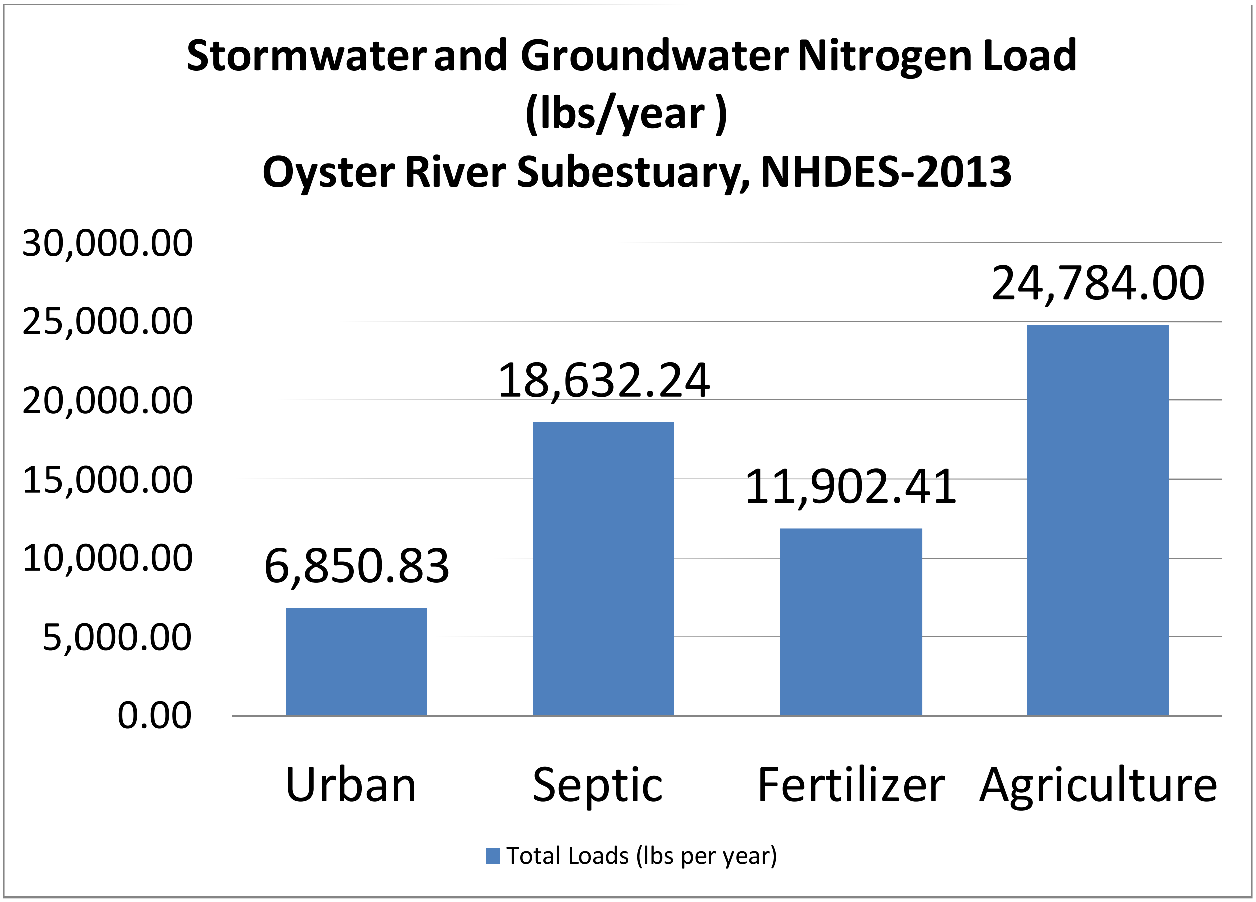
Note: Nonpoint source groupings have been defined by W&C for this memo.
Urban inputs include the following:

- Impervious Landcover Inputs
- Atmospheric Inputs delivered through developed lands (i.e. managed turf, lawn, etc)

Septic Inputs include septic sources.
Fertilizer inputs include all chemical fertilizer with exception of agricultural fertilizer.
Agriculture includes the following:

- Manure
- Agricultural chemical fertilizers
- Agricultural lands runoff

Figure 3: Total Nitrogen pollutant loading (excluding WWTF and natural sources) into the Oyster River waters from all communities grouped according to general land use category. Source: Draft Great Bay Nitrogen Non-point Source Study (NHDES, 2013).



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Agriculture includes the following:

- Manure
- Agricultural chemical fertilizers
- Agricultural lands runoff

URBAN LAND CONSERVATION AND OPERATIONS MANAGEMENT ACTIONS

Non-structural urban land conservation, management and operations prevent or reduce nutrient pollution migration into surface waters by reducing the exposure and generation of pollutants, preservation of un-built landscapes and/or providing a regulatory framework that minimizes the likelihood that built areas will increase nutrient migration into water bodies. Non-structural approaches to pollution prevention and management can be the most cost-effective and holistic practices within a watershed management framework. There are several components of non-structural management actions, each of which requires a sufficient management and tracking program to ensure implementation and effectiveness:

- Planning, design and construction that minimizes or eliminates adverse impacts;
- Pollution prevention measures aimed at minimizing exposure and release of pollutants;
- Education and training to promote awareness regarding the previous two components; and
- Conservation practices that ensure landscapes retain their hydrologic integrity which reduces flow volumes and pollutant export.

The following conservation practices and operations have been selected primarily for water quality improvements and are based on proven performance and the potential to reduce Nitrogen in stormwater and groundwater. Costs for non-structural management are highly variable and have not been included at this time. Cost estimates for these types of management actions will be developed in future phases of work and will be based on Durham/UNH policies, equipment and administration.

The following list of practices and operations includes references on effectiveness and general comments on the technology.

Urban Nutrient Management: Urban nutrient management plans address nutrient uptake by turf and landscape plants on urban pervious land. The management of turf or fertilizer application can be voluntarily implemented or included in a set of local or state laws. Urban nutrient management can result in significant reductions (according to established credit programs) but can be difficult to enforce or track. An expert panel in the Chesapeake Bay defined a core set of urban nutrient management practices based on research and current legislation and has been used herein as defined load reductions have been utilized in the Chesapeake Bay as a result of this management guidance. Local urban nutrient management guidelines may be utilized if load reduction percentages are agreed upon in later phases of work.

1. Consult with the local extension service, master gardener or certified applicator to get technical assistance to develop an effective urban nutrient management plan for the property.
2. Maintain a dense vegetative cover of turf grass to reduce runoff, prevent erosion, and retain nutrients.
3. Choose not to fertilize, or adopt a reduce rate/monitor approach or a small fertilizer dose approach.
4. Retain clippings and mulched leaves on the yard and keep them out of streets and storm drains.
5. Do not apply fertilizers before spring green up or after grass becomes dormant.
6. Maximize use of slow-release N fertilizer during the active growing season.
7. Set mower height at 3 inches or taller.
8. Immediately sweep off any fertilizer that lands on a paved surface.
9. Do not apply fertilizer within 15 to 20 feet of a water feature (depending on applicable state regulations) and manage this zone as a perennial planting, meadow, grass buffer, or a forested buffer.

10. Employ lawn practices to increase soil porosity and infiltration capability, especially along portions of the lawn that convey or treat stormwater runoff.

The expert panel developed a watershed model that assumed an average annual nitrogen fertilizer input on urban land of 43 lbs N/acre/year. The fertilizer application period was assumed to be 80 days in the spring and the fall. According to the model, there is a 3% reduction in delivered nitrogen load from pervious land for each 10% increment reduction of the current fertilizer input of 43 lbs/acre/year. The value of 43 lbs/acre/year (1 lbs per 1000 ft^2) of input on urban land and lawns is consistent with input loads used by NHDES in their Great Bay Non-Point Source Study. They used a prorated value of 1.28 lbs/1000ft^2 based on average fertilizer application rate and likely percent of lawns fertilized each year.

Implementation of urban nutrient management plans involve public education geared towards residence owners and businesses. One approach to public outreach is the retail method, which provides training and direct technical assistance to individual property owners as well as certification of commercial fertilizer applicators on appropriate management practices. This retail method is shown to be more effective than wholesale methods, which relies on passive outreach through social media. For example, one study conducted in four New England communities revealed that after having received extension service training, 55% of residents reported a reduction in fertilizer application (Aveni et al. 2013).

Appendix B provides an overview of regulatory and non-regulatory fertilizer control programs in New England.

<u>Street Sweeping:</u> The ability of street sweeping to reduce nutrient loads depends on factors such as equipment type, frequency of cleaning, conditions of roadways and catchments, and street sweeping methods. For example, higher nutrient removal efficiencies can be achieved through weekly sweeping using high efficiency regenerative air-vacuum sweeper technology, while the low end of nutrient reduction would be accomplished using a mechanical broom twice per year. Street sweeping can also be used to support leaf litter collection programs and catch basin cleaning practices. Removal efficiencies are based on acres of impervious surface swept using the street sweeping practice.

<u>Catch Basin Cleaning:</u> Catch basin cleaning involves removing material that has accumulated in catch basins to reduce the potential migration of these materials into downstream water bodies. Removal efficiencies are based on the acres of impervious drainage area that contributes to catch basins.

<u>Organic Waste and Leaf Litter Collection Program:</u> This practice involves management of leaf litter and organic waste through regular removal and disposal of these materials from impervious surfaces that contribute runoff to surface water bodies. The Draft NH MS4 Permit recommends a gathering and removal frequency of once per week from September to December for a phosphorous reduction credit, which may be applicable to nitrogen reduction as well. Removal efficiencies are based on acres of impervious surfaces that were managed under this program.

<u>Elimination of Illicit Discharge Connections and Discharges:</u> This practice involves the removal of illicit connections that contain untreated wastewater that are being discharged to surface water bodies. Removing illicit cross connections and relining sanitary sewer lines may be a cost effective method in comparison to structural stormwater treatment technologies. Removal efficiency is based on discharge flow (based on metered household water use) and nitrogen concentration in sewerage. The Draft NH MS4 Permit, Appendix H uses a nitrogen concentration of 40 mg/L, and also assumes 90% of water used goes to the sanitary sewer. The amount of nitrogen load reduction for elimination of illicit discharge can be calculated using the following equation:

TN Reduction (lbs/yr) = Discharge Flow (gal/day) x Water Use Factor (0.9) x TN (40 mg/L) x Conversion Factor (0.00304)

<u>Land Retirement/Conservation:</u> Land retirement practices improve water quality through long-term management of resource areas that generate minimal pollutants when compared to surrounding built

areas. Agricultural land retirement may also involve planting permanent vegetation on erosive agricultural cropland or pastureland. Conservation plans are used to protect and improve water quality by protecting and restoring undeveloped lands. Removal efficiencies are based on the number of acres retired/conserved and the extent to which the land was previously used.

Riparian Buffers: Riparian buffers are areas of permanent vegetation adjacent to a water body. Pollutants in runoff can be removed through plant uptake, as well as infiltration and temporary storage in the underlying soils. The riparian area is generally managed to maintain the integrity of stream channels and shorelines. A buffer should have a width of 100 feet and a minimum width of 35 feet and nitrogen removal can be 13-46% effective for grass buffers, and up to 65% effective for forest buffers. Higher removal efficiencies can be achieved depending on program management (Mayer *et al*. 2005). Removal efficiencies are based on the number of acres of buffer.

Rooftop Disconnection Programs: Rooftop disconnection practices utilize interception, infiltration, and filtration mechanisms to manage runoff. Simple disconnection systems direct runoff from rooftops to pervious areas, such as vegetated filter strips. Other disconnection systems include an alternative method to reduce runoff, such as bioretention and storage in vessels. Removal efficiencies are based on acres of vegetated filter strips since they are similar in practice to rooftop disconnection programs.

Erosion and Sediment Control: Erosion and sediment control practices are implemented during land development activities. These practices are designed to prevent sediment pollution and increases in runoff by retaining sediments on-site. Examples of erosion and sediment control include mulching, riprap, seeding, filter berms, sediment traps, and hay bales. Removal efficiencies are based on the acres of construction activity providing managed erosion and sediment control.

Forest Harvesting Practices: Forest harvesting best practices involve reducing the release of sediments and nutrients resulting from forest operations, which include road building, log removal, site preparation, and forest management. Removal efficiencies are based on forest harvest acres managed under best practices.

Public Education: Public education programs can increase awareness regarding nitrogen loading among the general public as well as municipalities, and can include informational brochures, public service announcements, and school programs. The programs should cover topics such as proper pet waste disposal, rooftop disconnections, impervious surface disconnections, and low-impact development.

Planning for Growth Control: Planning for growth control involves developing ordinances that can address low-impact development, stormwater runoff pollution, and land conservation.

Table 1: Urban Land Conservation and Operations Management Actions and Removal Efficiencies

System Category	Nitrogen Removal Efficiency
Urban Nutrient Management	17%[1]
Street Sweeping	3%[1] – 10%[3]
Catch Basin Cleaning	2%[3]
Organic Waste and Leaf Litter Collection Program	5%[3]
Elimination of Illicit Discharge Connections and Discharges	TBD
Land Retirement/Conservation	3-8%[1]
Riparian Buffers	13-65%[1]
Rooftop Disconnection Programs	25-50%[2]
Erosion and Sediment Control	25%[1] – 33%[4]
Forest Harvesting Practices	50%[1]
Public Education	TBD
Planning for Growth Control	TBD

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010
(2) Virginia DCR Stormwater Design Specification No. 1, Rooftop (Impervious Surface) Disconnection, March 2011.
(3) Draft NH MS4 Permit, Appendix F. The 10% reduction refers to phosphorous removal; however, this should be applicable to nitrogen removal as well.
(4) CBP Watershed Model: Appendix H

AGRICULTURAL LAND CONSERVATION AND OPERATIONS MANAGEMENT ACTIONS

Proper agricultural management practices can prevent non-point source pollution originating from sources such as chemical fertilizer and manure. Implementation of these practices must take economic impacts into consideration while maintaining environmental quality. The following agricultural practices and operations have been selected primarily for water quality improvements and are based on proven performance and the potential to address Nitrogen in agricultural runoff. The following list of practices and operations includes references on effectiveness and general comments on the technology.

Cropland Nutrient Management: Cropland nutrient management plans detail the optimum use of nutrients that can both minimize nutrient loss and maintain crop yield. Nutrient management plans will depend on soil type, expected crop yield, and nutrient availability, and should include guidelines for the amount, placement, and timing of nutrient application for each crop. It is recommended that management plans include a minimum reduction of 10% in nutrient application rates, and management plans are updated every two to three years. Removal efficiencies are based on percentage of acres under nutrient management.

Enhanced Nutrient Management: According to research conducted by the American Farmland Trust, nitrogen application rates are set approximately 35% higher than necessary for optimal crop growing conditions. A 15% reduction in nitrogen application rates to cropland would result in a 7% nitrogen removal efficiency. Included in this plan would be an incentive or crop insurance in case of crop yield loss.

Conservation Plans: Conservation plans are used to protect and improve water quality by protecting and restoring undeveloped lands. Removal efficiencies are based on the number of acres conserved and the extent to which the land was previously used.

Horse Pasture Management: This practice involves stabilizing small pasture animal containment areas, as well as maintaining a 50% pasture cover in order to reduce erosion and nutrient loss. Horse pasture management should be used in conjunction with stream protection with fencing when appropriate. Removal efficiencies are based on acres of horse pasture being managed. Although there is currently no established nitrogen removal efficiency for this practice, it may be comparable to the phosphorous removal efficiency of 20%.

Animal Waste Management Systems: This practice accounts for the proper handling, storage, and utilization of waste generated from confined animal operations. Liquid wastes are treated or stored in lagoons, ponds, or tanks, while solid wastes are stored in sheds or pits. Runoff should be controlled from roofs, feedlots, and loafing lots. Removal efficiencies are based on manure acres reduced. A manure acre is defined by the Chesapeake Bay Watershed Model as 145 Animal Units in an area which is susceptible to runoff and where high concentrations of confined animals are contained. (CBP Watershed Model: Appendix H)

Barnyard Runoff Control: Practices installed to control barnyard runoff includes roof runoff control, diversion of clean water from entering the barnyard, and control of runoff from barnyard areas. Nitrogen removal efficiency may vary depending on the presence of manure storage on-site.

Cover Crops: This practice involves planting and growing cover crops (i.e. rye, barley, wheat) on cropland, maintaining a vegetative cover with minimal disturbance of the surface soil. The cover crops capture and maintain nutrients within the root zone or in the plant matter directly, reducing erosion and nutrient leaching to groundwater. Captured nitrogen can be released and re-used for the next crop when cover crops are plowed in the spring. Factors that can influence nitrogen removal efficiencies include crop species, planting times, and fertilizer applications. Removal efficiencies are based on acres of land converted to grow cover crops.

Continuous No-Till: Continuous no-till practices involve eliminating soil disturbance by tillage equipment, such as plows and disks. This practice applies to multi-crop, multi-year rotation systems that retain crop residue on the field, and is recommended to be maintained for at least five years. Removal efficiencies can vary by geography. Removal efficiencies are based on acres of cropland planted using continuous no-till practices.

Loafing Lot Management: This practice involves stabilizing areas that are frequently and intensively used by people, animals, or vehicles. Stabilization will prevent manure and sediment runoff due to ground cover destruction. Stabilization methods include establishing a vegetative cover, surfacing the area with materials, or installing necessary structures such as concrete walkways. Removal efficiencies are based on acres of loafing lots being managed under this practice.

Water Control Structures: Water control structures include controlling runoff from surface drainage ditches by installing and maintaining boarded gate systems. Removal efficiencies are based on acres of drainage area being controlled with water control structures.

Stream Protection with Fencing: This practice involves fencing strips of land along streams to prevent streambank erosion and direct animal contact with surface waters. Removal efficiencies are based on linear feet of fencing along the streambank.

Table 2: Agricultural Land Conservation and Operations Management Actions and Removal Efficiencies

System Category	Nitrogen Removal Efficiency
Cropland Nutrient Management	5-39%[4]
Enhanced Nutrient Management	7%[1]
Conservation Plans	3-8%[1]
Animal Waste Management Systems	80%[1]
Barnyard Runoff	20%[1]
Cover Crops	30-45%[2]
Continuous No-Till	10-15%[1]
Loafing Lot Management	20%[1]
Water Control Structures	33%[1] - 40%[3]
Stream Protection with Fencing	60%[2] – 75%[4]

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010
(2) Tracking Restoration Efforts in Maryland's Tributaries (http://dnrweb.dnr.state.md.us/watersheds/surf/bmp/swbmp.asp)
(3) Neuse River Basin (North Carolina).
(4) CBP Watershed Model: Appendix H.

SEPTIC MANAGEMENT ACTIONS

Improper installation and maintenance of on-site septic systems can lead to migration of nitrogen and other pollutants in surface runoff and groundwater. Regulatory mechanisms have the potential to address non-point source pollution originating from individual sewage disposal systems (ISDS) but are primarily focused on new construction. Currently, New Hampshire regulates ISDS through state-wide policies on baseline minimum design and capacity requirements.

The DES has passed rules regulating the design of septic systems or, more broadly, ISDS. Env-wq 1000 requires that all plans for all newly installed ISDSes are sent for approval to the DES Subsurface Systems Bureau. Id. § 1003.02. Specifically, septic tanks are addressed beginning at § 1010, providing for capacity and design requirements. The regulations are highly technical and are overseen by the DES in its rulemaking and oversight capacity. Significantly, however, DES provides only briefly for mandatory inspection and pumping. See id. § 1023.01 ("Septic tanks shall be inspected for accumulation of sludge and surface scum at a frequency sufficient to allow the tank to be pumped by a licensed septage hauler when the combined thinness of the sludge and surface scum equal 1/3 or more of the tank depth."). The DES also provides for the minimum septic tank setbacks from varying bodies of waters, property lines, wells and other features. See id. § 1008.04. Notably, the mandatory setbacks are 75' from surface water and very poorly drained jurisdictional wetland and 50' from poorly drained jurisdictional wetland.

Municipal regulation of septic systems also exists through local ordinances; however, each town implements differing requirements with various levels of enforcement. The Town of Durham currently includes provisions in its Zoning Ordinance concerning septic design, installation, and zoning (Town of Durham, Zoning Ordinance 2006, Article XXIV). The Town's Septic System Code not only supports DES state-wide regulations, but also strives to enforce more rigorous septic design and zoning standards. Specifically, section 175-139 states that the location of the leaching field cannot be within 125' from any water body or very poorly/poorly drained soils, which is much more stringent than the DES standard of 75' for minimum septic tank setbacks. Enforcement involves an inspection of the system installation by the Town's Code Enforcement Officer (section 175-140); beyond this, however, there is no provision for regularly scheduled mandatory inspections or pumping.

Municipal and regional on-site wastewater management districts are a common alternative to state agency wastewater regulation. Such districts are generally established pursuant to three forms of legal authority. First, many states have existing legislation authorizing the voluntary formation of districts to assume responsibility for establishing standards, ensuring enforcement, and procuring funding for local and regional wastewater regulation. Second, municipalities can use their home rule authority to enact bylaws and regulations to be enforced by municipal officials in addition to state laws. Lastly, a legislature can enact special legislation enabling the formation of a particular regional district. States such as Massachusetts and Rhode Island have demonstrated that regional management districts can be more effective in regulating on-site sewage disposal, especially in enforcing mandatory inspections and maintenance. Currently, New Hampshire has no comparable law authorizing the general creation of management districts anywhere in the state. Without such enabling legislation, regional entities, other than individual municipalities, have no legal authority to impose or enforce more stringent regulations.

The following list of practices and management strategies include references on effectiveness and general comments on the technology.

Waste Water Management Districts: These districts are legal entities independent of the state which have the authority to enforce state or local laws and to provide a management entity responsible for effective ISDS management. One such district created pursuant to the Rhode Island law is the South Kingstown Onsite Wastewater Management Program (see "South Kingston, RI example" in Appendix A). The program has instituted an inspection schedule requiring compliance with stringent local standards established pursuant to town ordinances. In its first five years, the inspection program completed over 4500 inspections, discovering over 150 substandard ISDS and repairing almost 90 systems. The burden of paying for mandatory inspections and repairing substandard wastewater systems is left to the homeowner, but loan programs are available in RI to help residents with replacements and costly repairs.

Septic Pumping: Septic pumping is a management practice that increases the system's capacity to remove solids from wastewater and reduce nutrient leaching. It is recommended that septic tanks be pumped once every three to five years depending on ISDS loading. Waste water management districts provide a means to enforce mandatory septic pumping on a regular basis.

Septic Denitrification: Traditional septic systems typically include a holding tank to settle solids from the wastewater and a drain field to allow the wastewater to infiltrate through the ground. Septic denitrification involves replacing the traditional septic systems with advanced technology that can further treat and remove nitrogen through denitrification.

Table 3: Septic Management Actions and Removal Efficiencies

System Category	Nitrogen Removal Efficiency
Establishment of ISDS Wastewater District	TBD
Septic Pumping	5%(1)
Septic Denitrification	50%(1)

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010

STORMWATER RUNOFF TREATMENT TECHNOLOGIES

Denitrification

The natural microbial process of denitrification is a primary treatment method for removing excess nitrogen in runoff. Denitrification converts the water-soluble nitrogen compounds, especially nitrate, into nitrogen gas. These microbial processes are promoted in structural stormwater management systems by creating an anaerobic (oxygen-free) water-saturated zone that contains a carbon source such as wood chips. Management practices may also take advantage of naturally carbon-rich, anaerobic conditions that exist in wetlands and riverine corridors by infiltrating water into those soils.

Specific Approaches for Denitrification

When nitrogen removal from stormwater is desired, a water-saturated, anaerobic zone with a carbon donor can promote the natural process of denitrification to provide an effective solution (Hinman 2009, Kim *et al*. 2003), with bioretention cells specifically cited (Brown *et al*. 2009, Davis *et al*. 2001). Many existing stormwater treatment system designs may need modification to ensure denitrification. In addition, care must be taken to limit the anaerobic zone to only the zone where denitrification occurs, in order to avoid release of sequestered pollutants from other zones designed for aerobic filtration. Some studies show denitrification can occur in grass buffer strips (Cors and Tychon 2007) or in soil (Dietz and Clausen 2005, Elliott 2010), though the results suggest soil denitrification may not occur in all situations.

Reducing Runoff – Infiltration

Limiting "directly-connected" impervious surfaces is a sound strategy to treat nitrogen in storm water. Although it does not eliminate all DIN from the watershed, it does reduce the likelihood of direct transport to surface waters and affords opportunities for physical nitrogen removal in soils, vegetative uptake and denitrification, natural processes in surface soils that attenuate nitrogen species in runoff. Additionally, disconnection of runoff from low-nitrogen sources, such as rooftops, reduces the potential for transporting pollutants via concentrated flow in road ditches and pipes.

Infiltration Concerns near Drinking Water Wells or Sensitive Coastal Areas

Infiltrating large amounts of nitrogen-rich runoff into groundwater in certain sensitive locations should be avoided. Without attention to nitrogen removal before infiltration, DIN can accumulate in groundwater and pollute drinking water drawn from wells. Soluble forms of nitrogen can travel undiminished through groundwater into coastal waters, causing the same problems as stormwater runoff. Because groundwater transport can be slow and gradual, nitrogen eutrophication may only become apparent years after the loading begins (e.g., following neighborhood septic systems installations), at which point the problem will likely persist for decades even after sources are controlled.

Despite its limitations, infiltration of stormwater remains a viable option for reducing many harmful stormwater effects and system designs can be tailored to reduce the potential migration of nutrient species into groundwater.

Structural System Treatment Technologies

Stormwater management technologies that promote infiltration, denitrification and other pollutant removal features can be implemented as modifications to existing stormwater management facilities or as new stormwater management facilities to be incorporated into an existing storm drain system or built area.

There are three typical management goals considered for stormwater management retrofit facilities. These include:

- Stormwater quantity control (i.e. reducing peak rate of runoff) to prevent downstream flooding using systems typically designed to manage 2, 10, or 100-year recurrence storm events;
- Stormwater quality or Water Quality Volume (WQV) treatment typically associated with the 1-inch, 24-hour storm event; and
- Peak runoff rate attenuation for the Channel Protection Volume (CPV) typically associated with the 1-year recurrence storm event. The CPV helps to minimize erosion and other such impacts to downstream natural stream systems.

Selected stormwater technologies with potential to address nitrogen in stormwater can provide nutrient "credits" towards attainment of water quality management goals that can be quantified and tracked. . The structural stormwater management systems identified below are based on proven performance but feasibility and effectiveness in any location is highly dependent upon characteristics of the site (e.g., soil drainage, site dimensions, existing cover, available hydraulic head and elevations of existing infrastructure, etc.). A range of installation costs for these systems as retrofits has been provided for reference.

<u>Urban Filtering Practices (Rain Gardens, Bioretention):</u> Urban filter systems are usually designed as vertical flow media filters vegetated or vegetated/soil media systems, but may also include subsurface filtration processes. Surface systems are typically vegetated with grass and/or landscape plantings. Subsurface vertical flow systems usually designed with an inert subsurface filtration media (e.g. sand, gravel). In poorly draining subsoils, infiltration may be limited but volumetric losses via evapotranspiration can be enhanced and infiltration below the underdrain promoted, if appropriate. Filter systems have the potential to reduce overall stormwater volumes and peak flows and have been shown to be effective in reducing loads of certain pollutants, including nitrogen. As described previously, these systems can be designed to provide an anaerobic zone within the cross section of the filter bed to enhance Total Nitrogen removal and/or can include specific filter media designed for nutrient sequestration.

<u>Vegetated Open Channels or Dry Swales:</u> Vegetated open channels can provide water quality improvement via infiltration or filtration while conveying stormwater runoff and are typically utilized along linear transportation features. Surface systems involve filtering runoff through soil media and vegetation, while subsurface systems allow water to infiltrate into the subsoils. Vegetated open channels or dry swales can be designed and function as a subcategory of filtering practices and treatment processes can be similar.

<u>Urban Infiltration Practices:</u> Urban infiltration practices involve basins that are designed to provide storage and promote infiltration into the soil. These infiltration basins and trenches are constructed when soils meet specific infiltration design criteria, and can be vegetated or non-vegetated. Because these systems can provide complete infiltration, no underdrains are typically utilized with these systems. Permeable pavements are also associated with urban infiltration practices, and can utilize both infiltration and filtration mechanism to improve water quality. Infiltration practices can provide significant pollutant removal if designed appropriately and also have the potential to reduce runoff volume and attenuate peak flows. These systems should be carefully designed when nutrient pollutants are the target as infiltration of nitrogen species may result in the movement of pollutants in groundwater.

<u>Wet ponds:</u> Wet ponds are retention structures that store stormwater runoff, promoting the settlement of sediments and pollutants. Wet ponds can contain anaerobic zones and therefore provide some degree of denitrification depending on design. This technology is an older style of stormwater treatment and may have limited pollutant removal or contribute to increases in runoff temperature.

Dry Detention Basins and Extended Detention Basins: Dry detention ponds are primarily designed to reduce stormwater runoff volume and reduce peak flow by providing temporary storage. The water is released via surface discharge through an outlet control structure. An increased residence time can improve water quality via sedimentation and vegetative pollutant uptake but the primary design criteria for dry detention basins was historically peak rate reduction and therefore they offer minimal pollution control.

Gravel Wet Vegetated Treatment System (GWVTS): GWVTS are horizontal flow retention and filter systems. The GWVTS utilizes temporary storage and solids settling, filtration and biogeochemical processes as the mechanisms for pollutant removal. These systems can also provide peak flow attenuation and, through evapotranspiration, can reduce runoff volumes. These systems are especially well-suited on poorly draining soils or in locations with limited hydraulic head. This is one of the University of New Hampshire Stormwater Center's most successful systems for overall pollutant removal and particularly Nitrogen removal.

Below-Grade Treatment Train: Proprietary below grade treatment trains are diverse but typically include a physical settling and filtration component. These systems are well suited to stormwater treatment on parcels with limited available surface area. The system considered for project costs is the Contech® Hydrodynamic Separation and Filtration unit, but there are numerous other proprietary systems that may vary in cost. The below grade treatment train is typically an off-line, flow through system with a defined maximum flow through rate based on filter limitations. The below grade treatment train can provide modest pollutant removals but does not provide peak flow attenuation or overall volume reductions unless designed with upstream storage. For this exercise, this system type is assumed to only provide filtration.

Structural System Effectiveness and Cost

The following table provides reported treatment capabilities of each of the categories of treatment systems as described above. We acknowledge that removal efficiency can vary widely but many of the identified pollutant removal efficiencies have been established by EPA for nutrient reduction in the Chesapeake Bay TMDL (Cheseapeake Bay Program 2010).

Table 4: Stormwater Treatment Technology Nitrogen Removal Efficiency and Opinion of Cost

System Category	Nitrogen Removal Efficiency	Cost per acre of impervious area treated[(4)]
Urban Filtering	40%[(1)]	$57,000-131,000
Urban Infiltration	80-85%[(1)]	$32,000-$744,000[(5)]
Wet ponds	33%[(2)]	$46,000
Vegetated Open Channels	10-45%[(1)]	$83,000
Dry Detention Basins	25%[(2)]	$35,000
GWVTS	55-75%[(2)]	$80,000
Below-Grade Treatment Train	18-38%[(3)]	$270,000

(1) Estimates of County-Level Nitrogen and Phosphorus Data for Use in Modeling Pollutant Reduction, completed for the US EPA, December 2010

(2) UNH Stormwater Center 2012 Biennial Report

(3) Evaluation of the Stormwater Management StormFilter® system for the removal of total nitrogen, 2006.

(4) Costs may vary significantly based on installation location and relative size of system to size of drainage area. These opinions of cost reflect costs per unit impervious area treated based on delivered and placed material costs and include engineering, survey, construction bonds and contingency. These costs reflect treatment options for non-residential properties. Residential treatment options are typically lower cost per unit than non-residential options. Operating costs are often considered as an annual percentage (3-5%) of overall project costs but have not been included in this cost summary.

(5) High end cost estimate reflects cost of full depth reconstruction of existing surface asphalt pavement with porous asphalt pavement.

NITROGEN HARVESTING

The following non-traditional practices and operations have been selected primarily for water quality improvements and are based on their potential to address Nitrogen. The following list of practices and operations includes references on effectiveness and general comments on the technology.

Oyster Restoration: Oyster reefs provide a number of important ecological benefits to the Great Bay ecosystem, including nutrient removal through their filter-feeding mechanisms. It is estimated that one acre of live oyster reef can filter up to one ton of nitrogen each year (McKeton *et al*. 2012). However, the oyster population in the Great Bay has declined significantly over the past century due to overharvesting, pollution, and disease. Oyster restoration effort examples include the Cheseapeake Bay Oyster Management Plan adopted in 2004 and the Oyster Conservationist Program organized by the Nature Conservancy and University of New Hampshire. Oyster reefs are constructed using hard surfaces such as oyster shells on which hatchery-raised larval oysters can grow.

Urine Segregation: Urine segregation is a practice that can reduce nitrogen loads in domestic wastewater, potentially reducing costs and improving influent water quality for wastewater treatment facilities. The recovered nutrients can be treated or reused for applications such as agricultural fertilizer. It is estimated that 80% of the nitrogen found in sewage is from urine; therefore, urine segregation could potentially reduce 50-75% of nitrogen loads in wastewater (Hazen & Sawyer, 2009). Urine separation systems include toilets with separate collection bowls and effluent lines, which will convey urine to a small storage tank. Urine treatment options to remove and recover nitrogen include evaporation, precipitation, and electrochemical treatment.

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APPENDIX A: EXAMPLE ONSITE WASTEWATER MANAGEMENT PROGRAM: SOUTH KINGSTOWN, RI

BACKGROUND

The Town of South Kingstown, Rhode Island (Town) obtained the services of Woodard & Curran to review the scientific basis and implementation guidance of several Total Maximum Daily Load studies in order to develop a cost effective strategy for compliance with the Town's Municipal Separate Storm Sewer System (MS4) RIPDES permit and to initiate water quality improvement in the TMDL waterbodies. The following is a summary of the Town's Onsite Wastewater Management Program, presented herein, to provide an example of a septic management program utilized in a community similar to Durham, NH.

South Kingstown is a town in Washington County, Rhode Island. The population was 30,639 at the 2010 census. South Kingstown includes the villages of Kingston, West Kingston, Wakefield, Peace Dale, Snug Harbor, Tuckertown, East Matunuck, Matunuck, Green Hill, and Perryville. The University of Rhode Island is located in the village of Kingston.

A central portion of South Kingstown, including the villages of Wakefield, Peace Dale, Kingstown, West Kingstown, and the URI campus, is served by a sanitary sewer system that conveys wastewater to a treatment plant located in Narragansett. Outside these sewer service areas, all other areas of South Kingstown rely on private onsite wastewater treatment systems (commonly referred to as septic systems) for wastewater treatment and dispersal.

REGULATORY FRAMEWORK

In Rhode Island, Onsite Wastewater Treatment Systems (OWTS) traditionally referred to as Individual Sewage Disposal Systems (ISDS), fall under the regulatory authority of RIDEM, which issues administrative regulations governing their approval, design, installation, inspection, and management. Each municipality is authorized to adopt local ordinances which meet or exceed standards set forth in the state regulations and allow for local incentives and penalties to compliment state oversight. South Kingstown has created a local Onsite Wastewater Management Program, allowing the town to implement local OWTS ordinances and policies. In addition, the Rhode Island Coastal Resources Management Council has developed the Salt Pond Region Special Area Management Plan (SAMP), with OWTS requirements and recommendations focused specifically on the long-range preservation of sensitive salt pond and watershed resources.

RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

The General Laws of the State of Rhode Island grant authority to the Department of Environmental Management Office of Water Resources to regulate new, existing and replacement onsite wastewater treatment systems. On January 1, 2008 the "Rules Establishing Minimum Standards Relating to Location, Design, Construction and Maintenance of On-Site Wastewater Treatment Systems (OWTS)" became effective. These rules specify design flows and minimum setback distances, and designate certain critical resources within the State. The South Shore Coastal Ponds are among those areas identified as critical resources. In those areas identified as critical resources, all new sites, as well as those systems being rehabilitated, are required to install OWTS that are capable of nitrogen reduction.

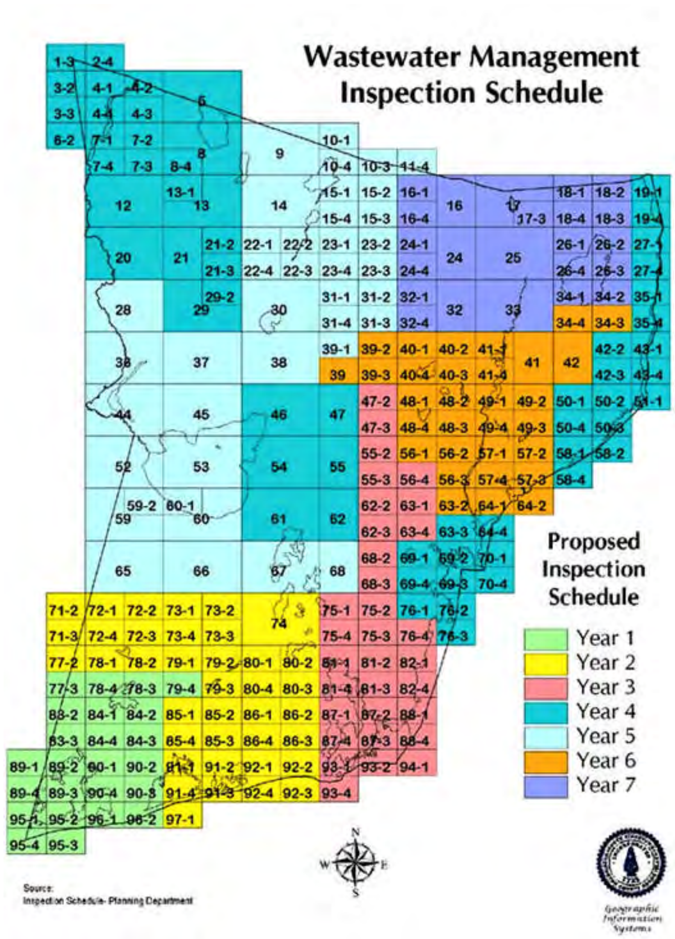
SOUTH KINGSTOWN ONSITE WASTEWATER MANAGEMENT PROGRAM

South Kingstown has adopted an ordinance and regulations creating a local Wastewater Management District (WWMD) under the authority of the State of Rhode Island General Laws, Title 45, Chapter 24.5:

§ 45-24.5-3 Declaration of purpose. – The purpose of this chapter is to authorize the cities and towns of the state to adopt ordinances creating waste water management districts (WWMD), the boundaries of which may include all or a part of a city or town, as specified by the ordinance. These ordinances must be designated to eliminate and prevent the contamination of state waters, caused by malfunctioning individual subsurface disposal systems (ISDS), through the implementation of ISDS inspection and maintenance programs. The waste water management district ordinance programs shall be designed to operate as both an alternative to municipal sewer systems and as a method to protect surface and ground waters from contamination.

The Town of South Kingstown adopted an Onsite Wastewater Management Ordinance in October 2001 which established a mandatory maintenance inspection of all OWTSs and cesspools. As set forth in the ordinance, this program is being implemented in seven phases based on the perceived environmental sensitivity of each geographic area. The inspection schedule is included as Figure 1.

Figure 1: South Kingstown Onsite Wastewater Management Inspection Schedule



- Provisions of the program include:
- Establishing an entity with the authority to manage local individual sewage disposal systems
- Making regular inspection and maintenance of septic systems mandatory
- Emphasizing the problem of cesspools as a sub-standard form of sewage treatment

- Instituting local penalties for non-compliance of up to $500 per day
- An initial Town notice to owners to inspect their systems (45-day compliance limit to schedule an inspection with a Town-approved Inspector)
- All cesspools and any system installed prior to 1970 must be pumped at the initial inspection
- Town-issued violation notice if repairs or upgrades are needed (proof must be submitted to Town within 30 days that actions have been taken)
- All septic tanks must be proven to be watertight
- All cesspools must be replaced within 5 years of the initial inspection or within 12 months of a property sale
- Remediation plans developed by owners of a lot containing more than one detached dwelling unit – these plans may include gray-water and shared systems
- A schedule for future pump-outs and inspections is determined by site-specific factors such as system age, household occupancy, tank size, sludge and scum measurements and date of last pump-out
- Reminder notices for next inspection and pump-out (pump-outs must be completed within 30 days and receipt submitted to Town) based on site-specific conditions
- Education and technical assistance.

As of March 2010, inspection notices had been mailed to property owners in District 1 through 5 and notifications of property owners in District 6 had begun. In the first five years of the program, over 5,000 notices were sent to property owners (Table 20). Most of these notices (87%) have resulted in a completed inspection. 153 individual septic systems were reported as failing, and at least 88 of these have been repaired. 408 cesspools have been identified through the program and 86 of these have been replaced.

Table 20: Number of Notified Properties, Inspections Completed, and Results by District

District	Properties	Inspections Completed	Number Passed	Number of Cesspools	Cesspools Replaced	Failed ISDS	ISDS Repaired	Deferred	Under Review	Not Inspected
Year 1	1269	1237	1212	65	11	25	13	6	0	25
Year 2	875	825	806	105	27	19	14	18	9	22
Year 3	1312	1222	1169	142	38	53	33	55	0	36
Year 4	966	857	824	76	10	33	20	59	0	50
Year 5	947	531	508	20	0	23	8	107	0	307
Totals Year 1-5	5369	4672	4519	408	86	153	88	245	9	440

To complement the enforcement of the ordinance mandates, the Town of South Kingstown has established a Community Septic System Loan Program (CSSLP) for property owners with failed onsite disposal systems or cesspools. The program is open to owner occupied and non-owner occupied property owners (up to a four unit property). Current features of the program include:

- 2% Fixed Rate
- Loan amounts to $25,000
- Loan terms to 10 years
- No income restrictions (with a maximum 45% debt to income ratio)
- Goals established for the continuing operation of the Onsite Wastewater Management Program include:
- Complete mailing of mandatory inspection notices to District 7 property owners
- Follow-up with property owners who have not met their inspection deadline
- Send out “Notice of Violation” letters to property owners with failed septic systems or cesspools
- Update and refine septic system tracking software as needed
- Prepare Wastewater Management Ordinance amendments as needed
- Mail mandatory inspection and pumping notices in accordance with initial inspection report

APPENDIX B: EXAMPLE FERTILIZER MANAGEMENT PROGRAMS IN NEW ENGLAND

BACKGROUND

Nutrient runoff pollution from improper fertilizer use is a major concern for the northeast region, especially given the increase in residential and commercial development in coastal areas. Recently, several New England states have made efforts to legislate nutrient content and application of turf and lawn fertilizers. There are also opportunities to regulate fertilizers on a local scale, including municipal ordinances and regional initiatives that push for more vigorous fertilizer standards and educational outreach.

The following is a summary of fertilizer regulations and programs implemented in the New England region to provide examples of fertilizer management in communities similar to Durham, NH.

REGULATORY FRAMEWORK

<u>New Hampshire</u>: The state of New Hampshire currently regulates the labeling, registration, and transportation of fertilizers and liming material (RSA 431). Under the Shoreland Protection Act (RSA 483), state law prohibits the use of fertilizers within 25 feet of the reference line of any public water, with the exception of limestone; beyond 25 feet, slow or controlled release fertilizer may be used (483-B:9, II(d)). The regulation also prohibits the application of any fertilizers within 50 feet of surface waters to maintain a waterfront buffer, with the exceptions of limestone, slow-release nitrogen, and low-phosphorus products (483-B:9, V(a)).

A bill was recently signed into law amending RSA 431 to regulate nitrogen and phosphorus content of fertilizers available for retail purchase. Specifically, the amendment includes the following nitrogen fertilizer provisions (431:4-a):

- No turf fertilizer sold at retail shall exceed 0.7 lbs per 1000 square feet of soluble nitrogen per application when applied according to the instructions on the label;
- No turf fertilizer sold at retail shall exceed 0.9 lbs per 1000 square feet of total nitrogen per application when applied according to the instructions on the label ;
- No turf fertilizer sold at retail shall exceed an annual application rate of 3.25 lbs per 1000 square feet of total nitrogen when applied according to the instructions on the label; and
- No enhanced efficiency fertilizer shall exceed a single application rate of 2.5 lbs per 1000 square feet of total nitrogen and an annual application rate of 3.25 lbs per 1000 square feet, nor release at greater than 0.7 lbs per 1000 square feet per month when applied according to the instructions on the label.

The bill also includes a provision that prohibits local government from regulating the registration, sale, formulation, or transportation of fertilizer (431:4-d). The bill will go into effect on January 1st, 2014.

Massachusetts: The Commonwealth of Massachusetts currently regulates the shipping, handling, and labeling of fertilizers (300 CMR 15.00) under the authority of M.G.L. c. 128, § 64 through 83. In 2012, a bill was signed to amend M.G.L. c. 128, § 65 with the following regulations pertaining to fertilizer application:

- No fertilizer shall be applied on lawn or non-agricultural turf between December 1 and April 1;
- No fertilizer shall be applied to any impervious surfaces. If application does occur, the fertilizer must be immediately cleaned and contained or disposed of legally; and
- No fertilizer shall be applied to areas within 20 feet of any surface water subject to the jurisdiction of the Wetlands Protection Act. The setback may be reduced to 15 feet where a drop spreader, rotary spreader with a deflector, or targeted spray liquid is used for fertilizer application.

Although the bill does not specifically regulate the application rate of nitrogen-containing fertilizers, it does include restrictions on the use of phosphorus-containing fertilizers. The act will take effect on January 1st, 2014.

There are also state regulations that allow the opportunity for more localized programs. For example, waterbodies listed in the Massachusetts List of Impaired Waters (303(d)) will require a Total Maximum Daily Load (TMDL) analysis that will determine the reduction of specific pollutants, such as nitrogen. Towns can implement fertilizer regulations in order to meet their local TMDL requirement.

The Massachusetts Department of Environmental Protection (MassDEP) also has a model Groundwater Protection Bylaw/Ordinance that provides protection of groundwater reserves. Communities could adopt this provision and expand it to allow for monitoring of excessive fertilizer use in large scale development using groundwater monitoring wells (Horsley Witten Group 2007).

NANTUCKET LOCAL REGULATION

The Town of Nantucket, Massachusetts is an example of a municipality that has successfully passed an ordinance regulating fertilizer content and application on a local level. The following is a summary of the Town's fertilizer regulation program.

The Massachusetts Estuaries Program (MEP) completed a report in 2006 on excessive nutrient loading of Nantucket's waterbodies, and considered fertilizers as a significant and controllable nutrient source. As a result, MassDEP issued three TMDLs in Nantucket's waters. The development of a local fertilizer ordinance became imperative in order to reduce nitrogen loading and achieve compliance with the TMDLs.

In 2010, the Town enacted the Home-Rule Petition process in order to authorize the Board of Selectmen (BOS) to introduce legislature regulating fertilizer application in the Town and County of Nantucket. The BOS appointed the Article 68 Work Group comprised of local stakeholders to assist in developing the legislation, which created a Best Management Practices (2010-2012) document that forms the basis of the fertilizer ordinance. The Nantucket BMP provides science-based guidelines on fertilizer management and nitrogen reduction, and serves as an educational document for fertilizer applicators.

The Board of Health (BOH) passed Local Regulation 75.00 on fertilizer content and application, effective January 1st, 2013, under the authority of M.G.L. c. 111, § 31. The Regulation serves to protect and improve the Town's water quality and aid in compliance with the embayment TMDLs through reduction in nitrogen and phosphorous loading. The Regulation includes performance standards for non-licensed and licensed fertilizer applicators. Specifically, the Regulation includes the following provisions for non-licensed applicators regarding fertilizer application rates on turf, other plants, or soil:

- The annual application rate for turf should not exceed 3.0 pounds of actual Nitrogen per 1000 square feet;
- The annual application rate for trees, shrubs, herbs, and other ornamental plantings should not exceed 2.0 pounds of actual Nitrogen per 1000 square feet;
- A single application rate for turf or other plants should not exceed 0.5 pounds of actual Nitrogen per 1000 square feet; and
- A single application rate using fast-release nitrogen fertilizer should not exceed 0.25 pounds N per 1000 square feet.

The Regulation also mandates that the Town's Board of Health maintain an education program that is based on the Nantucket BMP. The BOH is in the early stages of implementing such a program, with potential collaboration with the Department of Natural Resources (DNR). The program will target retailers and homeowners to promote awareness and encourage compliance. There are currently many existing non-regulated education programs in various Massachusetts communities that can be used as a model program for Nantucket. For example, the Town of Dennis has developed a "Clean-Green" Lawn Program in order to implement fertilizer education and management. The voluntary program consists of distributing flyers to the public on proper fertilizer application, aimed to reduce over-fertilization and prevent nitrogen leaching into the groundwater. Greenscapes Massachusetts Coalition is another program aimed to promote awareness on proper landscaping practices, with participants such as the North and South Rivers Watershed and the Connecticut River Watershed.

Enforcement of the Regulation will involve an appointed enforcement officer from the BOH or the DNR. Violators of this Regulation will be subject to noncriminal disposition, and the BOH may also suspend or revoke any license pursuant to the Regulation. Implementation of the fertilizer program may also require a water quality specialist to perform seasonal sampling.

REGIONAL FERTILIZER MANAGEMENT PROGRAMS

The Pleasant Bay Alliance developed a fertilizer management plan for the Pleasant Bay watershed, which includes the towns of Brewster, Chatham, Orleans, and Harwich. The plan recommends the implementation of best management practices for municipal turf management. The Alliance plans to work with each watershed town to adopt and implement the recommended municipal policy over the next five years. The plan also calls for coordination with golf courses to reduce nitrogen loads and public education efforts to reduce residential fertilizer use. A number of regional groups have already begun to implement fertilizer education programs, including Chatham and Orleans Conservation Commissions, Orleans Ponds Coalition, Friends of Pleasant Bay and Friends of Chatham Waterways, and regional garden clubs. According to the Pleasant Bay Resource Management Plan, these measures have the potential to reduce existing nitrogen load from fertilizers by approximately 5%. The plan also suggests limiting the size of lawns for future lots created in order to reduce future nitrogen load. This bylaw is currently being discussed by the Orleans Planning Board and is present in draft regulations for the Brewster Natural Resource Protection District (Pleasant Bay 2013).

The Cape Cod Commission developed a Regional Policy Plan (RPP), effective August 17, 2012, which presents policies and guidelines for development throughout Barnstable County. The RPP issued a maximum nitrogen load of five parts per million to the local aquifer and embayments. This provides indirect fertilizer application rate control on a regional level for new development and redevelopments. Building on this requirement, the Town of Mashpee in Cape Cod decided to include nitrogen loading regulations in its zoning bylaw, which requires subdivision plan applications to submit a water quality report with nitrogen loading calculations. The bylaw provides a standard lawn fertilizer rate of 1.08 lbs N per 1000 square feet.

The New England Interstate Water Pollution Control Commission (NEIWPCC) formed the Northeast Voluntary Turf Fertilizer Initiative in 2011, a regional effort that focuses on the impact turf fertilizers have on water quality. The initiative’s goal is to develop guidelines for New York and New England states on proper fertilizer application and formulation, with the intent of unifying various state and local fertilizer regulations. These regional, voluntary guidelines will make it easier to manufacture and purchase fertilizer products that minimize impact to the environment, as well as provide a clear public outreach message for New England. Several stakeholder meetings will be held to discuss mutually agreeable fertilizer guidelines, and will include participants such as manufacturers, retailers, state environmental agencies, municipalities, and the general community (NEIWPCC).

In 2010, the New Hampshire Coastal Protection Partnership (NH Coast) implemented a fertilizer and stormwater runoff education and outreach program in the Town of New Castle, NH. The program was a year-long pilot study aimed to promote awareness on proper lawn fertilizer techniques and the impacts of nitrogen pollution on estuaries among New Castle landowners. Education included the distribution of lawn care brochures to landowners, public events and workshops, and social media outreach via Facebook, Twitter, and monthly e-newsletters. The program also included a pledge to either not use lawn fertilizers or to only use low phosphorus, slow-release nitrogen fertilizers. By the end of the year, 77 homeowners in New Castle and the surrounding area had signed the pledge, and more than 1,500 had received hard copies of outreach materials. Based on the program’s success in New Castle, NH Coast developed a “community action toolkit” that will allow other coastal communities in New Hampshire to implement similar programs (NH Coast 2010).

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