Cobbett's Pond Watershed Restoration Plan

Final Draft: July 6, 2010



Prepared For:

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APPENDICES

1. INTRODUCTION

Geosyntec Consultants, Inc. (Geosyntec) was contracted by the Cobbett's Pond Improvement Association (CPIA) to develop a Watershed Restoration Plan (WRP) for Cobbett's Pond in Windham, NH. Financial support for this project was provided by a grant from the New Hampshire Department of Environmental Services (NHDES) with funding from the U.S. Environmental Protection Agency under Section 319 of the Clean Water Act.

Cobbett's Pond (302 acres) has experienced declines in water quality in recent years, as indicated by increasing in-lake phosphorus concentrations and increasing occurrences of nuisance blue-green algae blooms. Cobbett's Pond has been included on the Draft 2010 List of New Hampshire Threatened or Impaired Waters for "aquatic life" impairments related to low levels of dissolved oxygen and elevated levels of chlorophyll-a and total phosphorus. The lake was also listed as impaired for "primary contact recreation" due to recent blooms of cyanobacteria that have the potential to produce toxins.

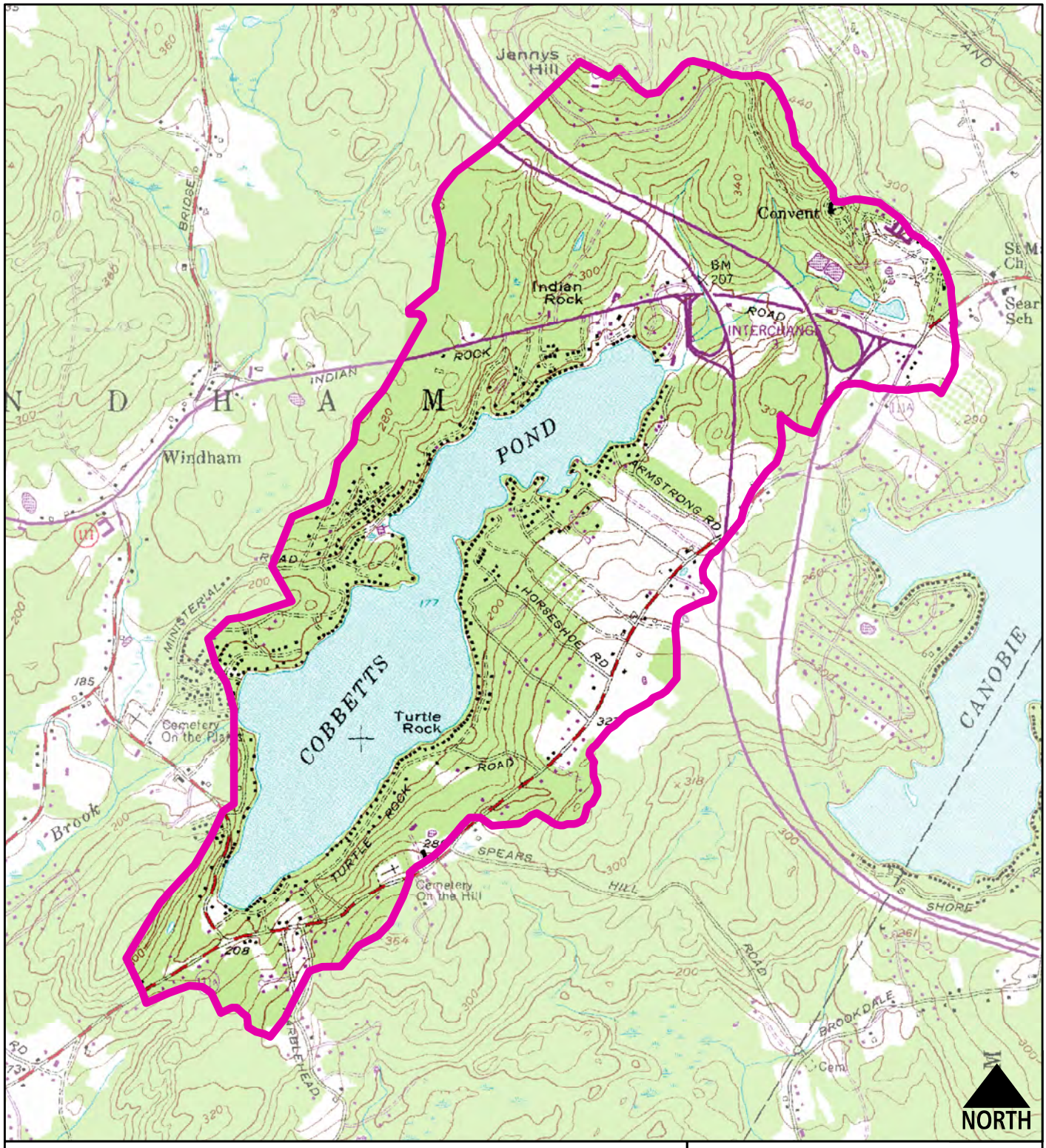
In freshwater lakes, phosphorus is usually the most important nutrient determining the growth of algae and aquatic plants. Because phosphorus is typically relatively less abundant than nitrogen, it is considered the "limiting nutrient" for biological productivity. As such, increases in phosphorus levels tend to be strongly correlated with decreased water clarity, increased algal abundance and other indicators of declining water quality. The primary purposes of this WRP are:

a. to identify and quantify specific sources of phosphorus contributing to the lake's water quality impairments; and

b. to develop a management plan to reduce phosphorus loading to the lake to a targeted level that would significantly improve in-lake conditions.

To achieve the goals listed above, this WRP includes the following nine elements, in conformance with the U.S. Environmental Protection Agency's guidance for watershed based plans:

1. Identify Pollutant Sources (Sections 2, 3 and 4)
2. Pollutant Load Reduction Estimates (Section 5)
3. Describe Nonpoint Source Pollution Management Measures (Section 6)
4. Estimate Technical and Financial Assistance (Section 7)
5. Public Information and Education (Section 8)
6. Implementation Schedule (Section 9)
7. Interim Milestones (Section 9)
8. Evaluation Criteria (Section 10)
9. Monitoring (Section 10)



Legend

Cobbett's Pond Watershed

0 600 1,200 2,400 3,600 Feet

USGS TOPOGRAPHIC MAP OF COBBETT'S POND WATERSHED

Cobbett's Pond
Windham, NH

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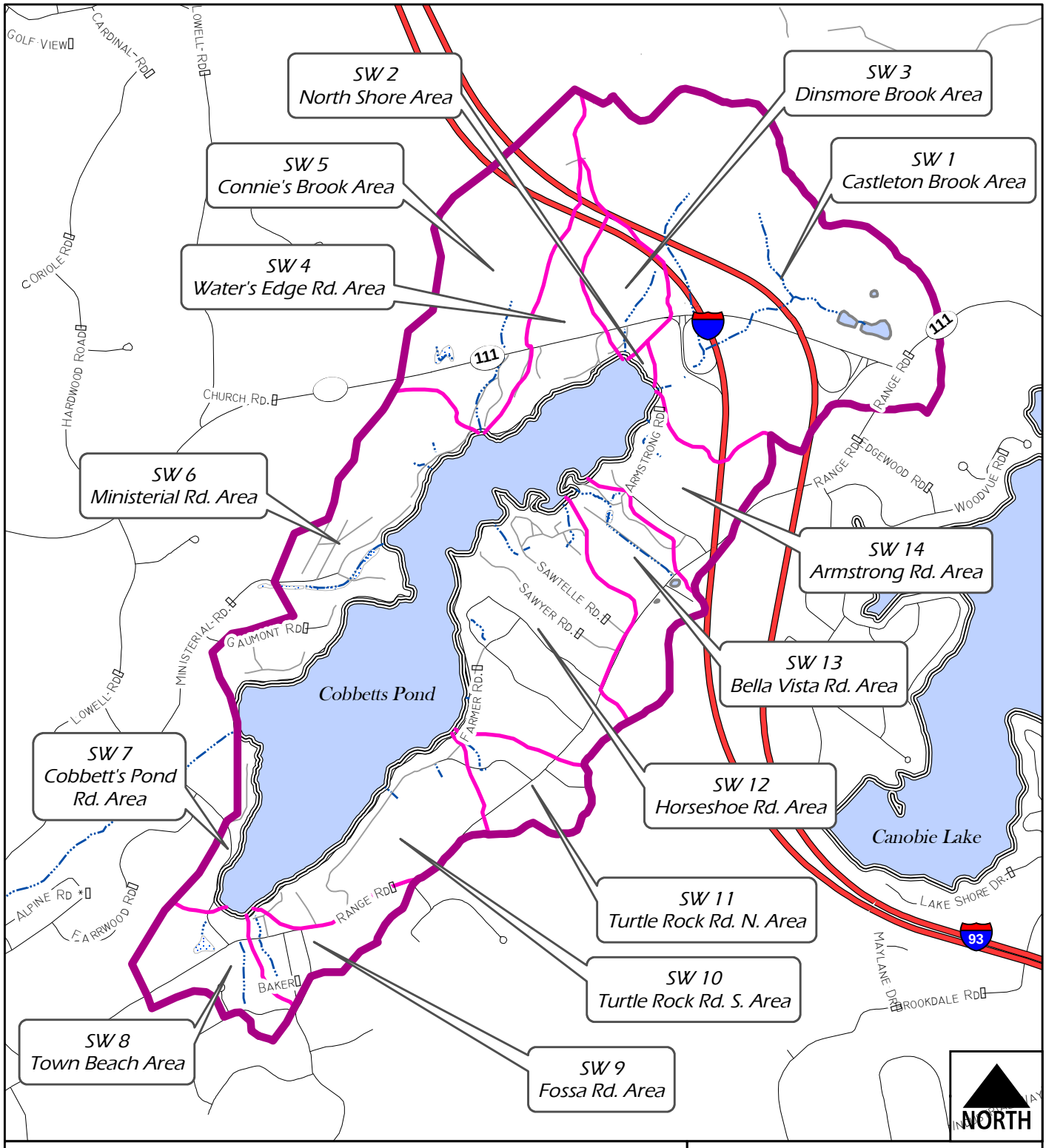
FIG 1

USGS Topographic Map data layer provided NH Granit Statewide GIS Clearinghouse



Legend

- Cobbett's Pond Watershed
- Subwatershed Boundary
- Stream
- Highway
- Major Road
- Water Body

0 600 1,200 2,400 3,600 Feet

COBBETT'S POND
SUBWATERSHEDS

Cobbett's Pond
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2. LITERATURE AND DATA REVIEW

2.1 Summary of Existing Water Quality Reports

This section provides a summary of the findings from several previous reports and data sources that address water quality conditions in Cobbett's Pond. The report summaries are presented below in chronological order.

NHDES Water Supply and Pollution Control Division – Biology Bureau
Cobbett's Pond Lake Trophic Data, 1986-1987

Summary of Comments:

- NHDES classified Cobbett's Pond as mesotrophic in 1986. In 1976, the pond was classified as oligotrophic. The change in trophic status was due to increased plant growth (sparse to abundant), and less hypolimnetic (pond bottom) dissolved oxygen. The report noted that the change in hypolimnetic oxygen was probably due primarily to a greater sampling depth and not an actual decline in water quality. At both ST1 and ST2, dissolved oxygen levels declined abruptly at depths greater than 9 meters.
- The whole water phytoplankton was 60% greens and 25% cryptomonads at ST1, with 65% greens and 20% diatoms at ST2. Tiny green flagellates were dominant (50%) at both stations.
- Plant growth in Cobbett's Pond was sparse in 1976. Plant surveys in 1985 and 1986 confirmed that the pond was ringed with abundant growth of *Potamogeton perfoliatus*, a species that was not observed during the 1976 survey. Other common plants included Elodea nuttallii, *Eriocaulon septangulare*, and Potamogeton Robbinsii. No non-native, invasive species were observed.

NHDES Water Division – Watershed Management Bureau
Cobbett's Pond Lake Trophic Data, 2003-2004

Summary of Comments:

- NHDES classified Cobbett's Pond as oligotrophic in 1976, mesotrophic in 1986, and eutrophic in 2003. There was an explosive growth *Potamogeton perfoliatus* in 1985 and the non-native *Myriophyllum heterophyllum* (Variable Milfoil) was first observed in 1995. Other trophic parameters have worsened over the years.
- VLAP data since 1988 show a worsening trend for chlorophyll-a, Secchi disk transparency and hypolimnetic phosphorus at both stations ST1 and ST2. Elevated phosphorus and total Kjeldahl nitrogen in the hypolimnion suggest internal nutrient loading.
- Elevated sodium, chloride and conductivity values indicate salt runoff from watershed roads, including the adjacent Interstate 93.
- Diatoms were very abundant during winter sampling.
- Numerous ducks, geese and seagulls were observed on the lake.
- Residents report that fishing is excellent and that an eagle visited the lake throughout the summer of 2003.

- *Potamogeton perfoliatus* was abundant around the entire shoreline. Growth of ten other species was observed to be sparse, including and the non-native Variable milfoil. Variable milfoil was treated with the herbicide Diquat in 1996, 1998, 202 and 2003 to help control its spread.

NHDES Volunteer Lake Assessment Program (VLAP)
2006 Biennial Report; 2010 Interim Report

Summary of Observations and Recommendations for Cobbett's Pond from 2006 and 2010 Reports:

- Chlorophyll-*a* is an indicator of algal abundance. September 2006 chlorophyll-a concentrations at both deep hole stations were below the state median but exceeded the median for similar lakes. The 2009 chlorophyll-a mean was greater than both the state and similar lake medians. Chlorophyll-*a* concentrations have increased significantly (worsened) during the VLAP sampling period of 1988 to 2009.

- In September 2006, Secchi disk transparency was greater than the state median but below the median. The 2009 mean transparency was slightly less than the state median and less than the similar lake median. The historical data indicates that the transparency has decreased (worsened) since monitoring began in 1988.

- In 2006, phosphorus concentrations at both deep spots were slightly greater than the state median and greater than the median for similar lakes. The 2009 mean epilimnetic phosphorus concentration was greater than the state and similar lake medians. The monitoring data suggest that internal phosphorus loading is occurring in the pond. In 2006, elevated phosphorus concentrations were also noted for Connie's Brook and Castleton Brook.

- In 2006, the dominant phytoplankton species at the deep spot locations were *Dinobryon*, *Rhizosolenia*, *Synedra* and *Ceratium*. A small amount of the cyanobacteria *Anabaena* and *Oscillatoria* were observed in 2006. A cyanobacteria bloom occurred in the pond during August 2009. A beach advisory was issued on 8/12/2009 and a lake warning was issued on 8/14/2009 notifying the public of the presence of potentially toxic cyanobacteria. The cyanobacteria were identified as *Anabaena* and *Microcystis*, both which have the potential to produce toxins. More detailed information on the 2009 algae sampling conducted by Geosyntec is provided in Section 3.4 of this report.

- The pond's pH ranged from approximately 7.4 in the epilimnion to 6.8 in the hypolimnion. The acid neutralizing capacity of the pond was well above the state median, indicating that the lake is not vulnerable to impacts from acid input.

- Conductivity in the pond and its tributaries continues to be much greater than the state median, indicating the influence of pollutants such as failed or poorly functioning septic systems, agricultural runoff, and road runoff containing road salt.

- Hypolimnetic oxygen concentrations were below 1 mg/L at both deep spots during the September sampling events, consistent with many previous sampling results. When oxygen levels are depleted to this extent, phosphorus that is normally bound in the sediment may be released into the water column.

2.1.1 Discussion of Phosphorus Concentration Data for Cobbett's Pond

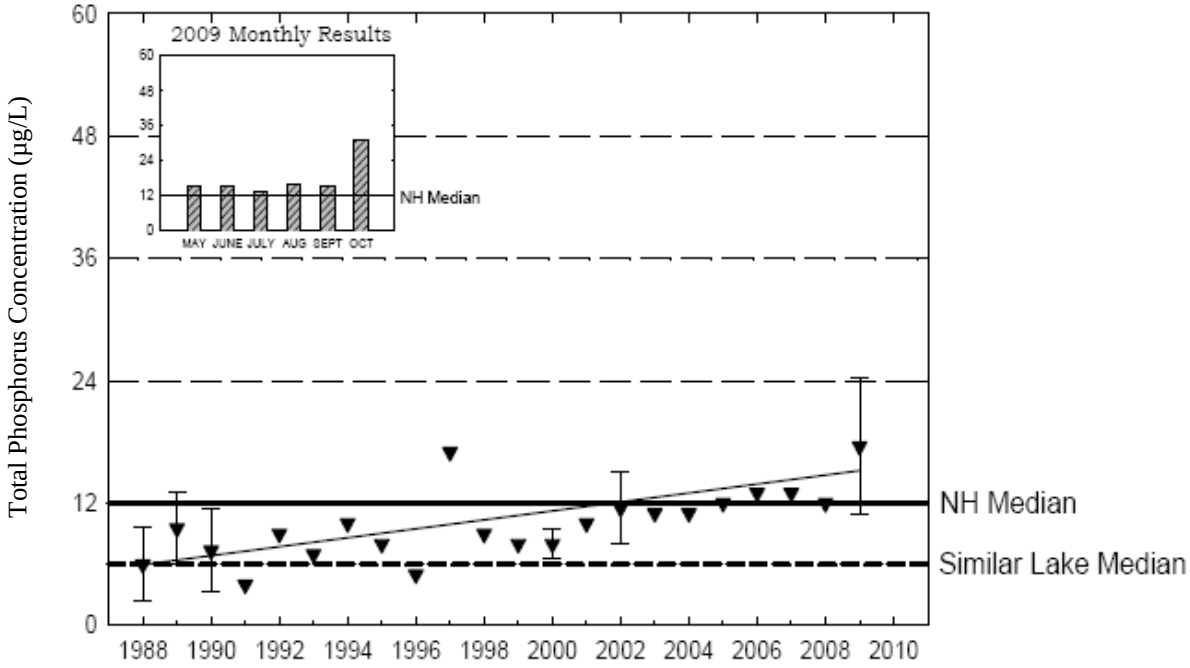
Eutrophication is the gradual process of nutrient enrichment in aquatic ecosystems such as lakes. Eutrophication occurs naturally as lakes become more biologically productive over geological time, but this process may be accelerated by human activities that occur in the watershed. Nutrients that contribute to eutrophication can come from many natural and anthropogenic sources, such as fertilizers applied to residential lawns and agricultural fields; septic systems; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges. Land development not only increases the sources of nutrients, but also decreases opportunities for natural attenuation (e.g. uptake by vegetation) of such nutrients before they can reach a water body.

Nutrients such as phosphorus and nitrogen can stimulate abundant growth of algae and rooted plants in water bodies. Over time, this enhanced plant growth leads to reduced dissolved oxygen in the water, as dead plant material decomposes and consumes oxygen. Phosphorus is typically the "limiting nutrient" for freshwater lakes, which means that plant productivity is most often controlled by the supply of this nutrient. As such, increases in phosphorus load in a lake watershed are closely correlated with increases in plant productivity and accelerated eutrophication.

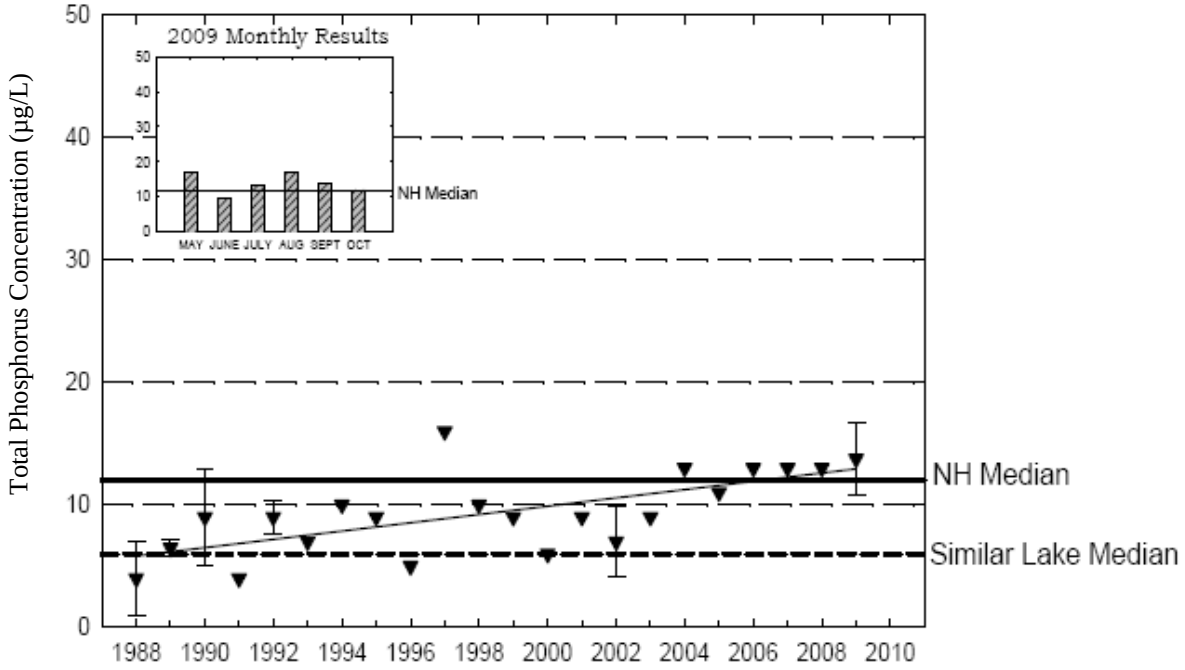
Figure 3 on the following page illustrates the historic trend for phosphorus concentrations in the epilimnion (surface water layer) of Cobbett's Pond. This data, collected between 1988 and 2009 through the NH-VLAP program, indicated a progressive increase in phosphorus concentrations over the 21 year period, with concentrations at both the North Deep Spot and South Deep Spot exceeding the median for New Hampshire lakes.

Figure 3. Historic Total Phosphorus Concentrations, Cobbett's Pond Epilimnion
(Figure from NH-VLAP 2009 Interim Report for Cobbett's Pond)

Station 1: Monthly and Historical Total Phosphorus Data



Station 2: Monthly and Historical Total Phosphorus Data



2.2 Review of Windham Ordinances and Regulations

Geosyntec reviewed the Town of Windham ordinances and regulations to identify (1) potential conflicts to the long-term goal of reducing stormwater pollutant loading to Cobbett's Pond, and (2) areas where existing ordinances and regulations may require modification and where revisions could be adopted to promote stormwater improvements such as Low Impact Development (LID) stormwater management practices.

As described below, the new Cobbett's Pond Watershed Protection Ordinance is by far the most significant local regulation related to land use, development and water quality protection for the Cobbett's Pond watershed. By establishing a new Watershed Protection Overlay District (WPOD), this ordinance creates a set of standards for the watershed that are more stringent than those which exist under Windham's Zoning Ordinance, Land Use Regulations, Site Plan Regulations and Subdivision Control Regulations.

<u>Cobbett's Pond Watershed Protection Ordinance (CPWPO)</u>

The CPWPO was passed by Town Meeting vote in March 2009. This ordinance represents a significant new regulatory tool for the protection and improvement of the Pond's water quality and has received considerable attention throughout New Hampshire and neighboring states as a model ordinance for lake protection. The CPWPO established a watershed protection overlay district (WPOD) that provides additional review requirements and performance standards for development projects and land use practices within the Cobbett's Pond watershed. A summary of some of the major elements of the CPWPO regulations is a follows:

- The CPWPO is generally supportive of LID stormwater management practices. Although LID is defined in the definitions section (Section 1.4.s), LID is not specifically mentioned at any other point in the regulations. However, in Section 1.6.c(2) (Review Requirements for Development in the Watershed Protection Overlay District), the ordinance requires that "*Best Management Practices (BMPs) are in place and are sufficient to remove or neutralize those pollutants that present a potential impact to the water body*." The definition of BMP in the ordinance references several NHDES publications which include a listing and description of LID practices, including bioretention, infiltration trenches, grassed swales, and the extensive use of vegetation to filter runoff prior to discharge to a waterbody.
- Specified activities and land uses are prohibited within the WPOD, including storage, use and disposal of hazardous materials;
- Land development proposals must include a hydrologic study documenting that the proposed project will provide "the same or a greater degree of water quality protection as existed on the sites(s)" at the time of application;
- Grading and removal of vegetation at development sites must be minimized and lawn area is limited to 10% of all dry land;
- Septic system pumping and inspection must occur at least every three years or more frequently if recommended by a licensed septic service provider;
- A 100-foot buffer zone shall be maintained along the edge of any tributary to Cobbett's Pond and all wetlands bordering those tributaries;

- Specified activities and materials are prohibited within the 100-foot buffer zone and within 25 feet of the buffer zone, including septic tanks/drain fields, trash containers, and the storage of hazardous materials, road salt, lawn fertilizers and other specified materials;
- Site construction standards prohibit impervious driveways within 75 feet of surface waters or wetlands, and limit the impervious surface area of any lot to 30%; and
- Application of fertilizers (including manure) and pesticides is prohibited within 200 feet of surface waters or wetlands.

Other Town Regulations

Geosyntec reviewed the Town of Windham Zoning Ordinance, Land Use Regulations, Site Plan Regulations, Subdivision Control Regulations and Water Supply Regulations. In general, Geosyntec found that these regulations neither specifically promote or present any significant barriers to the implementation of LID stormwater practices. As described above, the new CPWPO has created additional protective standards that are more stringent than these town-wide regulations. Several sections within the town regulations that could be modified for greater compatibility with LID stormwater practices are as follows:

- *Town of Windham Zoning Ordinance and Land Use Regulations:*
    - Section 611 provides specific provisions for Open Space Residential Development, and encourages flexibility in design "*to promote the development of balanced communities in harmony with natural land features*." A similar set of provisions could be included in these regulations to actively promote LID practices in new developments and allow similar flexibility in design standards where appropriate. LID ordinances are discussed below in Section 5.4.1.
    - Section 704.2 (Design of Off-Street Parking and Loading Spaces) states in 704.2.5 that parking and loading spaces "*shall be paved to the specifications prepared by the Planning Board with the advice of the Town Engineer*", except in the case of parking spaces for dwellings. These specifications should be updated to allow for design flexibility and encourage the use of permeable pavement products (e.g. interlocking concrete pavers, porous asphalt, open cell pavers).
    - Section 704.2.11 (Curbing) states that "*where landscaped areas abut parking areas and/or driveways, the landscaped areas shall be protected from vehicular encroachment by curbs and berms*". LID practices that can be incorporated into parking areas (e.g. bioretention) typically require "open drainage", which allows the free flow of stormwater runoff from paved areas into a downgradient treatment area. The requirement for curbs and berms should be revised to allow for design flexibility for parking areas incorporating LID practices, such as specifically allowing curb cuts, gaps in curbing, or alternate barriers to protect landscaping (e.g. timber fencing, bollards, etc.).
- *Town of Windham Subdivision Control Regulations:*
    - Section 602.18 (Curbs) states that granite curbing shall be used on all major and collector streets and that bituminous concrete cape cod berm shall be used on all secondary streets. As discussed above for parking areas, this section should be

revised to allow for design flexibility to promote LID practices to treat road runoff.

- Town of Windham Site Plan Regulations:
  - Section 1205 (Landscaping) includes specific provisions related to the function, aesthetics and siting of landscaping features on a development site. Given the integral nature of vegetation in many LID storm water practices (e.g. bioretention, rain gardens, vegetated water quality swales, vegetated buffers, etc.), this section should be revised to include a section specific to LID practices.

2.2.1 Review of Low Impact Development Regulatory Tools

Stormwater regulatory controls for residential, commercial and industrial development are changing. In the past, stormwater ordinances, subdivision regulations, and municipal development regulations focused on drainage and flood control to safely convey stormwater during storm events. Surface water protections at the federal and state levels are changing the stormwater paradigm to also require water quality treatment and stormwater volume reduction through the use of LID techniques. LID approaches recognize that land development alters the natural hydrologic cycle by increasing stormwater volumes, runoff velocity and pollutant loads, and by disrupting the natural cycle of infiltration and evapotranspiration. These adverse impacts can be controlled and minimized through the application of LID practices, which includes careful site planning and the use of both structural and nonstructural Best Management Practices (BMPs). LID techniques include: site planning, erosion and sediment controls during construction, minimizing impervious cover, maintaining existing vegetation, and use of practices such as bioretention, raingardens, porous surfaces, dry wells, and other structural controls to maintain or restore the natural site hydrology.

Land use is primarily regulated at the municipal local level through zoning, ordinances and bylaws. Every state has developed enabling legislation to allow local cities and towns to adopt regulations to control land use and manage stormwater. As the federal government and state environmental agencies continue to encourage LID, more communities are implementing LID regulatory controls. The New Hampshire Stormwater Manual was recently revised in December 2008 to provide technical guidance to municipalities on LID stormwater control techniques and to provide guidance on developing local regulatory control mechanisms. This manual is available at: (http://des.nh.gov/organization/divisions/water/stormwater/manual.htm).

The Regional Environmental Planning Program (REPP) has recently developed guidance for model ordinances and regulations including innovative land use techniques, for municipalities to use to develop their own local ordinances. *The Innovative Land Use Planning Techniques: A Handbook for Sustainable Development* contains chapters on multi-density zoning, environmental characteristics zoning and site level design. This Handbook specifically includes a model ordinance for stormwater management that is consistent with New Hampshire stormwater and water quality regulations. It is available at: http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm.

References to information on LID regulatory controls that have been implemented in New England communities is provided below:

- City of Nashua, NH. The City's Land Use Code was modified recently to allow alternative stormwater management techniques.

- New London, NH – New London's recently revised subdivision regulations specify the use of LID landscaping in new projects. Appendix A of the regulation presents a detailed section on LID Design Criteria. www.nl-nh.com/vertical/Sites/%7B26F9F697-D5BE-4423-95D7-E1EECBB7F549%7D/uploads/%7BFC33F5D8-5973-4395-9D45-8FA7EE164427%7D.PDF
- New Durham, NH – In March 2010, New Durham revised their Town Zoning Ordinance to require the use of LID controls for all new parking areas. www.newdurhamnh.us/Pages/NewDurhamNH_Planning/regs/zoning2010.pdf
- Connecticut. http://clear.uconn.edu/tools/lid_reg/index.htm. Listing of municipal LID regulations in CT.
- Massachusetts. http://www.mass.gov/envir/smart_growth_toolkit/pages/SG-bylaws-lid.html The Smart Growth Tool kit provides model LID bylaws and examples of LID practices. Approximately 30 communities in Massachusetts have passed LID regulations.
- Low Impact Development Center. www.lowimpactdevelopment.org The LID Center provides information to individuals and organizations on proper site design and LID techniques.

3. 2009 MONITORING DATA

3.1 Water Quality Monitoring

3.1.1 Water Quality Monitoring Methodology

Geosyntec conducted a water quality monitoring program at the following locations (Figure 4):

- Two (2) in-lake deep spot locations near the approximate 50-foot depth contour (NHDES-VLAP Station 1 and Station 2);
- Castleton Brook inlet;
- Connies Brook inlet;
- Dinsmore Brook inlet;
- Fossa Road inlet;
- Turtle Rock Inlet; and
- Bella Vista Inlet.

At each monitoring site on each monitoring date, Geosyntec sampled for the following parameters:

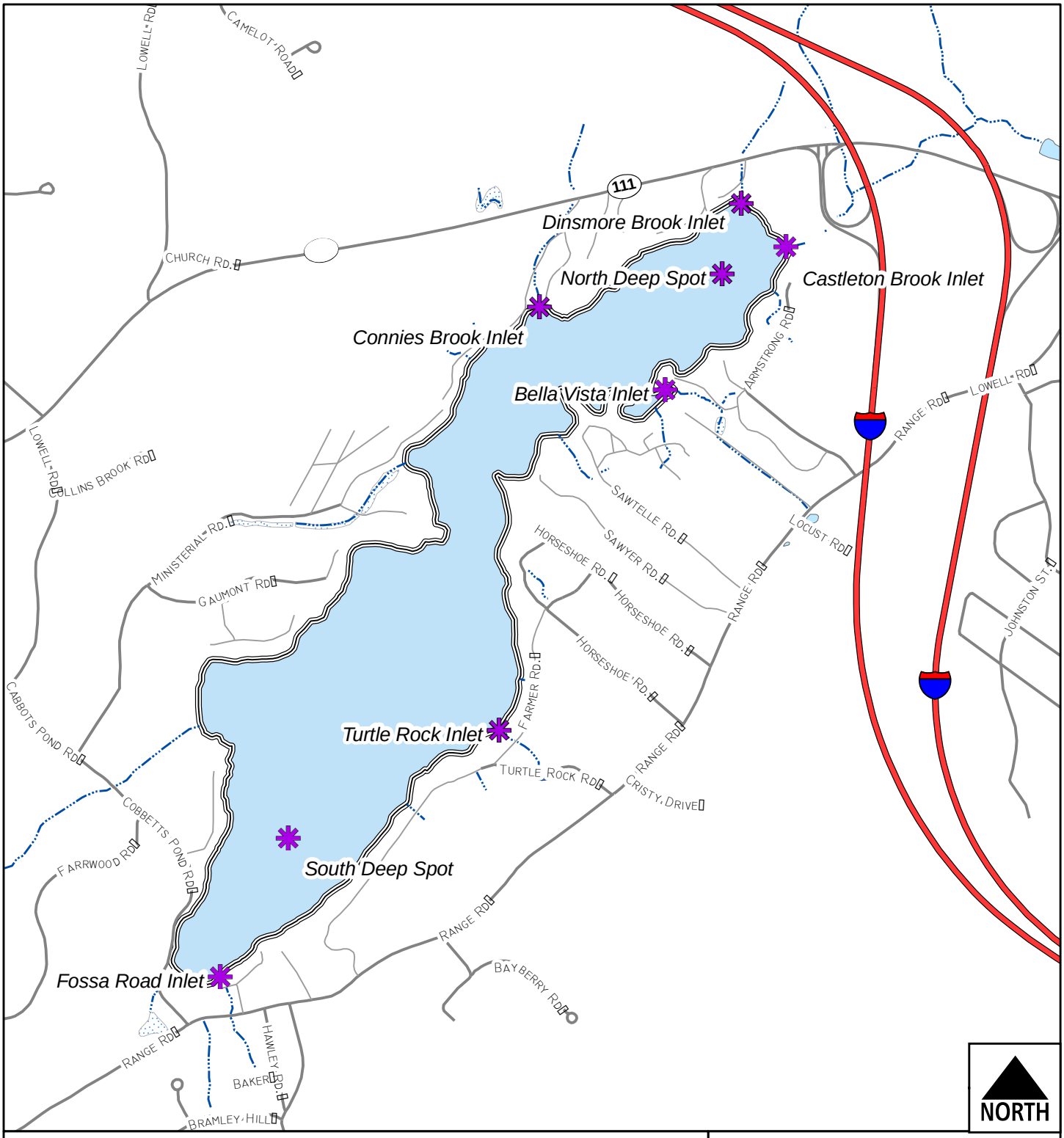
- Dissolved oxygen (in-situ);
- Temperature (in-situ);
- Specific conductance (in-situ);
- pH (in-situ);
- Turbidity (in-situ);
- Total phosphorus (lab);
- Chlorophyll-a (lab, samples at in-lake epilimnion stations only); and
- Secchi disk transparency.

In-situ measurements were taken with a YSI multi-parameter sampler (or comparable unit). Grab samples taken for laboratory analysis were obtained with a Kemmerer sampler and sent to the NHDES laboratory. Grab samples and in-situ analyses were taken just below the water surface at all tributary and storm water outfall sampling locations. At the two in-lake deep spot locations, (1) in-situ measurements were taken throughout the water column at 0.5-meter intervals and (2) grab samples for lab analyses were taken at three locations in the water column (epilimnion, metalimnion and hypolimnion).

Geosyntec conducted a six month water quality sampling program from May 2009 to October 2009. In addition, Geosyntec collected sets of samples during three storm events at the tributary and stormwater discharge sites listed above.

3.1.2 Water Quality Monitoring Results

The following paragraphs discuss selected results of the water quality monitoring program. A full record of the results is attached in Appendix A.



Legend

- Sampling Locations
- Stream
- Cobbett's Pond
- Pond
- Wetland
- Highway
- Major Road
- Minor Road

0 400 800 1,600 2,400 Feet

WATER QUALITY
SAMPLING LOCATIONS

Cobbett's Pond
Windham, NH

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FIG 4

Temperature/Dissolved Oxygen profiles are important measurements that aid in an understanding of a lake's stratification. A lake will typically be well mixed in the winter and then will separate into three layers throughout the summer. An upper layer (epilimnion) will contain warm water with high levels of dissolved oxygen caused by its contact with the atmosphere and wind/wave mixing. The middle layer (metalimnion) is a transition zone between the warm upper layer and the cooler, denser lower layer. The deepest layer (hypolimnion) typically exhibits low temperature and low DO concentrations, as biological decomposition of organic sediments depletes the available oxygen.

DO levels have an important impact on fish and other aquatic biota within a lake. Low dissolved oxygen concentrations can impair the health and spawning of fish and other organisms. Anoxic (oxygen depleted) conditions in the hypolimnion are also associated with the release of phosphorus from lake sediments back into the water column, fueling summer algae and plant growth.

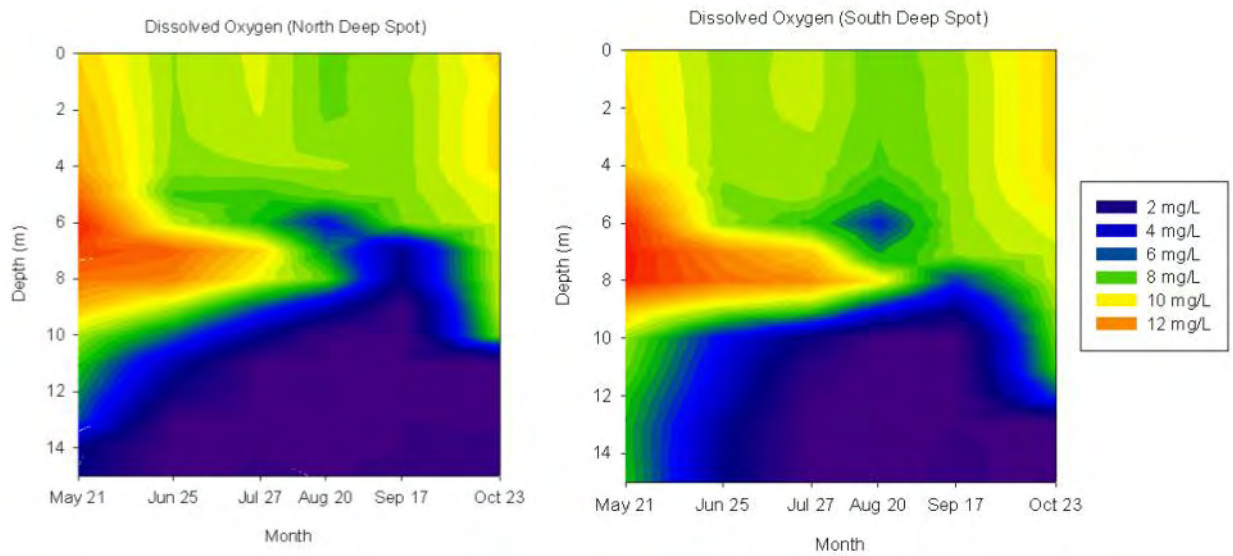


Figure 5. 2009 Dissolved Oxygen profiles for the North and South Deep Spot sampling locations.

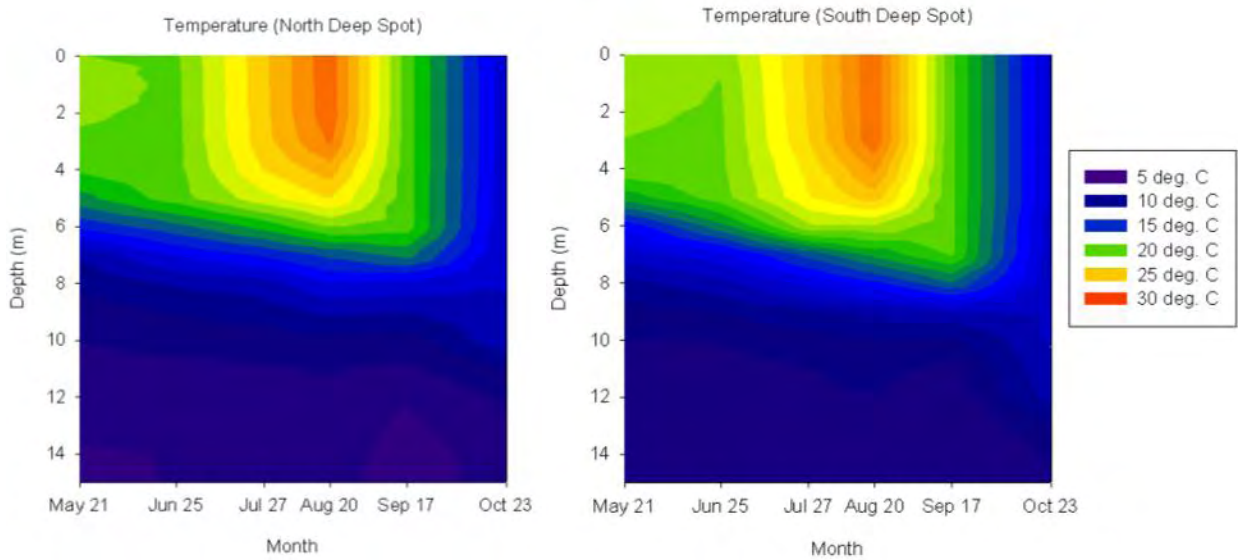


Figure 6. 2009 temperature profiles at North and South Deep Spot sampling locations.

As shown in Figures 5 and 6, Cobbett's Pond undergoes a typical summer thermal stratification. As the summer progresses, DO within the hypolimnion becomes progressively depleted due to decomposition of organic material in the sediment. By October, cooler temperatures eliminate the density barrier that exists during summer stratification, allowing DO to once again mix into the hypolimnion. A distinct increase in DO concentrations was observed in the metalimnion during the late spring/early summer months of 2009, possibly caused by abundant phytoplankton settling and collecting above the denser waters of the hypolimnion and releasing oxygen through photosynthesis.

Total phosphorus (TP) is a measure of all organic and inorganic phosphorus forms present in the water. In freshwater lakes, phosphorus is usually the most important nutrient determining the growth of algae and aquatic plants. Because phosphorus is typically relatively less abundant than nitrogen, it is considered the "limiting nutrient" for biological productivity. The NHDES considers epilimnion TP concentrations greater than 20 ug/L to be an indicator of eutrophic (nutrient-rich) conditions. The median TP concentration for New Hampshire lakes similar to Cobbett's Pond is 12 ug/l.

An average in-lake concentration was estimated by proportionally weighting observed 2009 total phosphorus concentrations by the volume of water within the layer which they were sampled. For example, epilimnetic concentrations received a higher weight in the averaging process because the epilimnion represents a higher proportion of the overall lake volume. The following equation describes the weighing calculation:

$$P_{avg} = \frac{\sum_{m=1}^{6}\left(0.27P_{N-E,m} + 0.05P_{N-M,m} + 0.008P_{N-H,m} + 0.49P_{S-E,m} + 0.15P_{S-M,m} + 0.04P_{S-H,m}\right)}{6}$$

where m represents one of the six sampling events, N signifies the North Basin, S signifies the south basin, and E, M, and H signify the epilimnion, metalimnion, and hypolimnion, respectively.

Based on the above equation and Geosyntec's 2009 sampling data, the estimated average in-lake TP concentration for Cobbett's Pond was 15.5 ug/l, 29% above the state median of 12 ug/l. This 2009 observed mean TP concentration is roughly equal to the modeled concentration of 15.6 ug/l predicted by the Vollenweider equation in Section 5.6. The lowest concentrations measured were 0.009 mg/l, occurring within the epilimnion and metalimnion on several dates. The highest concentration measured was 130 ug/l, measured at the North Deep Spot hypolimnion on September 17, 2009. According to the NHDES trophic classification system, an average TP concentration of 15. ug/l places Cobbett's in the middle of the "Average" category for this water quality parameter. A complete analysis of Cobbett's Pond's trophic classification based on the NHDES system and the Carlson Trophic Status Index is presented in Section 3.2 of this report.

NHDES Category	TP (ug/L)
Ideal	<10
Average	11-20
More than desirable	>15
Excessive	>40

Mean 2009 in-lake TP= **15.5 ug/L**

As shown below in Figure 7, TP concentrations in the South Deep Spot epilimnion (surface waters, 0-5m) were at or above the state median on all six sampling dates. The North Deep Spot epilimnion was at or above the state median on four dates and below the median on two dates.

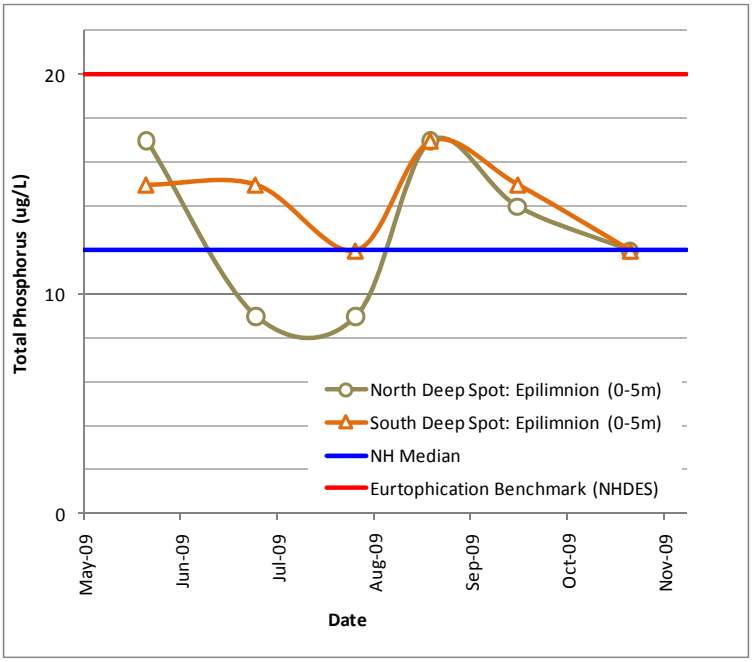


Figure 7. Epilimnion total phosphorus concentrations at the deep spot sampling locations.

Elevated TP concentrations at the North Deep Spot hypolimnion indicate that anoxic (oxygen depleted) conditions are causing phosphorus normally bound to lake sediments to be released into the water where it can fuel algae growth. This process is known as internal phosphorus loading. Figure 8 shows a dramatic pulse of phosphorus being released at the North Deep Spot hypolimnion as the summer progresses. Although similar anoxic conditions existed at the South Deep Spot during August and September 2009, hypolimnetic phosphorus concentrations were elevated rather modestly in comparison to the North Deep Spot.

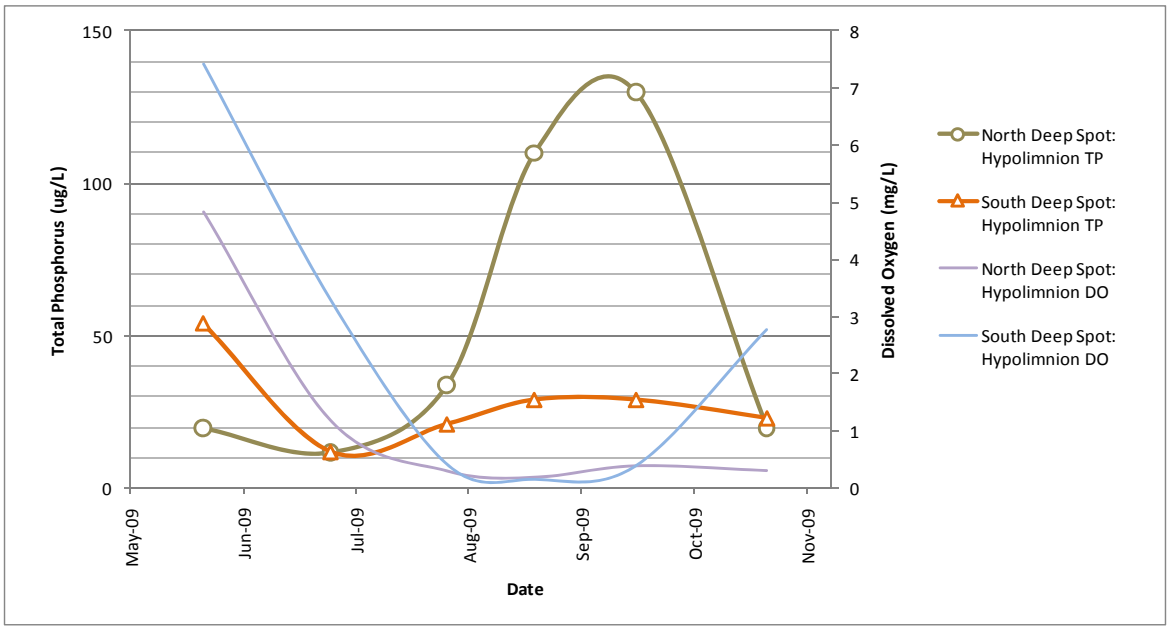


Figure 8. Hypolimnion total phosphorus and dissolved oxygen at the deep spot sampling locations.

TP measurements at the tributary monitoring locations ranged from 10 ug/L to 61 ug/L during the dry weather sampling events, and 16 ug/L to 75 ug/L during the wet weather sampling events. The Bella Vista Road tributary had the highest average dry weather concentration of 35 ug/L, and the Castleton Brook inlet had the highest one-time dry weather phosphorus concentration of 61 ug/L. The Fossa Road inlet had the highest average wet weather concentration of 59 ug/L, and Connie's Brook inlet had the highest one-time wet weather phosphorus concentration of 75 ug/L.

Chlorophyll-*a* measurements provide an indirect measure of algal biomass and, as discussed in Section 3.2, can be used as a metric to estimate a lake's trophic status. Chlorophyll-a is a green pigment used by plants, phytoplankton and cyanobacteria to convert sunlight into the chemical energy needed to convert carbon dioxide into carbohydrates. The median summer chlorophyll-a concentration for New Hampshire's lakes and ponds is 4.58 mg/m3 and the mean is 7.16 mg/m3. The NHDES categorizes chlorophyll-a results as follows:

NHDES Category	Chlorophyll-a (mg/m3)
Good	0-5
More than desirable	5.1-15
Nuisance amounts	>15

Mean 2009 chlorophyll-*a* concentration for summer months (June-Sept.) = **5.47 mg/m3**

The 2009 chlorophyll-*a* results for the North Deep Spot ranged from a high of 7.77 mg/m3 in late July to a low of 2.78 mg/m3 in late October. The South Deep Spot results ranged from a high of 7.60 mg/m3 in late May to a low of 3.27 mg/m3 in late October. The mean chlorophyll-*a* concentration for the summer months (June-September) was 5.47 mg/m3, with a mean of 5.87 mg/m3 at the North Deep Spot and 5.07 mg/m3 at the South Deep Spot. The slightly higher measurements

for the North Deep Spot are consistent with the slightly lower measurements for Secchi disk clarity at this location.

According to the Carlson Trophic Index (TSI), the summer chlorophyll-a results would classify Cobbett's Pond within the range for mesotrophic lakes, indicating moderately clear water and an increasing probability for hypolimnetic anoxia during the summer. The formula for calculating TSI from chlorophyll-a concentrations is:

$$TSI = (9.81)\ (\ln \text{Chlorophyll-a}) + 30.6$$

Based on an average 2009 summer chlorophyll-a concentration of 5.47 mg/m3, the formula above results in a TSI of 47.27. The TSI range for mesotrophic lakes is 40-50.

The **Secchi disk** is a weighted black and white disk that is lowered into the water by a calibrated chain until it is no longer visible. This method provides a measure of water clarity (light penetration), which is primarily a function of algal productivity, water color, and turbidity caused by suspended particulate matter. Water clarity influences the growth of rooted aquatic plants by determining the depth to which sunlight can penetrate to the lake sediments.

Secchi disk depths ranged from 4.5 ft (during the May sampling event at the north deep spot) to 12.5 ft (during the June sampling event at the north deep spot). The Cobbett's Pond mean summer Secchi disk clarity for the two deep spot sampling locations was 11 ft (3.35 m), which is considered to be "good" water clarity according to the NHDES trophic classification system.

NHDES Category	Water Clarity (m)
Exceptional	>4.5
Good	2- 4.5
Poor	<2

Mean 2009 summer Secchi disk = **3.35 m**

pH is a measure of acidity based on the presence of hydrogen ions. A pH of 7.0 is neutral. Values below 7.0 indicate acidic waters and values above 7.0 indicate basic waters. Lower pH values found at depth are due to biological decomposition that leads to anoxic (oxygen-depleted) conditions and other chemical reactions that reduce pH. Most fish cannot tolerate a pH below 4 or above 11, and their growth and health is affected by long-term exposure to a pH less than 6.0 and over 9.5.

pH values within Cobbett's Pond ranged from 6.1 to 7.7 during the 2009 monitoring, with the lower pH values found in the hypolimnion. The epilimnion (upper layer) pH values for the deep spots ranged from 6.9 to 7.7. The median pH value for the epilimnion in New Hampshire's lakes and ponds is 6.6. The tributaries exhibited a pH range of 6.8 to 7.8 during dry weather sampling events, and 5.3 to 7.9 during wet weather sampling events.

Specific conductance measures the ability of water to conduct electricity by measuring the presence of ions in solution. Chloride is typically the predominant ion found in surface waters, including man-

made sources of chloride ions such as wastewater and road salt. The primary natural sources of chloride ions in surface waters include the weathering of soils and rocks, and wet and dry precipitation. Regional variations in watershed geology can result in a wide range of "normal" conductance levels from lake to lake. However, abnormally high conductance levels can be an indicator of pollutants sources such as road salting, wastewater discharges, and runoff from developed areas. The median conductance value for New Hampshire's lakes and ponds is 0.04 mS/cm.

Conductivity measurements within Cobbett's Pond ranged from 0.19 mS/cm to 0.49 mS/cm. Conductivity measurements at the tributary monitoring locations ranged from 0.29 mS/cm to 1.00 mS/cm during the dry weather sampling events, and 0.01 mS/cm to 0.46 mS/cm during wet weather sampling events.

3.2 Trophic Status Assessment

Surface water bodies are typically categorized according to trophic state as follows:

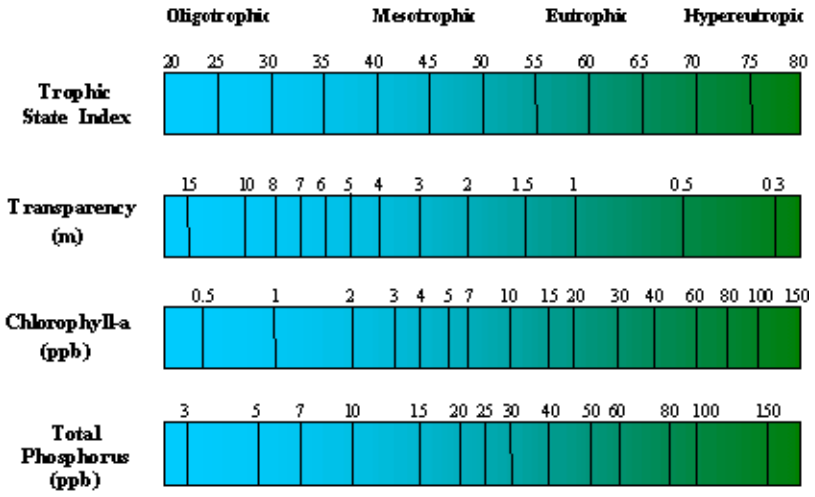
- **Oligotrophic:** Low biological productivity. Oligotrophic lakes are very low in nutrients and algae, and typically have high water clarity and a nutrient-poor inorganic substrate. Oligotrophic water bodies are capable of producing and supporting relatively small populations of living organisms (plants, fish, and wildlife). If the water body is stratified, hypolimnetic oxygen is usually abundant.
- **Mesotrophic:** Moderate biological productivity and moderate water clarity. A mesotrophic water body is capable of producing and supporting moderate populations of living organisms (plant, fish, and wildlife). Mesotrophic water bodies may begin to exhibit periodic algae blooms and other symptoms of increased nutrient enrichment and biological productivity.
- **Eutrophic:** High biologically productivity due to relatively high rates of nutrient input and nutrient-rich organic sediments. Eutrophic lakes typically exhibit periods of oxygen deficiency and reduced water clarity. Nuisance levels of macrophytes and algae may result in recreational impairments.
- **Hypereutrophic:** Dense growth of algae throughout the summer. Dense macrophyte beds, but extent of growth is light-limited due to dense algae and associated low water clarity. Summer fish kills are possible.

Geosyntec calculated the trophic status for Cobbett's Pond using both the Carlson Trophic Status Index and the New Hampshire DES trophic classification system. As described below, both methods resulted in mesotrophic classification for Cobbett's Pond.

3.2.1 Carlson Trophic Status Index

The Carlson Trophic State Index (TSI) is one of the most commonly used means of characterizing a lake's trophic state. As illustrated in the Figure 3, the TSI assigns values based upon logarithmic scales which describe the relationship between three parameters (total phosphorus, chlorophyll-a, and Secchi disk clarity) and the lake's overall biological productivity. TSI scores below 40 are considered oligotrophic, scores between 40 and 50 are mesotrophic, scores between 50 and 70 are eutrophic, and scores from 70 to 100 are hypereutrophic.

Figure 9. Carlson Trophic State Index
(Figure from 1988 Lake and Reservoir Restoration Guidance Manual. USEPA. EPA 440/5-88-002.)



The TSI for Cobbett's Pond was calculated based on Geosyntec's 2009 data as follows:

Transparency: Cobbett's Pond summer 2009 mean Secchi Disk = 3.35m;
TSI = 60 - 14.41ln Secchi Disk (m)
TSI = 42.6 (Mesotrophic)

Chlorophylll-a: Cobbett's Pond summer 2009 mean chlorophyll-a = 5.47ug/l;
TSI = (9.81) (ln Chlorophyll-a) + 30.6
TSI = 47.3 (Mesotrophic)

Total Phosphorus: Cobbett's Pond 2009 mean in-lake TP =15 ug/L;
TSI = (14.42) (ln TP ug/L) + 4.15
TSI = 43.2 (Mesotrophic)

Geosyntec collected data on a monthly basis from May through October 2009. Where a "summer mean" is referenced above (for chlorophyll-a and Secchi disk), it refers to the mean of the data collected on 4 sampling events which occurred during the summer (June 25, July 27, August 20 and September 17). The mean includes data collected at both the North Deep Spot and South Deep Spot. The DO ranking was based on August/September conditions when oxygen depletion was at its maximum. As shown in the calculations above, Cobbett's Pond has a TSI in the mesotrophic range for each of the three parameters.

3.2.2 NHDES Trophic Classification System

Geosyntec calculated Cobbett Pond's trophic status based on the NHDES trophic classification system and Geosyntec's 2009 data. The NHDES classification system assigns points based on summer dissolved oxygen levels, Secchi disk transparency, aquatic plant abundance and chlorophyll-a. The point total for all parameters is used to determine trophic class, as indicated below:

1. Summer Bottom Dissolved Oxygen	**Points**
a. D.O. >4mg/L	0
b. D.O. = 1 to 4 mg/L & hypolimnion volume ≤10% lake volume	1
c. D.O. = 1 to 4 mg/L & hypolimnion volume >10% lake volume	2
d. D.O. <1mg/L in <1/3 hypo. volume & hypo. volume ≤10% lake volume	3
e. D.O. <1mg/L in ≥1/3 hypo. volume & hypo. volume ≤10% lake volume	4
f. D.O. <1mg/L in <1/3 hypo. volume & hypo. volume >10% lake volume	5
g. D.O. <1mg/L in ≥1/3 hypo. volume & hypo. volume >10% lake volume	6
2. Summer Secchi Disk Transparency:	
a. > 7m	0
b. > 5m – 7m	1
c. > 3m – 5m	2
d. >2m – 3m	3
e. >1m – 2m	4
f. >0.5 – 1m	5
g. ≤0.5m	6
3. Aquatic Vascular Plant Abundance:	
a. Sparse	0
b. Scattered	1
c. Scattered/Common	2
d. Common	3
e. Common/Abundant	4
f. Abundant	5
g. Very Abundant	6
4. Summer Epilimnetic Chlorophyll-a (mg/m^3):	
a. <4	0
b. 4 - <8	1
c. 8 - <12	2
d. 12 - <18	3
e. 18 - <24	4
f. 24 - <32	5
g. ≥32	6

NH Trophic Classification	**Stratified Lakes**
Oligotrophic	0-6
Mesotrophic	7-12
Eutrophic	13-24

The NHDES Trophic Classification system results for Cobbett's Pond were as follows:

1. **Summer Bottom Dissolved Oxygen (DO):**
   DO <1mg/L in >1/3 hypolimnion volume and hypolimnion volume <10% lake volume = 4 points

2. **Summer Secchi Disk Transparency** (Cobbett's Pond summer mean = 3.35m): > 3m – 5m = 2 points

3. **Aquatic Vascular Plant Abundance:** Scattered/Common = 2 points

4. **Summer Epilimnetic Chlorophyll-a** (Cobbett's Pond summer mean= 5.74 mg/m3):
   4 mg/m3 - <8 mg/m3 = 1point

Total Score = **9 points**
Trophic Classification: **Mesotrophic**

The Secchi disk, chlorophyll-a and total phosphorus data used for the NHDES trophic classification was the same as used for the Carlson TSI. The plant abundance ranking is based on the Geosyntec survey conducted on July 27, 2009. As discussed in Section 3.3, Cobbett's Pond was characterized by sparse to moderate plant growth over the vast majority of its littoral zone. Approximately half (46%) of the sampling stations had trace (0-5% density) to sparse (6-25% density) growth, while approximately half (48%) had moderate growth (26-50% density). Based on these results, Geosyntec assigned the "scattered/common" ranking of 2.

Overall, the NHDES trophic classification system is consistent with the Carlson TSI for Cobbett's Pond, with both placing the pond within the mesotrophic range.

3.3 Aquatic Vegetation Survey

3.3.1 Aquatic Vegetation Survey Methodology

On July 27, 2009, Geosyntec conducted a macrophyte survey of Cobbett's Pond. Plant species were identified at 46 sampling locations (Figure 10) by visual inspection and by using an aquatic vegetation grappling hook to sample submerged vegetation. At each station, the plant growth density, biomass and dominant plant(s) were recorded. As categorized in Table 1, plant density is an estimate of aerial coverage when looking down to the lake bottom from the water surface. Biomass estimates the amount of plant matter within the water column. For example, a sampling station with dense growth of low-growing plants may have a high density estimate but a relatively low plant biomass estimate. A station with dense growth of a long, ropey plant like Variable Milfoil, with stems reaching the water surface, would have both high plant density and high biomass estimates.

3.3.2 Aquatic Vegetation Survey Results

General Notes:

- Cobbett's Pond was characterized by sparse to moderate plant growth over the vast majority of its littoral zone (area of rooted plant growth). Approximately half (46%) of the sampling stations had trace (0-5% density) to sparse (6-25% density) growth, while approximately half (48%) had moderate growth (26-50% density). Only 3 stations (7%) had dense or very dense plant growth.
- 28 species of macrophytes were documented in Cobbett's Pond during the 2009 survey. A list of the species observed is provided in Table 1, which organizes the species according to growth habit (submersed, floating-leaf and emergent). A tally sheet listing the results from each of the 50 sampling stations is provided in Table 2, including information on vegetation density, plant biomass, and dominant plants at each station.
- The 2009 species richness index for Cobbett's Pond was 5.2. The species richness index is the average number of species observed at the vegetation sampling stations. Over half (53%) of the species were observed at 3 stations or fewer out of the 46 sampling stations and 6 species were observed at only one sampling station.

Variable milfoil

Invasive/Non-native Species:

- **Variable Milfoil** (*Myriophyllum heterophyllum*) was the only invasive, non-native plant observed in Cobbett's Pond. This plant was found growing in very small quantities at only two sampling stations. One of these stations (station #36) was located just north of the midpoint along the pond's eastern shorline. The second station (station #16) was located in the southern portion of the western shoreline.

Robbin's Pondweed

Native Species:
Only seven plant species were observed at 25% or more of the 46 sampling stations. These seven native species, which comprised the majority of the plant assemblage in Cobbett's Pond, are described below.

- **Robbin's Pondweed** (*Potamogeton robbinsii*) was the most abundant and dominant species in the Pond. This submerged plant was observed at 74% of the sampling stations (23 stations) and was a dominant plant at 15 stations. Robbin's Pondweed is also known as Fernleaf Pondweed for the fern-like appaearence of its leaves. This plant was observed as part of a relatively low-growing undercanopy in many areas around Cobbett's Pond.

Little Floating Bladderwort

- **Bladderwort species,** including Little Floating Bladderwort (*Utricularia radiata*) and Common Bladderwort (*Utricularia vulgaris*) and were found throughout the Pond (37 stations, 80%), most often in small quantities. Little Floating Bladderwort was the most common of these species, although the bladderwort species were reported collectively because of the difficulty in confirming species identification at several sites due to specimens lacking key identifying features. When in flower, Little Floating Bladderwort is easily recognized by its yellow flower that is supported above the water by oblong leaves that act as pontoons. Bladderworts are carnivorous plants that trap and digest zooplankton (microscopic animals) in clusters of "bladders" for which they are named.

Musk Grass

- **Musk Grass** (*Chara vulgaris*) and **Rough Stonewort** (*Chara aspera)* are actually structured forms of algae rather than true vascular aquatic plants. Musk Grass was found at just over half of the sampling stations and was a dominant plant at 11 stations, second only to Robbin's Pondweed in dominance among all species in the 2009 vegetation survey. Musk Grass is easily identified by its brittle stems that have a musky, skunk-like odor when crushed. Rough Stonewort, found at 12 sampling stations, is similar in structure to Musk Grass but smaller.

Waterweed

- **Waterweed** (*Elodea canadensis*) was observed throughout the Pond (28 stations, 61%). This plant was generally found in relatively low quantities, although it was a dominant plant at 4 stations. Waterweed is a submergent plant that can grow in diverse conditions, sometimes to nuisance levels. The most notable growth of Waterweed during the 2009 vegetation survey was a dense, monotypic stand observed to the south of station #1 in the northeast corner of the Pond.

Wild celery

- **Water Celery** (*Vallisneria americana*) was found growing at 26 stations (57%) distributed around the Pond, but was not a dominant plant at any stations. This submergent plant has flat tape-like leaves, and both the leaves and underground tubers of the plant provide food for a variety of aquatic animals.

Bushy Pondweed

- **Bushy Pondweed** (*Najas flexilis*) is a slender, submerged plant that has a branched stem with narrow leaves that are oppositely arranged. This plant was found at 21 stations (47%) and was a dominant plant at 4 stations.

Table 1: Cobbett's Pond Aquatic Plant Species List (July 27, 2009)

Type	Scientific Name	Common Name
Submersed Species	*Chara aspera*	Rough Stonewort
	Chara vulgaris	Musk Grass
	Elatine minima	Small Waterwort
	Elodea canadensis	Waterweed
	Heteranthera dubia	Water Star-grass
	Isoetes sp.	Quillwort
	Myriophyllum heterophyllum	Variable Milfoil
	Najas flexilis	Bushy Pondweed
	Potamogeton bicupulatus	Snailseed Pondweed
	Potamogeton gramineus	Variable Pondweed
	Potamogeton perfoliatus	Clasping Pondweed
	Potamogeton pulcher	Heartleaf Pondweed
	Potamogeton pusillus	Small Pondweed
	Potamogeton robbinsii	Robbin's Pondweed
	Utricularia spp.	Bladderwort spp.
	Vallisneria americana	Water Celery
Floating Leaf Species	*Lemna minor*	Lesser Duckweed
	Nuphar variegatum	Yellow Water Lily
	Nymphaea odorata	White Water Lily
	Potamogeton natans	Floating Leaf Pondweed
Emergent Species	*Alisma plantago-aquatica*	Water Plantain
	Eleocharis robbinsii	Robbin's Spike Rush
	Eriocaulon sp.	Pipewort
	Juncus canadensis	Canada Rush
	Pontederia cordata	Pickerelweed
	Scheuchzeria palustris	Rannoch Rush
	Sparganium sp.	Bur-Reed
	Typha latifolia	Broad-leaf Cattail

Table 1: Aquatic Vegetation Survey Tally Sheet

Location: Cobbetts Pond, Windham NH
Date: 7/27/09 Surveyed by: Hartzel

Geosyntec consultants

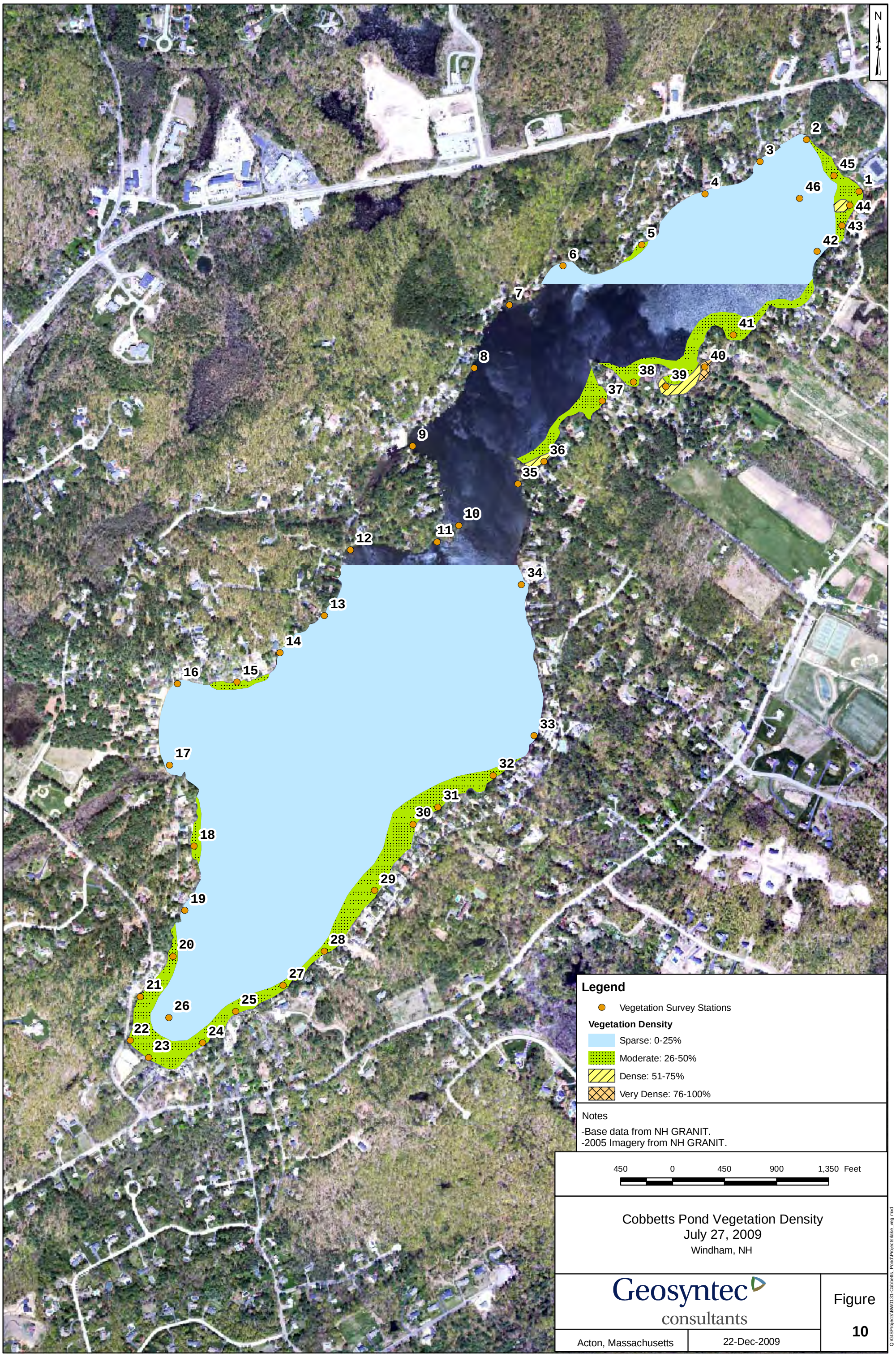
● species present at monitoring station ■● species dominant at monitoring station

Plant Species	# stations present	# stations dominant	Monitoring Locations																																																				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Bladderwort *(Utricularia spp.)*	37	2	●	●	●	●	●	●	■●		●		●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	●	●		●	●			●	●	●	■●	●	
Robbin's Pondweed *(Potamogeton robbinsii)*	34	15	●	●	●		●	●	■●	●			●	●		●		■●				●	■●	●	■●	■●	●		■●	■●	■●	■●	■●	●	●		●	●	■●	●	■●		●	●	■●	■●	■●	
Waterweed *(Elodea Canadensis)*	28	4	■●					●	●	●				●		●	●				●	●	●	●	■●	●	●		●	●	●	●	■●	●		●				●	●	●	●		●	●	■●	
Water Celery *(Vallisneria americana)*	26	0	●	●	●	●	●		●	●						●		●		●	●	●	●			●			●				●	●	●			●		●	●	●	●		●	●	●	
Musk Grass *(Chara vulgaris)*	24	11			●	■●	■●			■●	●	●				■●	●	●		●		■●				●		●	●	■●	■●	■●	●	■●		●					●		●	■●	●			
Bushy Pondweed *(Najas flexilis)*	21	4	●		■●	●	●			●	●			●				●		●	●										●		●	●	●	●	■●				●	■●	■●		●	●		
Rough Stonewort *(Chara aspera)*	12	0				●											●	●	●		●					●	●			●	●						●							●	●			
Pipewort *(Eriocaulon septangulare)*	6	0												●					●					●											●		●	●										
Heartleaf Pondweed *(Potamogeton pulcher)*	5	1	●																	●					●				●									■●										
Floating Leaf Pondweed *(Potamogeton natans)*	5	0																		●					●				●									●		●								
Robbin's Spike Rush *(Eleocharis robbinsii)*	5	0														●	●		●	●																								●				
Lesser Duckweed *(Lemna minor)*	4	0	●								●																														●	●						
Clasping Pondweed *(Potamogeton perfoliatus)*	4	0	●																						●	●																					●	
Small Pondweed *(Potamogeton pusillis)*	3	0																		●							●											●										
Rannoch Rush *(Scheuchzeria palustris)*	3	0	●						●							●																																
Cattail *(Typha latifolia)*	2	0																																							●	●						
Variable Pondweed *(Potamogeton gramineus)*	2	0									●																																	●				
Small Waterwort *(Elatine minima)*	2	0								●														●																								
Variable Milfoil *(Myriophyllum heterophyllum)**	2	0																●																				●										
Pickerelweed *(Pontederia cordata)*	2	0																																						●	●							
Water Star-grass *(Heteranthera dubia)*	2	0	●								●																																					
Yellow Lily *(Nuphar spp.)*	2	0																																					●	●								
White Lily *(Nymphaea odorata)*	1	1																																					■●									
Snailseed Pondweed *(Potamogeton bicupulatus)*	1	0																																								●						
Quillwort *(Isoetes sp.)*	1	0																			●																											
Water Plantain *(Alisma plantago-aquatica)*	1	0	●																																													
Canada Rush *(Juncus canadensis)*	1	0	●																																													
Bur-reed *(Sparganium sp.)*	1	0	●																																													
Plant Density Rating			2	1*	1	1	2	1*	1	1	1*	1*	1*	1	1	1	2	1	1*	2	1	2	2	2	2	2	2	1	2	2	2	2	2	2	1	1	1	3	2	2	3	4	2	1	2	2	2	0
Plant Biomass Rating			2	1*	1	1	1	1*	1	1	1*	1*	1*	1	1	1	1	1	1*	1	1	1	1	2	1	1	1	1	1	1	1	2	2	1	1	1	1	2	2	2	2	3	1	1	1	1	1	0
# of species present			13	3	5	5	5	3	5	6	6	1	2	4	1	7	5	7	4	8	6	5	4	5	6	6	5	2	7	5	6	4	5	6	5	4	5	7	4	7	8	6	6	6	7	5	5	0

* Non-native, invasive species

Key to Density and Biomass Ratings

	Density	Biomass
0	Absent: 0%	Macrophytes absent
1*	Trace: 0-5% density	Trace plant growth, macrophytes virtually absent
1	Sparse: 5-25% density	Scattered plant growth; or primarily at lake bottom
2	Moderate: 26-50% density	Plants generally protruding into less than half of water column
3	Dense: 51-75% density	Substantial growth through majority of water column
4	Very Dense: 76-100% density	Abundant growth throughout water column to surface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Legend
Vegetation Survey Stations
Vegetation Density
Sparse: 0-25%
Moderate: 26-50%
Dense: 51-75%
Very Dense: 76-100%
Notes
-Base data from NH GRANIT.
-2005 Imagery from NH GRANIT.
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Cobbetts Pond Vegetation Density
July 27, 2009
Windham, NH
Geosyntec consultants
Acton, Massachusetts
22-Dec-2009
Figure
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Q:\GIS\Projects\BW0131-Cobbetts_Pond\Projects\lake_veg.mxd

3.4 Algae Sampling

3.4.1 Algae Sampling Methodology

On the six sampling dates listed below in Table 10, Geosyntec collected samples from the two deep-spot sampling locations (North Deep Spot and South Deep Spot) for analysis of relative algal abundance to the genus level. The algae samples were analyzed at the NHDES Limnological Laboratory at no cost to the project.

Geosyntec collected the algae samples using an 80-micron phytoplankton net. The plankton net was towed vertically from mid-thermocline to the surface. The samples were stored in a 250 ml glass bottle and preserved with 1-2 drops of Lugol's solution.

The original scope of work for this project included three rounds of algae sampling scheduled for June, August and October 2009. However, in response to concerns related to nuisance cyanobacteria blooms that have occurred at Cobbett's Pond, Geosyntec conducted sampling during each of the six monthly in-lake sampling events to provide more robust data on seasonal phytoplankton population trends.

3.4.2 Algae Sampling Results

The results of the 2009 algae sampling results are presented below.

Table 2. Algae Sampling Results, May-October 2009

		% Dominance											
Division	**Genus**	**5/21/2009**		**6/25/2009**		**7/27/2009**		**8/20/2009**		**9/17/2009**		**10/23/2009**	
		ND	SD	ND	SD	ND	SD	ND	SD	ND	SD	ND	SD
Chrysophyta	Dinobryon	40	46			39	40		42		18	60	82
Bacillariophyta	Rhizosolenia		7	58	52								
Bacillariophyta	Synedra	34	32	27	18		10			7		9	
Bacillariophyta	Tabellaria	13		9	24	28	37	20	21	27	15		
Cyanobacteria	Oscillatoria					9							4
Pyrrophyta	Ceratium							45	30	30	40		
Cyanobacteria	Anabaena							12					4
Bacillariophyta	Asterionella											13	

Notes:

1. ND and SD refer to the North Deep Spot and South Deep Spot sampling locations, respectively.

The 2009 algae sampling results indicate that Cobbett's Pond was heavily dominated by golden-brown algae (Chrysophyta) and diatoms (Bacillariophyta) during the May, June and July sampling events. Diatoms and golden-brown algae are common in New Hampshire's less productive lakes and ponds. A mix of dinoflagellates (Pyrrophyta), diatoms and golden-browns were dominant during the August and September sampling event, with golden browns and diatoms dominating in October.

Also notable was the relative abundance of cyanobacteria (Ocillatoria and Anabaena) during the July (9% at North Deep Spot), August (12% at North Deep Spot) and October (4% at South Deep

Spot) sampling events. Following Geosyntec's August sampling, Cobbett's Pond experienced a cyanobacteria bloom. Based on additional sampling conducted by NHDES in response to a reported algae bloom, a beach advisory was issued by NHDES on 8/12/2009 and a lake warning was issued on 8/14/2009 due to the presence of the potentially toxic cyanobacteria Anabaena and Microcystis. Both Anabaena and Microcystis have the potential to produce toxins that are harmful to humans and wildlife if ingested. It is important to note that the presence of potentially toxin-producing cyanobacteria is common in fresh water bodies and that it is relatively uncommon for these cyanobacteria to produce toxins in levels that are considered a threat to human health. As a conservative standard, the NHDES recommends that a water contact advisory be issued when an algae bloom is comprised of over 50% cyanobacteria species or when the total cell count of a sample exceeds 70,000 cells/ml. These advisory guidelines are not based on the presence of toxins in the water, but reflect that such conditions have the potential to develop and change rapidly during a cyanobacteria bloom. The beach advisory was removed on 8/18/2009 and the lake warning was removed on 8/27/2009.

Anabaena sp.

3.5 Flow Monitoring

3.5.1 Flow Monitoring Methodology

Geosyntec conducted continuous flow monitoring at the following locations:

- Castleton Brook inlet;
- Dinsmore Brook inlet;
- Connies Brook inlet;
- Fossa Road inlet;
- Turtle Rock inlet;
- Bella Vista inlet.

Flows were monitored by installing *Solinst* automated water level recorders at available control points (i.e. culverts). In cases where no control points were available (Dinsmore Brook inlet and Bella Vista inlet), a temporary plywood weir was installed. Water level measurements from locations with culverts were converted to flows (cubic feet per second, cfs) using standard culvert equations available from the Federal Highway Administration (FHA, 2005). Water level measurements for locations with plywood weirs were converted to flows using the formula for a V-notch weir:

$$Q = C_d \frac{8}{15} \sqrt{2g} \tan \frac{\theta}{2} H^{5/2}$$

where Q is the discharge, Cd is a coefficient (~0.58), g is acceleration due to gravity (32.2 ft/s^2), Θ is the angle of the v-notch (in this case, 90°), and H is the distance between the water elevation and the weir invert.

In addition to the flow measurement, Geosyntec installed a tipping-bucket rain gage in a vacant lot along Armstrong Road to collect continuous precipitation data. Data from the flow and precipitation monitoring equipment was collected during monthly water quality sampling.

3.5.2 Flow Monitoring Results

Hydrographs (graphs of stream discharge over time) were produced to depict flow measurements at the 6 monitoring locations. The shapes of the hydrographs are useful in characterizing the behavior of stormwater and pollutant transport within a subwatershed. For instance, hydrographs that rise and fall gradually indicate that stormwater is moving slowly to the discharge point, most likely over vegetated surfaces. Slow moving stormwater has less erosive power and is more effectively filtered while moving over or through vegetated surfaces. A sharply rising hydrograph indicates stormwater flowing quickly from impervious surfaces such as roads and rooftops. Quickly moving stormwater can cause erosion of channels, degradation of stormwater infrastructure, and can cause more sediment to be delivered to the pond.

Figures 11 and 12 below show two hydrographs from a storm event on 7/31/09. The contributing subwatersheds are approximately the same size and slope, but have differing land use characteristics. The Fossa Road subwatershed (Figure __) has the highest percentage of impervious surfaces in the entire watershed, and quickly conveys stormwater to the measuring point via roads and roadside ditches. The Turtle Rock Road watershed (Figure ___) drains through a natural stream in a mostly forested area, resulting in a more gradually sloping hydrograph.

The full results of the flow monitoring are presented in Appendix B.

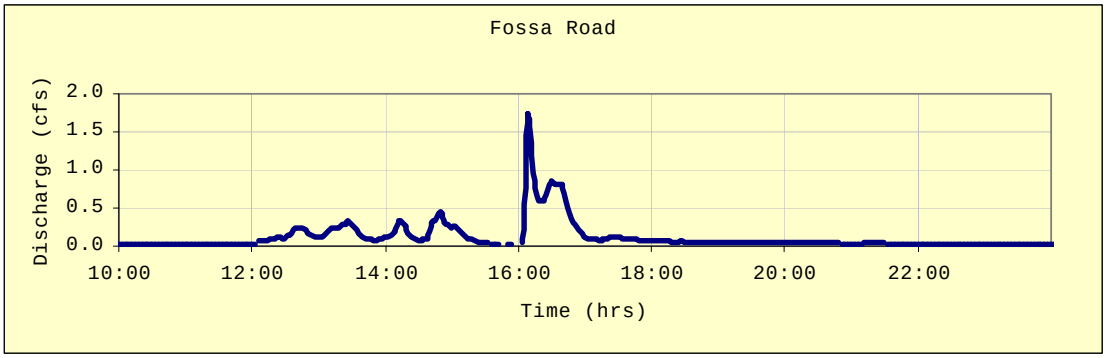


Figure 11. Fossa Road Subwatershed Hydrograph, 7/31/2009

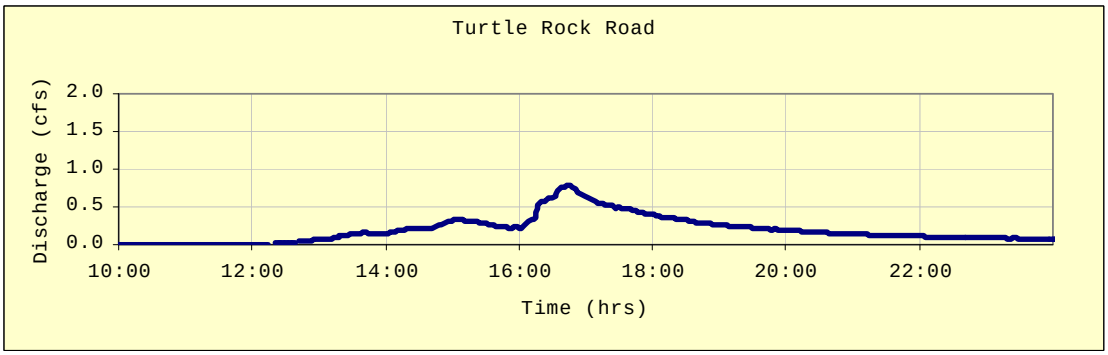
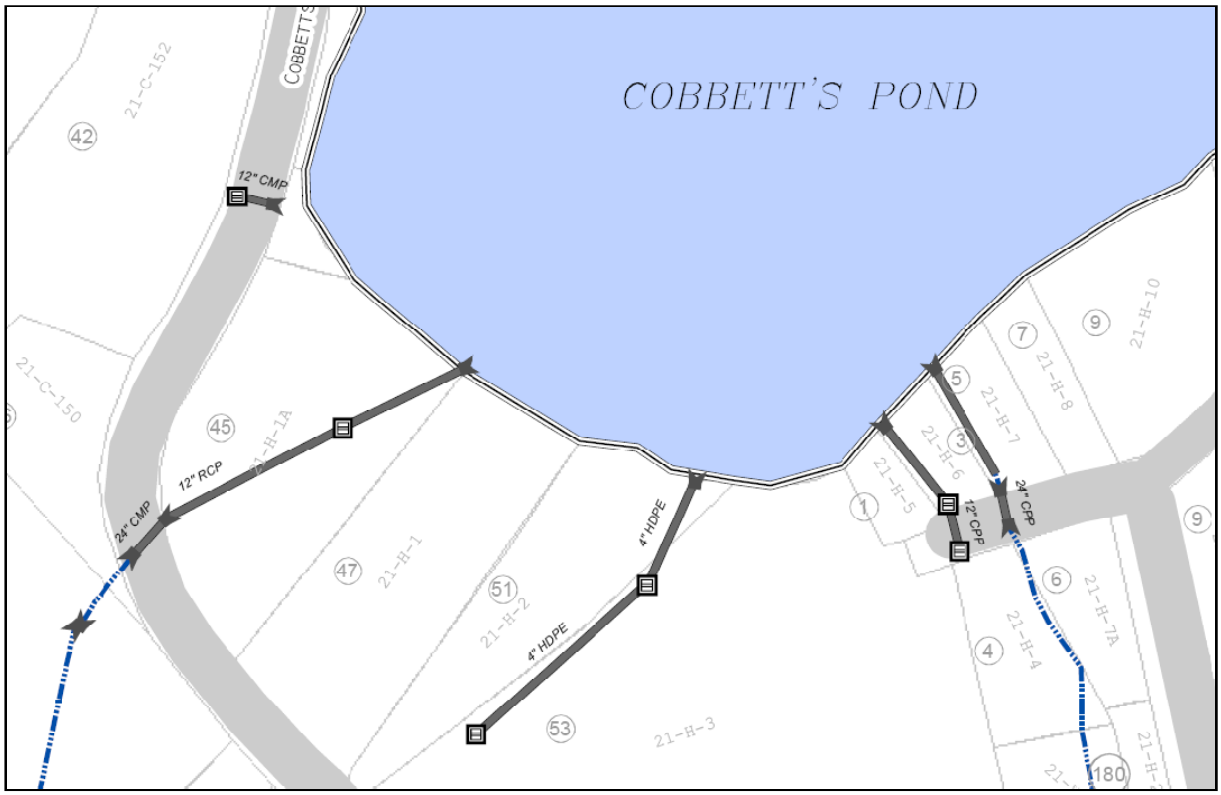


Figure 12. Turtle Rock Road Subwatershed Hydrograph, 7/31/2009

4. WATERSHED ASSESSMENT

4.1 Storm Drainage Mapping

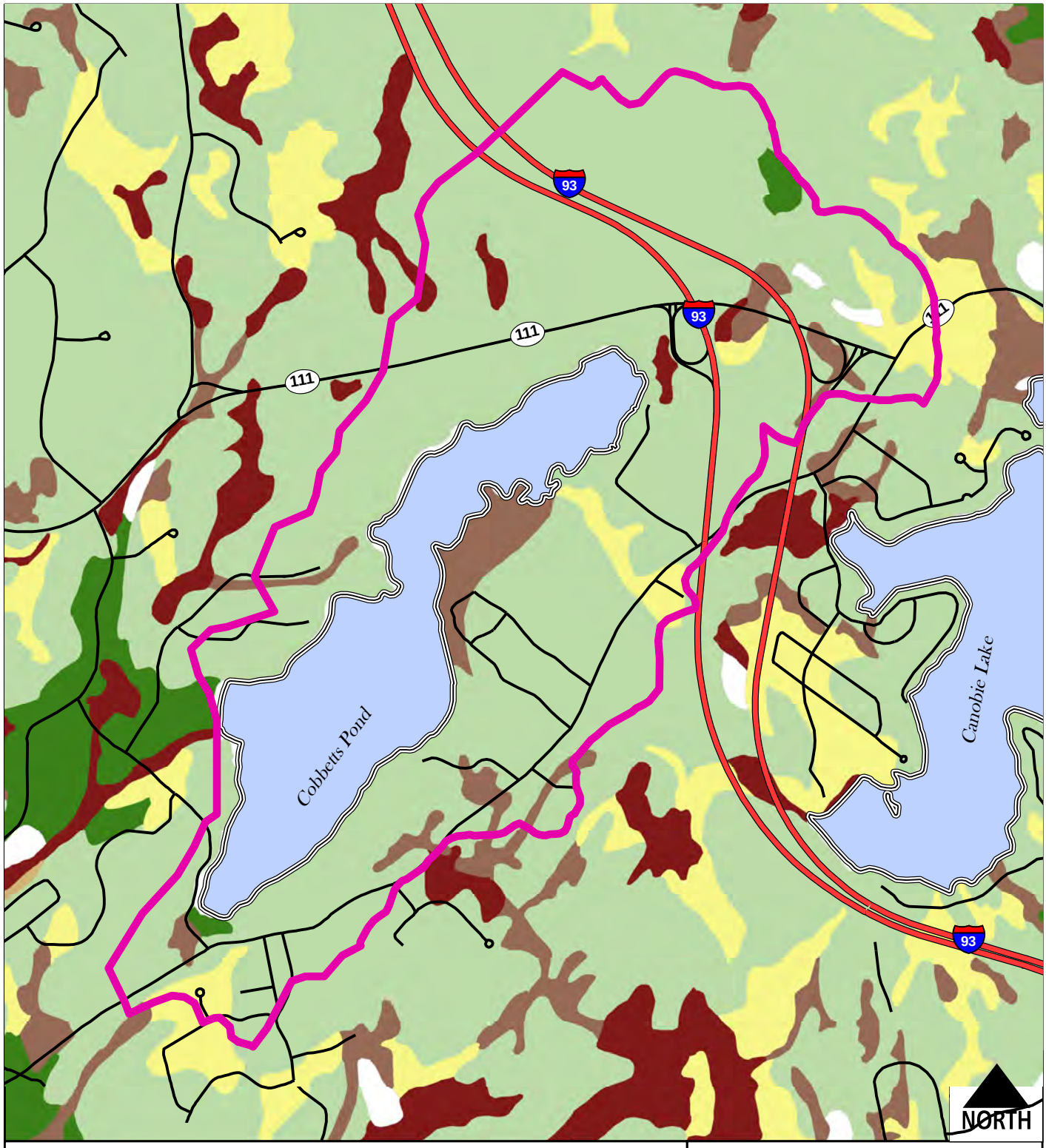
Geosyntec conducted a field investigation to identify and map all accessible storm drains and other surface water flow paths discharging to Cobbett's Pond (e.g. intermittent streams). Based on the field data collected, Geosyntec has created a series of maps which depict infrastructure locations (e.g. catch basins, culverts, pipe outfalls, etc.), pipe diameter, pipe type, etc. These drainage infrastructure maps are provided in Appendix C and will be provided to the CPIA and the Town of Windham in digital format to allow for future updating as structures are retrofit and new structures are installed.



Example section of the storm drainage map for Cobbett's Pond Road area at the southern tip of the lake, showing catch basins, drainage pipe connections and surface water flow paths.

4.2 Watershed Soils

The soils found within the vast majority of the Barrett Pond Watershed are well suited for bioretention cells, raingardens and other stormwater management techniques promoting infiltration. As shown on Figure 13 (USDA-NRCS Soil Survey Map), most of the watershed has soils that are classified as either "well drained" or "moderately well drained". This indicates that the native soils have a good capacity to infiltrate stormwater and that infiltrating stormwater practices can be expected to perform well without presenting unusual design challenges or cost implications in most areas.



Legend

- Cobbett's Pond Watershed
- Water Body
- Highway
- Major Road

NRCS Drainage Class

- Excessively
- Somewhat excessively
- Well
- Moderately well
- Somewhat poorly
- Poorly
- Very poorly
- Not rated
- Multiple classes

0 600 1,200 2,400 3,600 Feet

SOIL DRAINAGE CLASSES MAP

Cobbett's Pond
Windham, NH

Geosyntec consultants
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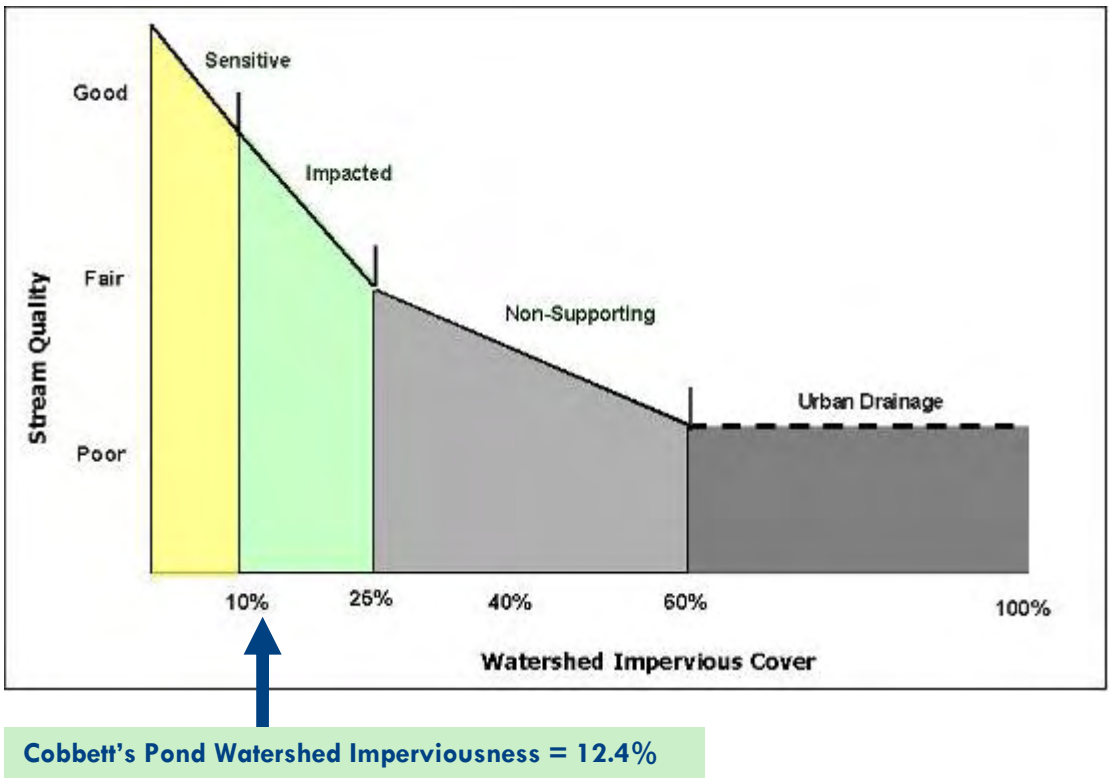
Acton, MA | 31-MAR-10 | FIG 13

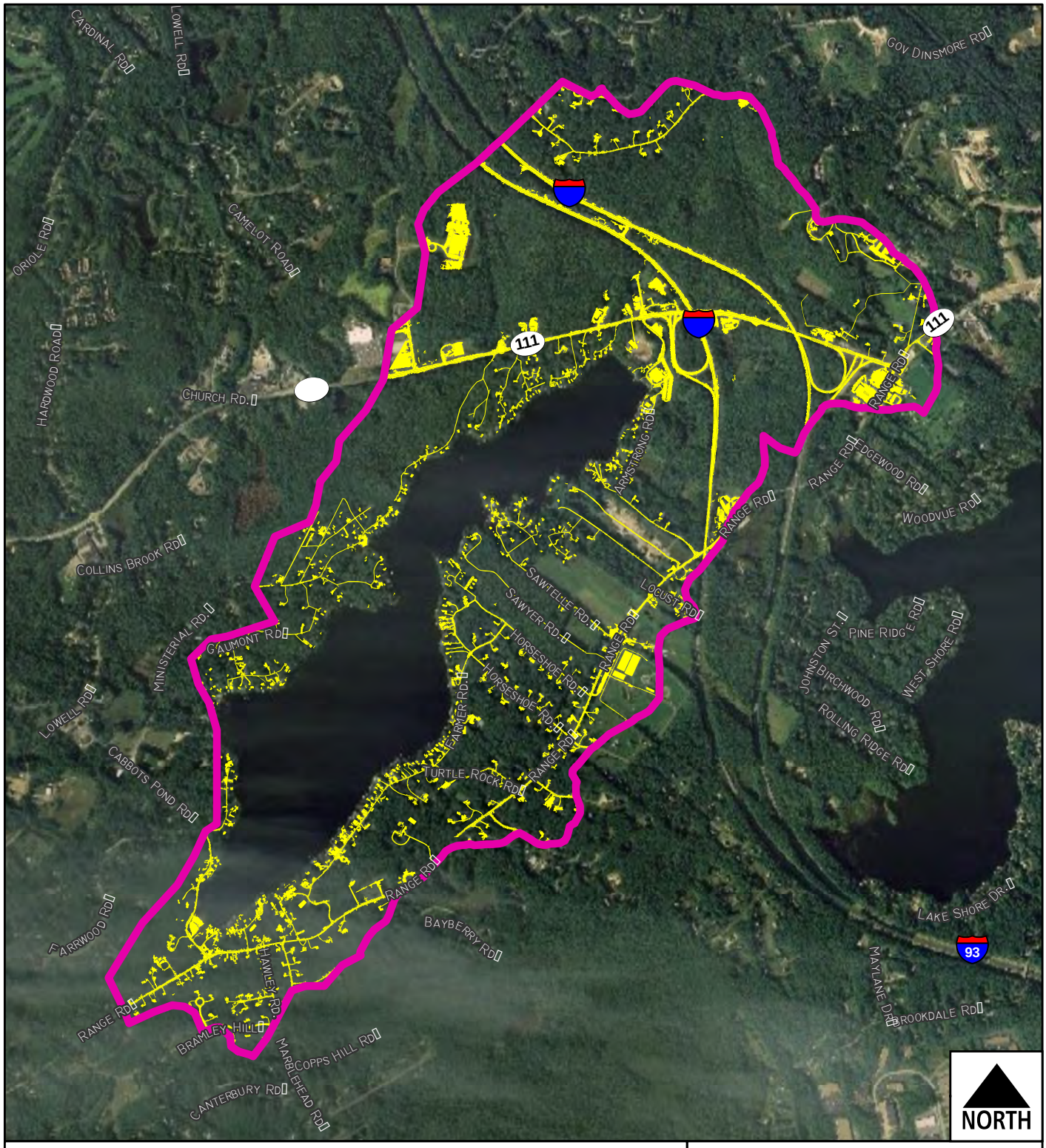
4.3 Watershed Imperviousness

Geosyntec mapped the impervious surfaces in the Cobbett Pond watershed based on an analysis of satellite imagery. Figure 15 shows that the impervious surfaces are estimated to comprise approximately 12.4% of the Cobbett's watershed. As shown below, the Impervious Cover Model developed by the Center for Watershed Protection predicts that at 10% impervious cover, streams begin to transition from the "sensitive" to "impacted" category with regard to stream quality indicators. As such, the Cobbett's Pond watershed appears to be at a critical juncture with regard to planning for future watershed development and related efforts to protect and restore the water quality of the Pond and its tributaries.

Geosyntec also assessed imperviousness at the subwatershed level as shown on Figure 16. Imperviousness of the subwatersheds ranged from a low of 8.0% (Subwatershed 6, Ministerial Road Area) to a high of 18.3% (Subwatershed 9, Fossa Road Area).

Figure 14. Impervious Cover Model, Center for Watershed Protection.





Legend

- Cobbett's Pond Watershed
- Impervious Surface

0 600 1,200 2,400 3,600 Feet

IMPERVIOUS SURFACES
WITHIN COBBETT'S POND WATERSHED

Cobbett's Pond
Windham, NH

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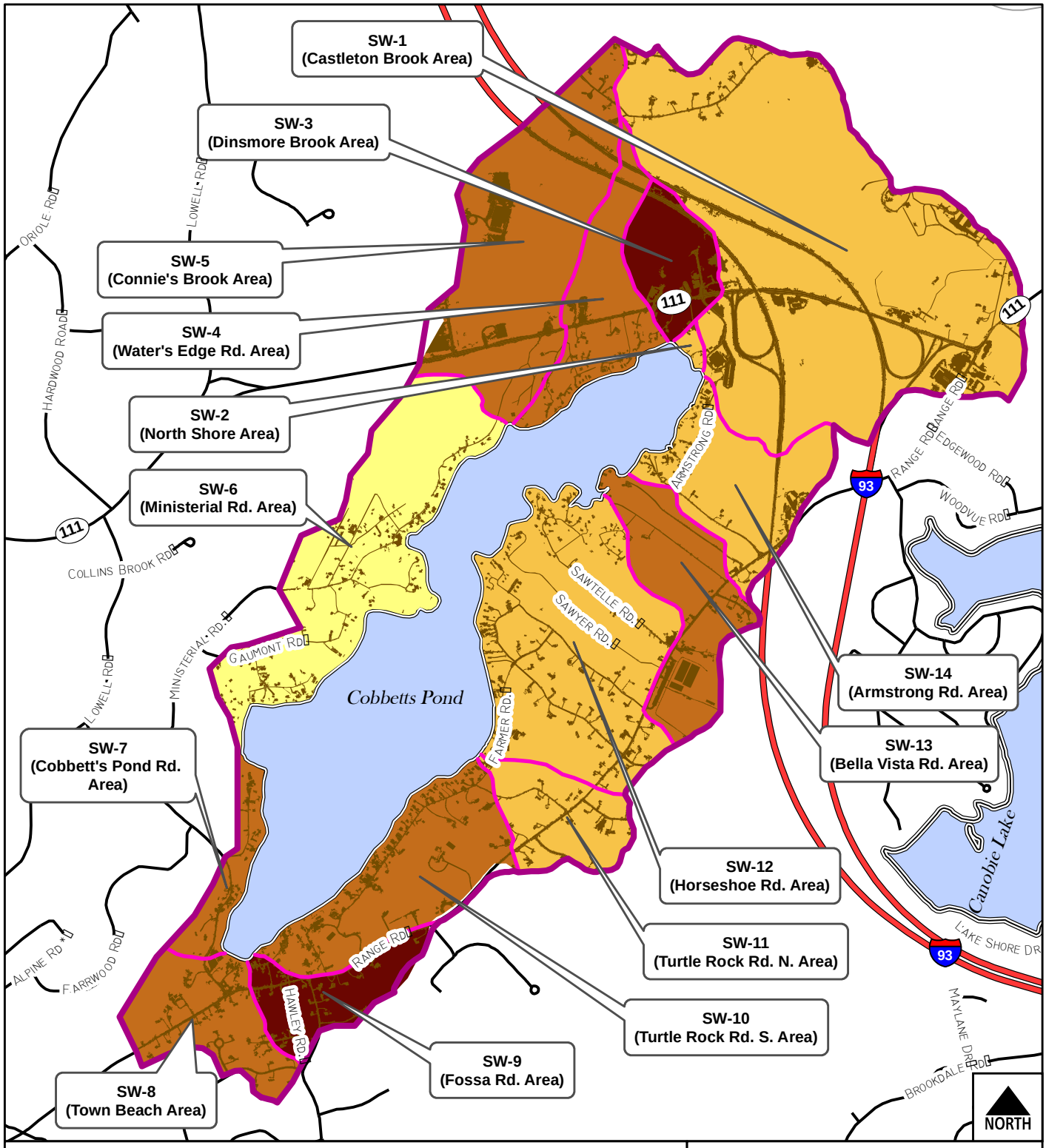
FIG

Acton, MA | 31-MAR-10 | 15



Legend

- Watershed Boundary
- Subwatershed Boundary
- Impervious Surface

Percent Impervious

<10 | 10-12.5 | 12.5-15 | >15

	SUBWATERSHED	% IMP
6	Ministerial Rd. Area	8.0
12	Horseshoe Rd. Area	11.1
1	Castleton Brook Area	12.0
2	North Shore Area	12.1
11	Turtle Rock Rd. N. Area	12.5
14	Armstrong Rd. Area	12.5
13	Bella Vista Rd. Area	12.7
4	Water s Edge Rd. Area	13.0
5	Connie s Brook Area	13.2
7	Cobbett's Pond Rd. Area	14.8
10	Turtle Rock Rd. S. Area	14.9
8	Town Beach Area	15.0
3	Dinsmore Brook Area	17.0
9	Fossa Rd. Area	18.3

0 500 1,000 2,000 3,000 Feet

COBBETT'S POND SUBWATERSHEDS IMPERVIOUS COVER

Cobbett's Pond
Windham, NH

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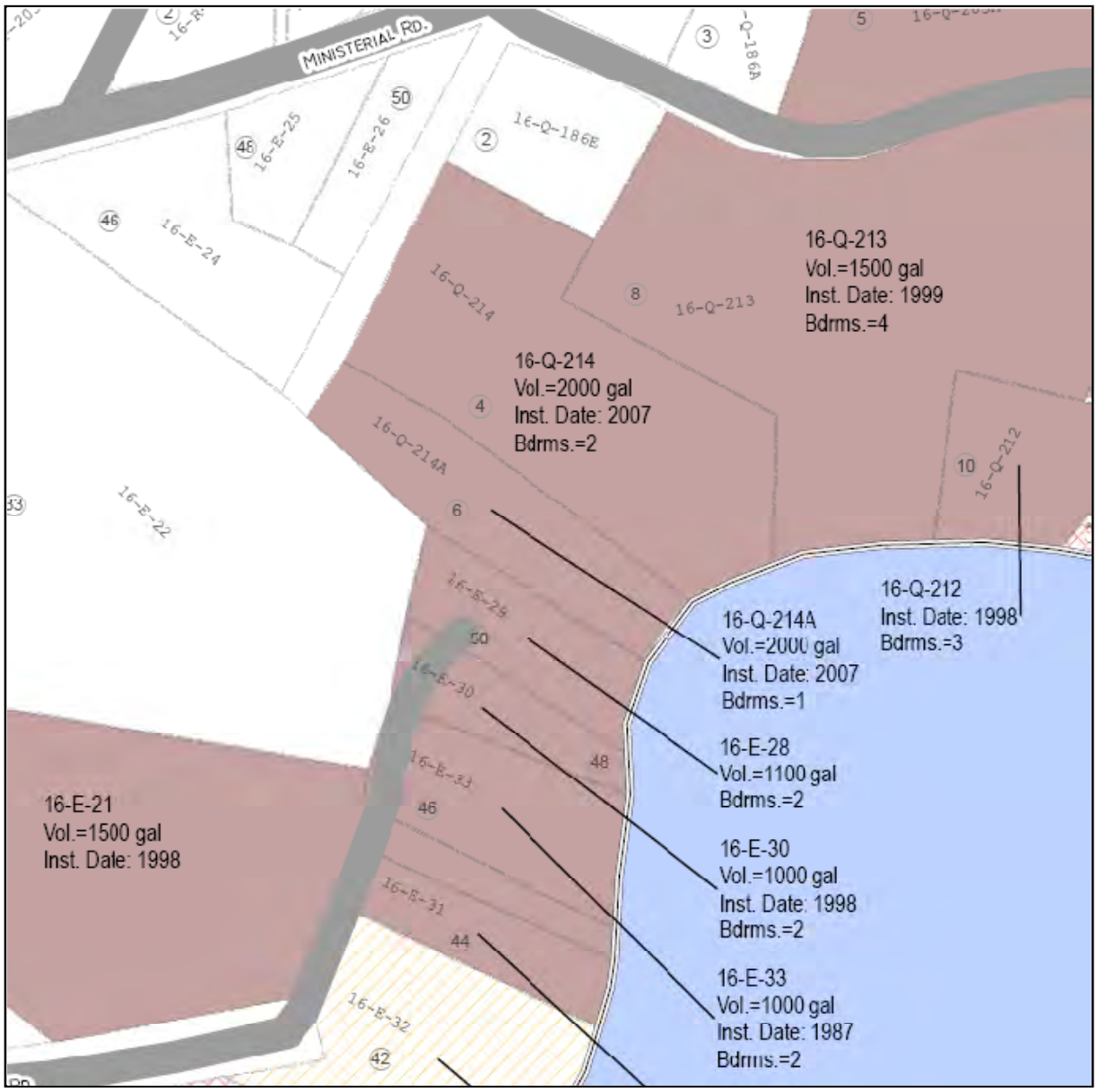
engineers | scientists | innovators

Acton, MA | 31-MAR-10

FIG 16

4.4 Septic System Investigation

Geosyntec conducted research on septic systems located around the perimeter of Cobbett's Pond to refine the data used to develop the Pond's phosphorus budget as presented in Section 4. Geosyntec collected all information available from the Windham Board of Health (BOH) on the location, age, capacity and type of septic system on properties bordering the lake perimeter. Once this data was collected, Geosyntec and the CPIA distributed a septic system information survey via email and hard copy mail to residences for which no BOH data was available. Upon compilation of all BOH data and survey responses, Geosyntec prepared a series of maps that present septic system available information for each parcel. These maps are provided as Appendix D.



Example section of the septic system map for the Ministerial Road/Gaumont Road area.

5. COBBETT'S POND PHOSPHORUS BUDGET

5.1 Land-Use Based Pollutant Modeling

Geosyntec conducted land-use based modeling to estimate annual phosphorus export from fourteen subwatersheds depicted on Figure 2. Land use data available at the New Hampshire GIS data clearinghouse (GRANIT) was used to represent the current Watershed's land-use condition. The land use data was primarily derived using the 1998 United States Geological Survey (USGS) 1:12,000-scale, black & white, Digital Orthophoto Quadrangles. Land-use pollutant export coefficients (represented in lbs/acre-yr) were derived from New Hampshire GIS data (GRANIT) information.

Table 3. Phosphorus Export Coefficients by NH GRANIT Land Use Category

Land Use Code	Land Use Category	Phosphorus Export Coefficient (lbs/ac-yr)
11	Residential Development	0.446
12	Industrial/Commercial Development	0.446
14	Paved Roads	0.446
17	Recreational	0.535
20	Agricultural	0.535
40	Forest	0.178
70	Open Land	0.446

Land use based exports are an average measure of pollutant export and are typically reported for specific land use categories. These data were used in a land-use based pollutant model to predict annual phosphorus loading from the Watershed. The area of each land cover type is shown below in Table 4. A table summarizing the results of the land-use loading model is provided in Table 5.

Table 4. Subwatershed Land Cover Areas (all values in acres)

Subwatershed	Residential	Commercial	Paved Road	Recreation	Agriculture	Forest	Open Land	Total
1: Castleton Brook Area	40.5	20.71	16.88	5.4	0.0	227.8	62.7	**374.0**
2: North Shore Area	2.5	0.0	0.1	0.0	0.0	0.0	0.0	**2.6**
3: Dinsmore Brook Area	2.6	7.6	1.8	0.0	0.0	22.6	4.3	**38.9**
4: Water's Edge Rd. Area	26.5	0.1	3.0	0.0	0.0	25.2	1.9	**56.7**
5: Connie's Brook Area	16.7	17.7	4.6	0.0	0.0	100.3	9.3	**148.6**
6: Ministerial Rd. Area	79.6	0.0	7.0	0.0	0.0	49.1	0.0	**135.7**
7: Cobbett's Pond Rd. Area	12.6	0.0	1.6	0.0	0.0	8.0	0.0	**22.1**
8: Town Beach Area	34.8	0.0	2.3	0.0	0.0	19.0	0.0	**56.1**
9: Fossa Rd. Area	21.6	0.0	1.8	0.0	0.0	5.4	0.0	**28.8**
10: Turtle Rock Rd. (South)	44.5	0.0	4.0	0.0	0.0	45.9	4.1	**98.6**
11: Turtle Rock Rd. (North)	14.4	0.0	1.3	0.0	0.0	29.0	0.2	**44.9**
12: Horseshoe Rd. Area	84.5	0.0	8.4	0.0	24.3	48.9	0.0	**166.0**
13: Bella Vista Rd. Area	17.4	0.0	3.2	0.0	33.1	17.0	0.0	**70.7**
14: Armstrong Rd. Area	16.7	2.7	2.8	0.0	6.1	38.8	4.6	**71.6**

Table 5. Subwatershed Pollutant Loading Summary

Subwatershed	Area (acres)	Estimated Annual Phosphorus Load (lb/yr)		% of Total Watershed Phosphorus Load
		Total	Per acre	
1: Castleton Brook Area	374.0	106.3	0.28	**25.7**
2: North Shore Area	2.6	1.1	0.42	**0.3**
3: Dinsmore Brook Area	38.9	10.6	0.27	**2.6**
4: Water's Edge Rd. Area	56.7	17.6	0.31	**4.3**
5: Connie's Brook Area	148.6	35.3	0.24	**8.5**
6: Ministerial Rd. Area	135.7	47.4	0.35	**11.4**
7: Cobbett's Pond Rd. Area	22.1	7.7	0.35	**1.9**
8: Town Beach Area	56.1	19.8	0.35	**4.8**
9: Fossa Rd. Area	28.8	11.5	0.40	**2.8**
10: Turtle Rock Rd. (South)	98.6	31.7	0.32	**7.6**
11: Turtle Rock Rd. (North)	44.9	12.3	0.27	**3.0**
12: Horseshoe Rd. Area	166.0	60.8	0.37	**14.7**
13: Bella Vista Rd. Area	70.7	30.0	0.42	**7.3**
14: Armstrong Rd. Area	71.6	21.6	0.30	**5.2**
Cobbett's Pond Watershed (total)	**1315.3**	416.0	**0.32**	**100%**

The land-use based phosphorus loading model provides a tool for estimating and comparing (1) total annual phosphorus loads (in pounds per year) and (2) annual pollutant load rates normalized to the watershed area (in pounds per acre per year) for each subwatershed. Land-use pollutant loading model estimates provide a useful comparative measure of the relative impact that each subwatershed has on lake water quality, and therefore can help in the prioritization of sites for watershed improvements. A brief summary of the land-use pollutant loading model results for each subwatershed is provided below:

Subwatershed 1 (Castleton Brook Area): Covering 374 acres to the northwest of the Pond, this is the largest subwatershed. This area is dominated by forested land (60.9%), open land (16.8%, including the Interstate 93 interchange), and residential land (10.8%). The estimated phosphorus load from this subwatershed is 0.28 lb P/ac/year, which accounts for 25.7% of the Pond's total predicted phosphorus load. Although this subwatershed contributes by far the largest phosphorus load to Cobbett's Pond, its loading rate is among the lowest of all subwatersheds.

Subwatershed 2 (North Shore Area): Subwatershed 2 is the smallest subwatershed (2.6 acres) and is located along the Pond's northern. Land use in this subwatershed is almost entirely residential (94.9%). As a result, this small subwatershed has the highest estimated phosphorus loading rate (0.42 lb P/ac/year), although this accounts for only 0.3% of the total predicted watershed load.

Subwatershed 3 (Dinsmore Brook Area): Subwatershed 3 includes 38.3 acres to the north of the Pond which drain to Dinsmore Brook. This subwatershed is primarily comprised of forest (58.1%) and commercial development (19.6%). The phosphorus loading rate from Subwatershed 3 is 0.27 lb P/ac/year, accounting for 2.6% of the total predicted phosphorus load.

Subwatershed 4 (Water's Edge Rd. Area): Subwatershed 4 covers 56.7 acres and drains the area between Dinsmore Brook (Subwatershed 3) and Connie's Brook (Subwatershed 5). Land cover is dominated by residential development along the shoreline (46.7%) and forest to the north of Route 111A (44.4%). The phosphorus loading rate from Subwatershed 4 is 0.31 lb P/ac/year and accounts for 4.3% of the total predicted phosphorus load.

Subwatershed 5 (Connie's Brook Area): Subwatershed 5 includes 148.6 acres draining to Connie's Brook. This subwatershed is predominantly forested (67.5%), with some commercial and residential development (12% each). The phosphorus loading rate of Subwatershed 5 is 0.24 lb P/ac/year, accounting for 8.5% of the Pond's total predicted phosphorus load.

Subwatershed 6 (Ministerial Rd. Area): This subwatershed includes a significant portion of the northwest shore of the Pond. It covers 135.7 acres between the Connie's Brook inlet and the Pond outlet. The subwatershed is dominated by residential development (58.7%) and forest (36.2%). The phosphorus loading rate of Subwatershed 6 is 0.35 lb P/ac/year, accounting for 11.4% of the Pond's total predicted phosphorus load.

Subwatershed 7 (Cobbett's Pond Rd. Area): Subwatershed 7 covers 22.1 acres between the Cobbett's Pond outlet and the Town Beach. The subwatershed is dominated by residential development (56.7%) along Cobbett's Pond Road and Horne Road. The phosphorus loading rate of Subwatershed 7 is 0.35 lb P/ac/year, accounting for 1.9% of the Pond's total predicted phosphorus load.

Subwatershed 8 (Town Beach Area): This subwatershed is located along the southwestern portion of the Cobbett's Pond watershed. It covers 56.1 acres and is dominated by residential development (62.0%) and forest (33.9%). The subwatershed drains through a wetland area north of Range Road onward to a culverted outlet at the Town Beach. The phosphorus loading rate of Subwatershed 8 is 0.35 lb P/ac/year, accounting for 4.8% of the Pond's total predicted phosphorus load.

Subwatershed 9 (Fossa Rd. Area): This subwatershed is located at the southern end of Cobbett's Pond, to the east of the Town Beach. The subwatershed is 28.8 acres and is 74.9% residential development. The watershed drains to the Fossa Road inlet. The phosphorus loading rate of Subwatershed 9 is 0.40 lb P/ac/year, accounting for 2.8% of the Pond's total predicted phosphorus load.

Subwatershed 10 (Turtle Rock Rd. South Area): This subwatershed is located along a long portion of the southern shore of Cobbett's Pond. It includes 98.6 acres between the Fossa Road inlet and a stream inlet running under Farmer Road. The subwatershed is dominated by residential development (45.2%) and forest (46.6%). The phosphorus loading rate of Subwatershed 10 is 0.32 lb P/ac/year, accounting for 7.6% of the Pond's total predicted phosphorus load.

Subwatershed 11 (Turtle Rock Rd. North Area): This subwatershed covers a 44.9 acre area around the northern portion of Turtle Rock Road. It drains to a stream that runs along Turtle Rock Road and under Farmer Road. The watershed is dominated by forest (64.6%) and residential development (32.0%). The phosphorus loading rate of Subwatershed 11 is 0.27 lb P/ac/year, accounting for 3.0% of the Pond's total predicted phosphorus load.

Subwatershed 12 (Horseshoe Rd. Area): This subwatershed covers a 166.0 acre area in the vicinity of Horseshoe Road and Sawtelle Road. The subwatershed is dominated by residential development (54.4%), with a mixture of forest (32.0%) and agriculture (7.9%). The phosphorus loading rate of Subwatershed 12 is 0.37 lb P/ac/year, accounting for 14.7% of the Pond's total predicted phosphorus load.

Subwatershed 13 (Bella Vista Rd. Area): Subwatershed 13 drains portions of Griffin Park, Range Road, and the Bella Vista Road area (including a new residential development between Armstrong Road and Bella Vista Road). Drainage is collected in a stream that runs along Bella Vista Road to a wetland area and onward to the Pond. The subwatershed is covered by a mixture of forest (24.1%), residential development (21.9%), recreational area (18.3%), and agriculture (31.2%). The phosphorus loading rate of Subwatershed 13 is 0.42 lb P/ac/year, accounting for 7.3% of the Pond's total predicted phosphorus load.

Subwatershed 14 (Armstrong Rd. Area): This watershed covers 71.6 acres between the Bella Vista Road stream inlet and the Castleton Brook inlet. A stream running under Armstrong Road is a significant path of drainage in the subwatershed. The subwatershed is dominated by forest (54.1%), with a mixture of residential (31.8%), open space (6.3%), and commercial development (3.8%). The phosphorus loading rate of Subwatershed 14 is 0.30 lb P/ac/year, accounting for 5.2% of the Pond's total predicted phosphorus load.

5.2 Phosphorus Loading From Septic Systems

Geosyntec conducted an assessment to estimate phosphorus loads from on-site sanitary systems located around the perimeter of Cobbett's Pond. On-site sanitary systems considered in the analysis included septic tanks with leaching fields, septic tanks with chambers, cesspools, holding tanks, chemical toilets, etc. As described in Section 4.4, Geosyntec developed a septic system inventory using information obtained through the Windham Board of Health records and a septic system questionnaire given to waterfront homeowners. This investigation included 293 parcels surrounding the Pond, of which 263 were occupied with a home. 231 of the homes either had a confirmed septic system on site or were assumed to have a septic system on site (when no information was available from Board of Health records or surveys). Homes that were serviced by holding tanks were assumed to contribute no phosphorus load to the pond.

As estimated by Derek Monson of the CPIA, 172 homes are occupied year-round and 91 are occupied seasonally. For this study, seasonal occupancy was assumed to be 3 months per year, resulting in an average occupancy of 9 months per year for all 263 homes.

The estimated phosphorus load to the Lake from on-site sanitary systems was 138 lbs P/yr, as calculated using the following equation:

$$M=(ES)(\#\ \text{Capita Years})(1-SR)$$

Where:

M is the predicted phosphorus loading;

ES is the phosphorus export coefficient of 1.1 lbs P/capita-year;

Capita Years is the product of the number of parcels with septic systems (231 parcels) multiplied by the average number of residents per parcel (2.9 residents/parcel for Windham, NH) and the average occupancy (9 of 12 months or 0.75); SR is the soil retention coefficient (0.75). ES was determined based on literature published by the US Geological Survey and the University of Delaware extension program.

The estimated total phosphorus load from septic systems (138 lb/year) represents 22% of the total annual estimated phosphorus load to the Lake.

5.3 Internal Phosphorus Loading

Internal recycling of phosphorus can be a significant source of overall phosphorus load to a pond. Lake sediments contain phosphorus that is bound to the sediment particles. During periods of anoxia (oxygen depletion), phosphorus can be released into the water from the sediment in soluble form, making it biologically available to fuel increased algal productivity.

As shown in Figure 8 (page 19), the north and south basins exhibited strikingly different patterns of internal phosphorus loading during the summer of 2009. Phosphorus concentrations at the North Deep Spot hypolimnion became dramatically elevated during the period of late summer anoxia, indicating the presence of phosphorus-rich sediments in that basin and a relatively high rate of

phosphorus release. By comparison, the increase in hypolimnetic P levels at the South Deep Spot was relatively modest.

Geosyntec estimated phosphorus release rates for the two basins by assuming that the hypolimnion did not exchange significant amounts of phosphorus with the epilimnion during summer stratification. The difference in hypolimnion phosphorus concentration between the beginning of the sampling season (May 21, 2009) and the time of the highest observed hypolimnion concentrations (September 17, 2009) was multiplied by a control volume (4 m^3, i.e. a 4 m deep hypolimnion over a 1 m^2 section of sediment) to obtain an estimated phosphorus release rate in $g/m^2/yr$. The estimated release rate was 0.44 $g/m^2/yr$ for the north basin and 0.06 $g/m^2/yr$ for the southern basin. Because shallower sediments were assumed to have lower release rates than the deepest sediments, the P release rates were varied linearly with depth, from a maximum value at deep spot locations to 0 $g/m^2/yr$ for sediments near the surface.

For this study, Geosyntec only measured dissolved oxygen at two deep spot locations within the lake. As such, the extent to which the pond's sediments are exposed to anoxia could not be accurately defined. Geosyntec calculated an internal load for scenarios where differing areas of sediment contribute to the internal phosphorus release. Figure 17 below shows the internal load in each basin for varying depths below which sediment P is released. As a low estimate, assuming that sediments at depths greater than 40 feet release phosphorus under anoxic conditions, approximately 24 lbs P/yr could be released. At the other extreme, assuming that all sediments at depths greater than 10 feet release phosphorus under anoxic conditions, approximately 120 lbs P/yr could be released. The actual annual internal load is most likely somewhere between these two estimates, possibly in the range of 60 to 80 lbs P/yr. A more refined estimate could be determined through additional future sampling and monitoring, including mapping the spatial extent and duration of anoxia during the stratified months.

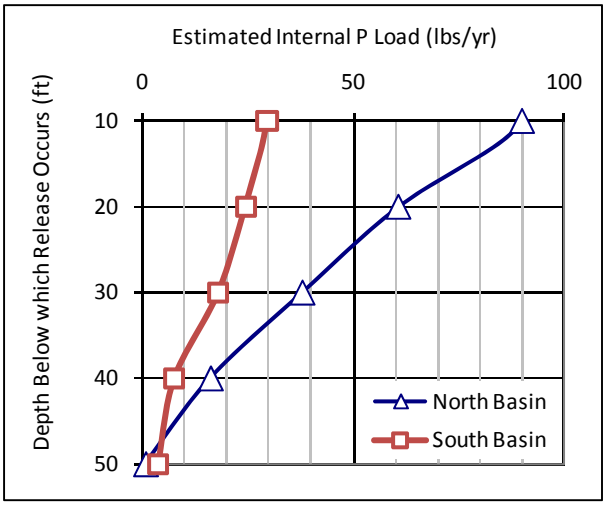


Figure 17. Estimated Internal Phosphorus Load from the Cobbett's Pond North and South Basins

5.4 Atmospheric Deposition

Atmospheric deposition of phosphorus is an estimate of the load of phosphorus delivered through wet or "dryfall" precipitation depositing phosphorus-containing particles directly on the lake surface. The annual atmospheric deposition load was calculated assuming a deposition rate of 0.185 lb P/ac/yr, for a total atmospheric load of 56 lb P/yr.

5.5 Estimated Annual Phosphorus Loading Budget

To estimate the annual external phosphorus loading budget for Cobbett's Pond, Geosyntec has combined the phosphorus load from septic systems and atmospheric sources with the watershed loading estimates derived from the land use pollutant loading model presented in Section 3.1 of this report.

The estimated annual external phosphorus budget of 630 lb/year is summarized below and presented in Figure 18. The estimated loads from this phosphorus budget are used in the Vollenwieder equation which predicts in-lake phosphorus concentrations in Section ____.

- The phosphorus load resulting from runoff from the varying land uses in the 14 subwatersheds of Cobbett's Pond accounts for 65% (406 lb) of the annual external phosphorus load to the lake.
- Phosphorus entering the lake through tributary baseflow accounts for approximately 5% (30 lb) of the total phosphorus load to the lake.
- Phosphorus loading from septic systems is estimated to account for 22% of the annual external phosphorus load. Geosyntec has estimated an annual load from septic systems of 138 lb P/year.
- Atmospheric deposition, including wet and dry deposition, is estimated to account for 9% of the annual external phosphorus load (56 lb P/year).

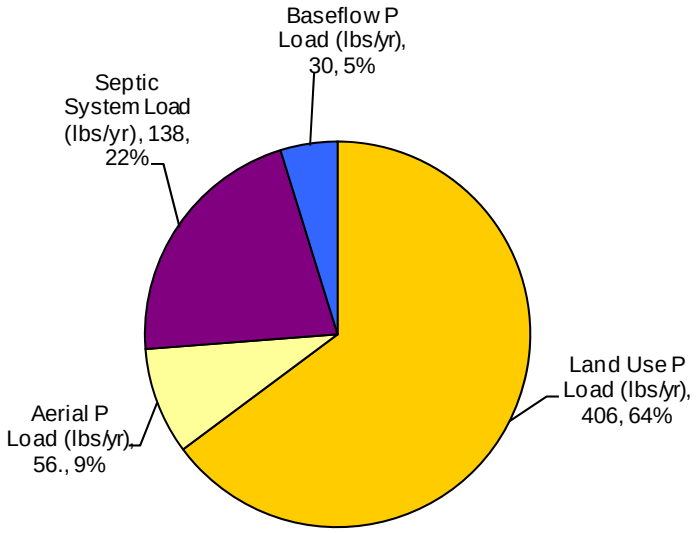


Figure 18. External Sources of Phosphorus to Cobbett's Pond.

5.6 Vollenweider Equation Results

The Vollenweider model is commonly used to predict in-lake phosphorus concentrations as a function of annual phosphorus loading, mean lake depth and hydraulic residence time. The Vollenweider model is based on a five-year study of about 200 waterbodies in Europe, North America, Japan and Australia.

The Vollenweider Equation is provided below, with calculations for Cobbett's Pond based on the phosphorus loading estimate discussed above, including phosphorus from stormwater runoff, septic systems, baseflow loading, and aerial deposition. For this calculation, Geosyntec estimates annual phosphorus loading to Cobbett's Pond to be 630 lb P/yr.

Vollenweider Equation:

$$P = \frac{L_p}{\left(q_s\left(1+\sqrt{\tau_w}\right)\right)}$$

where:

P = mean in-lake phosphorus concentration (mg/L);

L_p = annual phosphorus load/lake area, (grams/m2/year);

τ_w = hydraulic residence time (yr);

q_s = hydraulic overflow rate=mean depth /hydraulic residence time (m/yr)= z/ τ_w;

z = average depth (m)

Hydraulic residence time reflects the results of a water budget that Geosyntec calculated for Cobbeett's Pond Watershed.

$$\tau_w = Q/V$$

where:

Q = annual discharge passing through the pond (m^3/yr);

V = pond volume (m^3)

Annual discharge, Q, was taken from previous NHDES Lake Trophic Data reports. Volume, V, was estimated based on bathymetry maps of Cobbett's Pond. Table 9 below summarizes the parameters used in the Vollenweider calculation.

The Vollenweider equation contains an implicit assumption that particulate phosphorus becomes sequestered in lake sediment via settling to the pond bottom. The formula makes the assumption that settling velocity can be approximated as:

$$v = q_s\sqrt{\tau_w}$$

Typical measured values of settling velocity range from 5 to 20 m/yr (Chapra 1975). For Cobbett's Pond (q_s=2.35 m/yr, τ_w=2.12 yr),

$$v = q_s\sqrt{\tau_w} = 2.35\,\frac{m}{yr} \times \sqrt{2.12\ yr} = 3.42\ m/yr$$

or 3.42 m/yr (lower than the typical range). Using a low settling velocity value could lead to an erroneously high modeled in-lake P concentration. To provide a better representation of conditions specific to Cobbett's Pond, a settling velocity coefficient was included in the equation as described below.

Brett & Benjamin (2008) state, "…both the particulate phosphorus fraction and the particulate settling velocity distribution vary greatly during the course of the year in most lakes and especially between lakes, and… as a result, v is likely to have different values in different lakes, and during different seasons in a single lake, thereby reducing the predictive value of the equation." They statistically analyzed several variations of the Vollenweider model, including the version above and another version that assumed

$$v = q_s \cdot k\sqrt{\tau_w}$$

They found that the addition of a settling velocity coefficient as in the above formula yielded a better statistical fit to existing data for over 300 lakes. A similar approach has been used below to calibrate the Vollenweider equation to match the observed average in-lake P concentration (15 µg/L) for Cobbett's Pond.

Table 6: Vollenweider model parameters

VOLLENWEIDER MODEL PARAMETERS			
W	Total P Loading Rate	286	kg/yr
V	Volume	6,145,750	m3
z	Average Depth	5.1	m
Q	Annual Discharge	2,883,200	m3/yr
As	Lake Area	1,222,150	m2
L	Areal Loading Rate	234	mg/m2
q_s	Hydraulic Overflow Rate (m/yr)	2.35	m/yr
τ_w	Hydraulic Residence Time (yr)	2.12	yr
k	Settling Velocity Coefficient	3.7	

$$\text{In-lake P concentration} = \frac{L_p}{\left(q_s\left(1+\sqrt{\tau_w}\right)\right)} = \frac{234}{2.35\left(1+3.7\sqrt{2.12}\right)} = 15.6\ \mu\text{g/L}$$

Based on the estimated annual phosphorus load of 630 lb/yr, the Vollenweider equation predicts an in-lake phosphorus concentration of 15.6 µg/L.

Because of the particular bathymetry of Cobbett's Pond and the differences in water quality between the North and South basins, Geosyntec also modeled the pond as a two-basin system. The annual discharge for the north basin was estimated as approximately 70% of the annual discharge of the whole pond, based on 70% of the watershed draining to that basin. Annual discharge for the South Basin was assumed to be equal to that of the entire pond, given that the North Basin discharges to it. Phosphorus loads were divided according to the basin to which they

contributed. For example, if a home was on the shore of the South Basin, its septic load was allocated to the South Basin. The South Basin also receives an additional annual load of phosphorus from water flowing from the North Basin. This additional phosphorus load was calculated by multiplying the annual discharge from the North Basin by the average epilimnetic phosphorus concentration. The phosphorus loads for each basin are shown in Figure 19, and the Vollenweider Model Parameters for each basin are summarized in Table 7.

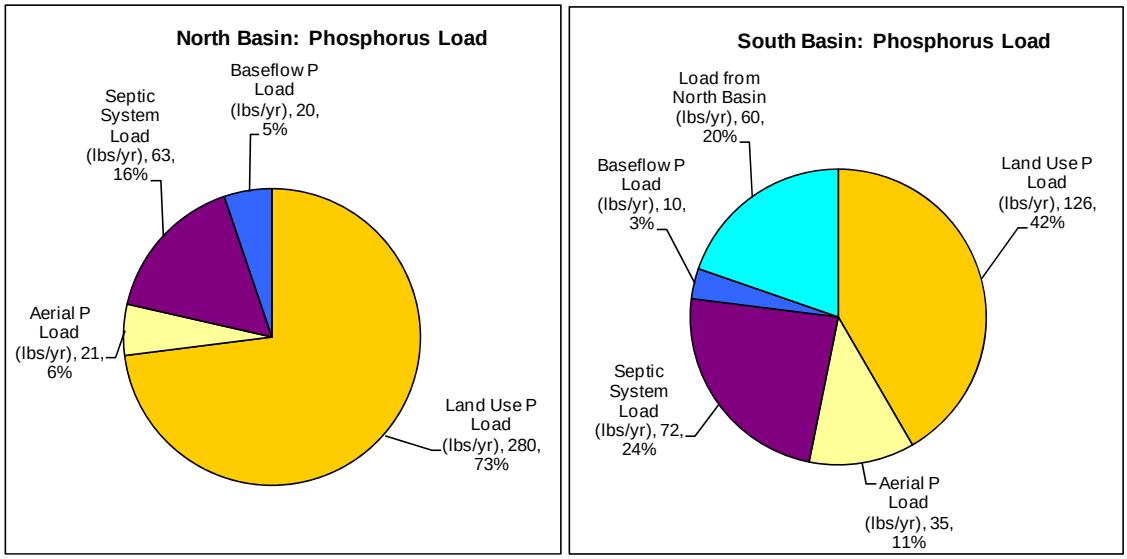


Figure 19. External phosphorus sources to the North and South Basin.

Table 7: Basin-specific Vollenweider model parameters

VOLLENWEIDER MODEL PARAMETERS (NORTH AND SOUTH BASINS)					
		NORTH BASIN		SOUTH BASIN	
W	Total P Loading Rate	174	kg/yr	137	kg/yr
V	Volume	2,073,450	m3	4,072,290	m3
z	Average Depth	4.5	m	5.4	m
Q	Annual Discharge	2,075,900	m3/yr	2,883,200	m3/yr
As	Lake Area	465,390	m2	765,760	m2
L	Areal Loading Rate	374	mg/m2	179	mg/m2
q_s	Hydraulic Overflow Rate (m/yr)	4.46	m/yr	3.76	m/yr
τ_w	Hydraulic Residence Time (yr)	0.99	yr	1.41	yr
k	Settling Velocity Coefficient	4.5		1.7	

When the loads and model parameters for the basins are separated, there are noticeable differences in each basin's phosphorus cycling behavior. Settling velocity coefficients were adjusted in order to calibrate the Vollenweider equation to achieve a phosphorus concentration of 15.6 ug/L in each basin. The North Basin had a coefficient of 4.5, which led to an estimated settling velocity of:

$$v = q_s \cdot k\sqrt{\tau_w} = 4.46 \cdot 4.5\sqrt{0.99} = 20\ m/yr$$

which is at the high end of the typical range of settling velocities provided in Chapra (1975). Given that settling velocity represents physical removal of particulate-bound phosphorus from the water column, and that 73% of the North Basin's Phosphorus load is from stormwater runoff, which is likely to contain particulate phosphorus, it is likely that the removal rate through settling in the North Basin is actually in the upper range of typical values. On the other hand, the South Basin's phosphorus load is comprised of sources that are likely contain mostly dissolved phosphorus, such as the septic system load and the load of phosphorus flowing in from the North Basin. As such, the South Basin has been estimated to have a significantly lower settling velocity coefficient of 1.6 and an estimated settling velocity of:

$$v = q_s \cdot k\sqrt{\tau_w} = 3.76 \cdot 1.7\sqrt{1.41} = 7.6\ m/yr$$

Understanding the difference in phosphorus settling in these two basins also helps to explain the differences in observed hypolimnetic phosphorus concentrations discussed in Section 3.1.2. The particulate sources of phosphorus to the north basin and its high phosphorus settling rate indicate that this basin has a high potential for significant phosphorus accumulation in sediments and therefore a high potential for release of sediment-bound phosphorus during periods of hypolimnetic anoxia. As discussed above, the peak 2009 summer hypolimnetic phosphorus concentrations indicate a strong pulse of phosphorus released from the sediment in the North Basin. In the South Basin, less phosphorus is removed from the system via settling, and the relatively lower phosphorus concentrations in the South Basin hypolimnion support the model results.

5.7 Recommended Phosphorus Reduction Goal

To improve water quality conditions in Cobbett's Pond and reduce the occurrence of nuisance algal blooms, Geosyntec recommends targeting an in-pond total phosphorus concentration reduction of 3.6 µg/L, which would reduce the current predicted concentration from 15.6 µg/L to 12 µg/L. This phosphorus concentration reduction would improve Cobbett's Pond to the median phosphorus concentration for similar New Hampshire lakes. This reduction is expected to improve in-lake conditions with regard to water quality indicators such as water clarity and algal abundance.

As shown in Figure 8, the Vollenweider equation predicts that the lake's phosphorus load must be reduced by 145 lb P/yr in order to achieve the recommended target in-lake phosphorus concentration of 12 µg/L. The recommended P load reduction represents approximately 20% of the estimated annual phosphorus load for the pond. Section 5 provides a discussion of how the recommended phosphorus load reduction may be achieved.

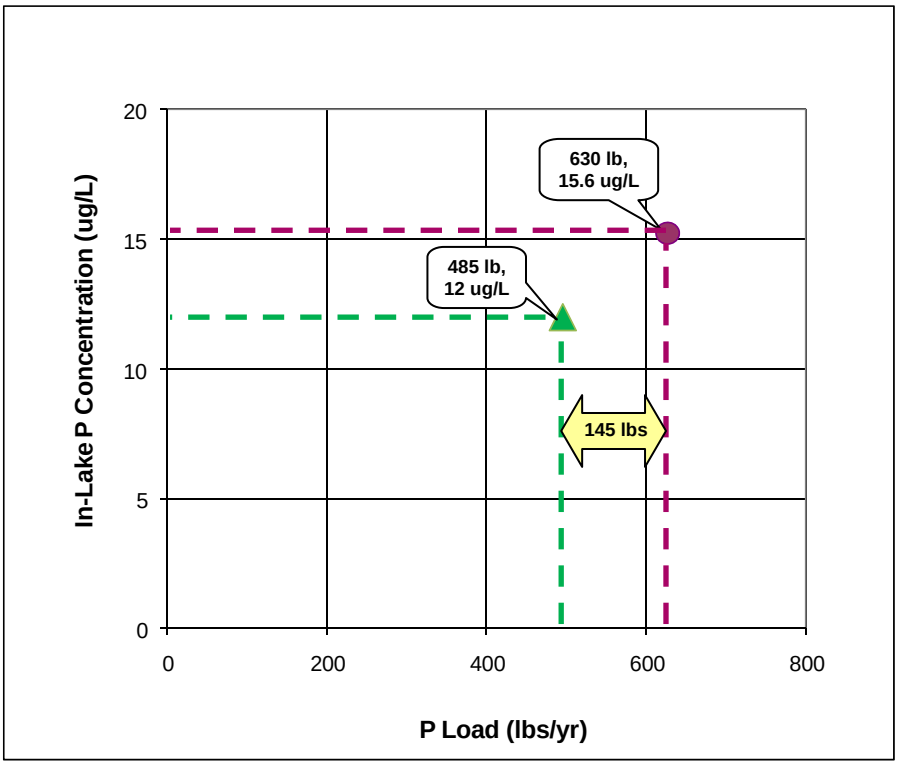


Figure 20. Vollenweider Plot for Cobbett's Pond

Based on the modeled annual phosphorus load estimate of 630 lb P/yr, the Vollenweider equation predicts that an annual load reduction of 145 lb P/yr would be required to achieve a target in-pond P concentration of 12 ug/L. Each reduction of 40 lb in annual P load is predicted to lower the in-pond P concentration by 1 ug/L.

6. OPTIONS FOR REDUCING PHOSPHORUS LOADING TO COBBETT'S POND

This section presents a discussion of potential measures that could be implemented in the Cobbett's Pond watershed to reduce phosphorus loading. This section provides a discussion of potential phosphorus reduction measures that relate to storm water management, septic systems, and watershed land uses. Table 9 (pg. 81) provides an overview and prioritization of all proposed measures that are presented in this Section.

6.1 Storm Water Management

6.1.1 Field Watershed Investigation

Robert Hartzel (Senior Water Resources Scientist, Certified Lake Manager) and Daniel Bourdeau, P.E. (Water Resource Engineer) of Geosyntec conducted a field watershed investigation on May 19-20, 2009 to identify potential storm water improvement sites and other opportunities to reduce phosphorus loading to Cobbett's Pond. Mr. Hartzel and Mr. Bourdeau are both Certified Professionals in Sediment and Erosion Control (CPESC). A CPESC is a recognized specialist in soil erosion and sediment control, with certification by the Soil and Water Conservation Society and the International Erosion Control Association.

The following pages provide descriptions of the sites identified during the field investigation and recommended improvements. It is important to note that the sites discussed in this section are not intended to be a comprehensive listing of all possible stormwater improvements in the Cobbett's Pond watershed. Rather, these sites are representative examples of potential stormwater improvements and retrofits that could be implemented at numerous sites throughout the watershed.

SITE 1: Castleton Center Parking Area

Site Summary:

The asphalt parking lot of the Castleton Banquet and Conference Center drains primarily to a catch basin located at its southern end (photo 1-1), which discharges via a culvert to Castleton Brook.

Proposed Improvement:

Several areas within the parking lot could be retrofit as bioretention areas to promote infiltration and reduce discharge of pollutants to Cobbett's Pond via surface water runoff. A schematic of a typical bioretention cell is provided as Figure 21. Proposed improvement areas include:

- Two grassed islands shown in photos 1-2 and 1-3. Renderings of bioretention cells in these areas are provided on the following page.
- The area in the immediate vicinity of the catch basin (photo 1-1) could also be retrofit as a bioretention cell with an overflow pipe to prevent flooding in the parking lot.

Estimated Cost: $27,900 - $34,100

Estimated Pollutant Load Reduction:

0.39 - 0.43 lbs P/yr

Photo 1-1

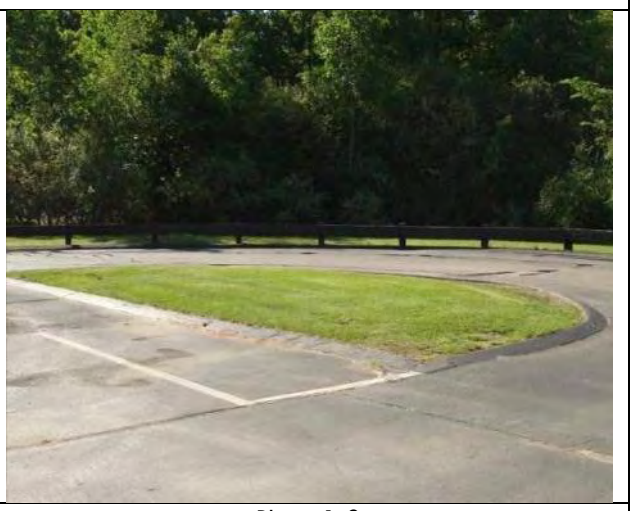


Photo 1-2

Photo 1-3

SITE 1: Castleton Center Parking Area *(continued)*

Renderings of proposed bioretention cells areas shown in photos 1-2 and 1-3 on the preceding page. The blue arrows indicate curb cut areas allowing storm water runoff to flow into the bioretention cell.

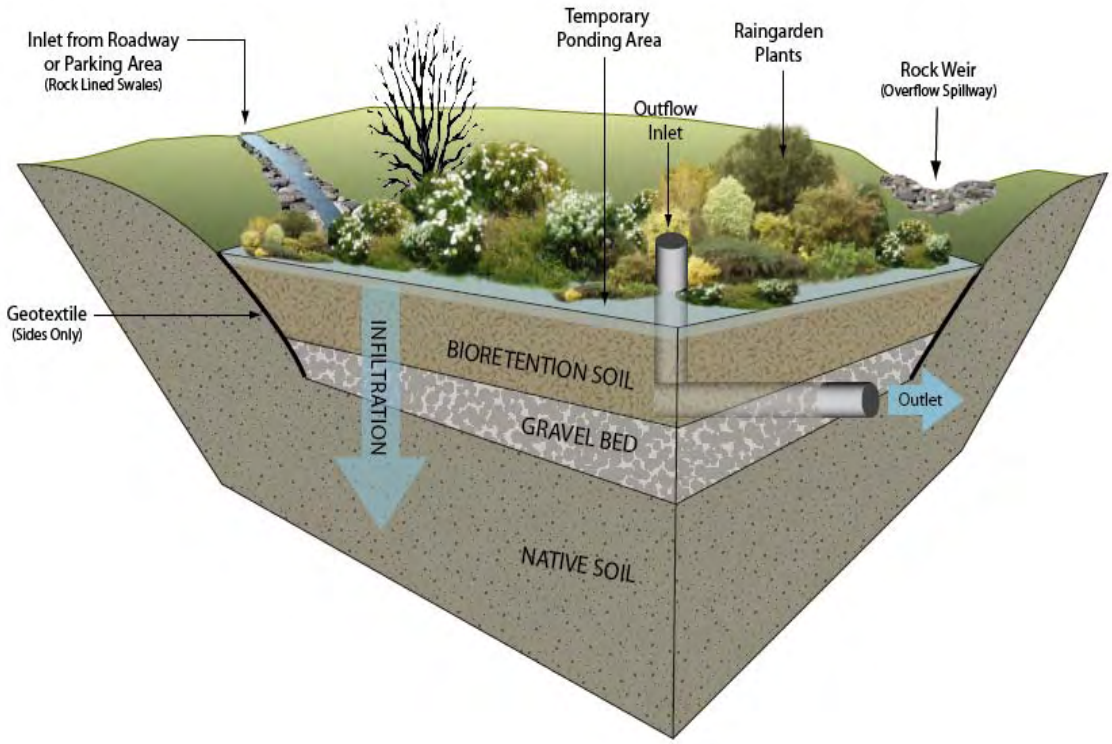


Figure 21. Cross-section of a typical bioretention cell with a riser pipe and outlet connection.

BIORETENTION CELLS are shallow landscaped depressions that incorporate plantings and an engineered soil mixture with a high infiltration rate. Bioretention cells are used to (1) control storm water runoff volume by providing storage capacity, (2) reduce peak discharge by increasing the travel time of storm water through a watershed, and (3) remove pollutants through physical, chemical and biological processes that occur in the plants and soil media.

Storm water that drains into a bioretention cell ponds temporarily and infiltrates the engineered soil mixture. Bioretention cells are typically designed to provide an infiltration rate approximately equal to the peak discharge rate for the 10-year, 24-hour storm event. Infiltration rates are enhanced during by uptake from vegetation within the cell.

Installed costs for engineering, materials and construction of a typical bioretention cell generally range from $3,000 up to $30,000 (for a large retrofit cell requiring significant earthwork). Pre-fabricated "planter box" bioretention cells (e.g., Filterra™) can treat storm water runoff from an area up to 0.25-acres and cost approximately $7,000 each (installed cost).

RAIN GARDENS are small-scale bioretention cells, constructed as shallow vegetated depressions designed to capture and infiltrate storm water runoff. Rain gardens are often appropriate for residential properties, to treat runoff from roofs driveways and lawns. The total installed cost of a typical rain garden is approximately $1,500 to $3,000, depending on garden size, soil conditions, type of plantings used, and other site conditions.

SITE 2: 6-8 Armstrong Road

Site Summary:

Erosion is occurring at a culvert that conveys runoff to the west under Armstrong Road (photo 2-1). Areas upgradient of the culvert (photo 2-2) to the north and south are also eroding and require stabilization.

Proposed Improvement:

- Stabilize culvert inlet with geotextile and rip-rap;
- Install water quality swale for approximately 30 feet to the north and south of the culvert.

Estimated Cost: $2,200 - $2,700

Estimated Pollutant Load Reduction:

0.34 - 0.38 lbs P/yr

Photo 2-1

Photo 2-2

SITE 3: Sawtelle Road

Site Summary:

Two catch basins on Sawtelle Road appear to be in disrepair. These catch basins were observed surcharging to the road during dry weather at the time of Geosyntec's site visit (photos 3-1 and 3-2).

Proposed Improvement:

- Retrofit existing catch basins with new deep sump catch basins;
- A stone wall exists on the side of the road opposite from the catch basins, allowing insufficient space for a swale between the wall and road. Pending review of property ownership and related easements, it may be possible to divert flows from the proposed deep sump catch basins to a vegetated water quality swale in the field on beyond the stone wall (photo 3-3).

Estimated Cost: $10,300 - $12,600

Estimated Pollutant Load Reduction:

0.18 – 0.22 lbs P/yr

Photo 3-1

Photo 3-2

Photo 3-3

SITE 4: Griffin Park

Site Summary:

Stormwater runoff from the Griffin Park parking lot flows via an existing grassed swale (photos 4-1 and 4-2) to a catch basin (photo 4-3) at the eastern edge of Range Road (Rt. 111A), just beyond the northwestern corner of the park.

Proposed Improvements:

A broad grassy area exists adjacent to the swale at its northernmost segment (photo 4-2). This area could easily be converted to a large bioretention area, promoting on-site infiltration and reducing the volume of stormwater discharging off-site to the storm drainage system at Rt. 111A. Proposed improvements include:

- Install 2,500 square foot bioretention cell;
- Install outlet structure; and
- Connect outlet structure to Rt. 111A catch basin
- A schematic overview of the proposed improvement locations is provided on the following page.

Estimated Cost: $34,500 - $42,200

Estimated Pollutant Load Reduction:

0.85 – 1.04 lbs P/yr

Photo 4-1

Photo 4-2

Photo 4-3

SITE 4: Griffin Park *(continued)*

Schematic of proposed Griffin Park bioretention cell area.

SITE 5a: Farmer Road

Site Summary:

Farmer Road intersects Horseshoe Road at two locations. Storm water in this area is collected by catch basins (photos 5-1 and 5-3) and grassed swales (photo 5-2). Geosyntec observed significant sediment accumulation around the catch basins at both Farmer Road/Horseshoe Road intersections

Proposed Improvement:

- Retrofit catch basins to bioretention cells with underdrains;
- Improve existing swale by re-grading to provide wider bottom width and install gravel subbase to promote infiltration and provide storage.

Estimated Cost: $22,000 - $26,900

Estimated Pollutant Load Reduction:

0.21 – 0.25 lbs P/yr

Photo 5-1

Photo 5-2

Photo 5-3

SITE 5a: Farmer Road *(continued)*

Rendering of bioretention cell (bottom photo) with riser pipe and adjacent grass filter strip proposed for the area shown in photo 5-3 (top photo).

SITE 5b: Farmer Road /Horseshoe Road

Site Summary: The catch basin shown in photo 5-4 is located on the northern side of Horseshoe Road, near the southern intersection with Farmer Road.

Proposed Improvement:

Install an approximate 60-foot long by 6-foot wide (360 s.f.) bioretention cell upgradient of the catch basin on the northern side of Horseshoe Road.

Estimated Cost: $4,600 – $5,700

Estimated Pollutant Load Reduction: 0.14 – 0.17 lbs P/yr

Photo 5-4

SITE 6: 20-24 Turtle Rock Road

Site Summary:

Soil erosion is occurring along the road edge and a drainage culvert near 20-24 Turtle Rock Road. This culvert drains directly to Cobbett's Pond via a 12-inch culvert pipe that discharges at 20 Turtle Rock Road.

Proposed Improvement:

- Install two vegetated water quality swales, extending 50 feet to the north and south of the culvert.
- Install riprap stabilization at the inlet of the culvert.

Estimated Cost: $3,300 - $4,000

Estimated Pollutant Load Reduction:

0.05 – 0.06 lbs P/yr

Photo 6-1

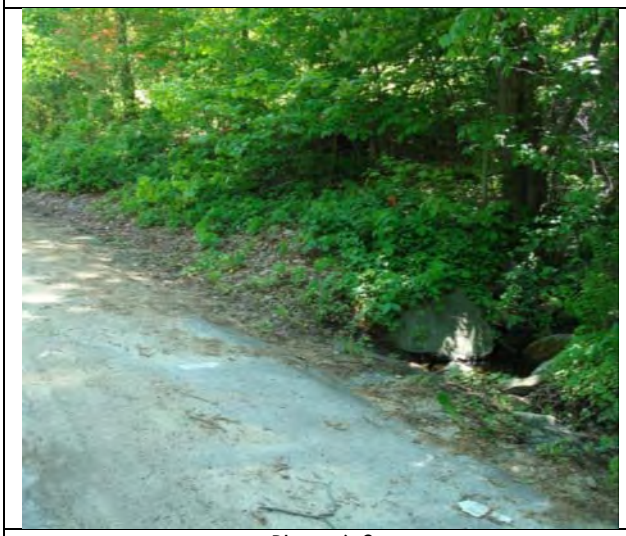


Photo 6-2

SITE 7: 34 Turtle Rock Road

Site Summary:

An existing catch basin (photo 7-1) is located within a grassed portion of the property at 34 Turtle Rock Road, close to where the driveway intersects the road.

Proposed Improvement:

Install raingarden (approximately 100 square feet) with riser pipe in area surrounding the catch basin.

Estimated Cost: $1,200 - $1,400

Estimated Pollutant Load Reduction: 0.01 – 0.02 lbs P/yr

Photo 7-1

SITE 8: 74 Turtle Rock Road

Site Summary:

A catch basin is located within an unpaved parking/storage area in the vicinity of 74 Turtle Rock Road (photo 8-2). This catch basin discharges directly to Cobbett's Pond via a 12-inch culvert pipe. A small adjacent section of Turtle Rock Road is also unpaved (photo 8-1).

Proposed Improvement:

- Pave the adjacent, approximately 2,300 square foot unpaved section of Turtle Rock Road with standard asphalt.

Estimated Cost: $10,800 - $13,200

Estimated Pollutant Load Reduction: 0.09 – 0.10 lbs P/yr

Photo 8-1

Photo 8-2

SITE 9: Summer Street Area

Site Summary:

A portion of the fields located to the north and east of Sawtelle Road drain to a drainage ditch located between the fields and the southern end of Summer Street. Fill has been placed in the ditch (photo 9-1), blocking the normal flow path within the ditch and directing erosive storm water flows across the adjacent property and along Summer Street.

Several major storms in March 2009 resulted in severe erosion in these areas (photo 9-2). Flooding and severe sediment accumulation also occurred at several downgradient culvert locations at Summer Street/Spring Street and Spring Road (photo 9-3).

Photo 9-1

Photo 9-2

Photo 9-3

Proposed Improvements:

- Restore drainage ditch. Remove fill blocking flow and construct stabilized vegetated swale with sufficient capacity to convey flows from the drainage area in a non-erosive manner;
- Re-grade and stabilize the eroding lawn, driveway and sections of Summer Street. Re-surface Summer Street with a specification hardpack to minimize future surface erosion and migration of fine-grained particles.
- Retrofit culverts to improve flow capacity and stability at Summer Street/Spring Street and Spring Road.

Estimated Cost: $10,000 – $12,200

Estimated Pollutant Load Reduction:

0.36 – 0.45 lbs P/yr

SITE 9: Summer Street Area *(continued)*

Aerial view of proposed improvement areas.

SITE 10: 60-62 Horseshoe Road

Site Summary:

Road drainage in the area of 60-62 Horseshoe Road is conveyed via a grassed swale and culvert as shown in photos 10-1 and 10-2.

Proposed Improvement:

- Convert the grassed swale on both sides of the driveway at 62 Horseshoe Road into a linear bioretention cell.
- Daylight (remove) an approximate 25-foot section of 15-inch corrugated plastic pipe culvert at 60 Horseshoe Road and convert this area to a linear bioretention cell that is contiguous with the two areas described above.

Estimated Cost: $9,700 - $11,800

Estimated Pollutant Load Reduction:

0.31 – 0.38 lbs P/yr

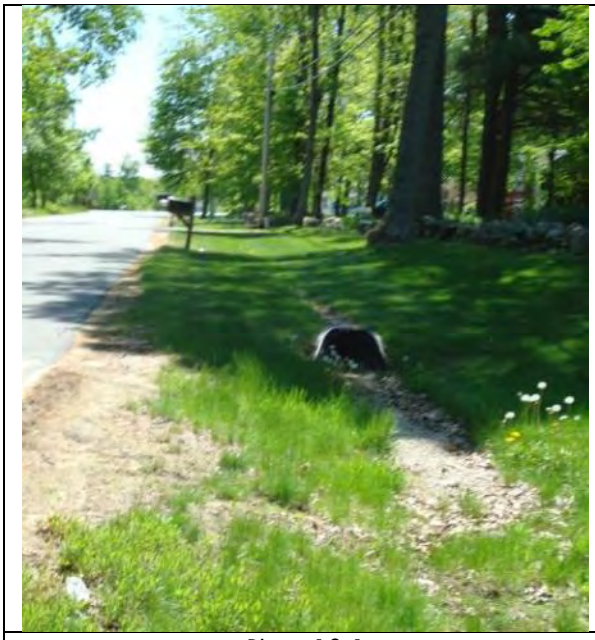


Photo 10-1

Photo 10-2

SITE 11: 58 Horseshoe Road

Site Summary:

A short paved flume directs stormwater from the area near 58 Horseshoe Road into a catch basin (photo 11-1). This catch basin ties into a 15-inch drainage pipe across the street that discharges to an intermittent channel at 35 Horseshoe Road, enters a 24-inch culvert and ultimately discharges to Cobbett's Pond at 34 Horseshoe Road.

Proposed Improvement:

The area in the immediate vicinity of the catch basin could be retrofit with a bioretention cell (approximately 400 square feet) with an overflow pipe to prevent flooding.

Estimated Cost: $5,100 - $6,300

Estimated Pollutant Load Reduction: 0.48 - 0.58 lbs P/yr

Photo 11-1

SITE 12: Woodland Ridge Area (Rt. 111)

Site Summary:

Road runoff has caused significant erosion on NH-DOT property just east of the Woodland Ridge development on the north side of Rt.111. Rilling and unstabilized soils were observed in a channel (photo12-2) that conveys storm water to a concrete culvert pipe. Geosyntec observed evidence of previous unsuccessful efforts to stabilize this area, including the coir fiber wattles observed in the channel (photo 12-3).

Proposed Improvements:

- Install curb and gutter along Rt. 111 approximately 500 linear feet;
- Install two catch basins with double grates on either side of Rt. 111;
- Install BaySeparator (or similar BMP) with associated storage manhole at proposed catch basins;
- Install a bioretention cell (approximately 500 square feet); and
- Construct energy dissipation structure, level spreader and rip-rap stabilized channel along the north side of Rt. 111; and
- Construct vegetated swale along the south side of Rt. 111.

Estimated Cost: $38,600 - $47,200

Estimated Pollutant Load Reduction:

1.68 – 2.05 lbs P/yr

Photo 12-1

Photo 12-2

Photo 12-3

SITE 13: 35 Cobbett's Pond Road

Site Summary:

Two catch basins in Cobbett's Pond Road drain to a rock-lined flume that has become filled with sediment. The catch basins discharge via a culvert that is perched approximately two feet above the rock-lined flume.

Proposed Improvement:

- Retrofit the outlet pipe to discharge at grade to a stone infiltration strip with a level spreader oriented parallel to the retaining wall (approximately 4-foot wide by 20-foot long).
- Immediately downgradient of the infiltration strip and level spreader, construct a 4-foot wide by 20-foot long raingarden planted with native shrubs on 3-foot centers. The size of the raingarden could be larger, pending discussions with the property owner.

Estimated Cost: $1,700 - $2,100

Estimated Pollutant Load Reduction:

0.19 – 0.23 lbs P/yr

Photo 13-1

Photo 13-2

SITE 14: Windham Town Beach

Site Summary:

A stormwater outfall at the Windham Town Beach receives flow from a wetland area to the south and adjacent portions of Cobbett's Pond Road. Road runoff from the north (photo 14-1) flows into a 12-inch concrete pipe via a grassed area located on the eastern side of the road (photo 14-2).

Proposed Improvement:

- Retrofit the grassed area shown in photo 15-2 to incorporate an approximate 400 square foot bioretention cell.

Estimated Cost: $5,100 - $6,300

Estimated Pollutant Load Reduction:

0.11 – 0.13 lbs P/yr

Photo 14-1

Photo 14-2

SITE 15: Fossa Road / Range Road (Rt. 111A)

Site Summary:

Just south of the intersection of Range Road and Fossa Road, an intermittent stream channel (photos 15-1 and 15-2) has become unstable and eroded due to high volume and velocity flows during large storm events. Significant sediment deposition has occurred at the outfall of this stream, which is located at 5 Lakeshore Road. The drainage for this stream includes a portion of Range Road to the east of Fossa Road (photo 15-3).

Proposed Improvement:

- Just east of the intersection of Range Road and Fossa Road, construct an approximately 90-foot long, 6-foot wide stone-lined swale to collect road runoff.
- Convey runoff from the swale described above to an 18" culvert under Fossa Road and discharge west of the road to a stone apron. Construct a cement headwall for the culvert inlet and outlet.
- At the outlet of the existing channel to the north of Range Road, install an approximately 65-foot long, 6-foot wide stone-lined swale, which discharges via a stone level spreader.
- From the swale/level spreader described above, re-construct the upgradient portion of the channel (approximately 160 linear feet) into a series of three stilling basins with level spreaders.
- Re-grade and stabilize the final 100 linear feet of eroded channel (downstream reach to existing culvert headwall, photo 15-2) with stone, geotextile, and plantings.

Estimated Cost: $37,500 - $45,900

Estimated Pollutant Load Reduction:

6.08 – 7.43 lbs P/yr

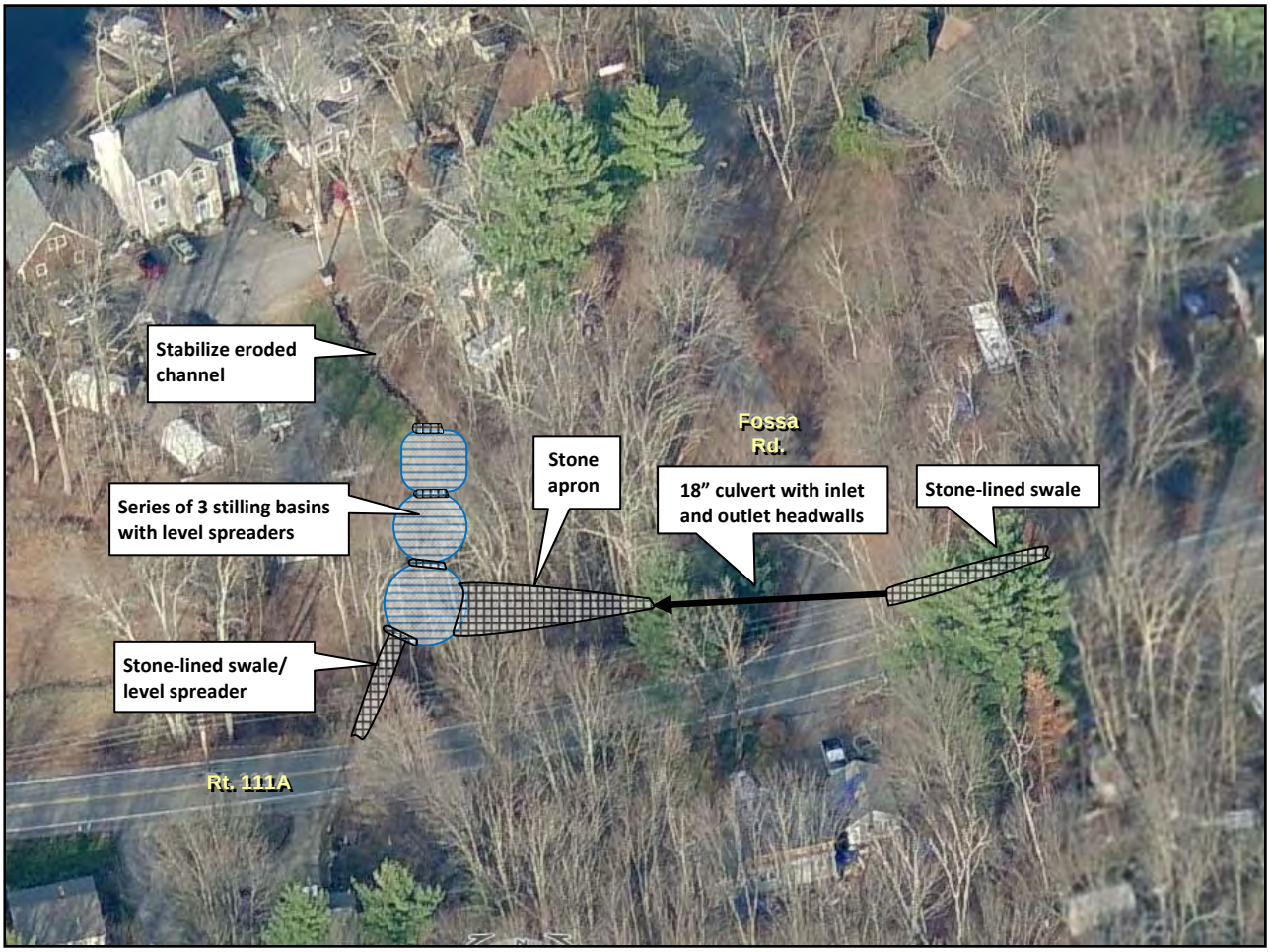
Photo 15-1

Photo 15-2

Photo 15-3

SITE 15: Fossa Road / Range Road *(continued)*

Aerial view of Site 15 and proposed improvement areas.



SITE 16: Hawley Road

Site Summary:

The northern edge of Hawley Road is eroding and rilled from the intersection with Baker Road to the intersection with Range Road (photos 16-1 and 16-2). At the intersection with Range Road, runoff from this area drains to a culvert with a concrete block headwall that is in disrepair and requires stabilization (photo 16-3).

Proposed Improvement:

- Stabilize the road edge with approximately 175 linear feet of grassed water quality swale, 4-feet wide.
- In conjunction with the water quality swales, install raingardens where adequate space exists to capture and infiltrate runoff from residential parcels (estimate 5 raingardens at 100 square feet each).

Estimated Cost: $12,200 - $14,900

Estimated Pollutant Load Reduction:

0.60 – 0.74 lbs P/yr

Photo 16-1

Photo 16-2

Photo 16-3

6.1.2 Estimated Storm Water BMP Pollutant Load Reduction

Phosphorus load reductions were estimated for each of the proposed improvements described above in Section 6.1.1. The phosphorus load reductions were estimated using published pollutant reduction rates for BMPs as follows:

The predicted phosphorus load entering each BMP was estimated based on the land cover in the drainage area contributing flows through the BMP. Each BMP drainage area was delineated based on United States Geological Survey (USGS) topography maps and Geosyntec's field investigations of the watershed and storm drainage structures.

Next, land use categories from existing land use data were assigned to the drainage area. An annual pollutant load was estimated for each catchment using the Simple Method described in the New Hampshire Stormwater Manual. This pre-BMP annual phosphorus load represents the amount of phosphorus expected to enter the Pond if the BMP was not in-place.

Next, published BMP phosphorus reduction values were used to estimate the total amount of phosphorus which is expected to be removed (provided that the BMP is properly installed and maintained). Reduction values were obtained from the New Hampshire Stormwater Manual when available. BMP reduction values not provided by the New Hampshire Stormwater Manual were obtained from the Massachusetts Stormwater Handbook. The post-BMP pollutant load represents the pollutant load predicted to enter the Lake if the BMP was installed. Table 9 provides a summary of the phosphorus load reductions estimated for each proposed BMP site. Appendix E includes the Simple Method calculations, phosphorus load reduction calculations and costing assumptions used for each site.

The BMPs proposed for Sites 1-16 are estimated to reduce the annual phosphorus load to Cobbett's Pond by 13.4 lb/year. This load reduction represents about 9% of the targeted phosphorus load reduction (145 lb/year) for Cobbett's Pond as discussed in Section 4.4. However, as previously stated, Sites 1-16 are not intended to be a comprehensive listing of recommended stormwater improvements in the Cobbett's Pond watershed. Rather, these sites are representative examples of potential stormwater improvements and retrofits that could be implemented at numerous sites throughout the watershed. Significantly greater phosphorus load reductions could be attained from a watershed-wide effort to improve stormwater management through LID practices (e.g. raingardens on residential lots) and improvements to existing storm water drainage features. As such, we estimate that a realistic range of potential phosphorus load reduction from a watershed-wide effort to install storm water BMPs is between 13.4 and 65 lb/year.

6.2 Potential Community Septic Systems Locations

Geosyntec conducted a preliminary review to identify potential areas for community septic systems (Table 8). The review was based on (1) the density of existing homes in close proximity to the Lake and (2) data on soil types and soil drainage classes in the areas surrounding the Lake. Nine potential sites for community septic systems serving 249 homes are shown in Figure 22. As shown in Figure 13, the majority of the soils surrounding the Lake have been classified by the USDA-NRCS as well-drained soils, which tend to be suitable for siting wastewater treatment facilities.

Geosyntec identified the nine areas listed below as potential sites for community septic systems. For each of the nine clusters of homes, the maximum piping distance from a home to a centrally located community septic system would be approximately 0.25 miles.

Table 8: Potential Community Septic Systems

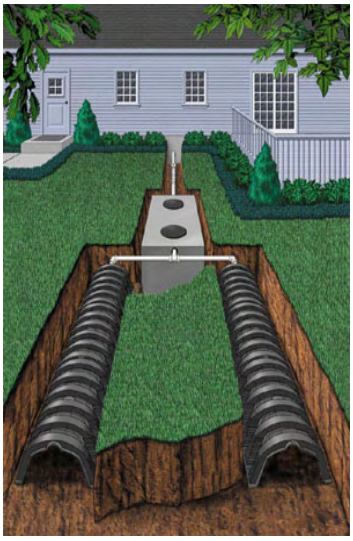
Area	Location	# of Shoreline Homes	Estimated P Reduction (lbs/yr)
1	Southern tip of the lake (from intersection of Cobbett's Pond Road /Horne Road to 8 Cheryl Road)	23	3.0 – 7.2
2	Horne Road/Fish Road area (from 2 Horne Road to 40 Fish Road)	20	2.6 – 6.3
3	Ash Street/ Gaumont Road / Viau Road area	35	4.6 – 11.0
4	1st Street / North Shore Road area (from 20 1st Street to 14 Gardner Road)	27	3.5– 8.5
5	Rocky Ridge Road area (from southern end of Bell Road to southern end of Water's Edge Road)	20	2.6 – 6.3
6	Northeast Shore area (from 35 Armstrong Road to 27 Walkeys Road)	26	3.4 – 8.2
7	Grove Street / Sawyer Road / Sawtelle Road area	32	4.2 – 10.1
8	Farmer Road / Horseshoe Road area (from 1 Farmer Road to 24 Horseshoe Road)	30	3.9 – 9.4
9	Turtle Rock Road area (18 Turtle Rock Road to southern end of Turtle Rock Road)	36	4.7 – 11.3
		Total:	**32.7 – 78.4**

The installed cost for a community septic system can vary widely depending on site specific conditions such as soils, slopes, piping distances, etc. In general, the cost of a community system per household will decrease significantly as the number of homes sharing the system increases. For general costing purposes, a cluster mound system servicing 25 homes will cost about $400,000 to install ($16,000 per house). This cost includes $150,000 to install the system and $250,000 to install piping connections, assuming an average of 100 feet of small diameter pipe per home at $10 per linear foot. Annual maintenance costs for this type of system are estimated at $5,000 ($200 annually per home).

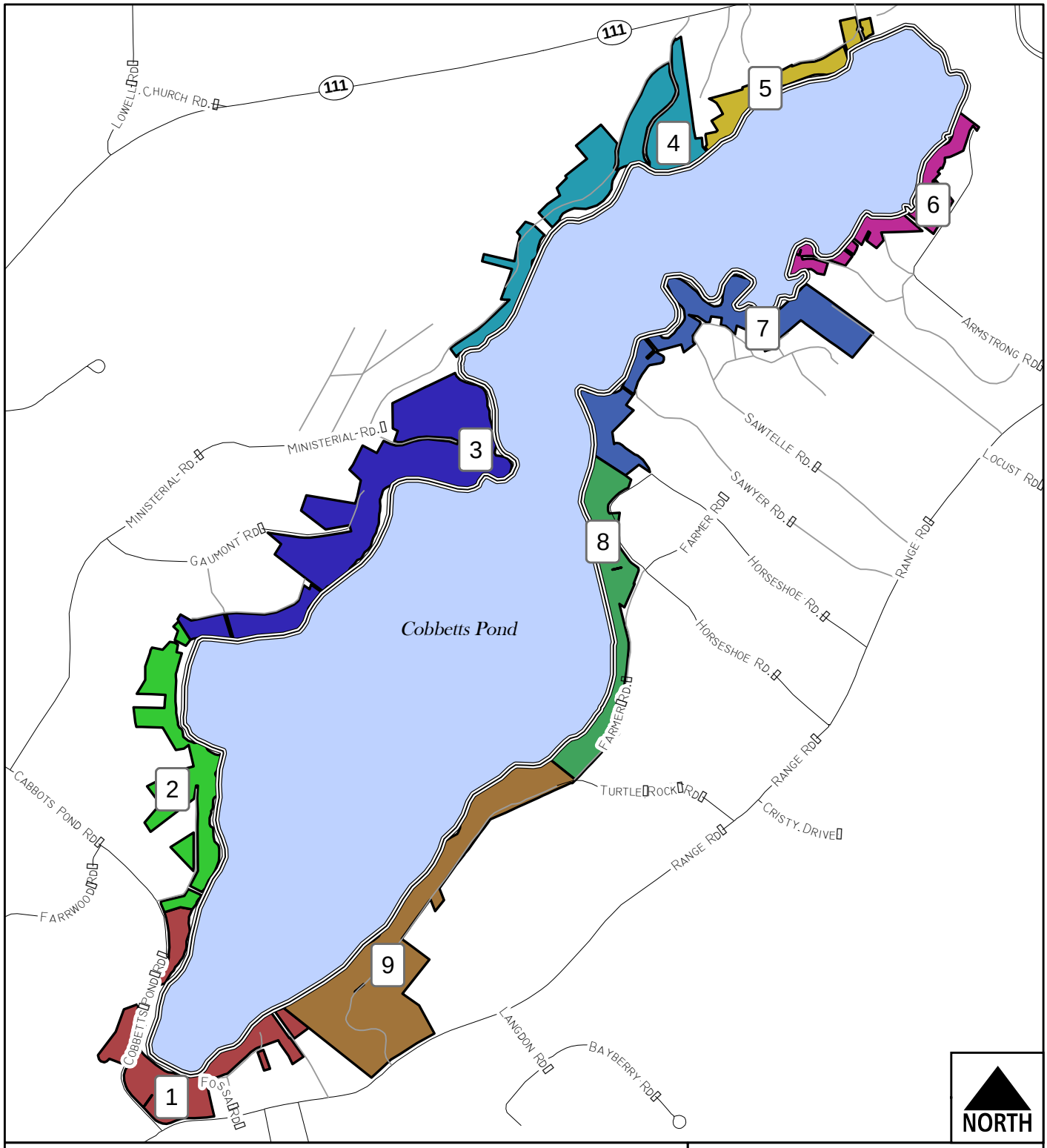
The potential phosphorus load reductions that may be achieved by installing community septic systems can vary widely depending on variables including: the proximity and condition existing on-site septic systems; the location of the proposed community septic systems (e.g.

distance from the lake); and treatment technology of the systems. For the 249 homes located within the nine potential community septic system locations, a conservative estimated phosphorus removal efficiency range of 25%-60% would result in an estimated total phosphorus load reduction of 32.7 to 78.4 lbs P/year. This reduction would represent 23% to 54% of the targeted annual phosphorus load reduction discussed in Section 4.4.

6.2.1 Septic System Maintenance - Cobbett's Pond Watershed Protection Ordinance (CPWPO)



As discussed in Section 2.2, the recently (March 2009) enacted CPWPO requires septic system pumping and inspection at least every three years. Pumping and inspection is required more frequently if recommended by a licensed septic service provider. This maintenance requirement will very likely result in a more frequent maintenance and improved function for septic systems around the Cobbett's Pond, particularly for systems that are found to found to be substandard and required to have more frequent pumping/inspection. The inspection program may also result in the identification of failing systems that will be required to be replaced. Although the CPWPO maintenance program will very likely reduce the phosphorus load from septic systems, the amount the reduction is difficult to estimate. If the maintenance program results in a 10%-15% net decrease in septic system phosphorus load, this would equal an annual load reduction of 13.8 to 20.7 lbs P/year.



Legend

- Water Body
- Highway
- Major Road

0 300 600 1,200 1,800 Feet

PROPOSED COMMUNITY SEPTIC SYSTEM REGIONS

Cobbett's Pond
Windham, NH

Geosyntec consultants
engineers | scientists | innovators

Acton, MA | 31-MAR-10

FIG 22

6.3 Phosphorus Loading From Watershed Land Uses

Landscaping/Lawn Fertilizers

Landscaping fertilizers can be a significant source of phosphorus from areas of residential development and other areas where grass lawns are maintained (e.g. office parks, schools, sports fields, etc.). The CPIA and/or the Town of Windham could develop a program to reduce pollution from fertilizer applications within the watershed. Such efforts are consistent with and would complement the CPWPO ban of fertilizer use within 200 feet of surface waters and wetlands. This program could be modeled after similar efforts that have been implemented successfully in other communities and include the following:

- As an incentive to promote the use of phosphorus-free fertilizers, the CPIA could offer this type of fertilizer to homeowners at a reduced price. Fertilizer retailers (e.g. local hardware stores, etc.) could be selected to provide reduced-priced fertilizer for homeowners living in the watershed. The retailers would be subsidized by for the balance of the fertilizer cost. Homeowners using the fertilizer would be provided signage (optional) to post in their yard, which would educate neighbors about the phosphorus-free fertilizer and its role in protecting water quality. A follow up survey is recommended to evaluate the performance of the program. Printed public outreach materials (e.g., brochure, flyer) are also recommended to ensure that watershed residents are informed of the program, including a discussion of the benefits of and options for "no-fertilizer" landscaping.
- Develop landscaping fertilizer bylaws or ordinances to reduce the use of phosphorus-based fertilizer. There have been numerous successful local ordinances regulating the use of phosphorus fertilizer on lawns. Examples include statewide programs in Maine and Minnesota, and county programs in Dane County (WI), Muskegon County (MI), and Ottawa County MI). A report on the effectiveness of the Minnesota law is available at: www.mda.state.mn.us/phoslaw.

The phosphorus load reductions that can be achieved by a fertilizer reduction program are expected to vary widely depending on how the program is structured and implemented. For purposes of developing a load reduction estimate for this report, we have assumed that the program would be targeted to the 400 residential homes located in closest proximity to Cobbett's Pond, and that 25% these homes (100 homes) fertilize a 2,000 square foot lawn area twice per growing season using 10-10-10 (N-P-K) formula fertilizer at a typical application rate of 3.5 lbs per 1000 square feet. If 25% to 50% of the homes using fertilizer are convinced to switch to phosphorus-free fertilizer, the amount of phosphorus applied to lawns within the Cobbett's Pond watershed would be reduced by approximately 117 to 233 lbs. per year. If 10% of the applied fertilizer phosphorus washes into the lake via storm water runoff, then the estimated annual phosphorus load reduction would range from 11.7 to 23.3 lbs. P/year.

Costs for a one-year fertilizer reduction program as described above are anticipated to be in the range of $8,000 to $10,000. These costs include printed outreach materials (brochure, signage, homeowner survey), and costs associated with providing a rebate or subsidy for purchase of phosphorus–free fertilizer. Assuming that 100 homes participated and purchased four bags of fertilizer, and assuming a rebate of $15 per bag, the total cost of the rebate would be $6,000.

Table 9: Summary of Proposed Actions to Reduce Phosphorus Loading

BMP Type	Site	Proposed Actions	Estimated Cost [1]	Estimated P Load Reduced (lb/yr)	Cost per lb. of P Reduced (x $1,000)	Priority
Stormwater BMPs	**Site 1:** Castleton Center Parking Area	• Install bioretention cells in 2 parking lot islands and one area adjacent to a catch basin.	$27,900 – $34,100	0.4 – 0.5	55.8 – 85.3	MEDIUM
	Site 2: 6-8 Armstrong Rd.	• Stabilize culvert inlet with geotextile and rip-rap; • Install water quality swale for 30 feet to the north and south of the culvert.	$2,200 - $2,700	0.3 - .0.4	5.5 – 9.0	MEDIUM
	Site 3: Sawtelle Rd.	• Retrofit 2 existing catch basins with new deep sump catch basins; • Pending review of property ownership/easements, potentially divert flows from the deep sump catch basins to a vegetated water quality swale in the adjacent field.	$10,300 - $12,600	0.2	51.5 – 63.0	HIGH
	Site 4: Griffin Park	• Install 2,500 square foot bioretention cell; • Install outlet structure; • Connect outlet structure to Rt. 111A catch basin	$34,500 - $42,200	0.9 – 1.0	34.5 – 46.9	HIGH
	Site 5a: Farmer Rd.	• Retrofit catch basins to bioretention cells with underdrains; • Improve existing swale by re-grading to provide wider base and install gravel subbase to promote infiltration and provide storage.	$22,000 - $26,900	0.2 – 0.3	73.3 – 134.5	LOW
	Site 5b: Farmer Rd. /Horseshoe Rd.	• Install an approximate 50-foot long by 6-foot wide bioretention cell upgradient of the catch basin on the northern side of Horseshoe Rd.	$4,600 - $5,700	0.1 – 0,2	23.0 – 57.0	LOW
	Site 6: 20-24 Turtle Rock Rd.	• Install 2 vegetated water quality swales, extending 50 ft. north and south of the culvert. • Install riprap stabilization at the inlet of the culvert.	$3,300 - $4,000	0.06	55.0 – 66.7	LOW
	Site 7: 34 Turtle Rock Rd.	• Install 100 s.f. raingarden with riser pipe in area surrounding the catch basin.	$1,200 - $1,400	0.02	60.0 – 70.0	LOW
	Site 8: 74 Turtle Rock Rd.	• Pave the 2,300 s.f. unpaved section of Turtle Rock Rd. with standard asphalt.	$10,800 - $13,200	0.1	108.0 – 132.0	LOW
	Site 9: Summer St. Area	• Restore drainage ditch. Remove fill blocking flow and construct vegetated swale with capacity to convey flows from the drainage area in a non-erosive manner; • Re-grade/stabilize the eroding lawn, driveway and sections of Summer Street. Re-surface Summer Street with a specification hardpack to minimize future erosion; • Retrofit culverts to improve flow capacity/stability at Summer St., Spring St. and Spring Rd.	$10,000 - $12,200	0.4 – 0.5	20.0 – 30.5	HIGH
	Site 10: 60-62 Horseshoe Rd.	• Convert the grassed swale on both sides of the driveway at 62 Horseshoe Road into a linear bioretention cell. • Daylight 25-ft section of 15-inch culvert at 60 Horseshoe Rd. and convert this area to a linear bioretention cell that is contiguous with the two areas described above.	$9,700 - $11,800	0.3 - .0.4	24.3 – 39.3	LOW
	Site 11: 58 Horseshoe Rd.	• Retrofit area adjacent to catch basin with 400 s.f. bioretention cell, overflow pipe	$5,100 - $6,300	0.5 – 0.6	8.5 – 12.6	MEDIUM
	Site 12: Woodland Ridge Area	• Install curb and gutter along Rt. 111 (approx. 500 linear feet); • Install 2 catch basins with double grates and a BaySeparator (or similar) with storage manhole on both sides of Rt. 111; • Install 500 s.f. bioretention cell on north side of Rt. 111; • Energy dissipation, level spreader and rip-rap channel on north side of Rt. 111; • Construct vegetated swale on south side of Rt. 111.	$38,600 - $47,200	1.7 – 2.1	18.4 – 27.8	HIGH
	Site 13: 35 Cobbett's Pond Rd.	• Retrofit outlet pipe to discharge at grade to a stone infiltration strip with a level spreader oriented parallel to the retaining wall (approximately 4-ft wide by 20-ft long); • Downgradient of the level spreader, construct a 4-ft wide by 20-ft long raingarden planted with native shrubs on 3-foot centers.	$1,700 - $2,100	0.2	8.5 – 10.5	HIGH
	Site 14: Windham Town Beach	• Retrofit the grassed area shown in photo 15-2 to incorporate an approximate 400 square foot bioretention cell.	$5,100 - $6,300	0.1	51.0 – 63.0	MEDIUM
	Site 15: Fossa Rd. /Range Rd.	• East of Range Rd./Fossa Rd. intersection, construct 90-ft by 6-ft. stone-lined swale to collect road runoff; • Convey runoff from swale to 18" culvert under Fossa Rd. and discharge west of the road to a stone apron. Construct a cement headwall for the culvert inlet and outlet; • At the outlet of the channel to north of Range Rd., install 65-ft by 6-ft stone-lined swale, which discharges via a stone level spreader; • Convert upgradient 160 ft. of the channel into 3 stilling basins with level spreaders; • Re-grade and stabilize the final 100 linear feet of eroded channel (to existing culvert headwall) with stone, geotextile, and plantings.	$37,500 - $45,900	6.1 – 7.4	5.1 – 7.5	HIGH
	Site 16: Hawley Rd.	• Stabilize the road edge with approx. 175 lf of grassed water quality swale, 4-ft wide; • Install raingardens on residential parcels (estimate 5 raingardens at 100 s.f. each).	$12,200 -$14,900	0.6 – 0.7	17.4 – 24.8	HIGH
Septic Systems	**Area 1:** Southern tip of the lake (intersection of Cobbett's Pond Rd. /Horne Road to 8 Cheryl Rd.)	Community septic system (23 homes).	$368,000	3.0 – 7.2	50.8 – 122.0	MEDIUM
	Area 2: Horne Road/Fish Road area (from 2 Horne Road to 40 Fish Road)	Community septic system (20 homes).	$320,000	2.6 – 6.3		MEDIUM
	Area 3: Ash Street/ Gaumont Road / Viau Road	Community septic system (35 homes).	$560,000	4.6 – 11.0		MEDIUM
	Area 4: 1st Street / North Shore Road area (from 20 1st Street to 14 Gardner Road)	Community septic system (27 homes).	$432,000	3.5– 8.5		MEDIUM
	Area 5: Rocky Ridge Road area (southern end of Bell Road to southern end of Water's Edge Road)	Community septic system (20 homes).	$320,000	2.6 – 6.3		MEDIUM
	Area 6: Northeast Shore area (from 35 Armstrong Road to 27 Walkeys Road)	Community septic system (26 homes).	$416,000	3.4 – 8.2		MEDIUM
	Area 7: Grove Street / Sawyer Road / Sawtelle Road area	Community septic system (32 homes).	$512,000	4.2 – 10.1		MEDIUM
	Area 8: Farmer Road / Horseshoe Road area (from 1 Farmer Road to 24 Horseshoe Road)	Community septic system (30 homes).	$480,000	3.9 – 9.4		MEDIUM
	Area 9: Turtle Rock Road area (18 Turtle Rock Road to southern end of Turtle Rock Road)	Community septic system (36 homes).	$576,000	4.7 – 11.3		MEDIUM
	Cobbett's Pond Watershed	CPWPO Septic System Maintenance Program	NA	13.8 – 20.7	NA	HIGH
Fertilizer Reduction	Cobbett's Pond Watershed	Fertilizer reduction program.	$8-10K (1 year)	11.7 – 23.3	0.3 – 0.8	HIGH
		TOTALS:	**$4,228,700 (low) $4,283,500 (high)**	**70.2 (low) 136.7 (high)**	**$30.9 (low) $61.0 (high)**	

1. Estimated ranges in cost are approximate and represent installed cost where applicable.

7. SUMMARY OF TECHNICAL AND FINANCIAL SUPPORT

7.1 Technical Support

Most of the phosphorus loading reduction measures described in Section 4.0 will require a moderate to high level of technical support. The required types of technical support include site topographic surveys, preparation of existing conditions base plans, and preparation of definitive site drawings by an Engineer that would be used for permitting, contractor bidding and construction. Stormwater improvement sites requiring low level of technical support would generally be appropriate for design-build construction using field manuals. A listing of the stormwater improvement sites according to estimated level of required technical support is as follows:

Level of Technical Support Required for Stormwater BMP Sites		
Low	**Moderate**	**High**
Site 2: 6-8 Armstrong Rd.	Site 4: Griffin Park	Site 1: Castleton Parking Area
Site 3: Sawtelle Rd.	Site 5a: Farmer Road	Site 9: Summer Street Area
Site 6: 20-24 Turtle Rock Rd.	Site 5b: Farmer Rd. /Horseshoe Rd.	Site 12: Woodland Ridge Area
Site 8: 74 Turtle Rock Rd.	Site 10: 60-62 Horseshoe Rd.	Site 15: Fossa Rd./Range Road
Site 16: Hawley Rd.	Site 11: 58 Horseshoe Rd.	
	Site 13: 35 Cobbett's Pond Road	
	Site 14: Windham Town Beach	

In addition to the technical support described above, construction of some of the projects described in Section 6 may require a Minimum Impact Wetlands Application to the NH DES Wetlands Bureau. Wetlands were not delineated as part of this project. As such, technical support from a New Hampshire certified wetland scientist would be required on sites where wetlands are present for wetland delineation and permitting support.

Improvements related to on-site wastewater management and the proposed community septic systems discussed in Section 6.2 will require a high degree of technical support from a wastewater engineering firm. Such support is expected to include a feasibility study with detailed investigations and recommendations on siting options and costing for the proposed community systems. Detailed engineering plans for the systems would then be required.

Other types of technical support that may be required for the required for the measures discussed in Section 6 include graphic design and printing support for public outreach and educational materials, septic system inspection services, and legal assistance for development of regulatory language for future municipal bylaws.

7.2 Financial Support

Site improvements and management recommendations described in Section 6 will require funding to install and complete. Likely sources of funding include, but are not limited to, CPIA dues and Cobbett's Pond Watershed District funding, Section 319 grant funds and NHDES Small Outreach and Education Grants. Alternative funding may be in the form of donated labor from the Town of Windham Highway Department, CPIA volunteers and local contractors. Brief descriptions of potential grant funding sources are provided below:

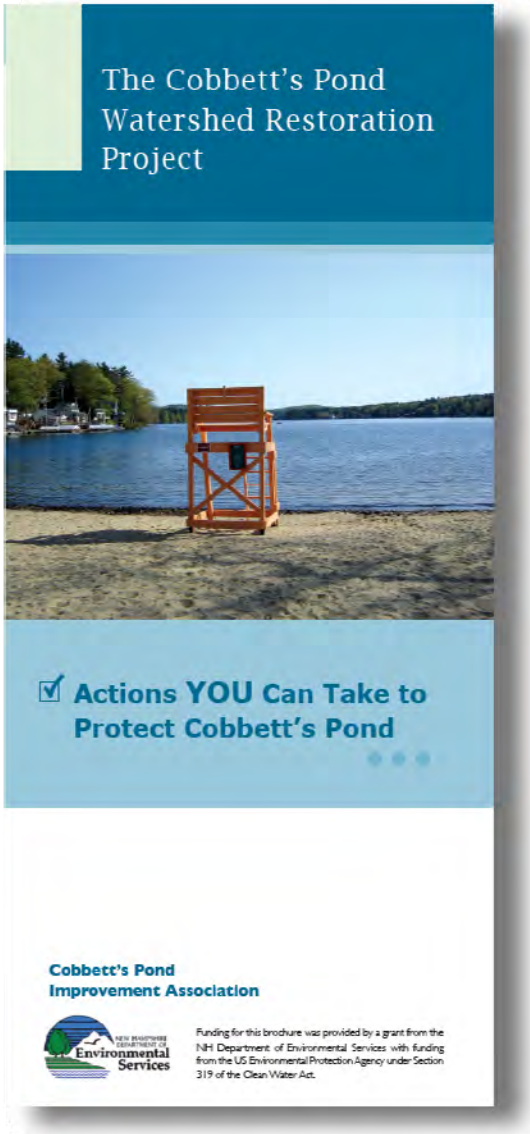
Section 319 Grant Funding: Funds for NH DES Watershed Assistance and Restoration Grants are appropriated through the U.S. Environmental Protection Agency under Section 319 of the Clean Water Act (CWA). Two thirds of the annual funds are available for restoration projects that address impaired waters and implement watershed based plans designed to achieve water quality standards. A project eligible for funds must plan or implement measures that prevent, control, or abate no-point source (NPS) pollution. These projects should: (1) restore or maintain the chemical, physical, and biological integrity of New Hampshire's waters; (2) be directed at encouraging, requiring, or achieving implementation of BMPs to address water quality impacts from land-use; (3) be feasible, practical and cost effective; and (4) provide an informational, educational, and/or technical transfer component. The project must include an appropriate method for verifying project success with respect to the project performance targets, with an emphasis on demonstrated environmental improvement.

Nonprofit organizations registered with the N.H. Secretary of State and governmental subdivisions including municipalities, regional planning commissions, non-profit organizations, county conservation districts, state agencies, watershed associations, and water suppliers are eligible to receive these grants. More information on the NH DES Watershed Assistance and Restoration Grants can be found at: http://www.des.state.nh.us/wmb/was/grants.htm.

Small Outreach and Education Grant: The NHDES provides funding to promote educational and outreach components of water quality improvement projects. This program provides small grants of $200 to $2,000 for outreach and education projects relating to NPS issues that target appropriate audiences with diverse NPS water quality related messages. These small grants are available year round on an ongoing basis, which allows applicants to move forward with outreach and education projects without having to wait for annual application deadlines. The NH DES Watershed Assistance Section administers the grant program using $20,000 each year from the U.S. EPA under Section 319 of the CWA. More information on the Small Outreach and Education Grant can be found at: http://www.des.state.nh.us/wmb/was/grants.htm.

8. PUBLIC INFORMATION AND EDUCATION

Public information and education will be used to enhance public understanding of the phosphorus loading reduction projects. Public awareness encourages the use of storm water improvements and other measures throughout a watershed. Public information and education about the BMPs implemented in the watershed are provided via a project website (listed below) and informational brochure. State grants are available, as described above, to assist with future public information and education efforts.



- **Project Website:** A project web site is available to provide the public with access to all project-related documents and reports. The website is a convenient method for reviewing and commenting on this watershed management plan and other project deliverables. The project website can be accessed at: http://projects.geosyntec.com/BW0131

- **Brochure:** In cooperation with the CPIA, Geosyntec developed an educational brochure specific to the Cobbett's Pond watershed and potential improvements and practices to reduce phosphorus loading to the lake. A copy of the brochure developed through this project is available from the CPIA.

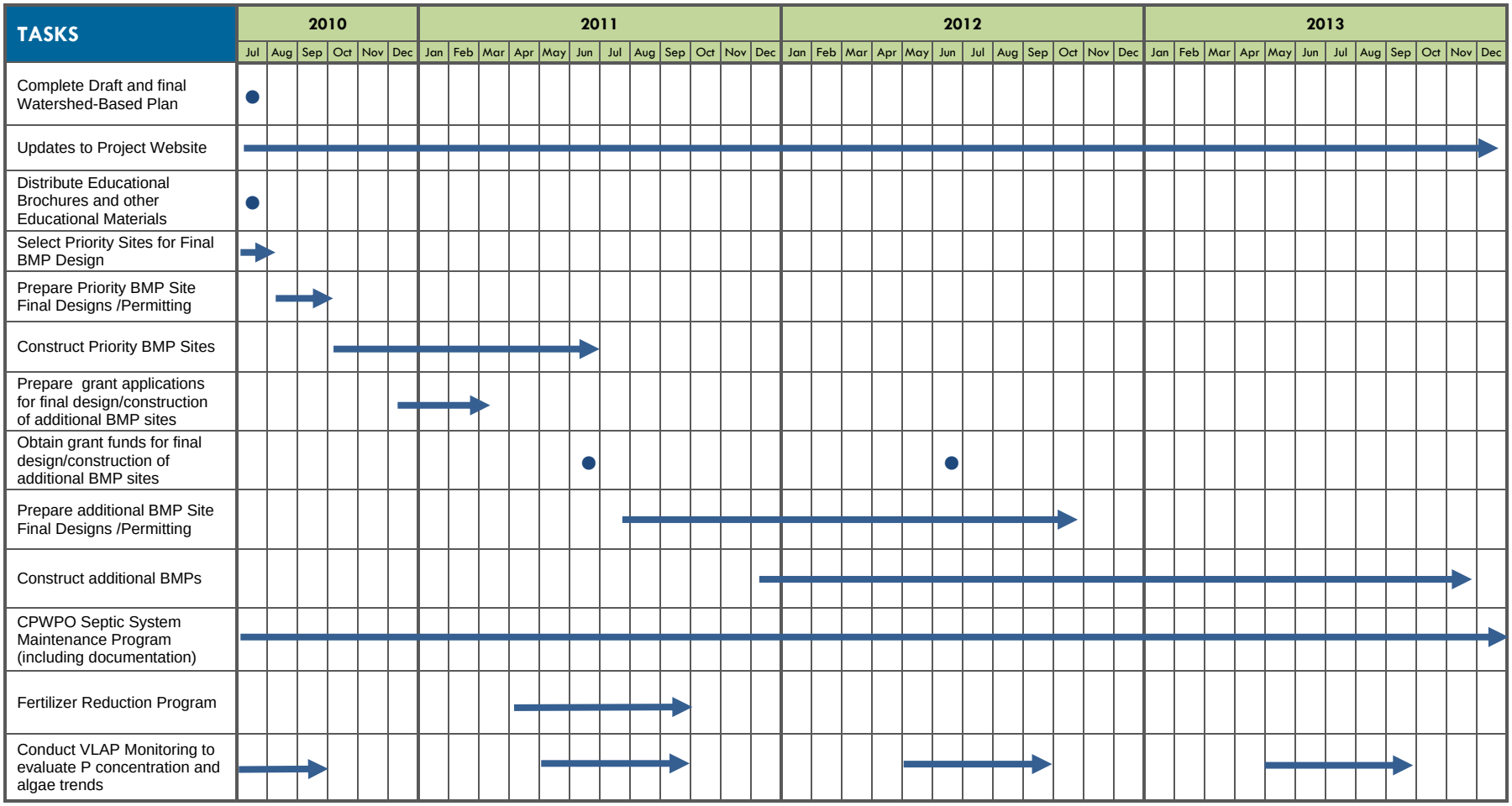
- ***Field Guide to the Aquatic Plants of Cobbetts's Pond*:** Geosyntec developed a field guide to the aquatic plants in Cobbett's Pond based on the results of the July 2009 aquatic vegetation survey conducted as part of this project. The field guide can be downloaded at: www.cobbettspond.org.

- **Public Education Workshops:** Geosyntec developed a series of four public education presentations and workshops to present the findings of this watershed management plan to the CPIA members, the Town of Windham and other watershed stakeholders. In addition to project-specific presentations presentations, Geosyntec also provided a workshop on "Lakeshore Landscaping". This workshop provided information on the siting, design and installation of LID landscaping techniques for residential properties. LID techniques presented included raingardens/bioretention, porous pavements, vegetated buffers, and other techniques focused on promoting infiltration and the use of native vegetation to reduce phosphorus loading in lake watersheds. Slides of the presentations and workshops can be viewed at the project website referenced above.

9. SCHEDULE AND INTERIM MILESTONES

The improvements recommended for Cobbett's Pond and its watershed are ranked in order of priority as described in Section 5 of this report. A proposed schedule and associated interim milestones for these improvements are provided below.

Figure 23. Cobbett's Pond Watershed Restoration Plan - Implementation Schedule and Interim Milestones



10. EVALUATION CRITERIA AND MONITORING

As discussed in Section 4, this watershed management plan recommends targeting an in-lake total phosphorus (TP) concentration for Cobbett's Pond of 12 µg/L. To achieve this TP concentration, the Vollenweider equation in Section 5 predicts that the annual phosphorus load to the lake must be reduced by an estimated 145 lb/year. Section 6 of this report describes management measures that may be implemented to achieve this targeted phosphorus load reduction. Geosyntec recommends the following monitoring and evaluation criteria to determine the effectiveness of these proposed measures in reducing in-lake phosphorus concentrations and improving the water quality of Cobbett's Pond.

- **Phosphorus Monitoring:** The CPIA should continue monitoring in-lake phosphorus concentrations through the NH-VLAP program. In-lake phosphorus measurements will provide the most direct means of evaluating the effects of measures which have been implemented specifically to reduce phosphorus loading. As discussed in Section 4.4, the in-lake phosphorus concentrations predicted by the Vollenweider equation are based on an assumption that the lake is uniformly mixed. As such, the results of epilimnetic phosphorus monitoring during the summer (when the lake is stratified) are likely to understate the phosphorus levels that would be measured if the lake was uniformly mixed. However, regular monitoring of phosphorus levels from a profile (samples from the epilimnion, metalimnion and hypolimnion) at the North Deep Spot and South Deep spot monitoring locations will provide useful data on phosphorus concentration trends in response to implementation of the measures recommended in Section 6.

- **Algae Monitoring:** In recent years, an increase in the reported incidence of nuisance blue-green blooms has been one of the most notable and visible symptoms of nutrient enrichment and declining water quality in Cobbett's Pond. Continued monitoring of the abundance and composition of the lake's algal community will provide a useful metric for understanding water quality trends in response to implementation of the measures recommended in Section 6.

- **Public Outreach, Education and Land Use Activities:** In addition to the monitoring efforts described above, the effectiveness of recommended measures related to public outreach and land use activities can be evaluated with several simple metrics, including:

    - Quantify the number of public education brochures that are distributed to watershed residents;
    - Quantify the number of homes involved annually in the CPWPO septic system maintenance program, including the number of septic system inspections and pump-outs conducted, the number of septic system required to perform more frequent inspections, etc.
    - Quantify the number of homes involved in the proposed fertilizer reduction program, including information on specific program elements such as the quantity of no-phosphorus fertilizer applied within the watershed.
    - Quantify other watershed improvements initiated by homeowners as a result of outreach and education efforts, such as installation of residential raingardens and other LID practices.

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Appendix A:

Water Quality and Flow Monitoring Data

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engineers | scientists | innovators

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www.geosyntec.com

To: Mr. Derek Monson, CPIA
From: Robert Hartzel, Geosyntec Consultants
Date: 8/3/2009
Re: June 2009 Cobbett's Pond Monitoring Results

Geosyntec Consultants is conducting on-going water quantity and quality monitoring as part of a Watershed Restoration Plan for Cobbett's Pond in Windham, NH. Water quality data is being collected monthly at selected in-pond and tributary locations, along with three additional collections at tributary locations during precipitation events. Water quantity is being measured at tributary locations and a rain gage is deployed in the watershed to record precipitation amounts.

The following tasks pertaining to water quality and flow monitoring were completed during the month of June:

Retrieval of Flow/Precipitation Data (6/18/2009): Water level data were collected at all of the tributary locations except for Dinsmore Brook. Precipitation and weather data were collected from the rain gage and pressure/temperature sensor on the NH state owned property along Armstrong Road. This period of data covers 5/27/2009 to 6/18/2009.

Installation of Flow Monitoring Equipment (6/20/2009): A plywood V-notch weir and water level logger were installed along Dinsmore Brook between Rt. 111A and Heron Cove Road.

Monthly Dry-weather Water Quality Sampling (6/25/2009): A dry weather sampling event was conducted at the deep spot and tributary locations. We are considering this event to be "dry weather," although it should be noted that 0.55 inches of precipitation fell over the previous three days (0.3 inches of which fell the previous day).

Figure 1 and Table 1 below show the monitoring locations and their identification codes. Figure 2 shows the results of water quantity monitoring at the tributary locations, along with a plot of precipitation intensity. Figure 3 presents the results of in-situ water quality profiles at the in-lake deep spot monitoring locations, and Tables 3 and 4 provide further water quality monitoring results. A brief description of the various parameters measured in this study is provided at the end of this document.

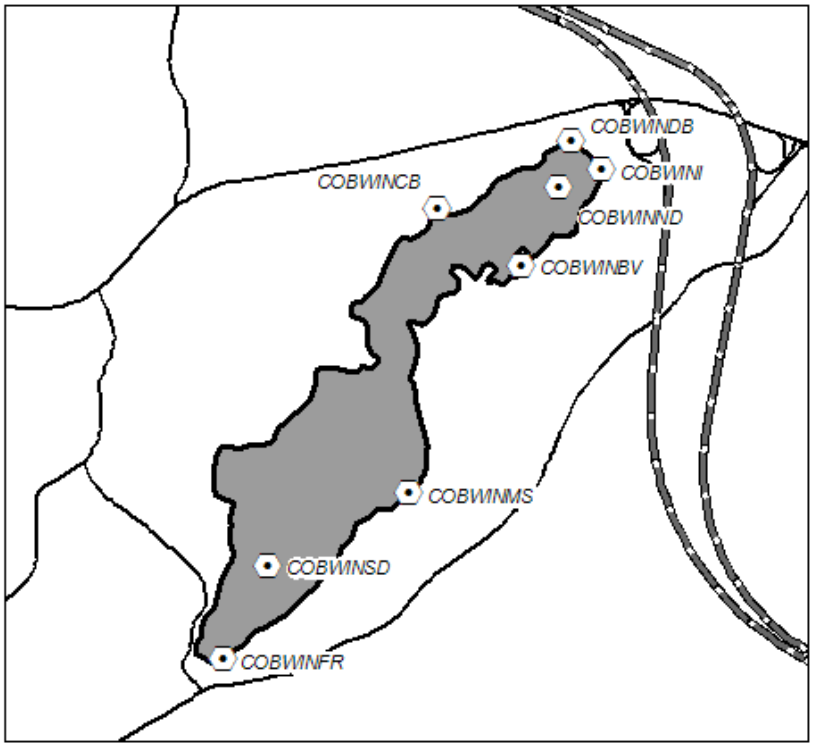


Figure 1. Sampling Location map with NHVLAP IDs.

Table 1. Sampling Locations and corresponding NHVLAP Station IDs.

Sampling Location	VLAP STATION ID
South Deep Spot	COBWINSD
North Deep Spot	COBWINND
Fossa Road Inlet	COBWINFR
Turtle Rock Road Inlet	COBWINMS
Bella Vista Road Inlet	COBWINBV
Castleton Brook Inlet	COBWINI
Dinsmore Brook Inlet	COBWINB
Connies Brook Inlet	COBWINCB

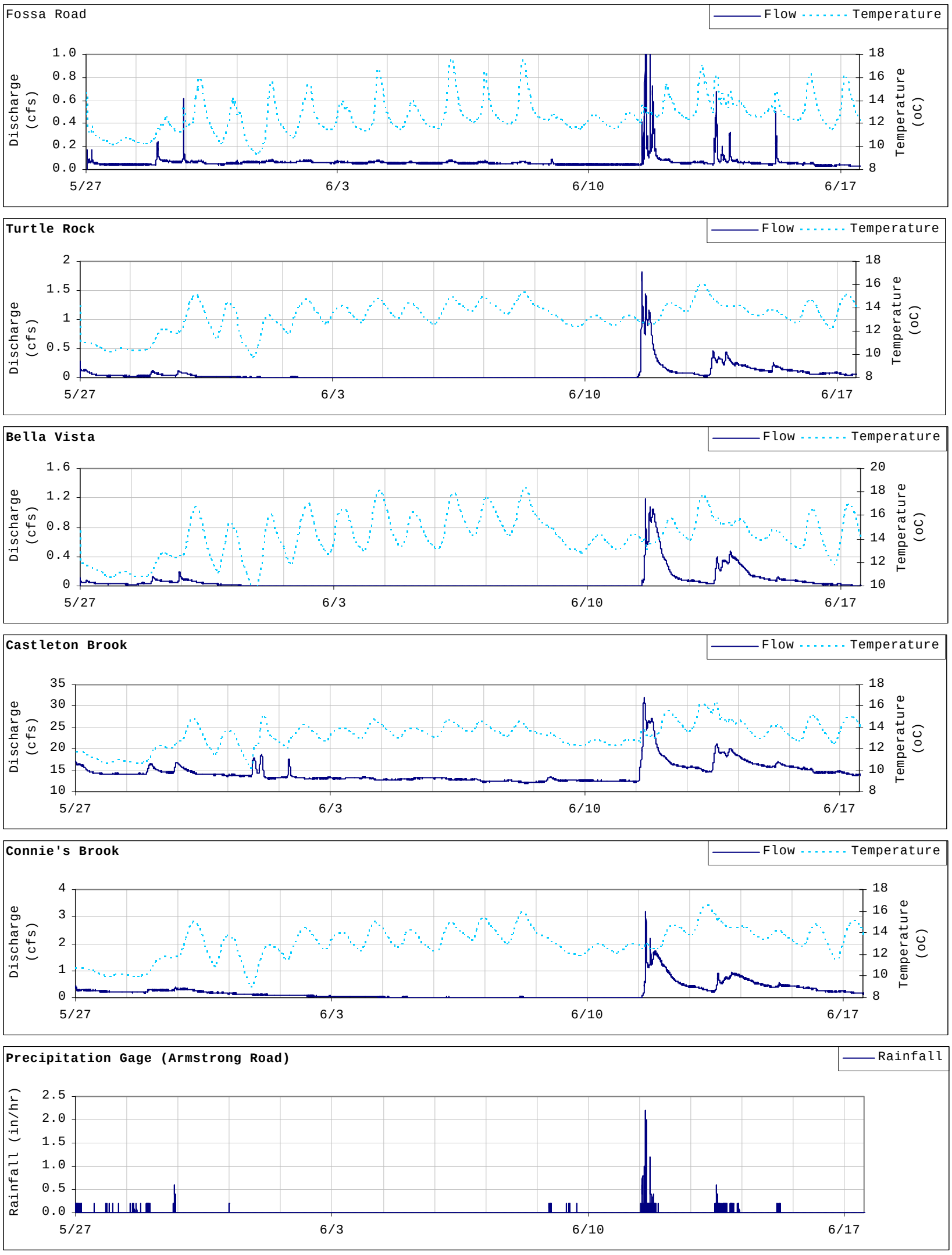
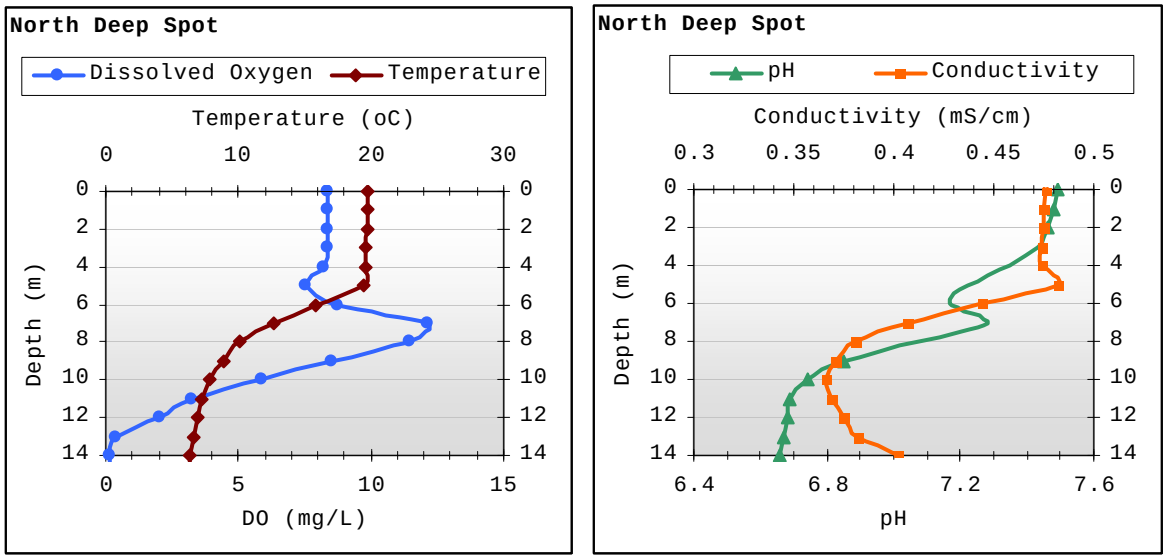
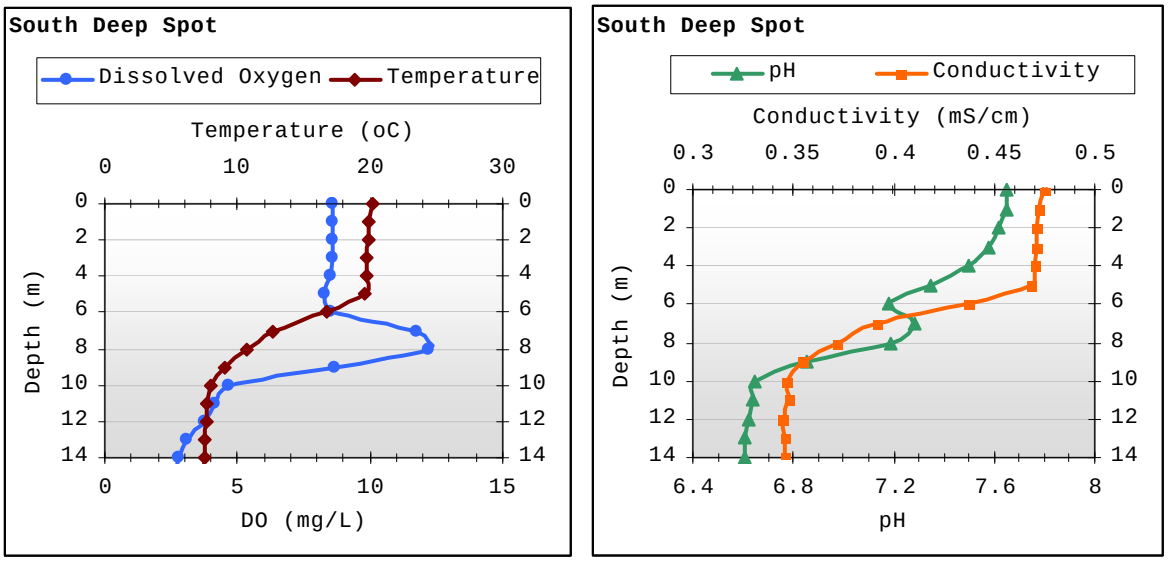


Figure 2. Discharge and Temperature monitoring for Cobbett's Pond Tributaries (5/27/2009-6/18/2009)



(North Deep Spot Secchi Disk Transparency = 12.5')



(South Deep Spot Secchi Disk Transparency = 13.0')

Figure 3. Deep Spot location water quality profiles (6/25/2009)

Table 2. Dry Weather Tributary in-situ water quality results (6/25/2009).

Site	Temperature (oC)	Conductivity (mS/cm)	DO (mg/L)	pH	Turbidity (NTU)
COBWINFR	14.3	0.623	9.6	7.1	0.1
COBWINMS	15.5	0.403	9.5	7.4	2.3
COBWINBV	16.1	0.669	9.2	7.3	1.5
COBWINI	15.2	0.711	8.1	7.0	1.3
COBWINDB	14.1	1.007	9.0	7.0	3.7
COBWINCB	15.7	0.417	9.3	7.3	ND

Table 3. Dry Weather Total Phosphorus / Chlorophyll-a sampling results (6/25/2009).

Site	Depth (m)	TP (mg/L)	Chl-a (ug/L)
COBWINSD	13	0.012	-
COBWINSD	7	0.015	-
COBWINSD	0	0.015	-
COBWINSD	COMP	-	4.3
COBWINND	13	0.015	-
COBWINND	7	0.024	-
COBWINND	0	0.009	-
COBWINND	COMP	-	5.2
COBWINCB	0	0.014	-
COBWINDB	0	0.013	-
COBWINI	0	0.015	-
COBWINI	DUP	0.013	-
COBWINBV	0	0.043	-
COBWINMS	0	0.012	-
COBWINFR	0	0.021	-
COBWINND	BLANK	ND	ND

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To: Mr. Derek Monson, CPIA
From: Robert Hartzel, Geosyntec Consultants
Date: 8/18/2009
Re: July 2009 Cobbett's Pond Monitoring Results

Geosyntec Consultants is conducting on-going water quantity and quality monitoring as part of a Watershed Restoration Plan for Cobbett's Pond in Windham, NH. Water quality data is being collected monthly at selected in-pond and tributary locations, along with three additional collections at tributary locations during precipitation events. Water quantity is being measured at tributary locations and a rain gage is deployed in the watershed to record precipitation amounts.

The following tasks pertaining to water quality and flow monitoring were completed during the month of July:

Retrieval of Discharge/Precipitation Data (7/27/2009): Water level data were collected at all of the tributary locations except for Connie's Brook (a water level probe was not collecting data properly). Precipitation and weather data were collected from the rain gage and pressure/temperature sensor on the NH state owned property along Armstrong Road. This period of data covers 6/18/2009 to 7/27/2009.

Monthly Dry-weather Water Quality Sampling (7/27/2009): A dry weather sampling event was conducted at the deep spot and tributary locations.

Figure 1 and Table 1 below show the monitoring locations and their identification codes. Figure 2 shows the results of water quantity monitoring at the tributary locations, along with a plot of precipitation intensity. Figure 3 presents the results of in-situ water quality profiles at the in-lake deep spot monitoring locations, and Tables 3 and 4 provide further water quality monitoring results. A brief description of the various parameters measured in this study is provided at the end of this document.

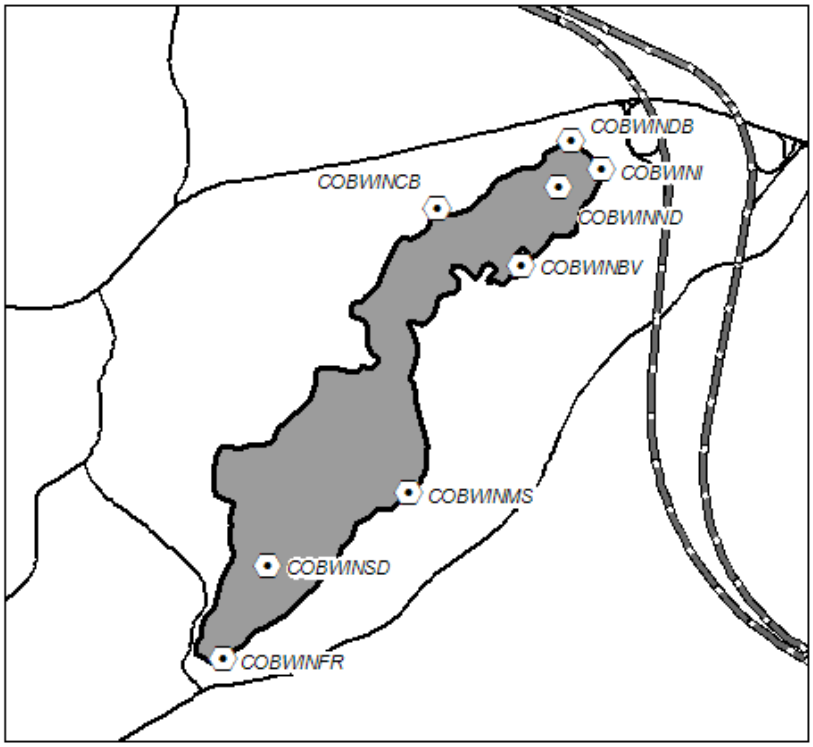

Figure 1. Sampling Location map with NHVLAP IDs.

Table 1. Sampling Locations and corresponding NHVLAP Station IDs.

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Turtle Rock Road Inlet	COBWINMS
Bella Vista Road Inlet	COBWINBV
Castleton Brook Inlet	COBWINI
Dinsmore Brook Inlet	COBWINB
Connies Brook Inlet	COBWINCB

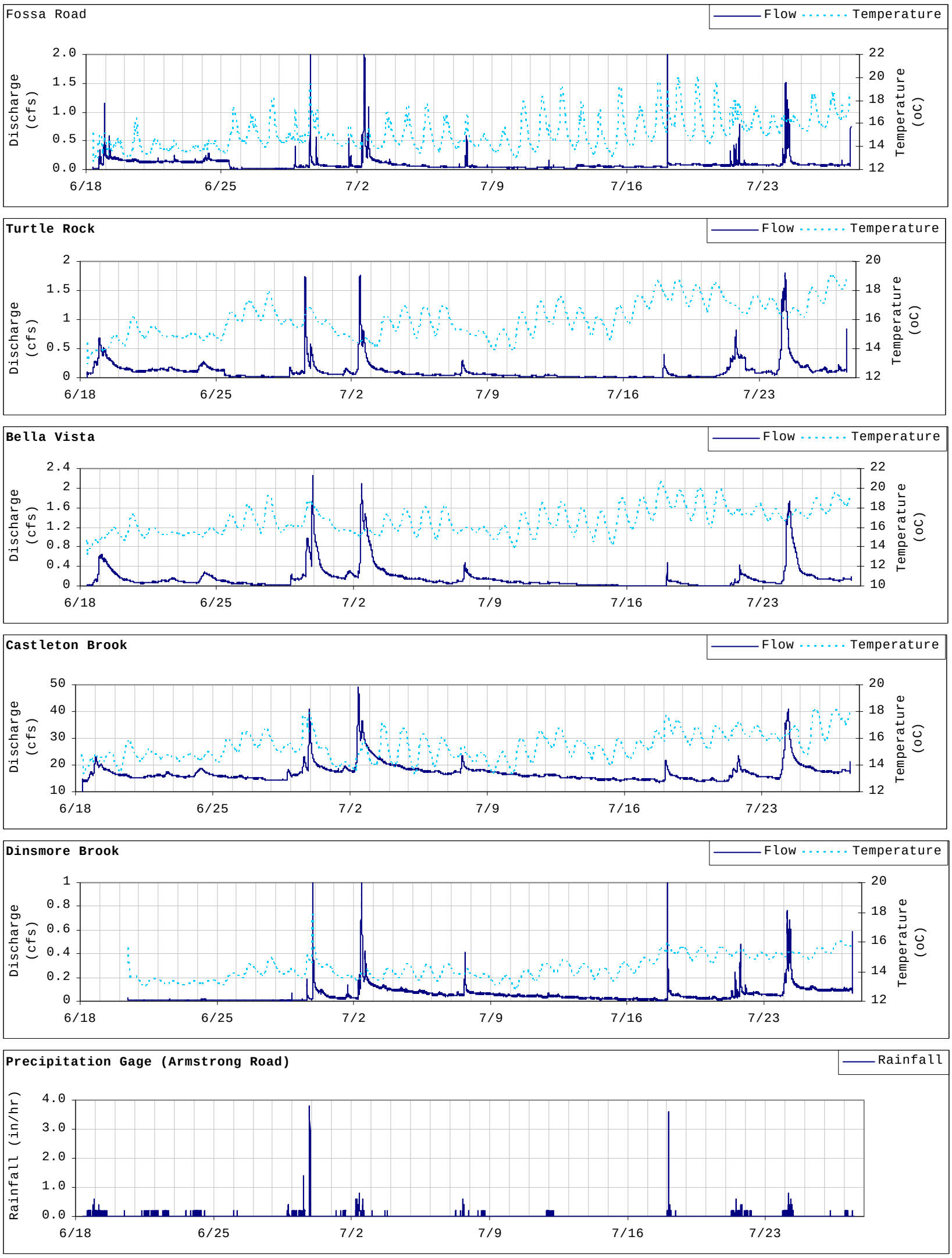
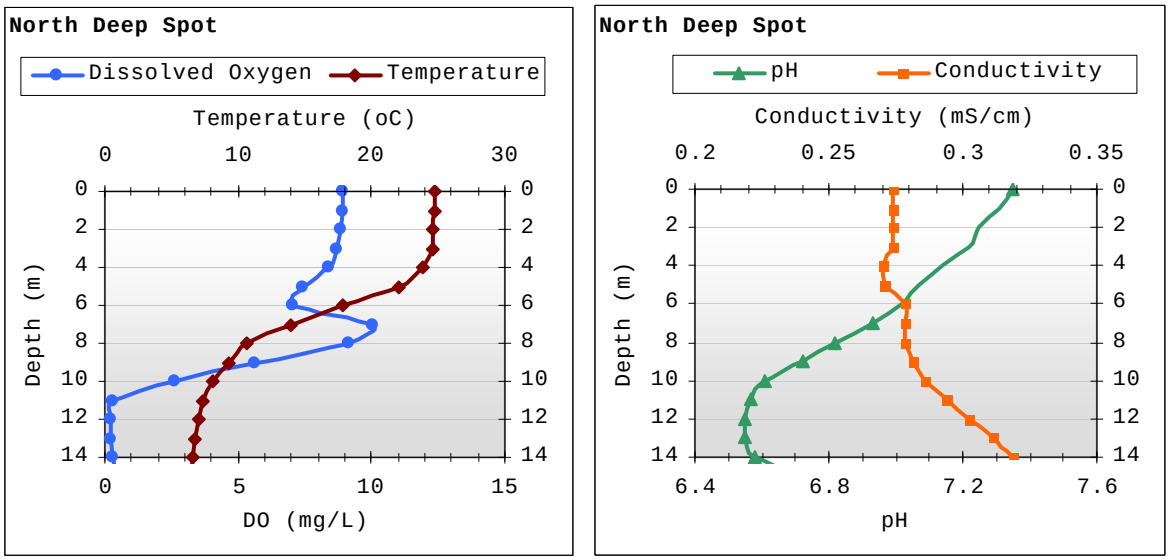
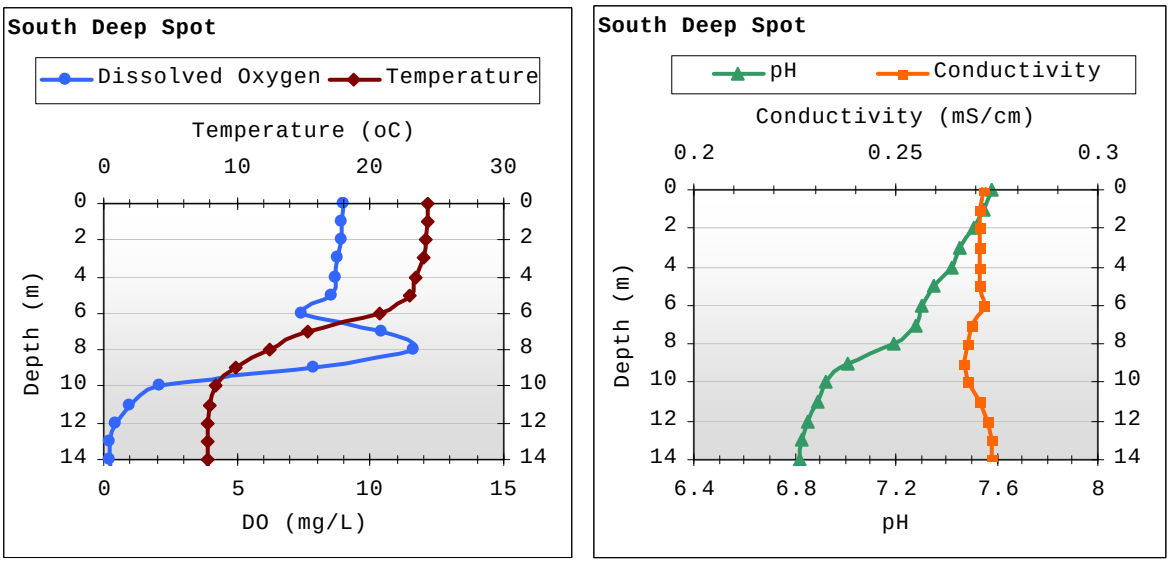


Figure 2. Discharge and Temperature monitoring for Cobbett's Pond Tributaries (6/18/2009-7/27/2009)



(North Deep Spot Secchi Disk Transparency = 9.5')



(South Deep Spot Secchi Disk Transparency = 9.5')

Figure 3. Deep Spot location water quality profiles (7/27/2009)

Table 2. Dry Weather Tributary in-situ water quality results (7/27/2009).

Site	Temperature (oC)	Conductivity (mS/cm)	DO (mg/L)	pH	Turbidity (NTU)
COBWINFR	19.2	0.400	9.2	7.2	ND
COBWINMS	20.2	0.369	8.9	7.3	ND
COBWINBV	19.9	0.372	8.6	6.8	ND
COBWINI	18.7	0.476	7.0	6.8	ND
COBWINDB	17.5	0.577	8.1	6.9	3.7
COBWINCB	19.7	0.354	8.8	7.2	ND

Table 3. Dry Weather Total Phosphorus sampling results (7/27/2009).

Site	Depth (m)	TP (mg/L)
COBWINSD	13	0.021
COBWINSD	7	0.022
COBWINSD	0	0.012
COBWINND	13	0.034
COBWINND	7	0.013
COBWINND	0	0.009
COBWINFR	0	0.016
COBWINMS	0	0.015
COBWINBV	0	0.053
COBWINBV	DUP	0.055
COBWINI	0	0.027
COBWINDB	0	0.049
COBWINCB	0	0.025
COBWINND	BLANK	0.012

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To: Mr. Derek Monson, CPIA
From: Robert Hartzel, Geosyntec Consultants
Date: 12/21/2009
Re: August 2009 Cobbett's Pond Monitoring Results

Geosyntec Consultants is conducting on-going water quantity and quality monitoring as part of a Watershed Restoration Plan for Cobbett's Pond in Windham, NH. Water quality data is being collected monthly at selected in-pond and tributary locations, along with three additional collections at tributary locations during precipitation events. Water quantity is being measured at tributary locations and a rain gage is deployed in the watershed to record precipitation amounts.

The following tasks pertaining to water quality and flow monitoring were completed during the month of August:

Retrieval of Discharge/Precipitation Data (8/20/2009): Water level data were collected at all of the tributary locations. Precipitation and weather data were collected from the rain gage and pressure/temperature sensor on the NH state owned property along Armstrong Road. This period of data covers 7/27/2009 to 8/20/2009.

Monthly Dry-weather Water Quality Sampling (8/20/2009): A dry weather sampling event was conducted at the deep spot and tributary locations.

Figure 1 and Table 1 below show the monitoring locations and their identification codes. Figure 2 shows the results of water quantity monitoring at the tributary locations, along with a plot of precipitation intensity. Figure 3 presents the results of in-situ water quality profiles at the in-lake deep spot monitoring locations, and Tables 2 and 3 provide further water quality monitoring results. A brief description of the various parameters measured in this study is provided at the end of this document.

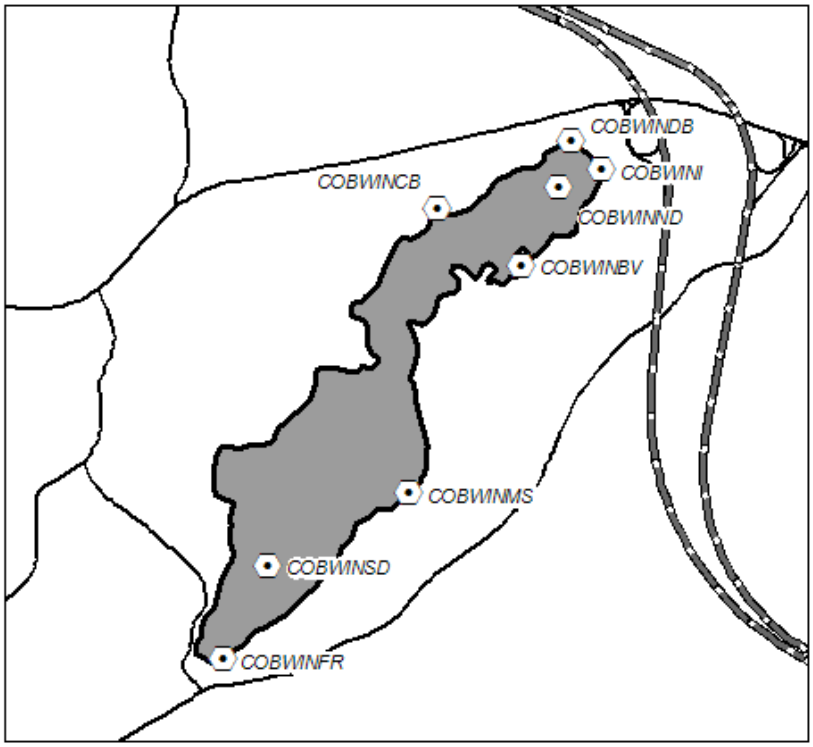


Figure 1. Sampling Location map with NHVLAP IDs.

Table 1. Sampling Locations and corresponding NHVLAP Station IDs.

Sampling Location	VLAP STATION ID
South Deep Spot	COBWINSD
North Deep Spot	COBWINND
Fossa Road Inlet	COBWINFR
Turtle Rock Road Inlet	COBWINMS
Bella Vista Road Inlet	COBWINBV
Castleton Brook Inlet	COBWINI
Dinsmore Brook Inlet	COBWINB
Connies Brook Inlet	COBWINCB

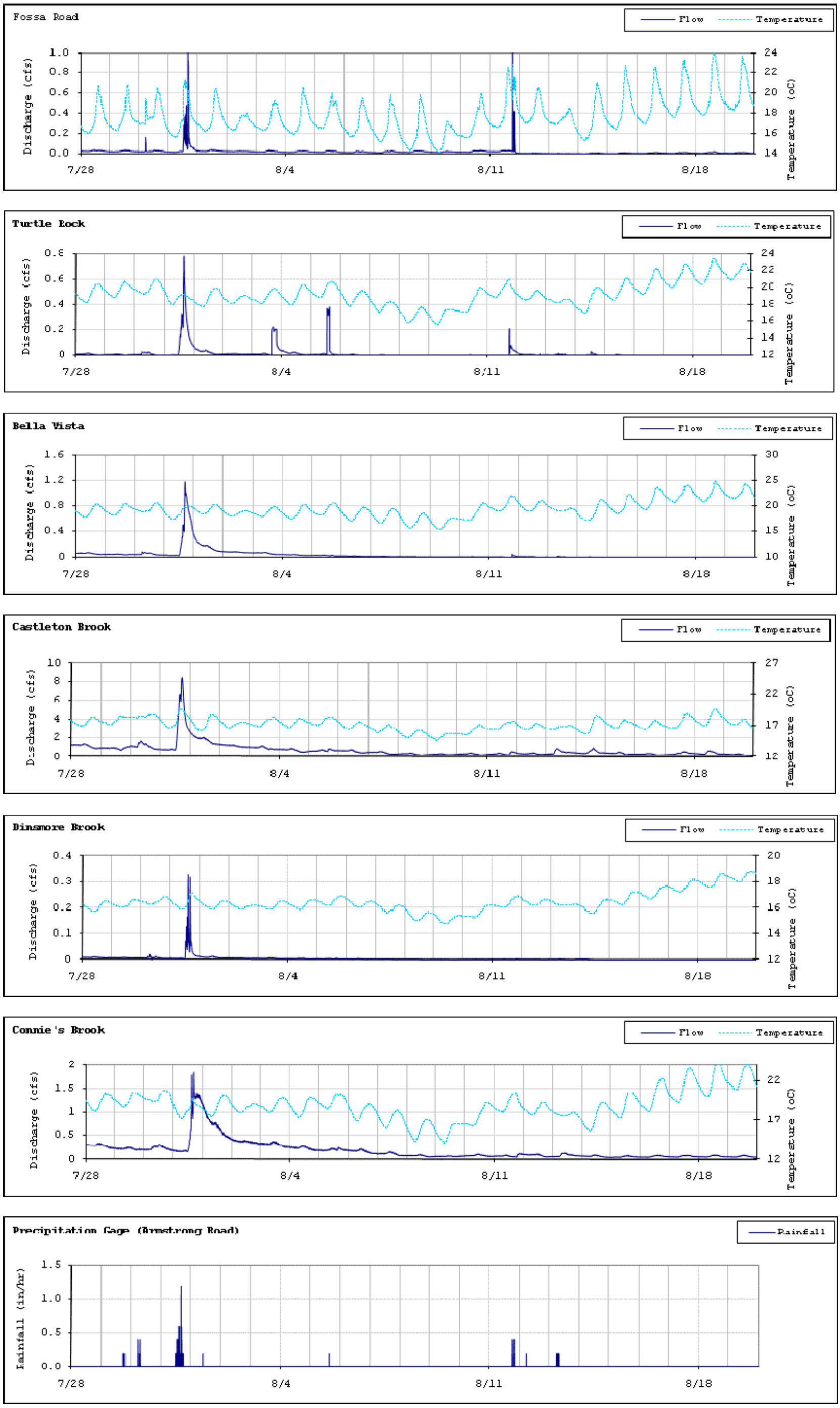
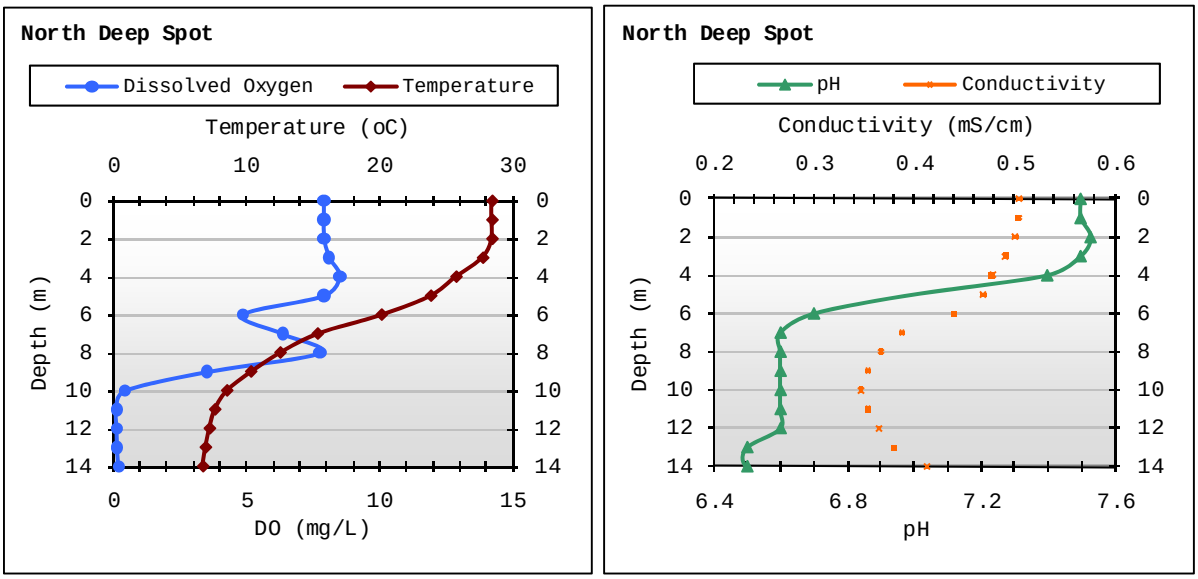
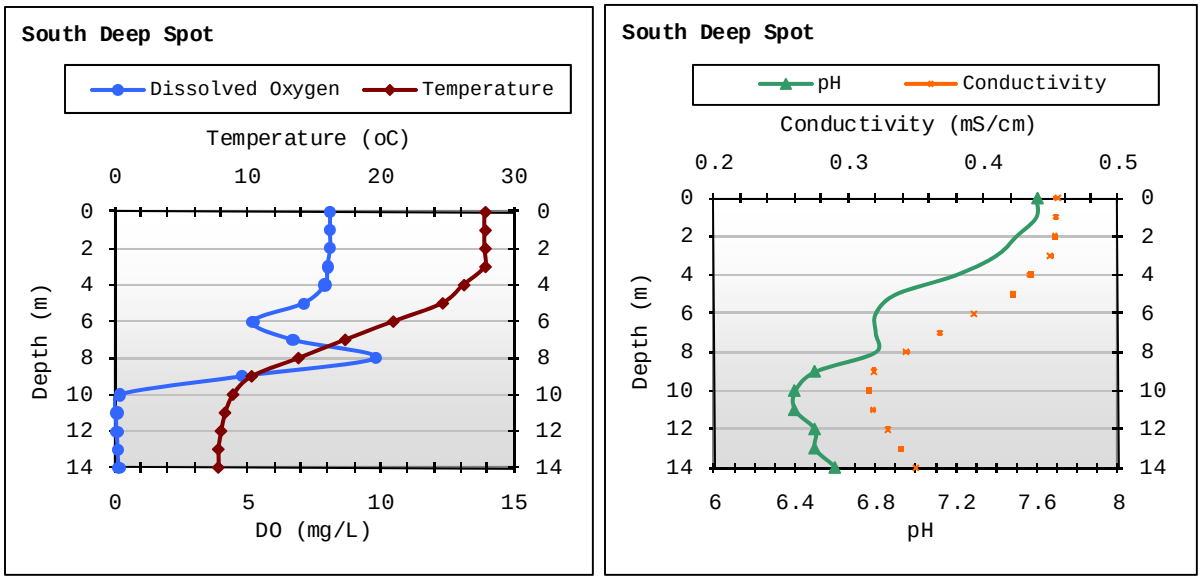


Figure 2. Discharge and Temperature monitoring for Cobbett's Pond Tributaries (7/27/2009-8/20/2009)



(North Deep Spot Secchi Disk Transparency = 10.0')



(South Deep Spot Secchi Disk Transparency = 10.5')

Figure 3. Deep Spot location water quality profiles (8/20/2009)

Table 2. Dry Weather Tributary in-situ water quality results (8/20/2009).

Site	Temperature (oC)	Conductivity (mS/cm)	DO (mg/L)	pH	Turbidity (NTU)
COBWINFR	17.3	0.707	8.8	7.1	ND
COBWINMS	21.2	0.555	8.8	7.5	ND
COBWINBV	*	*	*	*	*
COBWINI	16.8	0.907	6.9	6.9	ND
COBWINDB	18.7	0.847	7.4	7.1	ND
COBWINCB	20.7	0.735	9.9	7.4	ND

*At the time of sampling, stream COBWINBV was dry.

Table 3. Dry Weather Total Phosphorus and Chlorophyll-a sampling results (8/20/2009).

Site	Depth (m)	TP (mg/L)	Chlor-a (ug/L)
COBWINSD	COMPOSITE		5.67
COBWINSD	13.00	0.03	-
COBWINSD	7.00	0.02	-
COBWINSD	0.00	0.02	-
COBWINND	COMPOSITE		6.14
COBWINND	13.00	0.11	-
COBWINND	7.00	0.02	-
COBWINND	0.00	0.02	-
COBWINCB	0.00	0.06	-
COBWINDB	0.00	0.05	-
COBWINDB	DUP	0.06	-
COBWINI	0.00	0.06	-
COBWINBV	0.00	-	-
COBWINMS	0.00	0.03	-
COBWINFR	0.00	0.02	-
COBWINND	BLANK	ND	-

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To: Mr. Derek Monson, CPIA
From: Robert Hartzel, Geosyntec Consultants
Date: 12/21/2009
Re: September 2009 Cobbett's Pond Monitoring Results

Geosyntec Consultants is conducting on-going water quantity and quality monitoring as part of a Watershed Restoration Plan for Cobbett's Pond in Windham, NH. Water quality data is being collected monthly at selected in-pond and tributary locations, along with three additional collections at tributary locations during precipitation events. Water quantity is being measured at tributary locations and a rain gage is deployed in the watershed to record precipitation amounts.

The following tasks pertaining to water quality and flow monitoring were completed during the month of September:

Wet-weather Sampling Event (8/29/2009): Tributary sampling was performed during a precipitation event. Water quality parameters were measured and total phosphorus samples were collected.

Retrieval of Discharge/Precipitation Data (9/17/2009): Water level data were collected at all of the tributary locations except for Fossa Road Inlet (the water level probe was not collecting data properly). Precipitation and weather data were collected from the rain gage and pressure/temperature sensor on the NH state owned property along Armstrong Road. This period of data covers 8/20/2009 to 9/17/2009.

Monthly Dry-weather Water Quality Sampling (9/17/2009): A dry weather sampling event was conducted at the deep spot and tributary locations.

Figure 1 and Table 1 below show the monitoring locations and their identification codes. Figure 2 shows the results of water quantity monitoring at the tributary locations, along with a plot of precipitation intensity. Figure 3 presents the results of in-situ water quality profiles at the in-lake deep spot monitoring locations. Table 2 presents the results of the wet-weather sampling, and Tables 3 and 4 provide further water quality monitoring results. A brief description of the various parameters measured in this study is provided at the end of this document.

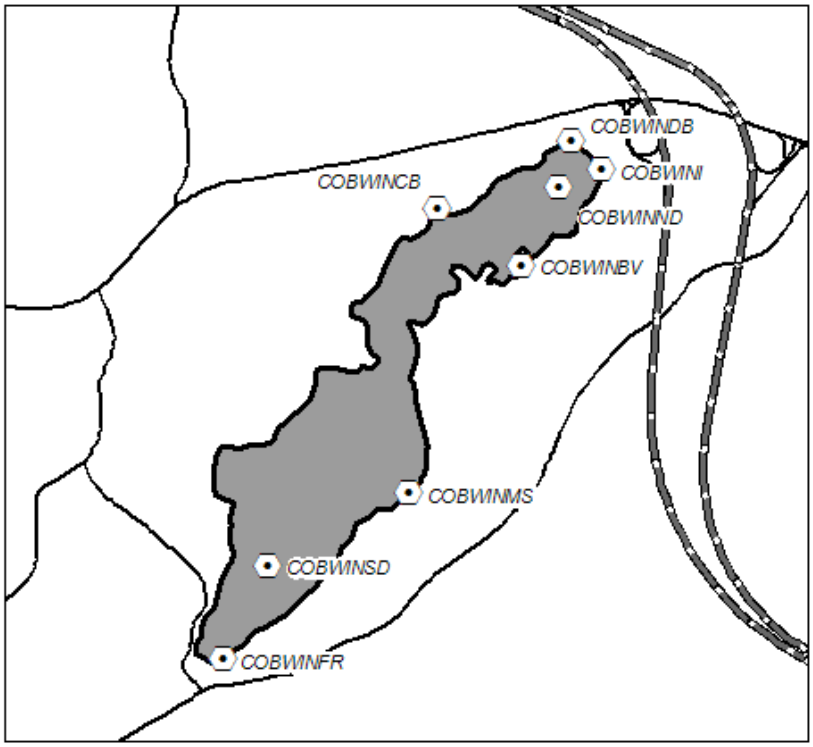

Figure 1. Sampling Location map with NHVLAP IDs.

Table 1. Sampling Locations and corresponding NHVLAP Station IDs.

Sampling Location	VLAP STATION ID
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Dinsmore Brook Inlet	COBWINB
Connies Brook Inlet	COBWINCB

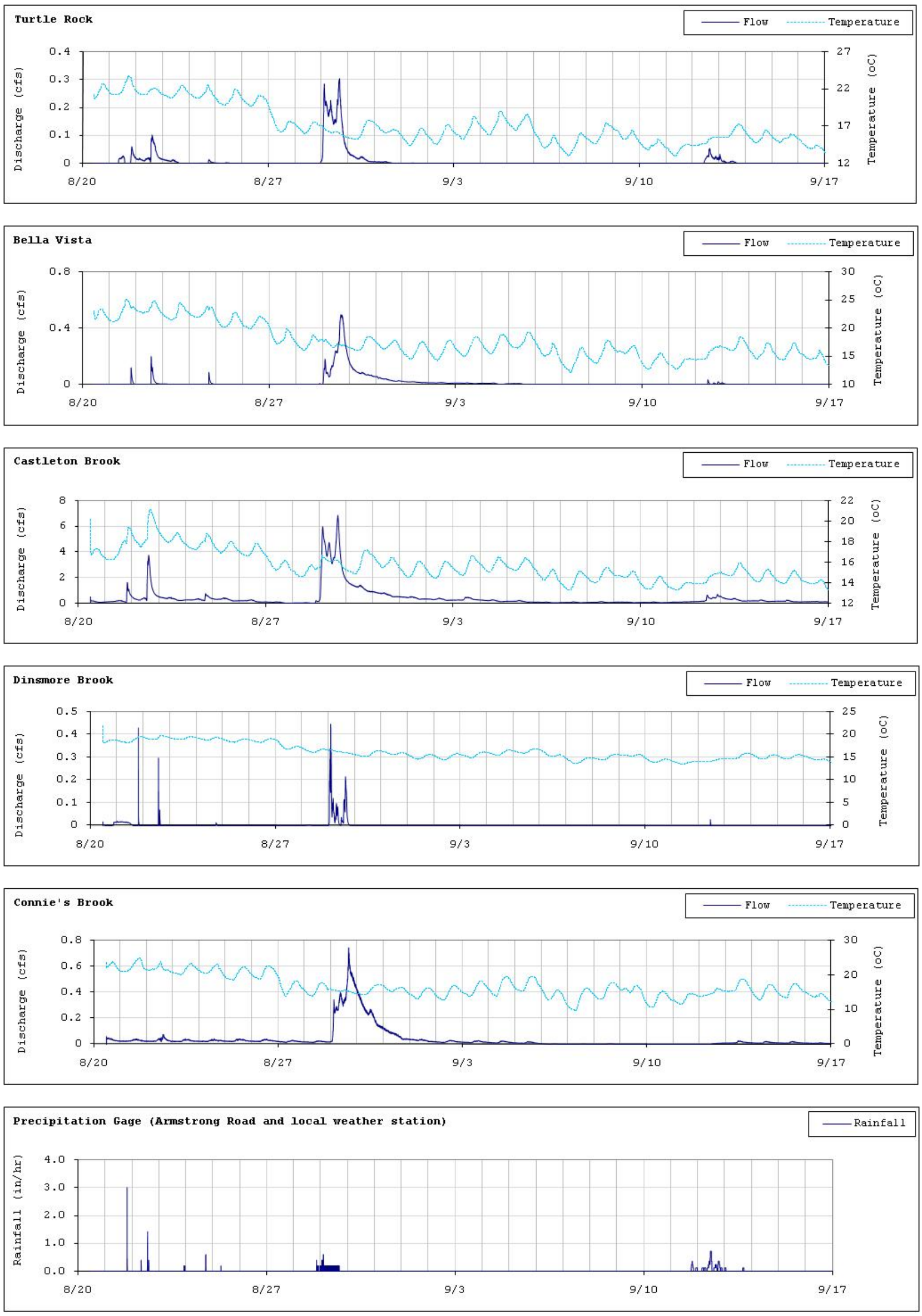
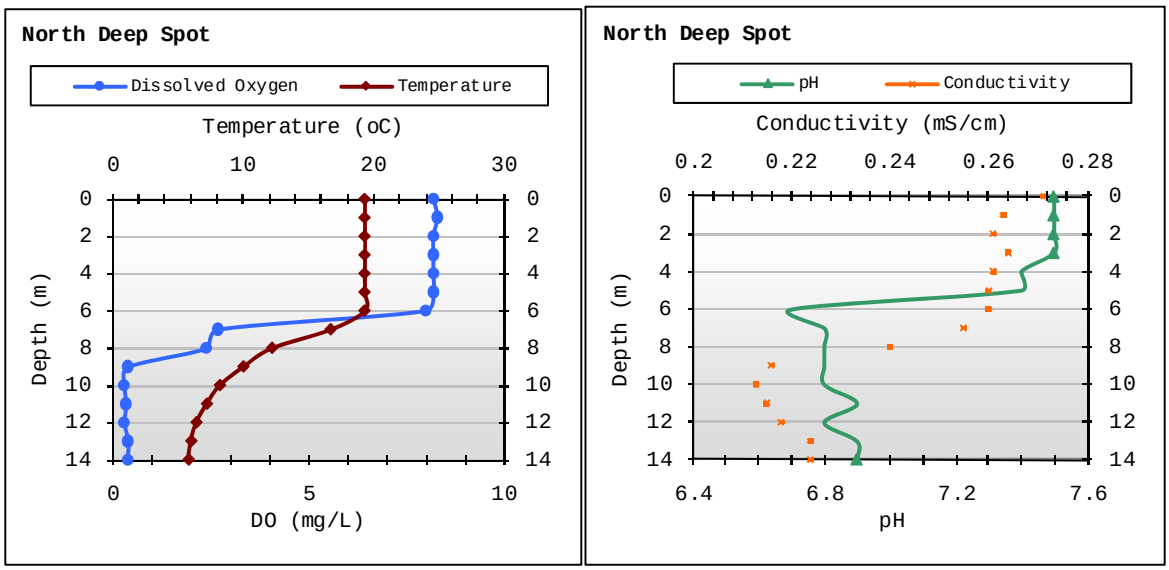
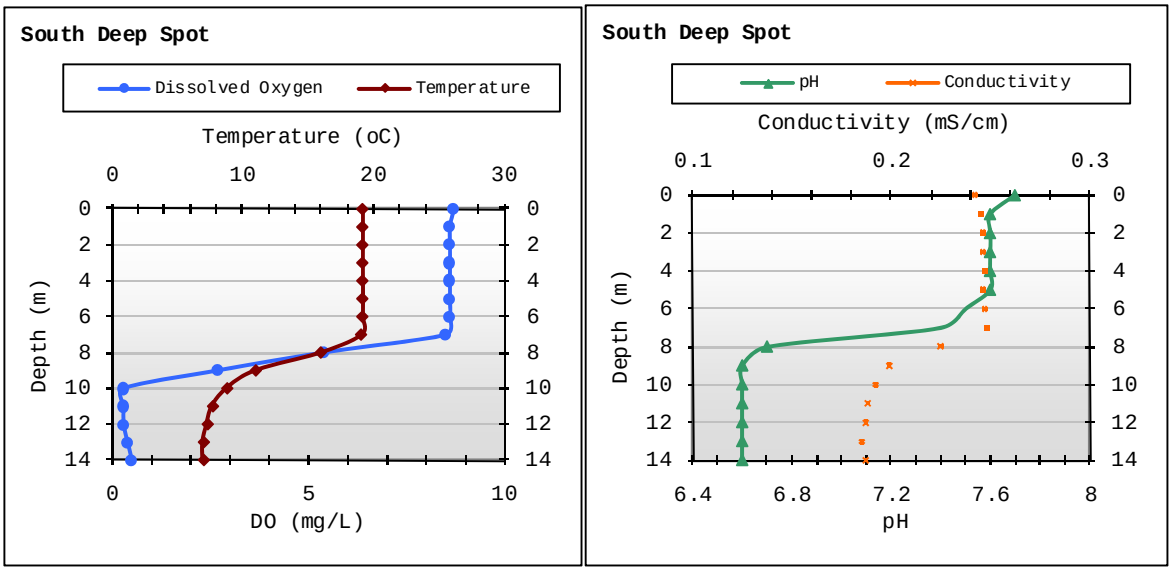


Figure 2. Discharge and Temperature monitoring for Cobbett's Pond Tributaries (8/20/2009-9/17/2009)



(North Deep Spot Secchi Disk Transparency = 11.0')



(South Deep Spot Secchi Disk Transparency = 11.5')

Figure 3. Deep Spot location water quality profiles (9/17/2009)

Table 2. Wet Weather Tributary in-situ water quality and Total Phosphorus results (8/29/2009).

Site	Temperature (oC)	Conductivity (mS/cm)	DO (mg/L)	pH	Turbidity (NTU)	Total Phosphorus (mg/L)
COBWINFR	15.9	0.097	9.0	7.9	3.9	0.054
COBWINMS	15.8	0.183	9.7	7.6	8.7	0.052
COBWINBV	16.5	0.202	8.0	7.3	2.7	0.058
COBWINI	16.0	0.240	8.3	7.2	30	0.051
COBWINDB	15.7	0.307	8.2	7.0	11.3	0.069
COBWINCB	15.2	0.404	9.4	7.2	11.5	0.075

Table 3. Dry Weather Tributary in-situ water quality results (9/17/2009).

Site	Temperature (oC)	Conductivity (mS/cm)	DO (mg/L)	pH	Turbidity (NTU)
COBWINFR	*	*	*	*	*
COBWINMS	*	*	*	*	*
COBWINBV	*	*	*	*	*
COBWINI	12.33	0.603	5.84	6.84	5.9
COBWINDB	12.72	0.579	10.25	7.4	28.2
COBWINCB	*	*	*	*	*

*At the time of sampling, streams COBWINFR, COBWINMS, COBWINBV, AND COBWINCB were dry.

Table 4. Dry Weather Total Phosphorus and Chlorophyll-a sampling results (9/17/2009).

Site	Depth	TP (mg/L)	Chlor-a (ug/L)
COBWINSD	COMPOSITE	-	3.73
COBWINSD	13	0.029	-
COBWINSD	7	0.018	-
COBWINSD	0	0.015	-
COBWINND	COMPOSITE	-	4.36
COBWINND	13	0.130	-
COBWINND	7	0.023	-
COBWINND	0	0.014	-
COBWINDB	0	0.016	-
COBWINI	0	0.019	-
COBWINCB	0	-	-
COBWINDB	DUP	-	-
COBWINBV	0	-	-
COBWINMS	0	-	-
COBWINFR	0	-	-
COBWINND	BLANK	-	-

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To: Mr. Derek Monson, CPIA
From: Robert Hartzel, Geosyntec Consultants
Date: 12/21/2009
Re: October 2009 Cobbett's Pond Monitoring Results

Geosyntec Consultants is conducting on-going water quantity and quality monitoring as part of a Watershed Restoration Plan for Cobbett's Pond in Windham, NH. Water quality data is being collected monthly at selected in-pond and tributary locations, along with three additional collections at tributary locations during precipitation events. Water quantity is being measured at tributary locations and a rain gage is deployed in the watershed to record precipitation amounts.

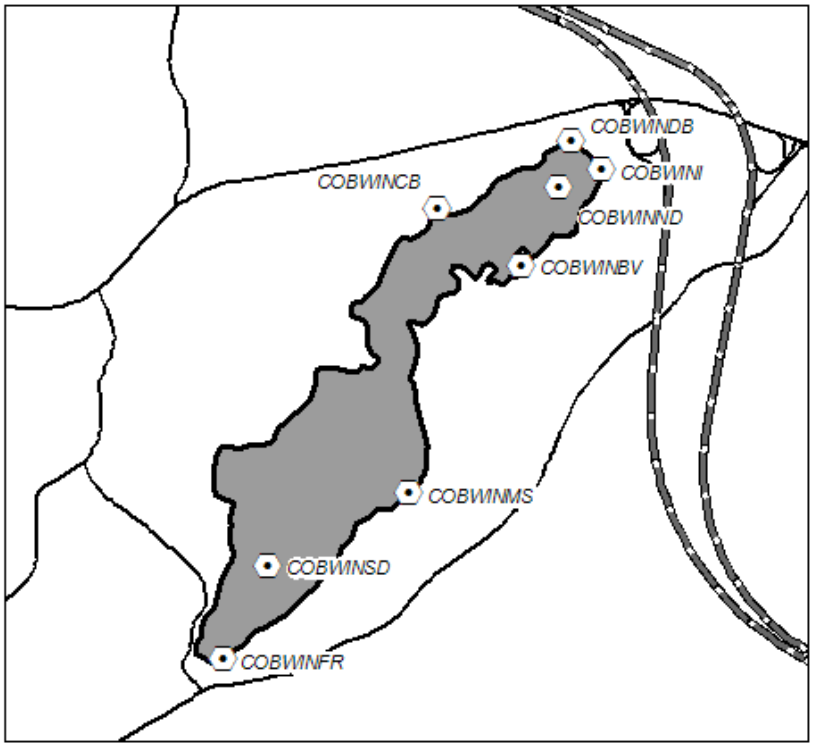
The following tasks pertaining to water quality and flow monitoring were completed during the month of October:

Monthly Dry-weather Water Quality Sampling (10/23/2009): A dry weather sampling event was conducted at the deep spot and tributary locations.

Wet--weather Water Quality Sampling (10/24/2009): A wet weather sampling event was conducted at the tributary locations. In-situ water quality parameters were measured and total phosphorus samples were collected.

Retrieval of Discharge/Precipitation Data (10/24/2009): Water level data were collected at all of the tributary locations. Due to memory limitations, the water quantity data since the last collection date on 9/17/09 is only partial. Precipitation data were collected from local weather stations (the gage at Armstrong Road lost power during this time period). This period of data covers 10/13/2009 to 10/24/2009.

Figure 1 and Table 1 below show the monitoring locations and their identification codes. Figure 2 shows the results of water quantity monitoring at the tributary locations, along with a plot of precipitation intensity. Figure 3 presents the results of in-situ water quality profiles at the in-lake deep spot monitoring locations. Table 2 presents the results of the wet-weather sampling, and Tables 3 and 4 provide further water quality monitoring results. A brief description of the various parameters measured in this study is provided at the end of this document.



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Bella Vista Road Inlet	COBWINBV
Castleton Brook Inlet	COBWINI
Dinsmore Brook Inlet	COBWINB
Connies Brook Inlet	COBWINCB

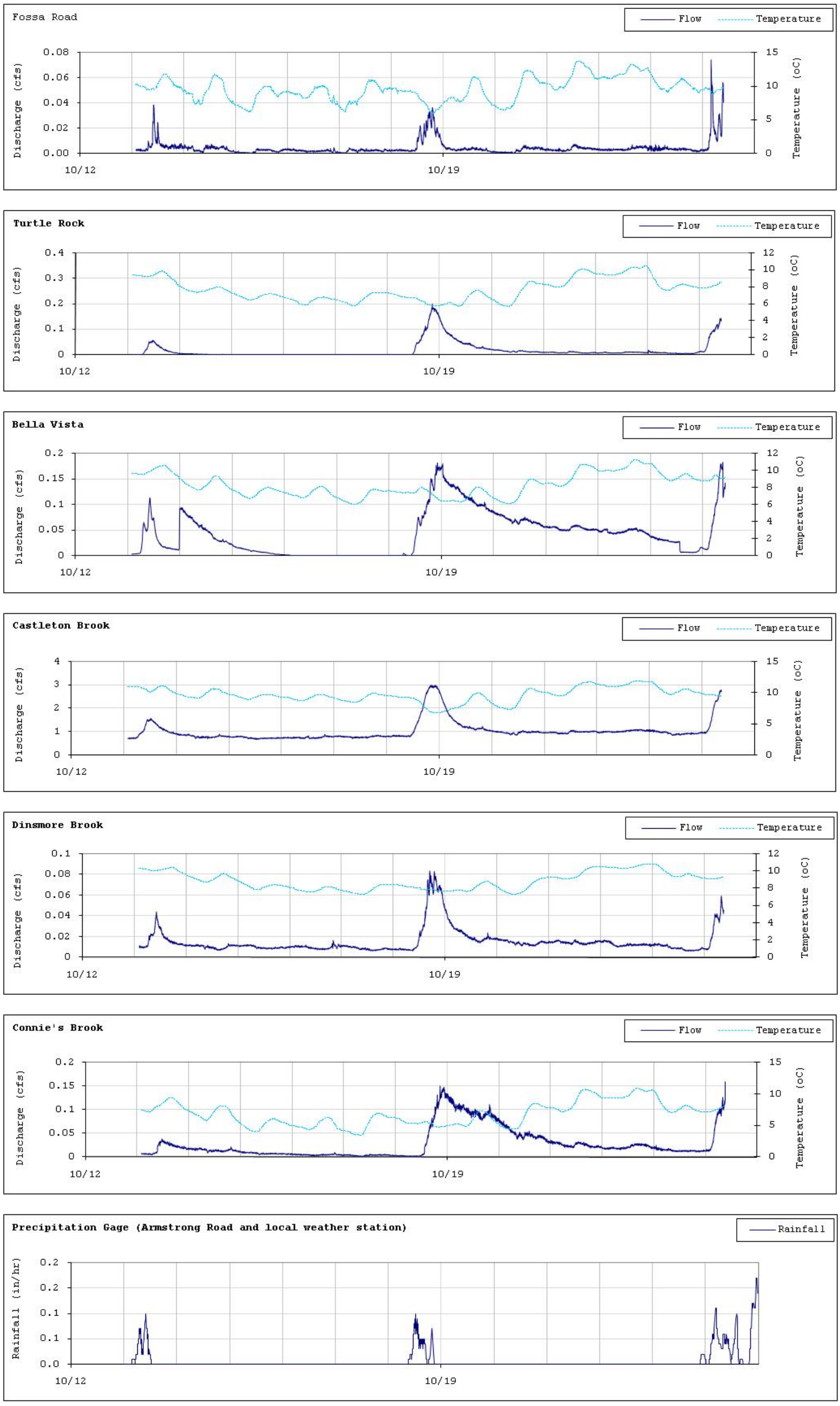
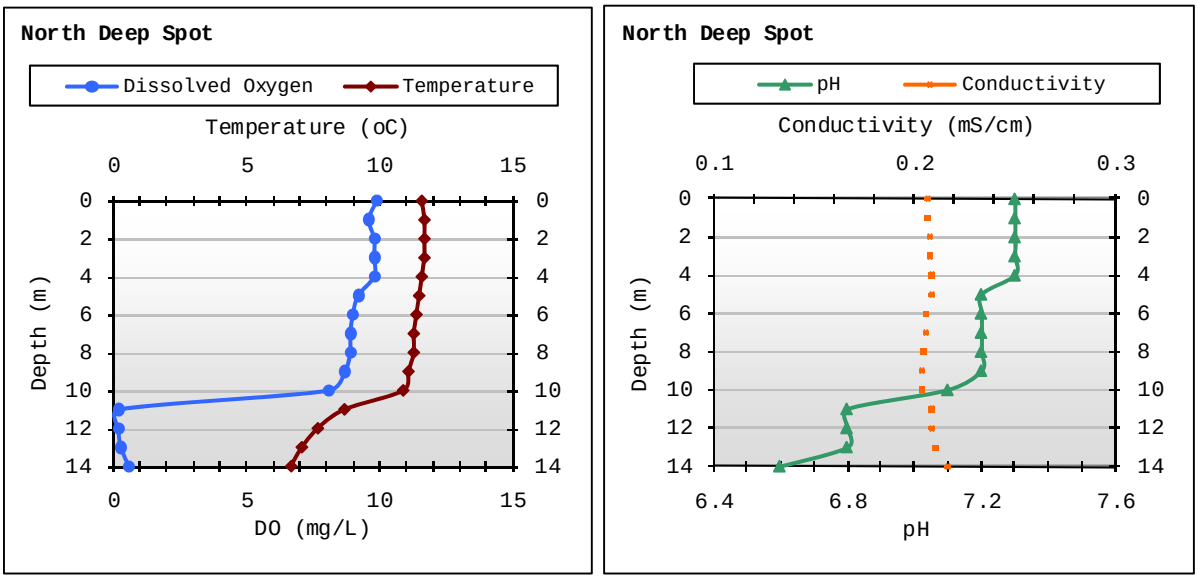
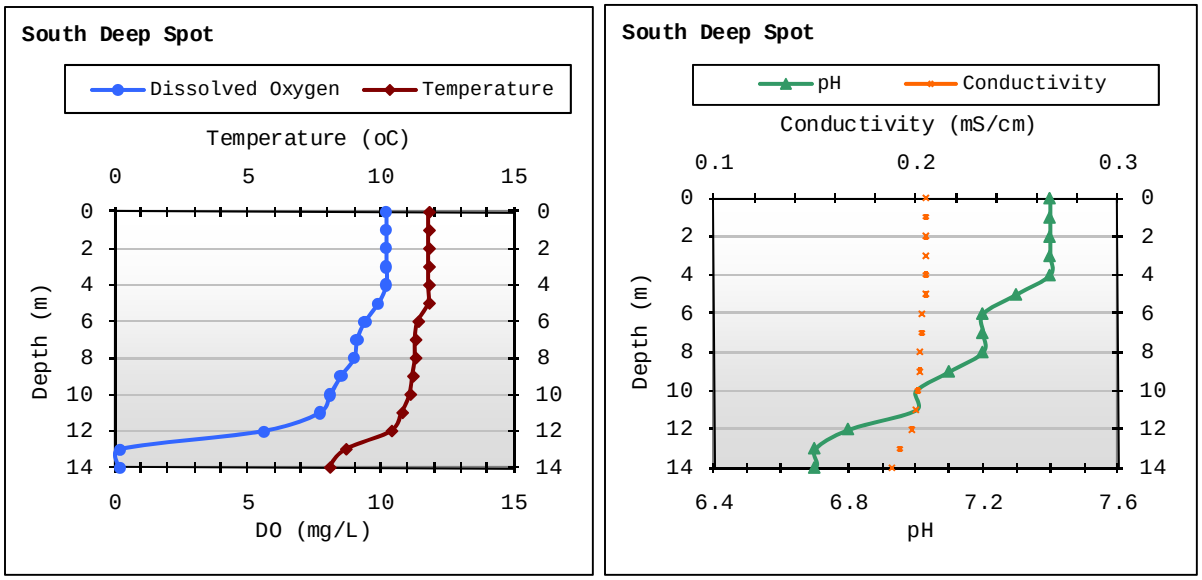


Figure 2. Discharge and Temperature monitoring for Cobbett's Pond Tributaries (10/13/2009-10/24/2009)



(North Deep Spot Secchi Disk Transparency = 8.0')



(South Deep Spot Secchi Disk Transparency = 7.0')

Figure 3. Deep Spot location water quality profiles (8/20/2009)

Table 2. Wet Weather Tributary in-situ water quality and Total Phosphorus results (10/24/2009).

Site	Temperature (oC)	Conductivity (mS/cm)	DO (mg/L)	pH	Turbidity (NTU)	Total Phosphorus (mg/L)
COBWINFR	9.8	0.132	9.9	6.6	7	0.071
COBWINMS	8.6	0.325	11.5	7.0	3	0.025
COBWINBV	9.3	0.310	10.7	7.0	68	0.058
COBWINI	8.8	0.298	10.5	7.8	4.7	0.020
COBWINDB	9.3	0.460	9.6	7.2	1.6	0.021
COBWINCB	8.2	0.315	11.1	7.3	1.7	0.016

Table 2. Dry Weather Tributary in-situ water quality results (10/23/2009).

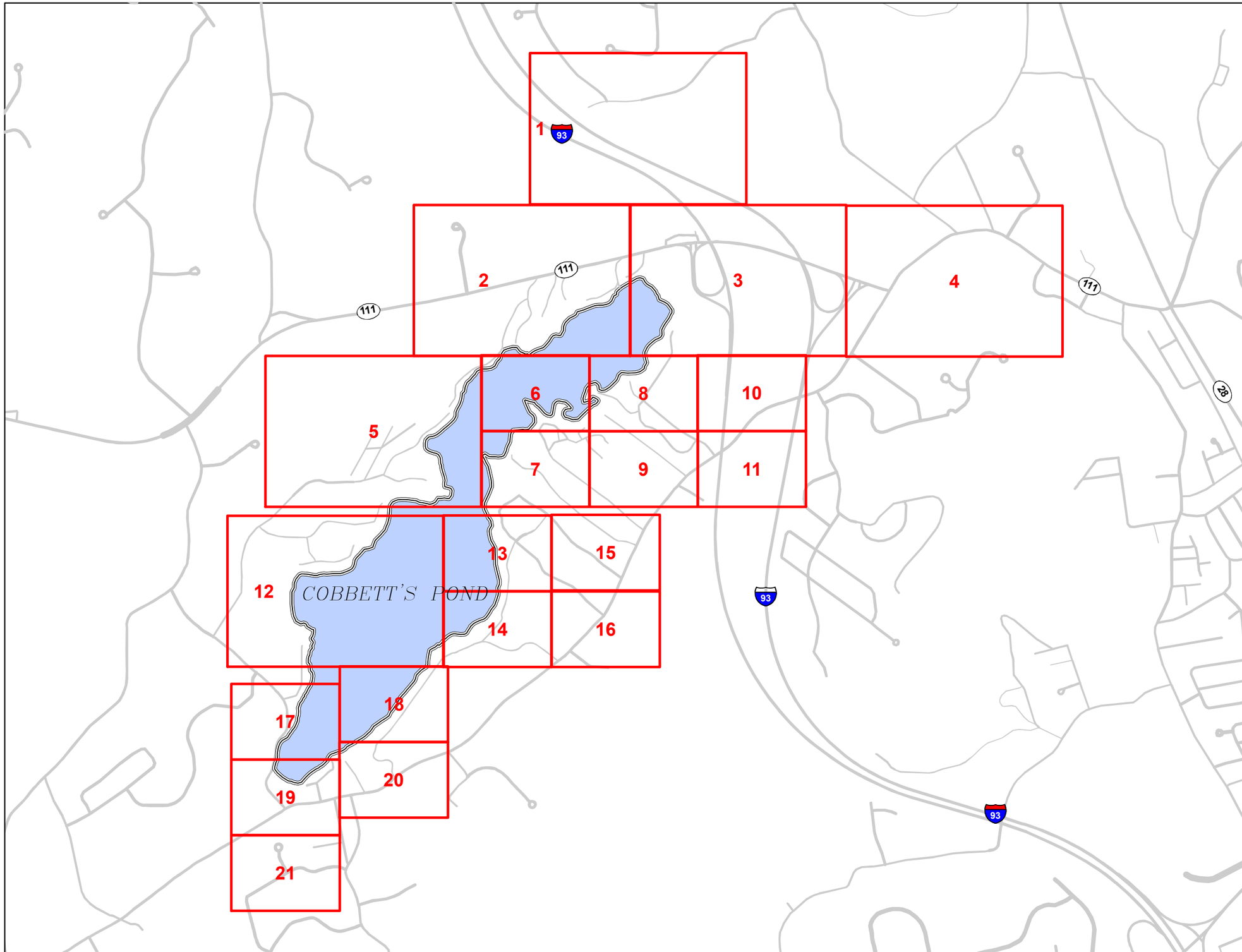
Site	Temperature (oC)	Conductivity (mS/cm)	DO (mg/L)	pH	Turbidity (NTU)
COBWINFR	11.6	0.319	8.7	6.9	1.3
COBWINMS	8.1	0.341	11.2	7.2	5.8
COBWINBV	9.4	0.291	9.6	7.2	0.1
COBWINI	9.9	0.482	8.3	6.9	1.9
COBWINDB	9.5	0.560	9.9	7.0	3.3
COBWINCB	8.2	0.480	11.0	7.3	0.1

Table 3. Dry Weather Total Phosphorus and Chlorophyll-a sampling results (10/23/2009).

Site	Depth	Date	Event	TP (mg/L)	Chlor-a (ug/L)
COBWINND	COMPOSITE	10/30/2009	Dry	-	2.78
COBWINND	13	10/23/2009	Dry	0.02	-
COBWINND	7	10/23/2009	Dry	0.015	-
COBWINND	0	10/23/2009	Dry	0.012	-
COBWINND	BLANK	10/23/2009	Dry	-	-
COBWINSD	COMPOSITE	10/30/2009	Dry	-	3.27
COBWINSD	13	10/23/2009	Dry	0.023	-
COBWINSD	7	10/23/2009	Dry	0.009	-
COBWINSD	0	10/23/2009	Dry	0.031	-
COBWINBV	DUP	10/23/2009	Dry	0.012	-
COBWINBV	0	10/23/2009	Dry	0.0093	-
COBWINCB	0	10/23/2009	Dry	0.0099	-
COBWINDB	0	10/23/2009	Dry	0.031	-
COBWINFR	0	10/23/2009	Dry	0.057	-
COBWINI	0	10/23/2009	Dry	0.014	-
COBWINMS	0	10/23/2009	Dry	0.024	-

Appendix B:

Stormwater Infrastructure Maps



NORTH

0 750 1,500 3,000 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

INDEX

Geosyntec consultants

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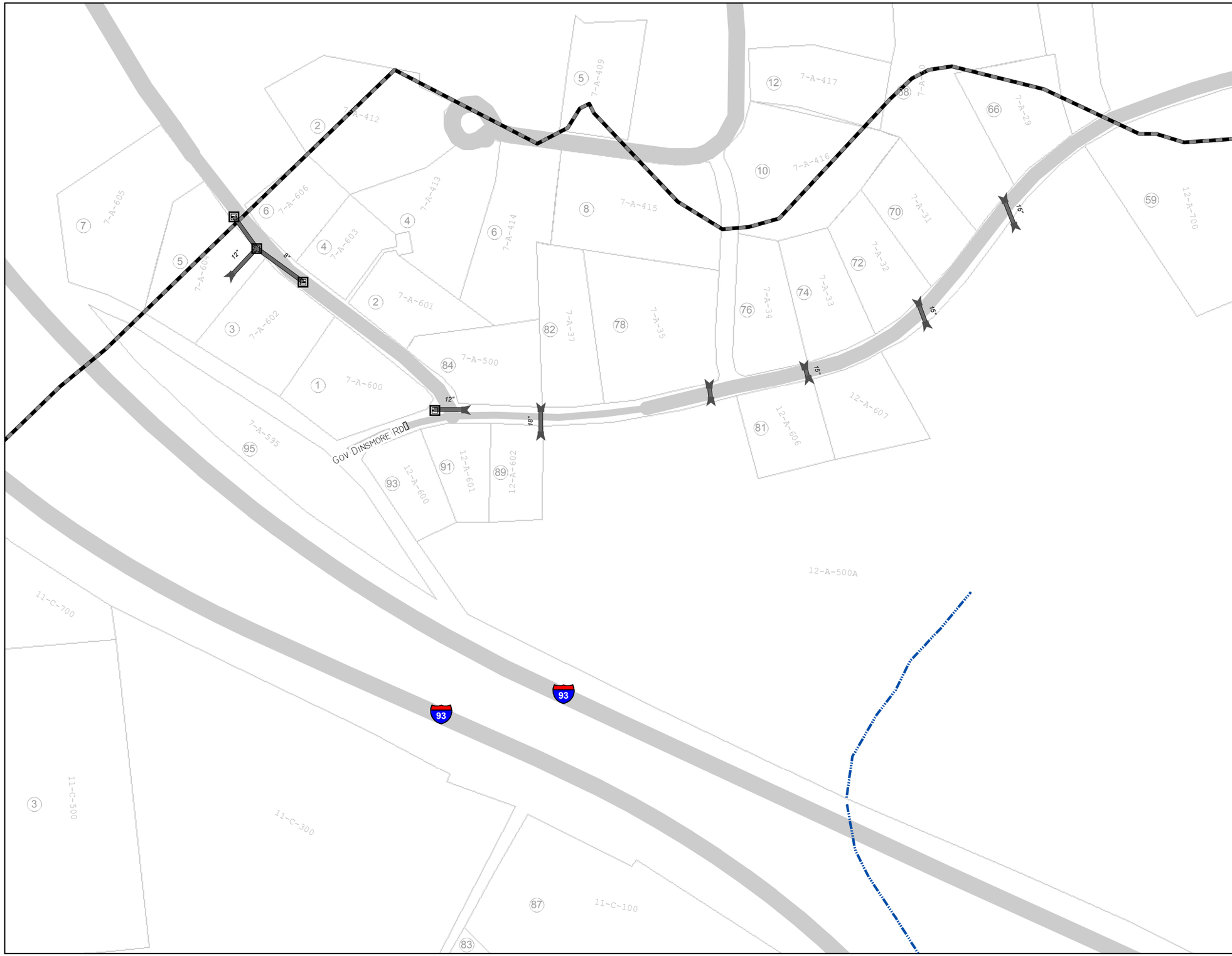

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 125 250 500 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 01

Geosyntec consultants

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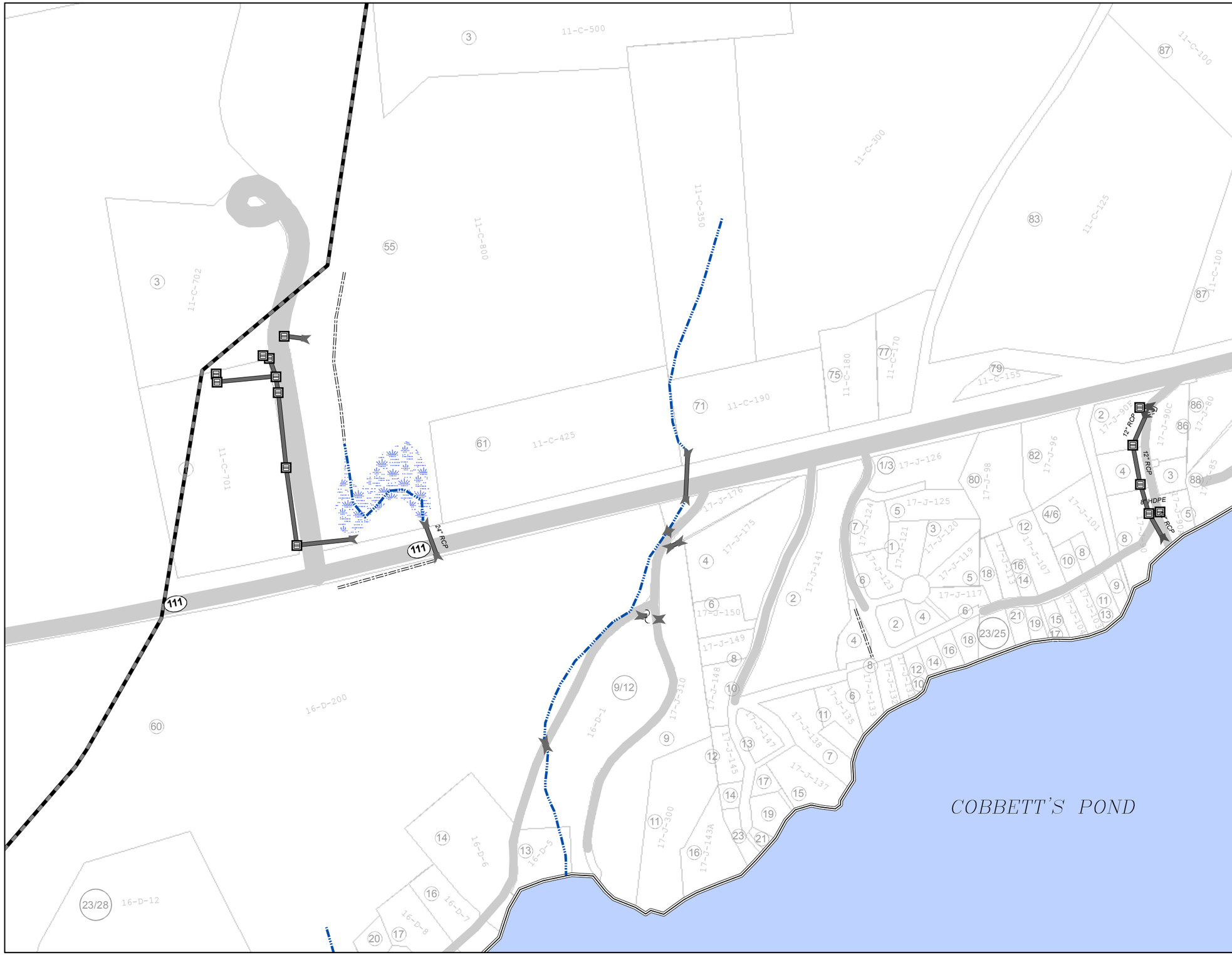

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 125 250 500 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 02

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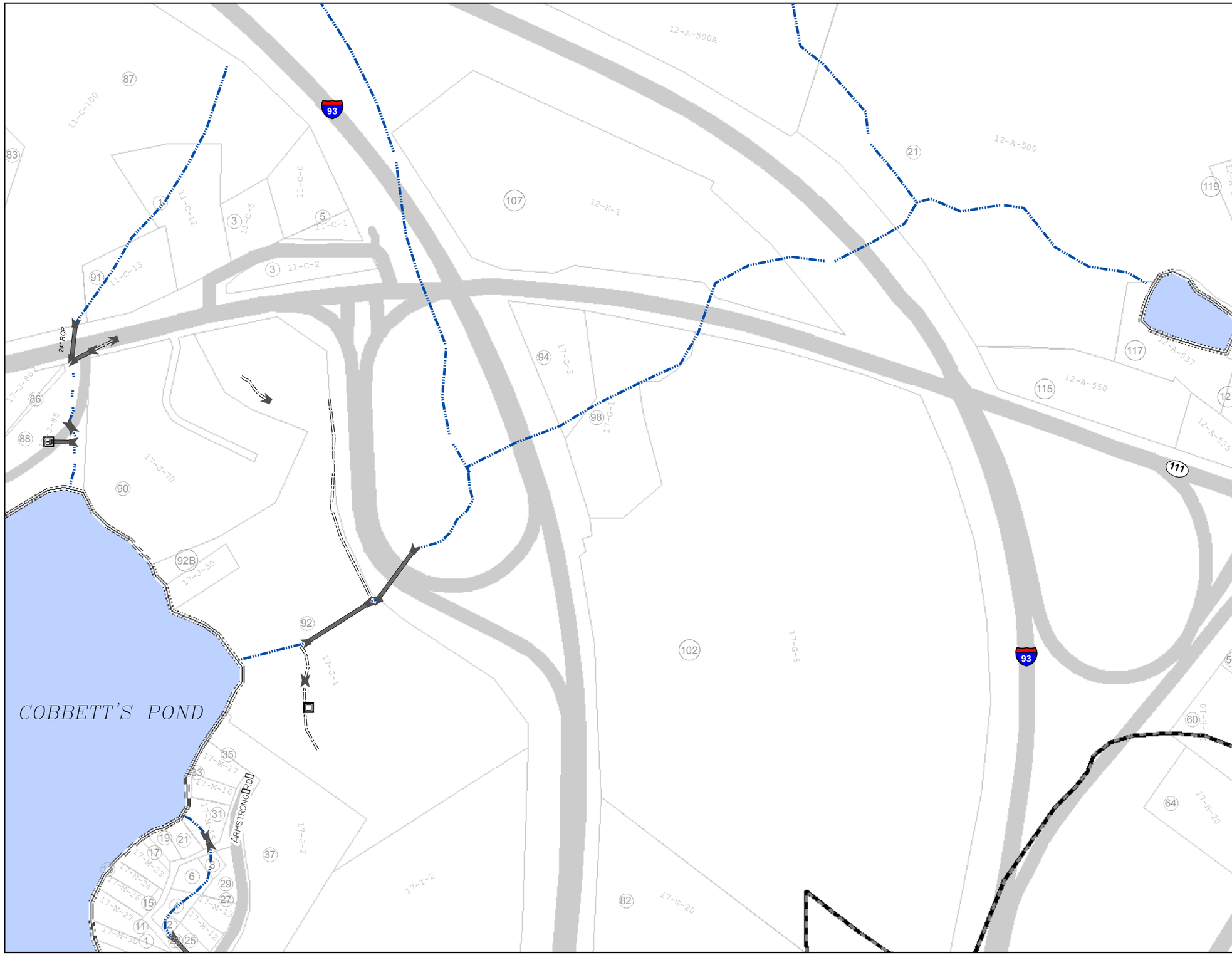

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- <all other values>
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 130 260 520 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 03

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NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- <all other values>
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 130 260 520 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 04

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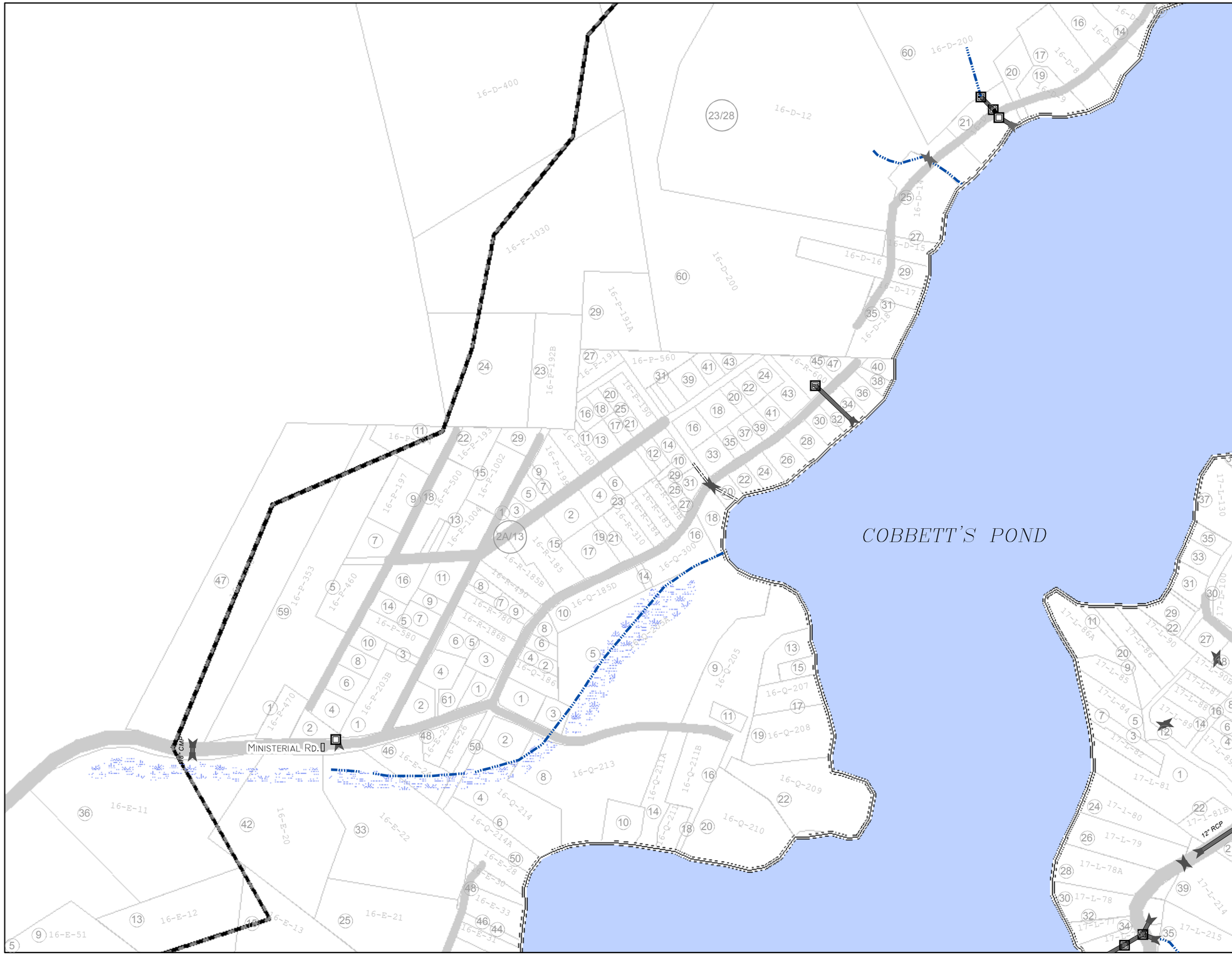

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- <all other values>
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 130 260 520 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 05

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NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 06

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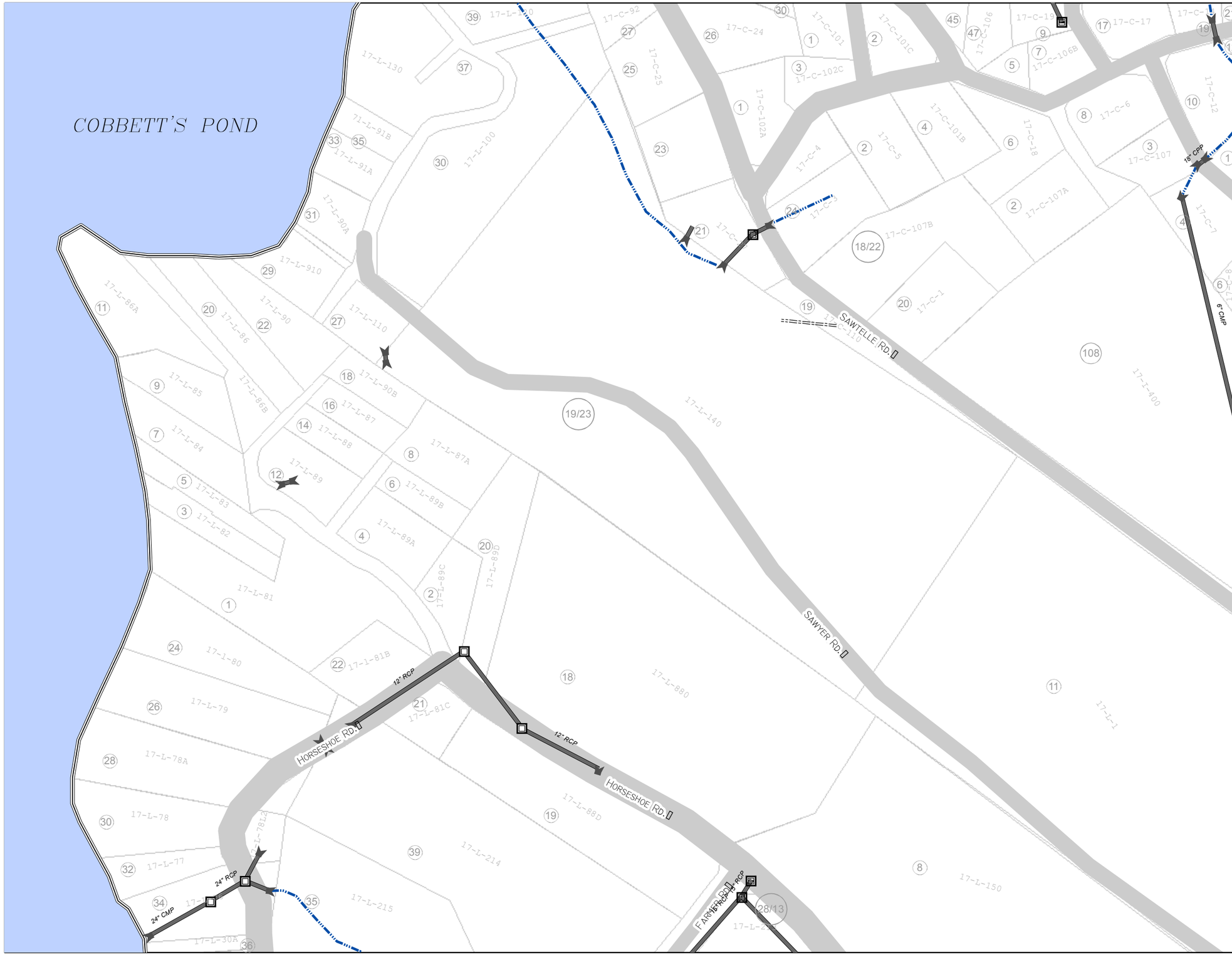

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 07

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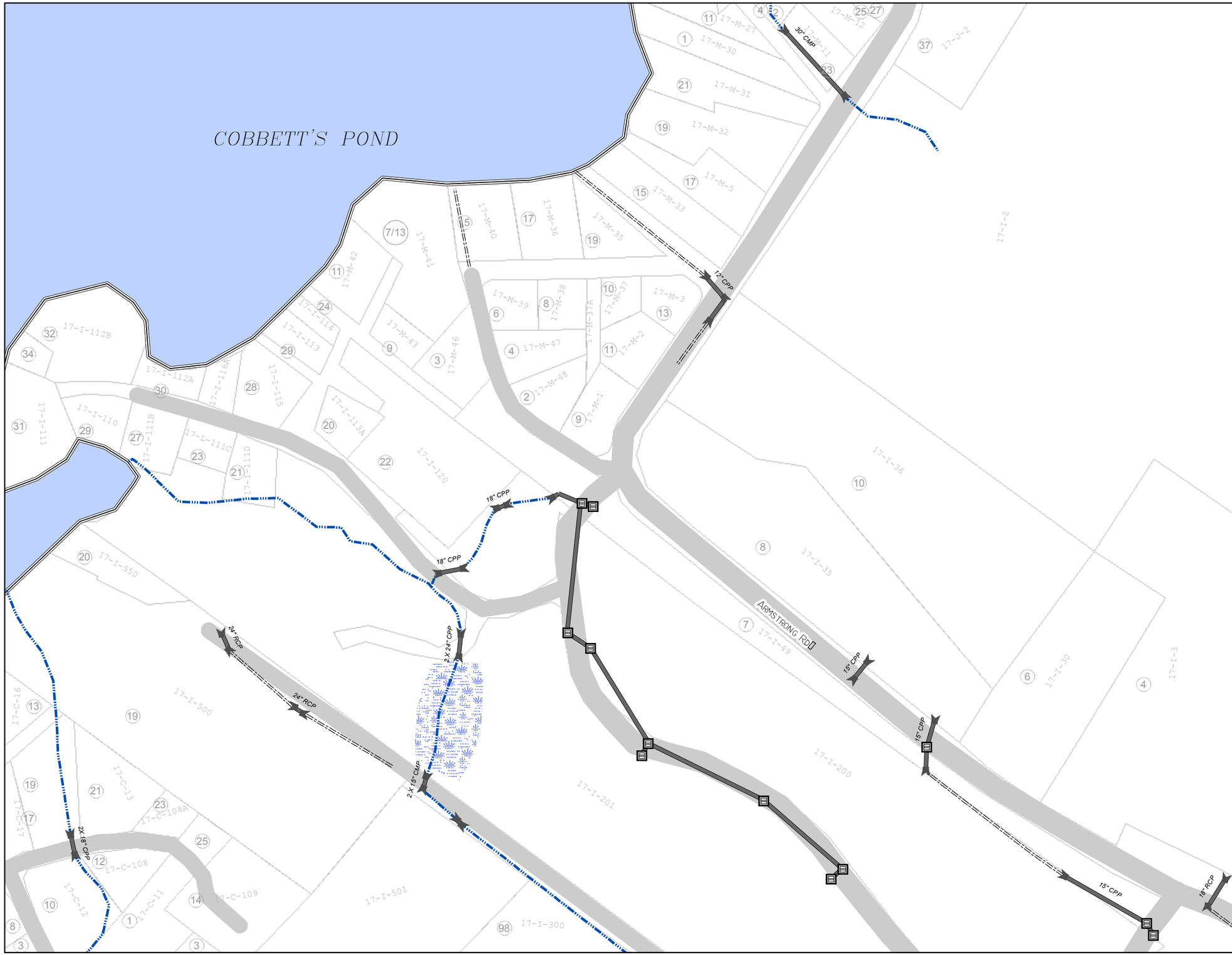

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 08

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NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 09

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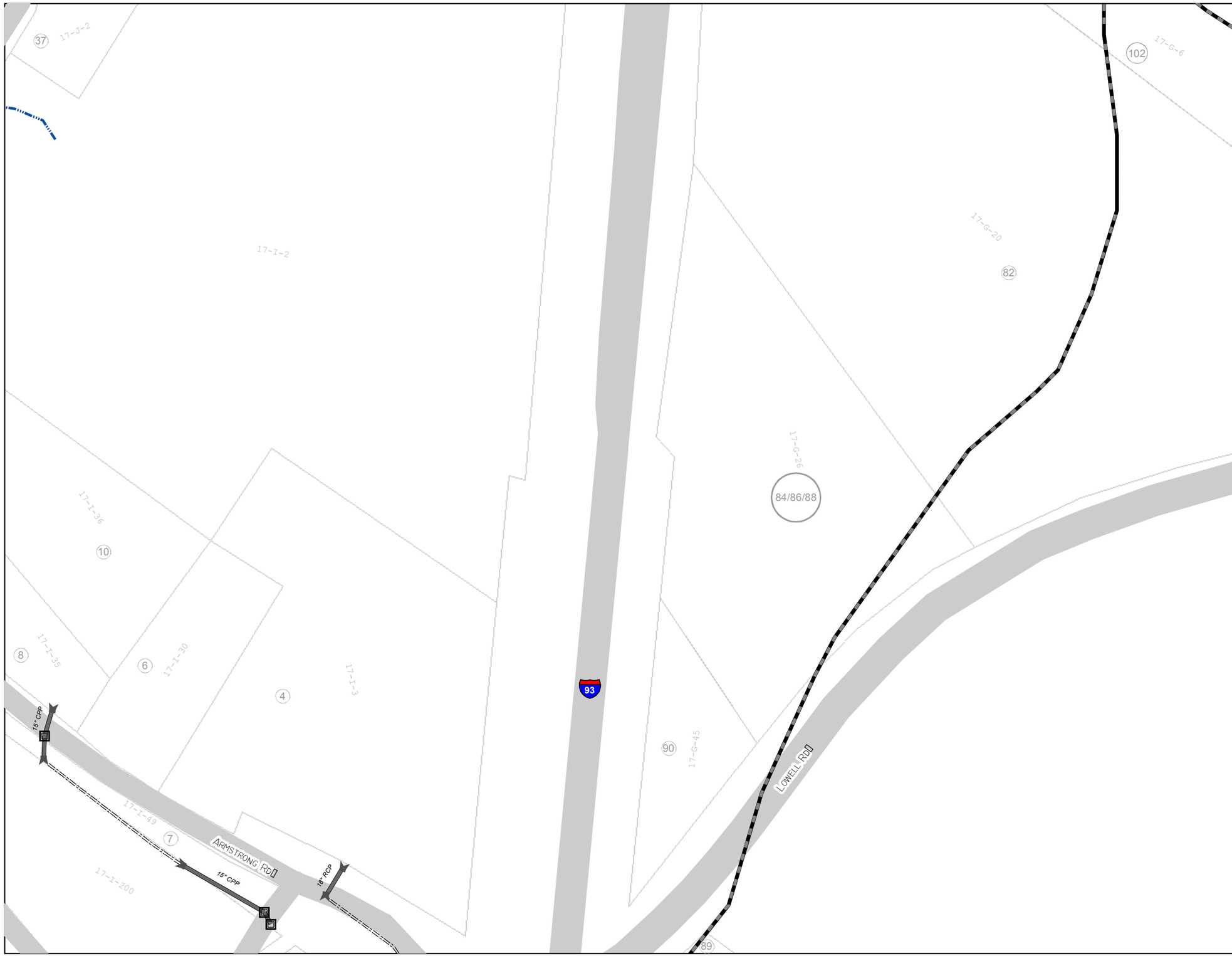

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 10

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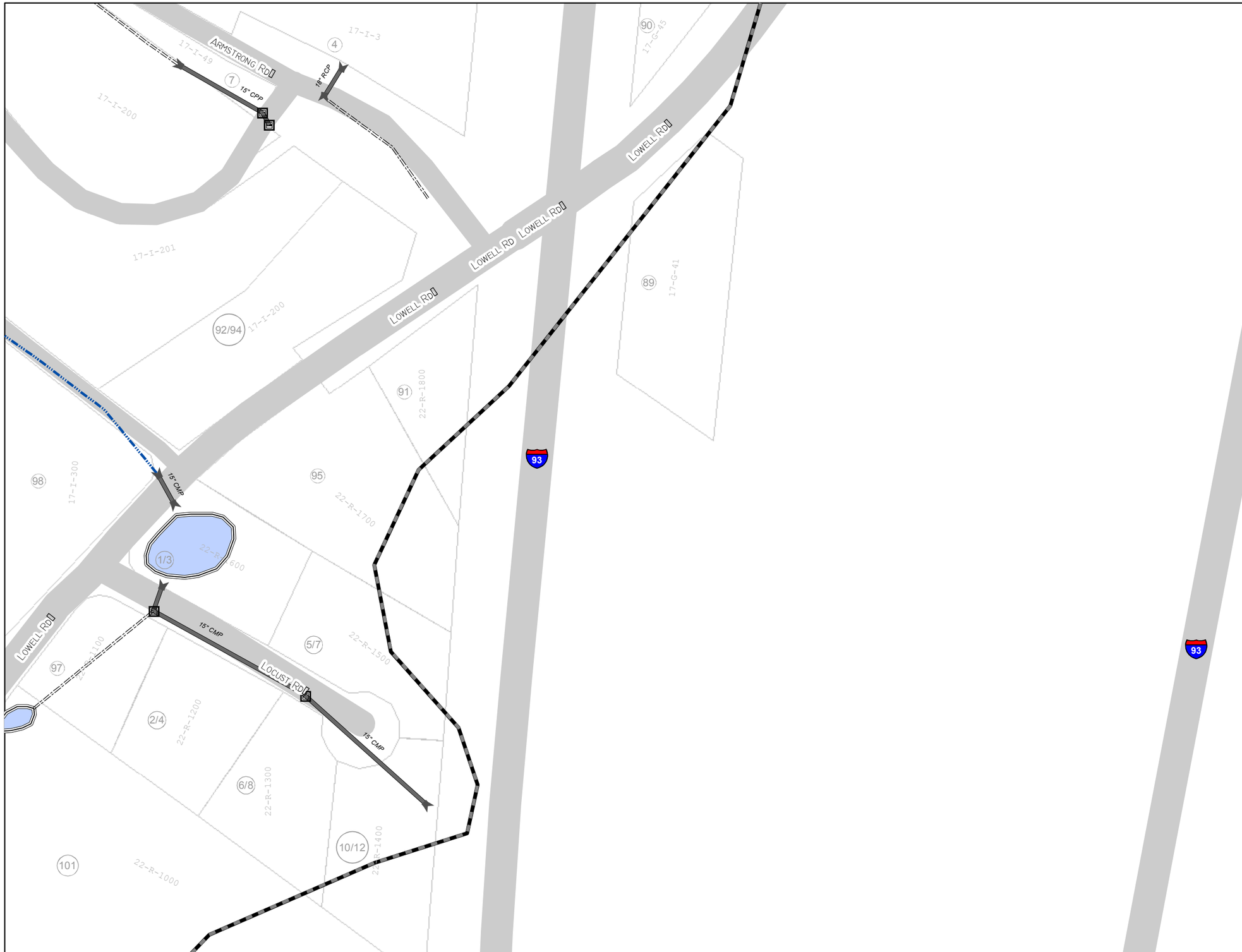

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 11

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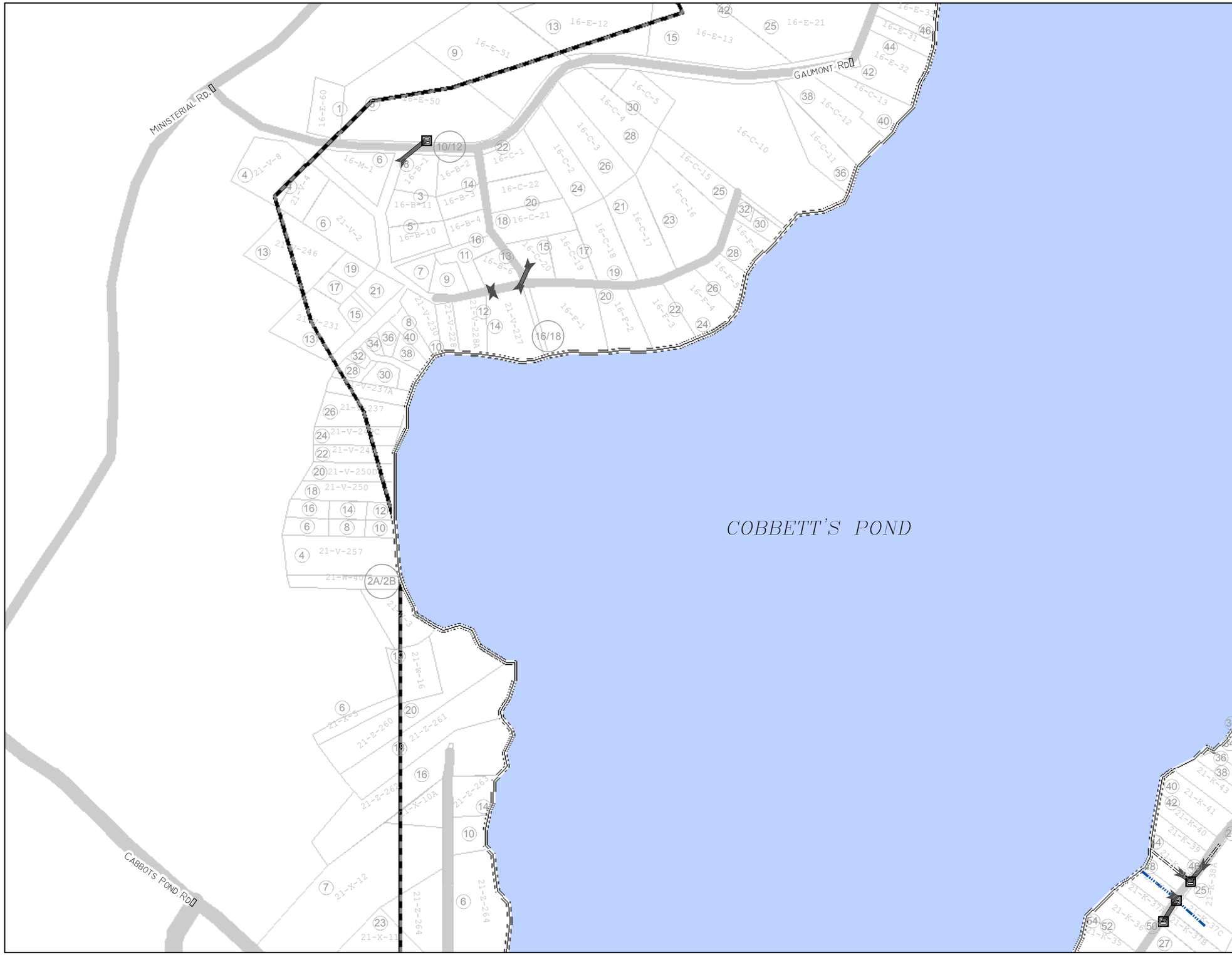

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- <all other values>
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 125 250 500 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 12

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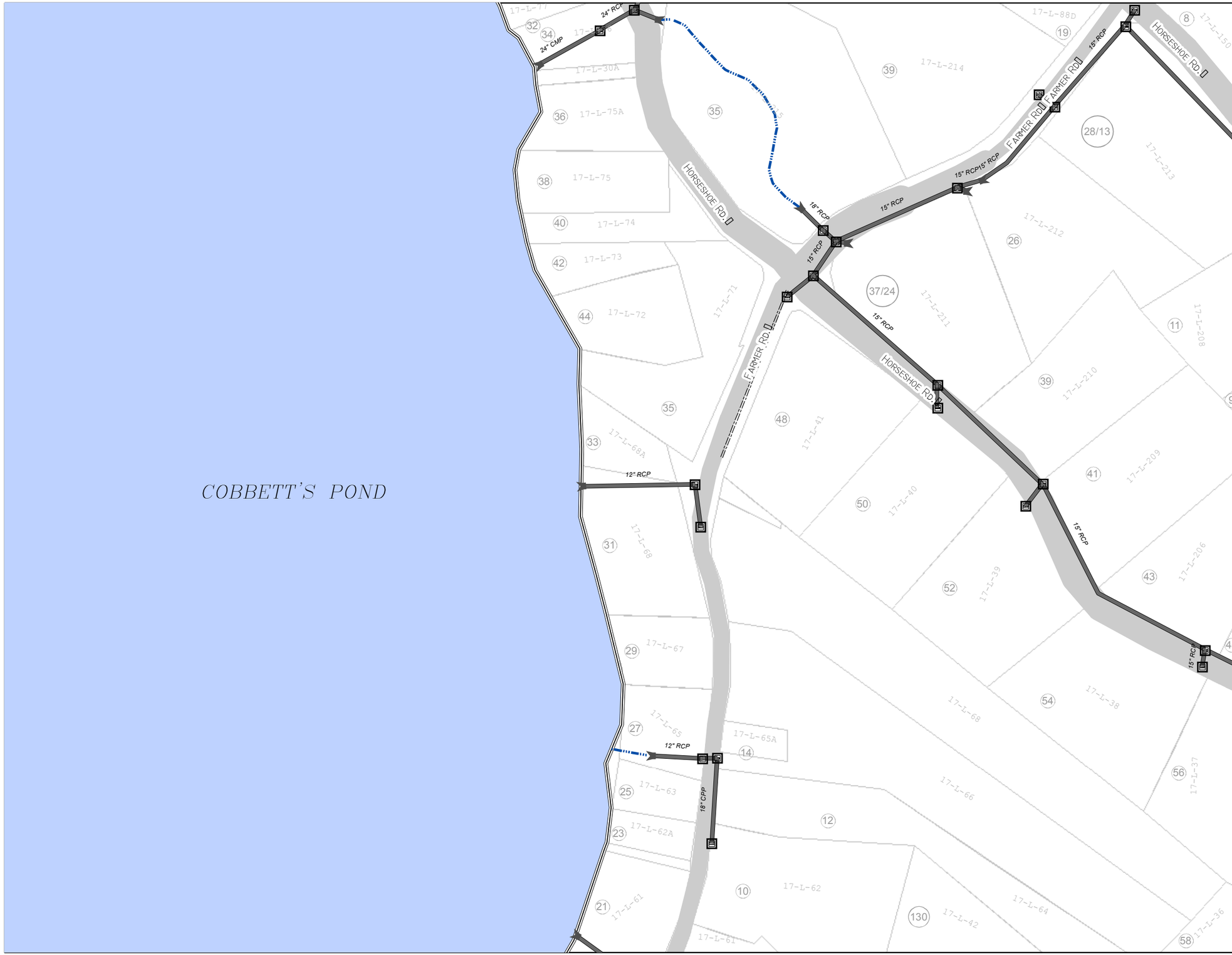

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 13

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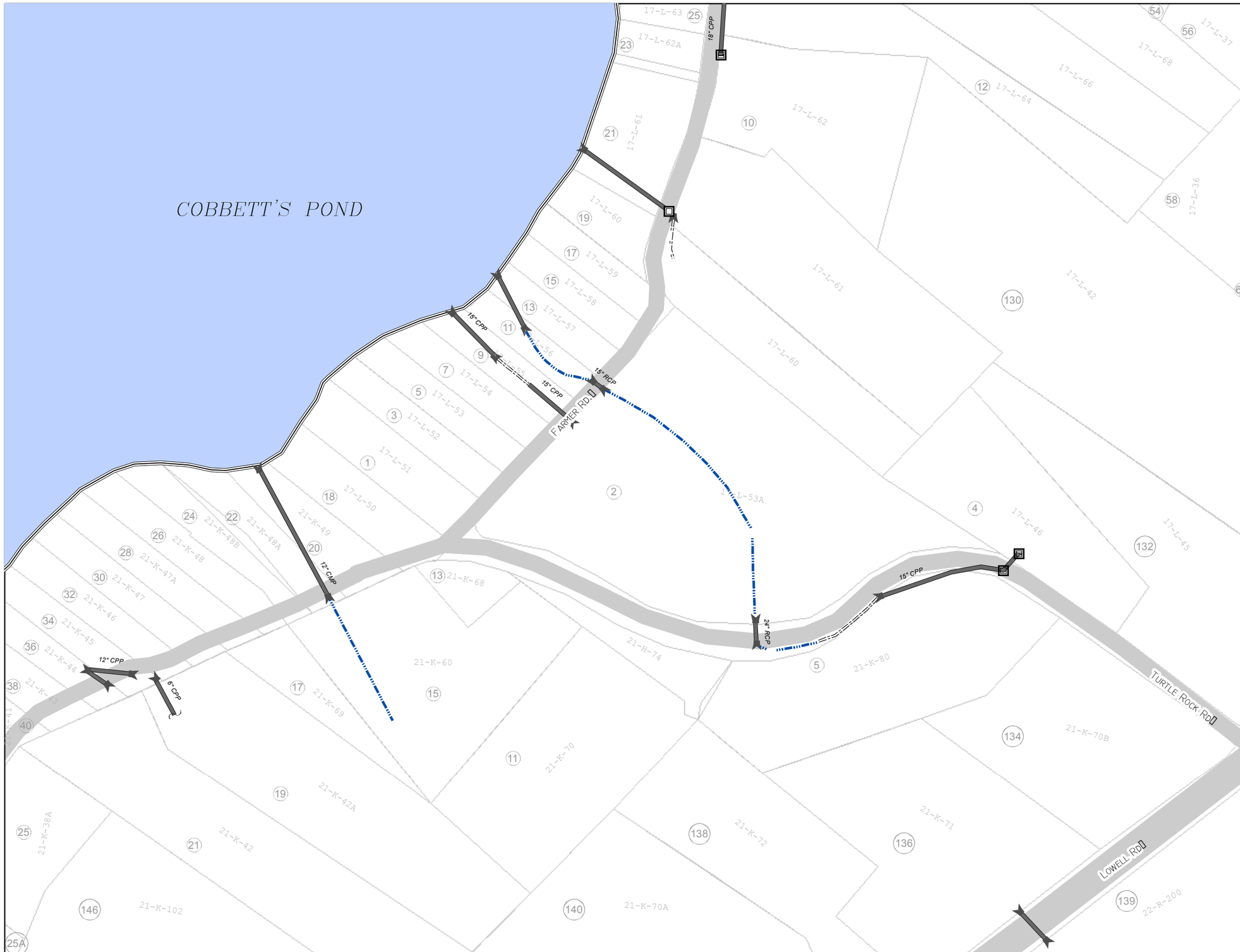

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 14

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NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 15

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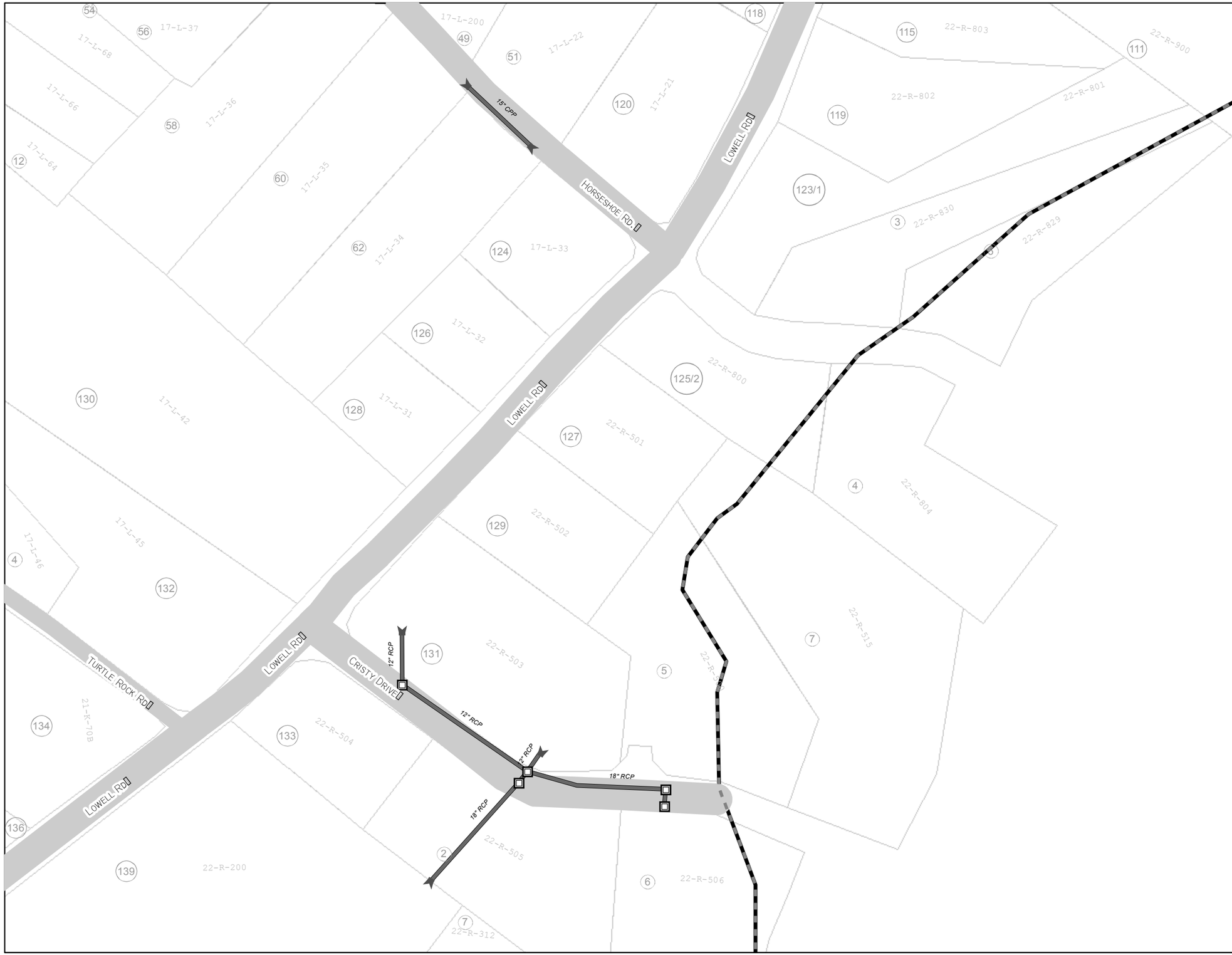

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 16

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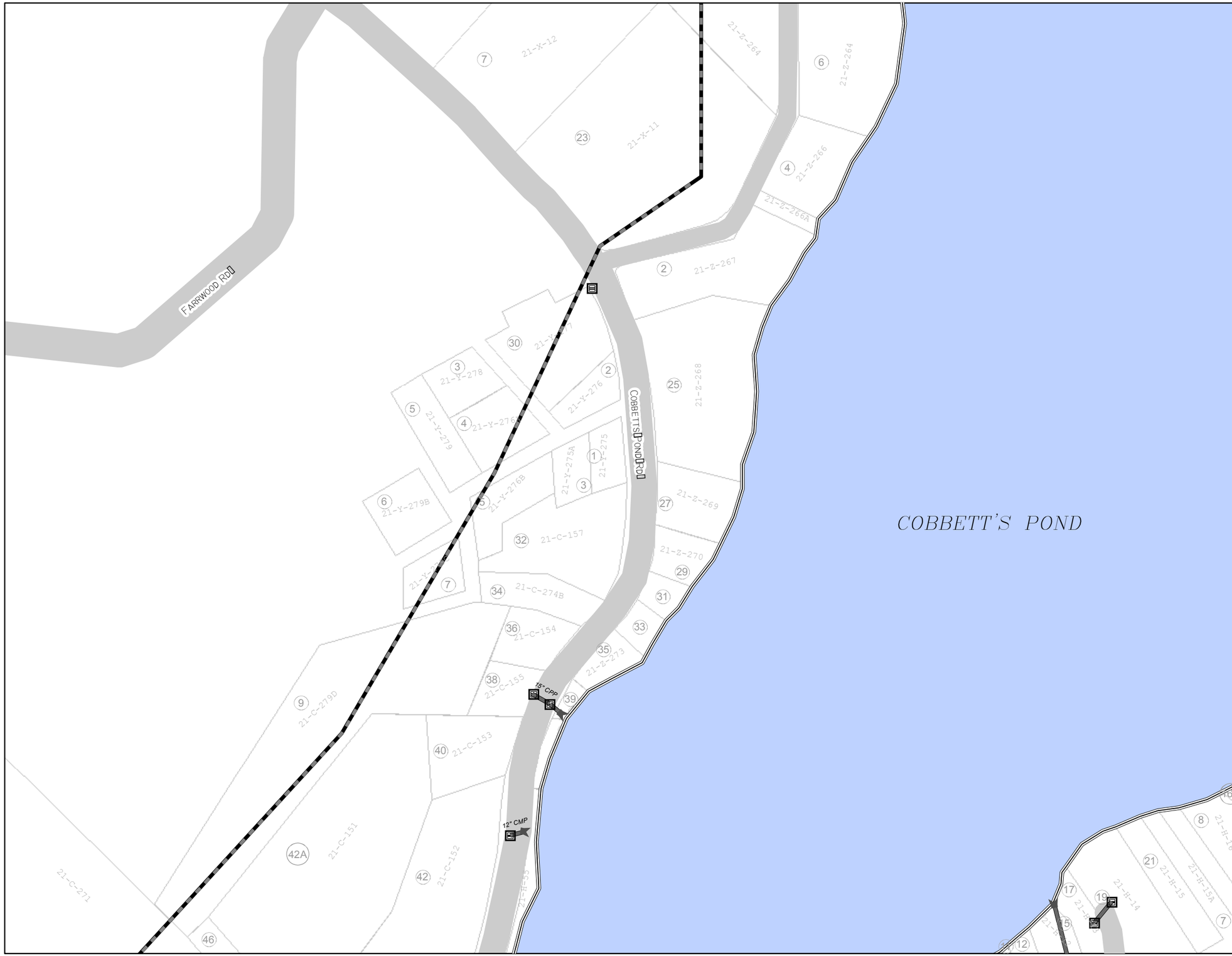

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 17

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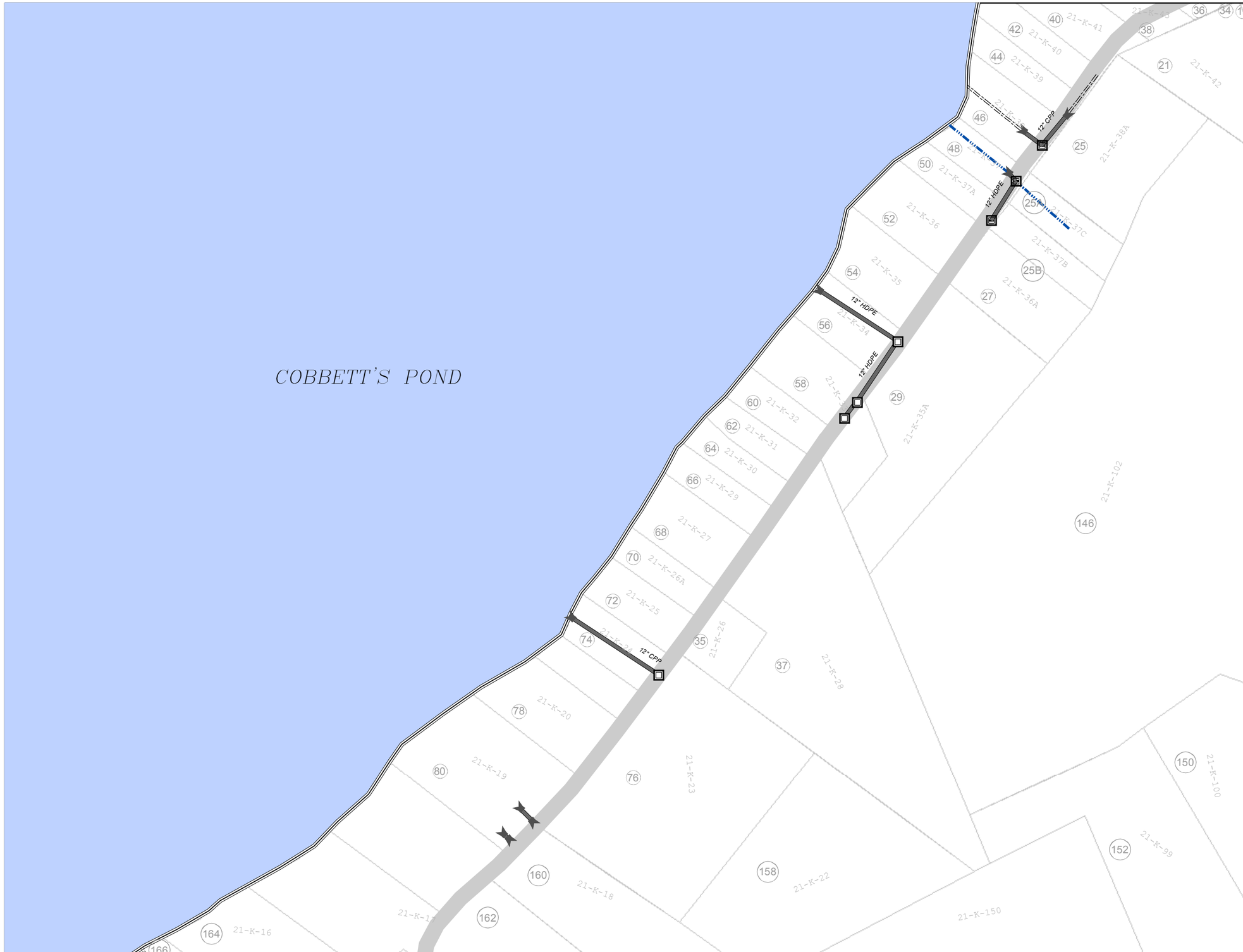

NORTH

Legend

- ▣ Catch Basin
- ➤ Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300
Feet

COBBETT'S POND
STORMWATER
INFRASTRUCTURE

MAP ID: 18

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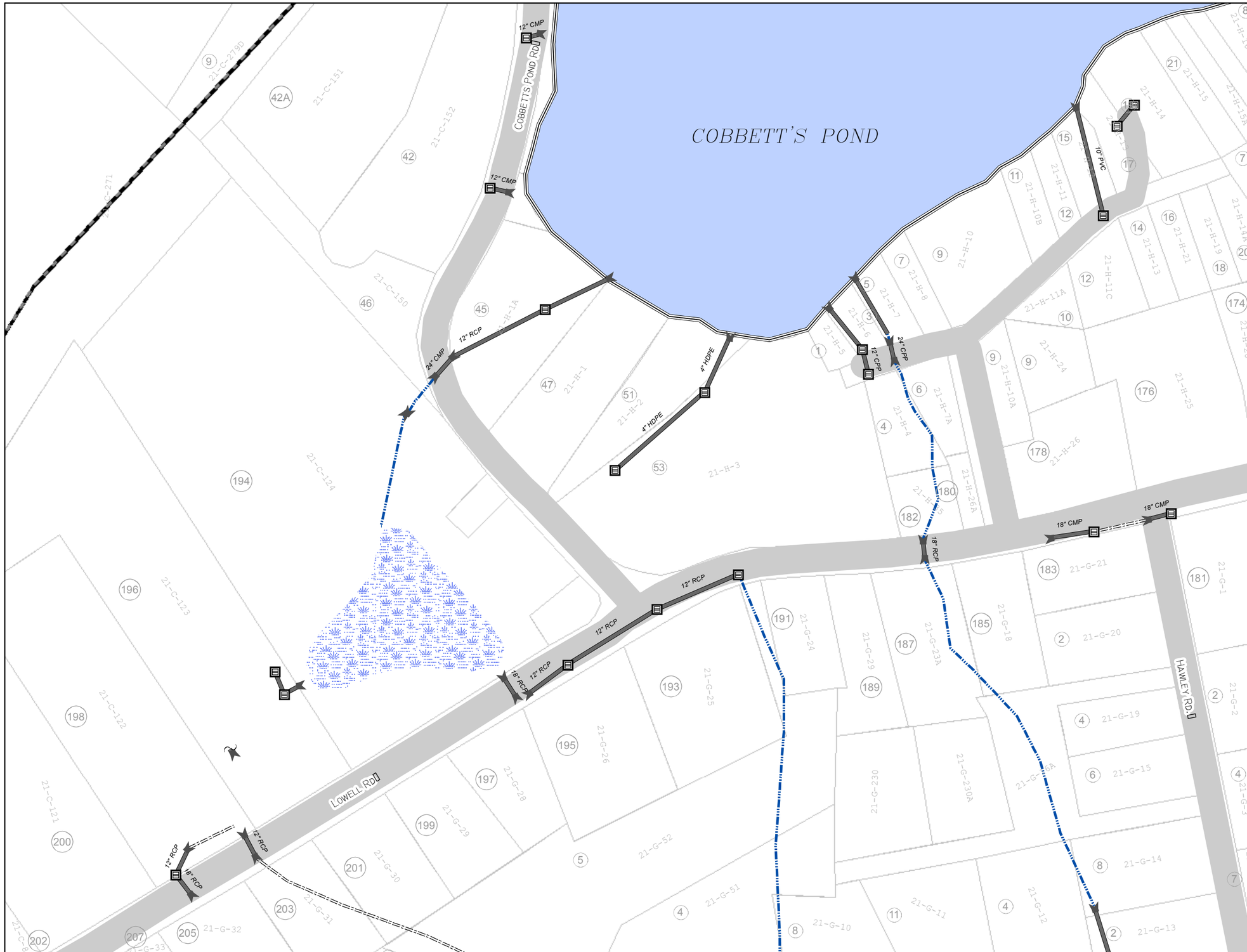

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 19

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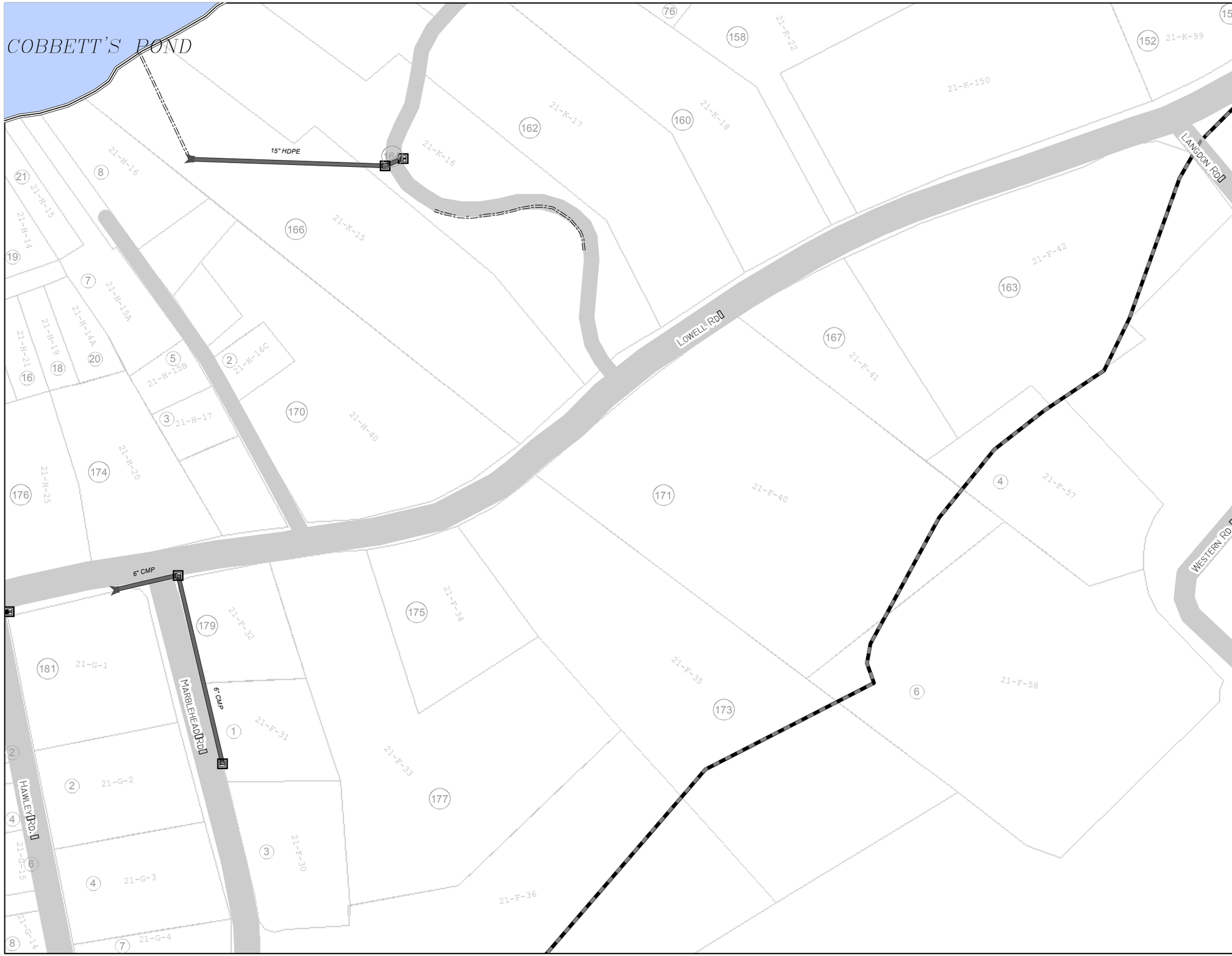

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Pavement
- Watershed Boundary
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 20

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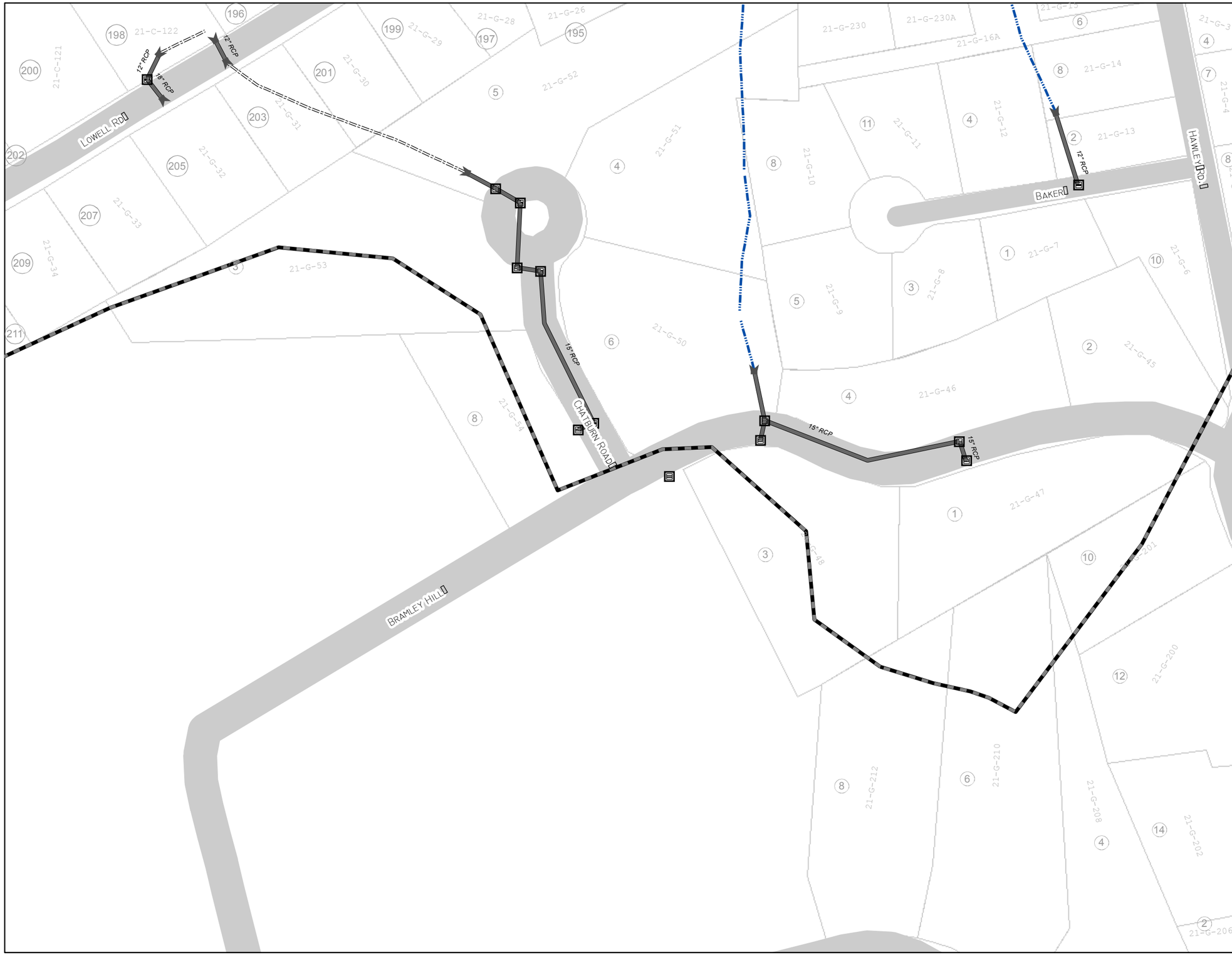

NORTH

Legend

- Catch Basin
- Culvert/Inlet/Outlet
- Drainage Swale
- Stream
- Drainage Pipe
- Pond
- Wetland
- Watershed Boundary
- Pavement
- Assessor's Parcels (approx.)

0 50 100 200 300 Feet

COBBETT'S POND STORMWATER INFRASTRUCTURE

MAP ID: 21

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Appendix C:

Septic System Inventory Maps

COBBETT'S POND WATERSHED RESTORATION PLAN

SEPTIC SYSTEM INVENTORY

Prepared for:

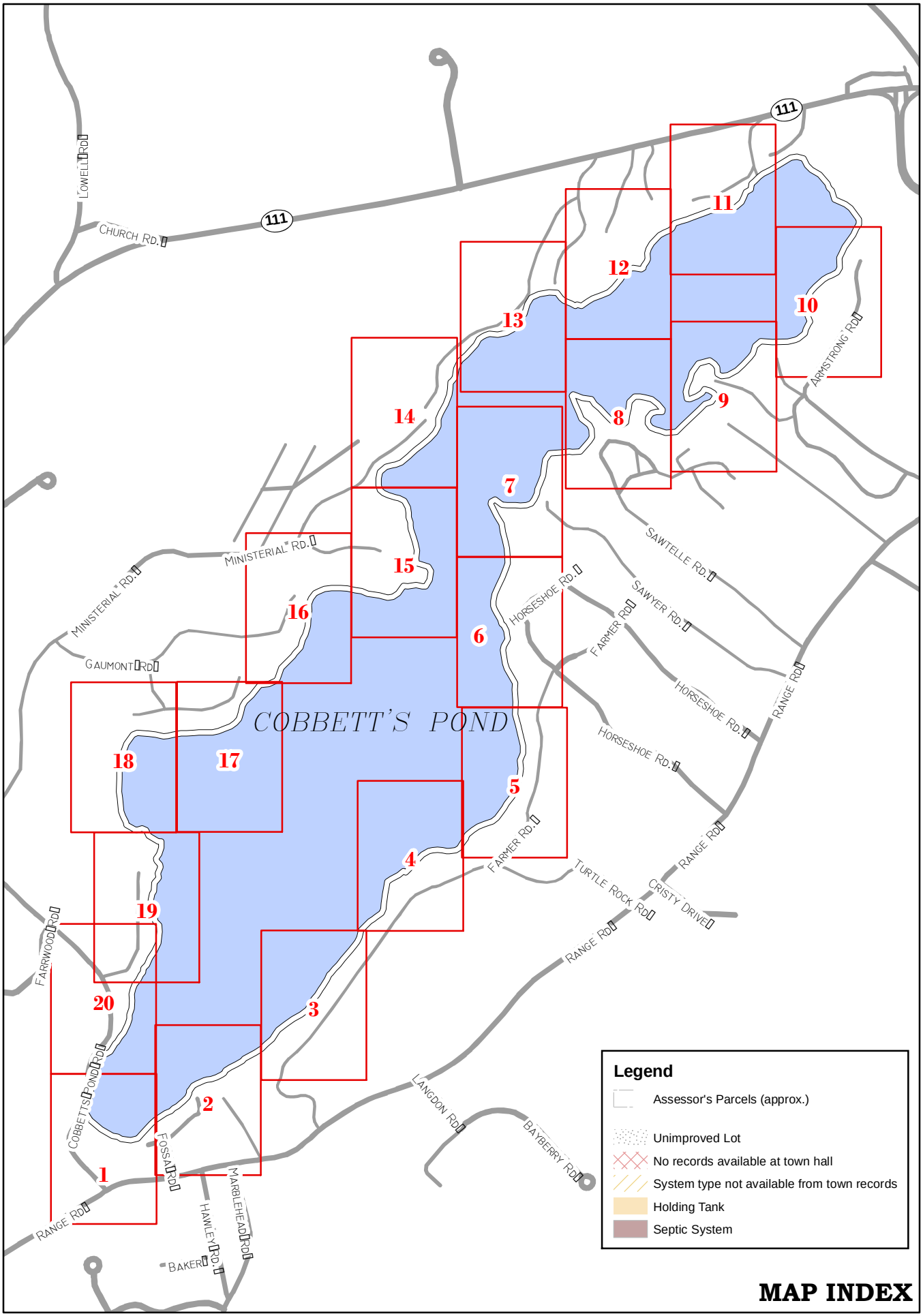
Cobbett's Pond Improvement Association
P.O. Box 192
Windham, NH 03087

Prepared by:

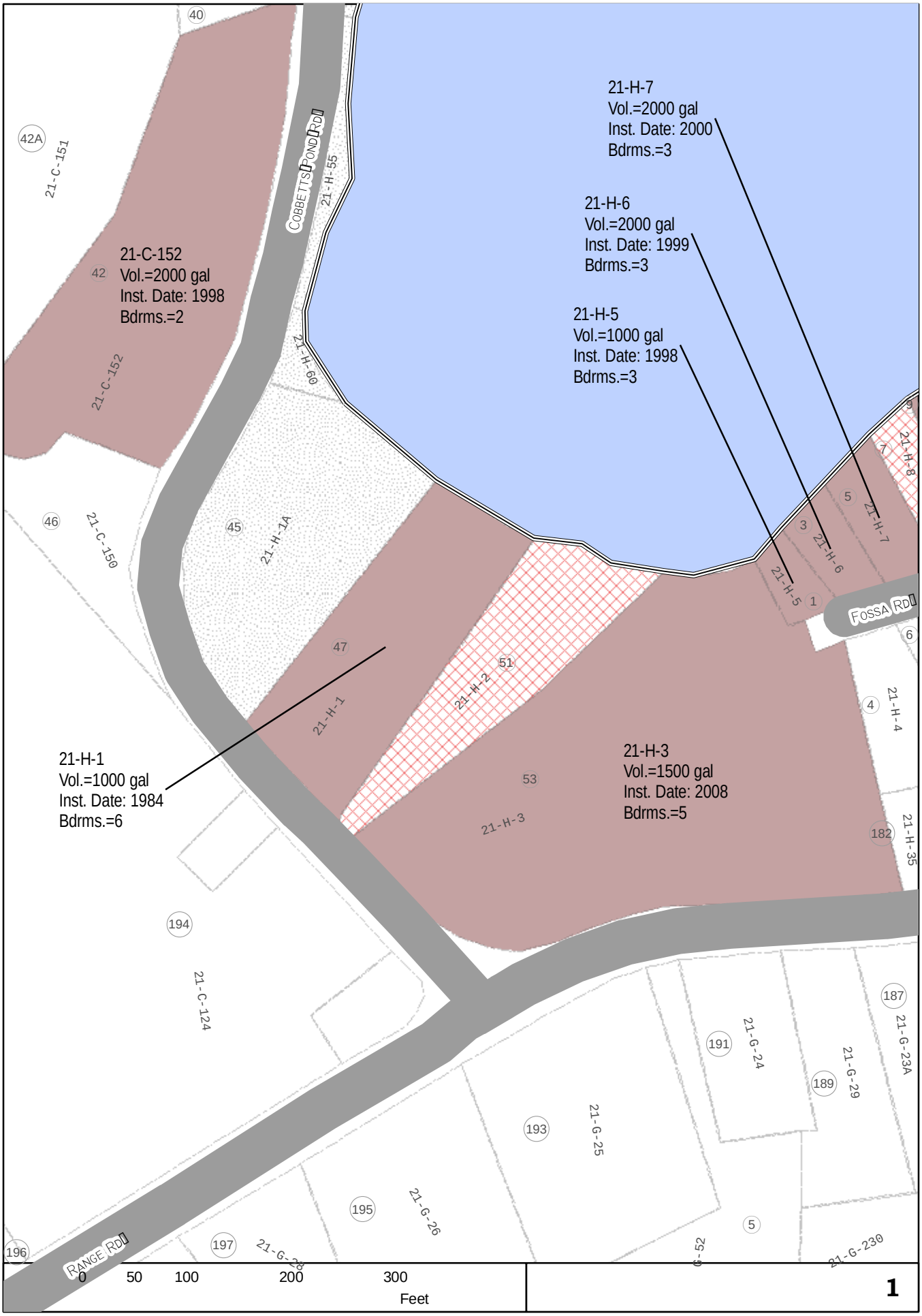
Geosyntec consultants
engineers | scientists | innovators

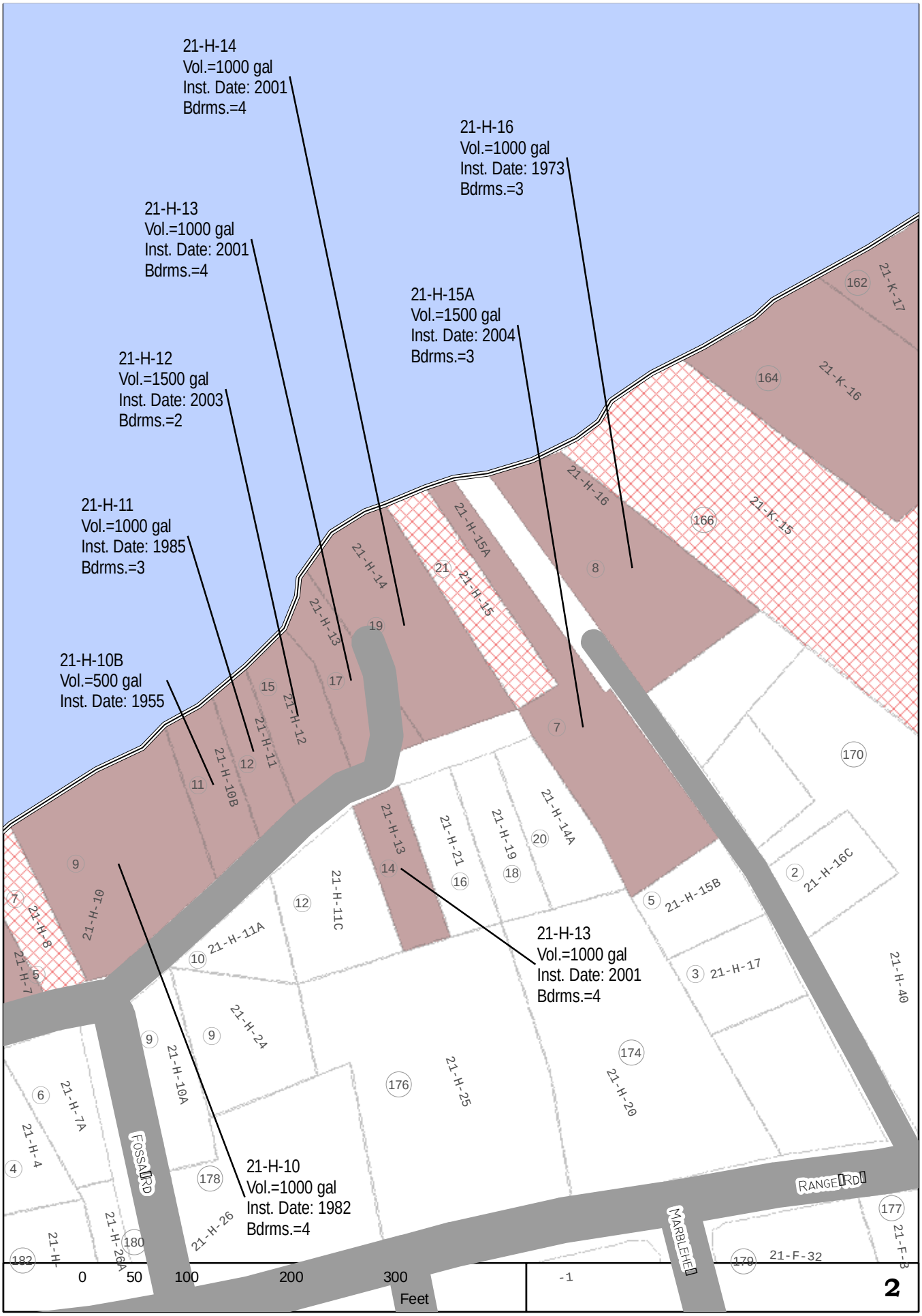
289 Great Road, Suite 105
Acton, MA 01720

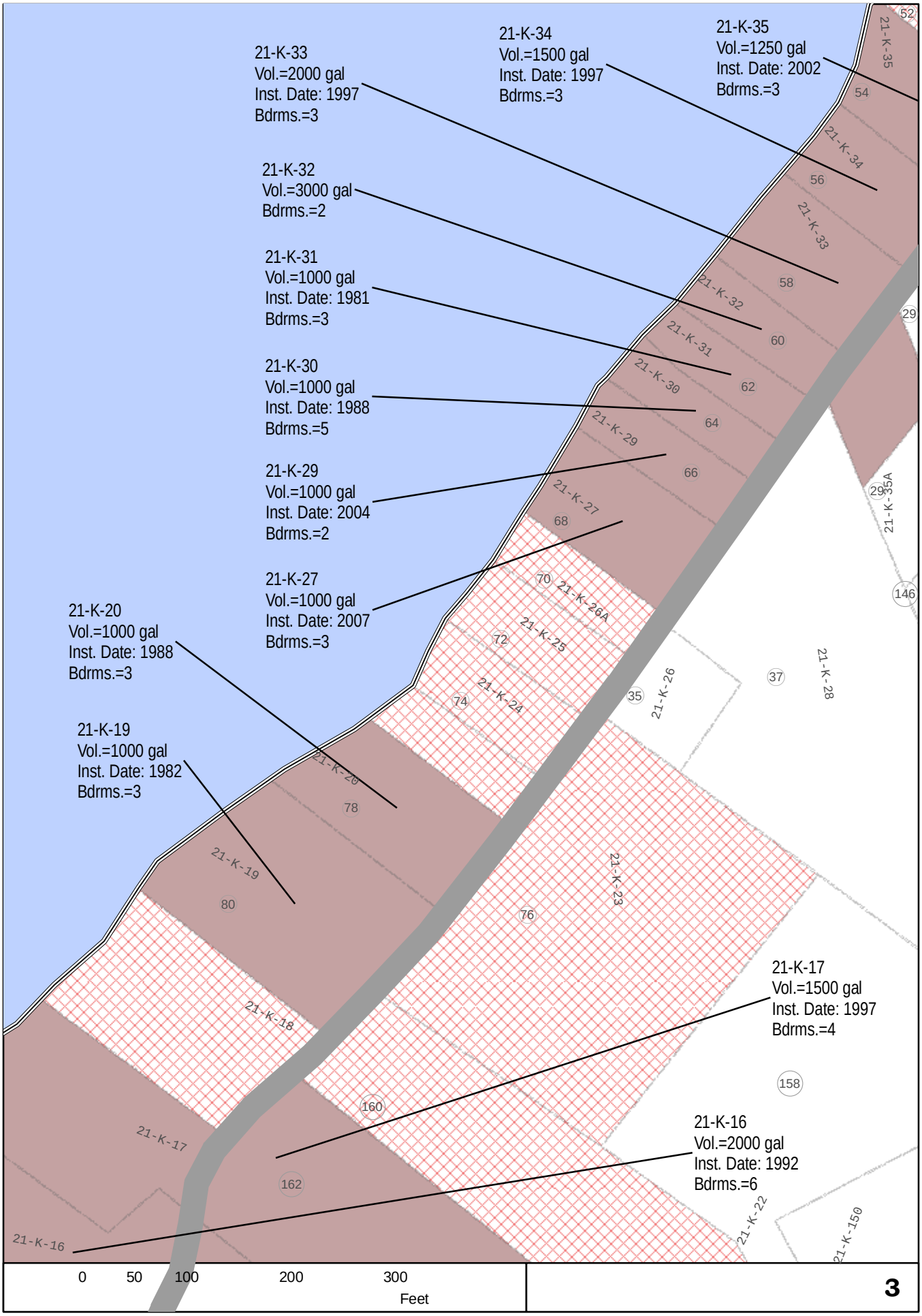
February 25, 2010

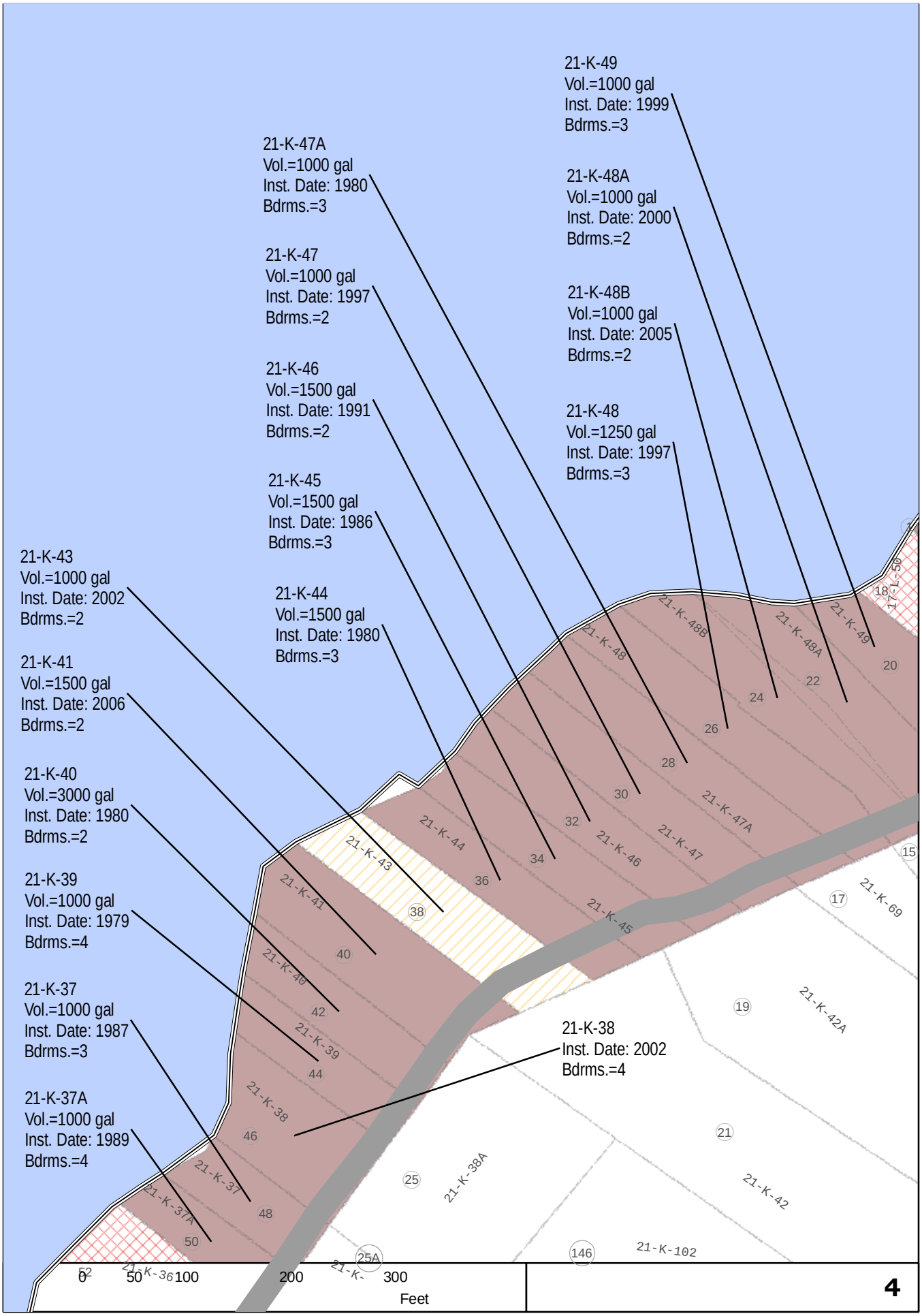

COBBETT'S POND
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
111
LOWELL RD.
CHURCH RD.
ARMSTRONG RD.
SAWTELLE RD.
SAWYER RD.
FARMER RD.
HORSESHOE RD.
RANGE RD.
TURTLE ROCK RD.
CRISTY DRIVE
LANGDON RD.
BAYBERRY RD.
MINISTERIAL RD.
GAUMONT RD.
FARRWOOD RD.
COBBETTS POND RD.
FOSSA RD.
MARBLEHEAD RD.
HAWLEY RD.
BAKER RD.
Legend
Assessor's Parcels (approx.)
Unimproved Lot
No records available at town hall
System type not available from town records
Holding Tank
Septic System

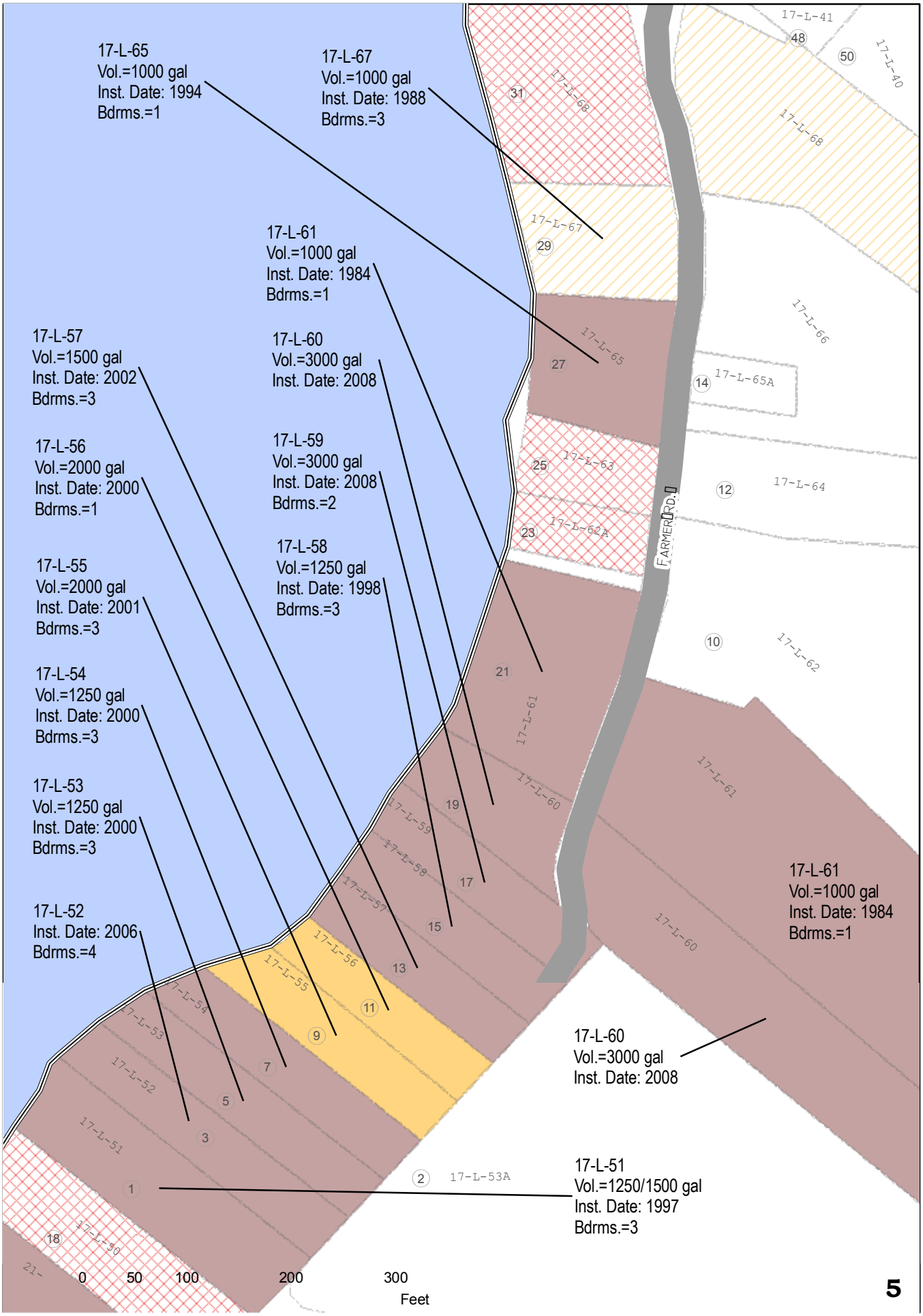
MAP INDEX

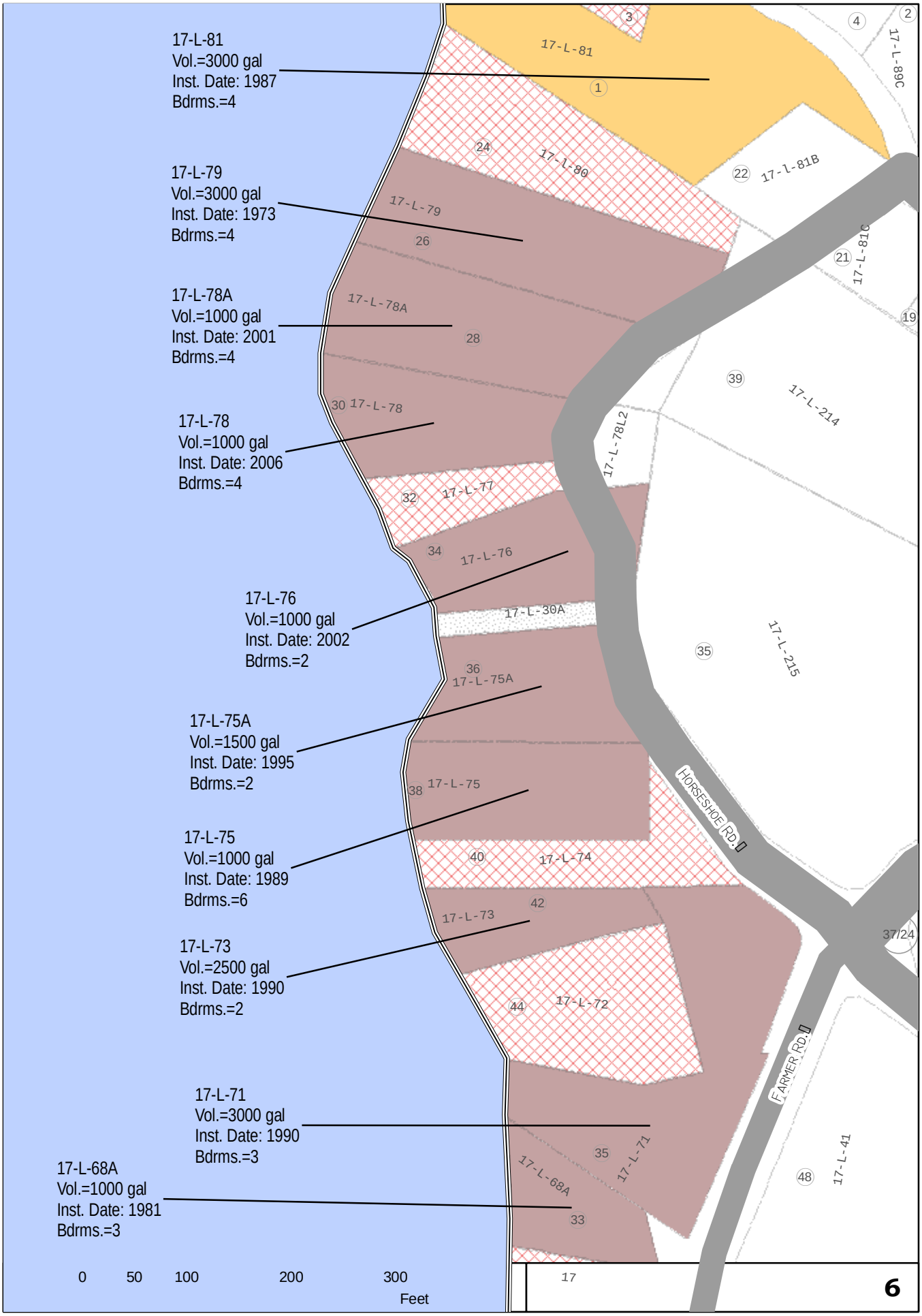

21-H-7
Vol.=2000 gal
Inst. Date: 2000
Bdrms.=3
21-H-6
Vol.=2000 gal
Inst. Date: 1999
Bdrms.=3
21-H-5
Vol.=1000 gal
Inst. Date: 1998
Bdrms.=3
21-C-152
Vol.=2000 gal
Inst. Date: 1998
Bdrms.=2
21-H-1
Vol.=1000 gal
Inst. Date: 1984
Bdrms.=6
21-H-3
Vol.=1500 gal
Inst. Date: 2008
Bdrms.=5
COBBETTS POND RD
FOSSA RD
RANGE RD
21-C-151
21-C-152
21-C-150
21-C-124
21-H-55
21-H-60
21-H-1A
21-H-1
21-H-2
21-H-3
21-H-4
21-H-5
21-H-6
21-H-7
21-H-8
21-H-35
21-G-23A
21-G-24
21-G-25
21-G-26
21-G-29
21-G-230
0 50 100 200 300
Feet

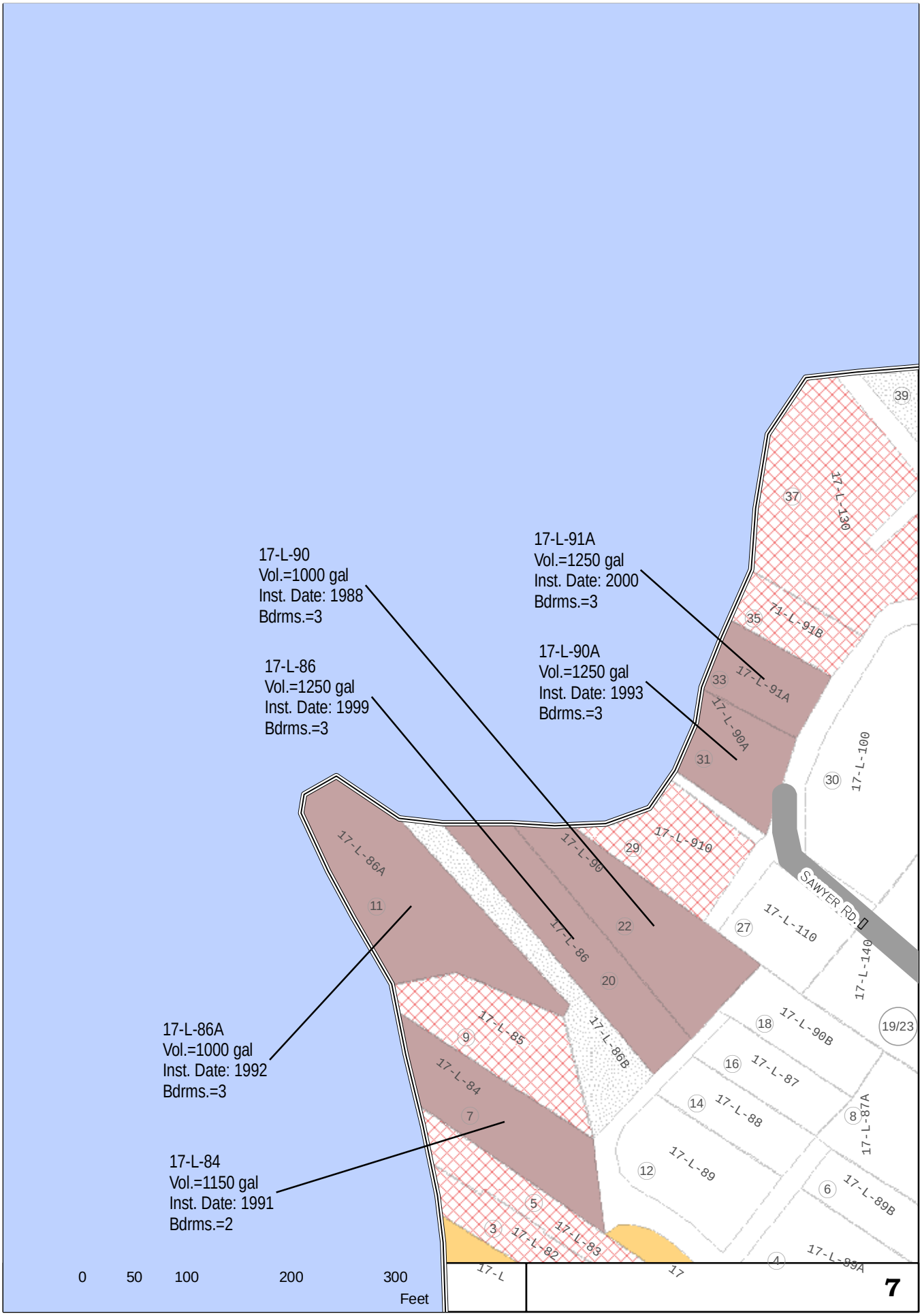

21-H-14
Vol.=1000 gal
Inst. Date: 2001
Bdrms.=4
21-H-16
Vol.=1000 gal
Inst. Date: 1973
Bdrms.=3
21-H-13
Vol.=1000 gal
Inst. Date: 2001
Bdrms.=4
21-H-15A
Vol.=1500 gal
Inst. Date: 2004
Bdrms.=3
21-H-12
Vol.=1500 gal
Inst. Date: 2003
Bdrms.=2
21-H-11
Vol.=1000 gal
Inst. Date: 1985
Bdrms.=3
21-H-10B
Vol.=500 gal
Inst. Date: 1955
21-H-13
Vol.=1000 gal
Inst. Date: 2001
Bdrms.=4
21-H-10
Vol.=1000 gal
Inst. Date: 1982
Bdrms.=4
21-K-17
21-K-16
21-K-15
21-H-16
21-H-15A
21-H-15
21-H-14
21-H-13
21-H-12
21-H-11
21-H-10B
21-H-10
21-H-8
21-H-7
21-H-11A
21-H-11C
21-H-14A
21-H-21
21-H-19
21-H-15B
21-H-16C
21-H-17
21-H-40
21-H-24
21-H-10A
21-H-25
21-H-20
21-H-7A
21-H-4
21-H-26
21-H-26A
21-F-32
21-F-3
FOSSA RD
RANGE RD
MARBLEHEAD
0
50
100
200
300
Feet
-1
2

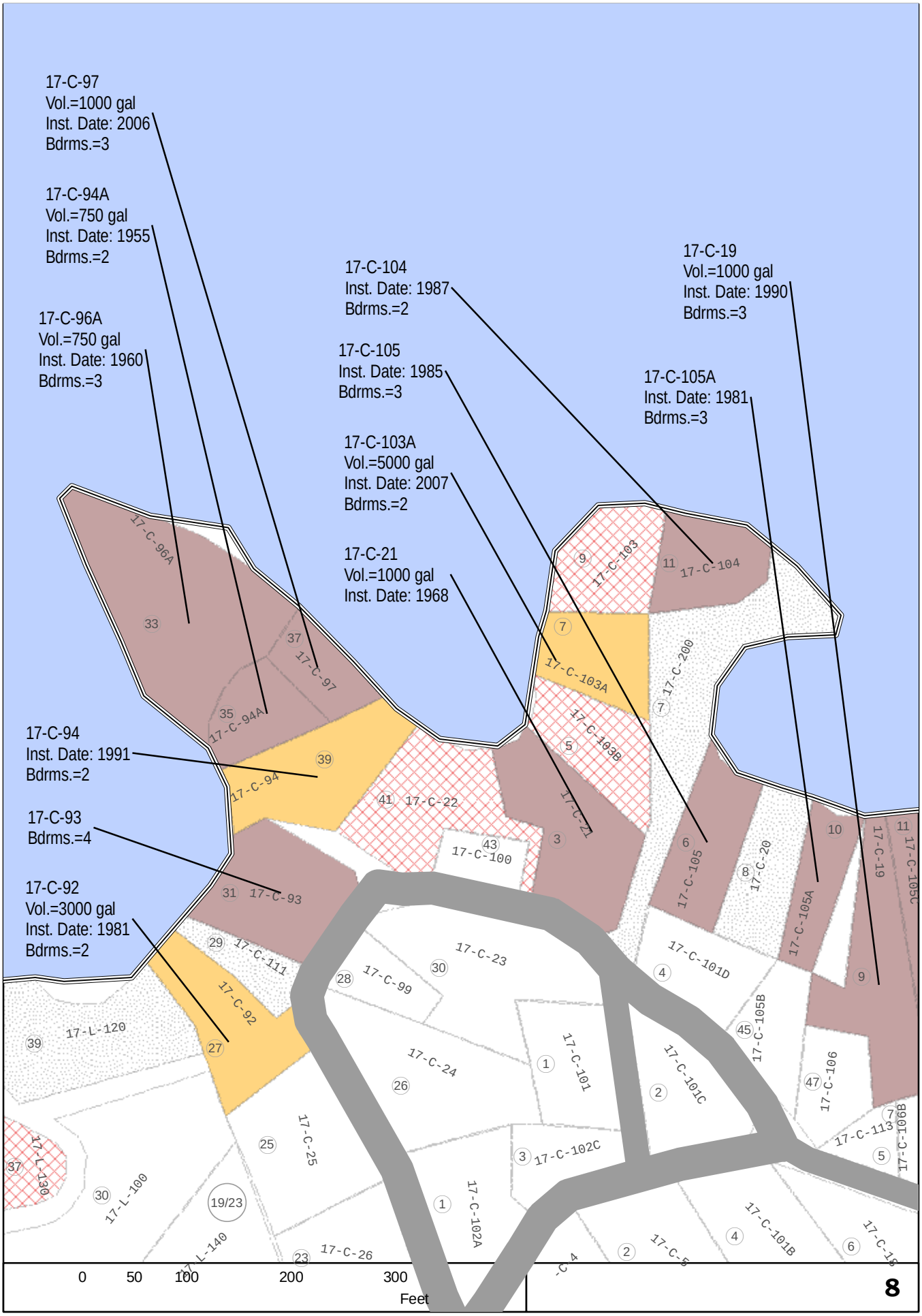

21-K-35
Vol.=1250 gal
Inst. Date: 2002
Bdrms.=3
21-K-34
Vol.=1500 gal
Inst. Date: 1997
Bdrms.=3
21-K-33
Vol.=2000 gal
Inst. Date: 1997
Bdrms.=3
21-K-32
Vol.=3000 gal
Bdrms.=2
21-K-31
Vol.=1000 gal
Inst. Date: 1981
Bdrms.=3
21-K-30
Vol.=1000 gal
Inst. Date: 1988
Bdrms.=5
21-K-29
Vol.=1000 gal
Inst. Date: 2004
Bdrms.=2
21-K-27
Vol.=1000 gal
Inst. Date: 2007
Bdrms.=3
21-K-20
Vol.=1000 gal
Inst. Date: 1988
Bdrms.=3
21-K-19
Vol.=1000 gal
Inst. Date: 1982
Bdrms.=3
21-K-17
Vol.=1500 gal
Inst. Date: 1997
Bdrms.=4
21-K-16
Vol.=2000 gal
Inst. Date: 1992
Bdrms.=6
21-K-35
21-K-35A
21-K-34
21-K-33
21-K-32
21-K-31
21-K-30
21-K-29
21-K-27
21-K-26A
21-K-25
21-K-24
21-K-26
21-K-28
21-K-20
21-K-19
21-K-23
21-K-18
21-K-17
21-K-16
21-K-22
21-K-150
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
29
29
146
37
35
158
160
162
0
50
100
200
300
Feet

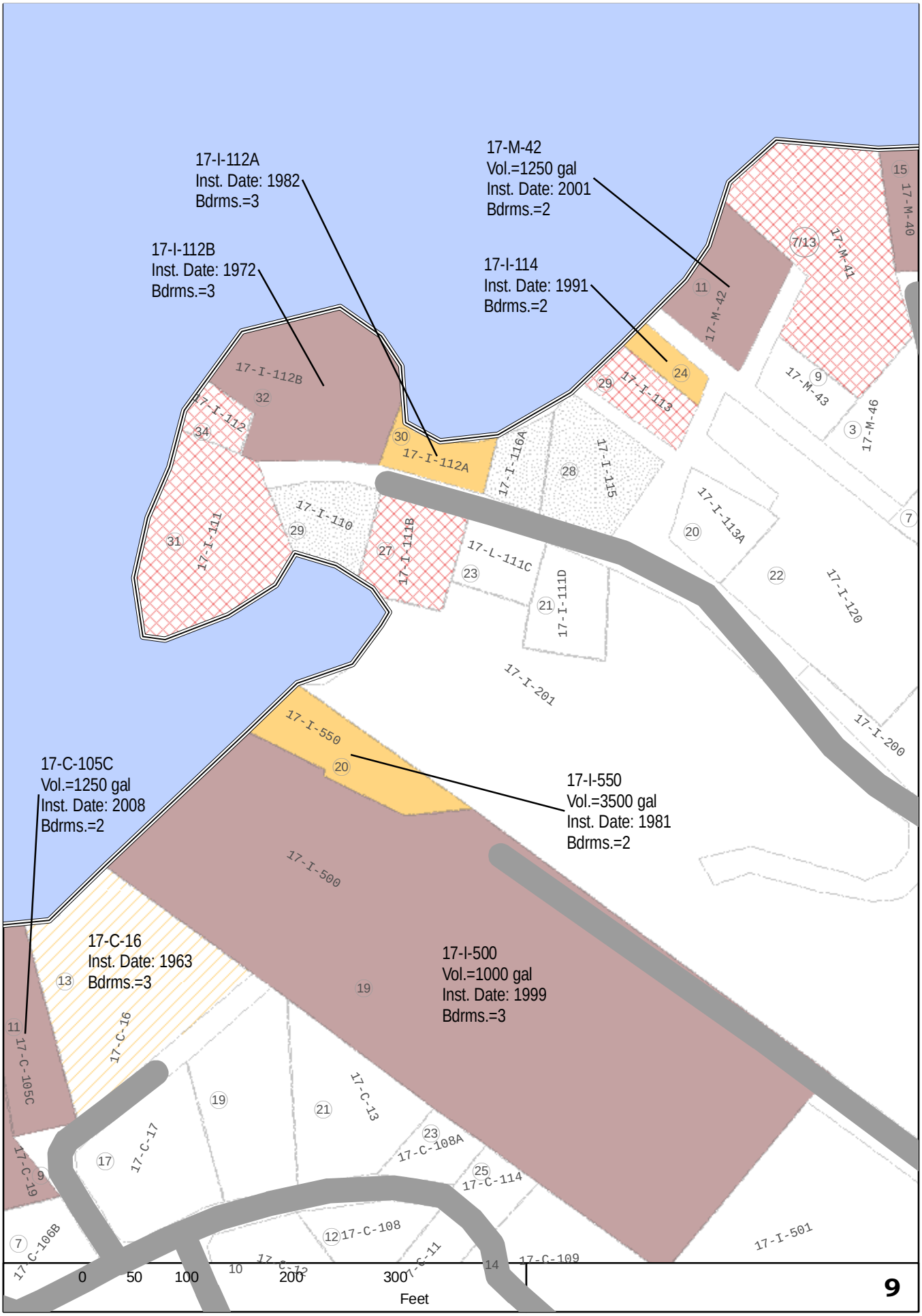

21-K-49
Vol.=1000 gal
Inst. Date: 1999
Bdrms.=3
21-K-47A
Vol.=1000 gal
Inst. Date: 1980
Bdrms.=3
21-K-48A
Vol.=1000 gal
Inst. Date: 2000
Bdrms.=2
21-K-47
Vol.=1000 gal
Inst. Date: 1997
Bdrms.=2
21-K-48B
Vol.=1000 gal
Inst. Date: 2005
Bdrms.=2
21-K-46
Vol.=1500 gal
Inst. Date: 1991
Bdrms.=2
21-K-48
Vol.=1250 gal
Inst. Date: 1997
Bdrms.=3
21-K-45
Vol.=1500 gal
Inst. Date: 1986
Bdrms.=3
21-K-43
Vol.=1000 gal
Inst. Date: 2002
Bdrms.=2
21-K-44
Vol.=1500 gal
Inst. Date: 1980
Bdrms.=3
21-K-41
Vol.=1500 gal
Inst. Date: 2006
Bdrms.=2
21-K-40
Vol.=3000 gal
Inst. Date: 1980
Bdrms.=2
21-K-39
Vol.=1000 gal
Inst. Date: 1979
Bdrms.=4
21-K-37
Vol.=1000 gal
Inst. Date: 1987
Bdrms.=3
21-K-37A
Vol.=1000 gal
Inst. Date: 1989
Bdrms.=4
21-K-38
Inst. Date: 2002
Bdrms.=4
0 50 100 200 300
Feet

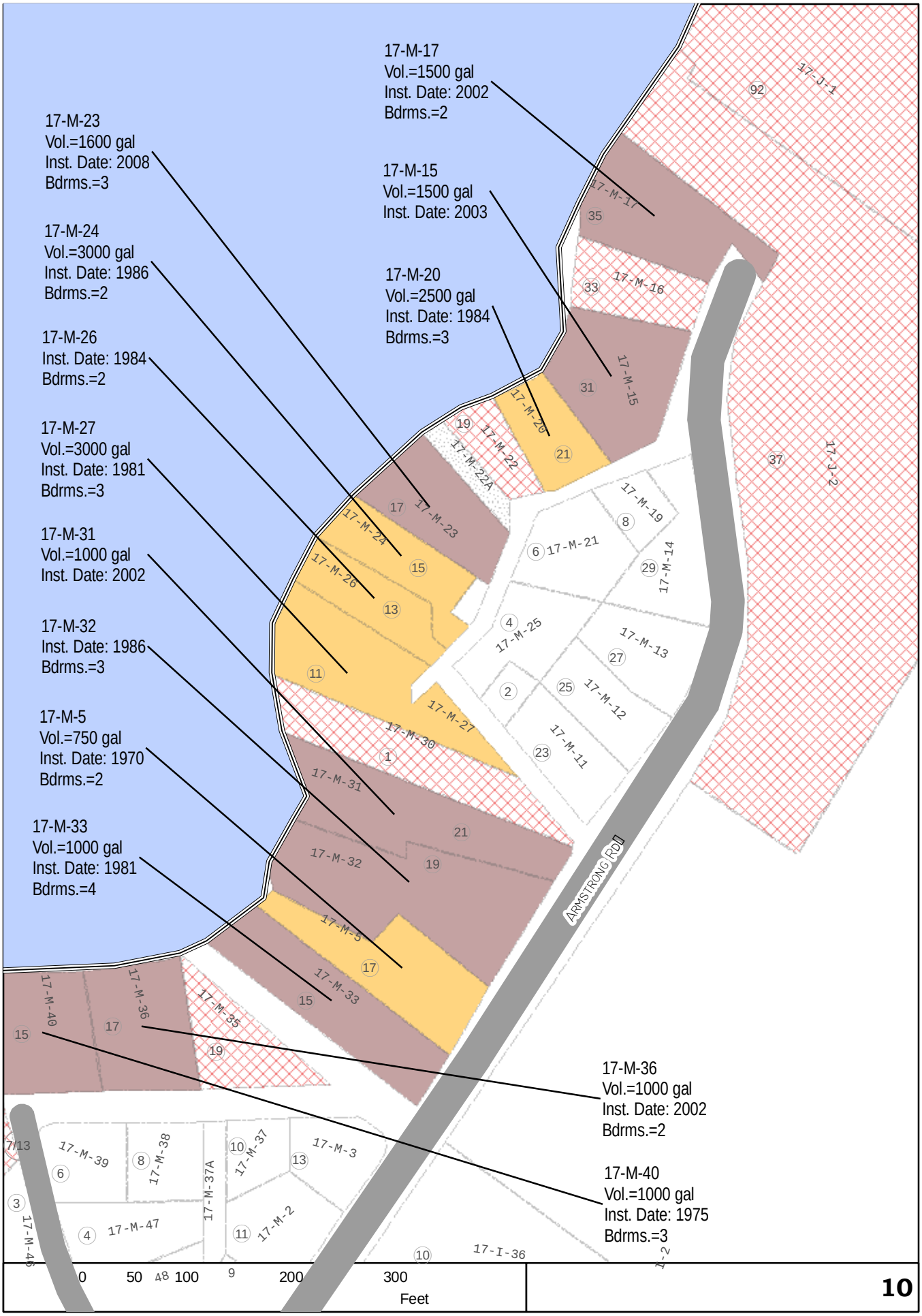

17-L-65
Vol.=1000 gal
Inst. Date: 1994
Bdrms.=1
17-L-67
Vol.=1000 gal
Inst. Date: 1988
Bdrms.=3
17-L-61
Vol.=1000 gal
Inst. Date: 1984
Bdrms.=1
17-L-57
Vol.=1500 gal
Inst. Date: 2002
Bdrms.=3
17-L-60
Vol.=3000 gal
Inst. Date: 2008
17-L-56
Vol.=2000 gal
Inst. Date: 2000
Bdrms.=1
17-L-59
Vol.=3000 gal
Inst. Date: 2008
Bdrms.=2
17-L-58
Vol.=1250 gal
Inst. Date: 1998
Bdrms.=3
17-L-55
Vol.=2000 gal
Inst. Date: 2001
Bdrms.=3
17-L-54
Vol.=1250 gal
Inst. Date: 2000
Bdrms.=3
17-L-53
Vol.=1250 gal
Inst. Date: 2000
Bdrms.=3
17-L-52
Inst. Date: 2006
Bdrms.=4
17-L-61
Vol.=1000 gal
Inst. Date: 1984
Bdrms.=1
17-L-60
Vol.=3000 gal
Inst. Date: 2008
17-L-51
Vol.=1250/1500 gal
Inst. Date: 1997
Bdrms.=3
17-L-41
17-L-40
17-L-68
17-L-67
17-L-66
17-L-65A
17-L-65
17-L-63
17-L-64
17-L-62A
17-L-62
17-L-61
17-L-60
17-L-59
17-L-58
17-L-57
17-L-56
17-L-55
17-L-54
17-L-53
17-L-53A
17-L-52
17-L-51
17-L-50
FARMER RD.
0 50 100 200 300
Feet

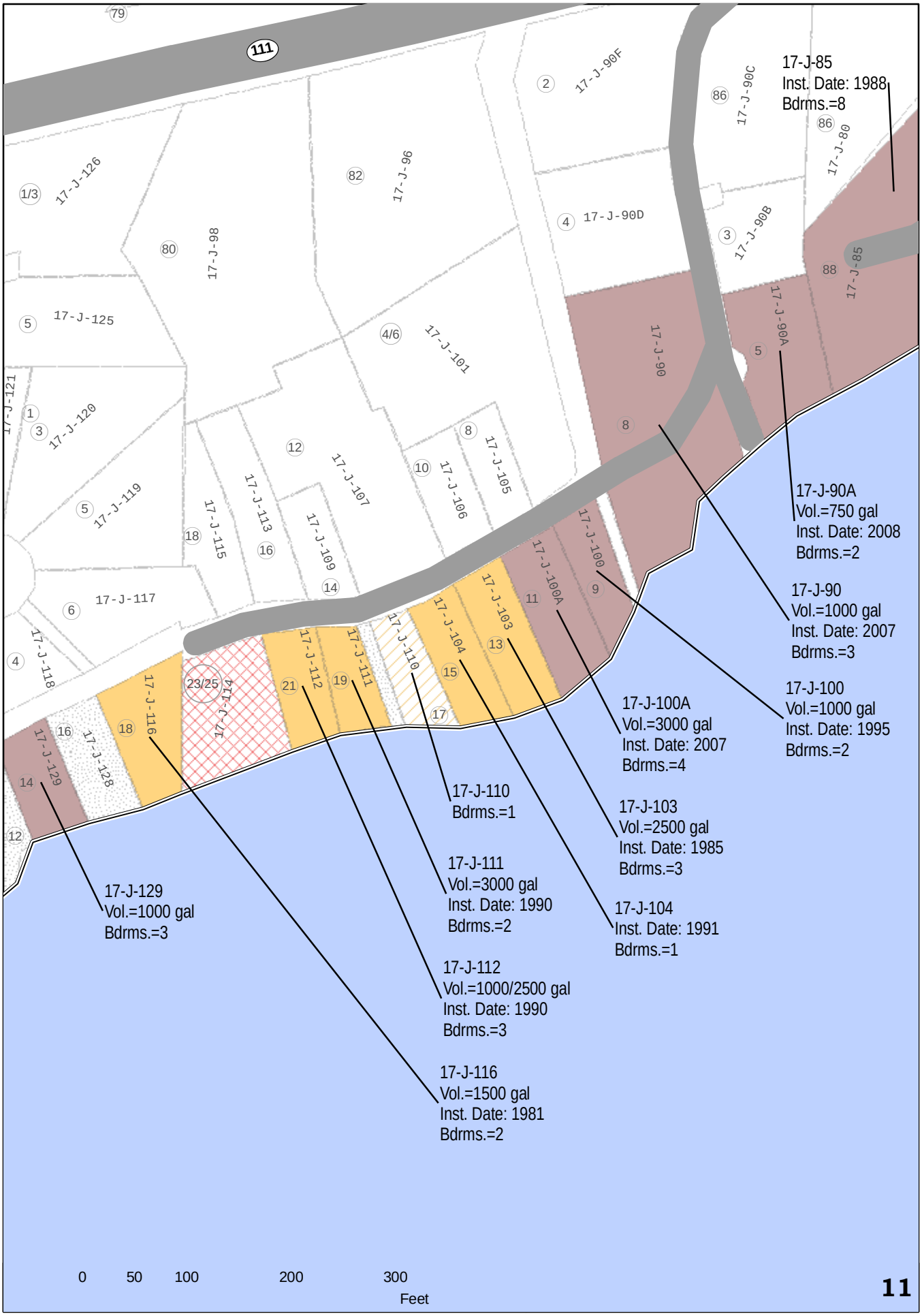

17-L-81
Vol.=3000 gal
Inst. Date: 1987
Bdrms.=4
17-L-79
Vol.=3000 gal
Inst. Date: 1973
Bdrms.=4
17-L-78A
Vol.=1000 gal
Inst. Date: 2001
Bdrms.=4
17-L-78
Vol.=1000 gal
Inst. Date: 2006
Bdrms.=4
17-L-76
Vol.=1000 gal
Inst. Date: 2002
Bdrms.=2
17-L-75A
Vol.=1500 gal
Inst. Date: 1995
Bdrms.=2
17-L-75
Vol.=1000 gal
Inst. Date: 1989
Bdrms.=6
17-L-73
Vol.=2500 gal
Inst. Date: 1990
Bdrms.=2
17-L-71
Vol.=3000 gal
Inst. Date: 1990
Bdrms.=3
17-L-68A
Vol.=1000 gal
Inst. Date: 1981
Bdrms.=3
17-L-81
17-L-80
17-L-81B
17-L-89C
17-L-81C
17-L-79
17-L-78A
17-L-78
17-L-77
17-L-76
17-L-30A
17-L-75A
17-L-75
17-L-74
17-L-73
17-L-72
17-L-71
17-L-68A
17-L-78L2
17-L-214
17-L-215
17-L-41
HORSESHOE RD.
FARMER RD.
0 50 100 200 300
Feet
17
6

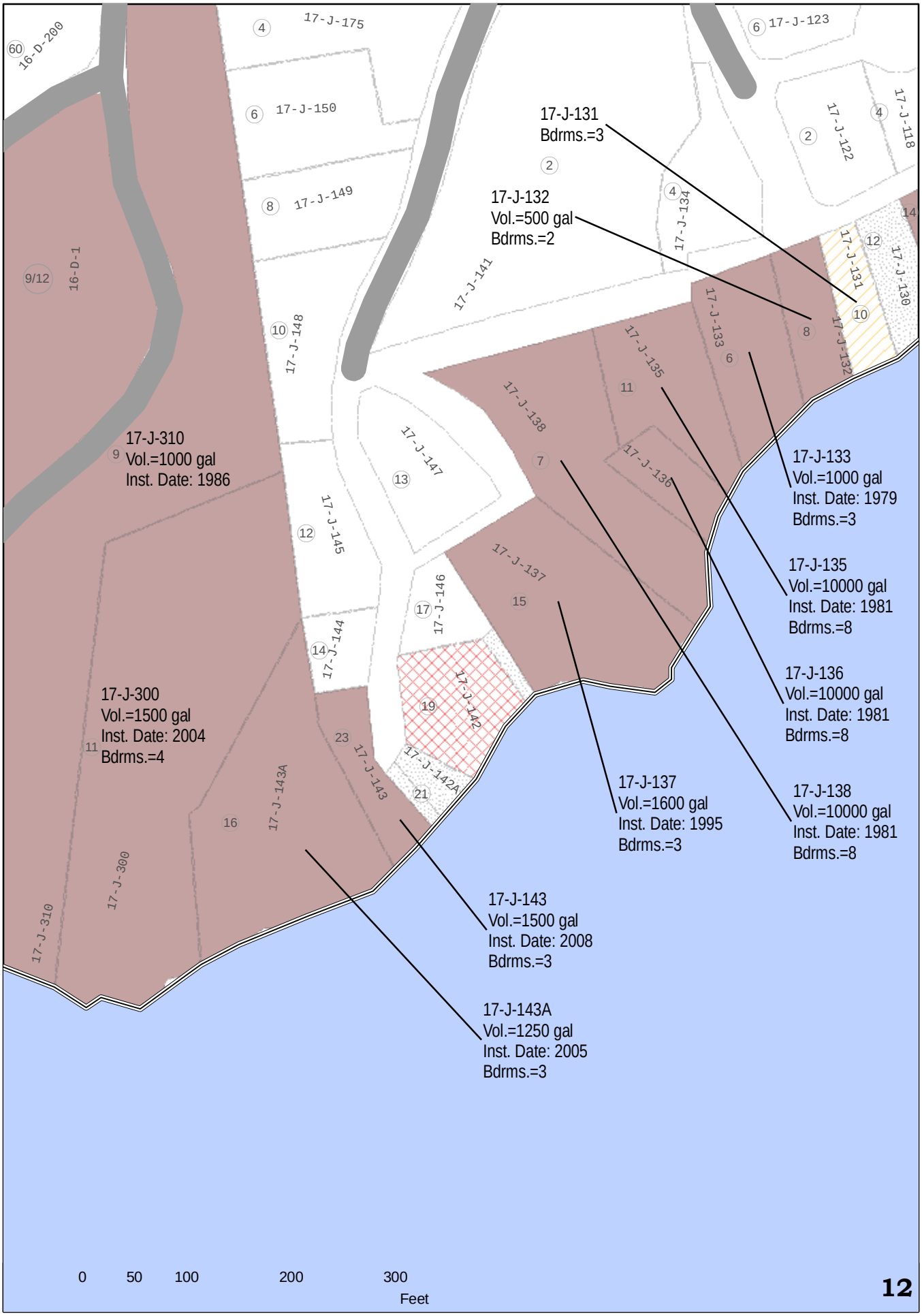

17-L-90
Vol.=1000 gal
Inst. Date: 1988
Bdrms.=3
17-L-91A
Vol.=1250 gal
Inst. Date: 2000
Bdrms.=3
17-L-90A
Vol.=1250 gal
Inst. Date: 1993
Bdrms.=3
17-L-86
Vol.=1250 gal
Inst. Date: 1999
Bdrms.=3
17-L-86A
Vol.=1000 gal
Inst. Date: 1992
Bdrms.=3
17-L-84
Vol.=1150 gal
Inst. Date: 1991
Bdrms.=2
17-L-86A
17-L-90
17-L-86
17-L-91A
17-L-90A
17-L-91B
17-L-130
17-L-910
17-L-100
17-L-110
17-L-140
SAWYER RD.
17-L-85
17-L-84
17-L-86B
17-L-90B
17-L-87
17-L-88
17-L-87A
17-L-89
17-L-89B
17-L-82
17-L-83
17-L-99A
17-L
17
39
37
35
33
31
30
29
27
22
20
19/23
18
16
14
12
11
9
8
7
6
5
3
4
0
50
100
200
300
Feet
7


17-C-97
Vol.=1000 gal
Inst. Date: 2006
Bdrms.=3
17-C-94A
Vol.=750 gal
Inst. Date: 1955
Bdrms.=2
17-C-96A
Vol.=750 gal
Inst. Date: 1960
Bdrms.=3
17-C-104
Inst. Date: 1987
Bdrms.=2
17-C-105
Inst. Date: 1985
Bdrms.=3
17-C-103A
Vol.=5000 gal
Inst. Date: 2007
Bdrms.=2
17-C-21
Vol.=1000 gal
Inst. Date: 1968
17-C-19
Vol.=1000 gal
Inst. Date: 1990
Bdrms.=3
17-C-105A
Inst. Date: 1981
Bdrms.=3
17-C-94
Inst. Date: 1991
Bdrms.=2
17-C-93
Bdrms.=4
17-C-92
Vol.=3000 gal
Inst. Date: 1981
Bdrms.=2
17-C-96A
17-C-97
17-C-94A
17-C-94
17-C-22
17-C-100
17-C-93
17-C-111
17-C-92
17-C-99
17-C-23
17-C-24
17-C-25
17-C-26
17-C-101
17-C-102A
17-C-102C
17-C-101C
17-C-101D
17-C-105B
17-C-106
17-C-113
17-C-106B
17-C-105
17-C-20
17-C-105A
17-C-19
17-C-105C
17-C-103
17-C-104
17-C-200
17-C-103A
17-C-103B
17-C-21
17-L-120
17-L-130
17-L-100
17-L-140
17-C-5
17-C-101B
0
50
100
200
300
Feet

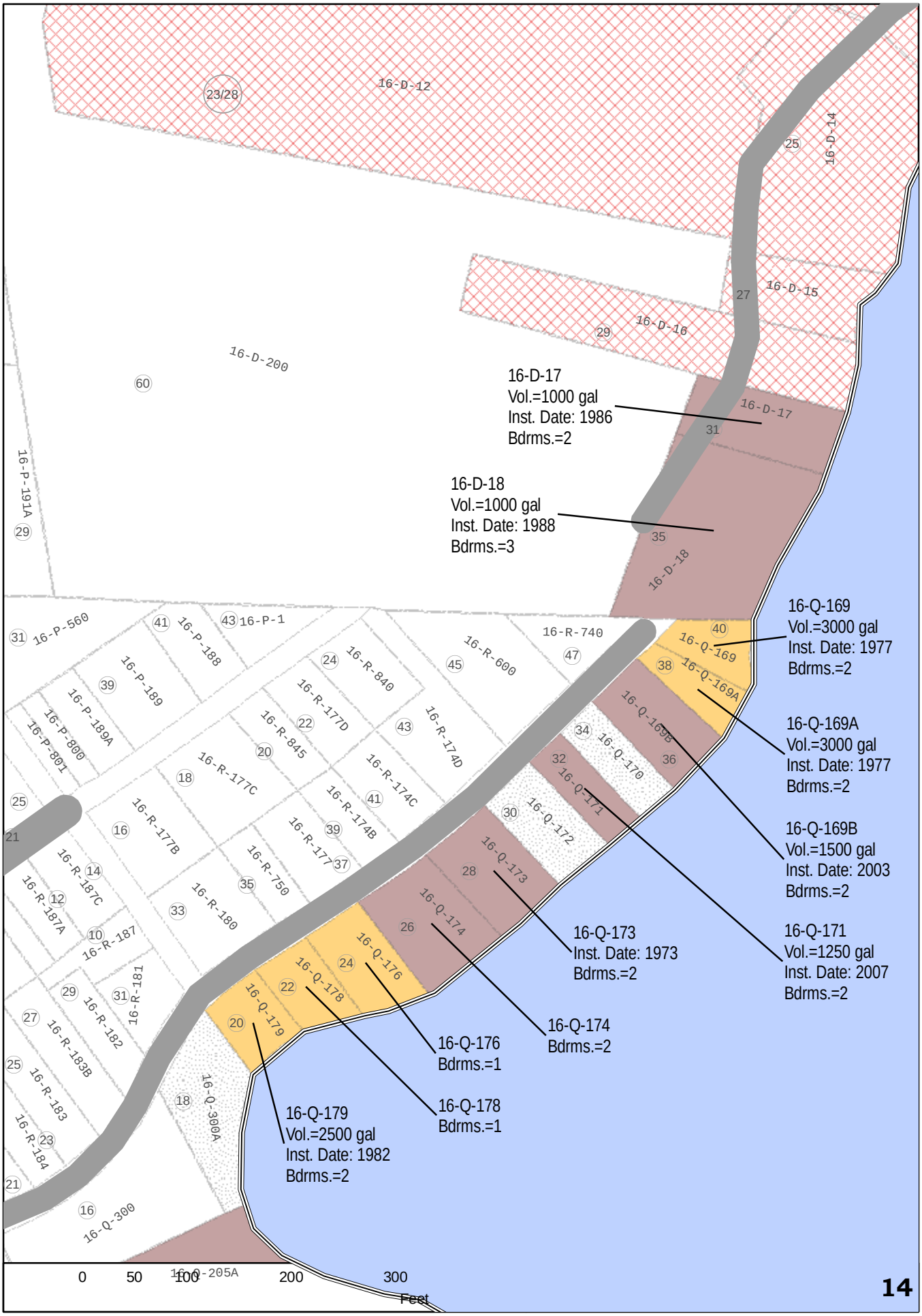

17-I-112A
Inst. Date: 1982
Bdrms.=3
17-M-42
Vol.=1250 gal
Inst. Date: 2001
Bdrms.=2
17-I-112B
Inst. Date: 1972
Bdrms.=3
17-I-114
Inst. Date: 1991
Bdrms.=2
17-C-105C
Vol.=1250 gal
Inst. Date: 2008
Bdrms.=2
17-I-550
Vol.=3500 gal
Inst. Date: 1981
Bdrms.=2
17-C-16
Inst. Date: 1963
Bdrms.=3
17-I-500
Vol.=1000 gal
Inst. Date: 1999
Bdrms.=3
17-I-112B
17-I-112
17-I-111
17-I-110
17-I-112A
17-I-116A
17-I-115
17-I-113
17-I-111B
17-L-111C
17-I-111D
17-I-113A
17-I-120
17-I-201
17-I-200
17-I-550
17-I-500
17-I-501
17-M-42
17-M-41
17-M-40
17-M-43
17-M-46
17-C-16
17-C-105C
17-C-17
17-C-19
17-C-106B
17-C-13
17-C-108A
17-C-114
17-C-108
17-C-11
17-C-109
0
50
100
200
300
Feet

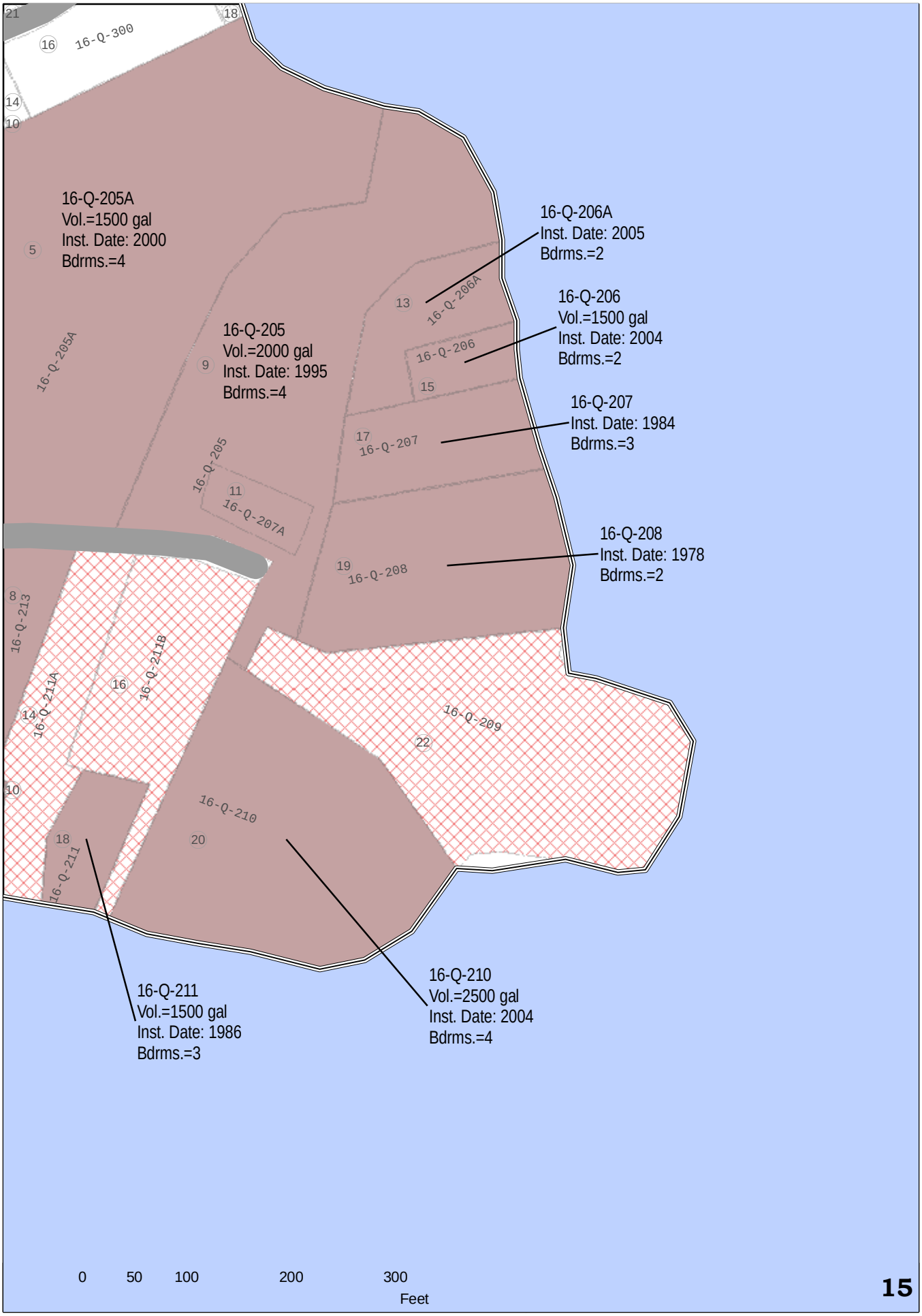

17-M-17
Vol.=1500 gal
Inst. Date: 2002
Bdrms.=2
17-M-23
Vol.=1600 gal
Inst. Date: 2008
Bdrms.=3
17-M-15
Vol.=1500 gal
Inst. Date: 2003
17-M-24
Vol.=3000 gal
Inst. Date: 1986
Bdrms.=2
17-M-20
Vol.=2500 gal
Inst. Date: 1984
Bdrms.=3
17-M-26
Inst. Date: 1984
Bdrms.=2
17-M-27
Vol.=3000 gal
Inst. Date: 1981
Bdrms.=3
17-M-31
Vol.=1000 gal
Inst. Date: 2002
17-M-32
Inst. Date: 1986
Bdrms.=3
17-M-5
Vol.=750 gal
Inst. Date: 1970
Bdrms.=2
17-M-33
Vol.=1000 gal
Inst. Date: 1981
Bdrms.=4
17-M-36
Vol.=1000 gal
Inst. Date: 2002
Bdrms.=2
17-M-40
Vol.=1000 gal
Inst. Date: 1975
Bdrms.=3
ARMSTRONG RD
0 50 100 200 300
Feet

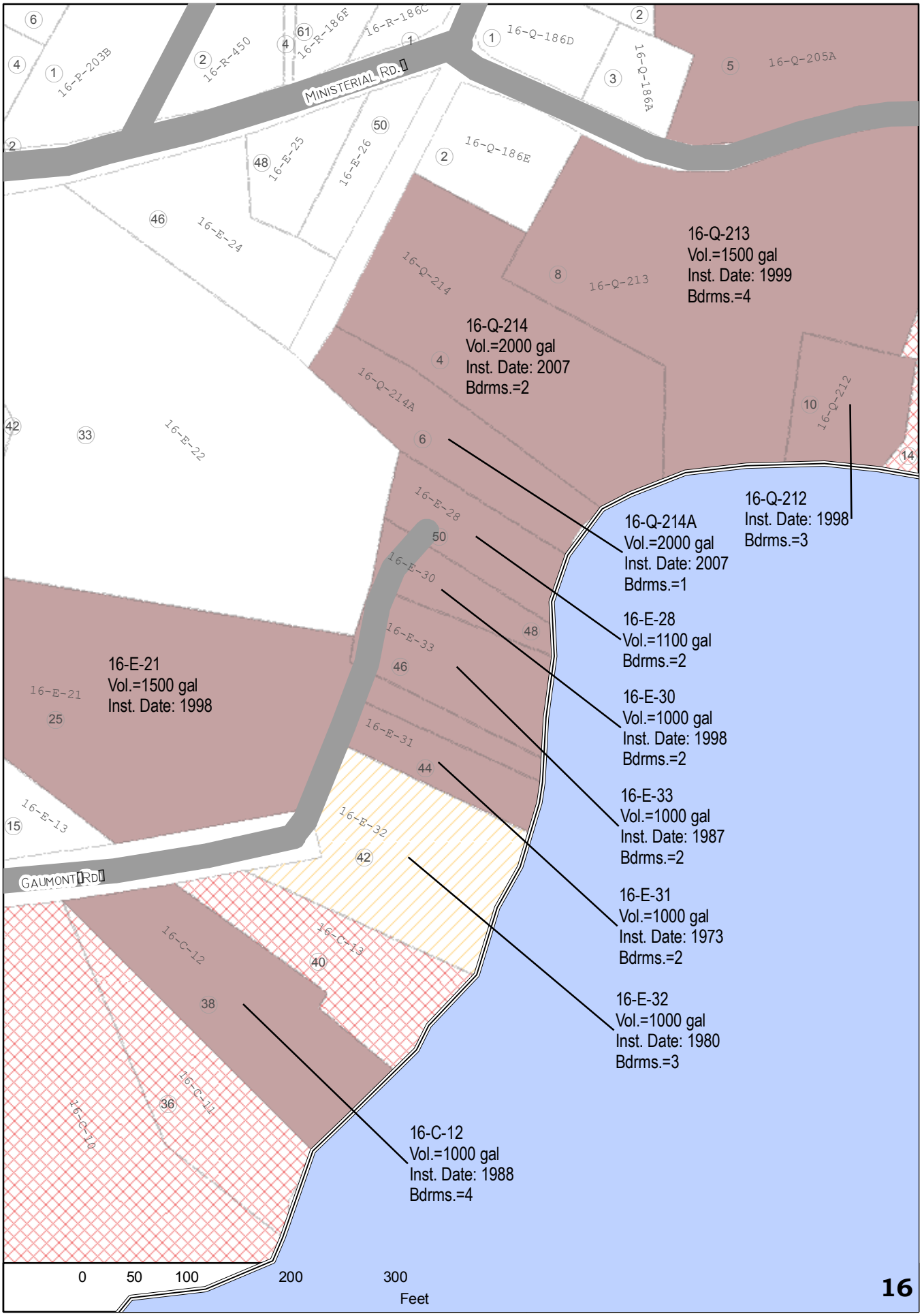

111
17-J-85
Inst. Date: 1988
Bdrms.=8
17-J-90A
Vol.=750 gal
Inst. Date: 2008
Bdrms.=2
17-J-90
Vol.=1000 gal
Inst. Date: 2007
Bdrms.=3
17-J-100
Vol.=1000 gal
Inst. Date: 1995
Bdrms.=2
17-J-100A
Vol.=3000 gal
Inst. Date: 2007
Bdrms.=4
17-J-103
Vol.=2500 gal
Inst. Date: 1985
Bdrms.=3
17-J-104
Inst. Date: 1991
Bdrms.=1
17-J-110
Bdrms.=1
17-J-111
Vol.=3000 gal
Inst. Date: 1990
Bdrms.=2
17-J-112
Vol.=1000/2500 gal
Inst. Date: 1990
Bdrms.=3
17-J-116
Vol.=1500 gal
Inst. Date: 1981
Bdrms.=2
17-J-129
Vol.=1000 gal
Bdrms.=3
0 50 100 200 300
Feet

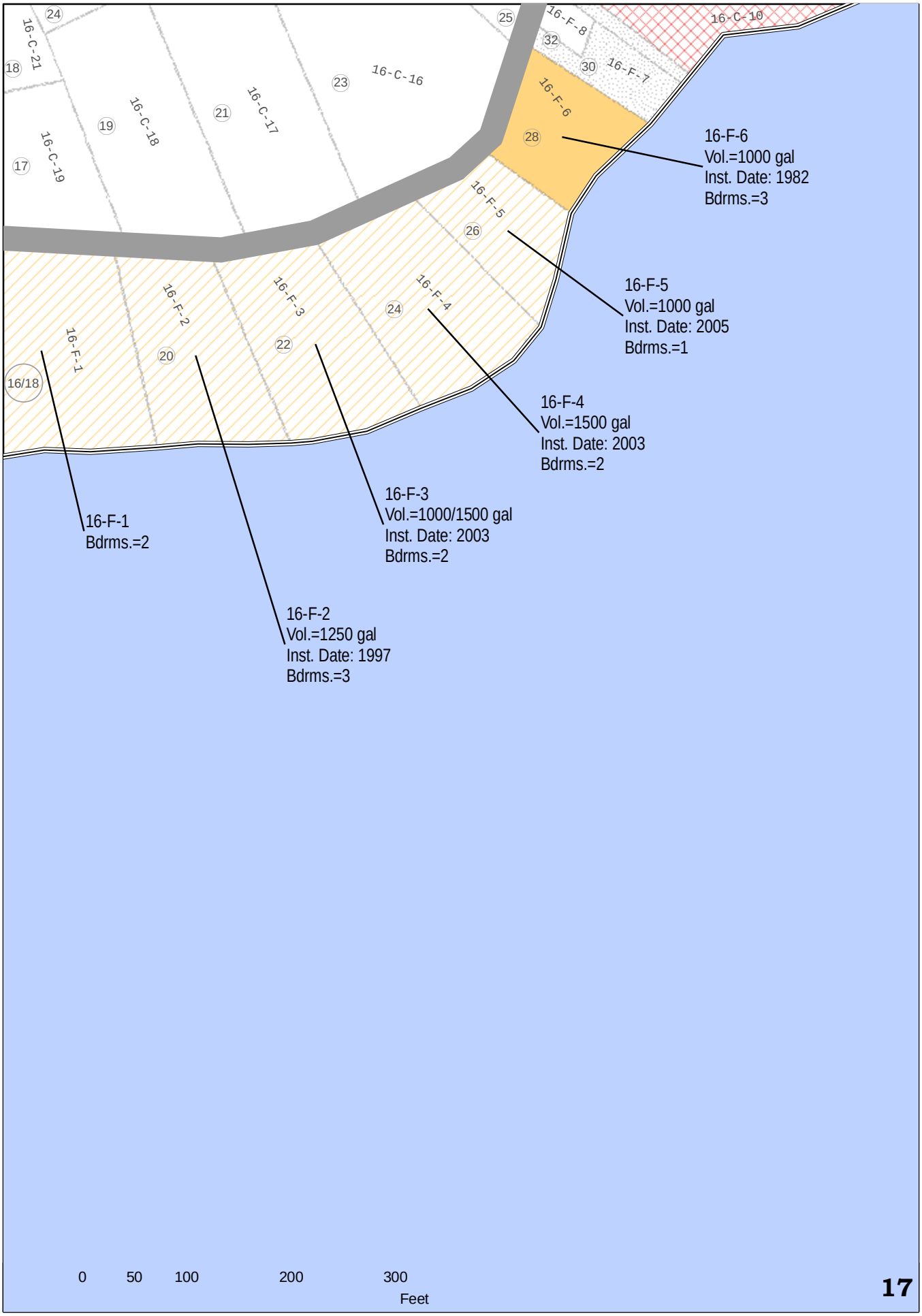

17-J-131
Bdrms.=3
17-J-132
Vol.=500 gal
Bdrms.=2
17-J-310
Vol.=1000 gal
Inst. Date: 1986
17-J-300
Vol.=1500 gal
Inst. Date: 2004
Bdrms.=4
17-J-133
Vol.=1000 gal
Inst. Date: 1979
Bdrms.=3
17-J-135
Vol.=10000 gal
Inst. Date: 1981
Bdrms.=8
17-J-136
Vol.=10000 gal
Inst. Date: 1981
Bdrms.=8
17-J-137
Vol.=1600 gal
Inst. Date: 1995
Bdrms.=3
17-J-138
Vol.=10000 gal
Inst. Date: 1981
Bdrms.=8
17-J-143
Vol.=1500 gal
Inst. Date: 2008
Bdrms.=3
17-J-143A
Vol.=1250 gal
Inst. Date: 2005
Bdrms.=3
0 50 100 200 300
Feet

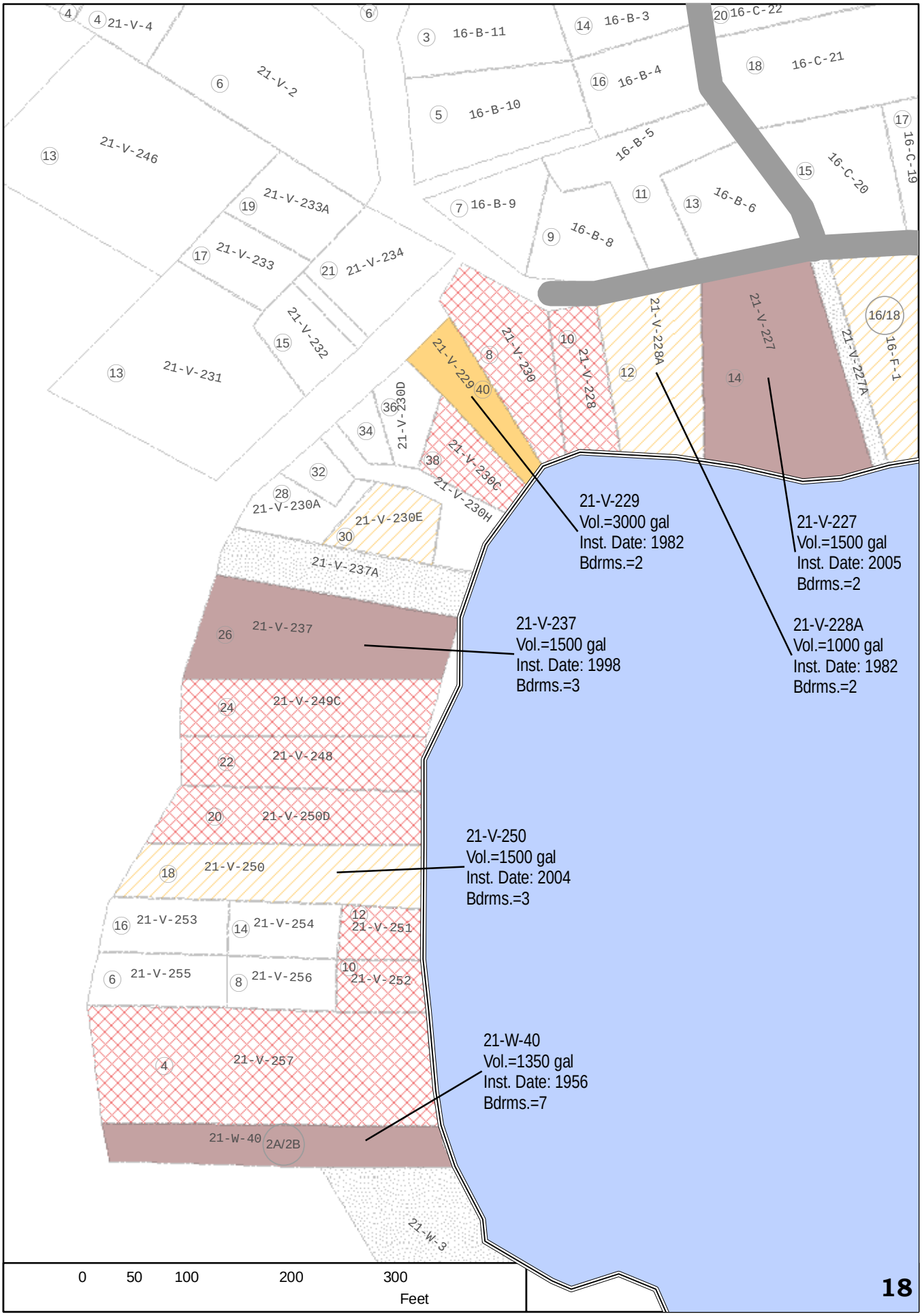

16-D-1
Vol.=1000 gal
Inst. Date: 1987
Bdrms.=3
16-D-6
Vol.=1500 gal
Inst. Date: 2008
Bdrms.=3
16-D-10
Inst. Date: 1989
Bdrms.=2
16-D-5
Vol.=1500 gal
Inst. Date: 2009
Bdrms.=3
16-D-7
Vol.=1500 gal
Inst. Date: 1992
Bdrms.=3
16-D-8
Vol.=1500 gal
Inst. Date: 1998
Bdrms.=3
16-D-9
Vol.=2500 gal
Inst. Date: 1982
Bdrms.=2
16-D-11
Vol.=2000 gal
Inst. Date: 1988
Bdrms.=2
16-D-200
16-D-6
16-D-1
17-J-310
16-D-5
16-D-7
16-D-8
16-D-10
16-D-9
16-D-11
16-D-12
60
9/12
14
9
13
16
17
20
19
23/28
25
0
50
100
200
300
Feet

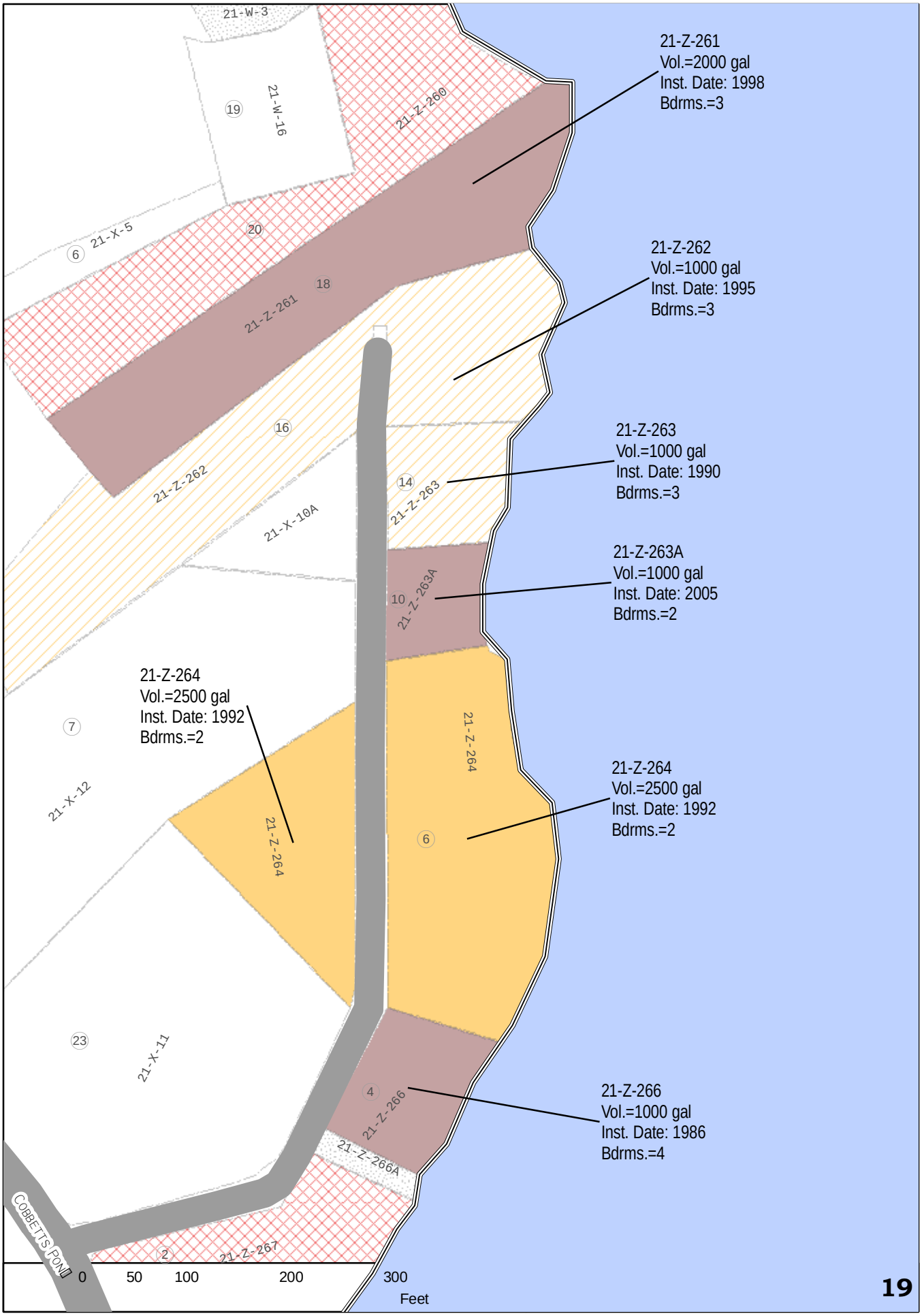

16-D-12
23/28
16-D-14
25
16-D-15
27
16-D-16
29
16-D-200
60
16-D-17
Vol.=1000 gal
Inst. Date: 1986
Bdrms.=2
16-D-17
31
16-D-18
Vol.=1000 gal
Inst. Date: 1988
Bdrms.=3
35
16-D-18
16-P-191A
29
16-P-560
31
16-P-188
41
16-P-1
43
16-R-740
47
16-R-600
45
16-R-840
24
16-P-189
39
16-P-189A
16-P-800
16-P-801
16-R-177D
22
16-R-845
20
16-R-174D
43
16-R-177C
18
16-R-174C
41
16-R-174B
39
16-R-177
37
16-R-177B
16
16-R-750
35
16-R-180
33
16-R-187C
14
16-R-187A
12
16-R-187
10
16-R-181
31
16-R-182
29
16-R-183B
27
16-R-183
25
16-R-184
23
21
25
16-Q-169
40
16-Q-169A
38
16-Q-169B
36
16-Q-170
34
16-Q-171
32
16-Q-172
30
16-Q-173
28
16-Q-174
26
16-Q-176
24
16-Q-178
22
16-Q-179
20
16-Q-300A
18
16-Q-300
16
16-Q-205A
16-Q-169
Vol.=3000 gal
Inst. Date: 1977
Bdrms.=2
16-Q-169A
Vol.=3000 gal
Inst. Date: 1977
Bdrms.=2
16-Q-169B
Vol.=1500 gal
Inst. Date: 2003
Bdrms.=2
16-Q-171
Vol.=1250 gal
Inst. Date: 2007
Bdrms.=2
16-Q-173
Inst. Date: 1973
Bdrms.=2
16-Q-174
Bdrms.=2
16-Q-176
Bdrms.=1
16-Q-178
Bdrms.=1
16-Q-179
Vol.=2500 gal
Inst. Date: 1982
Bdrms.=2
0
50
100
200
300
Feet

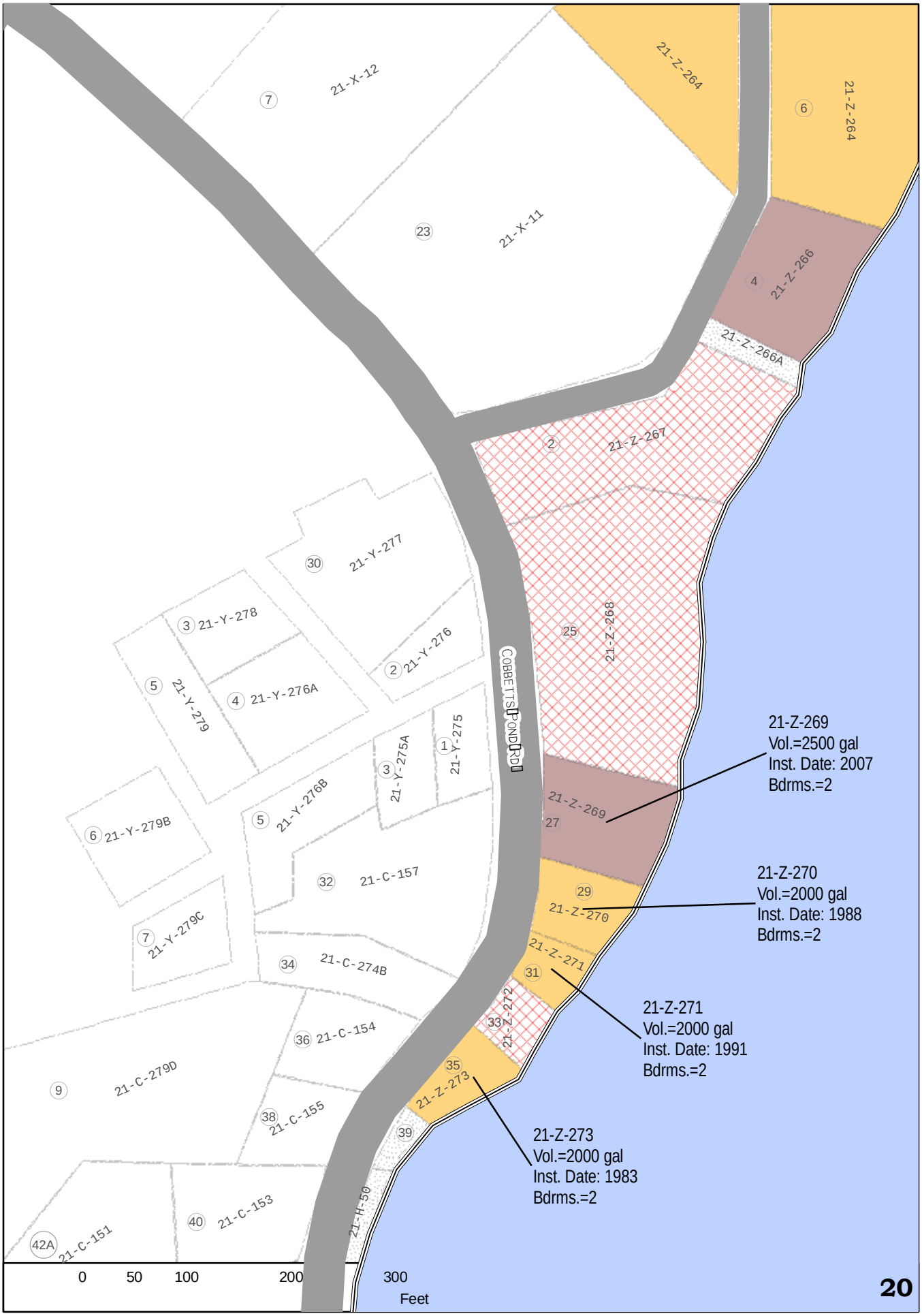

16-Q-300
16-Q-205A
Vol.=1500 gal
Inst. Date: 2000
Bdrms.=4
16-Q-206A
Inst. Date: 2005
Bdrms.=2
16-Q-206
Vol.=1500 gal
Inst. Date: 2004
Bdrms.=2
16-Q-205
Vol.=2000 gal
Inst. Date: 1995
Bdrms.=4
16-Q-207
Inst. Date: 1984
Bdrms.=3
16-Q-208
Inst. Date: 1978
Bdrms.=2
16-Q-211
Vol.=1500 gal
Inst. Date: 1986
Bdrms.=3
16-Q-210
Vol.=2500 gal
Inst. Date: 2004
Bdrms.=4
0 50 100 200 300
Feet


MINISTERIAL RD.
GAUMONT RD.
16-P-203B
16-R-450
16-R-186F
16-R-186C
16-Q-186D
16-Q-186A
16-Q-205A
16-Q-186E
16-E-25
16-E-26
16-E-24
16-E-22
16-Q-214
16-Q-213
16-Q-214A
16-Q-212
16-E-28
16-E-30
16-E-33
16-E-21
16-E-31
16-E-13
16-E-32
16-C-12
16-C-13
16-C-11
16-C-10
16-Q-213
Vol.=1500 gal
Inst. Date: 1999
Bdrms.=4
16-Q-214
Vol.=2000 gal
Inst. Date: 2007
Bdrms.=2
16-Q-212
Inst. Date: 1998
Bdrms.=3
16-Q-214A
Vol.=2000 gal
Inst. Date: 2007
Bdrms.=1
16-E-28
Vol.=1100 gal
Bdrms.=2
16-E-30
Vol.=1000 gal
Inst. Date: 1998
Bdrms.=2
16-E-33
Vol.=1000 gal
Inst. Date: 1987
Bdrms.=2
16-E-21
Vol.=1500 gal
Inst. Date: 1998
16-E-31
Vol.=1000 gal
Inst. Date: 1973
Bdrms.=2
16-E-32
Vol.=1000 gal
Inst. Date: 1980
Bdrms.=3
16-C-12
Vol.=1000 gal
Inst. Date: 1988
Bdrms.=4
0
50
100
200
300
Feet
16


16-C-21
24
18
16-C-19
17
16-C-18
19
16-C-17
21
16-C-16
23
25
16-F-8
32
16-C-10
30
16-F-7
16-F-6
28
16-F-5
26
16-F-4
24
16-F-3
22
16-F-2
20
16-F-1
16/18
16-F-6
Vol.=1000 gal
Inst. Date: 1982
Bdrms.=3
16-F-5
Vol.=1000 gal
Inst. Date: 2005
Bdrms.=1
16-F-4
Vol.=1500 gal
Inst. Date: 2003
Bdrms.=2
16-F-3
Vol.=1000/1500 gal
Inst. Date: 2003
Bdrms.=2
16-F-1
Bdrms.=2
16-F-2
Vol.=1250 gal
Inst. Date: 1997
Bdrms.=3
0
50
100
200
300
Feet


21-V-229
Vol.=3000 gal
Inst. Date: 1982
Bdrms.=2
21-V-227
Vol.=1500 gal
Inst. Date: 2005
Bdrms.=2
21-V-237
Vol.=1500 gal
Inst. Date: 1998
Bdrms.=3
21-V-228A
Vol.=1000 gal
Inst. Date: 1982
Bdrms.=2
21-V-250
Vol.=1500 gal
Inst. Date: 2004
Bdrms.=3
21-W-40
Vol.=1350 gal
Inst. Date: 1956
Bdrms.=7
0 50 100 200 300
Feet


21-W-3
21-W-16
19
21-Z-260
21-Z-261
Vol.=2000 gal
Inst. Date: 1998
Bdrms.=3
21-X-5
6
20
18
21-Z-261
21-Z-262
Vol.=1000 gal
Inst. Date: 1995
Bdrms.=3
16
21-Z-262
21-X-10A
14
21-Z-263
21-Z-263
Vol.=1000 gal
Inst. Date: 1990
Bdrms.=3
10
21-Z-263A
21-Z-263A
Vol.=1000 gal
Inst. Date: 2005
Bdrms.=2
21-Z-264
Vol.=2500 gal
Inst. Date: 1992
Bdrms.=2
7
21-X-12
21-Z-264
21-Z-264
Vol.=2500 gal
Inst. Date: 1992
Bdrms.=2
6
23
21-X-11
4
21-Z-266
21-Z-266
Vol.=1000 gal
Inst. Date: 1986
Bdrms.=4
21-Z-266A
COBBETTS POND
2
21-Z-267
0
50
100
200
300
Feet


21-Z-264
21-Z-264
21-X-12
21-X-11
21-Z-266
21-Z-266A
21-Z-267
21-Z-268
21-Y-277
21-Y-278
21-Y-276
21-Y-276A
21-Y-279
21-Y-275A
21-Y-275
21-Y-276B
21-Y-279B
21-C-157
21-Y-279C
21-C-274B
21-C-154
21-C-279D
21-C-155
21-C-153
21-C-151
21-H-50
COBBETTS POND RD
21-Z-269
21-Z-270
21-Z-271
21-Z-272
21-Z-273
21-Z-269
Vol.=2500 gal
Inst. Date: 2007
Bdrms.=2
21-Z-270
Vol.=2000 gal
Inst. Date: 1988
Bdrms.=2
21-Z-271
Vol.=2000 gal
Inst. Date: 1991
Bdrms.=2
21-Z-273
Vol.=2000 gal
Inst. Date: 1983
Bdrms.=2
0
50
100
200
300
Feet

Appendix D:

Stormwater BMP Load Reduction and Cost Estimate Data

TABLE D-1
SIMPLE METHOD CALCULATIONS

Yearly Precipitation	42.6	inches
Fraction Contributing to Runoff	0.85	

			RESIDENTIAL	COMMERCIAL	ROAD	AGRICULTURE	FOREST	REC	OPEN/HIGHWAY
		Runoff Coefficient (C)	0.3	0.7	0.85	0.1	0.1	0.15	0.2
		Event Mean Concentration (mg/L)	0.18	0.22	0.23	0.5	0.05	0.79	0.05
Site Number	Site Name	Total BMP Catchment Area (sf)	BMP Catchment Area by Land Use (sf)						
1	Castleton Center Parking Area	22871	0	22871	0	0	0	0	0
2	6-8 Armstrong Road	71905	25000	0	21900	0	25005	0	0
3	Sawtelle Road	47129	0	0	13140	0	33989	0	0
4	Griffin Park	52661	0	0	19500	0	0	33161	0
5a	Farmer Road	18116	0	0	3575	0	14541	0	0
5b	Farmer Road / Horseshoe Road	13637	10062	0	3575	0	0	0	0
6	20-24 Turtle Rock Road	4233	0	0	4233	0	0	0	0
7	34 Turtle Rock Road	2200	2200	0		0	0	0	0
8	74 Turtle Rock Road	3684	0	0	3684	0	0	0	0
9	Summer Street Area	-	-	-	-	-	-	-	-
10	60-62 Horseshoe Road	41908	38208	0	3700	0	0	0	0
11	58 Horseshoe Road	65248	59548	0	5700	0	0	0	0
12	Woodland Ridge Area (Rt. 111)	63164	0	53714	9450	0	0	0	0
13	35 Cobbett's Pond Road	19734	15234	0	4500	0	0	0	0
14	Windham Town Beach	9654	0	0	4827	0	0	0	4827
15	Fossa Road / Range Road (Rt. 111A)	1266037	814637	0	82600	0	368800	0	0
16	Hawley Road	51175	38175	0	13000	0	0	0	0

Site Number	Site Name		Runoff Volume (cf)						
1	Castleton Center Parking Area		0	48309	0	0	0	0	0
2	6-8 Armstrong Road		22631	0	56171	0	7545	0	0
3	Sawtelle Road		0	0	33702	0	10256	0	0
4	Griffin Park		0	0	50015	0	0	15009	0
5a	Farmer Road		0	0	9169	0	4388	0	0
5b	Farmer Road / Horseshoe Road		9109	0	9169	0	0	0	0
6	20-24 Turtle Rock Road		0	0	10857	0	0	0	0
7	34 Turtle Rock Road		1992	0	0	0	0	0	0
8	74 Turtle Rock Road		0	0	9449	0	0	0	0
9	Summer Street Area	-	-	-	-	-	-	-	-
10	60-62 Horseshoe Road		34588	0	9490	0	0	0	0
11	58 Horseshoe Road		53906	0	14620	0	0	0	0
12	Woodland Ridge Area (Rt. 111)		0	113457	24238	0	0	0	0
13	35 Cobbett's Pond Road		13791	0	11542	0	0	0	0
14	Windham Town Beach		0	0	12381	0	0	0	2913
15	Fossa Road / Range Road (Rt. 111A)		737450	0	211859	0	111285	0	0
16	Hawley Road		34558	0	33343	0	0	0	0

Site Number	Site Name		Phosphorus Export to BMP (lb/yr)							BMP Catchment P Export (lb/yr)
1	Castleton Center Parking Area		0.000	0.663	0.000	0.000	0.000	0.000	0.000	0.663
2	6-8 Armstrong Road		0.254	0.000	0.806	0.000	0.024	0.000	0.000	1.084
3	Sawtelle Road		0.000	0.000	0.484	0.000	0.032	0.000	0.000	0.516
4	Griffin Park		0.000	0.000	0.718	0.000	0.000	0.740	0.000	1.458
5a	Farmer Road		0.000	0.000	0.132	0.000	0.014	0.000	0.000	0.145
5b	Farmer Road / Horseshoe Road		0.102	0.000	0.132	0.000	0.000	0.000	0.000	0.234
6	20-24 Turtle Rock Road		0.000	0.000	0.156	0.000	0.000	0.000	0.000	0.156
7	34 Turtle Rock Road		0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.022
8	74 Turtle Rock Road		0.000	0.000	0.136	0.000	0.000	0.000	0.000	0.136
9	Summer Street Area[1]	-	-	-	-	-	-	-	-	0.450
10	60-62 Horseshoe Road		0.388	0.000	0.136	0.000	0.000	0.000	0.000	0.525
11	58 Horseshoe Road		0.605	0.000	0.210	0.000	0.000	0.000	0.000	0.815
12	Woodland Ridge Area (Rt. 111)		0.000	1.557	0.348	0.000	0.000	0.000	0.000	1.905
13	35 Cobbett's Pond Road		0.155	0.000	0.166	0.000	0.000	0.000	0.000	0.320
14	Windham Town Beach		0.000	0.000	0.178	0.000	0.000	0.000	0.009	0.187
15	Fossa Road / Range Road (Rt. 111A)		8.282	0.000	3.040	0.000	0.347	0.000	0.000	11.669
16	Hawley Road		0.388	0.000	0.478	0.000	0.000	0.000	0.000	0.867
									TOTAL:	**21.2**

1. P Load calculated using STEPL gully tool.

TABLE D-2
BMP COST AND LOAD REDUCTION ESTIMATES

					1	1	2	2	2	1	1	2	2	2	1	5	5	5	2	5					
					BIORETENTION	WATER QUALITY SWALE	DEEP SUMP CATCH BASIN	OUTLET STRUCTURE	RIP-RAP STABILIZATION	RAIN GARDEN	STANDARD ASPHALT	STONE CHANNEL	CURB	BAYSEPARATOR	CONSTRUCTED WETLAND (with sediment forebay)	FILL/COMPACTION	EXCAVATION/REMOVAL OF EARTH MATERIAL	304-AGGREGATE BASE COURSE (NH DOT 304.33) (8" THICKNESS)	CULVERT REPLACEMENT						
				Unit	sf	sf	ea	ea	sf	sf	sf	sf	lf	ea	sf	cy	cy	cy	ea						
				Cost/Unit	$11	$7	$3,000	$2,000	$8	$10	$4	$8	$20	$10,000	$2	$6	$3	$40	$3,000						
				Removal %[6]	0.65	0.35	0.05	0	0	0.65	0	0	0	0.8	0.45	-	-	-							
Site	Site Name	BMP Catchment Area (sf)	BMP Catchment P Export (lbs/yr)		QTY.															Total BMP Cost[4]	P Load Reduction %	P Load Reduction (lbs/yr)	Cost Range			P Load Reduction Range (lbs/yr)		
1	Castleton Center Parking Area	22871	0.66		2170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$31,031	0.65	0.43	$27,900	-	$34,100	0.39	-	0.47
2	6-8 Armstrong Road	71905	1.08		0	270	0	0	0	0	0	0	0	0	0	0	0	0	0	$2,457	0.35	0.38	$2,200	-	$2,700	0.34	-	0.42
3	Sawtelle Road	47129	0.52		0	400	2	0	0	0	0	0	0	0	0	0	0	0	0	$11,440	0.38	0.20	$10,300	-	$12,600	0.18	-	0.22
4	Griffin Park	52661	1.46		2500	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$38,350	0.65	0.95	$34,500	-	$42,200	0.85	-	1.04
5a	Farmer Road (site 1)	36232	0.30		1200	800	0	0	0	0	0	0	0	0	0	0	0	0	0	$24,440	0.77	0.23	$22,000	-	$26,900	0.21	-	0.25
5b	Farmer Road / Horseshoe Road	13637	0.23		360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$5,148	0.65	0.15	$4,600	-	$5,700	0.14	-	0.17
6	20-24 Turtle Rock Road	4233	0.16		0	380	0	0	15	0	0	0	0	0	0	0	0	0	0	$3,614	0.35	0.05	$3,300	-	$4,000	0.05	-	0.06
7	34 Turtle Rock Road	2200	0.02		0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	$1,300	0.65	0.015	$1,200	-	$1,400	0.01	-	0.02
8	74 Turtle Rock Road	3684	0.14		0	0	0	0	0	0	2300	0	0	0	0	0	0	0	0	$11,960	-	0.09	$10,800	-	$13,200	0.08	-	0.10
9	Summer Street Area	-	0.45		0	0	0	0	0	0	0	100	0	0	0	6	24	40	2	$11,060	0.90	0.41	$10,000	-	$12,200	0.36	-	0.45
10	60-62 Horseshoe Road	41908	0.52		750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$10,725	0.65	0.34	$9,700	-	$11,800	0.31	-	0.38
11	58 Horseshoe Road	65248	0.82		400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$5,720	0.65	0.53	$5,100	-	$6,300	0.48	-	0.58
12	Woodland Ridge Area (Rt. 111)	63164	1.91		500	100	2	0	100	0	0	0	500	1	0	0	0	0	0	$42,900	0.98	1.87	$38,600	-	$47,200	1.68	-	2.05
13	35 Cobbett's Pond Road	19734	0.32		0	0	0	0	80	80	0	0	0	0	0	0	0	0	0	$1,872	0.65	0.21	$1,700	-	$2,100	0.19	-	0.23
14	Windham Town Beach	9654	0.19		400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$5,720	0.65	0.12	$5,100	-	$6,300	0.11	-	0.13
15	Fossa Rd. / Range Rd. (Rt. 111A)	1266037	15.00		0	0	0	0	208	0	0	1760	0	0	8175	0	0	0	0	$41,722	-	6.75	$37,500	-	$45,900	6.08	-	7.43
16	Hawley Road	51175	0.87		500	700	0	0	0	0	0	0	0	0	0	0	0	0	0	$13,520	0.77	0.67	$12,200	-	$14,900	0.60	-	0.74
																					Total:	**13.39**				**12.05**	**-**	**14.73**

1. Unit costs from Charles River Watershed Association "
2. Unit costs based on past Geosyntec projects and contractor estimates
3. Cost Estimate from Stormtech product documents
4. Cost includes additional 30% to reflect mobilization, erosion and sediment controls, contingency, etc.
5. Cost estimate from RS Means catalog
6. Percent reductions taken from Volume 1 Appendix E of NH Stormwater Manual when available, from Volume 2 of Massachusetts Stormwater Handbook when not available