Village Pond Watershed Assessment

JULY 15, 2021 (REVISED OCTOBER 12, 2021)

Prepared by Cape Cod Commission Staff

Village Pond Watershed Assessment

CONTENTS

CAPE COD COMMISSION
3225 Main Street • P.O. Box 226 • Barnstable, MA 02630
508-362-3828 • Fax: 508-362-3136 • Email: frontdesk@capecodcommission.org
www.capecodcommission.org

Introduction

The Town of Truro requested technical support from the Cape Cod Commission to conduct a watershed assessment and localized study of stormwater issues within the Village Pond watershed and neighborhood of North Truro. Village Pond, also known as Pilgrim Pond and Standish Pond, is surrounded by medium and high-density (as defined by MassGIS land use) residential neighborhoods, an associated wetland, general business and limited business districts, and numerous paved surface roads. The neighborhood around Village Pond, referred to as Pond Village, is in the area of Pond Road, Shore Road, Route 6, and Highland Road.

Truro is a rural town on the outer peninsula of Cape Cod, bordered by Wellfleet to the south, Provincetown to the north, Cape Cod Bay on the west, and the Atlantic Ocean on the east. Nearly 70% of the Town of Truro is part of the Cape Cod National Seashore (CCNS), primarily located along the eastern side, abutting the Atlantic Ocean. It is characterized by sandy beaches, towering grassy dune cliffs, rolling hills as well as flat expanses.

Nutrient inputs from septic systems, fertilizer use, and stormwater runoff contribute to excessive algae growth in aquatic systems to the detriment of water quality and ecosystem health. Continued inputs of nutrients and pollutants will further degrade the health of Village Pond and wetland resources. The study was conducted to assess stormwater issues within the Village Pond watershed. The goals were to identify impacts of septic system effluent and untreated stormwater conveyances from impervious surfaces on water quality and wetland habitat. The tasks outlined for this project include:

- Task 1 – Conduct a watershed assessment by investigating prior studies as well as field assessments of onsite conditions
- Task 2 – Develop a pilot private well water monitoring plan
- Task 3 – Assess existing conditions of culverts at three specific locations (these are outside of the Village Pond watershed)
    - Little Pamet River under Route 6
    - Pamet River under Route 6 and North Pamet Road
    - Head of the upper Pamet River Valley

This report is a summary of the findings of these tasks.

VILLAGE POND WATER QUALITY

Village Pond is a small linear pond with an associated wetland. The pond is approximately three acres and almost entirely surrounded along the north and south by residential neighborhoods and roads. To the east are wetlands, a residential neighborhood and undeveloped land. To the west the pond is adjacent to a wetland and roads, and then beyond those are coastal dune, beach, and Cape Cod Bay. According to MassGIS the wetlands consist of shallow marshes and shrub wetlands. There is a perennial stream through the northeast section of wetland. The stream appears to connect to ditch, that is likely man-made, given its size and straightness, that runs eastward from the wetland to Shore Road. However, prior to the construction of Route 6, in the Cape Cod Commission Chronology Viewer, there appears to be a stream through the wetland that continues to Shore Road and beyond.

Village Pond is a freshwater pond located on the bayside of Truro with a small variety of fish including bullhead, largemouth bass, brook trout and smallmouth bass. It is publicly owned with both public and private access. There is a town landing located off Pond Road. The linear shape of the pond indicates it may be a flooded glacial valley, as opposed to a kettle hole pond. However, there are other possible ways this pond could have been created. Any changes made to the pond or surrounding area resulting in the creation of the pond predates 1938, according to the Cape Cod Chronology Viewer.

The water quality of the pond in Village Pond is unknown as there is no record of previous testing, however, anecdotally the water quality has decreased as noted by residents seeing increases in algae and decreases in water transparency. On September 21, 2021, a water sample was taken by Truro staff from a deep location within the pond and has been sent to a lab for analysis. The lab analysis results were not available in time to include in this report.

The water quality of the pond is impacted by both the surface water that enters the pond as runoff as well as the groundwater that seeps in below the surface. The health of Village Pond is directly related to the land use within, and the condition of its watershed.

STORMWATER

Stormwater is water that comes from rain and snowmelt. In a natural, undeveloped landscape stormwater absorbs into the ground (infiltrates). In developed areas where there are surfaces that are impervious (roofs, roads, parking lots), the stormwater cannot absorb and instead puddles and or flows over the surface (runoff) to an area that is pervious. As stormwater flows over impervious surfaces it can accumulate pollutants such as oil, grease, nutrients, and sediment and carry them to bodies of water or vegetated areas.

The largest inhibitor of infiltration is impervious surfaces. Reducing newly proposed impervious surfaces is important to reducing the amount of stormwater runoff. It is also important for communities to identify areas of existing impervious surfaces that could be reduced.

According to the Town of Truro's *Integrated Water Resources Management Plan* (IWRMP), Phase I (Weston & Sampson, 2014), the amount of impervious area in the Village Pond recharge area (ID 16) results in an average nitrogen load of 405 pounds/year, which is 78% of the total nitrogen load from stormwater (516 lbs/yr). Clearly, a reduction in impervious area and or stormwater treatment systems would lead to a reduction in nitrogen loading from stormwater runoff. Within the approximately 150-acre Pond Village recharge area, approximately 10.3 acres or 7% is impervious cover, of which approximately 8.3 acres (80%) are town and private roads.

Truro does not have a stormwater bylaw with associated regulations. Conducting a review of the bylaws to assess the town's ability to regulate stormwater management could be a valuable next step. Combining direct planning activities that can be implemented by the town with regulatory and administrative tools to promote and incentivize enhanced stormwater management throughout the entire community are important for improving overall stormwater management and pond health.

In the past the goal with stormwater management was to remove it as quickly as possible from roads. This was typically done with traditional or gray infrastructure such as storm drains, pipes, and paved conveyances that collect and move untreated stormwater away from the built environment, and often into nearby waterways. Recent understanding of stormwater pollutants and their impact on resource areas has resulted in increased interest in and design of low impact development (LID) for stormwater management. LID is the practice of using innovative stormwater management systems that emphasize conservation, use on site natural features, and have low impact on the environment. LID often includes "green" infrastructure, which is designed to mimic natural processes, using vegetation and soils to capture and treat rainwater where it falls, resulting in improved water quality and increased groundwater recharge.

FIELD OBSERVATIONS

Village Pond Watershed

Internet and computer file searches were conducted to locate existing reports and prior studies. Relevant information was acquired and subsequently informed the field work. These references can be found in the References section below (page 40).

Several field visits were conducted (11/10/20; 12/01/20; 02/24/21), including a post rain event to gain perspective on topography, land use, and stormwater runoff.

During the post rain event field visit (12/01/20) data were collected with the ESRI Collector application. Commission staff documented the presence of stormwater runoff, ponding, scouring, erosion, sedimentation, and infrastructure (presence, absence, condition, function). These locations, notes, and photographs were documented in the ESRI Collector application and uploaded to a map to provide examples of stormwater issues (Figure 1) in the Pond Village area. Descriptions of the stormwater issues can be found in Table 1.

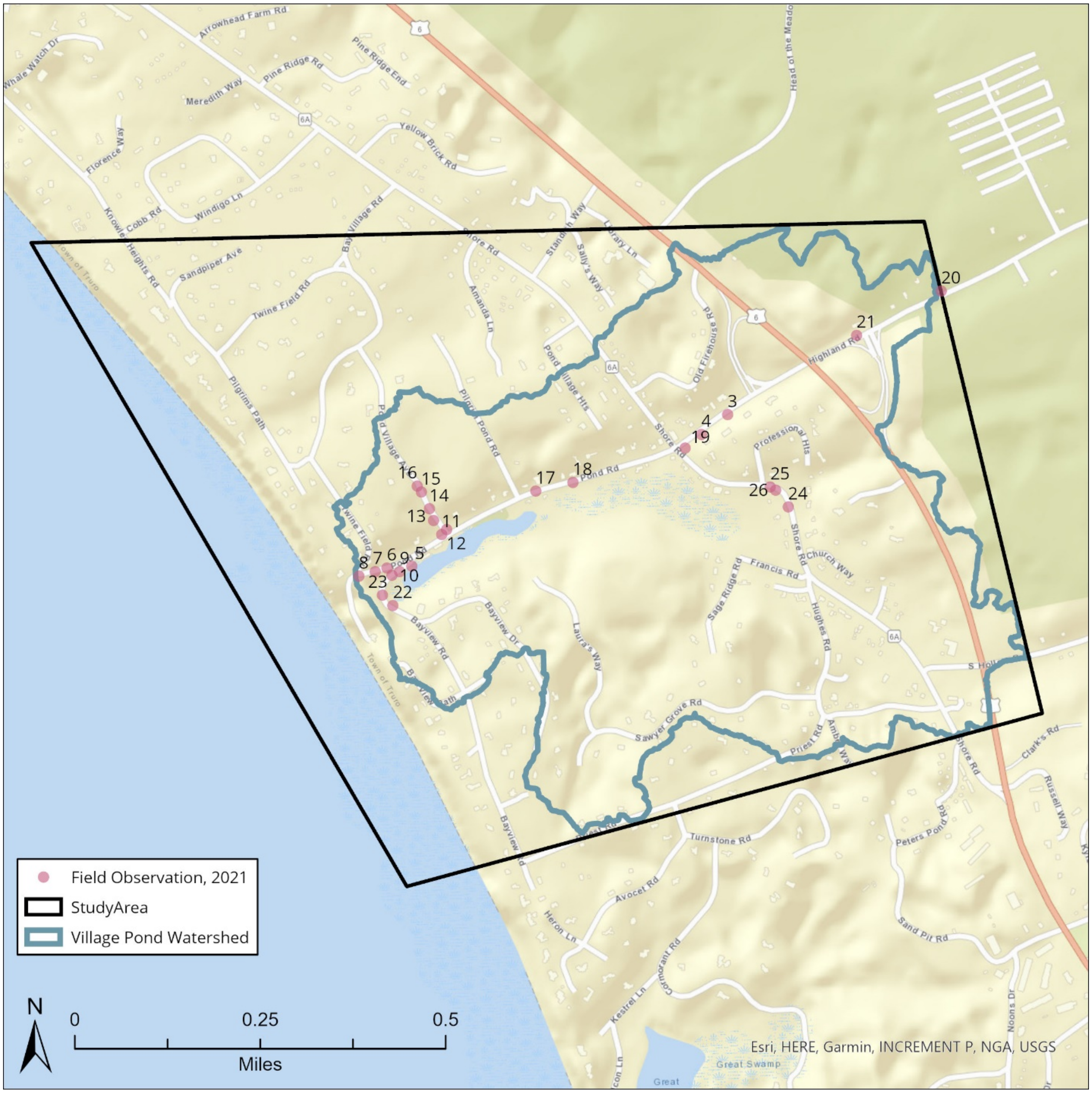

Figure 1. Locations of field observations of stormwater issues collected post rain event, December 2020.

Table 1. Field observations of stormwater issues in the Pond Village area of North Truro

Field Observation #	Evidence of runoff	Location	Field Notes	Longitude	Latitude
3		ROW	Storm drain	-70.0836613	42.0345107
4		ROW	Storm drain	-70.08435541	42.03413418
5	Sediment	ROW	Storm drain - evidence of ponding with sediment accumulation at Bay View Road stop sign.	-70.09200373	42.03165398
6	Sediment	ROW	Scouring and erosion. Paved flume directing runoff off Pond Road into steeply sloped vegetated area.	-70.09265391	42.03162686
7	Erosion	ROW	Scouring and sedimentation. Paved flume directing runoff off Pond Rd to steeply sloped vegetated area.	-70.09296094	42.03156236
8	Ponding	Parking	Ponding and sedimentation at top of the hill near entrance to beach parking area	-70.09339412	42.03147791
9	Ponding	ROW	Land adjacent to road pushed and dug back (man-made), possibly to encourage runoff and ponded water to pool here off the road = country drainage	-70.09232249	42.03155423
10		ROW	Land adjacent to road pushed and dug back towards pond, seemingly to encourage runoff to pool and runoff here = country drainage.	-70.09252885	42.03148051
11	Ponding		Storm drain. Severe ponding and some sedimentation too. Water nearly spans the width of Pond Village Ave.	-70.09120435	42.03226351
12	Ponding	ROW	Storm drain. Severe ponding with some sedimentation.	-70.09107191	42.03235537

Field Observation #	Evidence of runoff	Location	Field Notes	Longitude	Latitude
13	Erosion	ROW	Paved flume directing runoff off road into naturally vegetated area. Erosion and sedimentation.	-70.09141456	42.03253822
14	Erosion	ROW	Paved flume directing runoff off road to naturally vegetated area. Erosion, sedimentation, and scouring.	-70.09151833	42.03276734
15	Sediment	ROW	Paved flume directing runoff off road to vegetated area. Scouring and erosion too.	-70.09172335	42.03309726
16	Sediment	ROW	Paved flume directing runoff off Pond Village Ave to vegetated area.	-70.09182746	42.03321909
17	Ponding	ROW	Storm drain. Leaves and needles piled up. Water ponded on road near storm drain and in front of nearby driveway. Pipes/culverts running parallel to road can be seen in open grate.	-70.08871936	42.03308259
18	Sediment	Driveway	Not sure if driveway or ROW. South side of Pond Rd paved and sloping towards pond.	-70.08774647	42.03323648
19	Ponding	ROW	Possible location for SW treatment?	-70.08478448	42.03387107
20	Erosion	ROW	Land pushed and dug back away from road to allow runoff to drain. Sedimentation and ponding too.	-70.07801056	42.03685503
21	Sediment	Driveway	Lots of sedimentation from driveway.	-70.08024828	42.03602229

Field Observation #	Evidence of runoff	Location	Field Notes	Longitude	Latitude
22	Sediment	ROW	Bay View Road has a berm along the east side but beyond the berm there is a paved apron that leads to a dirt road that runs alongside the pond. Possibly providing a path for stormwater to runoff into wetland.	-70.09251008	42.03089424
23	Sediment	ROW	Paved flume leading to an area that has been pushed and dug back towards pond, seemingly to encourage runoff to pond here.	-70.09277972	42.03109771
24	Sediment	ROW	Lower area channeling runoff from road to vegetated area near the pond / wetland. Ponding, scouring and erosion to.	-70.08211459	42.03269027
25	Ponding	ROW	Paved flume to an area that has been pushed and dug back towards pond/wetland. Erosion, sedimentation, and scouring too.	-70.08257559	42.03308611
26	Ponding	Driveway	Driveway on Shore Rd.	-70.08243402	42.03302567

Twenty-six observations were documented, primarily along Pond Road. Several of these are listed in the Recommendations section below (pg. 30).

Onsite field verifications were also conducted for parcels within the recharge area of Village Pond. Factors such as land use, fertilizer use, impervious surfaces and connected impervious surfaces were documented. A few locations were of note including:

Pond Road – Across the street from 13 and 15 Pond Road there is a paved pull out of the road that slopes towards the pond and wetland. It appears to be used for residential parking. This impervious surface is a potential location for disconnecting the paved surface so that it does not serve as a conduit for stormwater runoff into the wetland/pond. This is known as impervious cover disconnection (ICD).

Bay View Road – During the November field visit several lawns in the Bay View Road and Bay View Drive area were observed to be dark green, a likely indication, especially at that time of year, of fertilizer application. The lawns in the area tend to be large, sloped, and are located on a high point within the watershed, upgradient of the pond and wetland.

Pond Village Heights Road – This location is noted in the IWRMP, Phase I, as having greater than 5 parts per million (ppm) nitrate in water samples. The area is largely residential with business-residential activity observed at one of the residences. The northern boundary of the watershed is at approximately house numbers 2 and 5. Given the paved road and the steep slope there is potential for nutrients, sediment, and other debris to get washed down slope in a rain event towards the water resources.

Professional Heights Road – This area may also have greater than 5 ppm nitrate in water samples as noted in the IWRMP, Phase I. The area is largely residential with some residential-business activities observed at a couple of the residences. Notably, much of the road and lawns are steeply sloped and there is a large area of imperviousness (hammerhead-like area) on the corner near house numbers 6, 8, and 10.

Pamet River Watershed

Also, during the field visits culvert assessments were conducted where the Pamet River flows under Route 6A and Route 6, and where Little Pamet River flows under Route 6 (Figure 2). The condition of the culverts as well as presence of erosion, scouring, sedimentation, and water flow were documented.

Figure 2. Culvert locations for Little Pamet River (Route 6) and Pamet River (Route 6A, Route 6, and North Pamet Road).

Task 1: Watershed Assessment

A watershed is an area of land that drains all the streams and rainfall to a common, low-lying area such as a pond, mouth of a bay or any point along a stream. Watersheds consist of surface water (streams, ponds) and all the underlying groundwater. Watersheds are also referred to as drainage basins or recharge areas. When rain falls on the ground, some of the water soaks in, or infiltrates the soil. The water in the shallow soil layer moves downhill or downgradient, through the soil and enters a stream or pond. The water that infiltrates deeper into the soil recharges the groundwater. Where the water travels and how much infiltrates depends on the soil characteristics and properties (sandy, gravelly, organic), how wet the soil is (soil saturation), land cover (roads, grass, forest) and the slope of the land. Flooding becomes more prevalent as the area of impervious surfaces increase, like the area on Highland Road between Shore Road and Route 6.

In many regions watersheds are determined by the topography of the land surface, but due to Cape Cod's geology, namely the sandy soils, the watersheds are determined by the contours of the groundwater table (Cambareri and Eichner, 1998). This is referred to as a recharge area. According to the USDA Natural Resources Conservation Service's Web Soil Survey, the soils in the Village Pond watershed consist primarily of Carver coarse sand and are in the hydrologic soil group (HSG) A (Figure 3). Sandy soils like Carver coarse sand are excessively drained, having high infiltration rates and low runoff potential. Additionally, hydrologic soil groups classify the soil properties that influence runoff potential and rate of infiltration. HSG A soils are defined as having high permeability and little runoff production. In 2004, USGS delineated recharge areas of Cape Cod (Walter, et al), including Village Pond in North Truro (Figure 4). This was done using groundwater models which simulated groundwater flow and represented the dynamic position of the freshwater/saltwater interface.

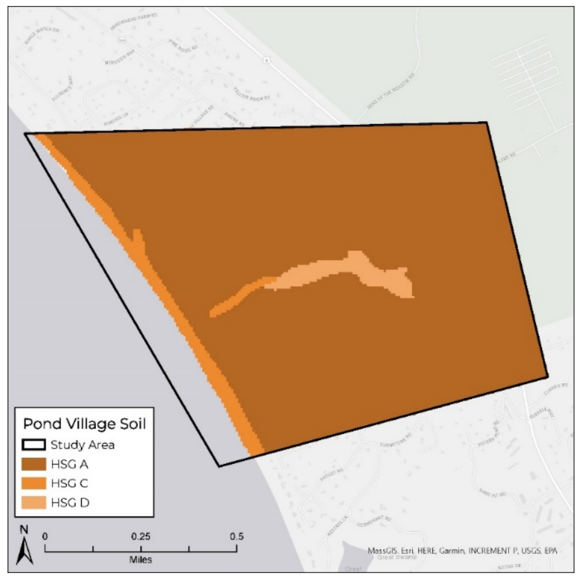

Figure 3. The soils in Pond Village are primarily in hydrologic soil group A which are characterized as having low runoff potential

Due to the soil properties in the Village Pond watershed, like most other watersheds on Cape Cod, the recharge area is the most useful delineation for the watershed and assessing impacts on the pond. Watersheds, as defined by recharge area, can be expanded by stormwater structures on nearby roads that pipe stormwater runoff and accompanying nutrients into the water body. Therefore, for the purposes of stormwater runoff, it is valuable to also delineate a watershed based on above ground characteristics, especially if there are steep slopes and/or impervious surfaces, which both facilitate surface water runoff.

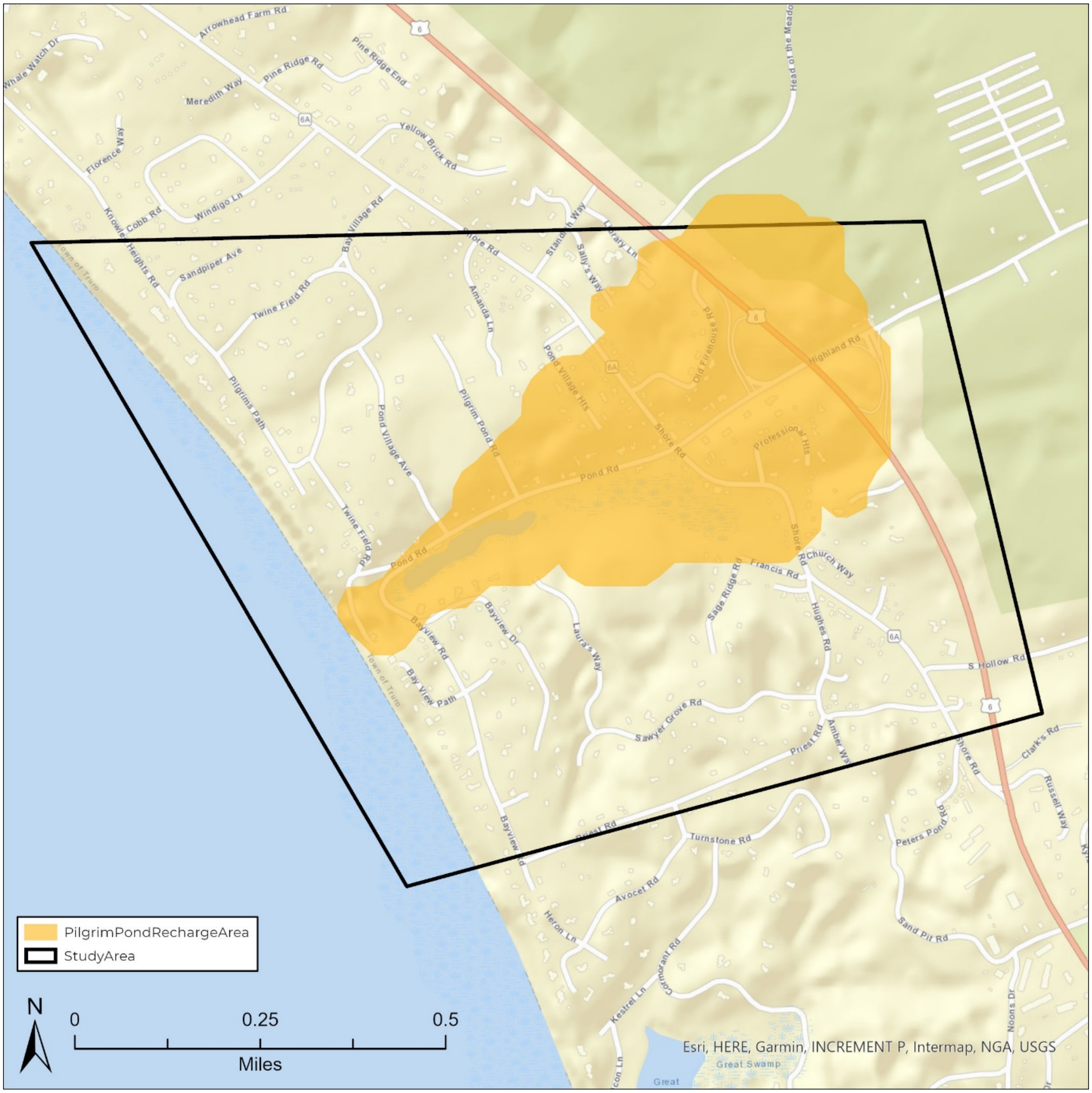

Figure 4. Recharge area for Village Pond as determined by USGS in 2004, as part of a groundwater recharge and travel time study.

To delineate the Village Pond watershed, a vector field rendering was generated which looked at flow direction and velocity based on land cover and topography (Figure 5). The watershed delineation (indicated in the thick blue line) is larger than the recharge area (yellow area depicted in Figure 4). However, it is unlikely, given the sandy soil and hydrologic group category (HSG A), that surface runoff makes its way from the outer reaches of this delineation to Village Pond or its associated wetland. The vector field rendering method provided flow direction of surface runoff depicted in the blue arrows noted in Figure 5. The direction of the arrow indicates the direction the surface runoff will flow, and the weight of the arrow (thickness) indicates velocity of the flow.

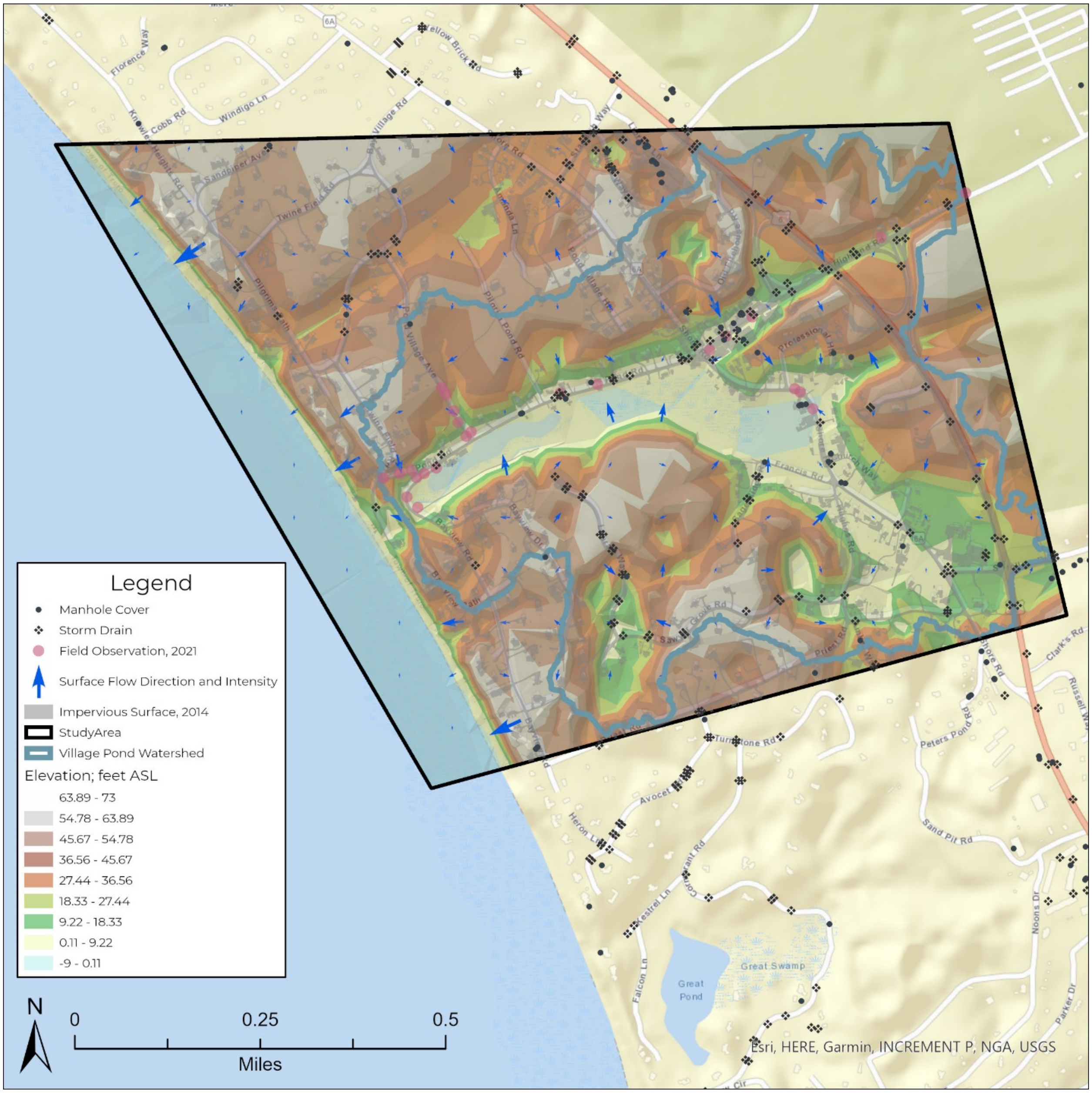

Figure 5. A vector field rendering of the Village Pond watershed using flow direction and velocity based on land cover and topography.

As part of this watershed delineation process, the catchment, or surface water accumulation, area for the storm drains located on Highland Road near Route 6 and the US Post Office was also determined (Figure 6). Catch basins and storm drains are often used interchangeably, however there is a difference. Catch basins are holes in the ground into which stormwater is collected. Storm drains are the grates on or at the sides of roads whose purpose is to capture stormwater runoff. In some situations, there are pipes connecting one catch basin to another or to a sewer system that carries the water away. Some catch basins in the Village Pond watershed connect to each other and or an outfall, but none connect to a sewer system. The symbol in Figure 5 for storm drain (black diamond) references a grate, as seen from the surface, without any speculation as to the catch basin structure. For the purposes of this report catch basin and storm drain will be used interchangeably.

The section of Highland Road at the base of the Post Office (PO) access drive consistently floods during rain events. This area is of particular interest as the catch basin where the flood waters accumulate is connected via a pipe to an outfall located on the southeast side of Shore Road. The pipe conveys untreated stormwater from a general business district dominated by impervious surfaces to a sensitive wetland resource area adjacent to Village Pond. Stormwater runoff that ponds at the base of the PO access drive minimally includes a small section of Shore Road, Highland Road, the general business district and associated parking lots, and the Route 6 westbound exit and entrance ramps. There are other catch basins in this area on Highland Avenue and they likely capture stormwater runoff from the much larger extent of Route 6 as indicated by the pink area in Figure 6.

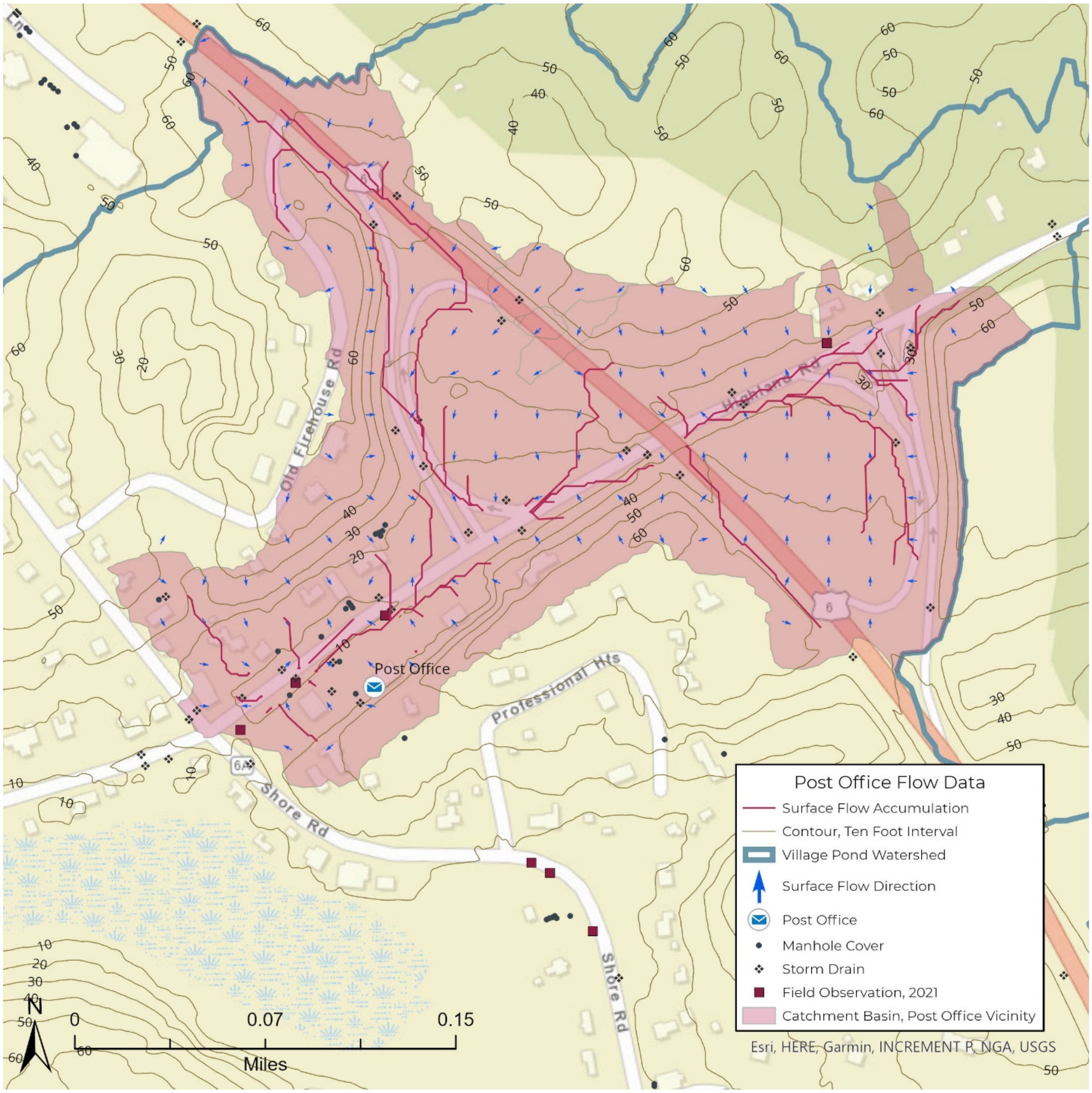

Figure 6. Catchment area for the storm drains located on Highland Road, near Route 6 and the US Post Office access drive.

To analyze the runoff potential in the Village Pond watershed, Commission staff utilized work done to develop the EPA Opti-Tool (Tool). The Tool is designed to assist in the planning and optimizing of stormwater management practices to provide the greatest benefit for achieving water resource goals, while balancing costs. Output from the Tool helps users determine the best stormwater management practices across changing and developing landscapes. The Tool is based on extensive research and modeling and incorporates inputs that are regionally representative stormwater data, precipitation data from Boston Logan Airport, and annual average load export rates from major land uses.

One of the main inputs to the Tool are hydrologic response units (HRUs). HRUs represent areas in our communities of similar physical characteristics that respond to precipitation and weather events in a similar way. The units in the hydrologic response units are newly defined categories comprised of the land use, land cover, and soil type. These characteristics assess the potential of an area to generate stormwater runoff and estimate potential pollutant loading. Land use plays a lesser role in terms of generating runoff but is necessary for determining the amount and type of pollutants likely to be present in the runoff. When considered together in newly categorized HRUs, runoff, phosphorus, and nitrogen load values can be calculated. Displaying runoff and pollutant loads on a map allows for quick visualize identification of "hotspots," or areas with significant potential to generate runoff during storm events.

Calculating runoff impacts consistently across towns or regions is important for monitoring current and potential impacts from stormwater and pollutant loads. Commission staff developed a standard for HRUs to ensure that each town in Barnstable County will have the same data and comparable stormwater impact calculations. HRU classification was performed on 10x10 meter grid cells, an area slightly larger than a two-car garage.

Hydrologic Response Unit data inputs for this analysis include:

> Land use describes how people use land. It represents the economic and cultural activities, (the built environment), that are practiced in a given place. Land use definitions or districts divide properties into different categories (residential, commercial, agricultural). This information was obtained from MassGIS 2016 Land Use. Classifying land use within the town is an important step in identifying areas that are more vulnerable to stormwater runoff and pollution (Figure 7).
>
> Land cover indicates the physical land type (grass, bare ground, asphalt) and was also obtained from MassGIS 2016 Land Use (Figure 8).
>
> Soil type refers to the makeup and characteristics of the soil, and specifically for this purpose, the hydrologic soil group (Figure 3). The soil data were obtained from USDA NRCS Soil Survey Geographic (SSURGO) Database.

An adjustment made by Commission staff to the HRU was a designation of an area as impervious or pervious. Impervious and pervious surfaces have a large impact on rain and runoff infiltration. Nonporous materials, such as roads, roofs, and parking lots, significantly obstruct infiltration of water. The impervious or pervious designations were determined using a 30% threshold. In a 10x10 meter grid cell, if more than 30% of the cell's area was impervious, then the entire cell was determined to be impervious. If 70% or more of the grid cell has pervious surfaces, the entire cell was determined to be pervious.

Figure 7. MassGIS land Use classifications used to create Hydrologic Response Units for the study area in North Truro.

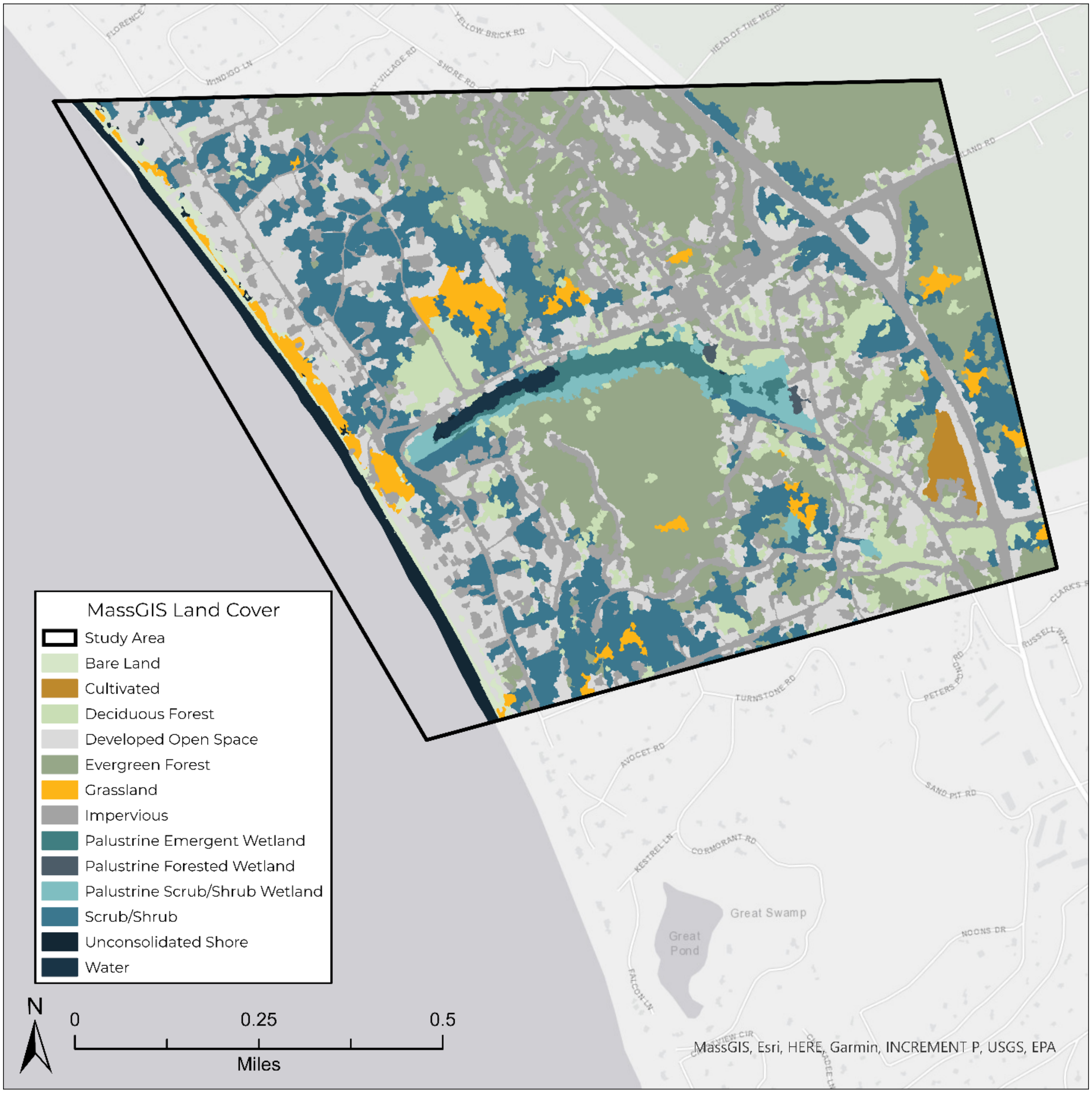

Figure 8. MassGIS Land Cover classifications used to create Hydrologic Response Units for the study area in North Truro.

The North Truro Village Pond Watershed was used as a pilot test for this modified HRU determination process. The modified HRU classifications were obtained by combining land cover and land use categories to create a condensed list of land types. These were then combined with soil data and percent of impervious surface and are depicted in Figure 9

For example, the general and limited business districts along Highland and Shore Roads have been reclassified into a modified HRU category that accounts for the land use (business), land cover (paved), soil (HSG A), and the percentage of paved surfaces present. The reclassified categories yielded a fair amount of commercially designated land that is dominated by impervious surfaces (roads, roofs, parking areas) as can be seen in Figure 9 (dark gray color).

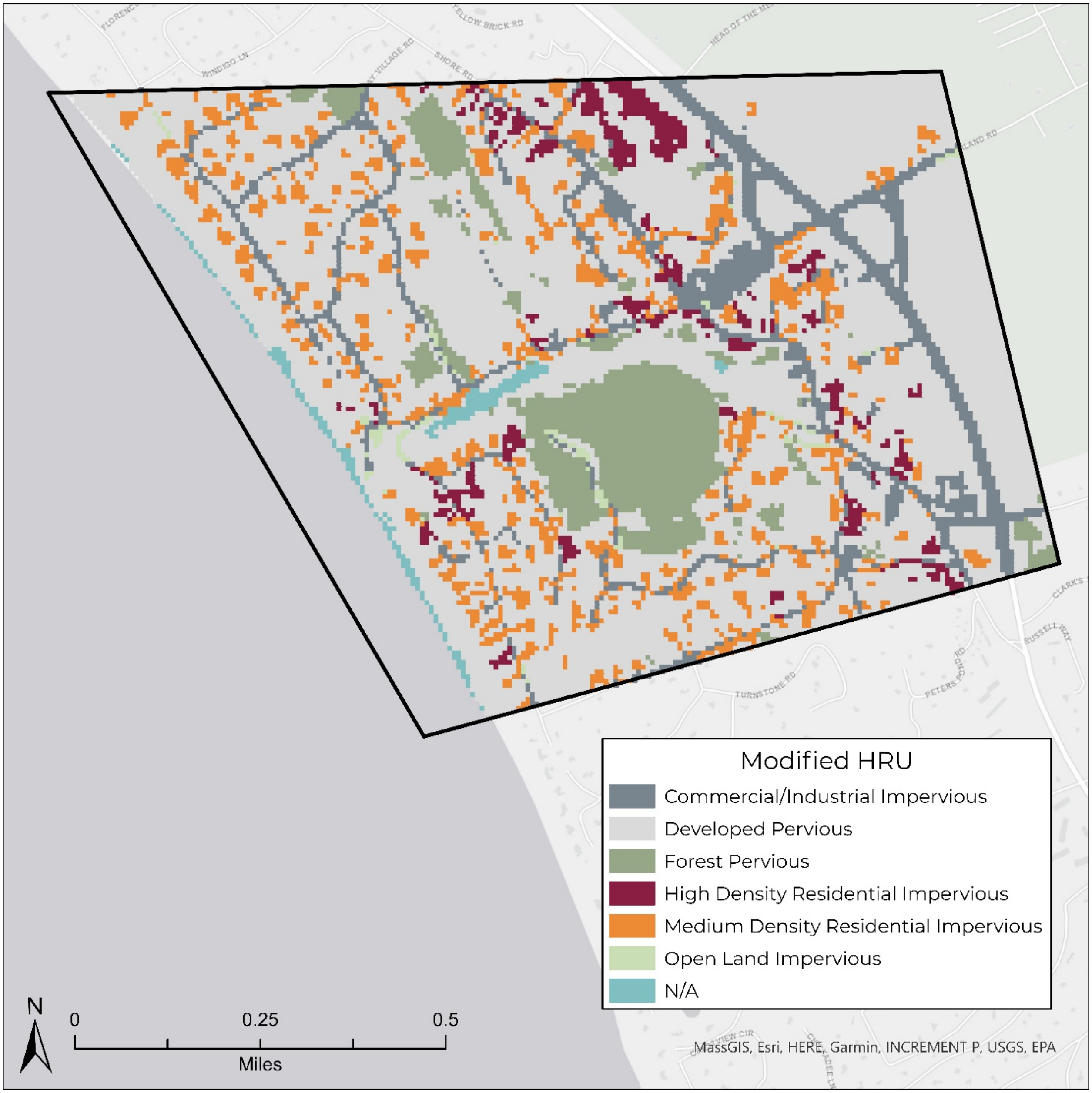

Figure 9. The modified HRU categories take into consideration land use, land cover, and soil type to generate classifications, as seen above, that reflect areas where the response to precipitation will be similar.

The reclassification of land use, land cover and soil type into modified HRU categories and subsequent analysis provided outputs of expected runoff in inches per year, nitrogen load in pounds per year, and phosphorus load in pounds per year for the Village Pond watershed.

Stormwater runoff is a common and unavoidable result of rainfall and melted snow from diffuse sources such as road, roofs, and sidewalks. With increasing intensity and frequency of storms, it is imperative that stormwater management systems can handle a high quantity of low-quality runoff. Understanding the areas and surface types that produce the highest levels of runoff is necessary to improve future and current stormwater systems. The average stormwater flow runoff potential is depicted in Figure 10. It can be seen from this figure that the runoff potential is high everywhere there is pavement and development, even in the medium density residential areas.

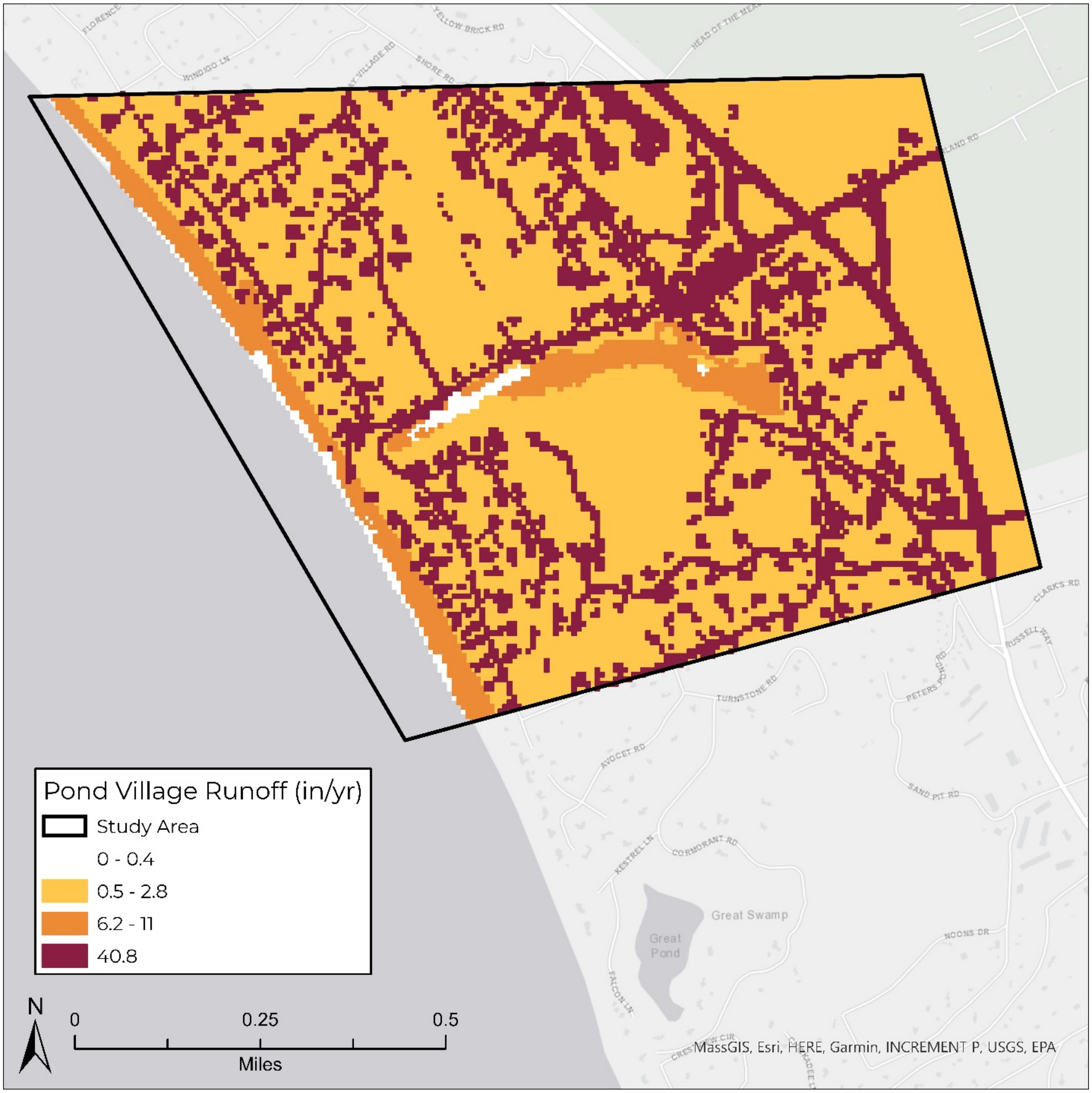

Figure 10. Average runoff volume (inches/year) as determined by HRU unit-area in Pond Village.

The annual average nitrogen and annual average phosphorus loads were also determined for the Pond Village area. As outlined in the Cape Cod Area Wide Water Quality Management Plan (208 Plan), nitrogen is significantly impacting water quality on Cape Cod, specifically coastal water quality. While 80% of nitrogen loads come from septic systems, the remaining 20% is a product of stormwater and fertilizers which can flow with runoff. Completing these calculations county-wide is extremely beneficial for discussions and actions around addressing this environmental issue of nitrogen loading from stormwater runoff.

Phosphorus is a key nutrient in freshwater ponds on Cape Cod, as it is often the limiting factor in aquatic plant productivity. This means that when phosphorus is in low supply, the rate of plant and algae growth is limited. Excess phosphorus concentrations will create an imbalanced system. Protecting ponds is a high priority due to their ecosystem and recreational value. Assessing the impact of stormwater and resultant nutrient loads will benefit the ongoing work to preserve pond ecosystems and water quality. The results highlight the critical areas of nutrient loading, which, as can be expected, correlate to areas of high-density development (defined by MassGIS land use as housing on smaller than ¼ acre lots) and impervious surfaces. In Figure 11, the results indicate the critical areas of phosphorus loading.

Figure 11. Pond Village modified HRU unit-area based annual average total phosphorus load (pounds/year).

As expected, these summary level analyses show that runoff volume is highest in the business districts and the high and medium density residential areas where the concentration of impervious surfaces is greatest. Total phosphorus, however, is highest in the residential areas, both high and medium density, but not in the general business districts.

Task 2: Private Well Water Monitoring Plan

The sandy outwash deposits on Cape Cod are highly permeable and capable of storing vast amounts of water in their pore spaces (spaces between the sand particles). The water that fills these spaces is referred to as groundwater. The groundwater system was designated as Cape Cod's Sole Source Aquifer by the US Environmental Protection Agency (EPA) in 1982, meaning that the water in the ground under our feet is the sole source of drinking water on Cape Cod. The aquifer is bound by the water table at its surface, the surrounding marine waters, and the bedrock below (LeBlanc et al., 1986).

The water in the ground (groundwater) gets there when rain or melted snow seeps into the ground (infiltrates). This water continues traveling through the soil until it reaches the groundwater (recharge). Because Cape Cod's soils are sandy with little organic material, the water quickly makes its way through the soil to the groundwater. This is good in terms of recharge but is not good in terms of filtering. Water travels through the soil so fast, there is little time for the soil to filter out contaminants and, because of the soil composition, contaminants have limited material with which to bind. Contamination of the aquifer would create a significant hazard to public health. Groundwater is susceptible to contamination from activities on the surface of the land including landfills and fertilizer and underground including septic systems and saltwater intrusion.

Sand has an iron coating that naturally binds phosphorus. Cape Cod has an abundance of sandy soils which can reduce phosphorus around conventional Title 5 leach fields by 50-90%. However, once all the phosphorus binding sites are occupied, the phosphorus can flow with the groundwater and eventually discharge into a pond (Robertson, et al., 1998).

The drinking water aquifer is a lens-shaped reservoir of freshwater that lies under the ground and sits on top of salt water, which is denser than freshwater. There are two lenses from which groundwater is extracted for drinking water in Truro, the Pamet Lens and the Chequesset Lens. The lenses are estimated to be 200-250 feet thick. The lens that supplies North Truro drinking water is the Pamet Lens.

The *Plan for Watershed Management for the Pamet Groundwater Lens* (CCC, 2008) provides guidance on drinking water protection, including a short-term priority to secure ownership of potential well fields within the Town of Truro and evaluate land uses necessary for appropriate Zone I and Zone II management. A watershed management consideration includes adoption of appropriate land use guidelines, policies and regulations that address water-quality concerns. According to the Plan, nearly the entire Town of Truro is supplied by private wells. Properties in northern Truro that are adjacent to the public water main extending along Route 6 and Route 6A from the Truro Central School to the Provincetown Truro town line are connected to the municipal water system operated by the Town of Provincetown.

In the summer of 2007, Truro's Water Resources Oversight Committee began implementing a water quality monitoring project to establish baseline nitrate information for private wells. All taxpayers with private wells were offered well testing by the summer of 2009. Water samples from approximately one third of the private wells were planned for testing each year. The results from 2007 samples had no exceedances above MassDEP's 10 ppm-N nitrate in drinking water limit. Two percent of the samples had nitrate concentrations between five and ten ppm. The average reported nitrate concentration was 0.92 ppm-N. Results from the following years (2008-2009) were not included in the 2008 Pamet Groundwater Plan.

According to the IWRMP Phase I, 2014, there are four areas in the Village Pond recharge area with elevated levels of nitrogen in the drinking water. The report recommends additional studies be conducted to determine where and what are the nitrogen sources, land use practices, septic system conditions, or well construction and hydrogeologic conditions.

For Task 2 a private well water monitoring plan was developed to sample well water from the homes located within the Village Pond recharge area (as defined by USGS, Figure 4). A standard operating procedure (SOP) was developed for the health department staff to follow (Appendix A, pg. 42). The collected samples will be brought to the Barnstable County Water Quality Laboratory and tested for the routine well analysis suite of parameters which includes:

- Coliform Bacteria
- Nitrogen
- Iron
- Copper
- Manganese
- Sodium
- pH
- Conductance

Additional parameters that may be measured include total suspended solids (TSS) and phosphorus. Samples are being collected by Truro Health Department staff.

Truro and Provincetown have an intermunicipal agreement (IMA) with respect to use of water, with Provincetown getting all its potable water from well fields located in Truro. Truro does not have a municipal drinking water supply for its residences. Water is obtained from private wells, except for a few business and other properties in North Truro as noted above. There has been recent interest in providing municipal drinking water to a few residential neighborhoods in North Truro, but this possibility is only in the beginning stages of discussion.

Also associated with this task was an outreach plan. In lieu of informational handouts and physical postings, a public presentation was provided via a video teleconferencing software platform on March 3, 2021, to explain the project, present the pilot well water plan, and answer questions from the public. The presentation is included as Appendix B (pg. 43).

Task 3: Culvert Assessment & Tidal Restoration

For Task 3 the existing conditions of culverts at three locations along the Route 6 corridor were assessed. Specific locations include:

- Little Pamet River under Route 6, just south of Long Nook Road
- Pamet River under Route 6 and North Pamet Road
- Head of the upper Pamet Valley (east extent of Pamet River – confined by Route 6 and Ballston Beach).

<u>Little Pamet River</u>

Little Pamet River is a stream located a few miles north of Pamet River. It flows west along Long Nook Road, under Route 6 and Castle Road and empties into Cape Cod Bay. For the purposes of this study, only the localized section of Little Pamet River immediately adjacent to the culvert under Route 6 was assessed. The restriction under Route 6 is not listed in the Cape Cod Atlas of Tidally Restricted Salt Marshes. At the time of the field visit (11/10/2020), the west, downstream side of the stream had no flow. The water was ponded with accumulated sand alongside and within the stream. The cement headwall was visible, but the culvert itself was under water and not visible. The upstream, eastern, side of the stream was also not flowing and had stagnant, rust-colored water. The top half of the culvert was visible above the water, is cement, and is part of the headwall structure. The wetland on both sides of the culvert is shrub swamp, according the MassDEP wetlands layer in MassGIS OLIVER, however the eastern side is denser with more woody vegetation and less *Phragmites australis*. The vegetation in the wetland on both sides of the culvert consisted of freshwater plants including common reed (*Phragmites australis*), highbush blueberry (*Vaccinium corymbosum*), willow tree (*Salix* sp.), common soft rush (*Juncus effuses*), cattails (*Typha* sp.), and sedges (*Carex* sp.).

There were no signs of scouring or erosion. There did not appear to be much velocity in the stream. The culvert was likely put in place at the same time Route 6 was constructed, 1952. In order to conduct a thorough culvert inspection to evaluate its condition and performance, the stream would need to be dewatered.

From the conditions evident at this culvert, the other tidal restrictions downstream of the Route 6 culvert (Castle Road, Old Colony Way, and Corn Hill Road) have more of an impact on the tidal restriction of Little Pamet River.

Pamet River

The Pamet River flows westward across nearly the entire width of Truro, connecting to Cape Cod Bay via Pamet Harbor. Originating just westward of the coastal dunes on the Atlantic Ocean near Ballston Beach the stream flows through a freshwater wetland to a culvert that spans under North Pamet Road and Route 6 and then through another culvert under Truro Center Road. For the purposes of this study, only the section of Pamet River, immediately adjacent to these culverts were assessed. Downstream of the restriction at Truro Center Road, the stream flows through an extensive salt marsh (Pamet Marsh) before emptying into Cape Cod Bay via Pamet Harbor.

According to the Cape Cod Atlas of Tidally Restricted Salt Marshes (2001), there are two existing restrictions on Pamet River, one at Truro Center Road/Route 6A (TR-3) and another under Route 6 and N. Pamet Rd (TR-4). Due to these restrictions, the river is divided into two hydrologically different sections, one estuarine and one freshwater.

The restrictions under Truro Center Road and Route 6 are impacting 152.4 acres of salt marsh to the east of North Pamet Road. The upstream wetland is contiguous with federally protected open space (CCNS). The tidal channel supports shellfish and potentially an anadromous fish run for sea-run brook trout.

Site TR-3 occurs at the Wilder Dike that supports Truro Center Road. The dike has a clapper valve on the seaward end of a 3-foot metal pipe, which only allows seaward flow of the Pamet River. The culvert and clapper valve were built in 1869 to block the flow of salt water from the Pamet Marsh to keep the water of upper Pamet River fresh.

Site TR-4 is immediately upstream of TR-3 and is a 4-foot culvert that spans under both Route 6 and North Pamet Road with a total length of 375 feet. It does not have any engineered flood control structure associated with it, but because of its size still restricts stream water flow.

At the eastern end of Pamet River, storm surges have over washed the barrier dune system on numerous occasions at Ballston Beach inundating the upper reaches of the Pamet River with saltwater. According to a study initiated by CCNS and the Town of Truro, conducted by the CCC and the Army Corps of Engineers (ACOE), enlarged culverts, 6 feet by 16 feet, at Route 6 and Wilder Dike could provide sufficient area to allow over wash water to exit the upper Pamet system in less than two days. Additionally, reducing the restrictions would allow regular inundation of seawater and potential salt marsh restoration in portions of the Pamet River marsh just upstream of the current restrictions. According to a study conducted by CCC (1997) tidal ranges within the river will not adversely impact wells or septic systems in the Pamet Valley.

Head of the Upper Pamet River Valley

The upper Pamet River is currently a freshwater system with a mixture of woodland, shrub swamp, and freshwater wetlands. The Upper Pamet River valley spans from Route 6 between North Pamet Road and South Pamet Road for over a mile (as the crow flies) to Ballston Beach and the Atlantic Ocean. The wetland is dominated by common reed (*P. australis*) and other freshwater wetland plants. The stream is slow flowing and meanders west from the dunes at Ballston Beach to Cape Cod Bay.

The Town of Truro, along with its partners US Dept of Agriculture, Cape Cod Conservation District, and the Woods Hole Group, are reviewing the scientific data available on the Upper Pamet River. The results will inform the process and plan for a new culvert under Truro Center Road.

There are no roads that cross the Pamet River in the upper reaches, east of North Pamet Road. Subsequently, there are no culverts associated with road crossings in the upper Pamet Valley.

Recommendations

Septic Systems/Wastewater Effluent

The Commission's Regional Policy Plan recommends a 300-foot setback for septic system leach fields from downstream water resource areas including for new and updated septic systems. When possible, this would be a good recommendation to consider.

As Truro moves forward with its newly adopted Board of Health Water Protection Regulations, (May 2021), which requires all cesspools to be replaced with modern septic systems by the end of 2023, the Town could consider recommending innovative / alternative (I/A) septic systems and provide incentives to encourage homeowners to install I/A septic systems designed to remove nitrogen to a 10 ppm level or better. Some ideas to incentivize include:

- Town provided grant
- Barnstable County Community Septic Management Loan Program, https://www.barnstablecountysepticloan.org/
- Allowing an additional bedroom or accessory dwelling unit (ADU).

This complies with the Town of Truro's 2005 Local Comprehensive Plan (LCP) Water Resource Goal 5 to encourage the use of private wastewater disposal systems other than septic systems specifically to protect water supplies and marine water quality. It is also consistent with the Section 208 Area Wide Water Quality Management Plan objectives.

There is also a Massachusetts State Revolving Loan Fund (SRF) which provides a low-cost funding mechanism to assist municipalities in complying with federal and state water quality requirements.

Another strategy to consider are permeable reactive barriers (PRB), which are installations of a reactive media to create a permeable "wall" positioned underground to intersect with the plume of contaminants moving with the groundwater. PRB technology is for *in situ* groundwater remediation, designed to capture and remove or breakdown contaminants, releasing uncontaminated water. PRBs can be designed to remove a variety of contaminants including nitrate. A pilot PRB project was conducted for the Salt Pond sub-embayment at the Salt Pond Visitor Center in Eastham. The PRB was constructed by injecting emulsified vegetable oil into the ground to intercept the nitrogen enriched groundwater. Microbes eat the oil and, in that process, create an environment conducive to denitrifying bacteria. The bacteria convert the nitrate to inert nitrogen gas. Preliminary data from pilot studies on Cape Cod indicate a reduction in nitrate, however additional data are needed to determine the percentage or mass of nitrate removal. A local study would have to be conducted to determine the best site model to characterize the hydrogeologic and environmental conditions of Village Pond Watershed.

Fertilizer

To reduce fertilizer runoff from lawns the following BMPs are recommended:

- Do not fertilize prior to a major rain event
- Avoid using fertilizers that contain phosphorus
- Hire a certified landscape professional to apply fertilizer so it gets applied properly
- Paths to a pond shore should meander, not provide a direct path to pond shore
- Maintain vegetated buffers between lawn and pond shores ($\geq$ 100 ft)

Consider developing and adopting a fertilizer management regulation consistent with the Cape Cod Commission's Cape-wide Fertilizer Management Development of Critical Planning Concern (DCPC), designated in 2013 (Ordinance 13-07).

Stormwater

There are several structural and nonstructural stormwater control measures that can be implemented to better manage stormwater. Stormwater bylaws can be used to promote environmentally sensitive development such as LID techniques that both filter stormwater and promote local groundwater recharge. Updating bylaws or introducing a new stormwater management bylaw and associated regulations can incentivize adoption of LID techniques for stormwater management. Consider implementing a pilot LID project on municipal owned property as a demonstration.

Several stormwater problem areas were observed during a field visit conducted within 24 hours of a rain event. There are several catch basins and directed flows that likely send untreated stormwater runoff directly into Village Pond and the wetland resources around the pond. Untreated stormwater carries sediment, pollutants, and fertilizer that may have a significant deleterious impact on water quality and ecosystem health of the wetland resources in the watershed. Some of these include:

Highland Road (Field Observation 4): At the base of the access drive to the US Post Office there is a catch basin that receives a large quantity of stormwater runoff; often more than it can contain. Additionally, this catch basin is piped under Highland Road and Shore Road to an outfall between 2 Pond Rd and 48 Shore Road, resulting in untreated stormwater runoff being directed to an area adjacent to the wetland associated with Village Pond. The ponded outfall discharge area is occasionally dredged by Massachusetts Department of Transportation (MassDOT). The volume of water in the ponded area can and does overflow directly into the wetland (personal communication, 2 Pond Road resident). This is an important location to direct, capture, and treat stormwater given the amount of impervious surface in the area and the outfall's proximity to the wetland resource area.

Intersection of Shore Road, Pond Road and Highland Road (Field Observation 19): There are several relevant issues in this area. On the southeastern side of the intersection there is a large area located within the right-of-way (ROW) that ponds and accumulates sediment. The catch basin near the base of the U.S. Post Office access drive ponds a considerable amount of stormwater (see Field Observation 4 above). In terms of impervious surface this area has extensive impervious cover which includes Route 6A, Highland Road, ROWs, parking lots, and the exit and entrance ramps to Route 6. There is potential to reduce and or disconnect impervious cover in this area. Disconnecting impervious cover aligns with managing runoff close to its source by creating pervious areas to allow infiltration.

There is likely enough space at this location to design and install an LID stormwater management system; either roadside vegetated swales along Highland Road and/or a bioinfiltration system at the southeast corner of Shore Road and Highland Road. At this location stormwater treatment systems should be designed to optimize removal of both nitrogen and phosphorus to reduce the impact of stormwater on both the drinking water supply as well as the freshwater ecosystem downstream of this area.

South side of Pond Road (Field Observation 18): There is a paved pullout area on the south side of Pond Road across the street from house numbers 13 and 15 Pond Road (Photograph 1). This paved area slopes towards the pond and serves as a conduit for stormwater runoff (Photograph 2). On each field visit cars were parked in this area; it is not clear if this is a private driveway or a ROW. This is an opportunity for impervious surface disconnection, which can be done by removing a portion of the paved surface between the road and the pullout. Or, if space allows, design a stormwater treatment system between the bottom of the pullout area and the wetland.

Photograph 1. Paved pullout area on the south side of Pond Road which serves as a conduit for stormwater to flow directly into the pond and wetland.

Photograph 2. Paved pullout area on the south side of Pond Road which serves as a conduit for stormwater to flow directly into the pond and wetland.

Intersection of Pond Village Avenue and Pond Road (Field Observation 11-16): Pond Village Avenue has a steep slope towards Village Pond and Pond Road. At the bottom of Pond Village Avenue, where it intersects with Pond Road, there was a large volume of ponded stormwater and accumulated sediment. The ponded water nearly spans the entire width of Pond Village Avenue (Photograph 3). The location of the catch basins at this intersection are good, the ponded water sits right on top of the grates. However there appears to be more runoff than the systems can hold and process. Given the regular maintenance and cleaning that the catch basins receive (personal communication, Jarrod Cabral), it is likely that the capacity needs to be revisited and a feasibility study conducted of additional or alternative solutions for stormwater management. The shallow depth of the groundwater is likely a factor for local catch basin capacity.

Photograph 3. Ponded stormwater and accumulated sediment at the intersection of Pond Village Avenue (on the right) and Pond Road. The ponded water nearly spans the width of Pond Village Avenue.

Photograph 4. The upper most paved flume on Pond Road. The vegetated area to the right likely serves to slow stormwater and promote infiltration.

Western Reach of Pond Road (Field Observation 6 and 7): There are two paved flumes located on the south side of Pond Road directing stormwater into a steeply sloped vegetated area between Pond Road and Bay View Road (Photograph 4). This natural vegetated area serves as an informal stormwater collection and treatment area. It may be worth a study to determine if the capacity and treatment of stormwater in this location can be improved with a formal LID stormwater system designed specifically to remove phosphorus and nitrogen.

Cold Storage Beach Parking lots (Field Observation 5): The Cold Storage Beach parking lots located at the western end of Pond Road to the north and south of the road show evidence of ponding and sedimentation. The stormwater on the lot to the north of the road was flowing across the paved surface and onto Pond Road. The lot to the south had numerous puddles. These paved lots possibly provide an opportunity for a pervious surface or an onsite stormwater treatment practice which would allow stormwater to infiltrate on location.

Bay View Road (Field Observation 9, 10, 23): There are several areas along Bay View Road, on the eastern side adjacent to the Village Pond wetland, where the soil and vegetation appear to have been plowed away from the road (Photograph 5). This looks to serve the purpose of encouraging stormwater to run off the road into these slightly depressed sandy areas. This strategy is good for getting the water off the road but directs the untreated stormwater into the wetland resource area. This stretch of road would be a good location for a vegetated swale into which stormwater can be directed and treated prior to infiltration into the groundwater and the adjacent wetland.

Photograph 5. Area adjacent to Bay View Road that has been plowed to facilitate stormwater to flow off the road.

Additional resources regarding site design best practices are available from:

- the United States Environmental Protection Agency (https://www.epa.gov/sites/production/files/2015-11/documents/region3_factsheet_lid_esd.pdf),
- the Metropolitan Area Planning Council (https://www.mapc.org/resource-library/low-impact-development-toolkit/),
- and other State and regional environmental and planning agencies (e.g. https://growsmartmaine.org/wp-content/uploads/2015/08/Enviro_Sensitive_DesignFinal-21-Nov-06.pdf).

Recommendations from the IWRMP (Weston & Sampson. 2014 and 2018) concerning stormwater

- Evaluate and create preliminary designs of infrastructure modifications for Route 6 drainage systems. Request MassDOT to incorporate new and improved stormwater infrastructure projects the next time Route 6 is maintained.
- A public education and outreach program regarding best management practices for septic system maintenance.
- Encourage the use of innovative and advanced septic system technology for improved nitrogen removal for new and updating septic systems.
- Establish one or more monitoring wells in the Pond Road commercial district and monitor twice a year in spring and fall.

Recommendations from the Plan for Watershed Management for the Pamet Groundwater Lens (CCC, 2008) concerning stormwater

- Develop a stormwater and spill-prevention and response plan.
- Evaluate stormwater outfalls and road-salting practices in sensitive areas such as the South Hollow (SH) well field. Stormwater collection and discharge facilities for State highways should be located and mapped, and alternative de-icing practices should be evaluated in partnership with the MassDOT.
- The Town of Truro should continue to monitor private water supplies for nitrate. Initial monitoring-program results indicate that the quality of private water supplies is generally good. Additional regulated analytes may be added during subsequent sampling rounds - such as ammonia, volatile and semi-volatile 18 organics - where nitrate concentrations exceed 5 ppm-N and as part of a 'sentry' monitoring program in Zone IIs.
- Incorporate low impact development design requirements into subdivision regulations and site-plan review process. Truro's subdivision regulations allow the use of vegetation to treat stormwater runoff, but do not require LID, a comprehensive land planning and engineering design approach with the goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds. Strengthened stormwater-management requirements for subdivisions are recommended by the LCP for consideration.
- The Town of Truro should initiate new local education and outreach programs to encourage community involvement and awareness of issues relating to water quality such as water conservation, disposal of pharmaceuticals and personal care products (PPCPs), and lawn-maintenance alternatives. Programs may be modeled after successful projects such as the Falmouth Friendly Lawn Project: http://www.preservefalmouthbays-ponds.org/content5.php.

Village Pond

Developing a pond or watershed management plan for Village Pond, with a variety of restoration options in and around the pond and their associated costs, would provide a clear path forward to improved water quality and ecosystem restoration. As part of this effort, the town could establish a water quality monitoring plan for Village Pond that includes monitoring at least twice a year during the growing season for parameters such as dissolve oxygen, water temperature, Secchi Disk depth, pH, conductivity, and collection of water samples for lab analysis of total nitrogen and total phosphorus.

Recommended Structural Controls

- Maintain and or install a vegetative buffer along the shoreline in as many locations around the pond as possible. Vegetative buffers are effective ways to slow and infiltrate stormwater runoff, reduce erosion and overuse, and keep ducks and geese away from the pond shoreline.

- Installation of retractable fencing along waterfront at Pilgrim Pond Park – retractable fencing has proven effective in preventing geese from utilizing shoreline areas and can be used to prevent waterfowl from using the area at night, during the summer season, and during the off-season. For more information, see http://www.virginialakemanagement.com/goose_dfence.php.
- Prioritize stormwater issues that are closest to the pond as they will have the most deleterious impact.
- Identify/repair/replace failing septic systems – bacterial and nutrient loading due to failed septic systems will be reduced if systems are identified and repaired or replaced.
- Other structural controls should be considered for the pond after a thorough study of the pond water quality is completed.

Nonstructural Controls

- Education and outreach about the importance of pumping septic tanks on a regular and frequent schedule. For example, every 2-3 years depending on use and proximity to pond.
- Place "Don't Feed Waterfowl" signs at strategic locations around Village Pond and distribute "Do Not Feed Waterfowl" literature at Village Pond, Post Office, Beach Sticker office, and high-profile tourist locations. Providing information brochures educating the public why feeding waterfowl is detrimental to their health as well as detrimental to the pond ecosystem and water quality may help reduce flock size and reduce bacterial loading.
- Create and/or enforce dog poop scooping regulation.
- Consider bylaw amendments that encourage low impact development techniques on new and redevelopment projects.

Nonpoint Source Strategies Recommended

- Expand water quality monitoring of Village Pond and stream at Shore Road to include sampling immediately after rainfalls of one inch or more.
- Implement periodic use of optical brightener pads in the pond to detect presence of laundry detergents (presence of optical brightener compounds may indicate pollution from septic).
    - If optical brightener pad testing is positive, expand monitoring area to bracket potential sources.

    - if future optical brightener pad testing is positive, facilitate dye testing for homeowners.
- Conduct wet weather water testing of yard drainage from Bay View Road and Bay View Drive residences.

Private Well Water

- Consider reestablishing the voluntary well water quality sampling program that was initiated in 2007 by the Water Resources Oversight Committee. The program was designed to sample one-third of the private wells in Truro every calendar year. The results can be compared with the baseline established from 2007-2009.
- Registration of wells – properties on which there is well water must register the well with the Truro Board of Health (BOH).
- Prior to approval of a drinking water well, the owner should take a water sample from the well and submit it to a state certified testing laboratory for analysis, with the cost to be borne by the owner. The results of all analyses should be submitted to the BOH. At a minimum, water must be tested for the following: total coliform, nitrate-nitrogen, pH, conductivity, sodium, and iron.
- Recommend all well owners have their wells tested at a minimum of every two years and at more frequent intervals when water quality problems are known to exist.
- Require well owners to have their well water tested if the property is rented (short or long term), requires a building permit, or has a septic inspection.
- Incentivize homeowners to have the well water tested by offering a reduced cost for beach sticker or transfer station sticker.

Priority Actions

1. A study of engineering alternatives for stormwater management in Pond Village should be undertaken.
2. Conduct detailed site assessments at the four Pond Village areas identified in the Weston & Sampson's IWRMP, Phase I, as having sample nitrate results exceeding 5 ppm (Highland Rd, northeast of Rt 6, across from east/north bound Rt 6 exit ramp; two located near Pond Village Heights Road; between the Post Office and Professional Heights). Evaluation should seek to identify where and what are the nitrogen sources: land use practices; septic system conditions; or well construction and hydrogeologic conditions.

3. Present preliminary stormwater management BMPs for Route 6 drainage systems to MassDOT. A recommended approach to facilitate communication may be modelled after Eastham's success coordinating with MassDOT through State Representative Sarah Peake.
4. Establish a public education and outreach program regarding best management practices for septic system maintenance.
5. Encourage and incentivize I/A septic system technology for improved nitrogen removal as replacements for the failed cesspools and for new and updating septic systems.

Funding Opportunities

Current state programs providing funding for lake or pond assessments include:

- Department of Conservation and Recreation (DCR), Lake and Ponds Program
- Department of Environmental Protection (DEP), Section 604(b) Water Quality Management Planning Grant Program
- DEP Section 319 Nonpoint Source Competitive Grant Program

Current state programs providing funding for culvert repair or replacement include:

- Department of Fish and Game, Division of Ecological Restoration (DER) – restores and protects rivers, wetlands, and watersheds for the benefit of people and the environment
- Municipal Vulnerability Preparedness Program (MVP) – focus is on improving resiliency and adapting to climate change

There are specific criteria and core principles for each of these grant programs in terms of matching funds, project goals, etc. Reference the specific funding opportunity to find the best match for the project. See Appendix C (pg. 44) for additional funding opportunities.

References

Cape Cod Atlas of Tidally Restricted Salt Marshes. December 2001, Cape Cod Commission.

Geist, D. 2015, Reducing Nitrogen Loading in Truro, MA. WPI Major Qualifying Project

Hydrologic Analysis of the Water Resources of Lower Cape Cod. 2001-2003. US Geological Survey.

Integrated Water Resources Management Plan, Phase I. October 2014, Weston & Sampson.

Integrated Water Resources Management Plan, Phase II. February 2018, Weston & Sampson.

LeBlanc, D.R., Guswa, J.H., Frimpter, M.H., and Londquist, C.J., 1986, Ground-water resources of Cape Cod, Massachusetts: U.S. Geological Survey Hydrologic Investigations Atlas HA-692, 4 plates, 1:24,000

Open Space and Recreation Plan. June 2015, Helios Land Design.

Pamet River Investigation Truro, Massachusetts. April 1998. U.S. Army Corps of Engineers, New England District.

Pamet River Investigation – Groundwater Assessment Study, Truro Massachusetts: Groundwater Impacts Associated with the Removal of the Tide Gate and Dike Structures. May 1997. Cape Cod Commission.

Plan for Watershed Management for the Pamet Groundwater Lens, September 2008, Cape Cod Commission.

Portnoy, J.W., MG Winkler, PR Sanford, CN Farris. 2001. Kettle Ponds Atlas for Cape Cod National Seashore: Paleoecology and Modern Water Chemistry. Cape Cod National Seashore, National Park Service, U.S> Department of the Interior. 119p.

Robertson, W.D., S.L. Schiff and C.J. Ptacek.1998. Review of phosphate mobility and persistence in 10 septic system plumes. Groundwater. 36:1000-1010.

Soil Survey, Natural Resources Conservation Services, United States Department of Agriculture. Web Soil Survey.

Truro Local Comprehensive Plan, 2005. Prepared by the Truro Local Comprehensive Planning Committee.

Walter, D.A., Masterson, J.P., and Hess, K.M., 2004, Ground-Water Recharge Areas and Traveltimes to Pumped Wells, Ponds, Streams, and Coastal Water Bodies, Cape Cod, Massachusetts, Scientific Investigations Map I-2857, 1 sheet

Appendix A

WELL WATER MONITORING SOP

https://barnstablecounty.sharepoint.com/:b:/g/dept/commission/team/projects/EQLpVl7aZTtPjHzMR-oX4okBfx0KSKbSJ5P6OnB2ZgfWwg?e=8xEa2h

Appendix B

PROJECT POWER POINT PRESENTATION

https://barnstablecounty.sharepoint.com/:b:/g/dept/commission/team/projects/EWnAabdUJIVOkVfAYg3Ww28BUgv7gjBuVlWKleV4KUCGoA?e=je4yVb

Appendix C

FUNDING SOURCES

https://barnstablecounty.sharepoint.com/:x:/g/dept/commission/team/projects/EcdmOY5O_iBClFm3rvVvdWMBhTZ--uEYob79XG1PbE2t6g?e=6vkH23

CAPE COD COMMISSION

3225 MAIN STREET • P.O. BOX 226 • BARNSTABLE, MASSACHUSETTS 02630
(508) 362-3828 • Fax (508) 362-3136 • www.capecodcommission.org