Maidford River and Paradise Brook

Water Quality Study and Pollutant Source Identification

National Water Quality Initiative

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1. Problem Definition/Background

This report documents the results of monitoring conducted by the RI Department of Environmental Management's Office of Water Resources on Upper Maidford River and Paradise Brook in support of the National Water Quality Initiative, described in greater detail below.

The Upper Maidford River (RI0007035R03-02A) and Paradise Brook (RI0007035R-03) are located at the eastern end of Middletown, Rhode Island. Both streams are tributaries to the Newport Water system, and are Class AA freshwater streams. With the exception of those properties serviced by private wells, the Newport Water system provides public water to all of Aquidneck Island. Newport Water maintains a distribution system which services retail customers in Newport, Middletown and a small section of Portsmouth. In addition, Newport Water provides water wholesale to the Portsmouth Water & Fire District and Naval Station Newport.

All nine source reservoirs of the Newport Water System exhibit degraded water quality. Water quality data collected in 2011 and 2012 on the nine source reservoirs by Fuss & O'Neil, under contract to Newport Water, showed that the nine reservoirs exhibit eutrophic to highly eutrophic characteristics, including elevated levels of total phosphorus and chlorophyll *a*, low water clarity, frequent algal and cyanobacteria blooms, and low levels of dissolved oxygen.

Both the Maidford River and Paradise Brook are impaired for fecal coliform bacteria. A TMDL was prepared by RIDEM and approved by EPA, for Upper and Lower Maidford River and Paradise Brook, for fecal coliform bacteria (Statewide Bacteria TMDL, 2011). The Upper Maidford River (RI0007035R-02A) is also on the State of Rhode Island's 2014 303(d) list as being impaired for biodiversity (Benthic-Macroinvertebrate Bioassessments), and lead.

Water quality sampling, conducted by the University of Rhode Island (1991-2003), documented a bacteria impairment and elevated nutrient levels in the Maidford River, based upon samples collected at a station located at Prospect Avenue. The bacteria impairment and elevated nutrient levels in the Maidford River were confirmed by subsequent sampling at the Newport Water intake structure, by Fuss & O'Neil (2011-2012) for Newport Water. Fecal coliform and Enterococci sampling was also conducted at multiple stations along both the Maidford River and Paradise Brook, by the Louis Berger Group for the Town of Middletown (2005). This round of sampling documented a pathogen impairment in Paradise Brook for the first time and further characterized the bacteria impairment to the Maidford River

As part of the National Water Quality Initiative (NWQI), RIDEM has agreed to utilize Section 319 funding to conduct monitoring of instream water quality on Upper Maidford River and Paradise Brook. This work supports the collaborative effort between the Natural Resources Conservation Service (NRCS), US Environmental Protection Agency (EPA) and the RI Department of Environmental Management to work in partnership to restore water quality in watersheds affected by agricultural pollution sources. The goal of this sampling program is to further characterize the water quality of the Maidford River and Paradise Brook, and to determine whether water quality, related to nutrients, sediments, or livestock-related pathogens, has improved as a result of recently installed agricultural best management practices (BMPs) installed with National Water Quality Initiative funding. However since neither the actual BMP location nor date of installation of any NWQI projects are known, theses sampling results may actually be representative of existing conditions prior to the implementation of BMPs planned for the future. In addition to the sampling results, this report documents both in-field and aerial photography observations of potential pollution sources and installed BMPs.

Larger watersheds, which are either not meeting state water quality criteria or are contributing to an impairment in waterbodies downstream, were selected to participate in the NWQI. The Sakonnet River

Watershed (HUC 010900040910) is one of three watersheds selected in RI for NWQI funding. RIDEM focused monitoring efforts in the Upper Maidford River and Paradise Brook watersheds (subwatersheds of the Sakonnet River watershed), because a large percentage of both watersheds are in agricultural land use, and both streams contribute to the Newport Water drinking water supply – all of which exhibit degraded quality, as described above.

Upper Maidford River

The headwaters of the Upper Maidford River (RI0007035R03-02A) begin near Meadow Lane, east of East Main Road. Two forks, forming the headwaters, begin south and east of Meadow Lane and converge just north of Wyatt Road. The river flows south, mostly through agricultural fields, until it crosses Berkeley Avenue. The river continues along the western side of Berkley and Paradise Avenues, through mainly residential land use. An intake structure, located near 544 Paradise Avenue, diverts some flow into both Nelson and Gardiner Ponds. Near the southern end of Paradise Avenue, the river turns east, and flows immediately south of Nelson Pond, through a Phragmites marsh, and is culverted underneath Hanging Rocks Road. The reach designated as the Upper Maidford River terminates at the confluence with an unnamed tributary, near the southwest corner of Gardiner Pond. The Lower Maidford River (RI0007035R03-02B) continues along the southern berm of Gardiner Pond, through Sachuest Marsh (a saltwater marsh), and discharges at Third Beach, located near the mouth of the Sakonnet River. This study was focused on the Upper Maidford River because nearly all the agricultural land use is located in the upper portion of the Maidford River watershed.

The Upper Maidford River watershed covers approximately 1500 acres. Agricultural land use occupies approximately half (48%) of the watershed. Developed areas (mainly residential) occupy 36% of the watershed. The remaining 4% of the watershed consists of wetland, open water, and other land uses. Non-developed areas, such as forest, occupy approximately 13% of the watershed. Impervious surfaces cover approximately 11.5% of the watershed.

Paradise Brook

Paradise Brook is a 2.5-mile long stream located in southeast Middletown, RI. The headwaters of Paradise Brook arise from a roadside ditch on the north side of Fayal Lane. The stream flows in a southerly direction along the west side of Third Beach Road. North of Green End Avenue, the stream flows mainly through active agricultural areas, although there is a forested area and cluster of four residential parcels at the southern end of this reach. South of Green End Avenue to the Newport Equestrian facility (located to the immediate west of Cordeiro Drive), the stream flows past a medium-density residential area. Downstream of Newport Equestrian, the stream jogs to the south-southwest through a forested area owned by the Norman Bird Sanctuary. The stream discharges into the northern end of Nelson Pond.

The Paradise Brook watershed covers approximately 350 acres. Agricultural land use occupies 38% of the watershed. Non-developed areas, such as forest, occupy approximately 31% of the watershed and developed areas (mainly residential) occupy 27% of the watershed. The remaining 4% of the watershed consists of wetland, open water, and other land uses. Impervious surfaces cover approximately 6.5% of the watershed.

2. Sampling Design

RIDEM conducted instream sampling at locations along the Maidford River and Paradise Brook. Samples were analyzed for turbidity, total suspended solids (TSS), total phosphorus, ammonia, Total Kjeldahl Nitrogen (TKN), nitrate, fecal coliform bacteria, and enterococci. Flow measurements were taken at each river sampling station, when conditions permitted.

Three instream sampling surveys were conducted during dry wet weather, with an additional three surveys taking place during wet weather (Table 1). Dry weather was defined as less than 0.25 inches of rainfall during the 48-hour period preceding a sampling event. Wet weather was defined as greater than 0.25 in. of rainfall during the 48-hour period preceding a sampling event.

Samples were collected at five stations in both the Maidford River and Paradise Brook. For one wet weather event, an additional river station and tributary station were added in the Maidford River watershed. During one dry weather survey, an abandoned artesian well, adjacent to the Maidford River, was also sampled. Figures 1 and 2 show the sampling locations for the study, and Table 2 describes the sample station locations, and the purpose/justification of locations.

As previously discussed, stations were selected in agricultural areas to help identify and bracket agriculturally-related source areas of sediment, nutrients and bacteria and to assess water quality – both post implementation for existing BMPs and prior to the implementation of BMPs planned for the future.

Table 1. Dates of Dry and Wet-Weather Sampling Events

Dry-Weather Sampling Events	Wet-Weather Sampling Events
4/2/15	12/9/14
4/15/15	9/30/15
1/5/16	10/29/15

Figure 1. Maidford River Sampling Locations.

Figure 2. Paradise Brook Proposed Sampling Locations.

Table 2. Station Locations

Station ID	Waterbody	Location	Purpose
MDF-SW-1	Maidford River	Headwaters of the Western Fork of the Maidford River Immediately Downstream of Pond, South of Meadow Lane	Most Upstream Location Possible, Upstream of Surface Agricultural Influence
MDF-SW-2	Maidford River	Wyatt Road	Brackets Agricultural Area North of Wyatt Road
MDF-SW-3	Maidford River	Berkeley Avenue	Sampled only once during Wet Weather, Brackets Agricultural Area Between Wyatt Road and Berkeley Avenue
MDF-HN	Ditch, Tributary to Maidford River	Ditch at Down-Gradient Boundary of Nursery, Located West of Berkeley Avenue	Sampled only once during Wet Weather, Characterizes Stormwater Quality Directly Discharged from Nursery
MDF-SW-3A	Maidford River	Berkeley Avenue Spur (aka Whitehall Museum Assess); Directly Opposite Wyndham Hill Road	Brackets Agricultural Area between Wyatt Road and Berkeley Avenue Spur
MDF-MH	Abandoned Town Artesian Well	Southwest of the Intersection of Berkeley and Green End Avenues	Sampled only once during Dry Weather, Characterizes Groundwater Quality
MDF-SF-1	Maidford River	Reservoir Avenue	Brackets Mixed Residential/Agricultural Area, Background Sample upstream of Sheep Farm
MDF-FO-1	Maidford River	544 Paradise Avenue at Newport Water Intake Structure, Downstream of Sheep Farm	Brackets Influence from Sheep Farm
PDS-SW-3A	Paradise Brook	Paradise Brook Headwaters, Fayal Lane	Most Upstream Location Possible, Upstream of Surface Agricultural Influence
PDS-SW-1	Paradise Brook	Mitchell’s Lane	Brackets Agricultural Area North of Mitchell’s Lane
PDS-SW-2	Paradise Brook	Green End Avenue	Brackets Agricultural Area between Mitchell’s Lane and Green End Avenue
PDS-OCI-5	Paradise Brook	Third Beach Road Island, Upstream of Equestrian Facility	Brackets mostly Residential Area, between Green End Avenue and Third Beach Road, Background Sample Upstream of Equestrian Facility
PDS-OCI-6A	Paradise Brook	Approximately 450 ft. West-Southwest of Terminus of Cordeiro Terrace, Downstream of Equestrian Facility	Brackets any Potential Influence from Equestrian Facility

3. Flow Measurements and Precipitation Conditions

Dry-Weather Flow

Maidford River

The upper reaches of the Maidford River, up-gradient of the Berkeley Avenue spur (MDF-3A), run dry from mid-spring to early winter. Flow was measured twice in April, 2015 and once in January, 2016. Flow at the headwater station ranged from 0.5 to 0.27 cfs (22-121 gal/min). Flow at the terminal station (MDF-FO-1) ranged from 1.95 to 2.64 cfs (875-1,185 gal/min).

During dry weather, there is obviously no stormwater runoff entering the steam. Flow is sustained by groundwater discharging into the streambed. Therefore dry-weather river water quality largely reflects groundwater quality. However, surface water sources that discharge directly to the streams (e.g. wildlife or livestock waste, and septic systems), may also affect water quality, during dry weather.

For each of the three dry-weather sampling events, flow was regressed against contributing area of the subwatershed that drains to each station (Figures 3-5). There was a very strong linear relationship between the flow at any given station and the drainage area upslope of that station. This strong relationship indicates that groundwater discharges into the stream at a steady rate as you move downriver. In other words, it appears that there are no reaches of the river that receive an inordinate amount of groundwater inflow and other reaches that receive less groundwater seepage than is explained by the size of the area that discharges to the reach. Therefore it appears that changes in dry-weather water quality between stations is more likely to be a result of local groundwater quality, and not because of groundwater discharge from areas far upstream of the sampling station.

3.1.2. Paradise Brook

Like the Maidford River, the upper reaches of the Paradise Brook are dry for most of the year. Specifically, the river is dry up-gradient of Green End Avenue (PDS-SW-2), from mid-spring to early winter. The maximum dry-weather flow, measured at the headwater station (PDS-SW-3A) was 0.008 cfs (3.6 gal/min). There was no flow at the first two stations, during the January, 2016 survey. Flow at the terminal station (PDS-OCI-6A) ranged from 0.39-0.82 cfs.

Unlike the Maidford River, there is not a linear relationship between flow and drainage area. There is very little flow, at the first three stations, north of Green End Avenue. The amount of flow, relative to the contributing drainage area, increases significantly south of Green End Avenue. Dry-weather flow generally increases about four-fold from Green End Avenue to Third Beach Road. Flow increases again by about 50% from Third Beach Avenue to the terminal station (PDS-OCI-6A). It therefore appears that groundwater is preferentially discharging to the stream south of Green End Avenue (PDS-SW-2). North of this station, the streambed lies in compact till, a relatively impermeable material. From Green End Avenue to Third Beach Road the streambed elevation drops approximately 65 feet. Since the surficial layer of till is only about 20 feet thick in the general area, it appears that the streambed has incised through the till and into much more porous fractured bedrock. Much of the groundwater discharging into the stream, south of Green End Avenue, may be from areas far upstream, including the headwaters area. Therefore, any changes in dry-weather water quality, in the lower portion of the river, may be at least partially caused by polluted areas in the upper reaches of the stream.

Figure 3. Maidford River Dy-Weather Flow vs. Station Subwatershed Area (4/2/15**).**

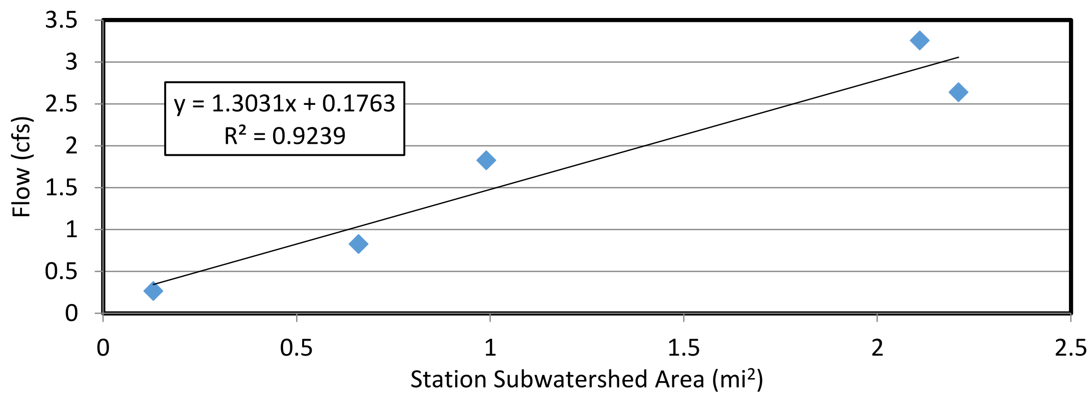


Figure 4. Maidford River Dry-Weather Flow vs. Station Subwatershed Area (4/15/15).

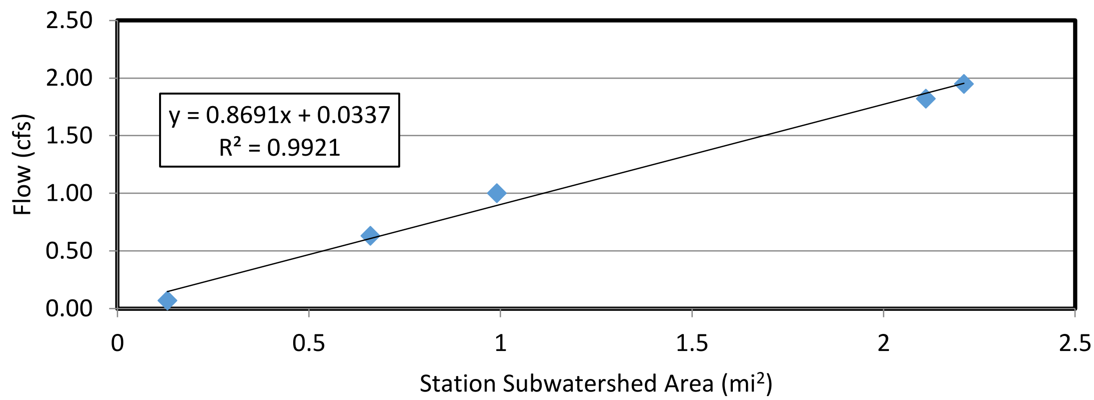


Figure 5. Maidford River Dry-Weather Flow vs. Station Subwatershed Area (1/5/16).

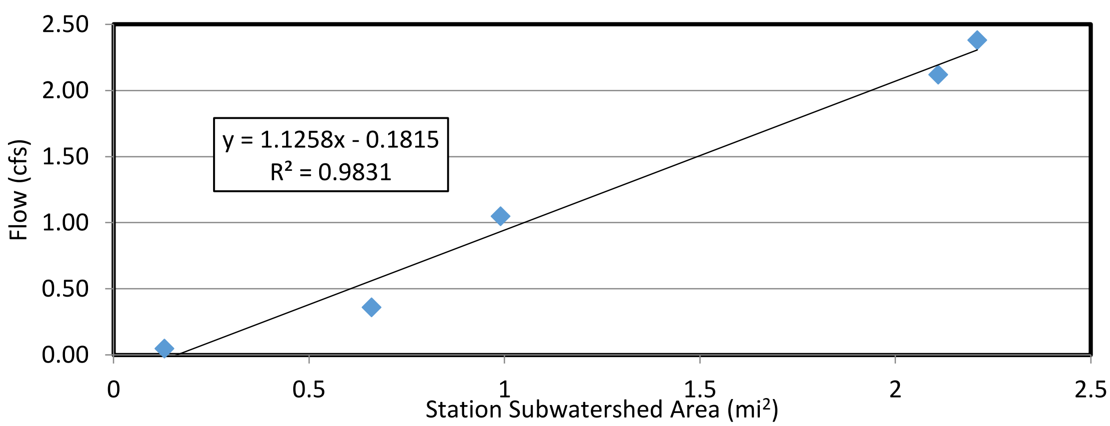


Figure 6. Paradise Brook Dry-Weather Flow vs. Station Subwatershed Area (4/2/15)

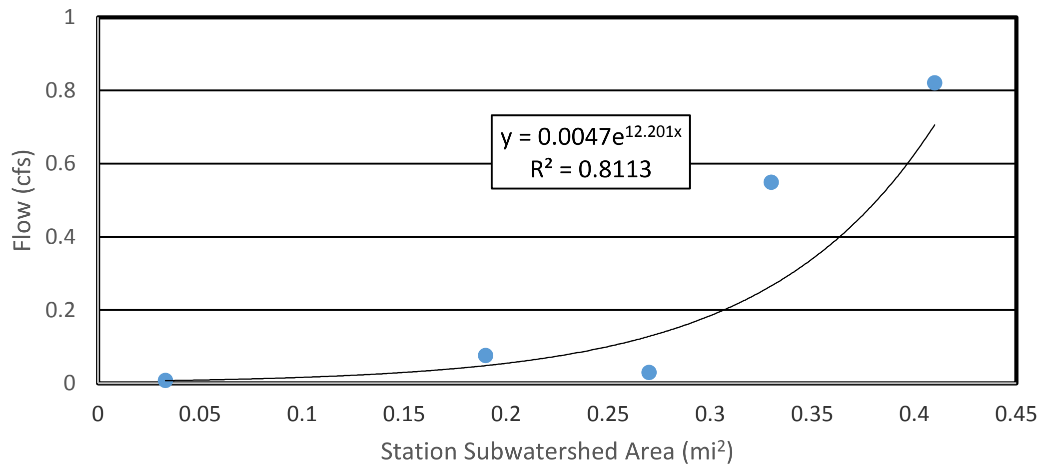


Figure 7. Paradise Brook Dry-Weather Flow vs. Station Subwatershed Area (4/15/15).

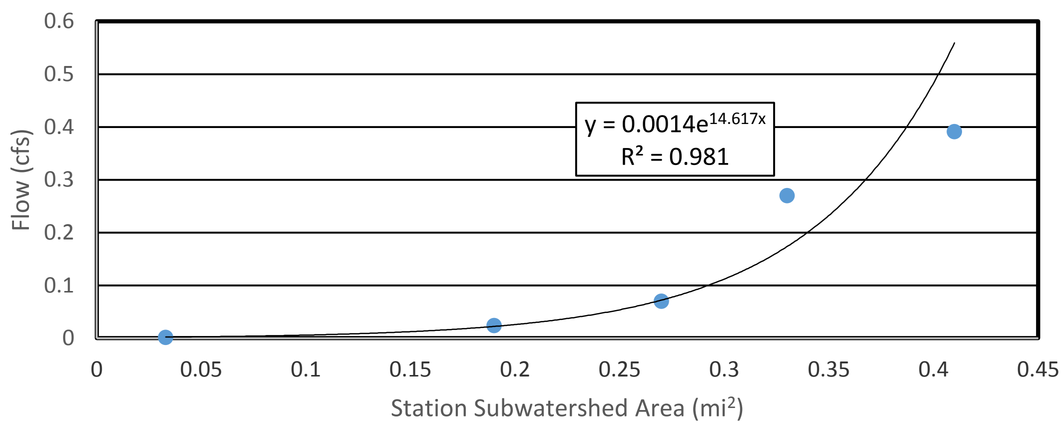
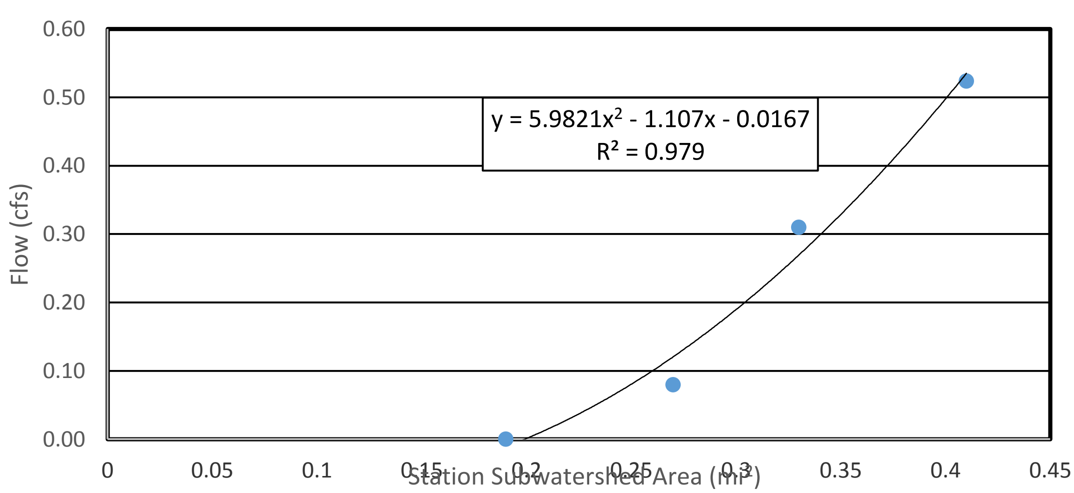


Figure 8. Paradise Brook Dry-Weather Flow vs. Station Subwatershed Area (1/5/16).



3.2. Wet-Weather Precipitation Conditions

Approximately 1.5-2.2 inches of rain fell during each of the three wet-weather monitoring events. Sampling was generally initiated at the headwaters of the Maidford River, and progressed downstream. The same procedure was then repeated for Paradise Brook.

During the first wet-weather event, on December 9, 2014, sampling of the Maidford River was initiated near the beginning of the rain event (Figure 9). Paradise Brook was sampled during the second half of the rain event. Sampling was concluded while it was still raining. The rainfall rate was very steady, during the entire storm.

Figure 9. Cumulative Rainfall and Station Sampling Times. December 9, 2014.

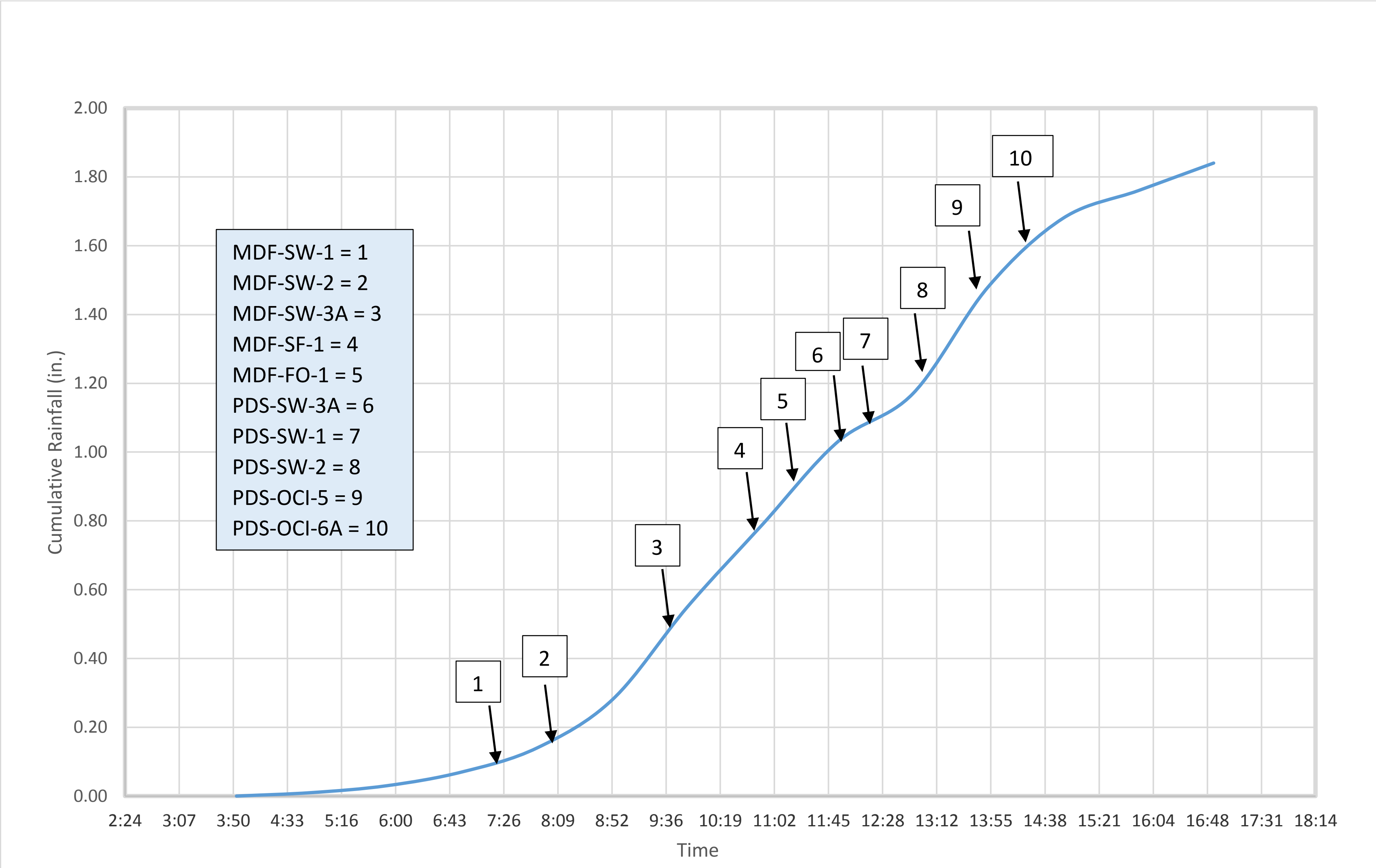


Figure 10. Cumulative Rainfall and Station Sampling Times. September 30, 2015.

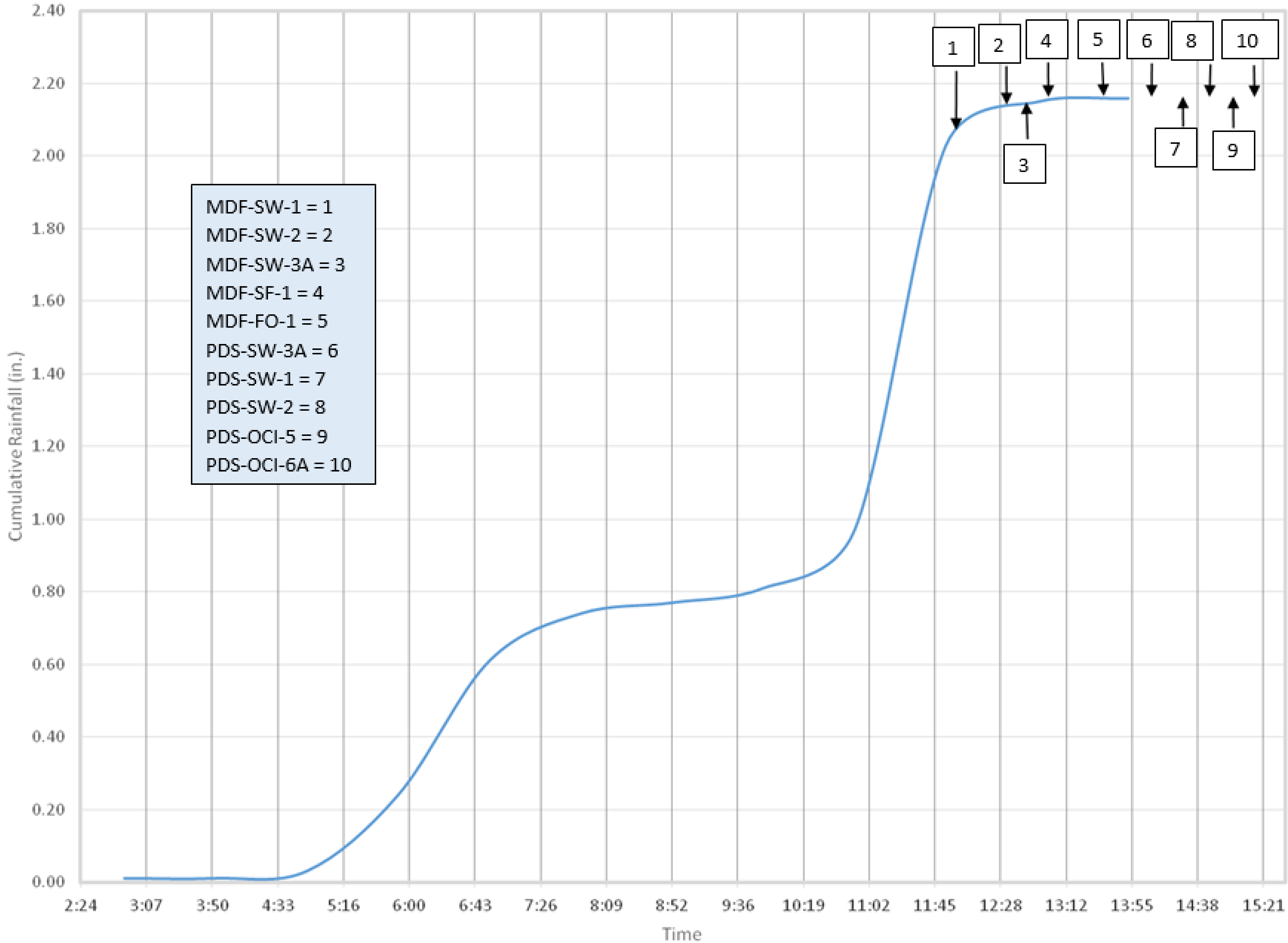
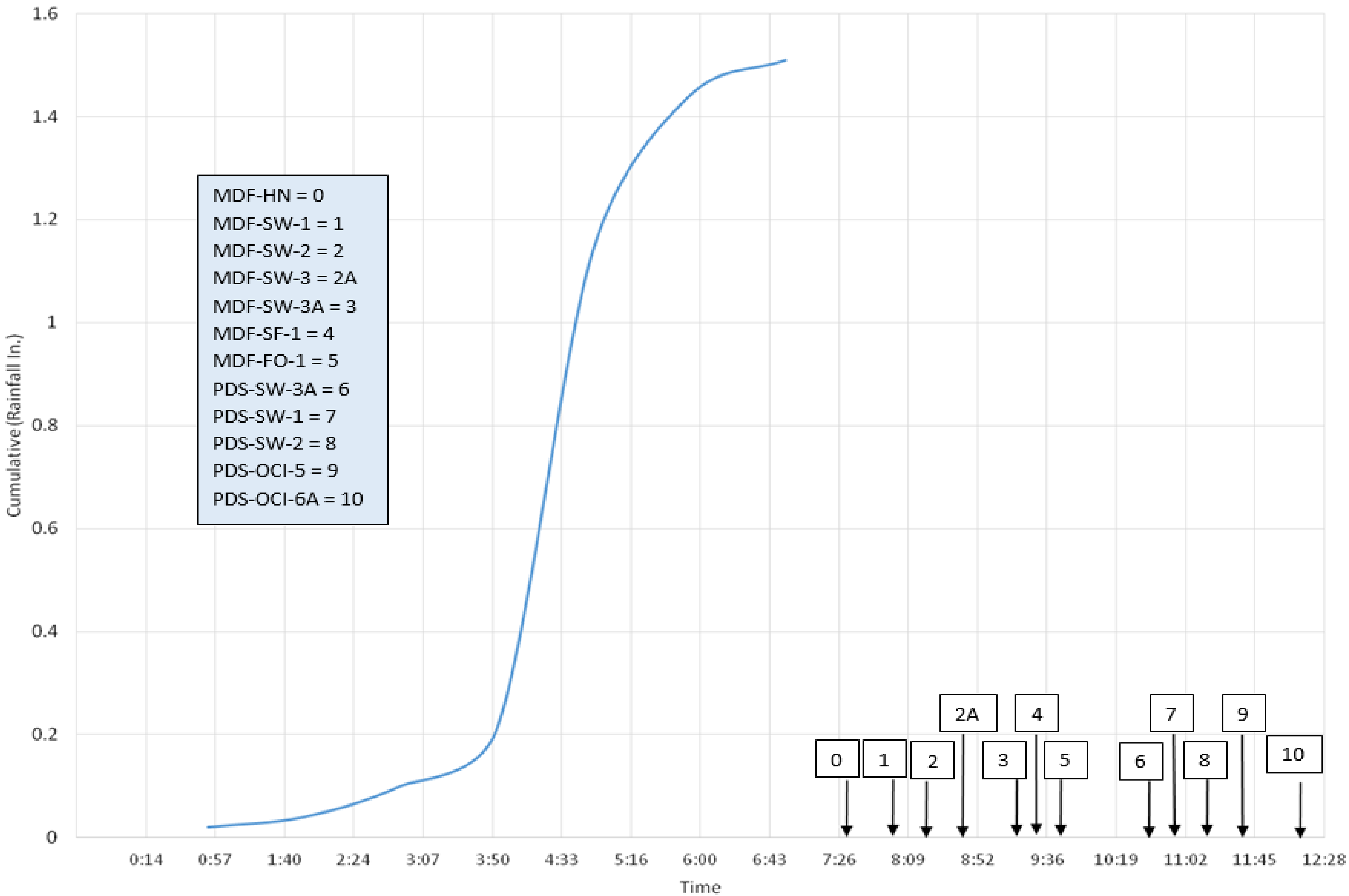


Figure 11. Cumulative Rainfall and Station Sampling Times. October 29, 2015.



During the October, 2015 rain event, sampling of the Maidford River was initiated near the end of the second and final pulse of precipitation (Figure 10). Sampling of the Maidford was then concluded at the very end of the wet-weather event. Sampling of Paradise Brook was not initiated until shortly after the rain event was over.

The most intense rain event occurred in October, 2015, with 1.5 inches of rain falling in almost 3 hours. Sampling was not initiated until shortly after the end of the rain event ended (Figure 11). Sampling of Paradise Brook began approximately four hours after the cessation of rainfall.

3.3 Wet-Weather Flow

3.3.1. Maidford River

The Maidford River is an extremely flashy stream. In other words, flow increases dramatically during precipitation events, relative to flow levels during dry weather. Flow was so rapid at Reservoir Avenue, during the December 2014 rain event, that a flow measurement was not possible, due to safety concerns. What was a slowly flowing stream, prior to the onset of rain, became a raging rapid only hours later. Because the spillway at the the terminal station at the Newport Water Intake, increased the depth of water in the impoundment immediately upstream, to about 6 feet, wet-weather flow measurements were also not possible at this location. Therefore wet-weather flow at the terminal station was estimated, by regressing flow vs. contributing drainage area.

The highest measured flow (83.7 cfs), recorded during the three wet-weather events, was measured by University of Rhode Island staff in December 2014, at Prospect Aveune (Figure 12). The estimated flow at the Newport Water intake on the same date was 120.8 cfs (almost 50 times greater than the maximum dry-weather flow at the same station). The lowest wet-weather flow at the Newport Water intake (22 cfs), occurred in October, 2015 (Figure 14).

Unlike dry-weather flow, the wet-weather flow vs. contributing drainage area is not a linear relationship (Figures 12-14). A hydrological study, performed by Fuss & O'Neil, determined that the culvert at the Berkeley Avenue spur (aka Whitehall Museum) is undersized, resulting in flooding of Berkeley Avenue. The undersized culvert causes flooding of a hay field on the north side of the Berkeley Avenue Spur. Floodwaters are culverted to a stormwater trench on the opposite (eastern) side of Berkeley Avenue, eventually rejoining the stream well south of the Berkeley Avenue spur. The undersized culvert at the spur can also slow flow velocities down enough to back up flow at the Berkeley Avenue culvert, causing that culvert to reach capacity and causing more flooding of Berkeley Avenue. Under these conditions, some of the flow upstream of Berkeley Avenue, enters the stormwater trench on the east side of Berkeley Avenue, re-entering the river well south of the Berkeley Avenue spur (Photo M32). Therefore a significant portion of the flow in the Berkeley Avenue area appears to bypass the spur, during high flow conditions. Figures 12-14 show evidence of the bottleneck at the Berkeley Avenue spur. Regardless of precipitation conditions, and flow levels at the downstream staions, the flow at the spur is approximaely 16 cfs (apparently the maximum capacity of the culvert). It is anticipated that, without the bottleneck at the Berkeley spur, the relationship between flow and contributing drainage area would have been much more linear.

3.3.2. Paradise *Brook*

Like the Maidford River, Paradise Brook is an extremely flashy stream. The maximum wet-weather flow recorded at Third Beach Road was 17 cfs (more than 20 times greater than the maximum dry-weather flow recorded at the same station). Flooding at the terminal station (PDS-OCI-6A), during wet weather, made flow measuements impossible. Therefore wet-weather flow at the terminal station was estimated, by regressing flow vs. contributing drainage area.

Paradise Brook wet-weather flow increased with contributing drainage area, in a linear fashion. In other words, stormwater runoff appears to discharge into the stream evenly throughout the watershed, with the flow at each station directly proportional to its contributing drainage area. This appears to indicate that, unlike in dry weather, any changes in water quality from station to station, were caused by pollution sources in that reach of the stream, not from sources far upstream of the upgradient station.

Figure 12. Maidford River Wet-Weather Flow vs. Station Subwatershed Area (12/9/14).

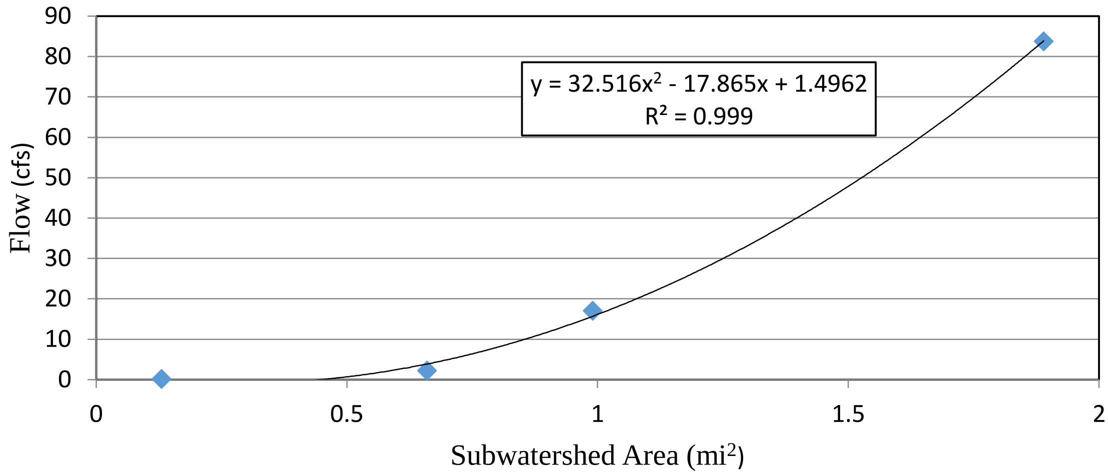


Figure 13. Maidford River Wet-Weather Flow vs. Station Subwatershed Area (9/30/15).

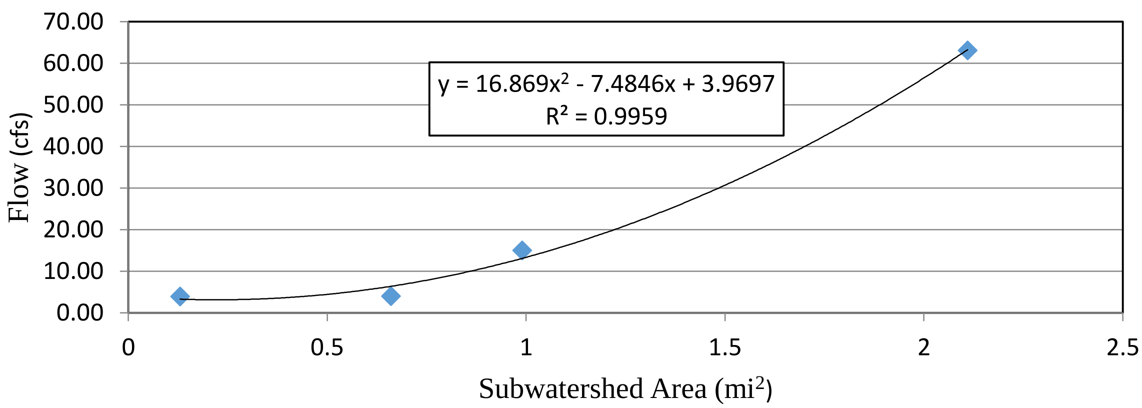


Figure 14. Maidford River Wet-Weather Flow vs. Station Subwatershed Area (10/29/15).

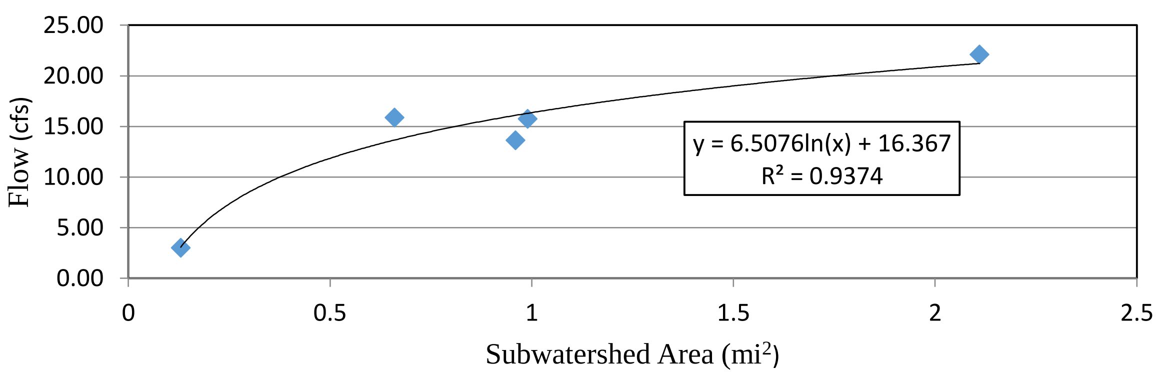


Figure 15. Paradise Brook Wet-Weather Flow vs. Station Subwatershed Area (12/9/14).

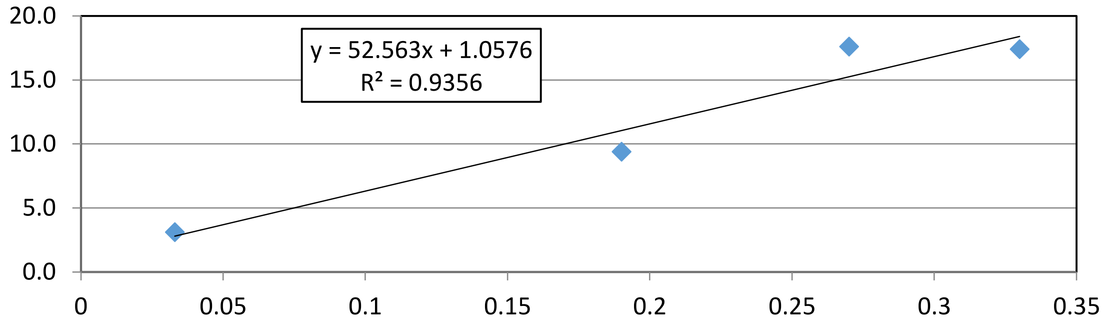


Figure 16. Paradise Brook Wet-Weather Flow vs. Station Subwatershed Area (9/30/15).

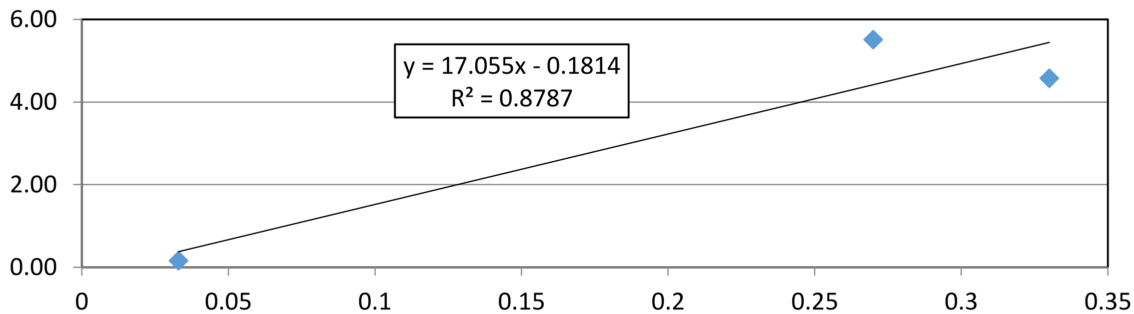
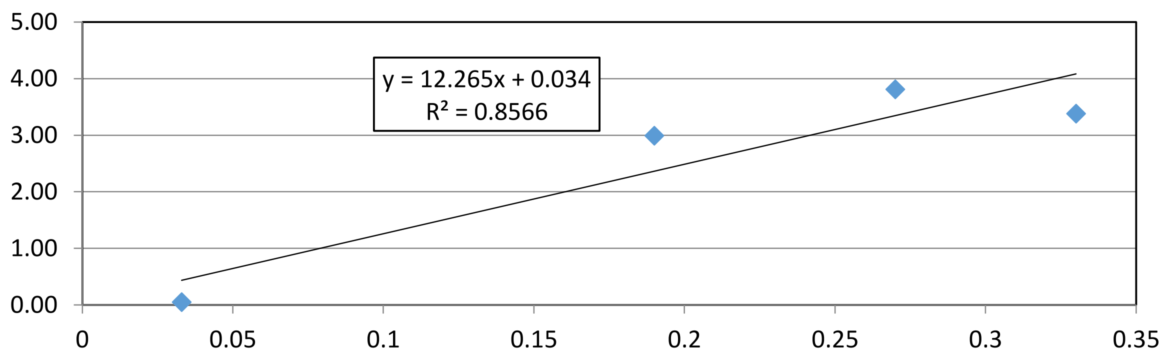


Figure 17. Paradise Brook Wet-Weather Flow vs. Station Subwatershed Area (10/29/15).



4. Brief Discussion of Sampling Parameters

Turbidity

Turbidity is measured using specialized optical equipment in a laboratory. A light is directed through a water sample, and the amount of light scattered is measured. The amount of scattered light is proportional to the quantity of suspended or dissolved particles present in the sample.

Particulate matter can include sediment (especially clay and silt), fine organic and inorganic matter, soluble colored organic compounds (e.g. tannins), algae, and other microscopic organisms. Sources of turbidity can include erosion from upland areas, and stream bank and stream bed erosion. Tannic acids, often associated with wetland areas, can cause water to be colored resulting in turbidity.

Total Suspended Solids (TSS)

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with stormwater. In the water, the pollutants may be released from the sediment or travel farther downstream.

High TSS, especially in terminal reservoirs, can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO).

The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes.

The flow rate of the water body is a primary factor in TSS concentrations. Fast running water can carry more particles and larger-sized sediment. Heavy rains can pick up sand, silt, clay, and organic particles (such as leaves and soil) from the land and carry it to surface water. A change in flow rate can also affect TSS; if the speed or direction of the water current increases, particulate matter from bottom sediments may be resuspended.

Most people consider water with a TSS concentration less than 20,000 ug/l to be clear. Water with TSS levels between 40,000 and 80,000 ug/l tends to appear cloudy, while water with concentrations over 150,000 ug/l usually appears dirty.

Phosphorus

Total phosphorus is typically the limiting nutrient controlling aquatic plant and algal growth in the freshwater environment. Above a certain threshold level, even small increases in phosphorus can cause eutrophication (excessive aquatic plant and algal growth in addition to low dissolved oxygen conditions) in waterbodies, especially lakes and ponds.

Phosphorus typically is adsorbed onto soil particles and does not easily dissolve in groundwater. Therefore phosphorus generally enters streams with stormwater runoff. However, some phosphorus can dissolve in groundwater and may enter streams as baseflow. Common sources of phosphorus include eroded sediment from upland areas, streambank erosion, fertilizer, livestock waste, pet waste, human waste, and the atmosphere.

Ammonia

Ammonia (NH_3) is toxic to fish and other aquatic organisms. Ammonium (NH_4), is the predominant form in the pH range of most natural waters, is less toxic to fish and aquatic life as compared to NH_3. As the pH increases above 8, the ammonia fraction begins to increase rapidly. In the rare situation that a natural water pH exceeds reaches 9, ammonia and ammonium would be nearly equal. Samples were analyzed for a combination of ammonia and ammonium. The results will be reported as ammonia in this report.

Common sources of ammonia/ammonium include human and animal wastes (including septic systems, leaky sanitary sewers, pet and wildlife waste, livestock, and manure applied to agricultural fields), decaying plant material, decay of soil organic matter (especially in anoxic soils), as well as certain fertilizers. Ammonia and ammonium most commonly enter surface waters through overland runoff or direct discharges from wastewater sources. Ammonia levels in streams are usually only elevated near sources of human or animal waste discharges. Ammonium is also the byproduct when organic matter in soils is mineralized to inorganic-nitrogen. Once in the soil, ammonium binds onto soil particles such as clay and organic matter. For that reason, ammonium is less likely to move vertically through the soil matrix into groundwater, as compared to nitrate. Under the right soil temperature and moisture conditions, ammonium will readily transform into the more mobile form of nitrate.

Total Kjeldahl Nitrogen (TKN)

The total Kjeldahl nitrogen (TKN) laboratory analysis includes nitrogen from organic nitrogen and ammonia+ammonium. Typically, the organic nitrogen fraction of TKN in surface waters is much higher than the ammonia+ammonium fraction. As will be demonstrated in the following pages, the ammonia/ammonium fraction is very low (typically below the detection limit), indicating that TKN values are largely representative of the organic nitrogen fraction.

Organic nitrogen includes all substances in which nitrogen is bonded to carbon. It occurs in both soluble and particulate forms. Organic nitrogen is found in proteins, amino acids, urea, living or dead organisms (e.g. algae and bacteria), and decaying plant material. Because nitrate is very low in forested and grassland areas, organic nitrogen is typically higher than nitrate in landscapes dominated by these more natural conditions. Soluble organic nitrogen is from wastes excreted by organisms, including livestock manure and human wastes, or from the degradation of particulate nitrogen from plants and plant residues. Some organic nitrogen is attached to soil particles and is associated with sediment losses to water. In nature, organic nitrogen can be biologically transformed to the ammonium form and then to the nitrite and nitrate form. Once in the nitrate or ammonium forms, these nutrients can be used by algae and aquatic organisms and thereby convert back to organic forms of nitrogen. Organic nitrogen sometimes makes up a significant fraction of soluble and particulate nitrogen in natural waters.

Nitrate

Samples were analyzed for a combination of nitrite plus nitrate. Nitrite (NO_2) is typically a short-lived intermediate product when ammonium is transformed into nitrate by microscopic organisms, and is therefore seldom elevated in waters for long periods of time. Nitrite is also an intermediary product as nitrate transforms to nitrogen gas through denitrification. Because nitrate is usually so much higher than nitrite, the combined laboratory concentration of nitrite plus nitrate will be reported as nitrate in this report.

Nitrate (NO3) is very soluble in water and is negatively charged, and therefore moves readily with soil water through the soil profile, where it can reach groundwater. Where groundwater remains oxygenated, nitrate remains stable and can travel in the groundwater until it reaches surface waters. When nitrate encounters low oxygen/anoxic conditions in soils or groundwater it may be transformed to N gasses through a biochemical process called "denitrification." Therefore, groundwater nitrate is sometimes lost to gaseous N before the nitrate impacted groundwater has enough time to travel to and discharge into streams. Typically a smaller fraction of nitrate reaches streams in stormwater runoff over the land surface, as compared to subsurface pathways.

Common sources of nitrate include: on-site septic systems, fertilizer, decaying plant material, and precipitation. Much of this nitrate does not initially enter the soils in this form, but results from the biological breakdown of ammonium and organic sources of N which originate as manure, fertilizer and soil organic matter. In the presence of oxygen, moisture, and warm temperatures, other forms of nitrogen will tend to transform into nitrate. Nitrate is the dominant form of nitrogen in groundwater, and is also dominant in rivers and streams with elevated total nitrogen. Where streams originate in areas of agricultural production, the nitrate form of nitrogen is usually substantially higher than organic nitrogen. Concerns about nitrate in our water include: human health effects when found elevated in drinking water supplies, aquatic life toxicity in surface waters, and increased eutrophication and correspondingly low oxygen in downstream waters.

Fecal Coliform Bacteria

Fecal coliform bacteria are quantified in the laboratory as the number of colony-forming units in 100 ml of water. Fecal coliform bacteria are the most common microbiological contaminants of natural waters. Fecal coliform live in the digestive tracks of warm-blooded animals, including mammals and birds and are excreted in the feces.

The numbers of pathogenic organisms present in waters are generally difficult to identify and isolate, and are often highly varied in their characteristic or type. Therefore, scientists and public health officials usually monitor nonpathogenic bacteria that are typically associated with harmful pathogens in fecal contamination and are most easily sampled and measured. These associated bacteria (e.g. fecal coliform) are called indicator organisms. Fecal coliform bacteria are not generally pathogenic (disease causing) organisms, and are only mildly infectious. For this reason these bacteria are relatively safe to work with in the laboratory. If large numbers of coliforms are found in water, there is a high probability that other pathogenic bacteria or organisms.

Pathogens may be transported to surface waterbodies by stormwater runoff or persistent sources, such as onsite wastewater treatment systems, and illicit discharges or transient sources, such as animals defecating in the waterbody. Large amounts of fecal coliform are released in the waste of farm animals and can be washed into streams by runoff from rain or irrigation. Urban areas contribute to fecal coliform contamination when wastes from dogs, cats, raccoons, and humans are carried into storm drains, rivers, and lakes during storms. Fecal coliform can also enter streams from illegal or leaky sanitary sewer connections, and poorly functioning septic tanks. In Rhode Island, fecal coliform concentrations are used to determine risk for shellfish consumption

Enterococci Bacteria

Enterococci are another indicator organism, used to predict the presence of pathogens in natural waters. Sources of enterococci are the same as fecal coliform bacteria. According to studies conducted by the EPA, enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to "die off", especially in saltwater. As a consequence, enterococci are used to determine risk associated with primary and secondary contact recreation activities in the State’s fresh and salt waters.

Table 3. Summary of Sampling Parameters

Parameter	General Description	Sources to Surface Waters	Health and Environmental Concerns	Criteria/Guidlines
Turbidity	Measured indirectly in lab by quantifying amount of scattered light.	Sediment, fine organic and inorganic matter, soluble colored organic compounds (e.g. tannins), algae, and other microscopic organisms.		**RIDEM Criteria:** Turbidity not to exceed 5 NTU over background.
Total Suspended Solids	Water sample is filtered and dry solids weighed. High TSS can often result in high nutrients, bacteria, pesticides, and metals (these pollutants often adsorbed onto soil particles).	Eroded sediment from upland areas, and streambed and streambank erosion.	May be associated with elevated bacteria, pesticides, metals, and organic carbon which may result in disinfection byproducts	**No EPA or RIDEM criteria** EPA guidance 25,000 ug/l for protection of juvenile fish, larvae, and eggs.
Total Phosphorus	Does not easily dissolve in groundwater and generally enters streams with stormwater runoff.	Eroded sediment from upland areas, streambank erosion, fertilizer, livestock waste, pet waste, human waste, atmosphere	Causes eutophication and hypoxia (low dissolved oxygen) in lakes and reservoirs	**RIDEM Criteria:** Average Total Phosphorus shall not exceed 0.025 mg/l (25 ug/l) in any lake, pond, kettlehole or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria **EPA Gold Book Standard:** 50 ug/l in any stream at the point where it enters any lake or reservoir; and 100 ug/l in streams not discharging directly to lakes or impoundments
Ammonia	Measured in lab together with ammonium. Low levels in most waters	Septic systems, leaky sanitary sewers, pet and wildlife waste, livestock, manure applied to fields, decaying plant material, decay of soil organic	Toxic to aquatic life	**RIDEM Criteria:** Toxicity varies with pH. (more toxic at higher pH). At highest pH toxic to salmonids at 885 ug/l.

		matter, and certain fertilizers. Mostly enters surface waters via overland runoff.		
Total Kjeldahl Nitrogen (TKN)	Lab measurement of ammonia/ammonium and organic nitrogen. Organic nitrogen is the chief component.	Organic nitrogen derived from living or decaying plant material and organisms, soil, and human and animal waste	Can convert to other forms of nitrogen.	**No RIDEM Criteria** **EPA Guidance for Northeastern Coastal Zone:** 300 ug/l
Nitrate	Measured in lab together with nitrite. Main form of nitogen in groundwater and high-nitrogen surface waters. Most nitrogen species can convert to nitrate.	Fertilizer, soil nitrogen, human and animal waste, decaying plant material, , and the atmosphere.	Methemoglobinmia in infants and susceptible adults. Toxic to aquatic life. Eutrophication and hypoxia (low dissolved oxygen), especially in coastal waters	**No RIDEM Criteria** **EPA Guidance for Northeastern Coastal Zone:** 310 ug/l
Total Nitrogen	Sum of TKN, nitrate and nitrite.	See above	See nitrogen parameters above	**No RIDEM Criteria** **EPA Guidance for Northeastern Coastal Zone:** 610 ug/l
Fecal Coliform	Quantified in lab as colony forming units per 100 ml.	Feces from warm-blooded animals	Indicator organism used to assess the probability of the presence of pathogenic bacteria and viruses	**RIDEM Criteria:** Primary Contact Recreational/Swimming Criteria- Not to exceed a geometric mean value of 200 MPN/100 ml and not more than 10% of the total samples taken shall exceed 400 MPN/100 ml, applied only when adequate enterococci data are not available.
Enterococci	Quanified in lab as Most Probable Number (MPN) per 100 ml.	Same as above	Same as above	**RIDEM Criteria:** Non-Designated Bathing Beach Waters Geometric Mean Density: 54 colonies/100 ml

5. Maidford River Sampling Results

Water quality sampling results are shown at the end of this document. Pollutant levels are represented in bubble charts as circles. The size of each circle is directly proportional to the pollutant concentration. Dry and wet weather concentrations vary greatly and are represented on different charts. Each of the three dry and wet weather surveys are shown on each of the charts, adjacent to the appropriate sampling station. Bubble charts are a quick and visually accessible way of showing changes in water quality from station to station.

In addition to size, bubbles were color-coded, so that pollutant concentrations could be compared to crieria or guidance levels. Green bubbles meet criteria or guidance. Red bubbles indicate an exceedance of State water quality criteria. Yellow bubles are indicative of an exceedance of guidelines (in the event that there are no criteria for the given pollutant).

5.1. Turbidity

Dry Weather

The dry-weather turbidity values were low, with a mean and maximum value of 1.1 and 2.3 NTU, respectively (Figure M1). RIDEM water quality criteria for turbidity is based on exceedances above the background level. For the Maidford River, background is interpreted as "naturally" occuring conditions, as found at the most upstream two stations, where the riparian corridor is naturalized. Dry weather values for both stations were averaged together to determine the background level for dry weather of 1.6 NTU. Comparing average values against this background level, no downstream station exceeds by more than 5 NTU.

Wet-weather

Wet-weather turbidity values were much higher than dry weather values (Figure M2). Sediment-laden stormwater was largely responsible for the increase in turbidity. The mean and maximum wet-weather turbidity values were 94 and 550 NTU, respectively. Wet weather values for the two upstream stations were averaged resulting in 10.5 NTU as the background for wet weather. Comparing average values against this wet weather background, all downstream stations exceed by more than 5 NTU.

Changes in turbidity were relatively consistent during the 12/9/2014 and 9/30/15 rain events, when the stream was sampled while it was still raining. The headwater stations (MDF-SW-1 and MDF-SW-2) were chosen as representative of background conditions, because the riparian corridor in this reach consists of a broad grassy marsh, which probably settles out a significant portion of any sediment that may be eroded from adjacent agricultural landuses. The 9/30/2015 flows were elevated at the headwaters relative to the first storm. Turbidity values at the headwater station (MDF-SW-1) were also slightly higher on 9/30/2015. The station was sampled at the end of the rain storm, unlike 12/9/2014 when it was sampled the beginning of the event. Elevated turbidity on 9/30/2015 was probably the result of sediment-laden stormwater, which was being slowly metered out of the headwater pond, after the rain event.

The largest increase in turbidity, recorded during the first two wet-weather events, was recorded at the Berkeley Av. spur (MDF-SW-3A). The maximum turbidity level (550 NTU) occurred at this station, where turbidity increased by 1-2 orders of magnitude relative to the upstream station on Wyatt Rd. (MDF-SW-2).

For both the 12/9/14 and 9/30/15 storms, turbidity decreased from the Berkeley Av. spur station to the station at Reservoir Av. (MDF-SF-1). Although on 9/30/15, the turbidity remained stable at the next station at the Newport Water Intake (MDF-FO-1), there was a significant increase in turbidity at MDF-FO-1 during the 12/9/14 survey (when flow was significantly higher).

The general pattern of turbidity changes recorded on 10/29/15 were similar to the previous wet-weather sampling event on 9/30/15. All turbidity values at the three downstream stations exceeded the criteria. However, turbidity values were much lower at the the three downstream stations, relative to the values recorded during the two previous storms. As previously discussed, sampling was conducted on 10/29/15 after the storm had ended. River flows on 10/29/15 were also significantly less than the previous two storms, with much less sediment-laden runoff being discharged to the stream, and apparently less streambank and streambed erosion.

Like the previous two storms, the biggest increase in turbidity occurred at the Berkeley Av. spur. Two new sampling stations were added for the 10/29/15 sampling event. One of these stations (MDF-SW-3) was located in the Maidford River immediately upstream (east) of Berkeley Av. The turbidity at this station (14 NTU) increased to 23 NTU at the Berkeley Av. spur (MDF-SW-3A). The other new station was located in a ditch at the edge of a nursery property, that as previously discussed discharges to the Maidford River on the downstream (western) side of Berkeley Av. The turbidity in the ditch was 78 NTU. The ditch was the the first station sampled on this date, because there was only a slight amount of flow in it (the other three ditches on the nursery property had already stopped flowing). The sediment-laden flow in the ditch caused a plume of sediment along one bank of the river that was very apparent.

5.2. Total Suspended Solids (TSS)

Dry Weather

Like turbidity, the dry-weather TSS values are low, with a mean and maximum value of 2,000 and 8,000 ug/l, respectively (Figure M3). Many TSS results were below the detection limit (1,000 ug/l). EPA guidance for TSS is 25,000 ug/l for protection of juvenile fish, larvae, and eggs. Suspended solids are mainly sediment. Decaying organic material may be a minor constituent of TSS, especially during low flow periods. Flow velocities during dry weather are not sufficient to cause significant streambank erosion or resuspension of streambed sediments.

Wet Weather

As was the case with turbidity, wet-weather TSS values were much higher than dry-weather values (Figure M4). The increase in wet-weather values was due to sediment-laden stormwater discharging to the stream, streambank erosion, and the resuspension of streambed sediment (bedload). The mean and maximum wet-weather TSS values were 108,000 and 450,000 ug/l, respectively. The mean wet-weather TSS value was more than 50 times higher than the dry-weather mean and four times greater than EPA suggested guidance (25,000 ug/l).

Wet-weather changes in TSS river values largely mimick patterns for turbidity discussed above. The TSS values at the headwaters station (MDF-SW-1) and at Wyatt RD. (MDF-SW-2) were below EPA suggested guidance, during all three storms. However, some suspended sediment was clearly visible at the headwaters station (MDF-SW-1) during the first two storms.

As was the case for turbidity, the largest increase in TSS, recorded during the first two wet-weather events, was recorded at the Berkeley Av. spur (MDF-SW-3A). The maximum TSS level (450,000 ug/l) occurred at this station, where the mean TSS concentration increased by a factor of 45 relative to the upstream station on Wyatt Rd. (MDF-SW-2).

During the first two rain events (12/9/14 and 9/30/15), TSS values decreased from Berkeley Av to the next station (MDF-SF-1) at Reservoir Av., probably due both to settling and dilution with cleaner water. On 12/9/14, during a moderate rain in the middle of the rain event, there was a 50% increase in TSS from Reservoir Av. to the Newport Water Intake (MDF-FO-1). In contrast, on 9/30/15, during a very light rain at the end of a rainstorm and significantly lower flow, a decrease in TSS was recorded at the terminal station, probably mostly due to settling.

The general pattern of TSS changes recorded on 10/29/15 were similar to the previous wet-weather sampling event on 9/30/15. Like turbidity values, TSS values were much lower relative to the values recorded during the two previous storms. River flows on 10/29/15 were significantly less than the previous two storms, apparently with much less sediment-laden runoff being discharged to the stream, as well as less significant streambank erosion, and resuspension of streambed sediments. Although the water at all stations was visibly turbid, TSS values met the suggested guidance (25,000 ug/l) at all river stations, except at MDF-SW-3A (Berkeley Av. spur or Whitehall Museum access).

Unlike turbidity, there was a significant increase in TSS from Wyatt Rd. (MDF-SW-2) to Berkeley Av. (MDF-SW-3). However, the TSS values at MDF-SW-3 (17,000 ug/l) were in-line with relatively low values recorded at both headwater stations during the previous rain event.

Like the previous two storms, the biggest increase in TSS occurred at the Berkeley Av. spur, relative to the station located immediately upstream (east) of Berkeley Av. The TSS at MDF-SW-3 (17,000 ug/l) increased to 26,000 ug/l at the Berkeley Av. spur (MDF-SW-3A). The TSS value in the ditch, conveying stormwater from the nursery operation west of Berkeley Av. and discharging into the river immediately downstream of Berkeley Av., was 42,000 ug/l. It is anticipated, based on wet-weather watershed observations, that the decrease in water quality recorded at the Berkeley Av. spur (Whitehall Museum access) would have been much more pronounced than the change recorded at Berkeley Av., if the samples were taken during a rain event, and not hours after the rain had ended. There was very little stormwater flow from the nursery during this event, relative to the previous wet-weather events. During previous and subsequent rain events there was a very marked decrease in water clarity in the Maidford River, from the upstream to downstream sides of the ditch.

There was a very significant decrease in TSS values, from Reservoir Av. to the terminal station, on 10/29/15. This decrease was probably mostly due to settling of sediment particles in the impoundment immediately upstream of the Newport Water intake (MDF-FO-1). Of course, this sediment would be resuspended during the next significant rain event.

5.3. Total Phosphorus

Dry Weather

As discussed previously the RIDEM numeric criteria for phosphorus (25 ug/l) is applicable to rivers only at the point where they enter lakes, ponds or in this case reservoirs. For the Maidford River, this criteria is applied only at station MDF-FO-1, the location of the Newport Water intake structure. This structure diverts water (via a 30 inch pipe) from the Maidford River to either Paradise (AKA Nelson) Pond or Gardiner Pond, both reservoirs of the Newport Water system. During periods of dry-weather flow, it appears that all of the flow from the Maidford River is diverted to one of the two reservoirs. The total phosphorus concentration, sampled at the Newport Water intake, was well below the criteria value during all three dry-weather sampling events. There were also no exceedances of the EPA Gold Book Standard guidance value (100 ug/l), which is applied to the upstream reaches.

The phosphorus concentration at MDF-MH1 (an abandoned artesian town well) was one of the lowest values recorded. The low phosphorus level, recorded at the Town well, supports the generally held notion that phosphorus is not readily dissolved and transported in groundwater.

Wet Weather

As was the case with TSS, wet-weather phosphorus values were much higher than dry-weather values (Figure M6). This was to be expected since phosphorus is generally adsorded onto soil particles, and often enters streams with eroded sediment. During the first wet-weather event (12/9/14), EPA suggested guidance was exceeded at all upstream stations, except the two most upstream stations (MDF-SW-1 and MDF-SW-2). During the two subsequent wet-weather events, EPA guidance was exceeded at all applicable stations. RIDEM criteria for phosphorus was exceeded at the terminal station (MDF-FO-1), during all three wet-weather events. The mean and maximum wet-weather total phosphorus values were 1,070 and 4,700 ug/l, vs. 26 and 55 ug/l during dry weather. The mean wet-weather total phosphorus value at the Newport Water intake (1,100 ug/l), exceeded the criteria (applied only to the inlets to ponds or reservoirs) by a factor of 20. The mean value for the remaining stations exceeds the suggested EPA guidance (100 ug/l) by a factor of more than 20. Although still very elevated, the phosphorus levels recorded during the 12/9/15 wet-weather event were significantly lower than those recorded during the wet-weather events in the fall of the following year, despite the fact that the stream was sampled in the middle of a moderate rain event and flows were the highest during the winter event. The probable reason for the lower phosphorus levels, recorded on 12/9/14, was that there was less fertilizer in the soil and less potential for plant decay at that time of the year.

Wet-weather phosphorus levels at the two stations in the headwaters region of the Maidford River do not track well with TSS values. This suggests that much of the phosphorus in the headwaters region is entering the stream in dissolved form (most paticulate phosphorus is adsorded onto soil particles). The mean wet-weather phosphorus level increased from 240 ug/l at the headwaters to 700 ug/l at Wyatt Rd. (MDF-SW-2).

Like turbidity and TSS, the largest increases in total phosphorus, especially during the first two wet-weather events, were recorded at the Berkeley Av. spur (MDF-SW-3A). The mean total phosphorus level at this location was 2,200 ug/l, with a maximum value of 4,700 ug/l.

The phosphorus levels, recorded on 10/29/15, from Berkeley Av. (MDF-SW-3) to the Berkeley Av. spur, increased only marginally, despite the fact that the phosphorus level in the ditch draining the nursery property (1,800 ug/l), at MDF-HN, was elevated relative to levels recorded in the river. As previously discussed, the stormwater runoff from the nursery had nearly ended when the sample was taken.

Phosphorus levels decline at Reservoir Av. (MDF-SF-1). During the 9/30/2015 and 10/29/15 phosphorus levels reamain virtually unchanged at the terminal station. On 12/9/14, phosphorus levels increased almost 50% from Reservoir Av. to the Newport Water intake (MDF-FO-1), tracking well with a 50% increase in TSS.

5.4. Ammonia

Dry Weather

Dry-weather ammonia levels were below the detection limit (100 ug/l) at all stations, during all three dry-weather sampling events (Figure M7).

Wet Weather

During the first two wet-weather sampling events, ammonia levels were below the detection limit at all stations, except for the Berkeley Av. station (MDF-SW-3A), on 9/30/15 (Figure M8). Ammonia levels were higher during the 10/29/15 event, with only one value, recorded at Reservoir Av., below the detection limit.

Elevated ammonia levels, recorded during the October storm, may have been due to ongoing practices at that time of year (e.g. the application of fertilizers or manure to farm fields to establish cover crops or the accelerated rate of plant decay at that time of year), or perhaps the higher levels were an artifact of the timing of the sampling during the October storm. The river was sampled in October hours after the rain ended, rather than during the storm as was the case for the prior rain events. Runoff may have dried up in the outer reaches of the watershed, but continued in areas closer to the stream, suspending waste sources in close proximity to the channel. The October flows were also much less than was recorded during the previous rain events, so the higher ammonia levels could have been recorded because there was less dilution.

On 10/29/2015 the ammonia level was above the detection limit and remained constant at the next station but doubled between Wyatt Rd. and Berkeley Av. (MDF-SW-3). Ammonia levels doubled again from Berkeley Av. to the Berkeley Av. spur (MDF-SW-3A). Note that the ditch at the boundary of the nursery property (MDF-HN) was sampled out of sequence, and was the first station sampled on that day. The ammonia level in the ditch was 300 ug/l. There was a slight increase in ammonia recorded at the terminal station (MDF-FO-1) on 10/29/15

5.5. Total Kjeldahl Nitrogen (TKN)

Dry Weather

The vast majority of dry-weather TKN values exceed EPA's suggested guidance level (300 ug/l). The mean dry-weather TKN value was 400 ug/l (Figure M9). During the two April, 2015 surveys TKN in the river ranged from 200 to 500 ug/l with the majority of the values in the 300-400 ug/l range. Since the dry-weather ammonia levels were all below the detection limit, the TKN values mostly reflect organic nitrogen, which generally does not move as readily in groundwater as nitrate. The single sample taken at the abandoned town well (MDF-MH-1) yielded a TKN value below the detection limit (100 ug/l). Although the movement of organic nitrogen in groundwater can not be entirely discounted, it appears that much of the elevated TKN levels may be caused by the decay of plant material and waste in close proximity to the stream or contiguous wet areas.

During the April surveys, TKN values in the northern portion of the study area tended to be slightly higher than at the two downstream stations. TKN values, during the January, 2016 survey, at the three most downstream stations were significantly higher than during the April surveys. There was a significant increase in TKN at the Berkeley Spur station (MDF-SW-3A).

Wet Weather

The wet-weather TKN values exceed EPA's suggested guidance level (300 ug/l), at all stations during all three wet-weather surveys (Figure M10). The mean wet-weather TKN value was 1070 ug/l, compared to the dry-weather mean of 400 ug/l. TKN consists largely of organic nitrogen, which does not dissolve readily in water. Dry-weather flows are sustained by groundwater discharge, and since TKN does not readily dissolve in groundwater, wet-weather flows are generally characterized by higher TKN than dry-weather flows.

TKN levels were elevated at the headwater station. TKN levels at the next station on Wyatt Rd. (MDF-SW-2) remain virtually unchanged, except for the 10/29/15 survey where there was an increase. On 10/29/15, there was a slight increase in TKN from Wyatt Rd. to the Berkeley Av. station (MDF-SW-3), from 900 to 1,100 ug/l. On the same date, the TKN level increased to 1,400 ug/l at the Berkeley Av. spur. The mean wet-weather TKN value was highest at the Berkeley Av. spur.

During both the 9/30/15 and 10/29/15 surveys, TKN levels dropped at Reservoir Av. and remained unchanged at the Newport Water intake. However, during the 12/9/14 survey, TKN increased from 640 ug/l at the Berkeley spur to 1,000 ug/l at Reservoir Av. (MDF-SF-1). The TKN value, recorded on 12/9/14, at the Newport water intake increased to 1,400 ug/l.

5.6. Nitrate

Dry Weather

Dry-weather nitrate levels were significantly higher than TKN values (Figure M11). The mean dry-weather nitrate concentration, for all river sampling stations, was 2,690 ug/l (a value more than six-fold greater than the mean dry-weather TKN concentration). Higher nitrate values reflect the fact that nitrate is more easily dissolved and transported in groundwater. The mean dry-weather nitrate concentration exceeds EPA's suggested guidance (310 ug/l) by a factor of more than eight-fold. The suggested guidance was exceeded at all stations, during each of the three dry-weather surveys, indicating consistently high levels of nitrate in groundwater throughout the watershed. It is noted that EPA's suggested guidance for ambient waters (310 ug/l) is well below the drinking water standard (of concern to private well owners) of 10,000 ug/l.

The highest nitrate level (5,590 ug/l) was recorded at the abandoned town well (MDF-MH-1). The maximum nitrate value recorded at a river station was 3,490 ug/l. The high nitrate value at the well relative to the levels recorded in the river stations, indicated that either cleaner groundwater was discharging into the channel upstream causing dilution, or there was significant denitrification taking place within the river corridor or adjacent wetlands. As previously discussed, when nitrate encounters low oxygen/anoxic conditions in soils or groundwater it may be transformed to nitrogen gas through a biochemical process called "denitrification." Therefore, groundwater nitrate is sometimes lost to gaseous nitrogen before the nitrate-impacted groundwater has enough time to travel to and discharge into streams. The denitrification process is enhanced by the presence of organic material (often found in abundance in wetland areas adjacent to streams). The apparent loss of nitrate at the river corridor highlights the importance of riparian buffers (especially wetland riparian areas) in at least partially mitigating the effect of contaminated groundwater on the water quality of the stream.

High nitrate levels were recorded at the headwaters of the western fork of the Maidford River (MDF-SW-1), during all three dry-weather surveys. During the April surveys, there was a significant decrease in concentration at MDF-SW-2 (Wyatt Road), probably due to dilution with relatively cleaner water, but also because there was significant denitrification taking place along the marshy area bordering the stream at the headwaters. A significant increase in nitrate occurred at the next downstream station (MDF-SW-3A; Berkeley Av. Spur) during the April surveys.

The nitrate concentrations observed in January were generally higher than those observed in April. This is probably due to the fact that denitrification is a bacteria-induced process, and bacteria are much less metabolically active in colder temperatures. Although the nitrate values were higher, the patterns in nitrate concentrations, recorded during the January survey, were very similar to those observed in April. The only exceptions are that in January there was not a significant decrease from the headwaters station (MDF-SW-1) to Wyatt Rd. (MDF-SW-2) (this may be the result of the suppression of denitrification in the marshy headwaters area, caused by colder temperatures) and there was a much more modest increase between stations MDF-SW-2 and MDF-SW-3A (Berkeley Av. Spur).

Wet Weather

Wet-weather nitrate levels were generally much lower than wet-weather TKN values (Figure M12). The mean wet-weather nitrate level was also less than one third of the mean dry-weather nitrate level (2,690 ug/l). The wet-weather nitrate values were lower than the dry-weather values, at each station, during all three wet-weather events. The lower wet-weather values resulted from the fact that surface stormwater flow has a significantly lower nitrate concentration than local groundwater. The mean wet-weather nitrate concentration, for all river sampling stations, was 700 ug/l, while the mean wet-weather TKN concentration was 1,070 ug/l. Higher TKN values reflect the fact that its major component (organic nitrogen) does not dissolve as readily as nitrate, with TKN generally transported in surface stormwater flow, while nitrate is transported mainly in groundwater. Therefore during wet weather, TKN is the major component of the total nitrogen value, whereas nitrate is the major component of total nitrogen during dry weather. The mean wet-weather nitrate concentration exceeds EPA's suggested guidance (310 ug/l) by a factor of more than two. The nitrate suggested guidance was exceeded at all stations, except for the two headwater stations, on some occasions.

The highest in-stream wet-weather nitrate level (2,540 ug/l) was documented at the headwaters of the Maidford River (MDF-SW-1), on 12/9/2014. The station was sampled at the beginning of a rain event and the flow was slight. The nitrate values decreased at each successive downstream station.

On 9/30/2015, the nitrate value at the headwater station again exceeded the suggested guidance, but decreased to fall below the suggested guidance at the next station at Wyatt Rd (MDF-SW-2). The wet-weather nitrate value increased to 1,020 ug/l at the Berkeley Av. spur. The nitrate value decreases at the next station at Reservoir Av. (MDF-SF-1) and remains relatively unchaged at the terminal station at the Newport Water intake.

On 10/29/2015, the nitrate values at the two headwater stations, met suggested guidance. However, at Berkeley Av. (MDF-SW-3), the nitrate level increased to 480 ug/l. Note that the ditch carrying stormwater from the nursey property, west of Berkeley Av., was sampled out of sequence (it was the first station sampled). The nitrate level documented in the nursery runoff (3,120 ug/l) was higher than any wet-weather values recorded in the river itself. The nitrate level remains nearly unchanged a short distance downstream at MDF-SW-3A. There was a relatively small increase in nitrate from the Berkeley Av. spur to Reservoir Av. (MDF-SF-1). The nitrate level remains little changed at the terminal station at the Newport Water intake.

5.7. Total Nitrogen

Dry Weather

The mean dry-weather total nitrogen concentration for all river sampling stations was 3,120 ug/l, a value which exceeds EPA's suggested guidance (610 ug/l) by a factor of more than five-fold. The suggested guidance was exceeded at all stations, during each of the three dry-weather surveys (Figure M13). Dry-weather total nitrogen levels largely reflect nitrate levels, which as previously discussed are many times greater than TKN level. Therefore patterns in total nitrogen level fluctuations between stations mimick the changes in nitrate concentrations.

Wet Weather

The mean wet-weather total nitrogen concentration for all river sampling stations was 1,760 ug/l (M14). Although significantly less than the dry-weather mean value (3,120 ug/l), the wet-weather mean total nitrogen concentration exceeds EPA's suggested guidance (610 ug/l) by almost a factor of three. The suggested guidance was exceeded at all stations, during each of the three dry-weather surveys.

The highest in-stream total nitrogen river value was recorded at the headwaters, on 12/9/20115. Nitrate values steadily decrease until the terminal station at the Newport Water intake.

On 9/30/2015, total nitrogen was elevated at the headwater station, decreased slightly at Wyatt Rd (MDF-SW-1), and increased significantly to 3,120 ug/l at the Berkeley Av. spur (MDF-SW-3A). The total nitrogen value decreased at the downstream stations.

On 10/29/2015, total nitrogen was elevated at the headwater station and rose fairly steadily at the next three stations at Wyatt Rd., Berkeley Av., and the Berkeley Av. spur, a short distance downstream. The highest wet-weather total nitrogen value (4,320 ug/l) was recorded at the ditch draining the nursery, located to the west of Berkeley Av. As previously discussed, the ditch was the first sample taken of the day. The rain had ended hours before sampling began and the ditch was barely flowing at that time. It therefore exerted less influence on the water quality of the stream, than would have been the case if all the ditches discharging nursery runoff were flowing. The total nitrogen concentration remained relatively unchanged at the two downstream stations.

5.8. Fecal Coliform Bacteria

Dry Weather

The dry-weather fecal coliform geomean, for all river sampling stations, was 7 CFU/100 ml. The maximum dry-weather fecal value was 112 CFU/100 ml, which is still well below the RIDEM geomean criteria of 200 MPN/100 ml (Figure M15). The highest mean fecal coliform concentration, for the three dry-weather sampling events, was recorded at Reservoir Av. (MDF-SF-1), which is downstream of a mainly residential area.

Wet Weather

The wet-weather fecal coliform geomean, for all river sampling stations, was 5,120 CFU/100 ml, more than 25 times greater than the RIDEM geomean criteria of 200 MPN/100 ml, and over 700 times greater than the dry-weather geomean. The fecal geomean criteria was exceeded at all stations, during all three wet-weather events (Figure M16).

The bacteria levels, recorded during the 12/9/2014 rain event, were lower than those recorded during the two subsequent wet-weather sampling events, probably because of cooler temperatures. The bacteria level at the headwaters station, already slightly exceeded the criteria value. The fecal level remains relatively stable at Wyatt Rd, but increased by a factor of five at the Berkeley Av. spur (MDF-SW-3A). The fecal levels double at the downstream station at Reservoir Av. (MDF-SF-1). The highest dry-weather fecal mean was also recorded at this station.

Bacteria were analyzed and quantified using serial dilutions. Unfortunately the dilutions, for the second wet-weather event (9/30/2015), were not carried out to an extent that was required for quantification. The result was that the fecal value at all stations was >16,000 CFU/100 ml. The fecal levels recorded during this event were higher than during the other wet-weather events, because of the relatively warm weather and the fact that the river was sampled during the tail end of a rainstorm, rather than after the rain had ended, as was the case for the 10/29/2015 event..

During the 10/29/2015 wet-weather event, the fecal value at the headwaters (8,000 CFU/100 ml) again greatly exceeded the criteria value. The fecal value declined to 3,000 CFU/100 ml at Wyatt Rd., but increased to 20,000 CFU/100 ml at Berkeley Av. (MDF-SW-2). The fecal value declined at the station a short distance downstream, at the Berkeley Av. spur (MDF-SW-3A). The value recorded at the nursery boundary (4,000 CFU/100 ml), discharging immediately downstream of of MDF-SW-3 was lower than the fecal level in the stream. The fecal value declines at the next station at Reservoir Av. and increases slightly at the terminal station.

5.9. Enterococci

Dry Weather

The dry-weather enterococci geomean, for all river sampling stations, was 5 MPN/100 ml. The maximum dry-weather enterococci value was 33 MPN/100 ml, which is still well below the RIDEM geomean criteria of 54 colonies/100 ml (Figure M17). Like fecal coliform, the highest mean enterococci concentration was recorded at Reservoir Av. (MDF-SF-1).

Wet Weather

The wet-weather enterococci geomean, for all river sampling stations (8,500 MPN/100 ml), was more than 40-fold greater than the criteria (54 MPN/100 ml.) The enterococci geomean criteria was exceeded at all stations, during all three wet-weather events (Figure M18). Like the fecal coliform results, the enterococci values were lowest on 12/9/2014 and highest on 9/30/2015. However changes in enterococci values, from station to station, do not necessarily track well with changes in fecal levels.

The enterococci criteria (54 colonies/100 ml) was exceeded at the headwaters station. Enterococci values at the headwaters ranged from 129 to 19,000 MPN/100 ml. The enterococci values at Wyatt Av. (579 to > 24,200 MPN/100 ml), increased relative to the headwater station, during all three wet-weather events.

Changes in the 9/30/2015 enterococci values cannot be accessed downstream of Wyatt Rd., since all values downstream were also greater than 24,200 MPN/100 ml. On 12/9/2014, the enterococci value increased from 579 MPN/100 ml at Wyatt Rd. to greater than 2,420 MPN/100 at the Berkeley Av. spur (MDF-SW-3A). Increases in fecal values were also documented at this location. On 12/9/2014, all enterococci values downstream of Berkeely Av. were greater than 2,420 MPN/100 ml. On 10/29/2015, the enterococci value at MDF-SW-3A (Berkeley Av.) decreased relative to the upstream station. Another decrease in enterococci was documented at the next downstream station at the Berkeley spur. Like the fecal value, the value recorded at the nursery boundary (16,700 MPN/100 ml) was elevated but inline with levels recorded in the river. On 10/29/2015 the enterococci level increased from 16,600 MPN/100 ml at MDF-SW-3A to 30,800 MPN/100 ml at Reservoir Av. It was the largest increase recorded during the wet-weather event.

6. Maidford River Pollutant Sources

Figure 18. Maidford Subwatershed 1. (Upgradient of MDF-SW-1; Meadow Lane)

Dry-Weather Sources (Upgradient of MDF-SW-1; Meadow Lane)

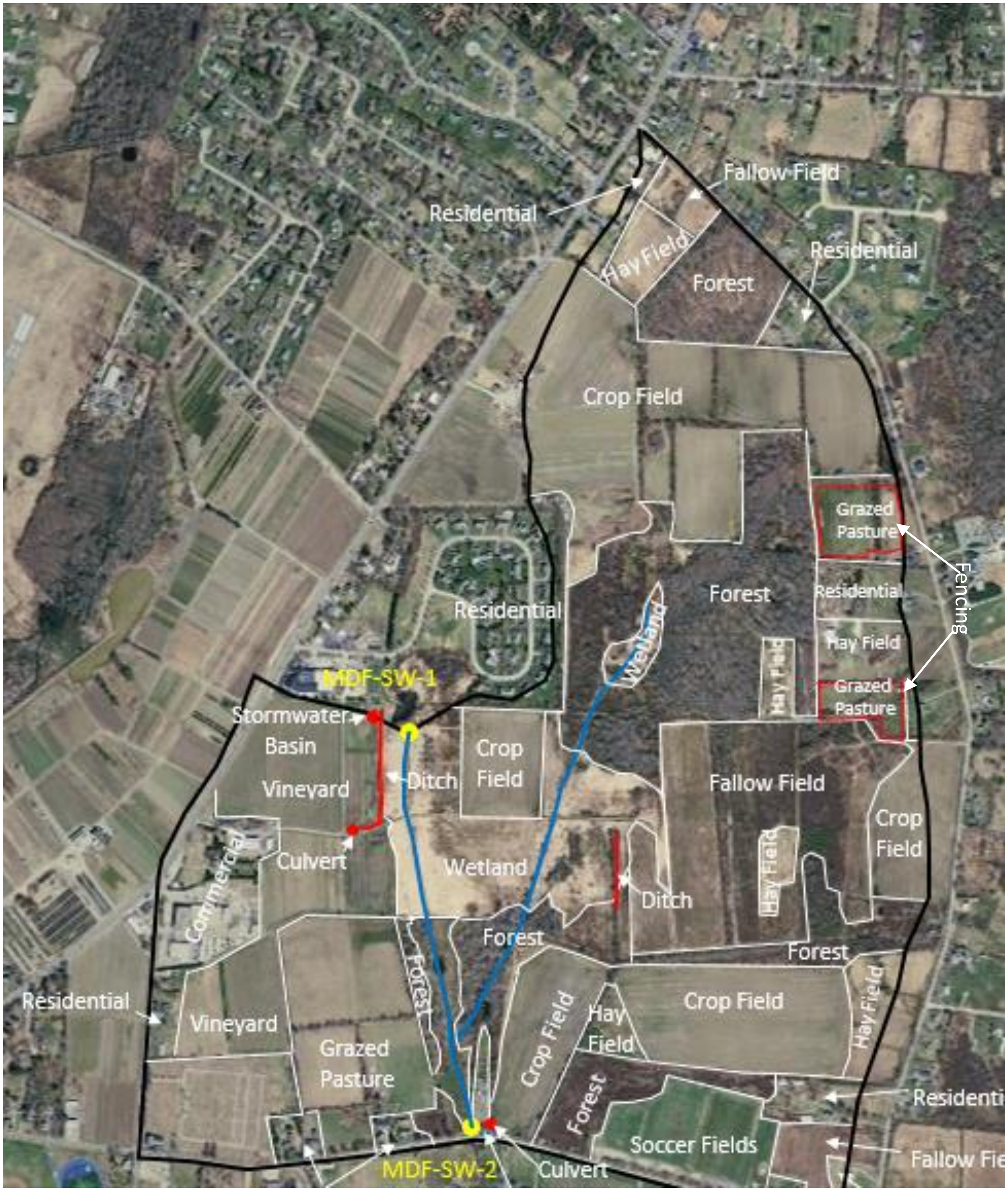
Elevated phosphorus and TKN levels were recorded during the 4/15/2016 dry-weather sampling event. Elevated TKN was also recorded, during the 1/2/2016 event. Nitrate was elevated during all dry-weather three events. Since there was no dry-weather flow into the farm pond at the headwaters of the Maidford River, the pond and contiguous wetlands are probably the source area, resulting in the elevated phosphorus and TKN, and to a lesser extent nitrate levels. Potential sources, common to all three pollutants, include decaying plant material, wildlife waste, leaky sanitary sewers, and bioturbation (waterfowl or other wildlife disturbing pond sediments). There is a sanitary sewer and pump station, serving a nearby subdivision on Meadow Ln, but there have been no recent reports of leaks and there was no evidence of such on the ground. Stormwater runoff, from nearby Meadow Ln., may be the ultimate source of nutrients in the pond sediment. Since nitrate dissolves and is transported readily in groundwater, the main potential source of nitrate may have been contaminated groundwater from the upper reaches of the watershed. Groundwater may have been contaminated by any of the following: fertilizers (including manure) applied to cropfields, residential lawns, and perhaps fertilizer application related to small nursery operations with plants in containers. Nitrate levels were extremely elevated. Since river baseflow, during dry weather, is the result of groundwater discharging into the stream, the high dry-weather nitrate levels were an indication of high levels of nitrate in groundwater in this uppermost portion of the watershed.

Wet-Weather Sources (Upgradient of MDF-SW-1; Meadow Lane)

Wet-weather nitrate was elevated, during two of the three wet-weather events, and phosphorus, TKN, fecal coliform and enterococci were elevated during all three events. Stormwater from nearby Meadow Ln. was probably the main potential source of all the above pollutants. Ammonia levels were above the detection limit, during the October wet-weather event. Although the wet-weather ammonia levels were very low, and not remotely approaching criteria levels, any ammonia levels, above the detection limit, may be significant in helping to identify sources. Dry-weather values were below the detection limit at all stations. Wet-weather values for the first two storms values were also below the detection limit, except at at a single station.

Stormwater from Meadow Ln. is a potential source common to all the above pollutants. A roadway culvert on Meadow Ln. drains to a wetland at the head of the small farm pond that forms the headwaters of the Maidford River. A significant amount of roadway sediment was observed in the wetland (Photo M4). In addition to sediment, other potential sources of pollutants in stormwater are pet and wildlife waste, leaky sanitary sewers, and lawn fertilzers. Wildlife waste and plant detritus from wetlands adjacent to the pond, are also potential sources of pollutants (Photo M5).

Figure 19. Maidford Subwatershed 2. (MDF-SW-1 to MDF-SW-2; Meadow Lane to Wyatt Road).



Dry-Weather Sources (MDF-SW-1 to MDF-SW-2; Meadow Lane to Wyatt Road)

There were no significant increases in pollutant concentrations at this station, during dry weather.

Wet-Weather Sources (MDF-SW-1 to MDF-SW-2; Meadow Lane to Wyatt Road)

Significant increases in phosphorus were recorded at this station, during all three wet-weather events, despite the fact that turbidity and TSS stayed relatively unchanged from the upstream station. Because phosphorus is generally adsorbed onto soil particles, the increase in phosphorus levels without a concomitant increase in turbidity or TSS, appears to indicate that a significant portion of the phosphorus load may have been adsorbed onto organic matter (e.g. animal waste) and not soil particles, or that the soil in this reach is more saturated with phosphorus, or dissolved phosphorus makes up a greater portion of the phosphorus load along this reach.

An increase in TKN concentration was recorded, during the October wet-weather event, only. Increases in enterococci were recorded, during all three wet-weather events. Ammonia was above the detection limit, during the October wet-weather event, only. Livestock, wildlife, and pet waste are potential sources, common to phosphorus, TKN, ammonia, and bacteria.

Another potential pollutant source is manure associated with a livestock operation, located to the immediate north of Wyatt Rd. The main pastures, of the cattle farm, are located well to the west of the stream. However, there is an ungated gap in a stone wall (Photo M14), that allows cattle access to a strip of land on both sides of the river. This area is partially forest and shrubland but there are many open grassy spaces that were clearly being grazed (Photo M13). Manure was also observed in many areas along this reach of the river, to the immediate north of Wyattt Rd., including in very close proximity to the channel (Photo M15).

There is a broad marsh area contiguous to the stream in this area, characterized by standing water for much of the year (Photo M6). These flooded conditions provide a pathway for pollutants to reach the stream. Wildlife waste and decaying plant material, within the marsh, were potential sources of pollutants.   Pet waste, from public walking trails in this reach, may also be a potential source of pollutants.

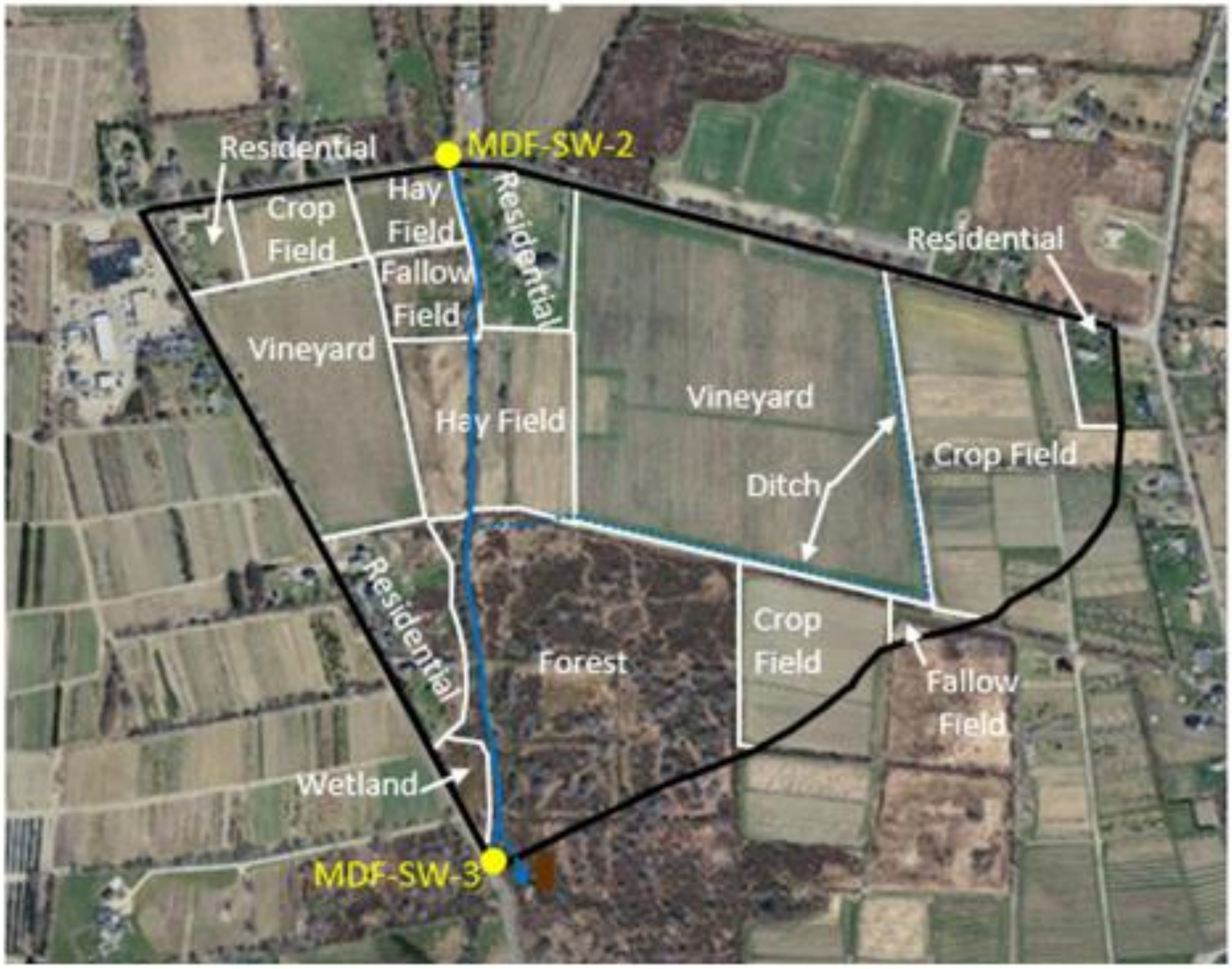
Fertilizer associated with a vineyard, located to the west of the river and east of East Main Rd., is a potential source of phosphorus (Photos M7-M11). An additional potential source is stormwater discharged from a culvert, located on vineyard property (M12). The culvert discharges to a ditch at the eastern edge of the vineyard. The pipe may be connected to the stormwater drainage system of East Main Rd. Stormwater discharge, contaminated by any leaky sanitary sewers, may also be a potential source of bacteria.

Various agricultural fields along this reach may be other potential sources of phosphorus. Either chemical fertilizer or manure applied to the fields could be an additional cause of the significant increase in pollutants recorded at this station. There are numerous crop fields, located to the north of the headwaters of the eastern branch of the stream. Another crop field is located east of the river to the immediate north of the Wyatt Rd. The northern part of this field appears to drain to this reach. A hay field is located between the east and west branches of the river, south of Meadow Ln. Lastly, there is a nursery, located on the west side of East Main Rd. Sediment-laden runoff from the northern end of the nursery enters the roadway (Photos M1-M3). In the event that the culvert on vineyard property, discussed above, is associated with the roadway stormwater drainage system, the nursery may also be an additional source of phosphorus to this reach.

Although there were not any significant changes in turbidity or TSS, field observations revealed that minor sources of sediment were evident along this reach. Stormwater from the culvert, discharging on vineyard property, was noticeably turbid (Photo M12). The ditch at the eastern edge of the vineyard was walked in a southerly direction (Photo M8). For most of the length of the ditch the stormwater appeared to be clear (Photo M9). However, once a saturated part of the vineyard was reached (Photo M10), a slight turbidity was observed in the ditch water (Photo M11). The vine trellises cut across the slope, and are separated by wide grassed isles, so the slope is broken up slowing flow velocities, and there is relatively little exposed soil, significantly limiting erosion.

Wet-weather turbidity was also observed in a ditch, located to the east of the eastern fork of the river, at the edge of wetland, contiguous to the stream (Photo M18). The ditch is located along a narrow forested corridor. The area that drains to the ditch, and located to its east, consisted of old farm field, currently overgrown mainly with multifora rose (Photo M19). Despite this naturalized contributing area, which stretched several hundred feet upslope of the ditch, the water in the nearly stagnant ditch was noticeably turbid. This is evidence of the erosivity of the fine soil in the watershed, even in relatively undisturbed areas.

Figure 20. Maidford Subwatershed 3 (in part). (MDF-SW-2 to MDF-SW-3; Wyatt Road to Berkeley Avenue).



Dry-Weather Sources (MDF-SW-2 to MDF-SW-3; Wyatt Road to Berkeley Avenue)

This station, located on Berkeley Av., was not sampled during dry weather.

Wet-Weather Sources (MDF-SW-2 to MDF-SW-3; Wyatt Road to Berkeley Avenue)

This station was sampled only once, hours after the end of a wet-weather event. There was a six-fold increase in fecal coliform bacteria, and more modest increases in TKN, nitrate and ammonia. Animal and human waste are potential sources, common to all three pollutants. Potential sources include manure applied to the hayfields, crop fields, and vineyards, located between Wyatt Rd. and Berkeley Av., in addition to a crop field to the north of Wyatt. Rd. These agricultural areas will be discussed in greater detail in the section below. Wildlife waste from nearby agricultural, wetland, and forested areas are an additonal possible source. Finally, stormwater from Wyatt Rd. and contaminated by pet and wildlife waste and septic systems associated with a few houses on Berkeley Av., are also potential waste-related sources. Additional potential sources of ammonia, TKN, and nitrate include decaying plant material. Fertilizers are another potential source of ammonia and nitrate.

Figure 21. Maidford Subwatershed 3. (MDF-SW-2 to MDF-3A; Wyatt Road to Berkeley Avenue Spur).

Dry-Weather Sources (MDF-SW-2 to MDF-3A; Wyatt Road to Berkeley Avenue Spur)

The highest dry-weather TKN and nitrate values, documented in the Maidford River, were recorded at the Berkeley Av. spur (aka Whitehall Museum access). Potential sources of TKN include septic systems, pet and wildlife waste, decaying plant material and manure applied to fields. Elevated TKN values are indicative of waste sources, located in close proximity to the stream.

Dry-weather nitrate values decreased from the headwater station to Wyatt Rd., probably due to denitrification as previously discussed. Although there was an increase in nitrate levels at the Berkeley Av. spur., levels were in line with nitrate levels at the headwaters. The probable source is groundwater. As previously discussed, there is a strong linear relationship between dry-weather flow and contributing watershed area. It therefore appears that most of the groundwater, discharging to the stream between Wyatt Rd. and Berkeley Av., was contaminated by pollutants within this reach. However, at least some groundwater, affecting this reach, could be originating from areas upgradient of Wyatt Rd. and even the headwaters region of the stream. The probable source of nitrate-enriched groundwater is fertilizers (including manure) applied to agricultural fields and residential lawns. Other potential sources include pet and wildlife waste, leaky sanitary sewers, septic systems, and plant decay.

Wet-Weather Sources (MDF-SW-2 to MDF-3A; Wyatt Road to Berkeley Avenue Spur)

As previously discussed, an undersized culvert, at the Berkeley Av. spur, causes flooding of a hay field on the north side of the roadway. Floodwaters are culverted to a stormwater trench on the opposite (eastern) side of Berkeley Avenue, eventually rejoining the stream well south of the Berkeley Avenue spur. The undersized culvert at the spur can also slow flow velocities down enough to back up flow at the Berkeley Avenue culvert, causing that culvert to reach capacity and causing more flooding of Berkeley Avenue. Under these conditions, some of the flow upstream of Berkeley Avenue, enters the stormwater trench on the east side of Berkeley Avenue, re-entering the river well south of the Berkeley Avenue spur (Photo M32). Therefore a significant portion of the flow in the Berkeley Avenue area appears to bypass the spur, during high flow conditions.

The highest turbidity, TSS, and phosphorus levels, recorded on the Maidford River, were recorded at the Berkeley Av. spur (MDF-SW-3A). During the first two rain events, TSS levels increased by as much as 23-fold, and phosphorus levels increased as much as nine-fold, relative to the upstream station (MDF-SW-2).

Sediment-laden runoff, from the nursery on the west side of Berkeley Av., is a significant source of sediment and phosphorus. During the wet-weather sampling events and other storms, sediment-laden runoff, with the appearance of chocolate milk, was observed in four eroded channels on nursery property (Photos M33-M36 and M40). The channels discharge to the stormwater sytem or the roadway itself and ultimately enter the Maidford River, via a ditch (Photos M39 and M41), immediately downstream (west) of Berkeley Av. On several different occasions, during wet-weather conditions, turbid runoff from the ditch caused a very apparent visible change in color in the river, on the downstream side of Berkeley Av. (Photo M42).

The volume and turbidity of stormwater runoff, from the nursery property was striking. Berkeley Av., at the river crossing, is frequently flooded, even by 2-in. storms. Runoff from the nursery contributes to the flooding, and the roadside ditch frequently floods the entire roadway, with floodwaters entering the river on both sides of the street (Photos M39 and M40). Debris (e.g soil and rocks) from flooding was observed covering the roadway at the river crossing. On one occasion after a storm, a bulldozer, followed by a street sweeper, were clearing debris from the roadway.

The third wet-weather sampling event took place hours after the cessation of rain, and the increases in turbidity, TSS and phosphorus levels, recorded at the Berkeley Av. spur, were much more muted. However, turbidity, TSS and phosphorus levels, recorded in a ditch on nursery property, were signicantly higher than levels recorded both at Berkeley Av. and the spur (Whitehall Museum access). It is anticipated, with supporting observational wet-weather evidence, that the nursery runoff would have had a much greater impact on river water quality during a significant rain event, rather that hours after the end of the event. Three of the four erosional channels, flowing off the nursery property, were no longer flowing at the time of the final wet-weather event, with only slight flow in the southernmost ditch that was sampled.

Other potential sources of sediment and phosphorus, include agricultural areas, upstream of Berkeley Av., discussed briefly in the above section, and elaborated below. Another potential source of sediment and phosphorus is streambank erosion and the resuspension of streambed sediments. The reach upstream of Berkeley Av. is steep, resulting in higher flow velocities (Photo M23 and M24).

A crop field, located north of Wyatt Rd. (MDF-SW-2), is another potential source of sediment and phosphorus to this reach. The southern portion of the field drains to a culvert and ditch that discharges on the eastern bank of the river, on the north side of the roadway. Water was sampled upstream of the ditch discharge, so some of the wet-weather increase in TSS, recorded at Berkeley Av. (MDF-SW-3) may be caused by sediment eroded from this corn field. After a subsequent rain storm, minor flooding was observed in the southwest corner of the field, and the runoff discharged to the ditch was visibly turbid (Photo M20).

Also after a subsequent rain event, the flow in a ditch, discharging to the Maidford River, immediately south of its exit from farmland into a forested area, was visibly slightly turbid (Photo M30). The ditch is located on the east side of the river, originating at the upslope boundary of a vineyard, immediately downslope of a stone wall that separates the vineyard from croplands upslope (Photo M25). The ditch cuts across the slope, but at the southeast corner of the vineyard it turns ninety degrees, and heads downslope. Some eroded sediment from the crop fields was observed entering the ditch across gaps in the stone wall (Photos M26 and M27), and also at its sharp turn at the southeast corner of the vineyard (Photo M28). The vineyard itself, as well as a separate vineyard area on the west side of the river are also potential sources, although there is much less exposed sediment as compared to the bordering crop fields. Like the vineyard to the north of Wyatt Rd., trellises cut across the slope, with relatively little exposed soil, and are separated by wide grassed isles, limiting soil erosion.

Other potential sediment and phosphorus sources include hayfields located along the reach, downslope of the vineyard areas, near Wyatt Rd. The hayfields, located on either side of the stream, extend to the top of the streambank (less than 10 ft. from the edge of water). Minor signs of erosion were observed, during the field inspection (Photo M22).

The maximum wet-weather ammonia and TKN levels, documented in the Maidford River, were recorded at the Berkeley Av. spur (MDF-SW-3A). Ammonia and nitrate levels increased at this station, during the September and October storms, and TKN levels increased, during all three storms. There was a significant increase in bacteria levels, recorded during the December storm.

During the October storm, a nursery ditch (MDF-HN) was sampled, and the nursery was determined to be a documented source of elevated levels of ammonia, TKN, and both fecal coliform and enterocooci. The nitrate concentration in the ditch, was significantly greater than recorded at any river sampling station, in wet-weather. A potential source common to all the pollutants, recorded in the ditch, is manure applied to nursery fields, and perhaps wildlife waste. Fertilizers applied to the nursery fields, are a potential source of ammonia and nitrate. Decaying plant material may have also been a source of ammonia, nitrate and TKN. On 11/5/2015, after a wet-weather event, green pellets were observed on nursery property, along the ditch, and within the river at Berkeley Av. (Photo M37 and M38). The pellets appeared to be fertilizer, which may have been a source of ammonia, nitrate, as well as phosphorus.

In addition to the nursery, located on the west side of Berkeley Av., other pollutant source areas include the agricultural fields and to a lesser extent residential areas, discussed in the above section. Most of these areas are located between Wyatt Av. and Berkeley Av., with the exception of a portion of a crop field, located to the north of Wyatt Rd, as previously discussed.

Figure 22. Maidford Subwatershed 4. (MDF-SW-3A to MDF-SF-1; Berkeley Avenue Spur to Reservoir Avenue).

Dry-Weather Sources (MDF-SW-3A to MDF-SF-1; Berkeley Avenue Spur to Reservoir Avenue)

There were no significant increases in pollutant concentrations at this station, during dry weather.

Wet-Weather Sources (MDF-SW-3A to MDF-SF-1; Berkeley Avenue Spur to Reservoir Avenue)

Although there were significant reductions in sediment and phosphorus levels at the Reservoir Av. station (compared to levels at the Berkeley Av. spur), visual observations confirmed that there were sources of sediment in this reach. One potential source is is an orchard and crop farm, located to the east of the river, upstream of Berkeley Av., which is hydraulically connected to the river via a swale (Photo M44). The swale drains an agricultual BMP (Photo M45). The BMP consists of a series of three grassed swales which cut across the slope of an orchard area, and are connected by culverts perpendiclar to the slope, at one end of each swale. The ditches are sloped in such a way as to direct runoff in the opposite direction of the flow in the swale up and downsope (stormwater in the swales flows in a zig-zag pattern), slowing runoff velocities and decreasing erosion potential. This agricultural BMP appears to be effective in limiting the loss of soil from erosion, and no sediment was observed in the grassed swales . However, after a subsequent rain event, a slight turbidity was observed in a terminal swale (Photo M46), which connects the BMP to the Maidford River. The swale discharges to a wetland area on the east side of the Maidford River (Photo M47), located to the immediate south of the roadway culvert. Discharge from the swale enters a ditch on the east side of Berkeley Av., flowing south into a 1000-ft long linear stormwater BMP along the roadway (Photo M50 and M51), and then discharges to the Maidford, via a culvert at Tally Ho Ct.

During several different wet-weather events, significantly turbid water, flowing at a significant velocity, was observed in the roadside ditch/linear stormwater basin. The source of the sediment is not known, but may be from floodwaters from the river itself, or from the swale discussed above. The day after one rain event, a turbid puddle was observed at a 3-4 ft culvert opening, draining Wyndham Hill Rd. (Photo M49), and discharging near the northern end of the linear stormwater basin. Wyndham Hill Rd is an entirely residential street, with thick lawns, and no observed bare soil. Despite this fact, soil appears to be eroding from this area.

A culvert draining into the Maidford River just north of the intersection of Berkeley Av. and Green End Av., and draining a roadside ditch on the east side of Berkeley Av., appeared to be discharging clear stormwater, when observed during wet weather (Photo M52 and M53). Another culvert discharging into the river southwest of the intersection, discharged visibly turbid stormwater (Photo M54).

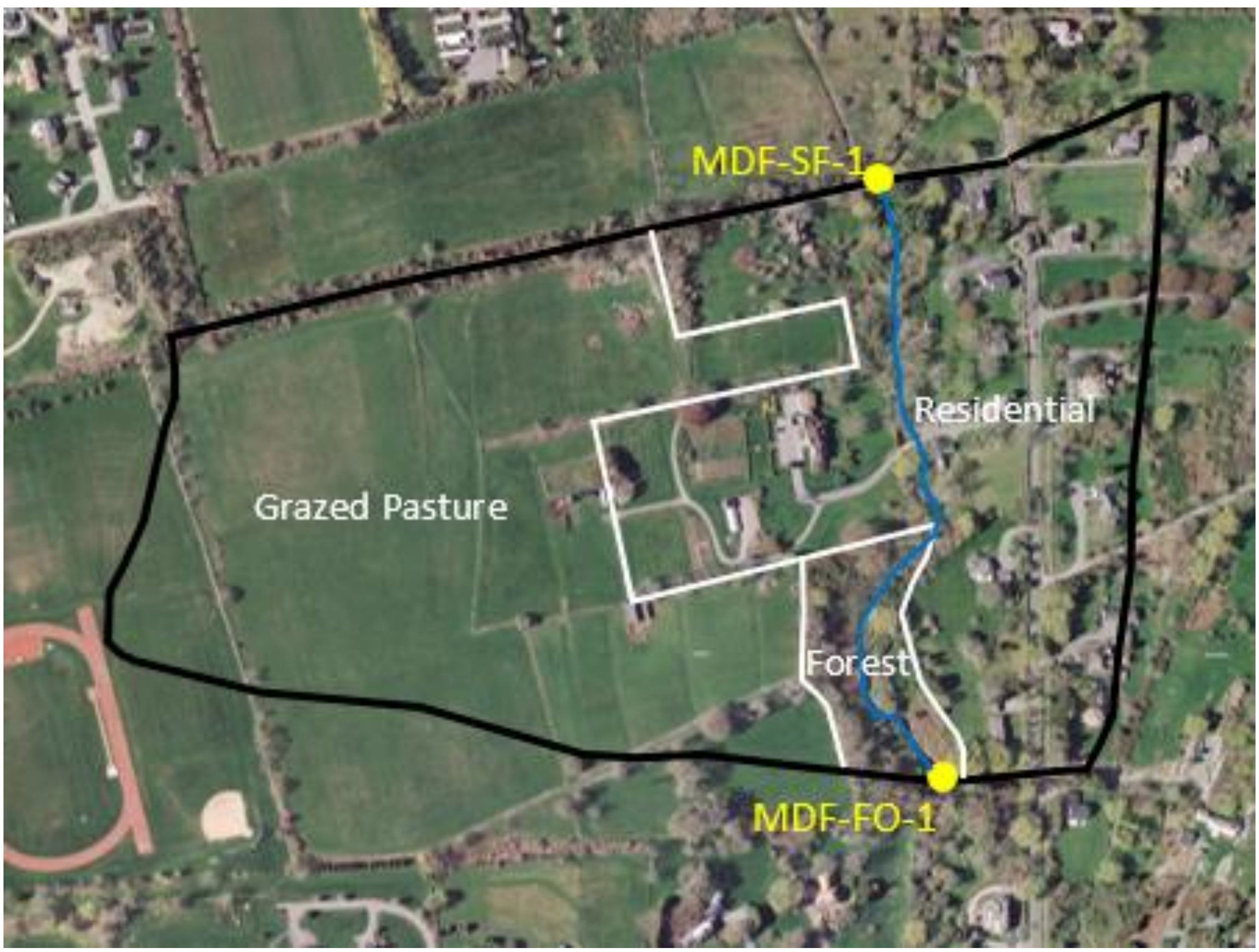
Sediment-laden stormwater from the roadway of Reservioir Av. (a dirt road), cascaded off the bridge, causing a clearly visible discoloration of the river (Photo M59). A tributary discharging to the west side of the river, and to the immediate north of reservoir Av. was generally clear, during most wet-weather events (Photo M58). Station MDF-SF-1 was located immediately downstream of the bridge.

An increase in TKN and fecal coliform bacteria, were documented only during the December storm. Nitrate and enterococci levels increased during the October wet-weather event only. The highest documented enterococci concentration was recorded at Reservoir Av. The area along this reach of the river is mostly residential, so the source of bacteria, and other pollutants, may have been pet waste or perhaps leaky sanitary sewers. Wildlife waste associated with residential areas, as well as forested and agricultural areas are other potential sources.

Potential agricultural sources of TKN and bacteria include the orchard and crop fields in the northeast portion of the watershed, as previously discussed above. There is also a cattle farm, located east of Paradise Av. and north of Cross Country Ln. The cattle farm is hydraulically connected to the river, via a channel that discharges to the Maidford River just downstream of Prospect Av. Inspection of aerial photographs revealed that there appears to be no fencing barring the cattle from the channel.

There are a few hay fields along this reach of the river, and several others scattered through the subwatershed, where manure may be applied. The decay of plant material and eroded sediment are additional sources of TKN (flows were highest during the December event possibly resulting in streambed and streambank erosion). Fertilizers are a potential source of nitrate.

Figure 23. Maidford Subwatershed 5. (MDF-SF-1 to MDF-FO-1; Reservoir Av. to Newport Water Intake).



Dry Weather (MDF-SF-1 to MDF-FO-1; Reservoir Av. to Newport Water Intake)

There were no significant increases in pollutant concentrations at this station, during dry weather.

***Wet Weather* (MDF-SF-1 to MDF-FO-1; Reservoir Av. to Newport Water Intake)**

There was a significant increase in turbidity, TSS, and phosphorus at the Newport Water Intake (MDF-FO-1) during the first wet-weather sampling event (12/9/2014). No erosional areas, outside of the river channel, were observed along this reach of the river, during a subsequent rain event. This station was sampled in the middle of the first wet-weather event, and flows were significantly higher than during the other two events, when there was a reduction of sediment and TSS (probably due to settling in the small impoundment upstream of the intake). The likely source of sediment and phosphorus, during the first wet-weather event, is resuspension of streambed sediments and streambank erosion. Eroded and undercut streambanks are evident along this reach (Photo M60). Much of this reach is characterized by armored streambanks, to help prevent further erosion (Photo M61). A large deposit of eroded sediment was observed along the river, upstream of the intake (M63).

TKN increased at the terminal station, at the Newport Water intake, only during the December storm. Nitrate levels increased significantly during the September wet-weather event. Ammonia levels were above the detection limit, only during the October wet-weather event. Potential sources of TKN include sediment, from streambed and streambank erosion, and the decay of plant material. In addition to the above sources, lawn fertilizers are a potential source of ammonia and nitrate. Despite the lack of a bacteria signal, additional potential sources of TKN, nitrate, and ammonia include manure associated with a sheep farm, located to the west of the river, leaky sanitary sewers along this reach, and pet and wildlife waste.

7. Paradise Brook Sampling Results

7.1. Turbidity

Dry Weather

The dry-weather turbidity values are very low, with a mean and maximum value of 1.7 and 4.5 ug/l, respectively (Figure P1). RIDEM water quality criteria for turbidity is based on exceedances above the background level. For Paradise Brook, background is interpreted as “naturally” occuring conditions, as found at the headwater station. Dry weather values at the headwater station were averaged together to determine the background level for dry weather of 1.4 NTU. Comparing average values against this background level, no downstream station exceeds by more than 5 NTU.

Wet Weather

Wet-weather turbidity values were much higher than dry-weather values (Figure P2). Sediment-laden stormwater is largely responsible for the increase in turbidity. The mean and maximum wet-weather turbidity values, for Paradise Brook, were 100 and 240 NTU, respectively (the mean and maximum wet-weather turbidity values for the Maidford River were 94 and 550 NTU). Wet weather values for the headwater station were averaged resulting in 9.4 NTU as the background for wet weather. Comparing average values against this wet weather background, all downstream stations exceed by more than 5 NTU.

Changes in turbidity were relatively consistent during the 12/9/2014 and 9/30/15 rain events. On 12/9/2014, Paradise Brook was sampled during a moderate rain, during the second half of the rain event. On 9/30/2015, the stream was sampled 1-2 hours after the event ended. The largest increase in turbidity, recorded during the first two wet-weather events, was recorded at Mitchells' Ln. Mean turbidity increased from 10 NTU at the headwaters to 200 NTU at Mitchell's Ln. (PDS-SW-1) (a twenty-fold increase).

For both the 12/9/14 and 9/30/15 storms, turbidity decreased significantly from Mitchell's Ln. to Green End Av. (PDS-SW-2). During the 9/30/2015 rain event, the turbidity value decreased at the next station (PDS-OCI-5). However, there was a slight increase in turbidity during the 12/9/2015 event. A decrease in turbidity at the terminal station (PDS-OCI-6A), was documented, during both the 12/9/14 and 9/30/15 storms. This lower reach was flooded during both these events, and as the flood waters spread out over the landscape, flow velocities were reduced, and a significant amount of sediment probably settled out.

On 10/29/2015, Paradise Brook was sampled several hours after the rain event ended. Turbidity values were therefore generally lower than recorded during the other two rain events. Like the first two rain events, the largest increase in turbidity was documented at Mitchell's Ln. (PDS-SW-1). Tubidity values remained relatively stable at the next two downstream stations. However, unlike the first two rain events, there was a significant increase in turbidity at the terminal station.

7.2. Total Suspended Solids (TSS)

Dry Weather

Like turbidity, the dry weather TSS values were very low, with a mean and maximum value of 3,000 and 6,000 ug/l, respectively (Figure P3). EPA guidance for turbidity is 25,000 ug/l for protection of juvenile fish, larvae, and eggs.

Wet Weather

As was the case with turbidity, wet-weather TSS values were much higher than dry-weather values (Figure P4). The mean and maximum wet-weather TSS values for Paradise Brook were 96,000 and 210,000 ug/l, respectively (the mean and maximum wet-weather TSS values for the Maidford River were 108,000 and 450,000 ug/l). The mean wet-weather TSS value was more than 30 times higher than the dry-weather mean and almost four times greater than EPA suggested guidance (25,000 ug/l).

Wet-weather changes in TSS river values largely mimick patterns for turbidity. Like turbidity, the greatest increase in TSS was recorded at Mitchell's Ln. (PDS-SW-2). However, the increase in TSS, on 12/9/14, at Third Beach Rd (PDS-OCI-5) was much more pronounced than the increase in turbidity at the same station. The maximum TSS value was recorded at Third Beach Rd and not at Mitchell's Ln., where the highest wet-weather turbidity value was recorded. Finally, there was a much more dramatic increase in TSS at the terminal station (PDS-OCI-6A) on 10/29/2015, than was recorded for turbidity. The source again was probably a small pond, that was slowly metering out suspended sediment-laden stormwater, from earlier during the storm. The pond appeared more turbid than the stream, downgradient.

7.3. Total Phosphorus

Dry Weather

As discussed previously, the RIDEM criteria for phosphorus (25 ug/l) is applicable to rivers only at the point where they enter lakes, ponds, and reservoirs. The Gold Book Standard guidance value (100 ug/l) is applicable to any reach of a river that discharges to a reservoir. Unlike the Maidford River, where there were no dry-weather exceedances of the EPA Gold Book Standard, almost half of the dry-weather phosphorus values, recorded in Paradise Brook, exceeded the standard (Figure P5).

The highest dry-weather total phosphorus values, recorded at either the Maidford River or Paradise Brook, were recorded at Mitchell's Ln. (PDS-SW-2). The mean dry-weather value at this station was 300 ug/l (almost 6 times greater than the highest dry-weather value recorded in the Maidford River). The dry-weather total phosphorus values, downstream of Mitchell's Ln., decrease steadily at each consecutive downstream station.

Wet Weather

As was the case with TSS, wet-weather phosphorus values were much higher than dry-weather values (Figure P6). This was to be expected since phosphorus is generally adsorded onto soil particles, and often enters streams with eroded soil. EPA suggested guidance and RIDEM criteria for phosphorus were exceeded at all applicable stations, during all three wet-weather events. The mean and maximum wet-weather total phosphorus values were 1,420 and 2,800 ug/l, vs. 120 and 320 ug/l during dry weather.

As recorded at the Maidford River, the phosphorus levels in Paradise Brook, recorded during the 12/9/14 wet-weather event, were significantly lower than those recorded during the wet-weather events in the fall of the following year, despite the fact that the stream was sampled in the middle of a moderate rain event and flows were the highest during the winter event. The probable reason for the lower phosphorus levels, recorded on 12/9/14, was that there was less fertilizer in the soil and less potential for plant decay at that time of the year.

Wet-weather phosphorus values were elevated at the headwater station at Fayall Ln. The highest wet-weather total phosphorus values, recorded during each of the three wet-weather events, were recorded at Mitchell's Ln. (PDS-SW-1). Phosphorus levels decrease at the next downstream station at Green End Av. (PDS-SW-2). During the 9/30/2015 and 10/29/2015 rain events, phosphorus levels remained relatively unchanged. However, during the 12/9/2014 event, there was a slight increase in total phosphorus recorded at Third Beach Rd. (PDS-OCI5). There was another slight increase in phosphorus at the terminal station.

7.4. Ammonia

Dry Weather

As recorded for the Maidford River, dry-weather ammonia levels in Paradise Brook were below the detection limit (100 ug/l) at all stations, during all three dry-weather sampling events (Figure P7).

Wet Weather

Although the majority of the wet-weather ammonia levels were below the detection limit (100 ug/l), levels were above the detection limit at a few stations (Figure P8). The ammonia level at the headwater station at Fayall Ln was 100 ug/l, during both the second and third wet-weather events.

The ammonia level at the next station at Mitchell's Ln. (PDS-SW-1) was 100 ug/l, during both the first and third wet-weather events. Since flow at Fayall's Ln. infiltrated into the bottom of a grassed swale, a short distance from the roadway, the ammonia level, recorded at Fayall, Ln., did not influence the level recorded at Mitchell's Ln. The ammonia level at the terminal station was 200 ug/l, during the third wet-weather event. This station was sampled hours after the rain event had ended.

7.5. Total Kjeldahl Nitrogen (TKN)

Dry Weather

All of the dry-weather TKN values, exceeded EPA's suggested guidance level (300 ug/l) (Figure P9). The mean dry-weather TKN value, recorded in Paradise Brook was 1,000 ug/l, which is significantly greater than the dry-weather mean recorded in the Maidford River (400 ug/l). The mean dry-weather TKN value, recorded in Paradise Brook, made up a much larger percentage of total nitrogen (26%), vs. 14% for the Maidford River. This is an indication that there are waste sources and decaying plant material closer to the stream in the Paradise Brook watershed vs. the Maidford River watershed. Since the dry-weather ammonia levels were all below the detection limit, the TKN values mostly reflect organic nitrogen, which generally does not move as readily in groundwater as nitrate.

The mean TKN concentration at the headwater station at Fayall Ln. was 1,000 ug/l. The highest TKN values were recorded at PDS-SW-1 (Mitchell's Ln.). The TKN value, during both the first and second dry-weather sampling events, was 2,200 ug/l at this location. During the April surveys, TKN values decrease at the downstream station (PDS-SW-2) at Green End Av. However, during the final dry-weather survey on 1/5/2016, the TKN value at PDS-SW-2 was elevated, despite the fact that there was no flow at the upstream station at Mitchell's Ln. TKN values remain fairly stable at the next station (PDS-OCI5A), located at Third Beach Rd. TKN levels decrease by more than half at the terminal station.

Wet Weather

The wet-weather TKN values exceed EPA's suggested guidance level (300 ug/l), at all stations during all three wet-weather surveys (Figure P10). The mean wet-weather TKN value was 1,390 ug/l, compared to the dry-weather mean of 1,000 ug/l. Higher TKN values are generally observed during wet weather, because organic nitrogen generally does not dissolve readily in groundwater, and is generally transported to rivers in surface runoff. Although the wet-weather mean was higher than the dry-weather mean TKN value, the difference between the two values were not as great as the difference recorded at the Maidford River, where the mean wet and dry-weather TKN values were 1070 ug/l and 400 ug/l.

TKN is elevated at the headwater station at Fayal Ln. The wet-weather TKN values were also elevated at Mitchell's Ln. (PDS-SW-1). The wet-weather TKN values decrease at the next downstream station, located at Green End Av. The TKN concentrations increase at Third Beach Rd. (PDS-OCI-5A), during all three wet-weather events. The TKN value decreased at the terminal station (PDS-OCI-6A) during the last two rain events, but it increased during the first rain event.

7.6. Nitrate

Dry Weather

Dry-weather nitrate levels were significantly higher than TKN values (Figure P11). The mean dry-weather nitrate concentration, for all river sampling stations, was 3,070 ug/l (slightly higher than the mean dry-weather value of 2,690 ug/l, recorded for the Maidford River). As previously discussed, nitrate readily dissolves and is easily transported in groundwater. The mean dry-weather nitrate concentration exceeds EPA's suggested guidance (310 ug/l) by almost a factor of ten. The suggested guidance was exceeded at all stations, during each of the three dry-weather surveys, indicating consistently high levels of nitrate in groundwater throughout the watershed.

Nitrate is elevated at the headwater station at Fayal Ln. The nitrate level at Mitchell's Ln. (PDS-SW-1) was well below all other dry-weather nitrate values recorded at either the Maidford River or Paradise Brook. The stream was not flowing at this location during the 1/5/2016 sampling event, and the 4/2/2015 duplicate sample at this location did not meet quality control specifications (although both the original sample and the duplicate were much lower than any the values recorded at other stations). The dry-weather nitrate levels increase with each consecutive downstream station. The biggest increase in nitrate was at Third Beach Rd., where the biggest increase in dry-weather flow was recorded.

Wet Weather

Wet-weather nitrate levels were generally much lower than wet-weather TKN values (Figure P12). The mean wet-weather nitrate level (720 ug/l) was also less than one fourth of the mean dry-weather nitrate level (3,070 ug/l). The lower wet-weather values resulted from the fact that surface stormwater flow has a significantly lower nitrate concentration than local groundwater. Higher wet-weather TKN values reflect the fact that its major component (organic nitrogen) does not dissolve as readily as nitrate, with TKN generally transported in surface stormwater flow, while nitrate is transported mainly in groundwater. Therefore during wet weather, TKN is the major component of the total nitrogen value, whereas nitrate is the major component of total nitrogen during dry weather. The mean wet-weather nitrate concentration exceeds EPA's suggested guidance (310 ug/l) by a factor of more than two. The nitrate suggested guidance was exceeded at all stations. Unlike the dry weather values, the wet-weather nitrate levels downstream of Mitchell's Ln remain relatively stable.

7.7. Total Nitrogen

Dry Weather

The mean dry-weather total nitrogen concentration for all river sampling stations was 4,010 ug/l, a value which exceeds EPA's suggested guidance (610 ug/l) by a factor of more than six-fold. The mean dry-weather total nitrogen value, recorded for Paradise Brook, was significantly higher than the mean value recorded at the Maidford River (3,120 ug/l). The suggested guidance was exceeded at all stations, during each of the three dry-weather surveys (Figure P13). Dry-weather total nitrogen levels largely reflect nitrate levels, which as previously discussed are many times greater than TKN level. Therefore patterns in dry-weather total nitrogen level fluctuations between stations mimick the changes in nitrate concentrations. The only exception was at Mitchell's Ln. (PDS-SW-1), where total nitrogen was dominated by the TKN component.

Wet Weather

The mean wet-weather total nitrogen concentration for all river sampling stations was 2,110 ug/l, compared to a mean of 1,760 ug/l, recorded at the Maidford River. Although only about half the dry-weather mean (4,010 ug/l), the wet-weather mean total nitrogen concentration exceeds EPA's suggested guidance (610 ug/l) by more than a factor of three. The suggested guidance was exceeded at all stations, during each of the three dry-weather surveys (Figure P14). During all three wet-weather events, total nitrogen values were highest at the headwaters at Fayal Ln.

7.8. Fecal Coliform Bacteria

Dry Weather

The dry-weather fecal coliform geomean, for all river sampling stations, was 17 CFU/100 ml. The maximum dry-weather fecal value was 1,700 CFU/100 ml (Figure P15). The two highest fecal coliform concentrations, were recorded at Fayal Ln. (PDS-SW-3A). This was the only station where the geomean criteria (200 CFU/100 ml) was exceeded.

Wet Weather

The wet-weather fecal coliform geomean, for all river sampling stations, was 16,600 CFU/100 ml, exceeding the criteria by a factor of 80. The fecal geomean criteria (200 MPN/100 ml) was exceeded at all stations, during all three wet-weather events (Figure P16). The wet-weather fecal coliform geomean for Paradise Brook was significantly higher than the wet-weather geomean of the Maidford River (5,120 CFU/100 ml).

The bacteria levels, recorded during the 12/9/2014 rain event, were lower than those recorded during the two subsequent wet-weather sampling events, probably because of cooler temperatures. The bacteria level at the headwaters station, already greatly exceeded the criteria value. Fecal coliform was elevated at Mitchell's Ln. (4,000 CFU/100 ml).. Fecal levels decrease at the next two downstream stations but increase significantly at the terminal station. On 9/30/2015, fecal values at all stations were greater than 16,000 CFU/100 ml.

The highest wet-weather fecal values were recorded during the 10/29/2015 rain event, a few hours after the rain ended. The fecal value at the headwaters (28,000 CFU/100 ml) again greatly exceeded the criteria value. The fecal concentration increased to 190,000 CFU/100 ml at Mitchell's Ln. (PDS-SW-1), which was the highest level recorded for either Paradise Brook or the Maidford River (the highest value recorded at the Maidford River on this date was 20,000 CFU/100 ml).

7.9. Enterococci

Dry Weather

The dry-weather enterococci geomean, for all Paradise Brook sampling stations, was 21 MPN/100 ml, which is below the geomean criteria, but significantly higher than the Maidford River geomean (8 MPN/100 ml). The maximum dry-weather enterococci value was 33 MPN/100 ml, which is still well below the RIDEM geomean criteria of 54 colonies/100 ml (Figure P17).
The maximum dry-weather enterococci value (76 MPN/100 ml) was recorded on 4/2/2015, at PDS-SW-1 (Mitchell's Ln.). The only other location where the dry-weather enterocci value exceeded the criteria (54 colonies/100 ml), was at Green End Av. (PDS-SW-2).

Wet Weather

The wet-weather enterococci concentrations, during the first sampling event (12/9/2014), were all greater than 2,420 MPN/100 ml (Figure P18). For the next wet-weather sampling event (9/30/2015), the lab diluted out the samples an another order of magnitude, but the concentrations were still too high to quantify, at that dilution. All enterococci values, recorded during the second sampling event, were greater than 24,200 MPN/100 ml.

During the 10/29/2015 rain event, the enterococci value at the headwater station (PDS-SW-3A) was 43,500 MPN. Like wet-weather fecal coliform, the highest wet-weather enterococci value (51,700 MPN/100 ml), recorded at either the Maidford River or Paradise Brook, was recorded at Mitchell's Ln. (PDS-SW-1). The enterococci concentrations remained relatively stable, at each consecutive station downstream, albeit slightly reduced from Mitchell's Ln..

8. Paradise Brook Polutant Sources

Figure 24. Paradise Subwatershed 1. (Up-Gradient of PDS-SW-3A; Fayal Lane).

Dry-Weather Sources (Up-Gradient of PDS-SW-3A; Fayal Lane)

EPA suggested guidelines for total phosphorus, TKN, and nitrate were exceeded at the headwater station, during dry weather. This was also the only station where the geomean criteria for fecal coliform (200 CFU/100 ml) was exceeded, during dry weather. The sampling station (PDS-SW-3A) was located close to the head of the watershed boundary, so the contributing source area is very limited. Potential sources, common to all pollutant exceedances, include septic systems and pet and wildlife waste. Additional potential sources of phosphorus and nitrate include lawn fertilizers.

At least two small-diameter pipes drain to the roadside ditch on the north side of Fayal Ln., which forms the headwaters of Paradise Brook. One pipe appears to be a French drain, at the rear of a lawn. The other pipe appears to be associated with a single family residence.

Wet-Weather Sources (Up-Gradient of PDS-SW-3A; Fayal Lane)

Turbidity, phosphorus, TKN, nitrate, fecal coliform, and enterococci values were elevated at the headwater station (PDS-SW-3A), during all three wet-weather sampling events. Ammonia levels were above the detection limit, during two of the three wet-weather events. Although ammonia levels were very low, even small concentrations may be indicative of a nearby source of human or animal waste.

As was the case in dry weather, potential sources, common to all pollutants, include septic systems and pet and wildlife waste. Additional potential sources of turbidity and elevated phosphorus are stormwater runoff from Fayall Ln., transporting road sands and eroded soil from adjacent grassed areas, and the resuspension of stream sediments, from past storms. Additonal potential sources of phosphorus, ammonia, and nitrate include lawn fertilizers.

Since flow at Fayal Ln. infiltrated into the bottom of a grassed swale a short distance downstream of the roadway, even during wet-weather events, pollutant levels recorded at the next station at Mitchell's Ln. were not influenced by the flow at Fayal Ln. (Photo P1).

Figure 25. Paradise Subwatershed 2. (PDS-SW-3A to PDS-SW-1; Fayal Lane to Mitchell's Lane).

Dry-Weather Sources (PDS-SW-3A to PDS-SW-1; Fayal Lane to Mitchell's Lane)

The highest dry-weather total phosphorus, TKN values, and enterococci concentrations, recorded at either the Maidford River or Paradise Brook, were recorded at Mitchell's Ln. (PDS-SW-1). Nitrogen from animal feces and urine is initially in the organic form (TKN). In time, the organic nitrogen is transformed to ammonia and nitrate. The presence of TKN may indicate that a waste source is close to the stream, and there has not been sufficient time for the breakdown of organic nitrogen to other forms of nitrogen. A common source of all three pollutants is animal waste associated with a mixed-livestock operation and a cattle farm.

The mixed-livestock operation (horses, llamas, donkeys) is located mostly west of the stream, in the south-central portion of the reach. Although there was a fence on the west side of the river, approximately 15 ft. from the stream, an ungated cartpath provided access to the opposite side of the stream, which was not fenced (Photo P6 and P7). Manure was observed on this farm in close proximity to the stream (Photo 18). Much of the area, adjacent to the stream and beyond the fencing, is saturated, when there is flow in the channel, and groundwater seepage may help transport pollutants to the stream, even during dry weather (Photos P17 and P19). A small farm pond, located beyond the fencing on the western side of the river, also connects the farm hydrologically to the river, via a ditch, providing another pathway for pollutants (Photo P5).

Another potential source of phosphorus is a cattle farm, which straddles the stream, in the north-central portion of the reach (Photo P4). Although the cattle were fenced approximately 100 ft. from the stream, the soil was saturated well west of the fencing. Old shallow swales or furrows convey groundwater seepage, in this saturated area to the stream. The seepage may be contaminated by manure.

What was previously a fallow field , located to the north of the cattle farm, has been recently cleared (Photo P11). Currently there is 0-5 feet of vegetated buffer in this area (Photo P3). A small area was also excavated, within the stream channel, at the up-gradient end of the recently cleared field, apparently as a water source for cattle (Photo P2). In the event that cattle are introduced within this area, without fencing to exclude them from the stream, the area may become a future source of bacteria and nutrients.

Although the nitrate level at Mitchell's Ln. (PDS-SW-1) was well below all other dry-weather nitrate values recorded at either the Maidford River or Paradise Brook, much of the groundwater from this reach probably discharges into Paradise Brook well south (downstream) of Mitchell's Ln. As previously discussed, there is no flow from the headwaters to Green End Av., from late spring to early winter (Photo P10). During this dry-season period, the flow at the two downstream stations, is likely being sustained, at least in part, by groundwater recharge from the headwaters and middle reaches of the river. Even during the wet season, when there is dry-weather flow along the headwater reach, much of the groundwater from the headwater reach probably discharges to the river well downstream of Mitchell's Ln.

A nursery is located at the top of a broad hill. Roughly one third of the nursery is within the watershed of Paradise Brook, with the remaining portion of the nursery in the watershed to the east. The nursery is a potential source of nitrate in groundwater in this area, and may be contributing to elevated nitrate levels observed in downstream stations during dry weather.

Wet-Weather Sources (PDS-SW-3A to PDS-SW-1; Fayal Lane to Mitchell's Lane)

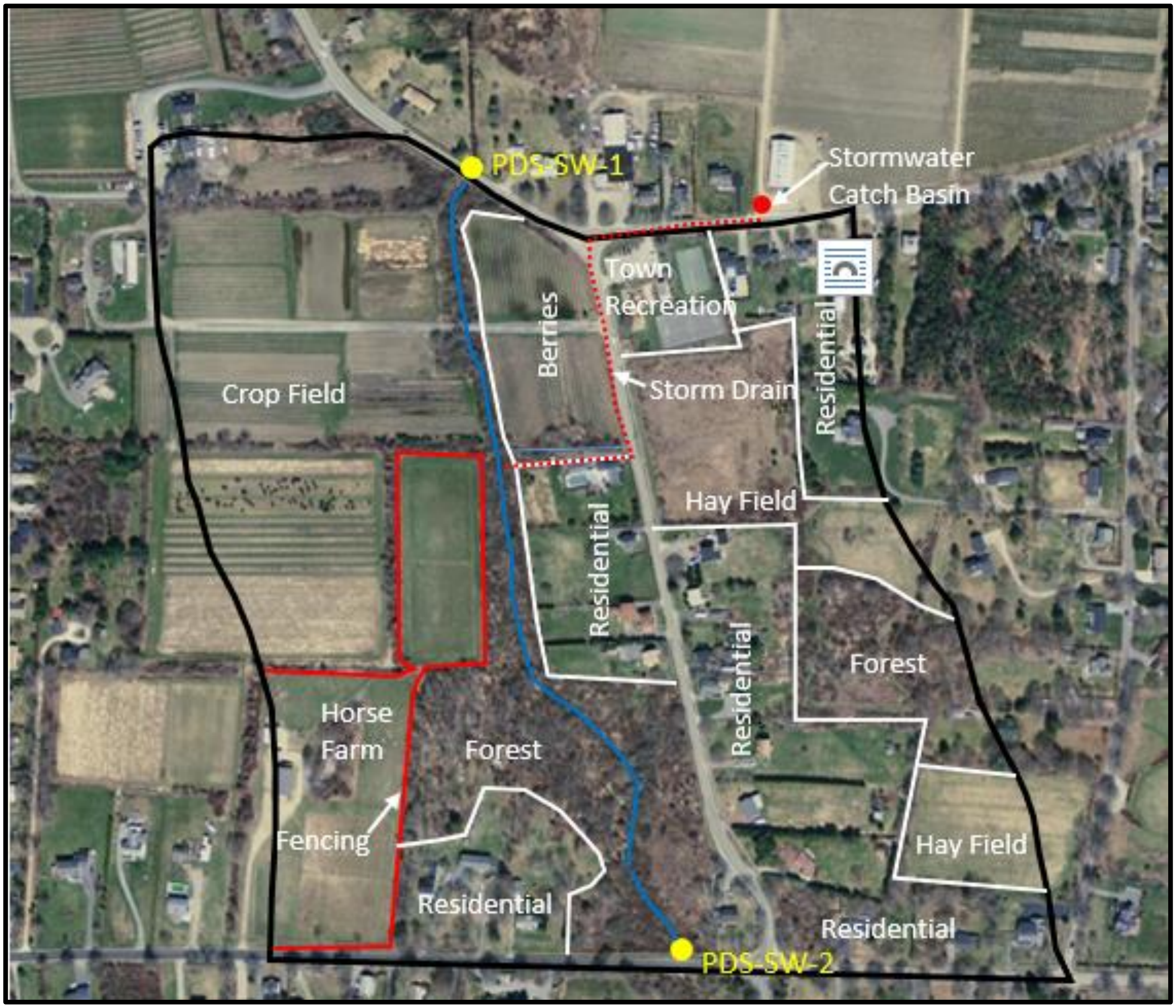
Turbidity, TSS, total phosphorus, TKN, nitrate, fecal coliform, and enterococci values were elevated at Mitchell's Ln (PDS-SW-1) during all three wet-weather events. The highest mean wet-weather turbidity, TSS, total phosphorus, and TKN concentrations in Paradise Brook, were recorded at Mitchell's Ln. The highest wet-weather fecal coliform and enterococci concentrations, documented in either Paradise Brook or the Maidford River, were also recorded at this station. Ammonia was above the detection limit, during two of the three storms. A common potential source of all the above pollutants are the previously discussed mixed-livestock operation, cattle farm, and nursery.

In addition to manure-derived nutrients and bacteria, both the mixed-livestock and cattle farms are potential sources of turbidity and TSS, as well as high levels of phosphorus, adsorbed onto eroded soil particles. Much of the lower portion of the mixed-livestock operation, upslope of the fencing, is characterized by unvegetated, saturated, mucky soils, that are easily erodible (Photo P19). The cattle farm also has saturated mucky soils upslope of the fencing. Animal traffic in these wet areas could further muck up the soils and cause more erosion, during periods of wet weather. During the December, 2014 rain event, much of the mixed-livestock and cattle farms were flooded. Any pollutants within the flooded area, would likely be transported by floodwaters directly to the river.

The nursery, located on the north side of Wapping Rd, to the east of the stream, is another potential source of all the pollutants discussed above. Although approximately 300 ft from the stream, a 400 ft. long pile of nursery compost, located at the western edge of the nursery contains at least some manure (Photo P14). Manure is likely applied to the nursery fields (Photo P16). TKN, ammonia, and phosphorus from decaying composted plant material, would likely be a more significant source during wet weather, since these pollutants are not readily transported in groundwater (Photo P15). Stormwater could also be contaminated with nitrate, from the compost pile and also from fertilizers.

The nursery operation is an additional potential source of eroded sediment, with associated higher levels of phosphorus and TKN . Although the nursery is located approximately 300 ft. east of the stream, and runoff from the northern portion is somewhat contained on the property by a stone wall, some evidence of erosion was observed in this area (Photos P12 and P13). A portion of the southwestern area of the nursery, drains to a detention basin, to the immediate west of the nursery property. The basin drains to Paradise Brook near the southern boundary of the mixed livestock operation. An inspection of Paradise Brook was conducted after a subsequent rain event, and the water in the ditch draining the basin, and within the basin itself, was noticeably more turbid than the flow in the river, immediately upstream (Photo P9).

Figure 26. Paradise Subwatershed 3: (PDS-SW-1 to PDS-SW-2; Mitchell's Lane to Green End Avenue).



Dry-Weather Sources (PDS-SW-1 to PDS-SW-2; Mitchell's Lane to Green End Avenue)

Dry-weather total phosphorus, TKN, nitrate, and enteroccoci bacteria levels at Green End Av. (PDS-SW-2) were elevated on 1/5/2016, despite the fact that there was no flow at the upstream station at Mitchell's Ln. An increase in nitrate was also recorded at this station, during the previous two dry-weather events. A common potential source of all the above pollutants, could be manure applied to a mixed orchard/crop operation, located to the west of the intersection of Third Beach Rd. and Mitchell's Ln. Other potential sources, common to all pollutants include septic systems and pet waste from the few houses on Third Beach Rd that border the stream in this reach, or wildlife waste along the forested riparian corridor. Decaying plant material, within the cropfields at the northern end of the reach or the forested riparian corridor, are potential additional sources of TKN and phosphorus. An additonal potential source of phosphorus is fertilizers applied to farm fields and residential lawns. Additional potential nitrate sources, located within this reach include manure and fertilizers applied to the mixed fruit/cropland operation, and decaying plant material.

Wet-Weather Sources (PDS-SW-1 to PDS-SW-2; Mitchell's Lane to Green End Avenue)

There were no significant wet-weather increases, in any pollutants, in this reach of the river. However, during a subsequent rainstorm, some minor erosion from the crop fields, on the west side of the river, was observed, resulting in

some sediment being transported to the stream (Photos P20 and P23). Runoff was generated from the surface of a dirt road, accessing the farm, and some channelized stormwater was observed on the lower portion of the field. There is an approximately 20-foot wide vegetated buffer along the stream in this area (Photo P22).

Although located upstream of this reach, the nursery located north of Wapping Rd is still a potential source of sediment along this reach. There is a catchbasin at the end of a dirt drive, near the nursery maintenance building, that apparently drains into the roadway drainage system, discharging to the river south of Wyatt Rd. (PDS-SW-1). After a subsequent rain event, turbid stormwater runoff, from the nursery, was observed discharging to the catchbasin.

Figure 27. Paradise Subwatershed 4. (PDS-SW-2 to PDS-OCI-5; Green End Avenue to Third Beach Road).

Dry-Weather Sources (PDS-SW-2 to PDS-OCI-5; Green End Avenue to Third Beach Road)

The mean dry-weather nitrate concentration more than doubles at Third Beach Rd, relative to the upstream station at Green End Av. The subwatershed, associated with this reach, is characterized mostly by low-density residential development. Two hay fields and a portion of a crop field are also located within the subwatershed. Potential dry-weather nitrate sources, exclusive to this reach, include septic systems, pet and wildlife waste, lawn fertilizers, and manure and fertilizer applied to farm fields. However, at least some of the increase in nitrate levels recorded in this reach, probably resulted from sources areas upstream of this reach, including sources in the headwaters region.

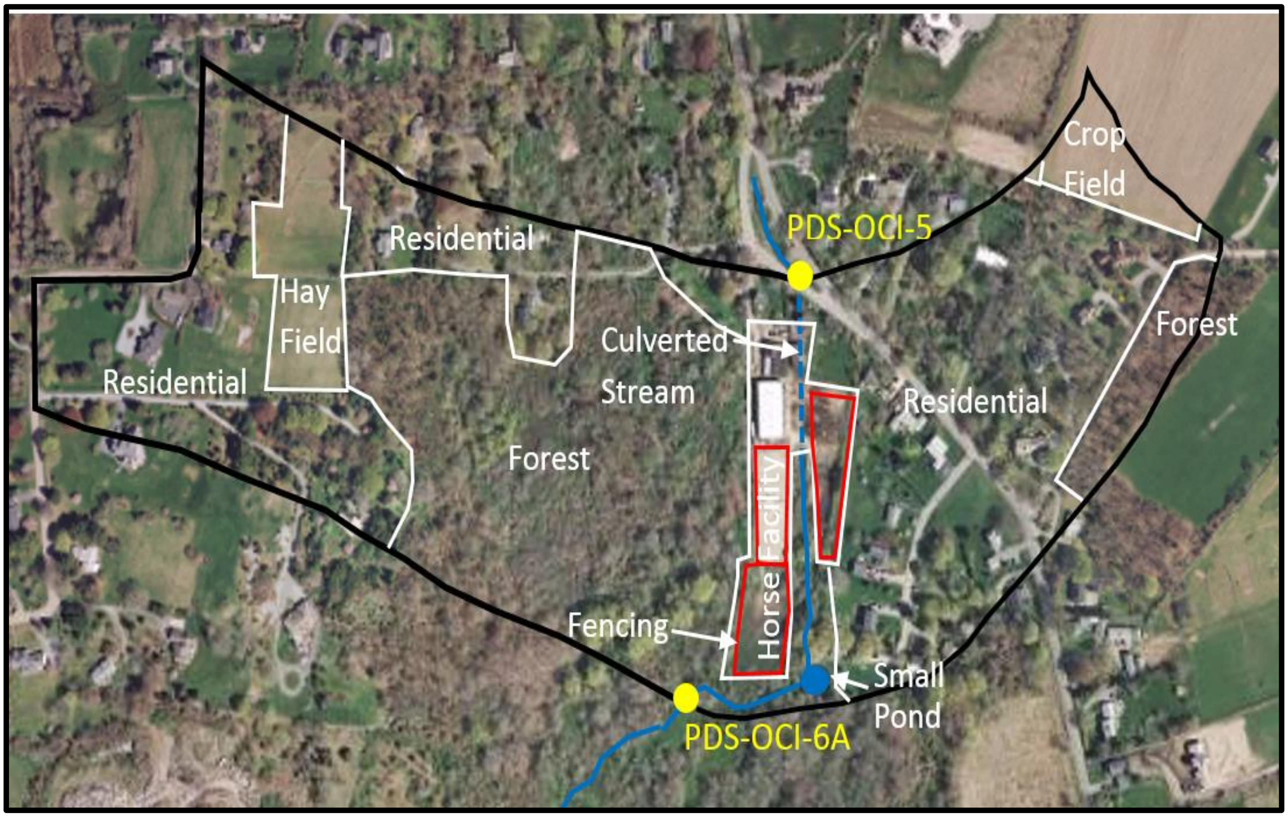
There was a 6-fold increase in dry-weather flow from Green End Av. to Third Beach Rd. The stream gradient drops 60 ft. the short distance between the two streets. The till layer in this area is relatively thin, and it appears the the stream bed along this reach has encised into the fractured bedrock aquifer, accounting for the increase in flow. Most of the groundwater flow from the headwaters area, is transported in the fractured bedrock aquifer, and not the relatively impermeable till layer above. Most of the groundwater flow and dissolved pollutants within the aquifer, do not discharge into the stream, in areas where the streambed is separated from the aquifer by the till layer. In areas where the streambed has incised through the till into the bedrock aquifer, such as appears to be the case south of Green End Av. , it creates a condition where there is a preferential flowpath transporting dissolved nitrate, potentially from upstream of the subject reach.

Wet-Weather Sources (PDS-SW-2 to PDS-OCI-5; Green End Avenue to Third Beach Road)

Wet-weather turbidity, TSS and phosphorus increased at Third Beach Rd. (PDS-OCI-5) during the December, 2014 wet-weather event. Flows were significantly higher during the December event, and increased flows coupled with the very steep stream gradient along this reach, probably resulted in the resuspension of bedload sediments and streambank erosion. The stream, along this reach, is bordered by residential lawns and much of the streambank in this area is armored to prevent streambank erosion. There is also the potential for the transport of eroded sediment from lawns. Other potential sources of elevated phosphorus include lawn fertilizers and pet and wildlife waste and septic systems.

An increase in TKN was recorded during all three wet-weather events. Potential sources include pet and wildlife waste, septic systems, decaying plant material, and eroded sediment.

Figure 28. Paradise Subwatershed 5. (PDS-OCI-5 to PDS-OCI-6A; Third Beach Road Reach to Cordeiro Terrace).



Dry-Weather Sources (PDS-OCI-5 to PDS-OCI-6A; Third Beach Road Reach to Cordeiro Terrace)

Dry-weather nitrate levels increased slightly at the terminal station (PDS-OCI-6A). As previously discussed, the source areas of the nitrate may be located upgradient of the subject reach. Local sources may include manure from an equestrian facility, septic systems, lawn fertilizers, and pet and wildlife waste.

Wet-Weather Sources (PDS-OCI-5 to PDS-OCI-6A; Third Beach Road Reach to Cordeiro Terrace)

There was an increase in phosphorus, TKN, and fecal coliform bacteria at the terminal station, during the December, 2014 wet-weather event only. Manure, associated with a horse facility, is a potential source, common to all three polutants. The lower paddock, at the rear of the facility, was almost completely flooded during this rain event. Of course, any pollutants within this flooded area would be readily transported to the stream, only a short distance away. Even during dry weather, from winter to early spring, much of the lower part of the lower paddock is saturated to the surface, supporting the growth of skunk cabbage, an obligate wetland plant (Photo P27). Additional potential sources of phosphorus include, eroded sediment and lawn fertilizers.

Ammonia levels were also above the detection limit, during the October, 2105 wet-weather event. Manure, septic systems, pet and wildlife waste, and decaying plant material are potential sources.

Modest increases in nitrate were recorded, during all three wet-weather events. Potential sources include manure, septic systems, pet and wildlife waste, fertilizers, and decaying plant material.

Appendix. Water Quality Results.

Figure M1. Maidford River Dry –Weather Turbidity (ug/l).

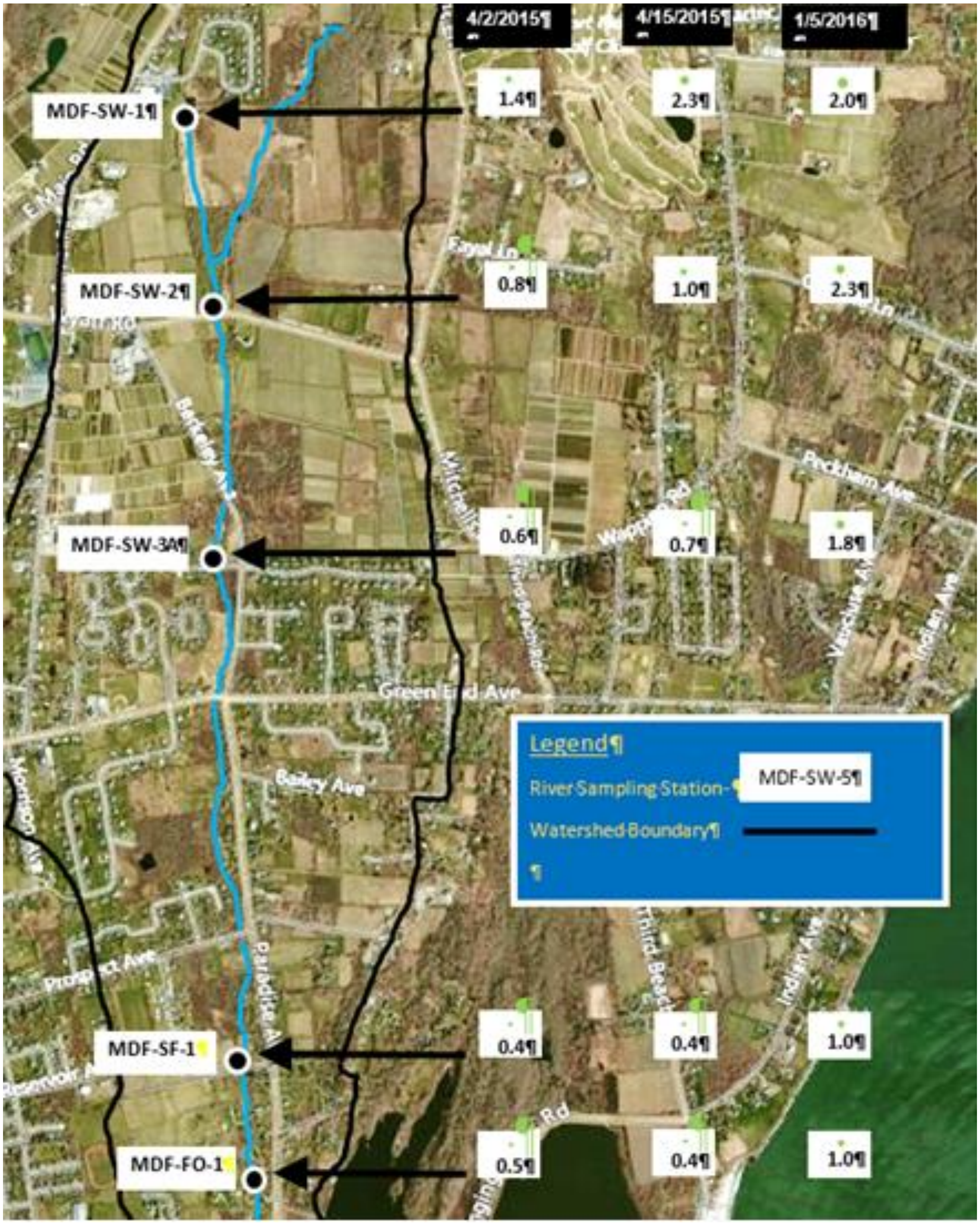


Figure M2. Maidford River Wet-Weather Turbidity (ug/l).

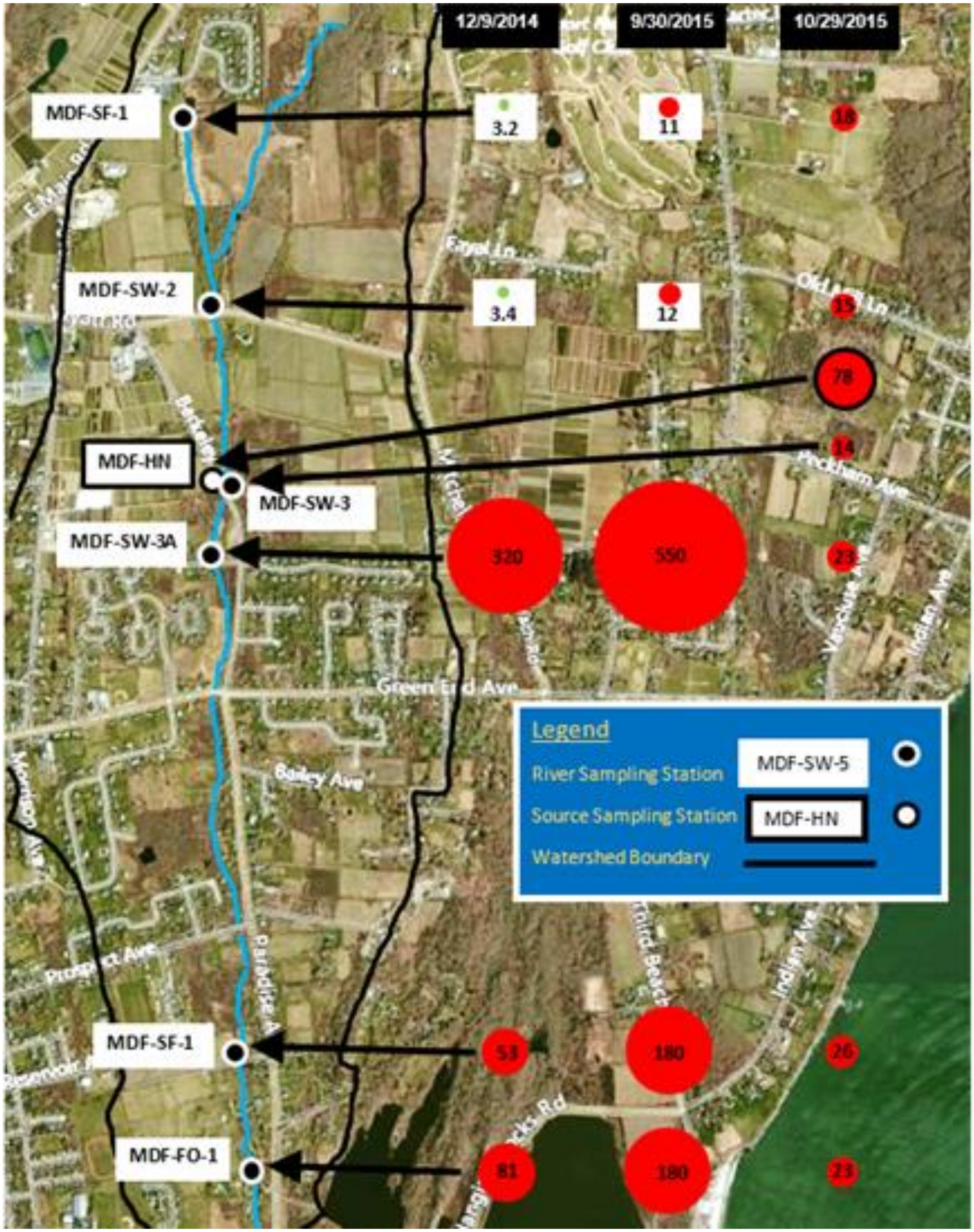


Figure M3. Maidford River Dry-Weather Total Suspended Solids (ug/l).

Figure M4. Maidford River Wet-Weather Total Suspended Solids (ug/l).

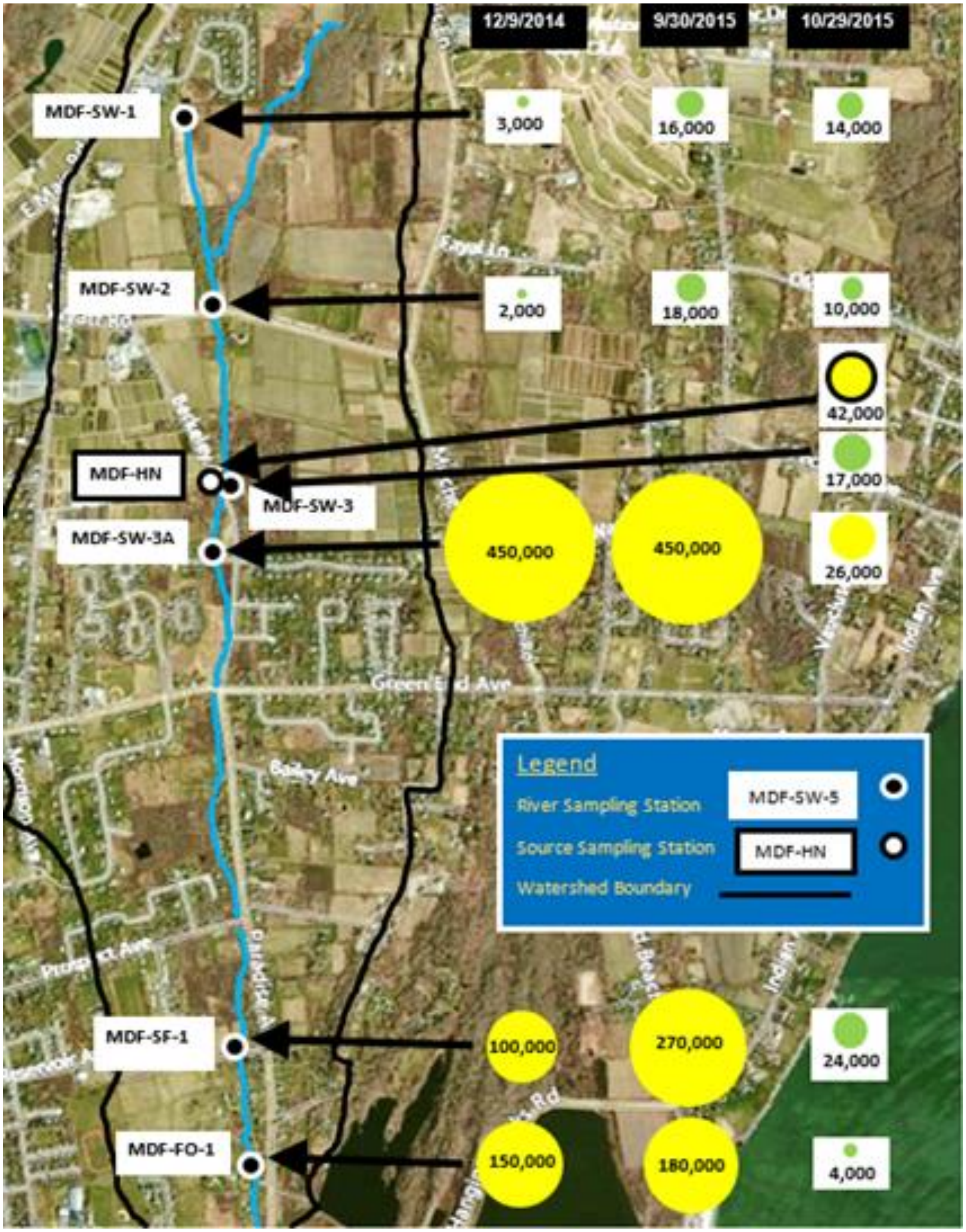


Figure M5. Maidford River Dry-Weather Total Phosphorus (ug/l).

Figure M6. Maidford River Wet-Weather Total Phosphorus (ug/l).

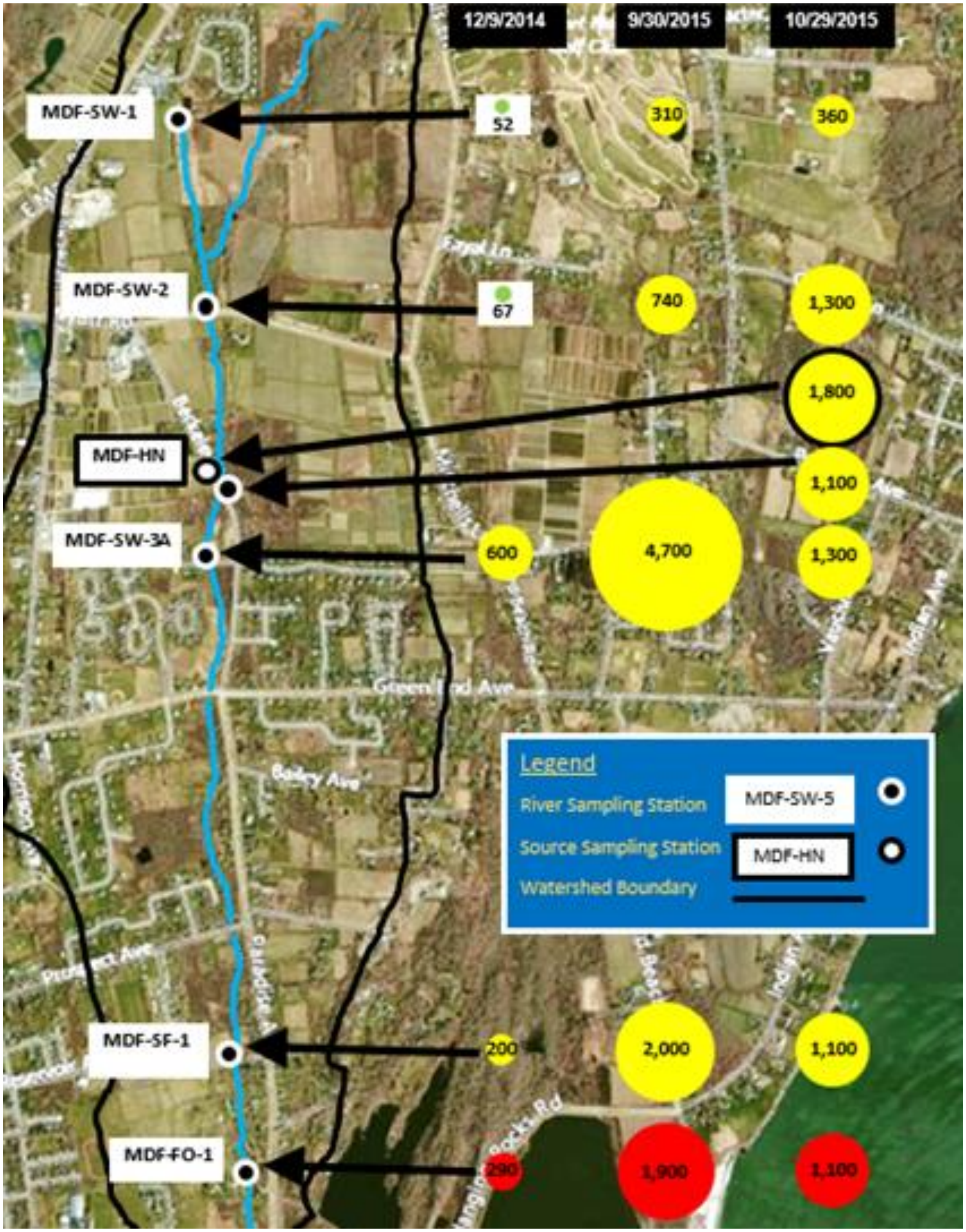


Figure M7. Maidford Rivert Dry-Weather Ammonia (ug/).

Figure M8. Maidford River Wet-Weather Ammonia (ug/l).

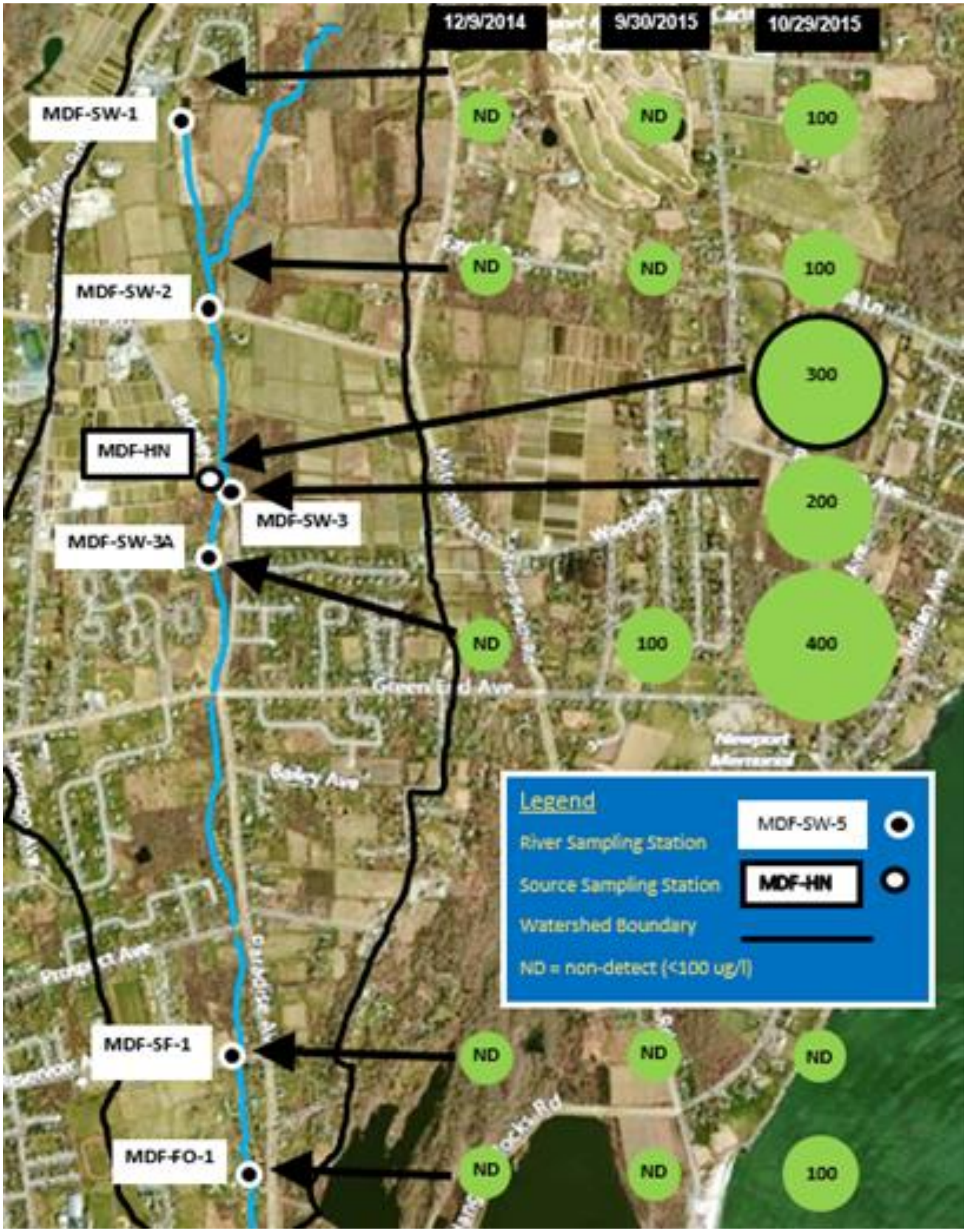


Figure M9. Maidford River Dry-Weather Total Kjeldahl Nitrogen (ug/l).

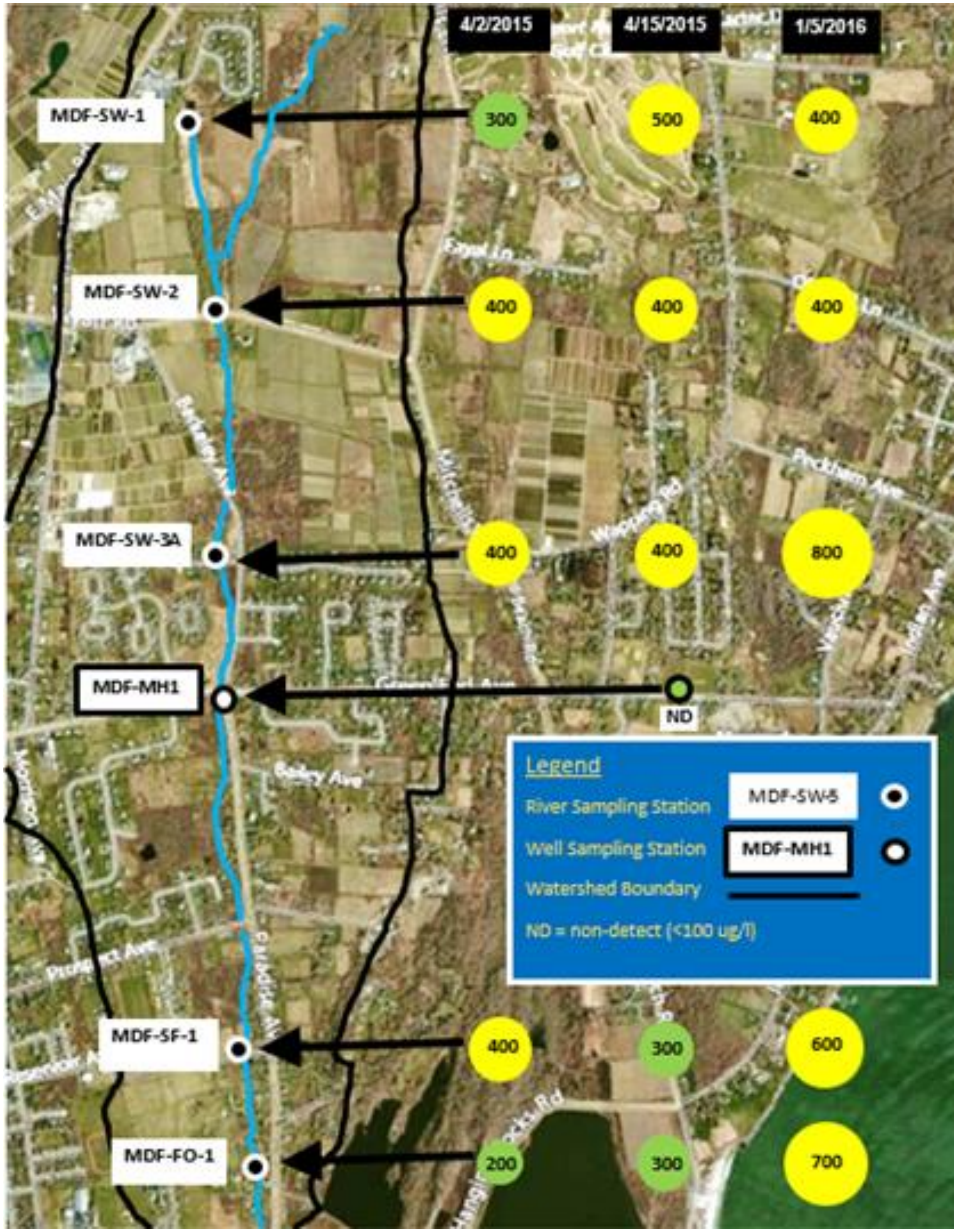


Figure M10. Maidford River Wet-Weather Total Kjeldahl Nitrogen (ug/l).

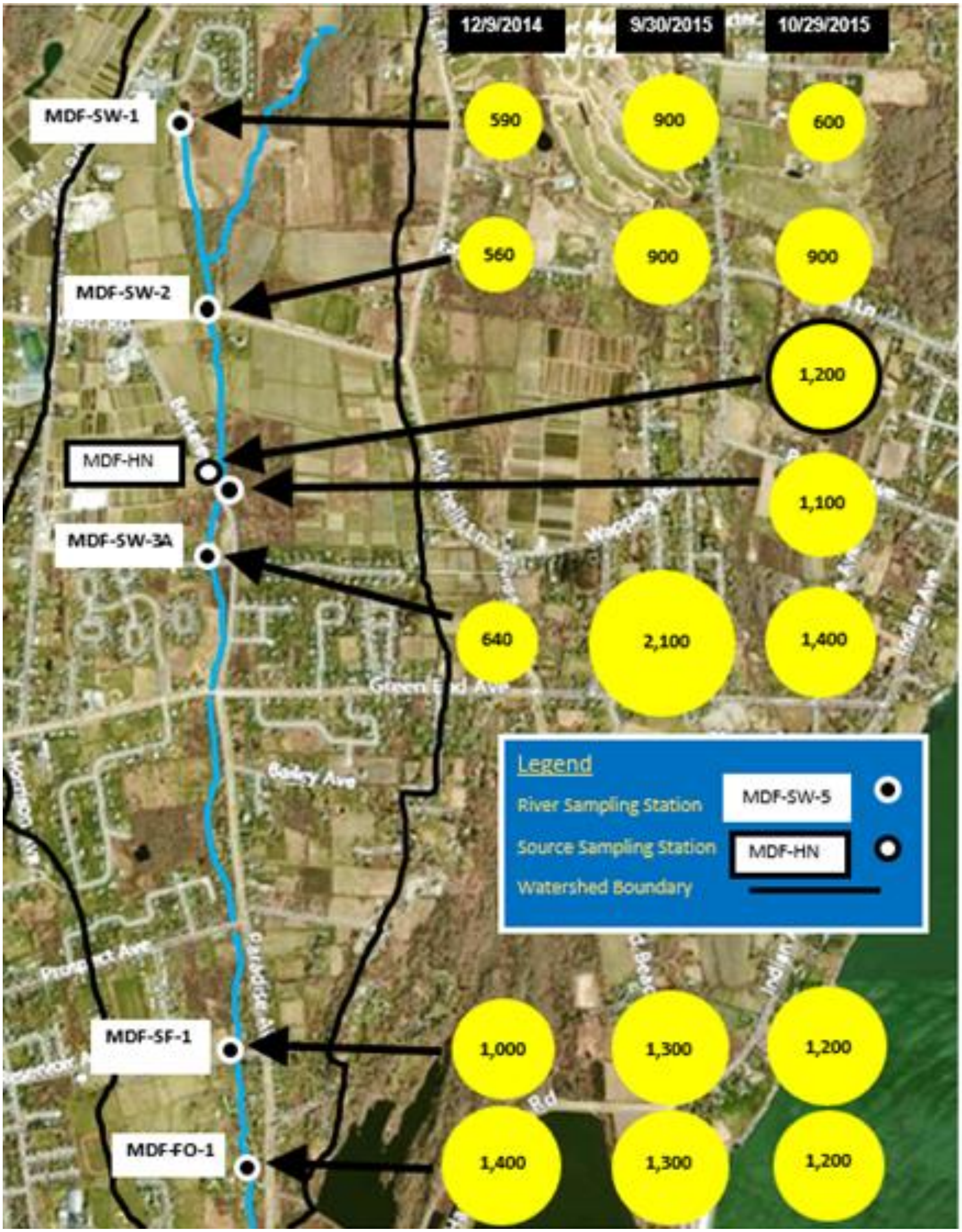


Figure M11. Maidford River Dry-Weather Nitrate (ug/l).

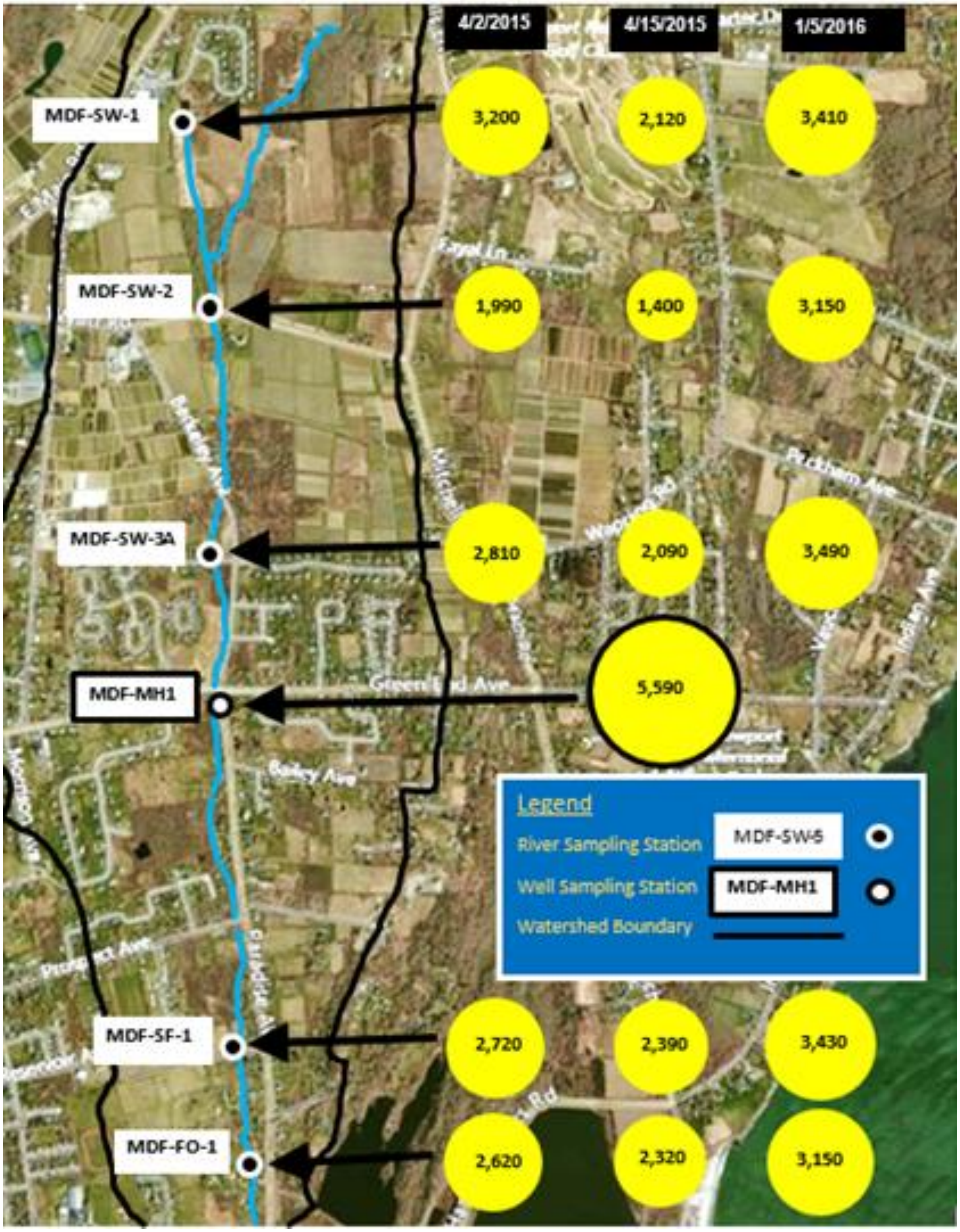


Figure M12. Maiford River Wet-Weather Nitrate (ug/l).

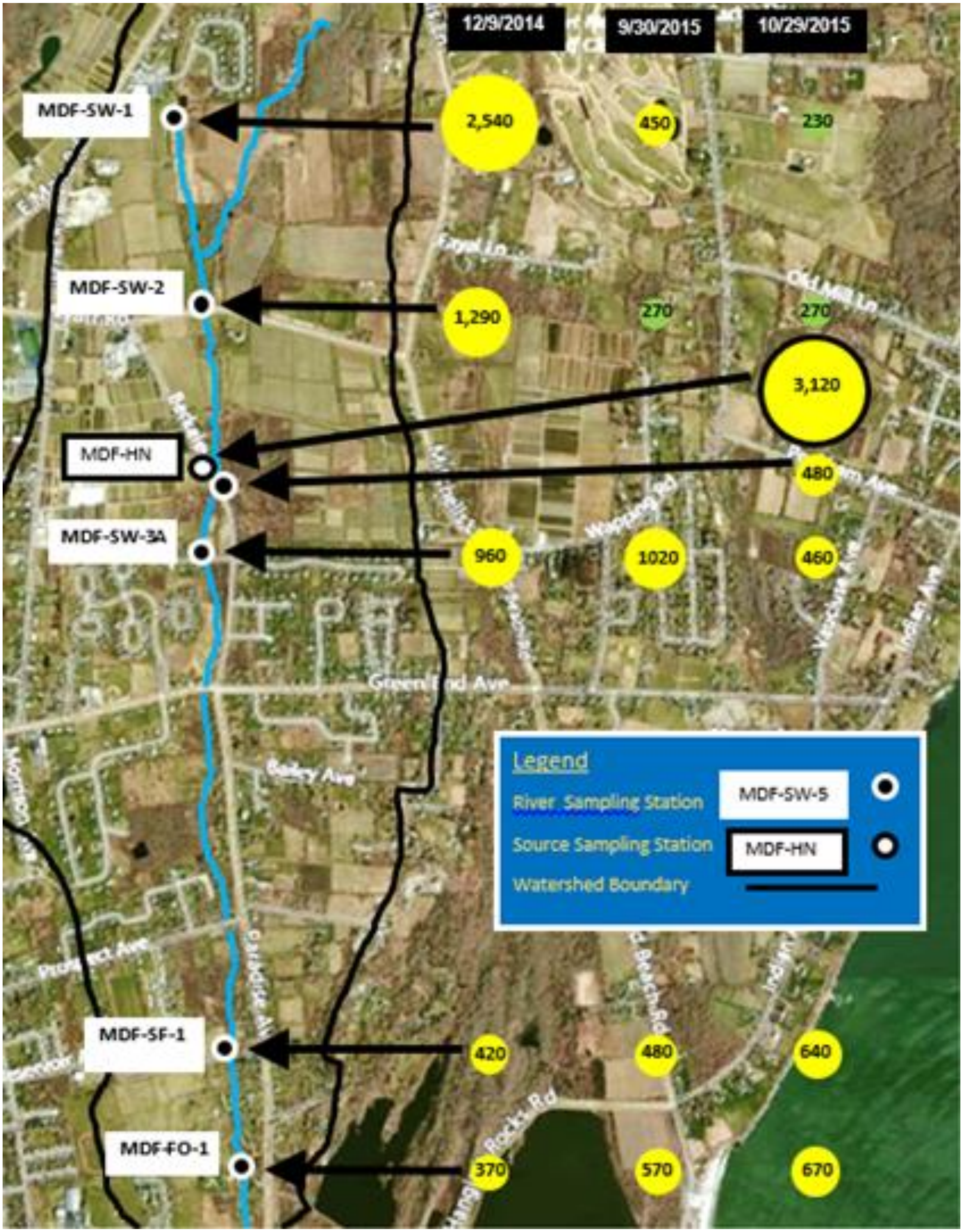


Figure M13. Maidford River Dry-Weather Total Nitrogen (ug/l).

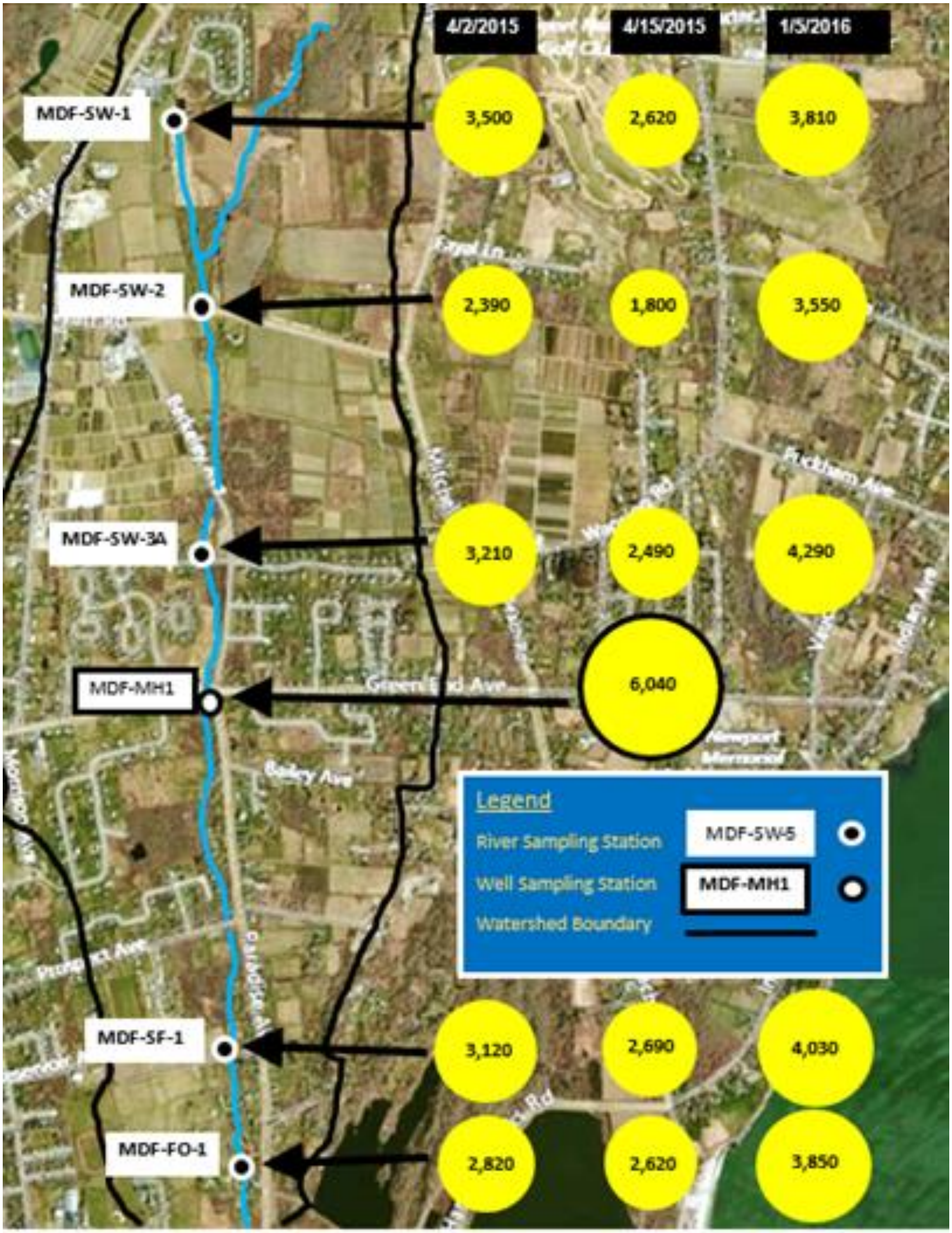


Figure M14. Maidford River Wet-Weather Total Nitrogen Results (ug/l).

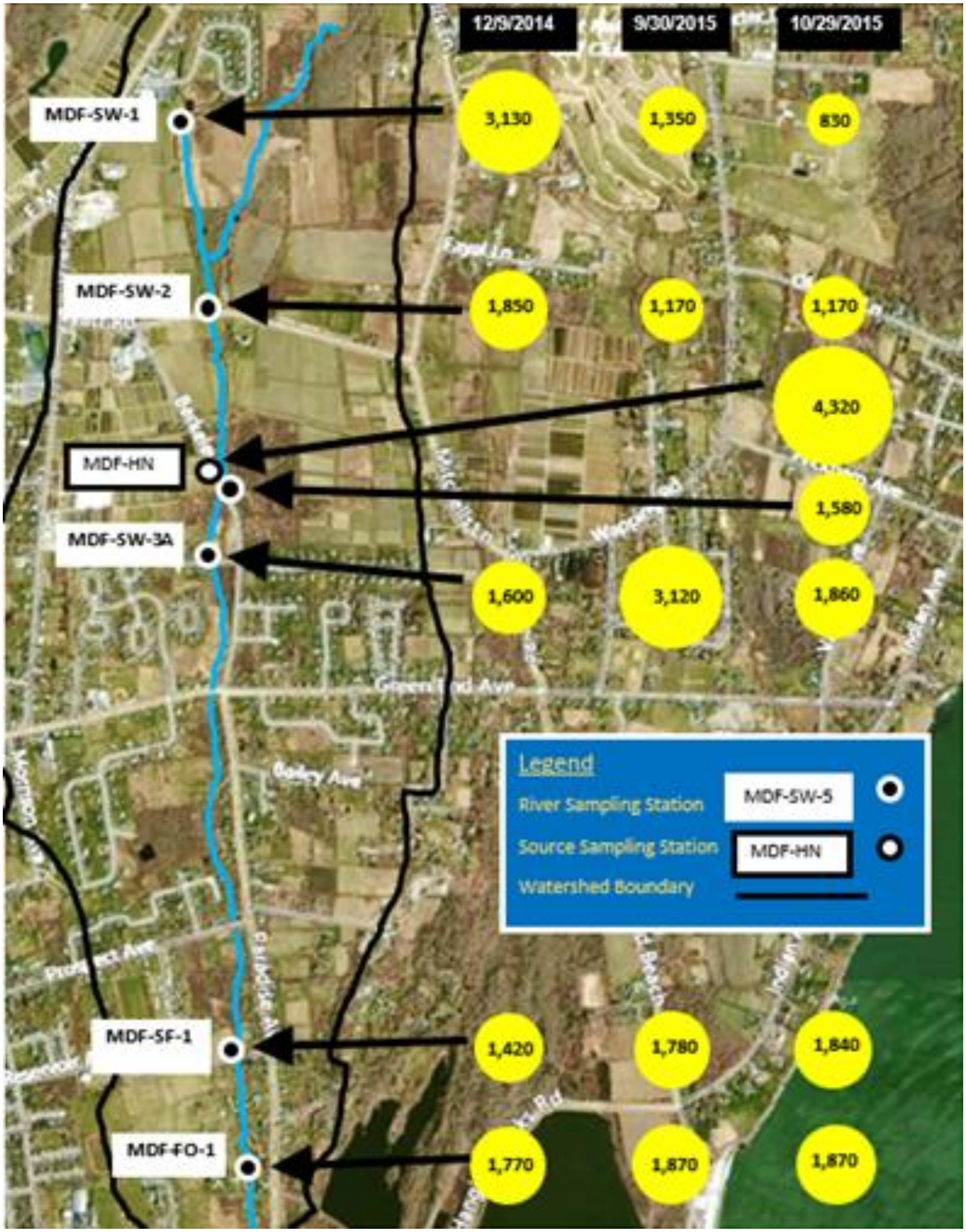


Figure M15. Maidford River Dry-Weather Fecal Coliform (CFU/100 ml).

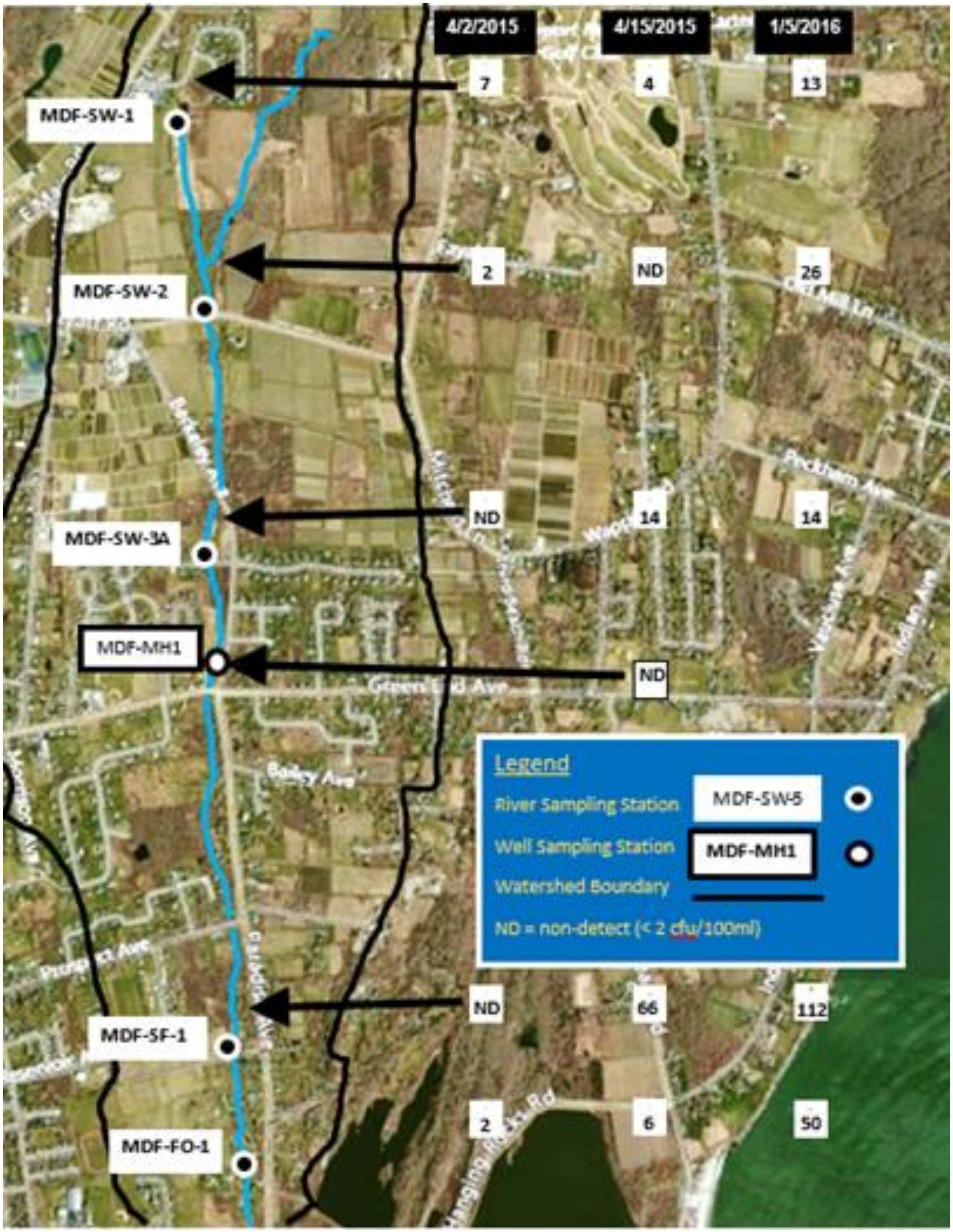


Figure M16. Maidford River Wet-Weather Fecal Coliform Results..

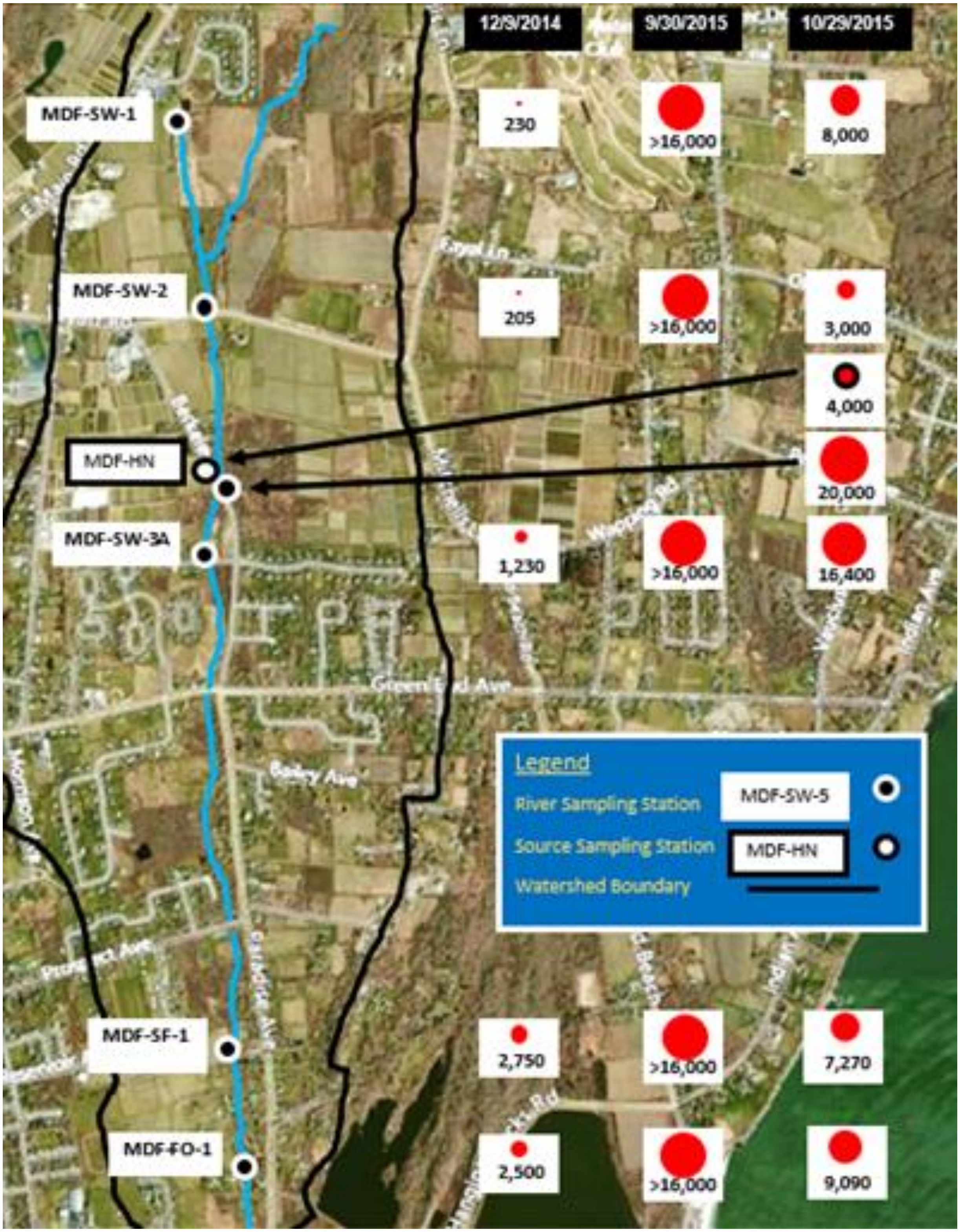


Figure M17. Maidford River Dry-Weather Enterococci (MPN/100 ml).

Figure M18. Maidford River Wet-Weather Enterococci Results (MPN/100 ml).

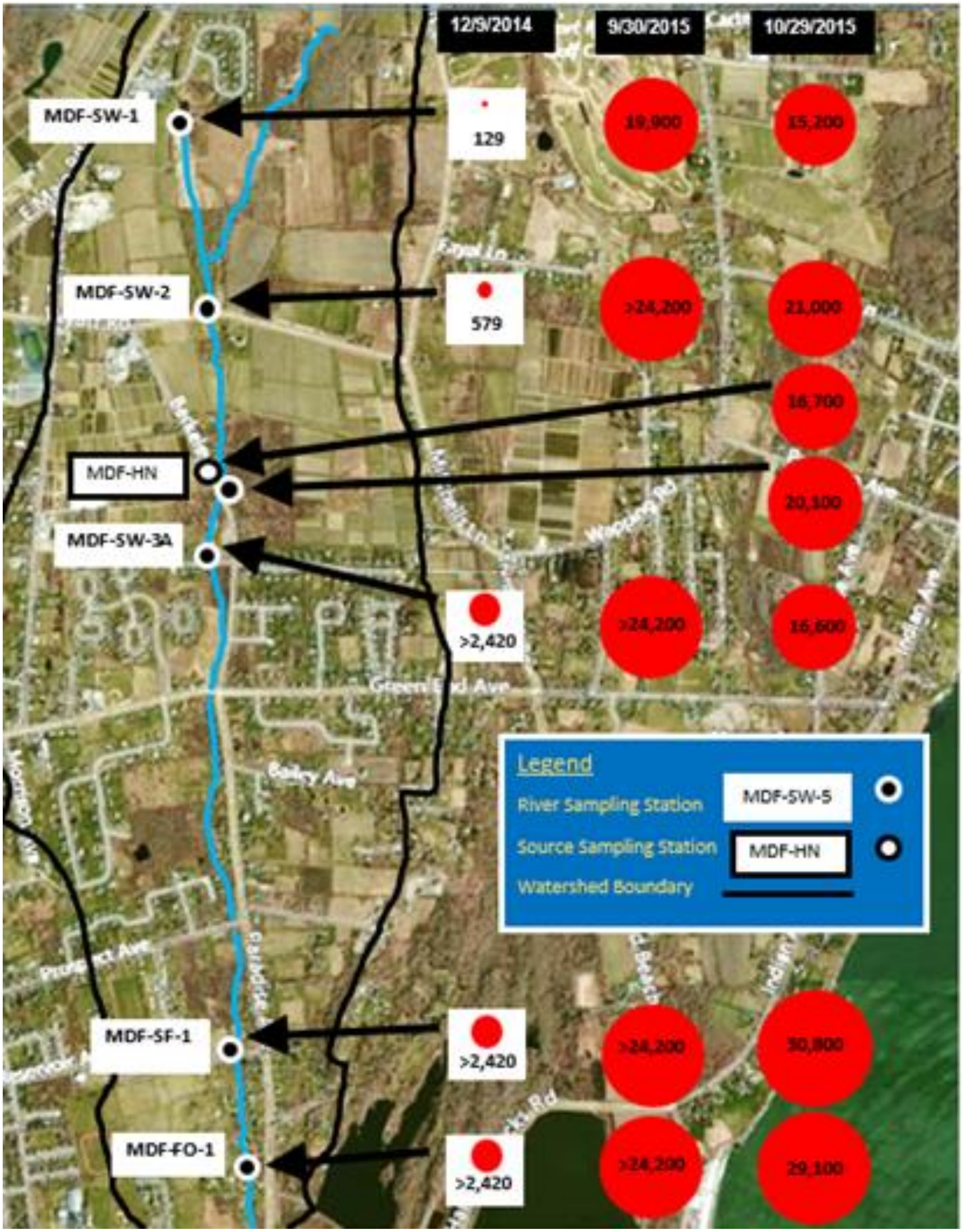


Figure P1. Paradise Brook Dry-Weather Turbidity (NTU).

Figure P2. Paradise Brook Wet-Weather Turbidity (NTU).

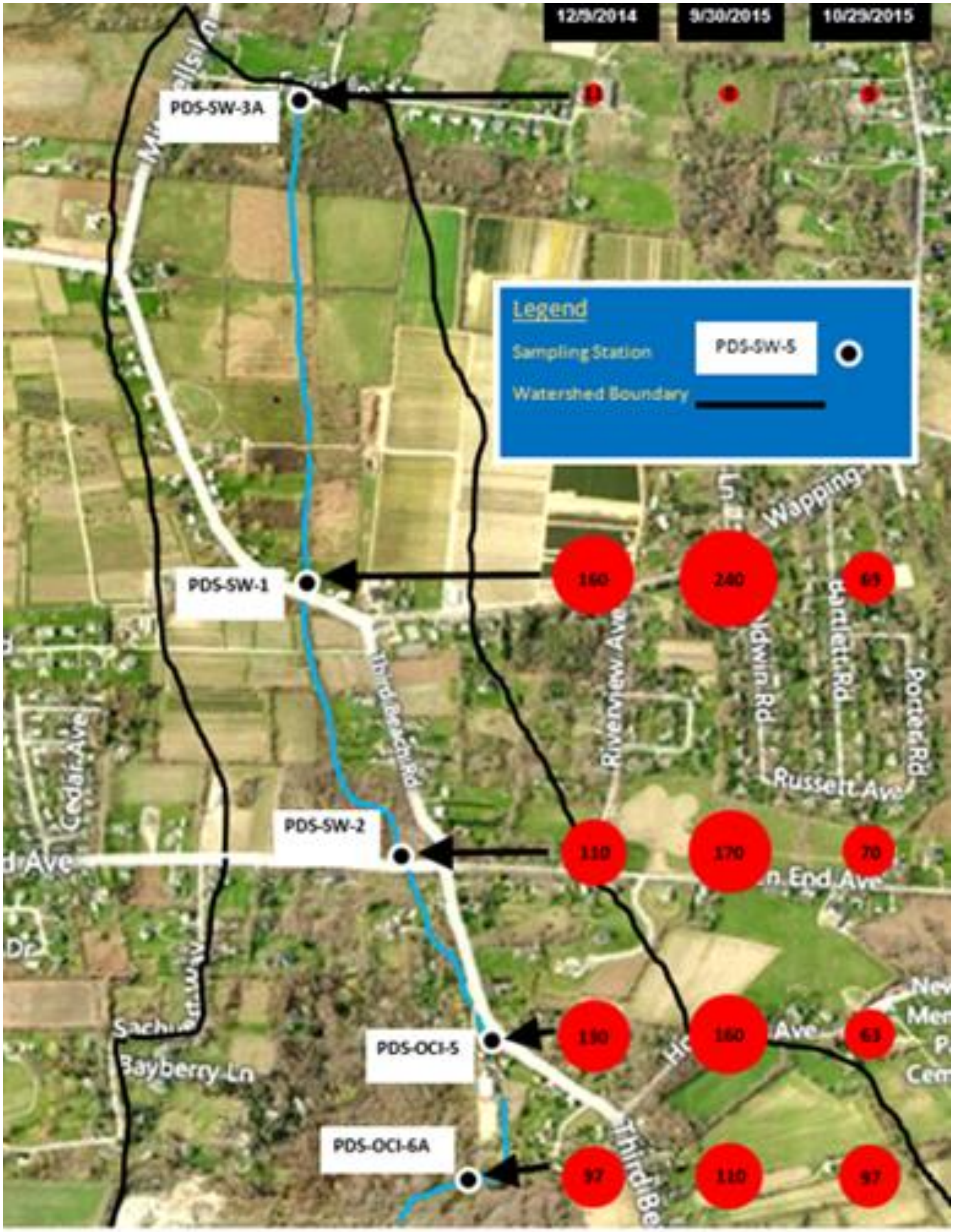


Figure P3. Paradise Brook Dry-Weather Total Suspended Solids (ug/l).

Figure P4. Paradise Brook Wet-Weather Total Suspended Solids (ug/l).

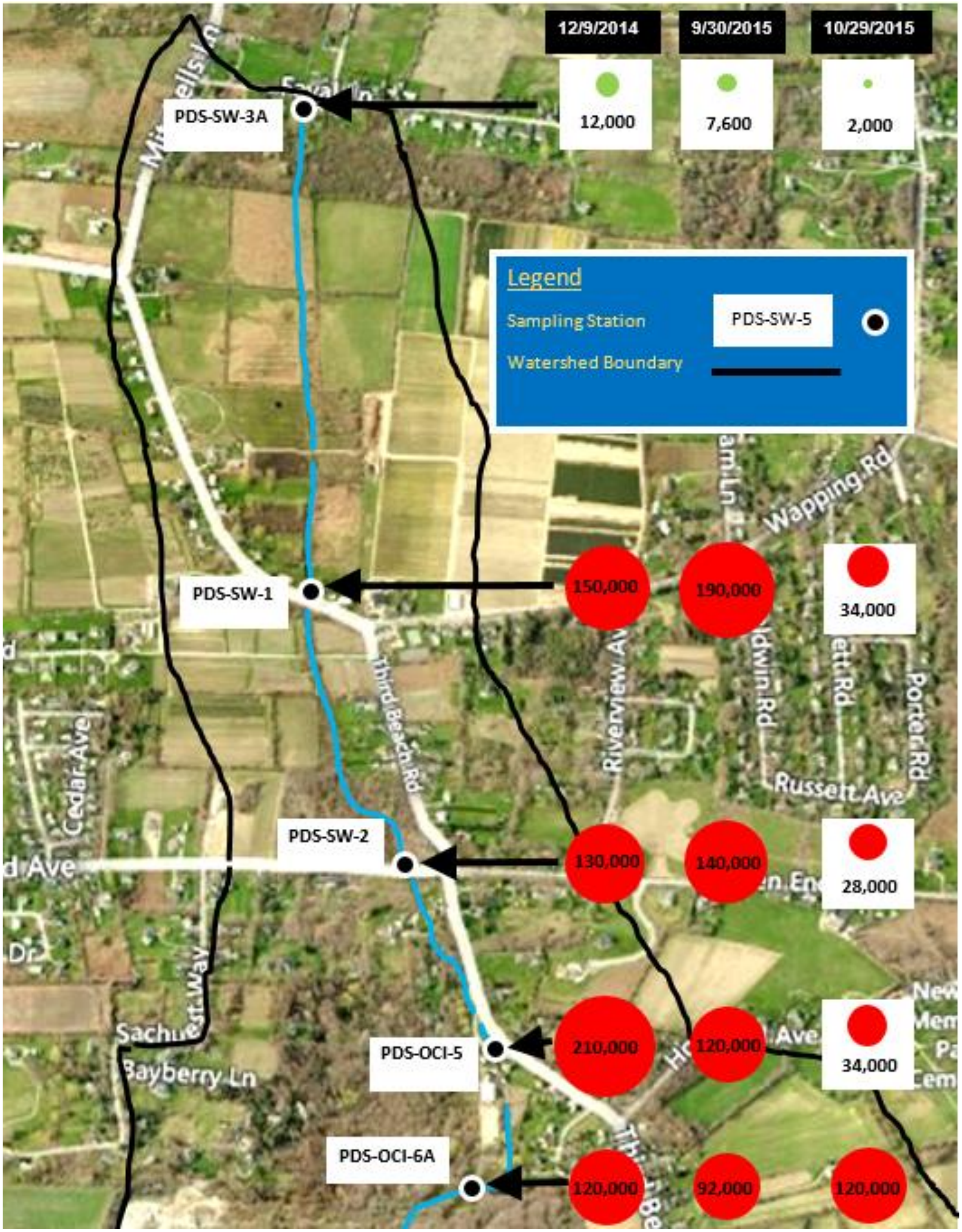


Figure P5. Paradise Brook Dry-Weather Total Phosphorus (ug/l).

Figure P6. Paradise Brook Wet-Weather Total Phosphorus (ug/l).

Figure P7. Paradise Brook Dry-Weather Ammonia (ug/l).

Figure P8. Paradise Brook Wet-Weather Ammonia (ug/l).

Figure P9. Paradise Brook Dry-Weather Total Kjeldahl Nitrogen (TKN) (ug/l).

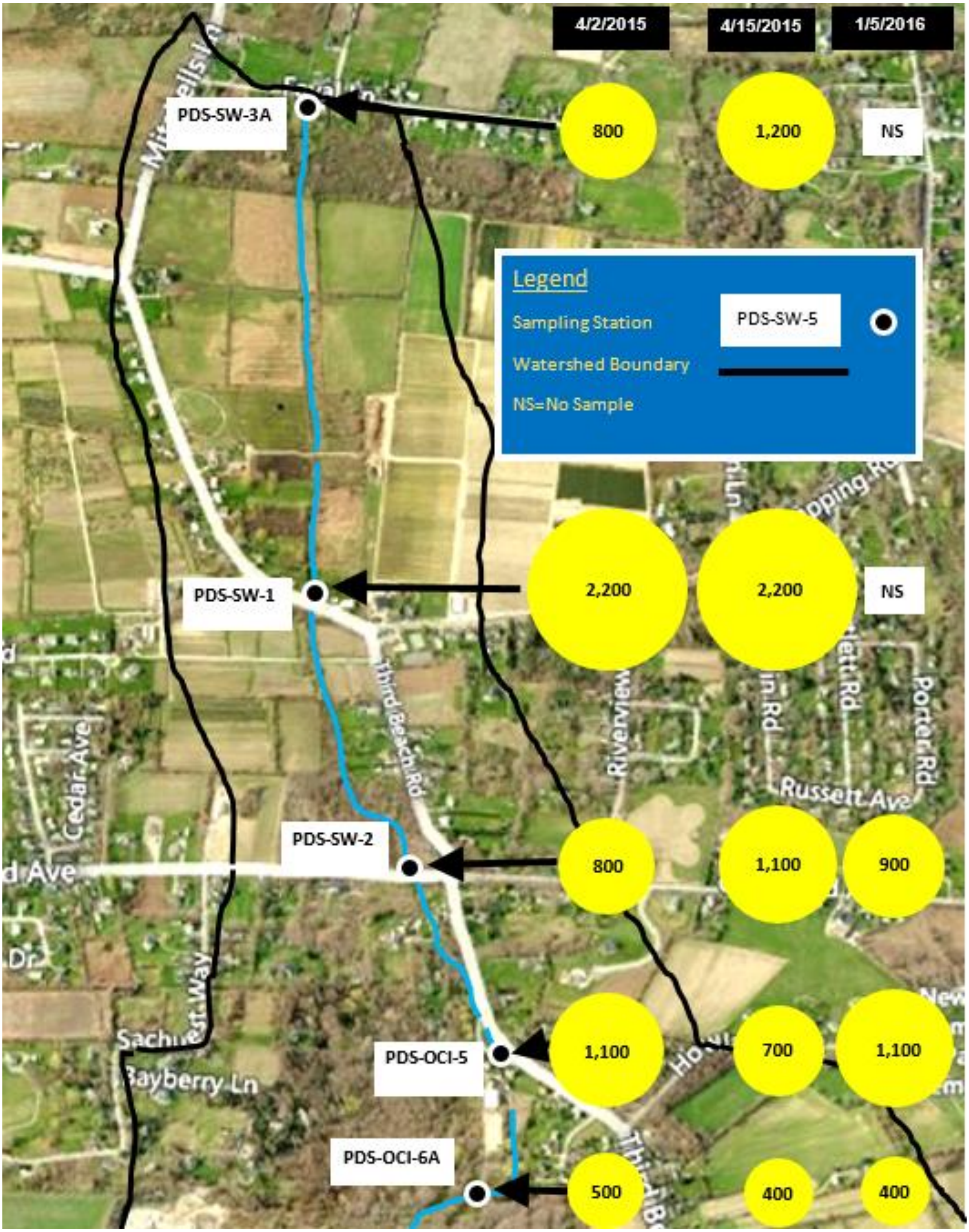


Figure P10. Paradise Brook Wet-Weather Total Kjeldahl Nitrogen (TKN) (ug/l).

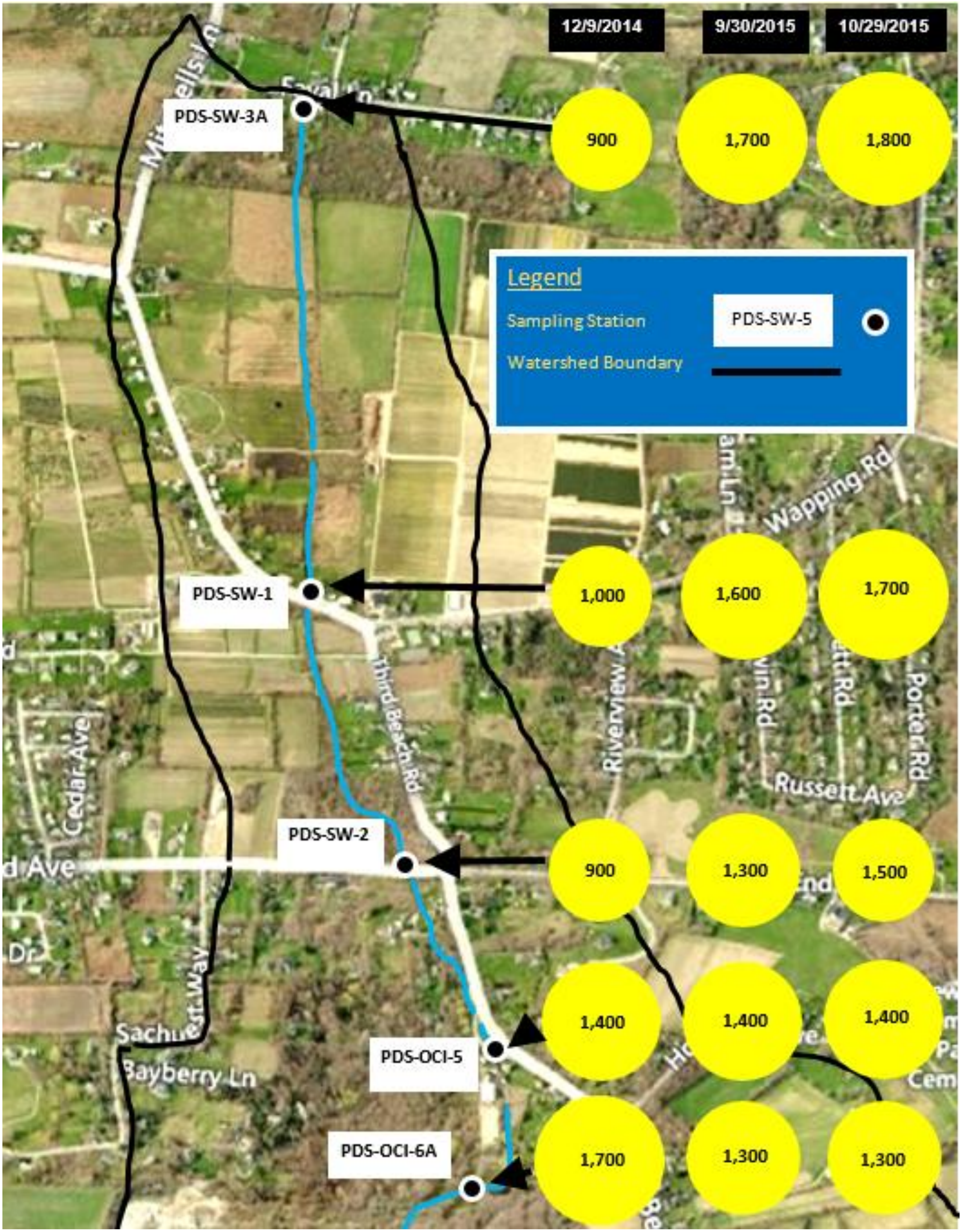


Figure P11. Paradise Brook Dry-Weather Nitrate (ug/l).

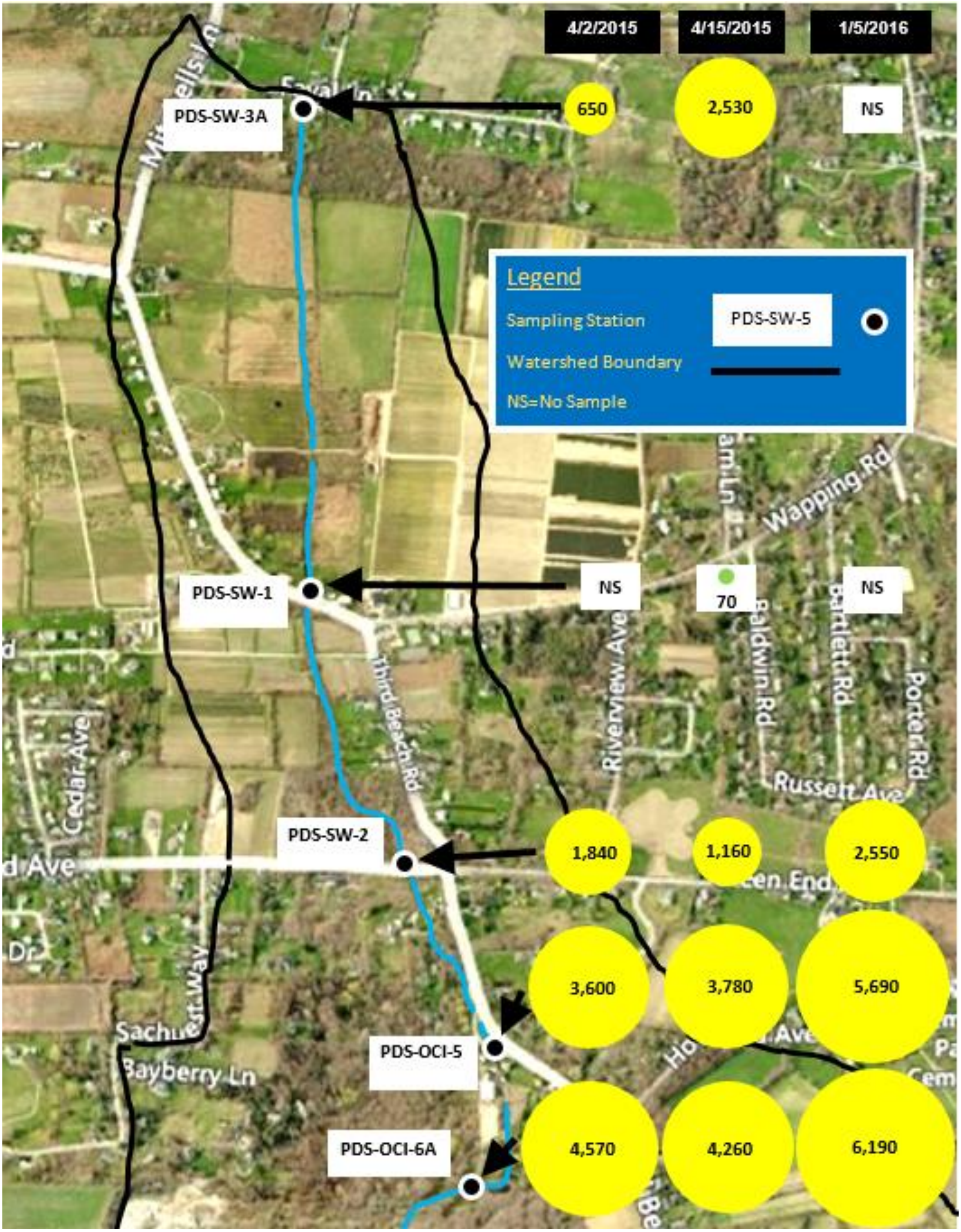


Figure P12. Paradise Brook Wet Weather Nitrate (ug/l).

Figure P13. Paradise Brook Dry-Weather Total Nitrogen (ug/l).

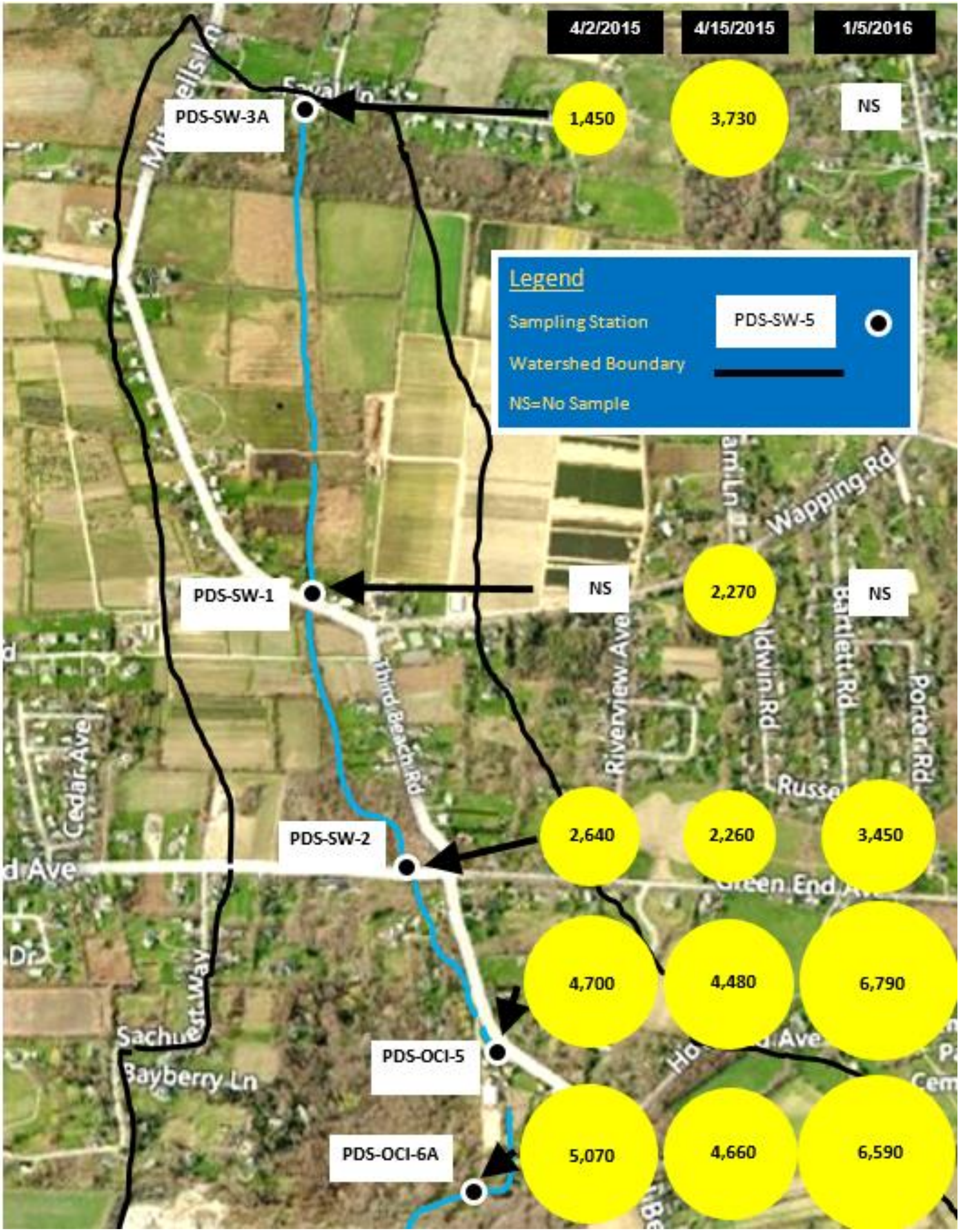


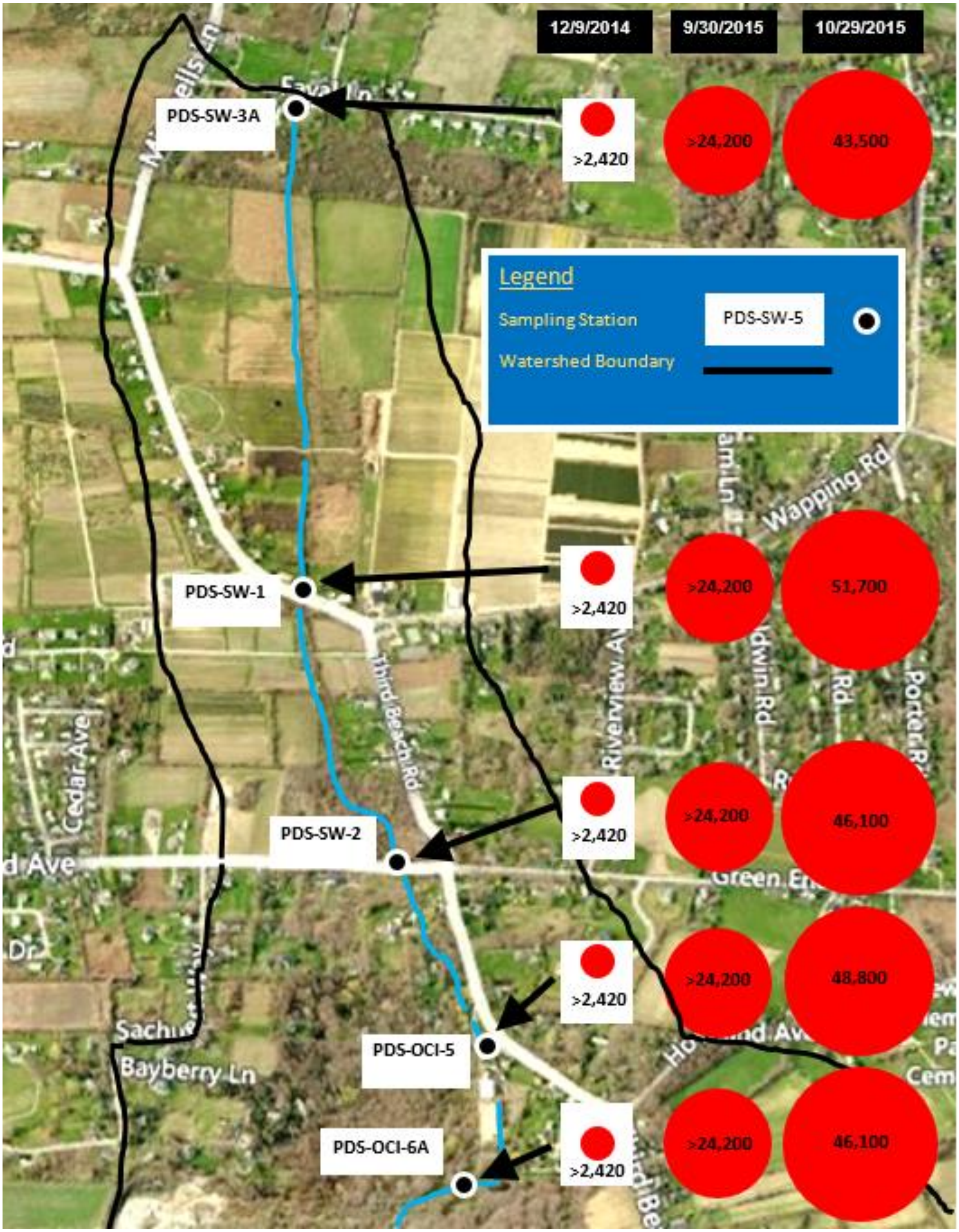
Figure P14. Paradise Brook Wet-Weather Total Nitrogen (ug/l).

Figure 15. Paradise Brook Dry-Weather Fecal Coliform (CFU/100 ml).

Figure 16. Paradise Brook Wet-Weather Fecal Coliform (CFU/100 ml).

Figure P17. Paradise Brook Dry-Weather Enterococci (MPN/100 ml).

Figure P18. Paradise Brook Wet-Weather Enterococci (MPN/100 ml).



Maidford River Dry Weather Results

Maidford River Dry Weather Results 4/2/15							
		Station ID	**MDF-SW-1**	**MDF-SW-2**	**MDF-SW-3A**	**MDF-SF-1**	**MDF-FO-1**
		Location	**Headwaters/ Meadow Ln.**	**Wyatt Rd.**	**Berkeley Av. Spur**	**Reservoir Av.**	**Newport Water Intake**
		Units					
Flow & Pollutant Concentrations	Flow	cfs	0.27	0.83	1.83	3.26	2.64
	Turbidity	NTU	1.4	0.79	0.63	0.44	0.51
	TSS	ug/l	< 1000	< 1000	4400	3600	2400
	Total Phosphorus	ug/l	20	27	27	42	20
	Ammonia	ug/l	< 100	< 100	< 100	< 100	< 100
	TKN	ug/l	300	400	400	400	200
	Nitrate	ug/l	3200	1990	2810	2720	2620
	Total Nitrogen	ug/l	3500	2390	3210	3120	2820
	Fecal Coliform	CFU/100 ml	7	2	< 2	< 2	2
	Enterococci	MPN/100 ml	5	1	1	5	4

Maidford River Dry Weather Results 4/15/15								
		Station ID	**MFD-SW-1**	**MFD-SW-2**	**MFD-SW-3A**	**MFD-MH**	**MFD-SF-1**	**MFD-FO-1**
		Location	**Headwaters / Meadow Ln.**	**Wyatt Rd.**	**Berkeley Av. Spur**	**Green End/ Berkeley Av. Intersection (Abandoned Town Artesian Well)**	**Reservoir Av.**	**Newport Water Intake**
		Units						
Flow & Pollutant Concentrations	Flow	cfs	0.07	0.63	1.00		1.82	1.95
	Turbidity	NTU	2.3	1.0	0.65	< 0.2	0.43	0.42
	TSS	ug/l	8000	2000	< 1000	< 1000	< 1000	1200
	Total Phosphorus	ug/l	55	21	23	18	18	19
	Ammonia	ug/l	< 100	< 100	< 100	< 100	< 100	< 100
	TKN	ug/l	500	400	400	< 100	300	300
	Nitrate	ug/l	2120	1400	2090	5990	2390	2320
	Total Nitrogen	ug/l	2620	1800	2490	6040	2690	2620
	Fecal Coliform	CFU/100 ml	4	4	14	< 2	66	6
	Enterococci	MPN/100 ml	13	< 2	2		4	4
	Bacteriophage	PFU/100 ml				< 2		

Maidford River Dry Weather Results 1/5/16							
		Station ID	**MDF-SW-1**	**MDF-SW-2**	**MDF-SW-3A**	**MDF-SF-1**	**MDF-FO-1**
		Location	**Headwaters/ Meadow Ln.**	**Wyatt Rd.**	**Berkeley Av. Spur**	**Reservoir Av.**	**Newport Water Intake**
		Units					
Flow & Pollutant Concentrations	Flow	cfs	0.05	0.36	1.05	2.12	2.38
	Turbidity	NTU	2	2.3	1.8	1	1.0
	TSS	ug/l	2400	<1000	<1000	1200	1200
	Total Phosphorus	ug/l	21	28	23	21	19
	Ammonia	ug/l	<100	<100	<100	<100	<100
	TKN	ug/l	400	400	800	600	700
	Nitrate	ug/l	3410	3150	3490	3430	3150
	Total Nitrogen	ug/l	3810	3550	4290	4030	3850
	Fecal Coliform	CFU/100 ml	13	26	14	112	50
	Enterococci	MPN/100 ml	2	9	23	33	30

Maidford River Wet Weather Results

Maidford River Wet Weather Results (12/9/14)							
		Station ID	**MDF-SW-1**	**MDF-SW-2**	**MDF-SW-3A**	**MDF-SF-1**	**MDF-FO-1**
		Location	**Headwaters /Meadow Ln.**	**Wyatt Rd.**	**Berkeley Av. Spur**	**Reservoir Av.**	**Newport Water Intake**
		Units					
Flow & Pollutant	Flow	cfs	0.16	2.24	17.05	87.92 *	98.42 *
	Turbidity	NTU	3.2	3.4	320	53	81
	TSS	ug/l	3000	2000	450000	100000	150000
	Total Phosphorus	ug/l	52	67	600	200	290
	Ammonia	ug/l	< 100	< 100	< 100	< 100	< 100
	TKN	ug/l	590	560	640	1000	1400
	Nitrate	ug/l	2540	1290	960	420	370
	Total Nitrogen	ug/l	3130	1850	1600	1420	1770
	Fecal Coliform	CFU/100 ml	230	205	1230	2750	2500
	Enterococci	MPN/100 ml	129	579	> 2420	> 2420	> 2420

*Flow estimated by regressing flows against subwatershed areas associated with each station.

Maidford River Wet Weather Results 9/30/15							
		Station ID	**MDF-SW-1**	**MDF-SW-2**	**MDF-SW-3A**	**MDF-SF-1**	**MDF-FO-1**
		Location	**Headwaters/ Meadow Ln.**	**Wyatt Rd.**	**Berkeley Av. Spur**	**Reservoir Av.**	**Newport Water Intake**
		Units					
Flow & Pollutant Concentrations	Flow	cfs	3.95	4.00	14.99	63.09	65.10*
	Turbidity	NTU	11	12	550	180	180
	TSS	ug/l	16000	18000	450000	270000	180000
	Total Phosphorus	ug/l	310	740	4700	2000	1900
	Ammonia	ug/l	< 100	< 100	100	< 100	< 100
	TKN	ug/l	900	900	2100	1300	1300
	Nitrate	ug/l	450	270	1020	480	570
	Total Nitrogen	ug/l	1350	1170	3120	1780	1870
	Fecal Coliform	CFU/100 ml	>16000	>16000	>16000	>16000	>16000
	Enterococci	MPN/100 ml	19900	>24200	>24200	>24200	>24200

*Flow estimated by regressing flows against subwatershed areas associated with each station.

Maidford River Wet Weather Results 10/29/15									
		Station ID	**MDF-SW-1**	**MDF-SW-2**	**MDF-SW-3**	**MDF-HN**	**MDF-SW-3A**	**MDF-SF-1**	**MDF-FO-1**
		Location	**Headwaters / Meadow Ln.**	**Wyatt Rd.**	**Berkeley Av.**	**Nursery (Direct Sample-Not on Mainstem)**	**Berkeley Av. Spur**	**Reservoir Av.**	**Newport Water Intake**
		Units							
Flow & Pollutant	Flow	cfs	3.01	15.88	13.63		15.76	22.10	24.85*
	Turbidity	NTU	18	15	14	78	23	26	22
	TSS	ug/l	14000	10000	17000	42000	26000	24000	4000
	Total Phosphorus	ug/l	360	1300	1100	1800	1300	1100	1100
	Ammonia	ug/l	100	100	200	300	400	<100	100
	TKN	ug/l	600	900	1100	1200	1400	1200	1200
	Nitrate	ug/l	230	270	480	3120	460	640	670
	Total Nitrogen	ug/l	830	1170	1580	4320	1860	1840	1870
	Fecal Coliform	CFU/100 ml	8000	3000	20000	4000	16400	7270	9090
	Enterococci	MPN/100 ml	15200	21000	20100	16700	16600	30800	29100

*Flow estimated by regressing flows against subwatershed areas associated with each station.

Paradise Brook Dry Weather Results

Paradise Brook Dry Weather Results (4/2/15)							
		Station ID	PDS-SW-3A	PDS-SW-1	PDS-SW-2	PDS-OCI-5	PDS-OCI-6A
		Location	Headwaters/ Fayal Ln.	Mitchell's Ln.	Green End Av.	Third Beach Rd. Island	Downstream of Equestrian Facility
		Units					
Flow & Pollutant Concentrations	Flow	cfs	0.008	0.076	0.03	0.55	0.821
	Turbidity	NTU	1.2	4.1	1.6	0.84	1.6
	TSS	ug/l	2000	6000	4000	3600	3200
	Total Phosphorus	ug/l	60	280	150	110	64
	Ammonia	ug/l	< 100	< 100	< 100	< 100	< 100
	TKN	ug/l	800	2200	800	1100	500
	Nitrate	ug/l	650	*	1840	3600	4570
	Total Nitrogen	ug/l	1450	**	2640	4700	5070
	Fecal Coliform	CFU/100 ml	256	2	< 2	< 2	4
	Enterococci	MPN/100 ml	10	76	29	10	15

*Sample did not meet quality control requirements.
**Unable to calculate.

Paradise Brook Dry Weather Results (4/15/15)							
		Station ID	PDS-SW-3A	PDS-SW-1	PDS-SW-2	PDS-OCI-5	PDS-OCI-6A
			Headwaters/ Fayal Ln.	Mitchell's Ln.	Green End Av.	Third Beach Rd. Island	Downstream of Equestrian Facility
		Units					
Flow & Pollutant Concentrations	Flow	cfs	0.002	0.02	0.07	0.27	0.39
	Turbidity	NTU	1.5	4.5	1.9	0.7	1.0
	TSS	ug/l	3600	3600	4800	1600	1200
	Total Phosphorus	ug/l	110	320	150	60	50
	Ammonia	ug/l	< 100	< 100	< 100	< 100	< 100
	TKN	ug/l	1200	2200	1100	700	400
	Nitrate	ug/l	2530	70	1160	3780	4260
	Total Nitrogen	ug/l	3730	2270	2260	4480	4660
	Fecal Coliform	CFU/100 ml	> 1600	6	4	4	66
	Enterococci	MPN/100 ml	21	29	27	3	6

Paradise Brook Dry Weather Results (1/5/16)							
		Station ID	**PDS-SW-3A**	**PDS-SW-1**	**PDS-SW-2**	**PDS-OCI-5**	**PDS-OCI-6A**
		Location	**Headwaters/ Fayal Ln.**	**Mitchell's Ln.**	**Green End Av.**	**Third Beach Rd. Island**	**Downstream of Equestrian Facility**
		Units					
Flow & Pollutant Concentrations	Flow	cfs	*	*	0.08	0.31	0.52
	Turbidity	NTU	*	*	1.3	0.59	0.8
	TSS	ug/l	*	*	2000	2400	2000
	Total Phosphorus	ug/l	*	*	84	60	42
	Ammonia	ug/l	*	*	<100	<100	<100
	TKN	ug/l	*	*	900	1100	400
	Nitrate	ug/l	*	*	2550	5690	6190
	Total Nitrogen	ug/l	*	*	3450	6790	6590
	Fecal Coliform	CFU/100 ml	*	*	86	82	58
	Enterococci	MPN/100 ml	*	*	62	41	54

*No flow.

Paradise Brook Wet Weather Results

Paradise Brook Wet Weather Results (12/9/14)							
		Station ID	**PDS-SW-3A**	**PDS-SW-1**	**PDS-SW-2**	**PDS-OCI-5**	**PDS-OCI-6A**
		Location	**Headwaters/ Fayal Ln.**	**Mitchell's Ln.**	**Green End Av.**	**Third Beach Rd. Island**	**Downstream of Equestrian Facility**
		Units					
Flow & Pollutant Concentrations	Flow	cfs	3.1	9.38	17.61	17.4	22.61*
	Turbidity	NTU	11	160	110	130	97
	TSS	ug/l	12000	150000	130000	210000	120000
	Total Phosphorus	ug/l	220	890	680	730	780
	Ammonia	ug/l	< 100	100	< 100	< 100	< 100
	TKN	ug/l	900	1000	900	1400	1700
	Nitrate	ug/l	830	820	720	660	680
	Total Nitrogen	ug/l	1730	1820	1620	2060	2380
	Fecal Coliform	CFU/100 ml	> 8000	4000	3400	3200	5400
	Enterococci	MPN/100 ml	> 2420	> 2420	> 2420	> 2420	>2420

*****Flow estimated by regressing flows against subwatershed areas associated with each station.

Paradise Brook Wet Weather Results (9/30/15)							
		Station ID	**PDS-SW-3A**	**PDS-SW-1**	**PDS-SW-2**	**PDS-OCI-5**	**PDS-OCI-6A**
		Location	**Headwaters/ Fayal Ln.**	**Mitchell's Ln.**	**Green End Av.**	**Third Beach Rd. Island**	**Downstream of Equestrian Facility**
		Units					
Flow & Pollutant Concentrations	Flow	cfs	0.16	3.06	5.51	4.58	6.81*
	Turbidity	NTU	8.4	240	170	160	110
	TSS	ug/l	7600	190000	140000	120000	92000
	Total Phosphorus	ug/l	900	2800	2200	2200	1900
	Ammonia	ug/l	100	<100	<100	<100	<100
	TKN	ug/l	1700	1600	1300	1400	1300
	Nitrate	ug/l	1580	360	370	420	500
	Total Nitrogen	ug/l	3280	1960	1670	1820	1800
	Fecal Coliform	CFU/100 ml	> 16000	> 16000	> 16000	> 16000	> 16000
	Enterococci	MPN/100 ml	> 24200	> 24200	> 24200	> 24200	> 24200

*****Flow estimated by regressing flows against subwatershed areas associated with each station.

Paradise Brook Wet Weather Results (10/29/15)							
		Station ID	**PDS-SW-3A**	**PDS-SW-1**	**PDS-SW-2**	**PDS-OCI-5**	**PDS-OCI-6A**
		Location	**Headwaters/ Fayal Ln.**	**Mitchell's Ln.**	**Green End Av.**	**Third Beach Rd. Island**	**Downstream of Equestrian Facility**
		Units					
Flow & Pollutant Concentrations	Flow	cfs	0.05	2.99	3.81	3.38	5.06*
	Turbidity	NTU	8.7	69	70	63	97
	TSS	ug/l	2000	34000	28000	34000	120000
	Total Phosphorus	ug/l	380	2100	1800	1900	1800
	Ammonia	ug/l	100	100	<100	<100	200
	TKN	ug/l	1800	1700	1500	1400	1300
	Nitrate	ug/l	1570	490	530	600	640
	Total Nitrogen	ug/l	3370	2190	2030	2000	1940
	Fecal Coliform	CFU/100 ml	28000	190000	120000	37000	28000
	Enterococci	MPN/100 ml	43500	51700	46100	48800	46100

*****Flow estimated by regressing flows against subwatershed areas associated with each station.