Falmouth Study Streams Stressor Report

Individual Watershed Reports

January 2022

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Background

During the field seasons of 2017, 2018 and 2019 the Maine Department of Environmental Protection's (DEP) Watershed Unit conducted a special study of several streams in Falmouth, Maine – Norton Brook, Webes Creek, Mill Creek, Chenery Brook, Scitterygusset Creek and Hobbs Brook. The special study was in support of the "Falmouth Proactive Watershed Management" Coastal Community Grant Project awarded to the Greater Portland Council of Governments. Four of the study streams drain to Mussel Cove – Norton Brook, Webes Creek, Chenery Brook and Mill Creek. These stream watersheds are in Falmouth's high growth coastal area and were chosen for additional study due to their location in an area with continuing development pressure, and the likelihood of threat to stream health. Hobbs Brook was chosen for study due its water quality impairment. Scitterygusset Creek is a coastal stream that drains to the Presumpscot River and underwent preliminary study, but an individual watershed report has not been completed. Mussel Cove did not undergo additional study as a part of this project, but the DEP Marine Unit provided an analysis of the embayment for this report.

Following is detailed information of the surveying, monitoring and assessment methods and findings of this special study of Mussel Cove tributaries and Hobbs Brook, along with a discussion of known data on Mussel Cove. The information in this report is summarized in the *Falmouth Stream Stressor Report Summary (January 2022)*. The *Summary Report* and this *Individual Watershed Report* were finalized in January 2022, with the only substantive change from the drafts released in early 2020 being the addition of some information about Scitterygusset Creek in the Summary Report and the addition of the Hobbs Brook Watershed Report to this report.

Figure 1. Coastal Area Study Stream Map: Watersheds and Surveying and Monitoring Locations.

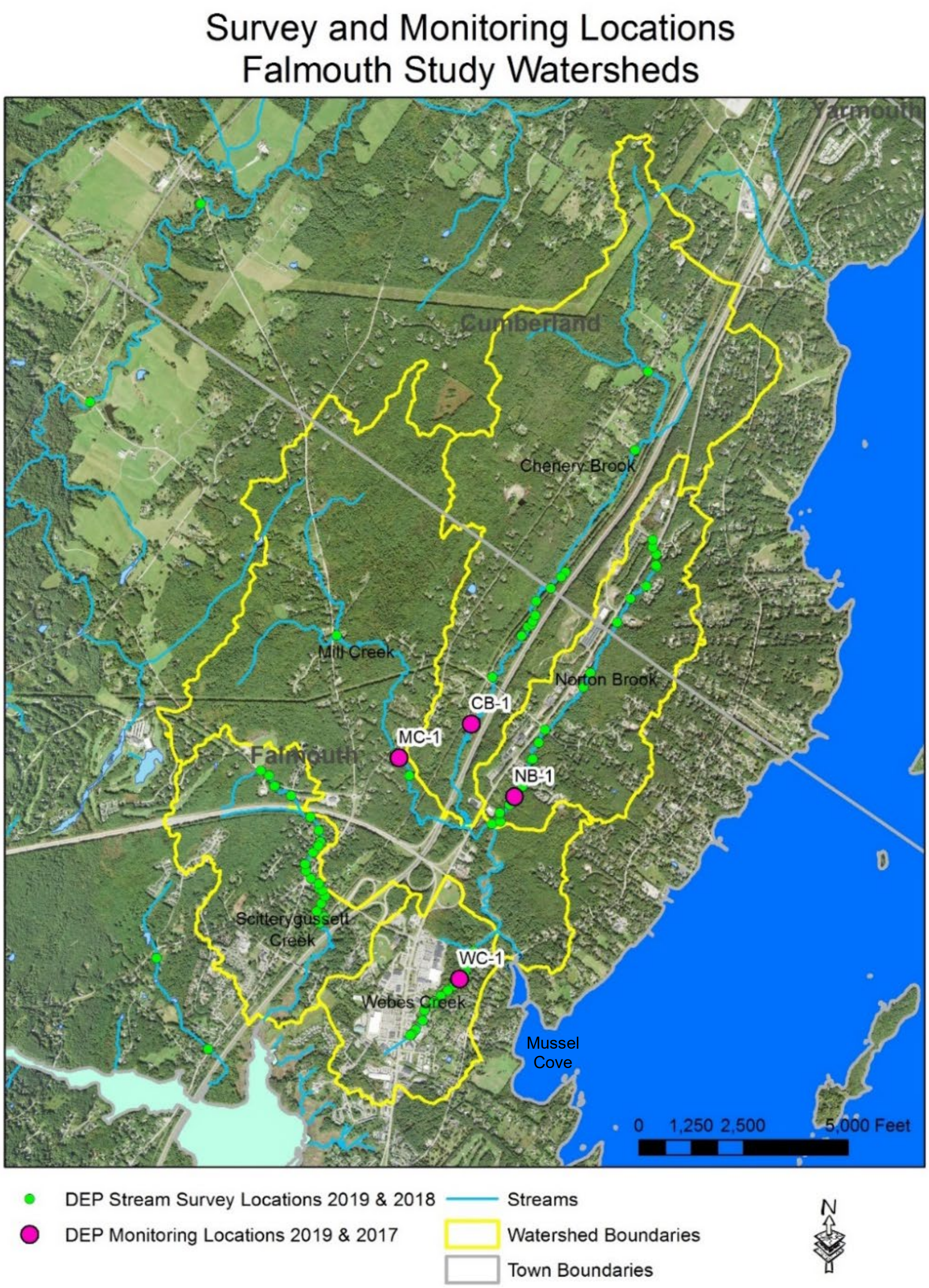
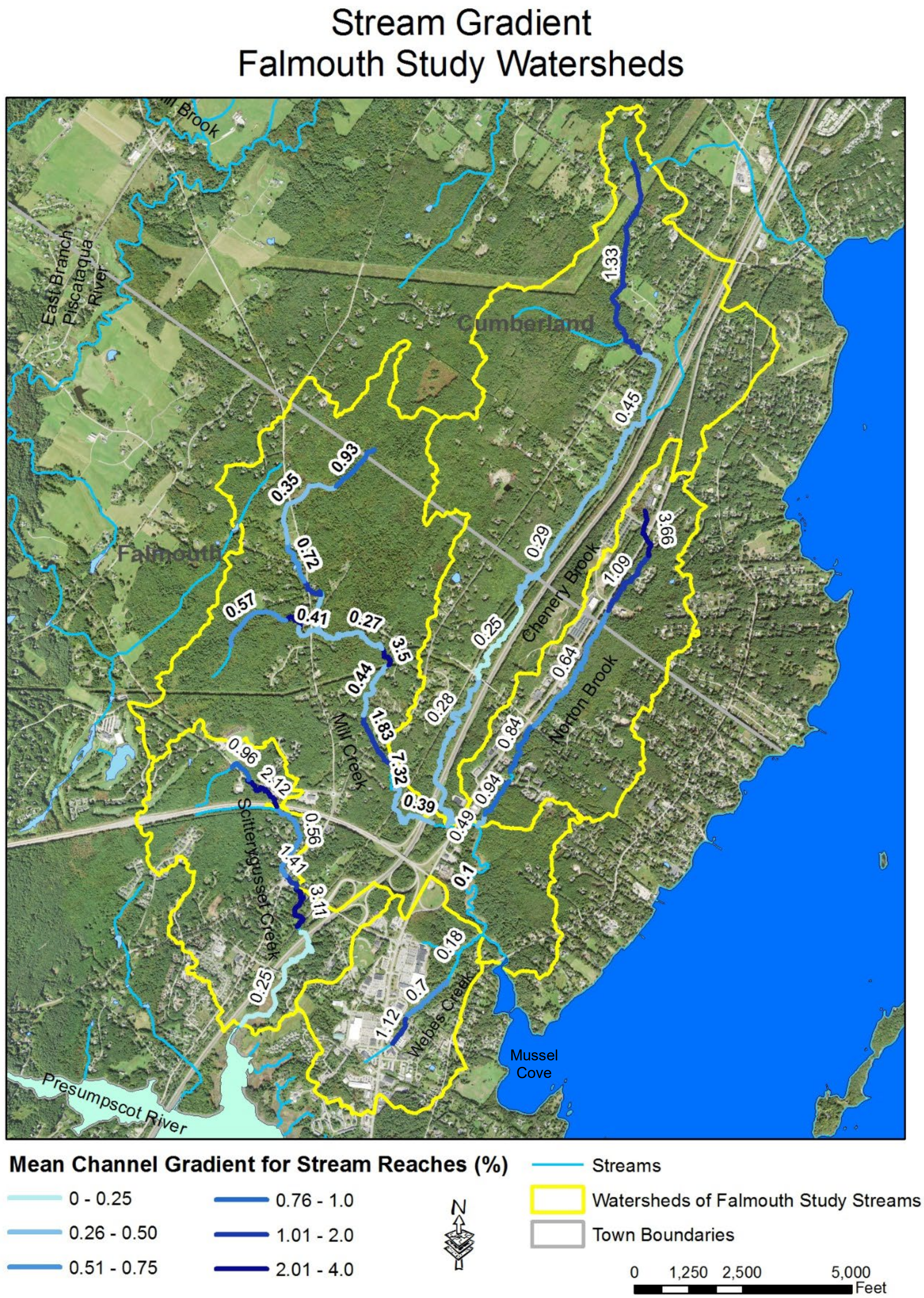


Figure 2. Coastal Area Study Streams Gradient Map.



Norton Brook

Norton Brook is a 2.0 mile long stream that drains south from a forested wetland behind the Seafax property on the west side of Route 1 in Cumberland. It crosses to the east side of Route 1 just south of Casco Bay Drive, and parallels Route 1 as it flows south to its junction with Mill Creek behind the Protection Professionals property in Falmouth. It is a free-flowing freshwater stream except for the last 500 feet which are at times brackish due to tidal influences.

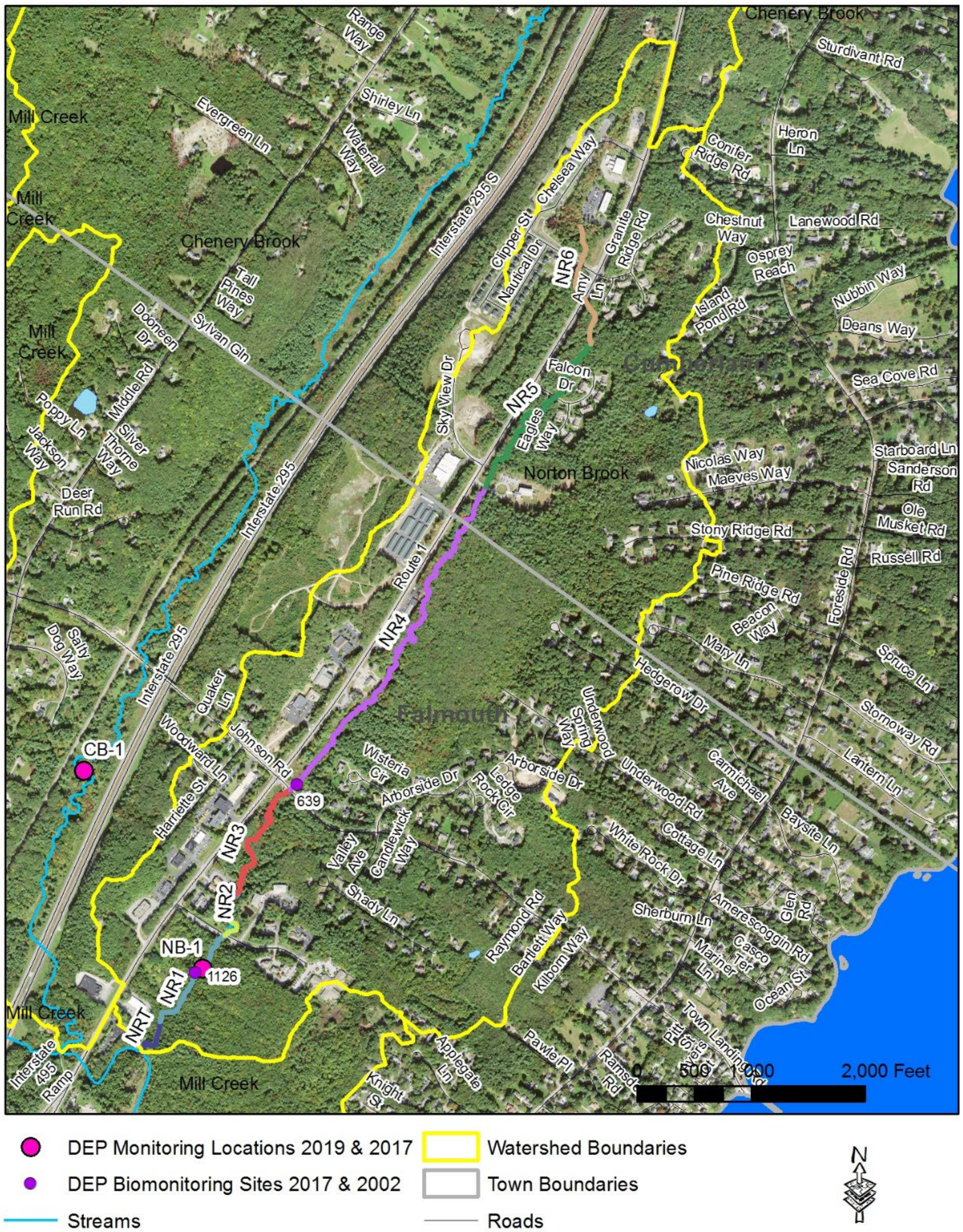
Watershed Characterization

The Norton Brook watershed is split between the towns of Cumberland and Falmouth, with the upper third of the 510-acre watershed area in Cumberland and the remainder in Falmouth. Since the western boundary of the watershed is a ridge line between interstate 295 and Route 1, the area west of Route 1 accounts for only 25% of the watershed. The majority of the watershed drains the west side of the hills between Route 1 and Route 88.

The watershed is mostly forested but contains 80 acres of impervious cover (15.8% IC, 2018 estimation) as well as the landscaped areas associated with the impervious cover. Much of the impervious cover is associated with commercial, office, storage, light industrial and multifamily residential land use along the Route 1 corridor and in the Northbrook Drive Business Park. The remaining impervious cover is single family residential development along and off of Johnson Road and Casco Bay Drive, as well as the western portions of some subdivision development accessed from Foreside Road. In 2004 the impervious cover in the watershed was only 47.6 acres (9.3% IC), so about 40% of the impervious cover was constructed within the last 15 years.

Norton Brook-
Reach NR1

Study Watershed Reach Names
Norton Brook



Geologic and Topographic Setting

Bedrock Geology, Surficial Geology and Soils. The valley in which Norton Brook lies is bounded by two metamorphic bedrock ridges, the Richmond Corner Formation on the west and the Torrey Hill Formation on the east. The bedrock base of the valley is the more easily eroded metamorphic rocks of the Hutchins Corner Formation. The western ridge is covered with a thin layer of glacial till, and the east ridge and the most northern portion of the valley are covered with reworked terminal moraine deposits of sand and silt which are shallow to bedrock on the top of the ridge. The southern portion of the valley is overlain with marine clay sediments of the Presumpscot Formation. The soils reflect the surficial geology with shallow till soils on the western slope, sandy soils on the eastern slope, silt loam soils in much of the stream corridor and, on the lower portion of the eastern slope, coarse loamy soils overlying silt loam soils.

Stream Gradient and Substrate. With the exceptions of a short ledge drop just upstream of Northbrook Drive and the most upstream reach from the Casco Bay Drive crossing to just below the Route 1 crossing, Norton Brook is a low gradient stream with channel slopes ranging from 0.6% to 1.1%. This is not surprising given that much of the channel sits on Presumpscot Formation marine clay covered with varying amounts of alluvial sands and silty sands. In the upper reaches, where the stream runs through coarser soils the substrate is a combination of sands, silty sands, gravel and some cobbles, particularly in the headwater reach.

Riparian Condition

Despite Norton Brook's proximity to Route 1 and the concentration of commercial development to the south, nearly the entire riparian corridor of the stream is forested. South of Johnson Road and north of the Friends School of Portland, the vegetation is relatively mature upland mixed growth forest. Along the lowest gradient stretches from just downstream of Johnson Road up to the Friends School the brook flows in and out of riparian floodplain wetlands of red maple, alder and both native and invasive shrubs. Except near the five stream crossings (Northbrook Drive, Johnson Road, the Friends School entrance, Falcon Drive and Route 1), the forest on the east side of the stream extends uninterrupted 300 to 1,000 feet up the slope. On the west side the width of the forest cover can drop to 50 feet or less adjacent to the commercial and business development along Route 1.

Habitat

Reach NRT. Starting at the confluence with Mill Creek, the first 400 feet or so of Norton Brook is tidal. The substrate is principally silty sand on marine clay. The channel is somewhat incised as is typical in tidal reaches. There is some woody debris, but no debris dams.

Reach NR1. This low gradient reach extends from head of tide about 1000 feet upstream to Northbrook Drive. The substrate is sand or silty sand with many meander bars and sand deltas at the outlets of two intermittent tributaries that drain gullies on the east side of the watershed. There is a large debris dam near the lower end of the reach which provides some habitat complexity both in substrate and velocity. In the stretch between the two tributaries a large abandoned culvert that provided the stream crossing for a discontinued road lies parallel to the stream in the stream channel. This restriction and the likely heavy stormflows from the upstream tributaries that drain most of the Northbrook Business Park has resulted in severe erosion of the western bank of Norton Brook, thus contributing more sand to the downstream deltas and bars. The DEP macroinvertebrate monitoring station is located just downstream of this tributary. It is apparent that the sand substrate in this reach is not stable and is likely altered during large runoff events.

Reach NR2. This very high gradient 330 foot reach extends from Northbrook Drive to the top of the ledge drop cascade. The substrate just upstream of the road crossing is a mixture of sand, gravel and cobble. The substrate in the cascade is ledge and boulders with some cobbles and gravel.

Reach NR3. Reach 3 extends from the top of the ledge drop 1550 feet upstream to the Johnson Road Crossing. It is mostly a low gradient reach with a substrate of sand and silty sand and some woody debris. A large intermittent tributary draining residential development along and accessed from Johnson Road enters about a third of the way up the reach.

Reach NR4. This meandering, very low gradient 4,000 foot reach extends from Johnson Road to the Friends School. The substrate is sand and silty sand. Woody debris provides limited habitat and flow diversity. Because of the low gradient, baseflow velocity in the long runs is very low in this reach.

Reach NR5. Reach 5 extends 2,000 feet from the Friends School upstream past Falcon Drive to a relatively new double culvert crossing 300 feet downstream of Route 1. The reach has moderately low gradient with substrate of sand and gravel with some cobbles. The channel is slightly incised with undercut banks in some places. The volume of baseflow is very limited because of the small contributing drainage area.

Reach NR6. This high gradient 1,150 foot reach extends from the top of Reach 5 under Route 1 upstream to Casco Bay Drive. Substrate in the steepest parts of this reach is boulder and cobble, with a mixture of cobble, gravel and sand in lower gradient sections.

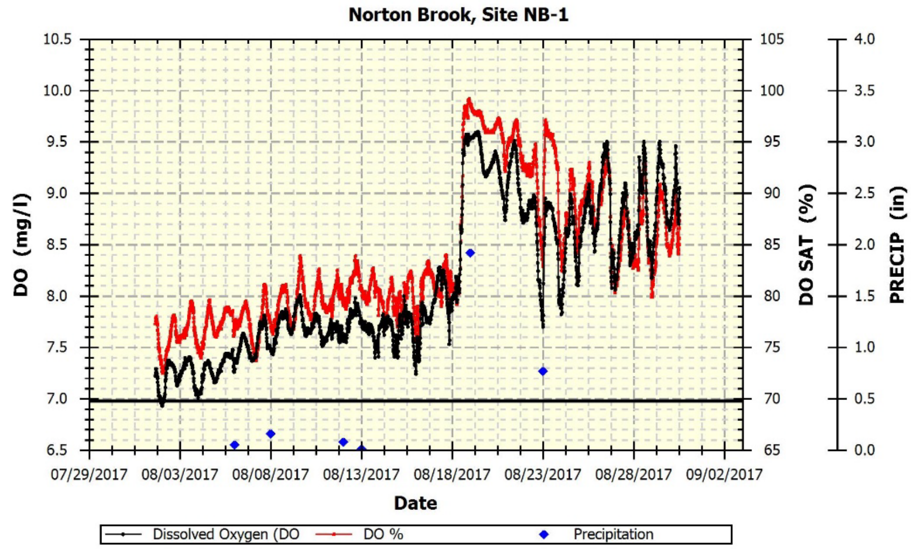
All reaches. All reaches except 2 and 6 showed at least some indication of unstable substrate, particularly Reach 1. Observations of Norton Brook during periods of little precipitation indicate that the volume, and in runs and pools the velocity, is very low, thus limiting both the amount and quality of available habitat.

Stream Crossings/Culverts. Three of the six road crossings (Johnson Road, Friends School and the double culvert downstream of Route 1) are hanging culverts that likely prevent upstream migration of fish except during very high flows. While the culvert under Falcon Drive is not hanging, flow of water over the broad concrete apron is so shallow during low to moderate flow that upstream passage is unlikely. Except in very low flow conditions, upstream passage is possible for the two remaining crossings – Northbrook Drive and Route 1.

Water Quality

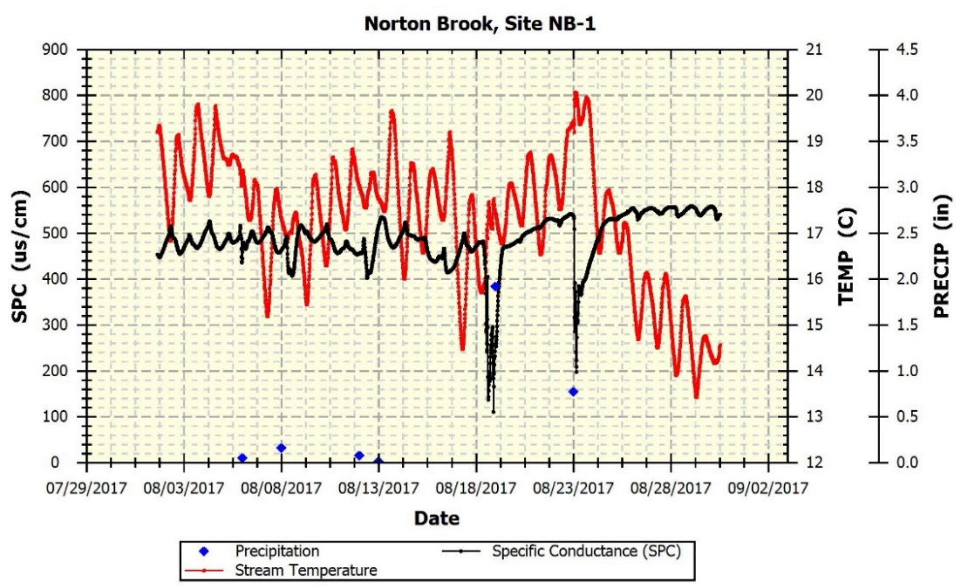
Temperature. Temperature was measured at Site NB-1 with a continuous data logger at the biomonitoring station August 1, 2017 to August 30, 2017, coincident with the period of deployment rock bag artificial substrates to monitor the macroinvertebrate community. The logger took measurements every 15 minutes. Temperature ranged from 13.1˚ C to 19.9˚ C with an average of 17.0˚ C.

Dissolved Oxygen. Dissolved oxygen (DO) was measured at Site NB-1 with a continuous data logger at the biomonitoring station August 1, 2017 to August 30, 2017, coincident with the period of deployment rock bag artificial substrates to monitor the macroinvertebrate community. The logger took measurements every 15 minutes. During this period DO concentration averaged 8.13 ppm with a minimum of 6.93 ppm. Percent saturation averaged 83.8% with a minimum of 72.5%. The diurnal variation in DO concentration was minimal, suggesting there was very little loss of oxygen due to algal respiration in this reach of the stream. This could be due to the fact that the stream is shaded by intact riparian cover, to a lack of sufficient nutrients to support significant algal production or to a combination of these factors. The period of time, only 0.6%, when DO concentration was below the 7.0 ppm standard for Class B streams was limited to the first night after deployment, and it only dropped to 6.93 ppm.



Daytime DO readings taken at 26 points in the stream during the July 11, 2018 stream walk with very low stream flow showed only 4 instances of concentrations less than 7.0, with the lowest readings being just downstream of the wetland source of the stream above Casco Bay Drive and in the tidal reach just above the confluence with Mill Creek.

Specific Conductance. Specific conductance (SPC) was measured at Site NB-1 with a continuous data logger at the 2017 biomonitoring station August 1, 2017 to August 30, 2017, coincident with the period of deployment rock bag artificial substrates to monitor the macroinvertebrate community. The logger took measurements every 15 minutes. During this period SPC ranged from 110 µs to 558 µs, with an average of 486 µs and a median value of 488 µs. During this period, there was very little precipitation and the stream was at low baseflow most of the time. Nearly all of the lowest readings (<300 µs) occurred during and shortly after a half inch rain event on August 18. This pattern of higher conductivity during baseflow than during storms indicates that many of the ions contributing to the conductivity are in the groundwater. In urban and urbanizing streams, the most likely culprit is chloride because of the high amounts of deicing salts that are applied in the watershed and the fact that, unlike most other ions, chloride is not attenuated in the soil.



Specific conductance was also measured at 26 sites during the 2018 stream walk. At this time the stream was at a very low baseflow, with most of the flow derived from groundwater. Starting in the headwaters at Casco Bay Drive the SPC is 900+ µs, reflecting significant chloride contamination of the groundwater from adjacent parking lots and dense residential development. Just downstream of Route 1 SPC jumps to 1250 µs due, no doubt, to the influence of deicing salts on the groundwater adjacent to the highway. Approximately 300 feet downstream of Route 1 a tributary draining the more lightly developed east side of the upper watershed joins the mainstem. SPC in the mainstem above the confluence is still very high at 1170 µs, but below it drops to 750 µs, reflecting dilution of the Route 1 impact by low chloride tributary water. SPC remains in this range for 3000+ feet despite the fact that the stream is at times very close to Route 1. This is probably due to the fact that tributaries and springs from the lightly developed and comparatively large east side of the watershed are continuing to provide dilution of the Route 1 salt impact. At the point where the Route 1 culvert draining the Scir `x Pharmacy development and the west side of Route 1 discharges into Norton Brook the SPC jumps to 830 µs and stays in the 800s downstream to Northbrook Drive. The higher conductance in this stretch is likely due to the density of commercial development along Route 1 as well as residential development along Johnson Road. Downstream of Northbrook Drive SPC drops to +/- 600 and stays there until head of tide where it rises dramatically near the confluence with Mill Creek.

Biological Condition

The macroinvertebrate community in Norton Brook has been sampled using rock bags on two occasions. The first was in August of 2002 at a site just upstream of Johnson Road (Site 639). The second was in August of 2017 at a site approximately 450 feet downstream of Northbrook Drive (Site 1126). In Maine's statutory Water Classification Program (38MRSA§465) Norton Brook is classified as a Class B stream. Evaluation of the composition and structure of the community collected in both sampling events indicated that the community failed to meet the narrative biological criteria for Class C streams, let alone for Class B. Additional evaluation of the taxa present in these two events gives some indication of the reasons for the impairment.
While neither the 2002 nor the 2017 community met minimum biological criteria, the 2002 sample contained more individuals and a higher diversity of taxa than the 2017 sample. The 2002 Johnson Road sample suggested a community with habitat limitations, particularly low baseflow velocity with little water exchange, but did not suggest that the habitat was unstable. The 2017 sample below Northbrook Drive had considerably fewer taxa, and the taxa present suggested the habitat/substrate was unstable and subject to frequent physical alteration. This was confirmed by the fact that one of the rock bags was completely covered with sand. Under these conditions taxa that have very short life cycles make up a large portion of the community. The composition of the community also suggested that low baseflow velocity was a likely issue. Neither sample showed signs of toxicity or low dissolved oxygen stress, as both contained taxa that are not usually present under those conditions.

Likely Stressors to the Biological Community

Both the continuous monitoring data and discrete measurements collected during the stream walk for temperature and dissolved oxygen indicate that neither are likely to be stressors to the biota in Norton Brook. The cool water (maximum temperature of 19.9 degrees C) and dissolved oxygen that only rarely dropped below 7 ppm suggest good conditions for both the macroinvertebrate and fish communities.

Current Stressors

- *Frequent disturbance of the substrate.* Both the habitat assessment during the 2018 stream walk and the composition of the macroinvertebrate community point to frequent disturbance of the sandy substrate as the most important current stressor to the biota in Norton Brook. When substrate sediment is relocated in every large storm event, it is difficult for the taxa living in and on the sediment to avoid being washed downstream. As a result, the taxa that are most abundant in the remaining community are ones with short life cycles that can re-establish themselves quickly after a significant runoff event. Taxa with annual life cycles (only one generation per year) like mayflies, stoneflies and caddisflies have a hard time maintaining themselves in these conditions.

  The fact that imperviousness in the watershed has increased dramatically in the last two decades, and that much of the runoff from impervious areas is delivered very efficiently to the stream with no or limited detention may explain why this stressor appears to be dominant in Norton Brook.
- *Very low baseflow.* Norton Brook has a very small ground watershed, so during the extended periods of little or no precipitation that have been typical of the last five summers, and also of the summers of 2001, 2002, and 2003 the flow in the stream gets very low. This is no doubt exacerbated by the sandy composition of much of the stream's substrate, which allows significant hyporheic flow (flow through the substrate) thus further reducing surface flow over the substrate. In summers without long periods of droughty weather, the biological community may fare better than it has in the relatively dry summers of 2002 and 2017.

Future Stressors

- *Baseflow chloride toxicity.* The specific conductance measurements below Northbrook Drive (450 to 600 µs) where the 2018 macroinvertebrate samples were collected do not suggest that baseflow chloride toxicity was a significant stressor on that community. Generally speaking, when SPC exceeds 900 µs it is likely the threshold of chronic toxicity for chloride (230 mg/l) has been exceeded. Between Northbrook Drive and Falcon Drive, SPC ranges from 750 to 850, dangerously close to the threshold. Above and below the Route 1 crossing SPC is between 900 and 1250, suggesting that baseflow chloride toxicity may be currently impairing the macroinvertebrate community in that reach. *At the very least, there is a high risk that baseflow chloride toxicity could become a significant stressor if future development of the watershed does not address groundwater contamination with deicing salts.*

Stressors associated with downstream watersheds – Mussel Cove

- *Nitrogen.* Norton Brook is a tributary to Mill Creek which in turn drains to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. Addition of any of the following land uses to the Norton Brook watershed has the potential to exacerbate the impairments to the stream's biota:

- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage.
- Any new impervious area that has deicing salts regularly applied to it, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Low density, single family residential development will have significantly less potential impact because it is not likely to discharge as much runoff or use as much salt as the above listed uses.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Norton Brook watershed:

Commercial, Institutional, Office, Multi-family Residential

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.

- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
    - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
    - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

<u>Resource Protection and Restoration.</u>

- *Shoreland Zoning.* One thing that Norton Brook has working for it is its relatively intact stream corridor. With the exception of some encroachment from development adjacent to Route 1, most of the immediate riparian area is covered with natural, though not necessarily native, vegetation and, for most of its length it is well shaded. Maintaining this natural corridor is essential to prevent any further impairment of the biological community and to allow recovery of the stream from its current stressors. Shoreland zoning currently prevents structures within 100 feet of the stream, but only provides for a 25 foot buffer where natural vegetation is maintained. This buffer should be expanded to prevent significant disturbance of the vegetation within no less than 100 feet of the stream. Ideally this standard would also be applied to the tributaries, particularly the ones that have at least some flow in the summer. A further shoreland zone (i.e. 250 feet) which would allow some development but would maintain an essentially forested character would provide a significant wildlife corridor and, at least as important, reproductive habitat for the adult insects that lay their eggs in the stream (e.g. mayflies, stoneflies, caddisflies) and could be considered for the east side of the stream.

- *Instream habitat enhancement.* In addition to attenuation of high stormflow discharges from intensely developed areas, it will likely be necessary to take measures to increase substrate and habitat stability in the stream channel. Strategic placement of structures such as log bars, root wads, and K dams can help the most vulnerable sections of the stream retain its sediment and enhance habitat by providing diversity of both substrate and flow velocity. Any work in the stream corridor should include removal of the abandoned culvert in Reach NR1.

<u>Further assessment needs.</u>

- *Fluvial geomorphological assessment.* Effective instream enhancement measures will require a detailed assessment of the stream channel by a qualified fluvial geomorphologist. The assessment would include recommendations on the location and design of any instream structures.

- *Culvert evaluation.* The four culverts with upstream passage issues should evaluated for potential mitigation.
- *Assessment of functionality of existing stormwater infrastructure.* Approximately one third of the non-residential developments along Route 1 have either stormwater detention basins or vegetated under-drained soil filters, both of which should provide some level of stormwater detention and, in the case of the filters, some removal of traditional pollutants (not chloride). Initial observation of these suggests that some, if not the majority, are not functioning as their design intended and that nearly all could be modified or enhances to provide more effective detention of stormwater. Evaluation of the potential of these systems for upgrades or modifications would be an important first step towards reducing flashy stormwater discharges to Norton Brook.
- *Additional monitoring.*
  - Biological monitoring. Collection and evaluation of macroinvertebrate samples in future years would help assess the recovery potential of the stream and document the effectiveness of any restoration efforts. Particularly, it would be beneficial to collect this information for some less droughty summers than 2002 and 2017. A wetter summer with shorter dry periods might increase the level of the primary current stressor (frequent disturbance of the substrate), but would increase baseflow velocity, habitat availability and dilution of chloride laden groundwater. Understanding how the community responded to such different conditions could provide additional guidance for protection and restoration efforts.
  - Specific conductance. Repetition of conductivity screening in various stream reaches and, if possible, continuous monitoring with data loggers will help evaluate if baseflow chloride toxicity is becoming a more or less important stressor.

Webes Creek

Webes Creek, also known as Webes Brook, is a 0.71 mile Class B stream that flows northeast in a valley between Route 1 and Foreside Road. It begins in a stormwater outfall in the northern corner of the Ace Hardware Parking lot off Route 1 and outlets into Mill Creek, about 750 feet upstream of the Foreside Road crossing. The lower 40% of the stream is subject to at least some tidal influence, including intermittently brackish water. The remainder is a free flowing, freshwater stream.

Watershed Characterization


Webes Creek - Reach WR1

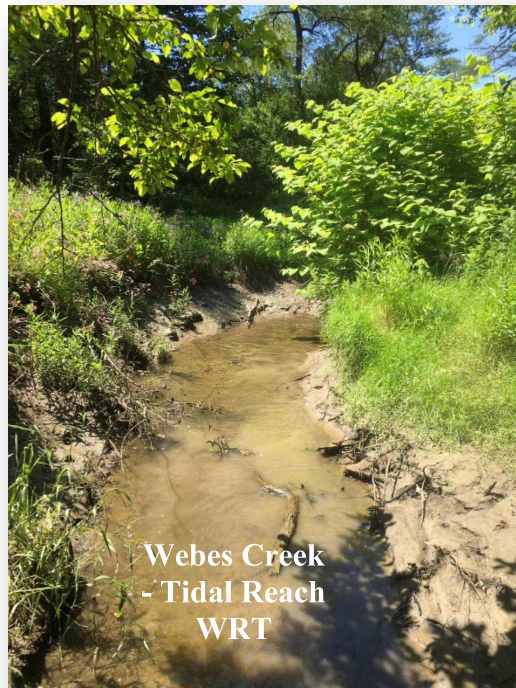
The Webes Creek watershed is bounded on the east by Foreside Road and the west by a low ridge that separates it from the Scitterygussett watershed. It extends from the Interstate 495 ramp south to the Volkswagen dealership and the northern edge of Foreside Estates. With 35% of its 337 acres covered by impervious surfaces it is the most densely developed watershed in Falmouth and one of the most densely developed watersheds in Maine. The large majority of this impervious area is found in the commercial, business and transportation land use along the Route 1 corridor. Residential land use along Depot Road and Foreside Road account for the remainder. Most of the non-residential development drains to the stream via one of three major outfalls: (1) a tributary that discharges to Webes Creek in its tidal reach and drains the most northern part of the Route 1 corridor, including the Bucknam Road intersection and most of the Shaw's Shopping Center parking lot; (2) a stormwater outfall/ditch draining the mid-portion of the Route 1 corridor that discharges into to Webes Creek just upstream of Depot Road; and (3) the stormwater outfall at which the stream originates that drains the southern portion of the Route 1 corridor.

Geologic and Topographic Setting

<u>Bedrock Geology, Surficial Geology and Soils.</u> The Webes Creek valley is bounded by metamorphic bedrock ridges on the east and the west. With the exception of some coarse marine deposits overlying glacial till on the top of the eastern ridge, the watershed is overlain with Presumpscot Formation marine sediments. As a result, the soils in the watershed are dominated by low permeability silt loams, with some small areas of very fine sandy loams.

Study Watershed Reach Names
Webes Creek

Stream Gradient and Substrate. The portion of the stream that appears to be subject to at least some tidal influence extends roughly 1600 feet (based on local observations) upstream from Webes Creek's confluence with Mill Creek. The amount of tidal influence varies dramatically within this reach, with the greatest and most frequent influence nearest the outlet to Mill Creek and only slight and infrequent influence (spring and/or king tides) in the most upstream portion. Stream gradient in this reach is very low, with a mean channel slope of 0.18 %. The substrate of the stream bottom in this reach ranges from gravelly sand over hard clay to silty sand over hard clay.
While the entire length of Webes Creek is low gradient, the mean channel slope of 0.70 % in the reach between "head of tide" and Depot Road is somewhat higher than the tidal reach. The substrate includes varied depths of gravel, gravelly sand, sand and silty sand over the underlying marine clay. There are a few places where the underlying hard clay is exposed.


Webes Creek - Tidal Reach WRT

Mean channel slope is slightly higher at 1.12 % in the uppermost reach of the stream between its stormwater outfall start and Depot Road. In the flattest part of this reach, just upstream of Depot Road, the substrate is a deep, soft mixture of sand, silt and clay. Gradient increases as one moves upstream where the substrate is gravel on hard clay.

Riparian Condition

The riparian corridor of Webes Creek consists principally of a shrub/scrub floodplain ranging in width from 40 feet to 100 feet. The floodplain is bounded by slopes that are covered in mixed forest except where development encroaches. With the exception of many invasive plants in the floodplain, the vegetation is natural except for:

- A stretch extending 500 feet upstream from a point 1250 feet upstream of the confluence with Mill Creek, in which landscaping from residential development along Foreside Road encroaches on the floodplain and the eastern slope
- A stretch extending 500 feet downstream of Depot Road and upstream to the headwater stormwater outfall where the corridor is altered by commercial development and, on the east side downstream of Depot Road, residential landscaping

Alders and other shrubs provide reasonable shade for much of the stream's length except in a few places where the stream channel is particularly wide, where landscaping extends to the channel itself, and in the most downstream half of the tidal reach where the floodplain is dominated by salt tolerant grasses.

Habitat

DEP staff conducted a stream walk on Webes Creek on June 28, 2019. Much of the following is a result of observations during that walk up the stream channel.

The habitat of Webes Creek has been altered in many ways. According to a person who has lived and worked adjacent to the stream all his life, the stream was channelized with a bulldozer in the 1950's. This is reflected in the non-tidal portions of the stream by the relative straightness of the channel for such a low gradient system, with limited meanders, usually in response to current or recent debris dams. The historic, and in part current, sewer line adjacent to the north side of the stream may also be confining channel movement. This results in a system with low habitat diversity. The substrate in the wetted channel ranges from silty sand, to sand, to gravely sand to gravel. Most if not all of this material is underlain by hard marine clay. The principal source of the deposited sand and gravel is likely from erosion of the stream's banks and the stream channel, though some of the sand may come from soil erosion in the watershed. While the sand and gravel could provide reasonable habitat for many of the macroinvertebrates (insects, crustaceans, mollusks) that would be expected in a free flowing freshwater stream, the quality and utility of this habitat is severely compromised by the high storm flows that the stream receives from its highly impervious watershed.

The sand and gravel substrate is in a state of frequent flux. This is evident from the nature of the sand bars in the channel as well as indirect observation. In August of 2019 the DEP deployed bags of rocks in the stream in order to evaluate the macroinvertebrates that would colonize the introduced substrate. When the bags were retrieved after a four week deployment, they were buried in sand and therefore useless for evaluation, indicating that sand is moving freely in the system and the habitat it provides is not stable. During the period of deployment there were two significant, but not exceptionally large storm events (1.8 and 1.4 inches, Portland Jet Port). Storms of this magnitude are not infrequent, and the amount of sand movement evident during the deployment period suggests that organisms trying to live in or on the substrate could be washed downstream with the sediment.

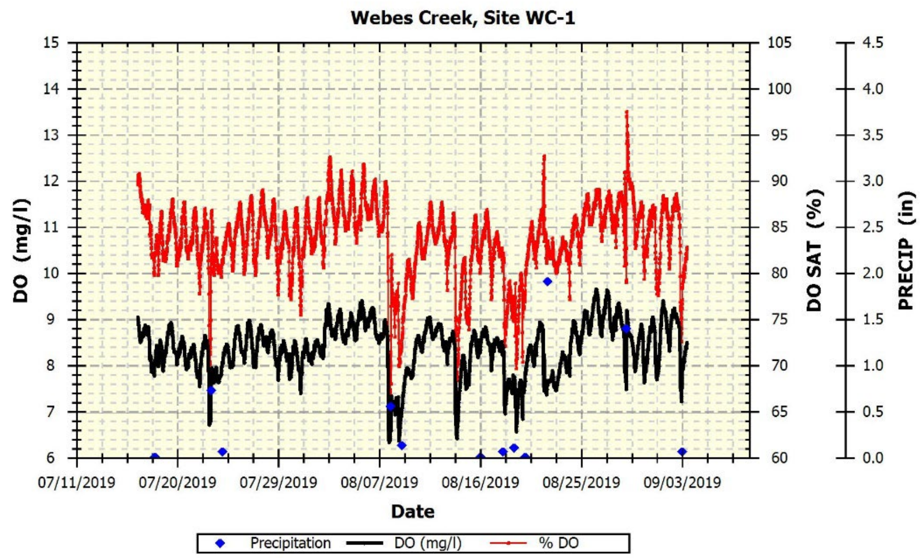
In addition to the physical alterations of the channel discussed above, habitat is compromised by extremely low baseflow during periods of extended dry weather, and a general lack of diversity in baseflow velocity in some stretches. The watershed is small and highly impervious, so low baseflow is to be expected, especially given the frequency of relatively dry summers in recent years.

Water Quality

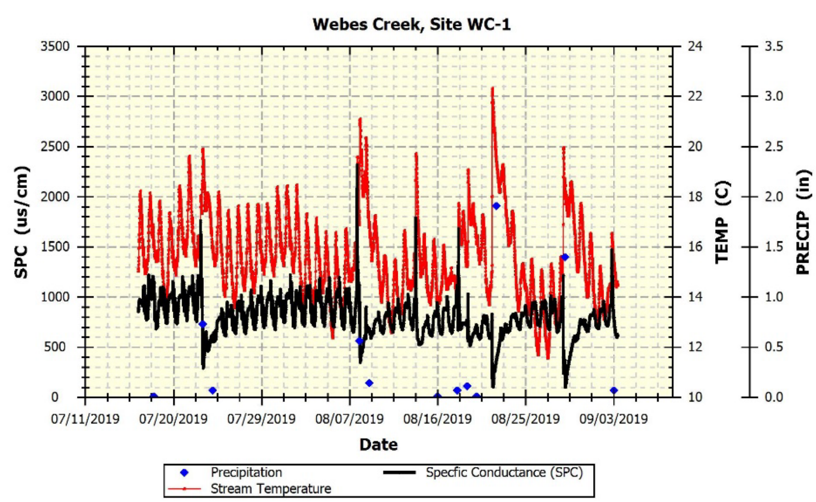
Temperature, dissolved oxygen and specific conductance were monitored during the June 28th stream walk and with continuous data loggers at Site WC-1 that recorded measurements every 15 minutes from August 6, 2019 to September 3, 2019, while the data loggers were deployed.

<u>Temperature.</u> During the June 28, 2019 stream walk water temperature ranged from 16˚C to 20˚C, with the warmest temperature just downstream and upstream of Depot Road where shade is limited. The continuous logger data in August generally indicated daytime high temperatures between 15˚C and 18˚C, with early morning temps 3 to 4 degrees lower. During storm events temperature spiked to 20˚C or higher, usually dropping to 18˚C or cooler within a day or less.

Dissolved Oxygen. Daytime DO measurements collected during the stream walk were above the Class B standard of 7 ppm except for two readings taken upstream of Depot Road that were 6.3 ppm and 6.8 ppm. DO concentrations from the August logger data generally ranged from 7.5 to 9.5 ppm with diurnal swings of only 0.5 to 1.5 ppm, suggesting only minimal oxygen loss due to algal respiration. DO drops slightly below 7.0 ppm for short periods during storm events. This may be a function of flushing of lower DO water from upstream wetlands and detention basins or it may simply be associated with the warmer temperature of the stormwater runoff.



Specific Conductance/Chloride.
In urban and urbanizing streams, the most likely cause of elevated baseflow specific conductance (SPC) is chloride because of the high amounts of deicing salts that are applied in the watershed and the fact that, unlike most other ions, chloride is not attenuated in the soil. The chronic toxicity threshold for chloride is 230 mg/l according to EPA's Water Quality Criteria. Correlation of SPC and chloride measurements from other urban stream watersheds indicate that this threshold is likely to be exceeded if SPC is greater than 900 µs.
The SPC continuous logger measurements for Webes Creek taken at at Site WC-1 illustrate several interesting phenomena that support this assertion. To put the following discussion in perspective, the SPC typical of natural streams is +/- 100 µs. During periods of dry weather and low baseflow SPC exhibits daily diurnal swings between 700 µs and 1200 µs. The highest values occur in the evening, peaking around 10:30 PM, the lowest around 6:00 AM. This suggests that high conductivity groundwater from the upper developed part of the watershed is being diluted by lower conductivity groundwater from less developed areas downstream. During the day evapotranspiration by flood plain vegetation is reducing the amount of dilution provided, so



conductance rises. Overnight, the groundwater flow into the stream from the floodplain recovers, dilution increases and conductance drops.

When a storm event occurs there is an initial, very short-term spike in conductance to as high as 2,600 µs. This spike is immediately followed by a precipitous drop to very low SPC, around 200 µs and a less steep rise over a period of two to three days to the baseflow equilibrium diurnal swing SPC. The initial spike in conductance indicates that, during the period between storms, high conductance groundwater has seeped into the stormwater infrastructure in the upper watershed. It is immediately flushed out of the stormwater system with the first runoff, after which it is followed by low conductivity stormwater. The magnitude of the spike correlates with the time period between storms – the longer the period the more high conductivity groundwater can seep into the storm sewer system and the higher the SPC spike. During the days after the storm the stream gradually returns to a groundwater dominated system.

Specific conductance was measured at 12 sites during the June 28, 2019 stream walk at a time between storm events when the stream was at a low baseflow. SPC measurements during the stream walk ranged from 733 µs above head of tide near the logger station at Site WC-1 to 1047 µs about 400 feet downstream of Depot Road and all measurements upstream of the logger station exceeding 900 µs. These readings were taken between 10:00 AM and 2:00 PM near the midpoint of the logger data's diurnal swing, so the peak values for the day were probably 200 to 300 µs higher.

Nutrients, Metals and Hydrocarbons. No data has been collected on these typical stormwater pollutants. However, given the large amount of road surface and parking in the watershed, there is no doubt that the concentrations of phosphorus, nitrogen, heavy metals and some hydrocarbons are at least somewhat elevated during the first flush of intense storms.

Biological Condition

Rock bags were deployed to collect a sample of the macroinvertebrate community in Webes Creek at station WC1 for four weeks in August 2019. Unfortunately, during the deployment the bags were buried in the sandy substrate and were not able to be used as valid samples. While there is no direct data on which to base an evaluation of the biota in the stream, the fact that at the end of the deployment period the bags were buried in approximately six inches of sand suggests that the community is likely impaired. It is likely that this is a result of a combination of (1) erosion of sediment beneath and around the bags that allowed them to sink into the substrate during a period of high storm flow and (2) deposition of sand, probably later in the storm event, that covered the bags and the eroded area. This combination of erosion and sedimentation indicates that a substantial amount of substrate is being disturbed and washed downstream, where it is later deposited. This disturbance is also likely to wash the biota living in the substrate downstream as well. During the period of deployment there were two storms events that exceed 1.0 inch (1.8 in and 1.4 in) at the Portland Jetport. Storms of this magnitude occur frequently. In the 12 month period from September 2018 thru August 2019 there were 18 storms with ≥ 1.0 inch of rain, 8 with ≥ 1.5 inches and 3 with ≥ 2.0 inches recorded at the Jetport. Such frequent disturbances of the substrate make it difficult for macroinvertebrates with annual life cycles (e.g. mayflies, stoneflies and caddisflies) to survive. The very high amount of impervious area (35%) in the watershed results in dramatically higher stormflows for any given storm event than the stream channel would otherwise receive.

Likely Stressors to the Biological Community

Current Stressors. The habitat, water quality and biological information discussed above strongly suggest that (1) neither temperature or low dissolved oxygen are significant stressors to the biological community and (2) at least three stressors – frequent disturbance of habitat, baseflow chloride toxicity and low baseflow velocity – are currently impacting the biota of Webes Creek.

- *Frequent disturbance of the substrate.* Evidence from both the habitat assessment during the stream walk and the buried rock bags indicate that the predominantly sandy substrate of Webes Creek is being disturbed and transported during moderate and frequent storm events. This type of unstable habitat greatly limits the composition and diversity of the macroinvertebrate community as well as the quality and abundance of food available for resident fish.

- *Baseflow chloride toxicity.* Both the stream walk and logger SPC data suggest that during extended low baseflow the chloride concentration in Webes Creek, for half, if not most of the day exceeds the 230 mg/l threshold for chronic toxicity. It is likely that this is having an impact on biota in the stream that are sensitive, which includes a lot of the macroinvertebrates that normally inhabit freshwater streams.

- *Very low baseflow.* The very low baseflow discussed in the Habitat section reduces the velocity of flow to the point where many of the insects that rely on stream flow to deliver food to their nets or pass oxygen over their gills cannot be supported. During wetter summers than 2015 to 2019, this stressor may not have much effect on the community, but in dry summers it probably at least exacerbates the effect of other stressors. Some of this low baseflow is natural because the watershed is small and much of it is underlain with marine clay which has only limited groundwater storage potential. This natural limitation is exacerbated by the addition of large impervious areas which prevent any significant infiltration of rainfall.

- *Other likely stressors.* Conventional pollutants associated with stormwater from highly impervious urban areas include nutrients, heavy metals and hydrocarbons. Though these have not been monitored in Webes Creek, it is likely that the runoff from the watershed's parking lots has relatively high concentrations of these.

  Observation of the stream and the fact the there is only a slight diurnal swing in dissolved oxygen concentrations suggest that growth of algae in the stream is not an issue, but this may be a function of effective shade over much of the channel and not of low nutrient levels. Loss of shade might result in sufficient algal production to reduce night time DO to that point that it becomes a stressor.

  Though many of the metals and hydrocarbons will be quickly transported to Mussel Cove during significant storm events, some may accumulate in the silty sand sediments found in the lowest gradient sections of the stream. These could have a toxic effect on sensitive insects trying to live in the substrate.

Potential Future Stressors. Given the fact that the watershed of Webes Creek is already quite urban, most of the stressors associated with urban watersheds are already in play. While there are no obvious new stressors that are of concern, it is likely that the watershed will continue to develop, and additional impervious area and the increased storm intensity associated with climate change could substantially increase the impact on the biological community from the two most important current stressors (frequent disturbance of substrate and baseflow chloride toxicity) unless the new development incorporates, to the greatest extent possible, measures to minimize these stressors.

Stressors associated with downstream watersheds – Mussel Cove

- *Nitrogen.* Webes Creek is a tributary to Mill Creek which in turn drains to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. Addition of any of the following land uses to the Webes Creek watershed has the potential to exacerbate the impairments to the stream's biota:

- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage.
- Any new impervious area that has deicing salts regularly applied to it, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Low density, single family residential development will have significantly less potential impact because it is not likely to discharge as much runoff or use as much salt as the above listed uses. Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Webes Creek watershed:

Commercial, Institutional, Office, Multi-family Residential

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
  - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
  - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Resource Protection and Restoration.

- *Shoreland Zoning*. Below Depot Road, most of immediate riparian area adjacent to Webes Creek is covered with natural, though not necessarily native, vegetation and, for most of its length it is well shaded. Maintaining this natural corridor is essential to prevent any further impairment of the biological community and to allow recovery of the stream from its current stressors. Webes Creek is not currently designated for protection under the Falmouth shoreland zoning ordinance. It should be zoned to prevent new development and significant disturbance of the vegetation within no less than 100 feet of the stream. Ideally this standard would also be applied to the tributaries, particularly the ones that have at least some flow in the summer.

- *Instream habitat enhancement.* In addition to attenuation of high stormflow discharges from intensely developed areas, it will likely be necessary to take measures to increase substrate and habitat stability in the stream channel. Strategic placement of simple structures such as log bars, root wads, and K dams can help the most vulnerable sections of the stream retain its sediment and enhance habitat by providing diversity of both substrate and flow velocity. The potential for enhancement will likely be limited by restrictions to access and low stream gradient.

<u>Further assessment needs.</u>

- *Fluvial geomorphological assessment.* Effective instream enhancement measures will require a detailed assessment of the stream channel by a qualified fluvial geomorphologist. The assessment would include recommendations on the location and design of any instream structures.
- *Assessment of functionality of existing stormwater infrastructure.* Some of the more recent developments in the Webes Creek watershed incorporate stormwater management practices, particularly stormwater detention. Evaluation of the potential of these systems for upgrades or modifications would be an important first step towards reducing flashy stormwater discharges to Webes Creek.
- *Additional monitoring.*
    - Biological monitoring. Some evaluation of macroinvertebrate community in future years would help assess the recovery potential of the stream and document the effectiveness of any restoration efforts. It may be necessary to use a different sampling method than the rock bag deployment given the apparent magnitude of sand movement in the stream. It would be beneficial to collect this information for at least one future droughty summer and one wetter summer. A wetter summer with shorter dry periods might increase the level of the primary current stressor (frequent disturbance of the substrate), but would increase baseflow velocity, habitat availability and dilution of chloride laden groundwater. Understanding how the community responded to such different conditions could provide additional guidance for protection and restoration efforts.
    - Specific conductance. Repetition of conductivity screening in various stream reaches and, if possible, continuous monitoring with data loggers will help evaluate if baseflow chloride toxicity is becoming a more or less important stressor.

Chenery Brook

Chenery Brook is a 4.0 mile long stream that starts in the town of Cumberland as an intermittent swale in the power line just north of Tuttle Road. After crossing Tuttle Road it drains south through forest passing the western end of the Butterworth Farm Road before turning southeast and crossing Middle Road. A short distance downstream of Middle Road it turns south-southwest and parrallels the railroad track until, just downstream of the Falmouth town line it turns southeast and passes under the tracks. It then flows southwest in the confined valley between the railroad and Interstate 295, crossing Johnson Road and the interstate just upstream of its confluence with Mill Creek. Approximately 40% of the stream's length and 25% of its watershed are in town of Falmouth, with the remainder in Cumberland.

Watershed Characterization

Chenery Brook – Reach CR2

Chenery Brook's approximately 1300 acre watershed is mostly forested with relatively light single family residential land use. Only 7% of the watershed is covered with impervious surfaces and approximately one third of that is Interstate 295. The interstate and the railroad are both prominent features that confine the valley in which much of the stream flows.

Geologic and Topographic Setting

<u>Bedrock Geology, Surficial Geology and Soils.</u> The Chenery Brook watershed is underlain by metamorphic rocks of the Hutchins Corner Formation. The stream valley is overlain by Presumpscot formation marine clay. It is bounded on the east by a ridge that separates the Chenery and Norton Brook watersheds and on the west by the ridge that separates the Chenery and Mill Creek watersheds. Both ridges are covered with a thin layer of glacial till. The marine clay that underlies the stream channel is mostly covered by alluvial sands, silts and rarely gravel. The soils in the watershed generally reflect the underlying parent material with silt loams and very fine sandy loams in the valley and coarser sandy loams and loamy sands on the ridges.

Figure 5. Chenery Brook Watershed and Study Reaches.

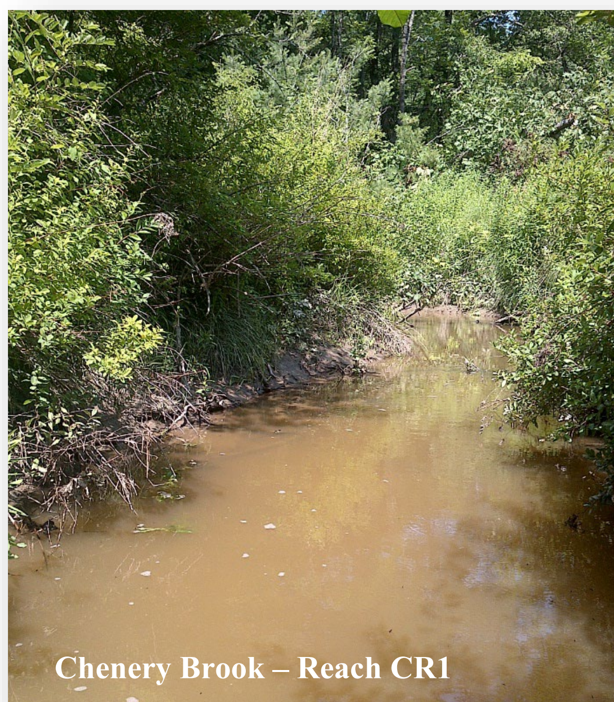
Stream Gradient and Substrate. For most of its length between Middle Road and head of tide at the I 295 crossing, Chenery Brook is a very low gradient stream with mean channel slopes of 0.2% except in three short drops – downstream of Middle Road, downstream of the railroad crossing and just upstream of Johnson Road. The drop at Johnson Road is enhanced by a man-made boulder and cobble dam which impounds a deep, very slow run for approximately 1,000 feet upstream. Substrate in the channel ranges from bare marine clay in some riffles to silty sand and sand in the slower reaches which account for the majority of the stream, to gravel and some cobble in the somewhat steeper sections.

Riparian Condition

With the exception of some fields in the headwater reach and a few spots where residential landscaping encroaches in Cumberland, the entire length of the Chenery Brook is bounded by natural riparian vegetation. Where the bottom of the valley floor is narrow the riparian cover is dominated by forest. In places where the valley is broad riparian cover includes more shrub-scrub or meadow floodplain wetland. This is the case for most Reach CR3, which extends about 4,000 feet upstream from the railroad crossing, and is partially located in a power line corridor where large woody vegetation is discouraged.

Habitat

This habitat assessment is not as detailed as the Norton Brook and Webes Creek assessments because a walk of the entire stream channel was was not performed. The assessment is based on observations at a number of key sites along the stream corridor.


Chenery Brook – Reach CR1

Reach CRT. This tidal reach extends from the confluence with Mill Creek up to the I 295 culvert. The substrate is principally silty sand on marine clay. The channel is somewhat incised as is typical in tidal reaches.

Reach CR1. This is a very low gradient reach between the I 295 crossing and Johnson Road. It meanders through forest and flood scrub wetlands that provide much but not complete shade to the channel. The stream is incised in places with high banks, particularly on the outside of meanders, so access to the floodplain is not always available. It has typically long, slow runs with relatively rare riffles. The substrate is a mixture of sand bars and silty sand over clay, with the hard clay exposed in many of the riffles. Some diversity in habitat and velocity is provided by woody debris, which is present but not abundant.

Reach CR2. Most of Reach CR2 is very low gradient except immediately upstream of its beginning at Johnson Road and immediately downstream of its upstream terminus at the railroad crossing. The man-made dam upsream of Johnson Road impounds a long, relatively deep run, depriving the stream of habitat and flow diversity for for nearly 1,000 feet. The valley between the interstate and railroad is narrow and fairly steep in this reach so riparian cover is mostly forest and the stream is well shaded. The stream meanders less in this reach and the floodplain is limited because of the steep valey slopes. Substrate in the long, slow run is silty sand on clay with little habitat diversity except that created by woody debris. Substrate above the run is a mix of sand, sand bars and some gravel in the riffles with much greater habitat and flow diversity.

Reach CR3. Most of this reach, which extends upstream from the railroad crossing to a foot bridge adjacent to residential development on Shirley Lane, consists of a low gradient stream that meanders through a broad, 75 to 150 foot wide shrub-scrub and meadow wetland. Stream banks are steep and sometimes quite high where the outside of the meanders meet the steep slope of the valley on the west or the wooded slope created by fill for the railroad on the east. Shade is limited due to the nature of the flooplain vegetation and, for some of the reach, by the control of woody vegetation resulting from managment of the power line corridor. The bottom substrate appears to be mostly sand on marine clay with typical meander bar formation and hard clay exposed in higher velocity stretches on the outside of the some meanders.

Chenery Brook – Reach CR3

Reach CR4. For much of Reach CR4, which extends from the footbridge to the Middle Road Crossing, habitat is similar to Reach CR3, with the stream channel meandering in a broad, mostly shrub-scrub valley except where landscaping encroaches on the east. In a stretch extending 1,000 feet downstream from Middle Road the valley narrows and the gradient steepens. In this section substrate is coarser, with gravel, sand, and some cobbles; shade is consistent because of the forest riparian cover; and both habitat and flow diversity increase.

Reach CR5. No direct observations were made of habitat in this reach. Habitat is likely very similar to uppermost section of Reach CR4, but due to the very small watershed, the stream likely has little or no flow during extended dry periods.

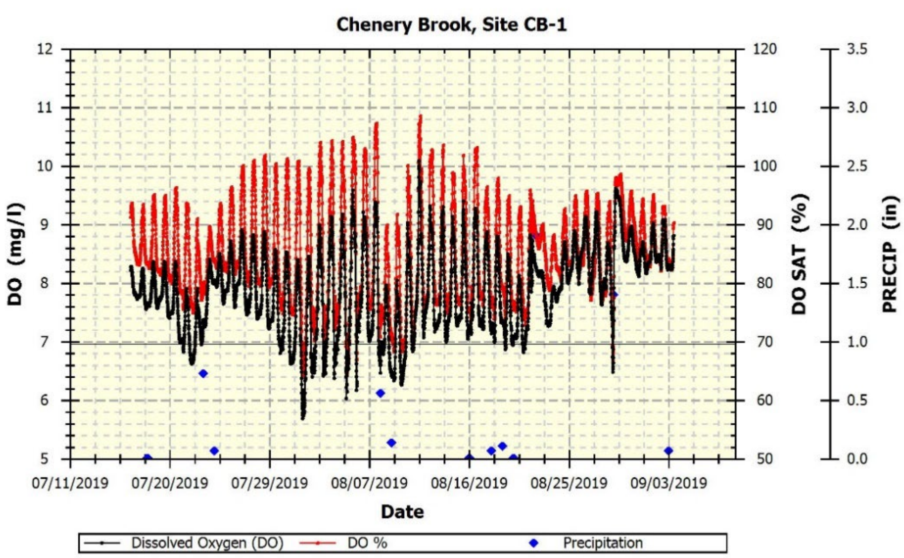
All non-tidal reaches. Though the Chenery Brook watershed is not that small (about 2 square miles) observation of the stream during a very dry period in 2018 showed very little flow, particularly in the upper reaches. This limits both the velocity of flow and the availability of wetted substrate. These particularly low flows are likely due to the shallow to bedrock till and silty marine clay soils that cover the watershed, neither of which have the ability to store much groundwater, thus limiting the volume of baseflow in extended dry periods.

Water Quality

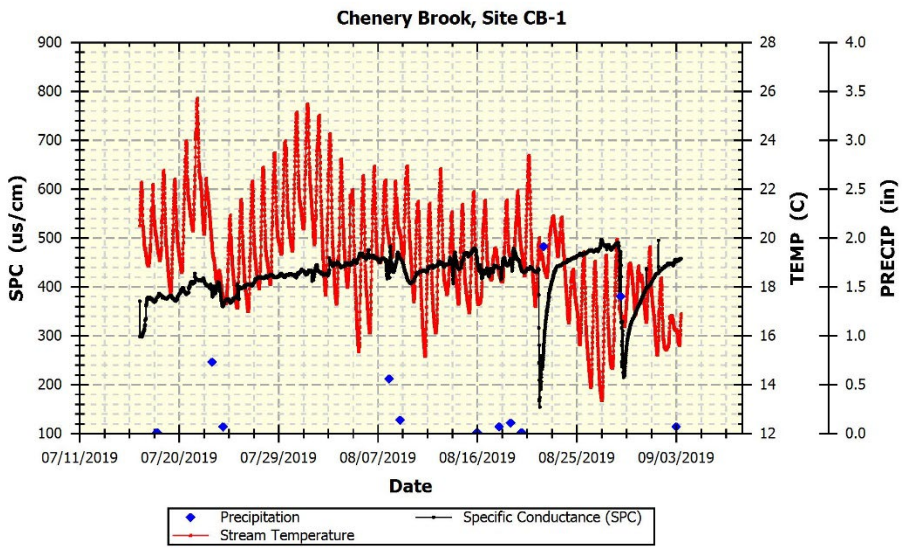
Data loggers were deployed at a site approximately 1,500 feet downstrem of Johnson Road from July 16, 2019 to September 3, 2019. The loggers recorded temperature, dissolved oxygen and specific conductance at 15 minute intervals over that period.

Temperature. For much of the time that the data loggers were deployed, daytime temperatures in Chenery Brook exceeded 20˚C, and rose to over 24˚C on several days in late July and early August. These high temperatures are likely due to 1) the fact that shade is limited in many places upstream of the site due to the shrub/scrub/meadow, as opposed to forest, vegetation on the floodplain; and 2) the low velocity of baseflow in these low gradient reaches allows a long period of exposure in unshaded areas.

Dissolved Oxygen. From July 30 to August 11 night time dissolved oxygen concentrations dropped below the 7.0 ppm Class B water quality standard. This coincided with large diurnal swings of 2.0 to 3.5 ppm, indicating that the low nighttime DO was a result of periphytic algal respiration. Some growth, though not excessive growth of filamentous algae was observed upstream of the site. This suggests that nutrient levels in the brook are high enough to support significant algal production under optimal conditions and that shade is insufficient to limit that production.



Specific Conductance. During logger deployment, specific condutance at the logger station ranged between 400 µs and 500 µs, except dutring and immediately after the two largest rain events, when it dropped to around 200 µs. While these values do not suggest chloride levels that are high enough to be problematic by themselves, the fact that conductance decreases when baseflow is diluted by stormwater runoff indicates that most of the conductivity, and likely chloride, in the stream is from groundwater sources. The biggest source of chloride in the watershed is deicing salt applications on I 295, and infiltration of meltwater on the inslopes and swales that drain the road surface may explain why conductance is significantly higher than would be expected in a more natural watershed.



Biological Condition

During August of 2019 rock bags were deployed near the logger station to sample the macroinvertebrates (insects, crustaceans, worms and mollusks) living in Chenery Brook. Unfortunately, the taxonomic evaluation of these samples is not yet completed, so there is little known about the health of the stream's biological community at this point. When data becomes available this report will be updated.

Stressors to the Biological Community

Current Stressors. The water quality data and habitat analysis suggest that two stressors are currently impacting Chenery Brook's biota. These are likely to be most significant in the slower reaches without forest riparian cover and include lack of diversity in habitat and flow, and low baseflow velocities.

- *Lack of habitat and flow diversity.* The low gradient of much of Chenery Brook results in many long runs with uniformly sandy substrate on hard clay. In these runs the only variation in flow and substrate is provided by large woody debris and debris dams. The non-forested nature of the flooplain riparian cover in many of these runs limits the amount of woody debris that is deposited in the channel and its associated habitat diversity. Though we do not yet have data to confirm this, it is likely that this lack of variation in habitat in turn results in macroinvertebrate and fish communities that are limited to taxa that do well in low velocity and sand/silty sand substrates.

- *Low baseflow velocities.* As discussed in the habitat section, baseflow in Chenery Brook during extended periods of dry weather can get very low. The resultant extremely low velocity in runs and very limited wetted bottom in riffles renders much of the stream uninhabitable by many of the taxa native to Maine free-flowing streams. As a result of climate change, droughty summers are becoming more frequent so this stressor, which is otherwise a function of natural stream coniditions, is likely to become even more limiting.

Potential Future Stressors.

- *Diurnally depressed dissolved oxygen.* The amount of periphytic algae in streams is limited by the avalability of light and nutrients. The relatively large swing in durnal DO discussed in the water quality section indicates that both light and nutrients are currently sufficient to support significant algal production in Chenery Brook. At this point the dirunal depression of DO does not drop low enough to be a serious stressor on the stream's biota. However, if either nutrient levels increased or shading of the stream channel decreased in the future, dirunal depletion of DO might result in loss of many taxa from the community.
- *Baseflow chloride toxicity.* With the exception of the interstate and the railroad, land use in the Chenery Brook watershed is mostly relatively sparse single family residential and forest, neither of which result in high levels of contamination of the groundwater with chloride. As long as this land use pattern continues it is unlikely that baseflow chloride concentration will rise to a level that is problimatic, but if land use were to shift toward commercial, institutional or office development the apparently small volume aquifer that feeds baseflow could become contaminated and salt intolerant stream biota could be lost.

- *Frequent disturbance of the substrate.* Because of the relatively low impervious cover in the Chenery Brook watershed, the current storm flow regime in Chenery Brook is close enough to natural that movement of the sand substrate in the stream, while more frequent than in streams with coarser, less erodible substrates, is likely not preventing maintenance of a healthy macroinvertebrate community. If highly impervious watershed development in concert with the more intense and frequent precipitation associated with climate change resulted in substantially higher and flashier stormflows, the frequency of disturbance of the sandy substrate could result in impairment of the stream's macroinvertebrate community. Specifically, it would likely shift the biota from taxa with annual life cycles (e.g. stoneflies, mayflies and caddisflies) to taxa with much shorter life cycles (e.g. midges, crustaceans).

Stressors assciated with downstream waters.

- *Nitrogen.* Chenery Brook is a tributary to Mill Creek which in turn drains to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. Substantial addition of any of the following land uses to the Chenery Brook watershed has the potential to degrade the stream's biota:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to dramatically increase nutrient levels in the stream, resulting enhanced algal production and lower night time dissolved oxygen.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could also elevate stream nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of the stream channel.
- Large impervious areas that have deicing salts regularly applied to them, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Falmouth's current zoning in the watershed prevents some of these land uses. The exception is the land between I 295 and the railroad, which is zoned as Business and Professional. This area is the stream corridor for much of Chenery Brook in Falmouth, and, because of steep slopes and/or floodplain, is largely unsuitable for this type of development. Rezoning of this area to more compatible land uses should be considered.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Chenery Brook watershed:

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:

  - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
  - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Agriculture. Although it is unlikely that significant commercial agriculture will be established in the Chenery Brook watershed, the following practices should be required to minimize export of nutrients to the stream if such land use is proposed:

- Commercial livestock or horse operations
  - incorporate conservative manure management practices
  - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
  - incorporate practices which minimize soil loss from cultivated fields
  - distribute runoff from cultivated areas into adjacent natural buffers

Commercial, Institutional, Office, Multi-family Residential. If zoning in the watershed is altered to allow significant development of this type, the following practices should be required, or at least encouraged.

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Resource Protection and Restoration.

- *Shoreland Zoning.* Maintaining this natural corridor of Chenery Brook is essential to preventing impairment of the stream's biota. Chenery Brook is not currently designated for protection under the Falmouth shoreland zoning ordinance. Its corridor should be zoned as stream protection to prevent significant disturbance of the vegetation shade and terrestrial habitat adjacent to the stream.
- *Instream habitat enhancement.* The lack of habitat and flow diversity in the lower gradient reaches of Chenery Brook could be addressed by strategic additions of large wood in the stream channel. These could both provide additional substrate for colonization by macroinvertebrates and improve the diversity of flow velocity in the long runs. The potential for enhancement may be limited by restrictions to access and low stream gradient.

Further Assessment Needs. The results, when available, of the macroinvertebrate samples collected in 2109 may point to a need for additional assessment of the stream and its corridor. If the macroinvertebrate community appears to be already under significant stress, more data may be needed to characterize the source and scope of the stressor(s) that are indicated. As conditions in the watershed change due to new development, monitoring should be repeated to see if the stream or its biota have been altered.

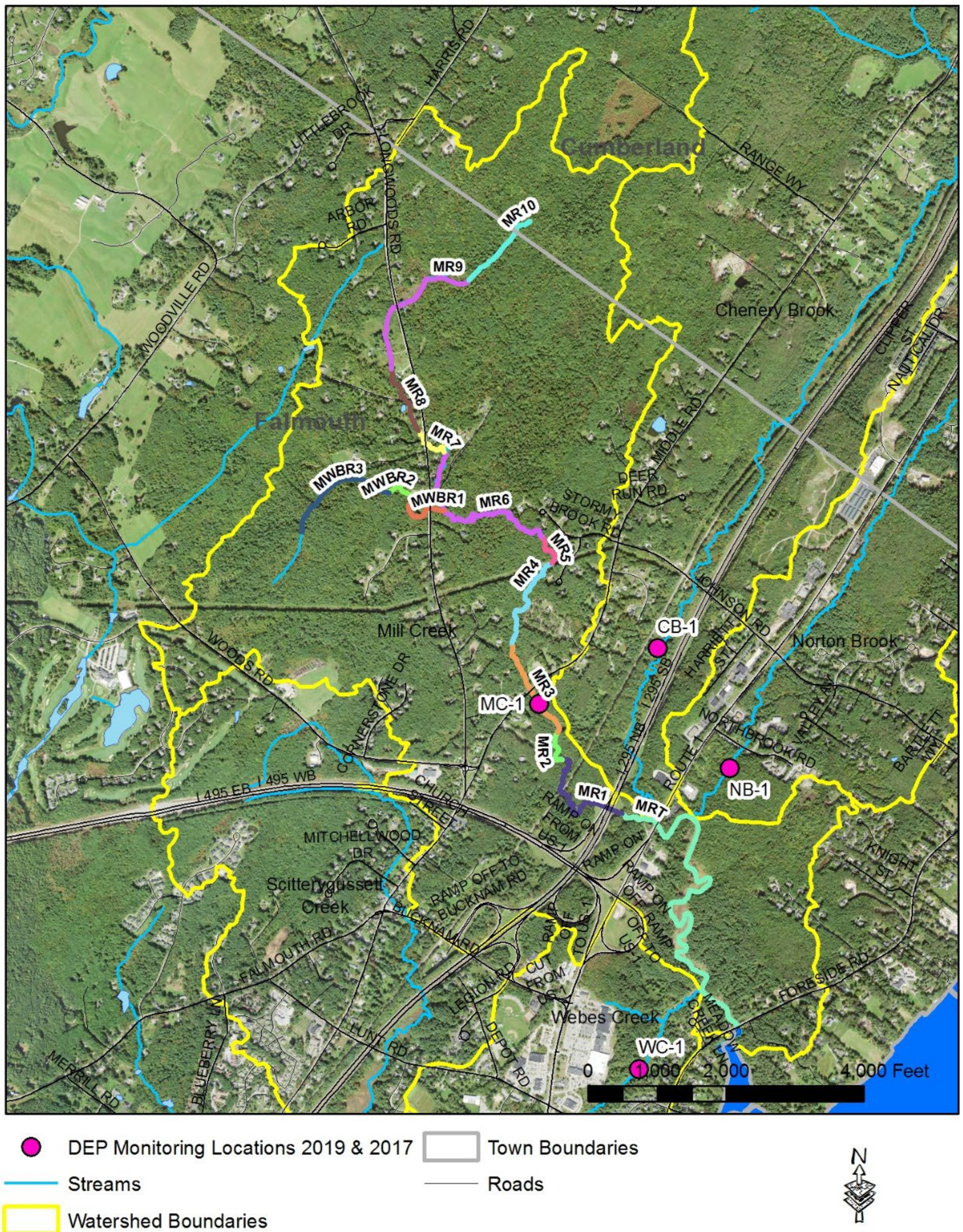
Mill Creek

Mill Creek is a 3.7 mile long Class B stream with its headwaters in a mix of forested uplands and wetlands just northeast of the Falmouth/Cumberland boundary and roughly 2000 feet east of the junction of Longwoods Road and Arbor Road. It flows west southwest until it crosses Longwoods Road where it turns south for approximately 2000 ft before re-crossing Longwoods Road near Paddington Way. The stream continues south along the east side of Longwoods Road until it is joined by the smaller west branch just downstream of Thomas Way, at which point it drains east and then south through the forest between Longwoods and Middle Roads. It crosses Middle Road approximately 0.5 miles south of the Johnson Road intersection and continues in a southerly direction until it turns east and crosses first the railroad and then I 295, at which point it becomes tidal. It is joined by Chenery Brook just upstream of its Route 1 crossing, and then by Norton Brook 700 feet downstream of the crossing. It then meanders in a southerly direction until it is joined by Webes Creek 750 feet upstream of the Foreside Road bridge. Just downstream of the bridge Mill Creek drains into the upper mudflats of Mussel Cove.

Watershed Characterization

The total watershed area of Mill Creek in 3,485 acres (approximately 5.5 square miles). If the sub-watersheds of Norton Brook, Chenery Brook and Webes Creek are discounted, the remaining watershed area (its direct watershed), including portions that drain to the tidal sections upstream of the Foreside Road Bridge, is 1,345 acres. Land cover in the direct watershed is mostly forest with moderately dense single family residential development associated with Longwoods Road and Middle Road, as well as a section of I 495 and portions of the 495 and Bucknam Road interchanges. Only 6.0% of the direct watershed is covered with impervious surfaces, 25% of which are associated with the interstates and their interchanges. While the % impervious area in the direct watershed remains fairly low – it is the lowest of the four Mussel Cove tributary streams – imperviousness has increased from 4.7% to 6.0% in the period between 2004 and 2018, and virtually all of this growth was associated with residential development (including associated roads and driveways), reflecting an increase of at least 30% during that timeframe in residential land use.

Study Watershed Reach Names
Mill Creek



Geologic and Topographic Setting

Bedrock Geology, Surficial Geology and Soils. With the exception of a small area in the vicinity of Route 1, the direct watershed of Mill Creek is underlain by metamorphic rocks of the Hutchins Corner Formation. The tidal portion of the stream valley is covered by the marine clay of the Presumpscot Formation. It is bounded on the east by a ridge of reworked terminal moraine deposits of sand and silt and on the west by the Webes Creek sub-watershed. Nearly all of the portion of the watershed that drains to the free flowing stream upstream of I 295 is overlain with a thin layer of glacial till. The exception to this is a finger of marine clay deposits that extend up the relatively confined stream valley to the vicinity of Chandler Drive and Stormy Brook Road. Soils in the upper watershed are mostly shallow to bedrock till soils.

Stream Gradient and Substrate. Unlike the other Mussel Cove tributaries, the gradient of Mill Creek's channel is highly varied, with several fairly steep drops. Going upstream from the Foreside Road Bridge the tidal portion of the channel is very low gradient with a mean slope of 0.1%. Above the interstate the slope increases slightly to 0.3% as the stream passes under the railroad. It remains low gradient for roughly 600 feet upstream of the railroad crossing, where the channel suddenly steepens in a series of bedrock and boulder cascades in which it gains 30 feet of elevation in 200+ feet. Upstream of the cascade gradient moderates, ranging from 0.5 to 2.0% with variably frequent riffles as the stream crosses Middle Road and continues up to the vicinity of Stormy Brook Road, where gradient increases to 3.5% in a series of short ledge drops. Upstream of this the gradient of the main stem is quite low to the headwaters, ranging between 0.25% and 0.95%, with the exception of a short, somewhat steeper section just downstream of the Longwoods Road crossing. The channel slope of the West Branch is also fairly low, around 0.5%, except for a steep section 600 to 1000 feet upstream of Longwoods Road.

Riparian Condition

Within the tidal reach much of Mill Creek passes through tidal wetlands, and in these areas riparian cover is natural wetland vegetation. In the upper portion of this reach and in the remaining free flowing reaches of the stream the riparian cover is natural forest except in the immediate vicinity of the road and interstate crossings and in the reaches where the stream parallels Longwoods Road where some of the residential yards extend into the riparian area.

Habitat

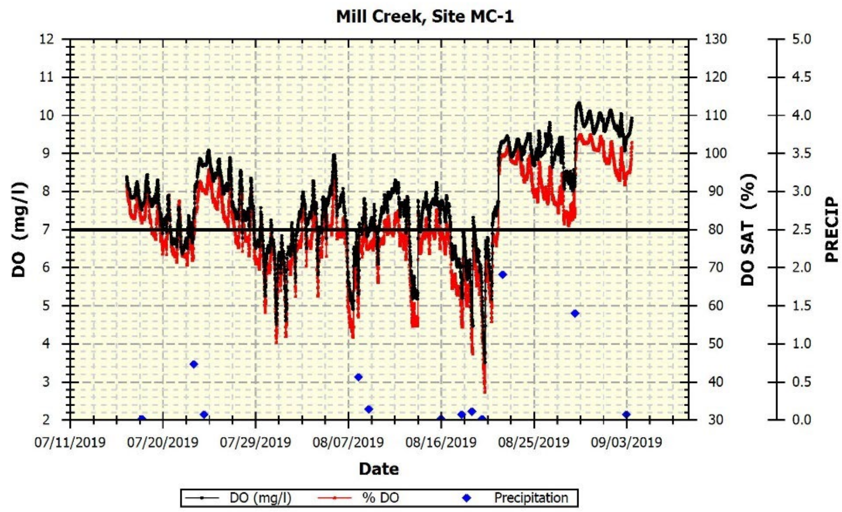
This habitat assessment is not as detailed as the Norton Brook and Webes Creek assessments because a walk of the entire stream channel was was not performed. The assessment is based on observations at a number of key sites along the stream corridor. While no comprehensive assessment of the in-stream habitat in Mill Creek has been performed, it appears that, with the exception of the road, interstate and railroad crossings, the condition of the habitat is mostly natural. In the tidal reach the substrate in the channel is mostly sand and silty sand on marine clay. In the remainder or the stream, substrate varies with gradient and underlying surficial geology, with the steepest reaches (MR2 and MR5) principally cascade/pool habitat with bedrock, boulders and cobbles. The moderate gradient reaches (MR3, MR7 and MWBR2) have mostly riffle/run habitat with an occasional pool, and with cobbles and some boulders in the riffles and a mixture of sand, gravel and cobbles in the runs. The lower gradient reaches (MR1, MR4, MR6, MR8, MR9, MR10, MWBR1 and MWBR3) have riffle/run habitat with the length of run between riffles increasing and the coarseness (sand and gravel, sand, silty sand) of the substrate decreasing as channel slope decreases.

While the physical condition of most of Mill Creek appears to be natural with little evidence of instability or anthropogenic alteration, the baseflow hydrology may limit the biological community. The summer of 2018 was droughty with very infrequent precipitation. This was also true, though to a lesser degree in the late summer of 2019, and in the summers from 2014 to 2017. In early September of 2018 the sand and gravel reach in the main stem east of Longwoods Road just upstream of the confluence with the West Branch was observed to be so dry that, while there was some water in the pools, runs between the pools were completely dry with only some subsurface (hyporheic) flow. In the pool/riffle/run reach downstream of Middle Road there was only a trickle of surface flow between the pools. In August of 2019, conditions at these sites were similar to 2018, though not quite as extreme. In both years, the available habitat for the inhabitants of the stream that require flowing water was virtually non-existent, at least in these two reaches. While the watershed above the upstream site is fairly small (0.6 square miles), it is surprising that the flows drop so low at the lower Middle Road site which drains nearly 1.5 square miles. Some of this is probably natural given the limited groundwater storage in the shallow to bedrock soils that cover most of the watershed. However, the recent increase in the frequency and duration of summer droughty periods which may be associated with climate change contributes significantly to the problem and may exacerbate it in the future.

Water Quality

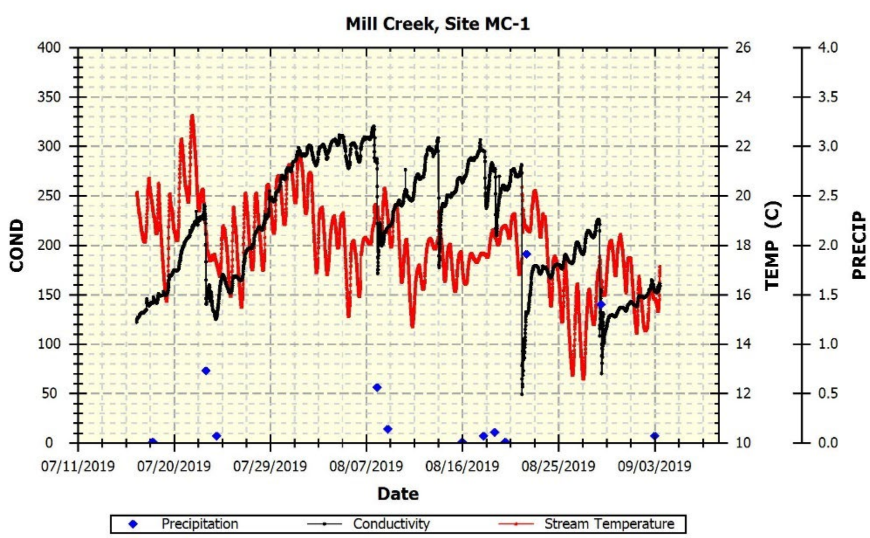
Data loggers were deployed at a site approximately 200 feet downstrem of Middle Road from July 16, 2019 to September 3, 2019. The loggers recorded temperature, dissolved oxygen and specific conductance at 15 minute intervals over that period.

Temperature. Water temperature over the period ranged from 13˚C to 23˚C and fluctuated within this range mostly as a function of air temperature. The 23˚C reading occurred on a day when air temperature reached 94˚F and the 13˚C during a period when daytime air temperature highs were in the high 60s or low 70s. Streams such as Mill Creek are often quite cool during baseflow regardless of air temperature because their flow is mostly derived from cold groundwater, but, as discussed in the habitat section above, surface flows were so low in Mill Creek in late July and August that the residence time of water in pools was long enough for high air temperatures to cause substantial warming.



<u>Dissolved Oxygen.</u> At times during the deployment dissolved oxygen concentrations (DO) at the monitoring station was lower than expected given the land use and riparian cover in the Mill Creek watershed. During the period from late July through mid-August DO frequently dropped below the Class B standard of 7.0 ppm. On several occasions DO dropped diurnally below the Class C 5.0 ppm standard, with one instance as low as 3.5 ppm. The periods of lowest early morning DO depression occur after long periods without significant rainfall and likely correlate with the lowest flows in the stream. It may be that at these lowest flows the residence time of water in pools is sufficiently long to allow bacterial digestion of benthic organic matter to deplete oxygen more than it usually would. This effect would also be enhanced by relatively limited reaeration in downstream riffles due to decreased turbulence. These oxygen concentrations are likely low enough to be problematic for sensitive organisms, but the condition is likely “natural”, except that the high frequency and extended duration of periods of droughty weather that give rise to these extreme low flows may be a result of climate change.

<u>Specific Conductance.</u> Specific conductance (SPC) rises during the dry periods between storm events to as high as 320 µs when the stream flow is derived from groundwater. As soon as low conductivity stormwater runoff reaches the stream, SPC drops precipitously reflecting dilution of the groundwater by the runoff. The magnitude of the decrease appears to be a function of the amount of precipitation. Following the biggest rainfall (1.9 inches) of the monitored period SPC dropped from 282 µs to 49 µs, the lowest value recorded during the deployment. Since SPCs in totally natural settings range from 50 µs to 100 µs, it is likely that the groundwater that



contributes to baseflow in Mill Creek is contaminated with chloride from deicing salts applied, in this instance, to Middle Road, but the contamination is likely not high enough to be a significant stressor on the biological community.

Biological Condition

During August of 2019 rock bags were deployed near the logger station to sample the macroinvertebrates (insects, crustaceans, worms and mollusks) living in Mill Creek. Unfortunately, the taxonomic evaluation of these samples is not yet completed, so there is little known about the health of the stream's biological community at this point. When data becomes available this report will be updated.

Stressors to the Biological Community

Current Stressors. The water quality data and habitat analysis suggest that two stressors are currently impacting Mill Creek biota – extremely low baseflow during droughty periods and diurnally low dissolved oxygen concentrations extreme low flows.

- *Low baseflow*. The very low baseflow conditions discussed in the habitat and water quality sections above impact the macroinvertebrate and fish communities of Mill Creek in several ways. During these periods, most of the water in the stream is in the pools and runs, and the velocity of flow in these areas is so low as to be immeasurable. The very small amount of flow in the riffles – often just a trickle – is so shallow and narrow that it provides little if any viable habitat for organisms adapted to living in a free flowing stream. These include many of the mayfly, stonefly and caddisfly taxa. The wetted area in pools and runs is also greatly reduced, thus limiting the habitat availabe for other taxa that do not require moving water. As discussed above, this condition is partly natural and has probably been a stressor in Mill Creek during particularly dry summers in the past, but the apparent increase in the frequency of droughty periods in recent years may be increasing the effect of this stressor. The magnitude of the impact of this stressor on the macroinvertebrate community will be better understood after analysis of the taxonomic data from the 2019 macroinvertebbrate sampling is completed.
- *Diurnally low dissolved oxygen*. Early morning DO concentrations in Mill Creek drop to very low levels during periods of extreme low flow. As discussed in the water quality section above, these low DO concentrations are likely a function of the very low flows in the stream and not attributable to excessive algal production and associated nutrient inputs. The concentrations are low enough to affect the viability of particularly sensitive organsms (e.g. mayflies, stoneflies and brook trout) if the condition persists for a period of time, but the impact on these organisms when exposure is for a relatively short duration during relatively infrequent events is less well understood. As with the low flow stressor, the magnitude of the the impact of these low DO events on the macroinvertebrate community will become evident when analysis of the 2019 taxonomic data is completed.

Potential Future Stressors

- *Baseflow chloride toxicity*. The Mill Creek watershed is mostly relatively sparse single family residential and forest land use, neither of which result in high levels of contamination of the groundwater with chloride. As long as this land use pattern continues it is unlikely that baseflow chloride concentration will rise to a level that is problematic, but if land use were to shift toward commercial, institutional or office development the apparently small volume aquifer that feeds baseflow could become contaminated and salt intolerant stream biota could be lost.

Stressors Associated with Downstream Waters

- *Nitrogen*. Mill Creek and its tributaries drain to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. While the topographical and geological setting and the relatively low density of development in the watershed may make it more resilient than its tributary streams, substantial addition of any of the following land uses to the Mill Creek direct watershed has the potential to degrade the stream's biota:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to dramatically increase nutrient levels in the stream, resulting enhanced algal production and lower night time dissolved oxygen even in moderate flow conditions.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could also elevate stream nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater

runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of the stream channel.

- Large impervious areas that have deicing salts regularly applied to them, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Falmouth's current zoning in the watershed prevents some of these land uses, but if significant zoning changes are proposed the above should be considered.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Mill Creek direct watershed:

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
    - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
    - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Agriculture. Although it is unlikely that significant commercial agriculture will be established in the Mill Creek watershed, the following practices should be required to minimize export of nutrients to the stream if such land use is proposed:

- Commercial livestock or horse operations
    - incorporate conservative manure management practices
    - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
    - incorporate practices which minimize soil loss from cultivated fields
    - distribute runoff from cultivated areas into adjacent natural buffers

Commercial, Institutional, Office, Multi-family Residential. If zoning in the watershed is altered to allow significant development of this type, the following practices should be required, or at least encouraged.

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms) unless their location in the watershed indicates that peak flows in the stream would be lessened by an early release. To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.

- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Resource Protection and Restoration.

- *Shoreland Zoning.* Maintaining the natural corridor of Mill Creek is essential to preventing impairment of the stream's biota. Most of its corridor is currently zoned as stream protection. This should be expanded to include the West Branch and the portion of the main stem upstream of the confluence with the West Branch to prevent significant disturbance of the vegetation shade and terrestrial habitat adjacent to the stream.

Further Assessment Needs. The results, when available, of the macroinvertebrate samples collected in 2109 may point to a need for additional assessment of the stream and its corridor. If the macroinvertebrate community appears to be already under significant stress, more data may be needed to characterize the source and scope of the stressor(s) that are indicated. As conditions in the watershed change due to new development, monitoring should be repeated to see if the stream or its biota have been altered.

Mussel Cove

Mussel Cove is an approximately 0.1 square mile (~55 acres), intertidal embayment characterized by a narrow, 0.5 mile long channel extending from the Rt. 88 (Foreside Rd.) crossing to the Cove mouth. Mussel Cove begins at its intersection with Mill Creek, remains constricted through a shallow sill approximately 0.25 mile from the Rt. 88 overpass, and then broadens before opening to the inner Casco Bay.

Habitat

Mussel Cove is composed mostly of intertidal silt and sand flats, with some scattered boulders and ledge in the upper intertidal and at the Cove mouth. The Cove is bounded by segments of narrow, fringing salt marsh around its upper intertidal perimeter, and a dense, fringing bed of eelgrass (*Zostera marina*) at its mouth. The eelgrass bed ranges from 300-500 ft in width, and has been present since prior to 1993. The upland boundary is characterized by fringing to more extensive tree cover, behind which are residential lawns and/or fields. No more than approximately a dozen ramps and floats extend from the upland over the intertidal shoreline.

Figure 7. Mussel Cove Map.

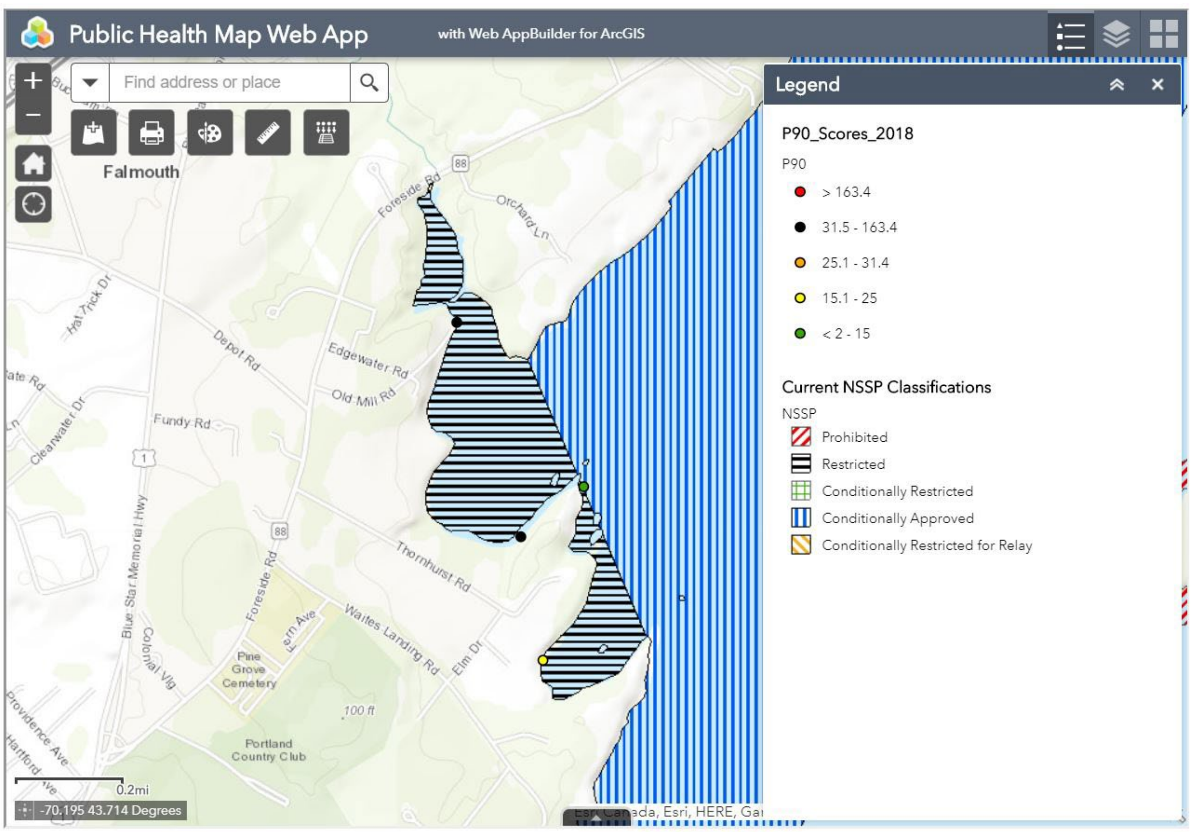
Water Quality

Known studies of Mussel Cove water quality occurred during spring-summer 2006-2008[1] and on four dates in summer-fall 2013 (Maine DEP unpublished data). While a sparse data set and representative mostly of Mussel Cove mouth conditions, available information demonstrates a marine-dominated embayment with temperature and salinity ranging from approximately 6°C to 19°C, and 24 ppt to 31 ppt (April to November), respectively. Available observations indicate low turbidity (mean 2.49 NTU), low dissolved inorganic nitrogen (<0.01 mg/L to 0.12 mg/L) and phosphorus (<0.01 mg/L to 0.21 mg/L) concentrations, and the potential for bacterial and/or algal productivity to influence dissolved oxygen and pH conditions. Total nitrogen concentrations from the 2013 survey reflect levels typical for inner Casco Bay's marine-dominated embayments (0.15

[1] Libby, S., Anderson, D. and B. Keafer. 2010. Red Tides in Inshore and Offshore Casco Bay and Their Relationship to Local and Gulf of Maine Physical and Biological Conditions: Final Report to the Casco Bay Estuary Partnership. October 2010.

mg/L to 0.31 mg/L; mean = 0.25 mg/L (n=6)). Libby, Anderson and Keafer (2010)[1] demonstrated influence at the mouth of Mussel Cove from Portland Harbor-area freshwater sources including the Presumpscot River, whose influence was observed most notably during spring (April, May) monitoring dates. The influence of Mill Creek on quality of the upper, constricted portion of Mussel Cove is not known, though localized freshening and eutrophication immediately following storm events could be reasonably expected. Similarly, the influence of surface flow off residential land during heavy rainfall could affect the water quality character overlying tidal flats and within pore water close to shore.

Mussel Cove (Area No. 13[2]) is currently "restricted" to the harvest of clams, quahogs, oysters and mussels due to elevated scores of fecal indicator bacteria, as monitored year round by the Maine Department of Marine Resources (ME DMR). Two survey sites located within Mussel Cove demonstrated geometric mean values and 90th percentile scores of 6.30 CFU/100 mL and 44 CFU/100 mL, respectively (inner site) and 5.80 CFU/100 mL and 48 CFU/100 mL, respectively (outer site) during 2018. Additional fecal coliform scores are available for 2015-2017 through ME DMR's Public Health Map Web App[3], and generally demonstrate higher scores for the inner embayment site.



[2] https://www.maine.gov/dmr/shellfish-sanitation-management/closures/documents/13.pdf
[3] https://www.maine.gov/dmr/shellfish-sanitation-management/maps/index.html

Biological Condition

No studies of the biological community are known from Mussel Cove, although the community is anticipated to consist of those benthic organisms typical of small grain size, intertidal and shallow subtidal habitats (polychaetes, bivalves, and small crustaceans). Larger crustaceans such as crabs are likely, and finfish like winter flounder and striped bass as well as marine mammals such as seals may also occupy Mussel Cove in search of food resources during tidal inundation. The persistent and dense eelgrass present at the mouth of the Cove may locally increase biological diversity and abundance of some species known to inhabit this habitat type for refuge or forage.

Stressors to the Biological Community

Sufficient water quality data gaps exist that inhibit robust assessments of biological stressors. The well documented, elevated levels of fecal indicator bacteria keep the intertidal and shallow subtidal flats restricted to harvest due to potential human health impacts, which may help to protect the natural abundance and distribution of shellfish within Mussel Cove. The periodic high levels of fecal bacteria, however, may reflect localized eutrophication of Mussel Cove. Nutrient sources to the Cove likely include wildlife contributions introduced from Mill Creek and the intertidal shoreline, runoff from urban and residential land, and human discharges from vessels operating or moored within or just outside the mouth of Mussel Cove. While the sparse nitrogen data available do not demonstrate elevated concentrations of nitrogen, the potential for increased vulnerability exists if nitrogen levels increase or loading becomes more persistent through storm events. The architecture of Mussel Cove offers quality habitat for nuisance macroalgae and accumulation of organic matter, both of which would fuel increased productivity and corresponding extremes of dissolved oxygen and pH. Additionally, eutrophication of Mussel Cove could lead to deterioration of the eelgrass resource, thereby reducing valuable subtidal habitat and water quality benefits.

Management Implications

<u>Future Land Use.</u> Addition of any of the following land uses to the Mussel Cove watershed, including its direct watershed and tributaries, has the potential to degrade the cove's habitat, result in nuisance macroalgae and exacerbate the events of elevated fecal bacteria:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to dramatically increase nutrient and bacteria levels in the cove.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could elevate cove nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of tributary stream channels and result in increased loading of sediment and nitrogen to the cove.

Falmouth's current zoning in the watershed prevents some of these land uses in the direct watershed, but rezoning in areas.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Mussel Cove watershed:

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
    - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
- Minimize the use of fertilizers and pick up pet waste.

Agriculture. Although it is unlikely that significant commercial agriculture will be established in the Chenery Brook watershed, the following practices should be required to minimize export of nutrients to the stream if such land use is proposed:

- Commercial livestock or horse operations
    - incorporate conservative manure management practices
    - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
    - incorporate practices which minimize soil loss from cultivated fields
    - distribute runoff from cultivated areas into adjacent natural buffers

Commercial, Institutional, Office, Multi-family Residential

- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Resource Protection and Restoration.

- *Eelgrass protection.*
    - Encourage recreational vessel operators to avoid anchoring or dragging fishing gear within eelgrass beds and adjacent habitat.
    - Provide resources to recreational vessel operators about available pump out vessels and shore-side locations to avoid dumping of human waste.
- Protect fringing marsh habitat by keeping people and their belongings off the marsh surface.
- Avoid direct impacts on marine habitat by shoreline structures, and minimize indirect impacts, like shading, of intertidal and subtidal vegetation.

Further assessment needs.

- *Identification of sources of fecal bacteria.* Conduct bacteria monitoring to identify and bracket any bacterial hotspots, including tributary streams. Investigate potential sources through shoreline surveys and watershed surveys. Consider any potential sources, including leaking sewer lines and connections, malfunctioning septic systems, pet waste, wildlife and hobby farms.

- *Additional monitoring.*
    - Report any evidence of widespread, dense and/or persistent green macroalgal cover in the intertidal zone to the Friends of Casco Bay.
    - Monitor the health of the eelgrass bed at the mouth of the Cove by observing fouling (generally trailing, fluffy brown growth) on the conspicuous ends of shoots during low tides. Compare the appearance of the shoots and degree of fouling to eelgrass along the shoreline to the north and south of the Cove to determine qualitative differences in water quality that may affect the eelgrass health.

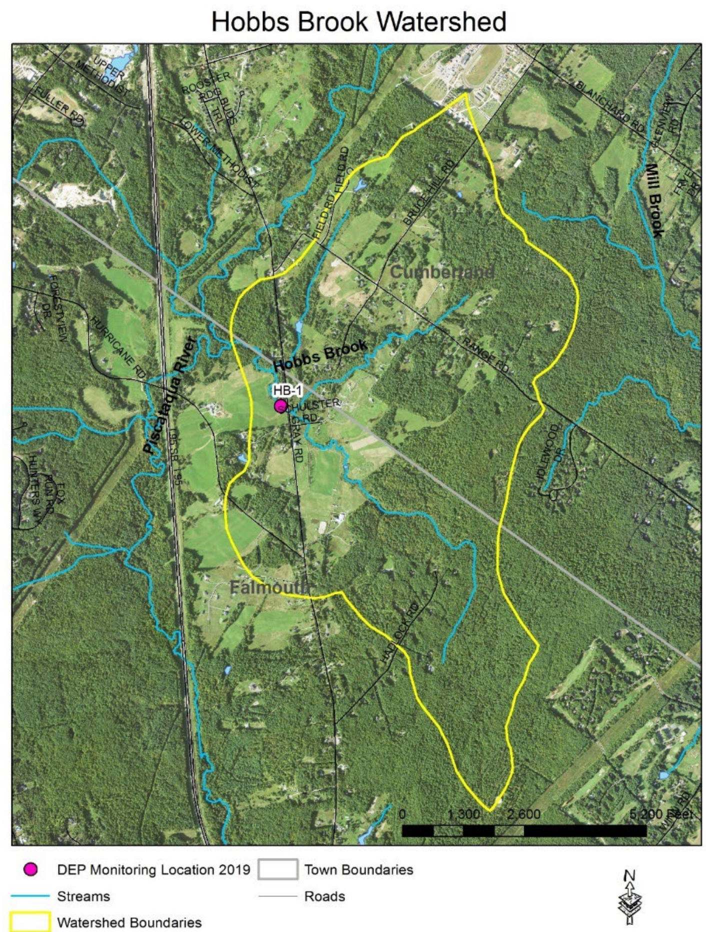
Hobbs Brook

Hobbs Brook is a 1.5 mile long stream that starts just north of Range Road in the town of Cumberland. The brook is joined by a tributary from Falmouth just prior to crossing Gray Road, and another tributary from Cumberland soon after. The brook feeds into the Pisacataqua River about half a mile upstream of the river's crossing of I-95 at Hurricane Road. Hobbs Brook is a Class B stream and does not meet water quality standards for dissolved oxygen and E. coli. Summary information about the stream and its watershed is available in Appendix 6-18 of the [Maine Statewide TMDL for NPS Pollution]() (2016).

Watershed Characterization

Hobbs Brook's watershed is approximately 1447 acres (2.26 sq miles). Landuse consists of forested (60.3%), agriculture (34.5%), developed (4.4%) and wetland (0.8%). (Maine NPS TMDL, 2016)

Figure 8. Hobbs Brook Watershed & Monitoring Site

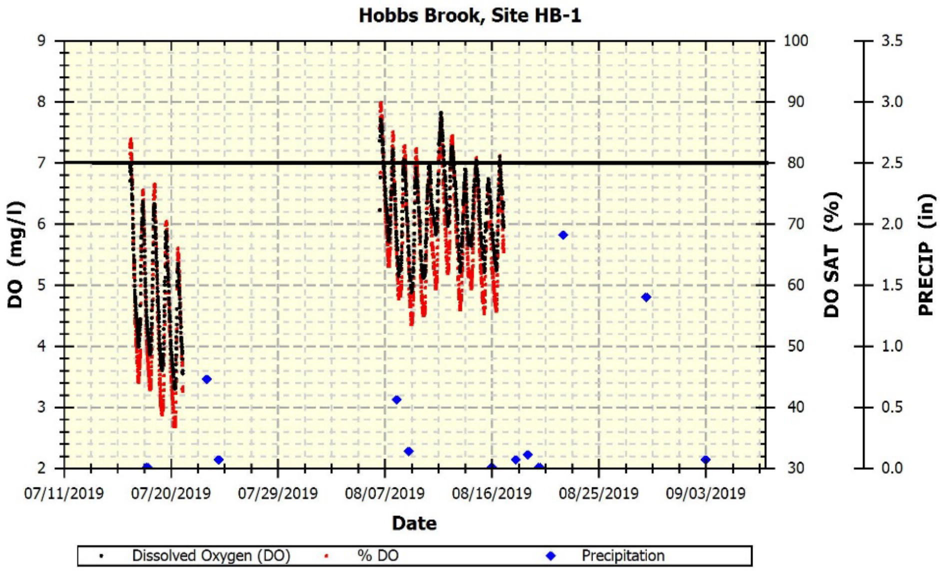


Water Quality

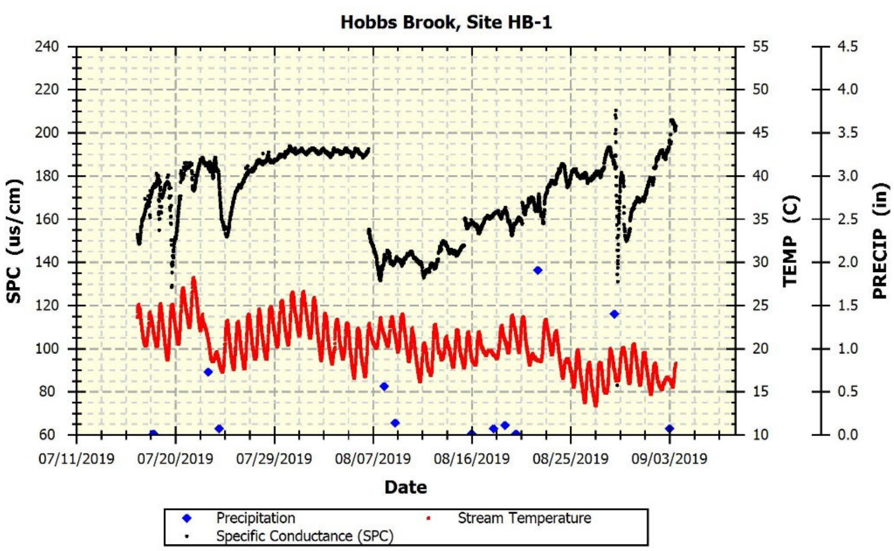
Data loggers were deployed (Site HB-1) approximately 200 feet downstream of Gray Road, alongside a hayfield from July 16, 2019 to September 3, 2019. The data loggers recorded temperature, dissolved oxygen and specific conductance at 15 minute intervals over that time period. The dissolved oxygen logger was partially buried when checked mid-deployment and at retrieval. Data was removed from analysis for those periods the logger appeared buried.

<u>Temperature</u>. Water temperature over the period ranged from 13˚C to 28˚C, with a mean value of 20˚C. Maine's regulations relating to temperature (06-096 CMR Chapter 582) require that discharge of pollutants not raise the temperature of any river and stream above the EPA criteria for indigenous species (23 °C maximum and 19 °C weekly average). While there are no licensed discharges on the brook, the EPA criteria indicate that during the deployment period, Hobbs Brook likely does not meet the temperature needed for indigenous species.

Dissolved Oxygen. The dissolved oxygen logger was partially buried in sediment when checked mid-deployment and at retrieval. Data was removed for the periods it appeared to have been buried. Dissolved oxygen was predominantly below the Class B standard of 7.0 ppm, with values from 3.3 ppm to 7.8 ppm, and a mean value of 5.8 ppm for the period recorded. The diurnal swing was regularly around 2 ppm, with a maximum of 3 ppm, indicating that the low nightime dissolved oxygen was a result of periphytic algal respiration. This suggests that nutrient levels in the brook are high enough to support significant algal production under optimal conditions and that shade is insufficient to limit that production. The overall low dissolved oxygen levels indicate increased bacterial respiration as well.



Specific Conductance. During logger deployment, specific conductance ranged between 83 µs and 210 µs, with a mean value of 170 µs. These values do not suggest chloride levels that are problematic. While not problematic to stream biota at current levels, baseflow specific conductance decreased with rainfall, suggesting slight chloride contamination of the groundwater at that location which was approximately 200 feet downstream of Gray Road.



Biological Condition

During August of 2019 rock bags were deployed near the logger station to sample the macroinvertebrates (insects, crustaceans, worms and mollusks) living in Hobbs Brook. Unfortunately, the taxonomic evaluation of these samples is not yet completed. The results will be made available when the evaluation is complete.

Stressors to the Biological Community

Hobbs Brook – HB-1 Monitoring Location

Current Stressors. The water quality data and watershed analysis suggest that two stressors are currently impacting Hobbs Brook's biota. These are likely to be most significant in the slower reaches without forest riparian cover.

- *Depressed dissolved oxygen.* The amount of periphytic algae in streams is limited by the avalability of light and nutrients. The relatively large swing in diurnal DO indicates that both light and nutrients are currently sufficient to support significant algal production in Hobbs Brook and likely results in loss of many taxa from the community. The overall low DO levels indicate increased bacterial respiration as well, possibly from manure sources given the watershed landuse.
- *Lack of habitat diversity.* The lack of forested riparian cover in many areas limits the amount of woody debris that is deposited in the channel and its associated habitat diversity. It is likely that this lack of variation in habitat in turn results in macroinvertebrate and fish communities that are limited to taxa that do well in low velocity and sand/silty sand substrates.

Stressors associated with downstream waters.

- *Phosphorus and Nitrogen.* Hobbs Brook is a tributary to the Piscataqua River which in turn drains to the Presumpscot River, then drains to Casco Bay. Phosphorus is the limiting nutrient for algal production in the freshwater Piscataqua and Presumpscot Rivers and nitrogen is the limiting nutrient in the saltwater bay. While an analysis of the Piscataqua River and Presumpscot River was not completed as a part of this study, the input of nutrients from tributaries, including Hobbs Brook should be included in such an analysis.

Management Implications


Hobbs Brook – upstream from Gray Rd crossing

Future Land Use. Substantial addition of any of the following land uses to the Hobbs Brook watershed has the potential to further degrade the stream's biota:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to increase nutrient levels in the stream, resulting in enhanced algal production and lower night time dissolved oxygen.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could also elevate stream nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of the stream channel.
- Large impervious areas that have deicing salts regularly applied to them, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the watershed:

Agriculture. The following practices should be required to minimize export of nutrients to the stream:

- Commercial livestock or horse operations
  - incorporate conservative manure management practices
  - isolate clean runoff (e.g. roof) from high use areas
  - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
  - incorporate practices which minimize soil loss from cultivated fields
  - distribute runoff from cultivated areas into adjacent natural buffers

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:

  - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
  - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Commercial, Institutional, Office, Multi-family Residential. If zoning in the watershed allows significant development of this type, the following practices should be required, or at least encouraged.

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

<u>Resource Protection and Restoration.</u>

- *Riparian Buffer Restoration*. Allowing woody vegetation to grow along the impacted riparian corridors is essential to restoring the stream's biota. Larger, woody vegetation would allow for the natural addition of large wood to the stream, increasing habitat diversity. Larger vegetation would also provide shading of the stream, cooling it down and decreasing growth of algae.
- *Shoreland Zoning*. Maintaining areas of natural corridor of Hobbs Brook are also essential to restoring the stream's biota. Hobbs Brook is not currently designated for protection under the Falmouth shoreland zoning ordinance. Its corridor should be zoned as stream protection to prevent further disturbance of the vegetation shade and terrestrial habitat adjacent to the stream.

- *Instream habitat enhancement.* The lack of habitat and flow diversity in the brook could be addressed by strategic additions of large wood in the stream channel. These could both provide additional substrate for colonization by macroinvertebrates and improve dissolved oxygen due to increased velocity.

Further Assessment Needs. The results, when available, of the macroinvertebrate samples collected in 2109 may point to a need for additional assessment of the stream and its corridor. If the macroinvertebrate community appears to be under significant stress, more data may be needed to characterize the source and scope of the stressor(s) that are indicated. As conditions in the watershed change due to new development, monitoring should be repeated to see if the stream or its biota have been altered.