TECHNICAL MEMORANDUM

To: Brendhan Zubricki[1] and Dave Lash[2]

From: Candice Constantine, PhD, PE[3] and Nick Nelson, CERP[4]

Date: August 17, 2022 **Project:** Alewife Brook Restoration

Re: Assessment Findings and Recommendations

This memorandum summarizes our assessment of hydrologic and geomorphic conditions from Chebacco Lake to approximately 2,500 feet downstream along Alewife Brook in Essex, Massachusetts (Figure 1). It provides a discussion of the challenges and opportunities associated with improving fish passage and flooding conditions and recommended strategies to address the problems.

Introduction

Alewife Brook flows approximately 1.5 miles from Chebacco Lake to the tidally-influenced Essex River with no dams or water control structures obstructing flow. As a designated Great Pond, Chebacco Lake is critical spawning habitat for river herring migrating upstream in the spring. The Town, state agencies, local organizations, and residents have long monitored Alewife Brook and herring runs, observing decreased populations in recent decades. Over a similar timeframe, residents have noted rising lake levels and increased incidences of flooding along Chebacco Lake.

Past efforts to support fish migration have included removal of beaver and beaver dams and clearing of vegetation deemed to be restricting water flow. While the project partners are able to maintain clear passage through much of the brook, a 1,000-foot section adjacent to, and upstream of, the Town's drinking water wells is currently a wide shrub-dominated wetland with multiple flow paths. Low, or non-existent, flows result in compromised fish passage in some years.

The project partners include:

- Chebacco Lake and Watershed Association;
- Town of Essex;
- Massachusetts Division of Marine Fisheries;
- Ipswich River Watershed Association;
- Seaside Sustainability; and
- Essex Conservation Commission.

[1] Town Administrator, Town of Essex, MA
[2] Chebacco Lake and Watershed Association
[3] Project Manager, Inter-Fluve
[4] Senior Fluvial Geomorphologist, Inter-Fluve

Figure 1. Alewife Brook in the study area. Flow is from south to northeast, originating in Chebacco Lake. The red star indicates the location of the Town wells. Project subreaches are labeled. Project location in regional context shown in inset. Orthoimagery and topographic map from USGS (2021).

Inter-Fluve was contracted by the Town of Essex to investigate the hydrologic and geomorphic conditions affecting fish passage and flooding in the study area. This memo describes our data collection and analyses and provides recommendations for improving fish passage conditions and relieving flooding.

Project Goals and Objectives

The goals of the project are to better understand the factors constraining fish migration along Alewife Brook and contributing to elevated water levels in Chebacco Lake and to develop strategies for improving conditions related to both issues. Potential strategies may include revitalization of the channel, alteration and management of vegetation, and well water extraction mitigation.

Existing Data Review

The drainage area to Chebacco Lake is approximately 3,600 acres or 5.6 square miles (Salem State College, 1998). Streamstats (USGS, 2016) provides an estimate of approximately 5.3 square miles, which is reasonably close given potential differences in measurement methods. The watershed includes five ponds in addition to the lake, which are connected by small streams and ultimately lead to Chebacco Lake. Alewife Brook is the only outlet to the lake. The drainage area of Alewife Brook at Pond Street is approximately 6.3 square miles (USGS, 2016) and includes a tributary that enters the brook downstream of the groundwater extraction wells run by the Town of Essex.

GEOLOGY/SOILS/AQUIFER

The study area is underlain by glacial deposits of sand and gravel and wetland soils that are poorly drained and rich in organic material (MassGIS). Glacial deposits in the vicinity range in thickness from 0 to 80 feet (Sablock, 1998) and form a local unconfined aquifer from which the Town of Essex draws its water supply. Ledge outcrops and shallow bedrock are observed in the vicinity of the study area, particularly to the east. The Middle Reach flows between two bedrock outcrops that locally confine the creek. (Figure 2).

Review of historical USGS topographic maps[5] shows that the natural brook outlet to Chebacco Lake was north of its current location (Figure 3). Maps show that the outlet was likely moved sometime between 1932[6] and 1942[7]. The current outlet and the upstream approximately 1,200 feet of Alewife Brook would have been created using mechanical dredging to remove soil and vegetation and establish a new dominant flow path. The 1945 Marblehead quadrangle gives a lake elevation of approximately 43 feet NAVD88.[8]

[5] Topo viewer and all referenced maps available at https://ngmdb.usgs.gov/topoview/viewer/#4/40.01/-100.06, accessed May 26, 2022

[6] Survey date on the USACE Cape Ann Quadrangle published in 1942

[7] Survey date on the USGS Marblehead North quadrangle published in 1945

[8] Elevation on map is given as 44 feet relative to the National Geodetic Vertical Datum of 1929 (NGVD29). The local conversion to the 1988 datum (NAVD88) is -0.951 feet.

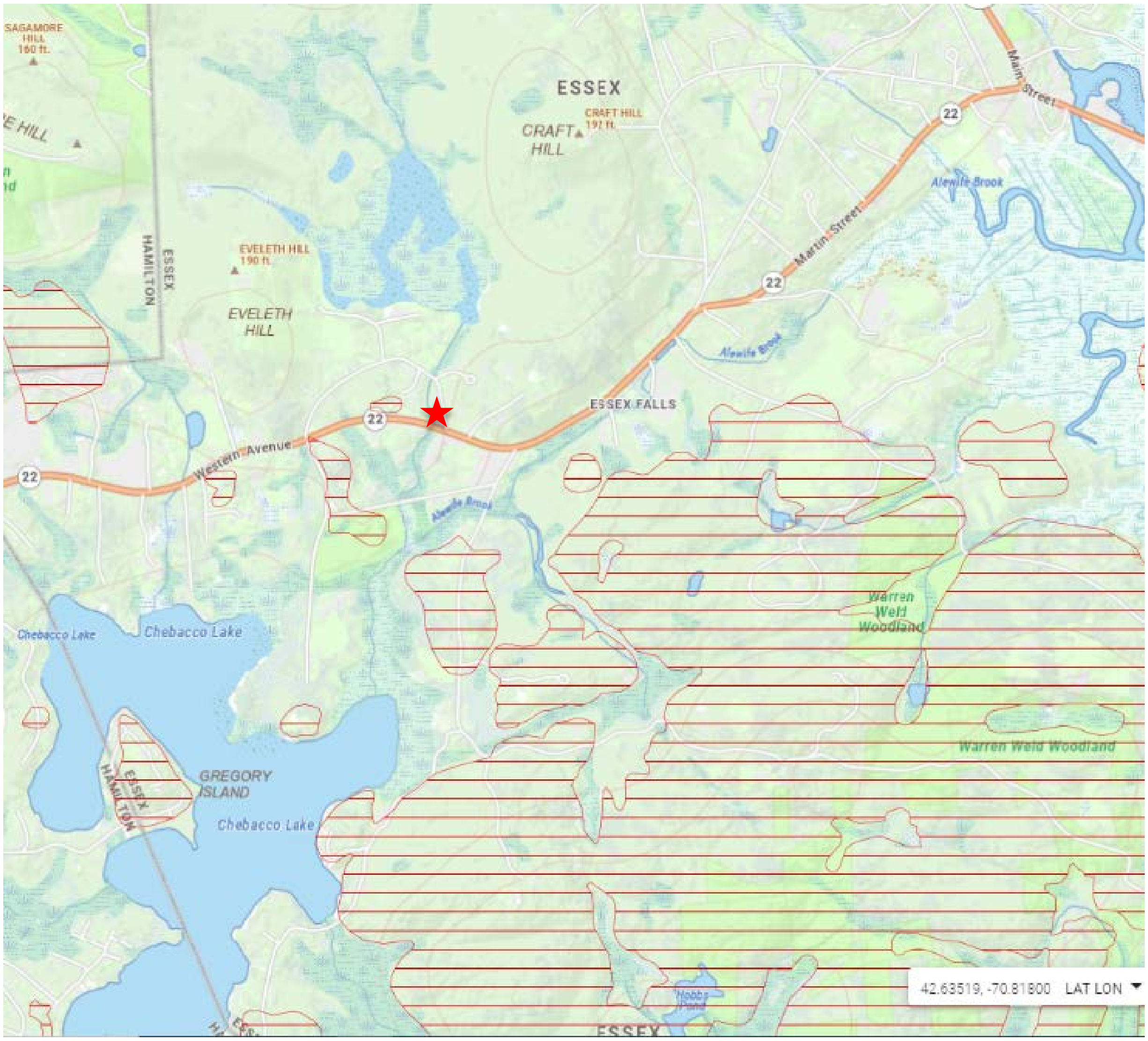

Figure 2. Map of shallow bedrock and outcrops in red hatch (MassMapper). Alewife Brook is visible flowing north out of Chebacco Lake. The red star indicates the location of the Town wells within the study area.

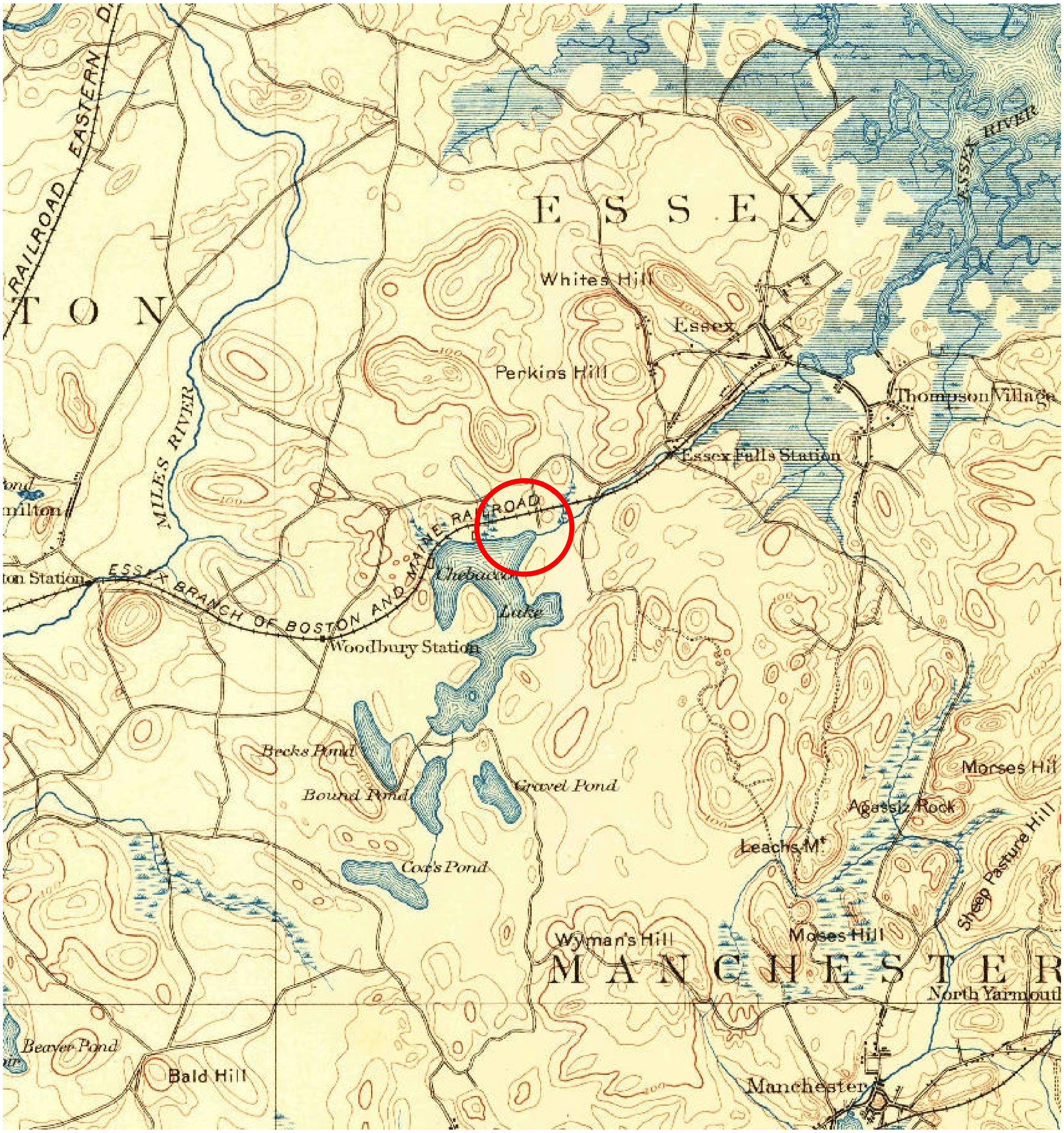

Figure 3. Portion of the 1888 USGS Salem, MA topographic map. Surveyed in 1886. Red circle shows the historical outlet of the lake in the north.

HYDROLOGY

The USGS hosts a web-based application, Streamstats, that provides a convenient user interface and map analysis tool for quickly estimating many drainage basin characteristics. These characteristics are often used to implement the regional regression equation method for estimating streamflow. The Massachusetts regional regression equation requires the following drainage basin characteristics: drainage area, the mean basin elevation, and the percentage of the drainage basin characterized as storage (open water or wetland), which can attenuate flood flows. These characteristics for the study area are shown in Table 1, with the watershed or drainage area defined as the contributing area upstream of the Pond Street crossing. The results of the StreamStats analysis for peak streamflow in Alewife Brook upstream of Pond Street are shown in Table 2.

Table 1. Characteristics of the contributing watershed to the study area

Characteristic	Value	Unit
Drainage Area	6.3	Square miles
Percentage of Drainage Basin Characterized as Storage (Open Water or Wetland)	30.3	Percent
Mean Basin Elevation	74.6	Feet (NAVD88)

Table 2. Peak discharge estimates at Pond Street predicted using StreamStats (USGS)

Recurrence Interval (years)	Discharge (cfs)
2	87
5	141
10	184
25	245
50	295
100	347
200	402
500	480

Because of the uncertainty involved with the regional regression equation, it is helpful to check the results against field data when possible. Inter-Fluve measured discharge during the course of the current study; however, conditions were not particularly wet around the measurement dates. Sablock (1998) recorded a high discharge event in Alewife Brook on April 12, 1997 during snowmelt following a large snowstorm in early April. Peak flow was measured to be 2.5 m^3/s or approximately 88 cfs. Flow records from nearby USGS gages show that the event was the highest event recorded that year. The peak flow associated with the event occurred prior to April 12, but flows on April 12 were still elevated relative to normal. The agreement between the field measurement during an annual high flow event (88 cfs) and the 2-year flood peak predicted using StreamStats suggests that the StreamStats estimates may provide reasonable, planning-level approximations for Alewife Brook.

The channel and adjacent wetland floodplain through the study area (see Figure 7) are mapped by FEMA as within Special Flood Hazard Area Zone A. Zone A covers areas anticipated to be inundated by a 100-year return period event (e.g., 1% annual change of exceedance) but for which detailed hydraulic modeling has not been carried out and thus Base Flood Elevations have not been defined.

CLIMATE

Climate change has impacted, and will continue to impact, aquatic ecosystems by altering riparian vegetation, water temperature, and hydrologic patterns. Work by Collins et al. (2009, 2014, 2019) indicates a statistically significant increasing trend in peak annual flood discharges in the New England region. This is linked to findings by Huang (2017), who observed an increase in high magnitude precipitation events in the region. Huang (2017) also noted increased variability in precipitation frequency, which increases the likelihood of droughts. The recent (2022) Massachusetts State Climate Summary published by NOAA (Runkle et al., 2022) further demonstrates these trends, showing increased frequency of extreme precipitation events and rising temperatures that contribute to water demand even in drought years (Figure 4 and Figure 5).

Extreme drought conditions were most recently observed at the site in 2012-13, 2016-17, and 2020[9], causing Alewife Brook to run dry. At present (July 2022) all of Essex County is in a Severe Drought, according to the National Drought Monitor (Figure 6). Alewife Brook had run dry at Pond Street by July 7, 2022.

[9]Data from https://www.drought.gov/states/massachusetts#historical-conditions and corroborated by field observations by Ben Gahagan, Massachusetts Division of Marine Fisheries (personal communication dated July 18, 2022). Ben Gahagan also noted the channel running dry in 2014.

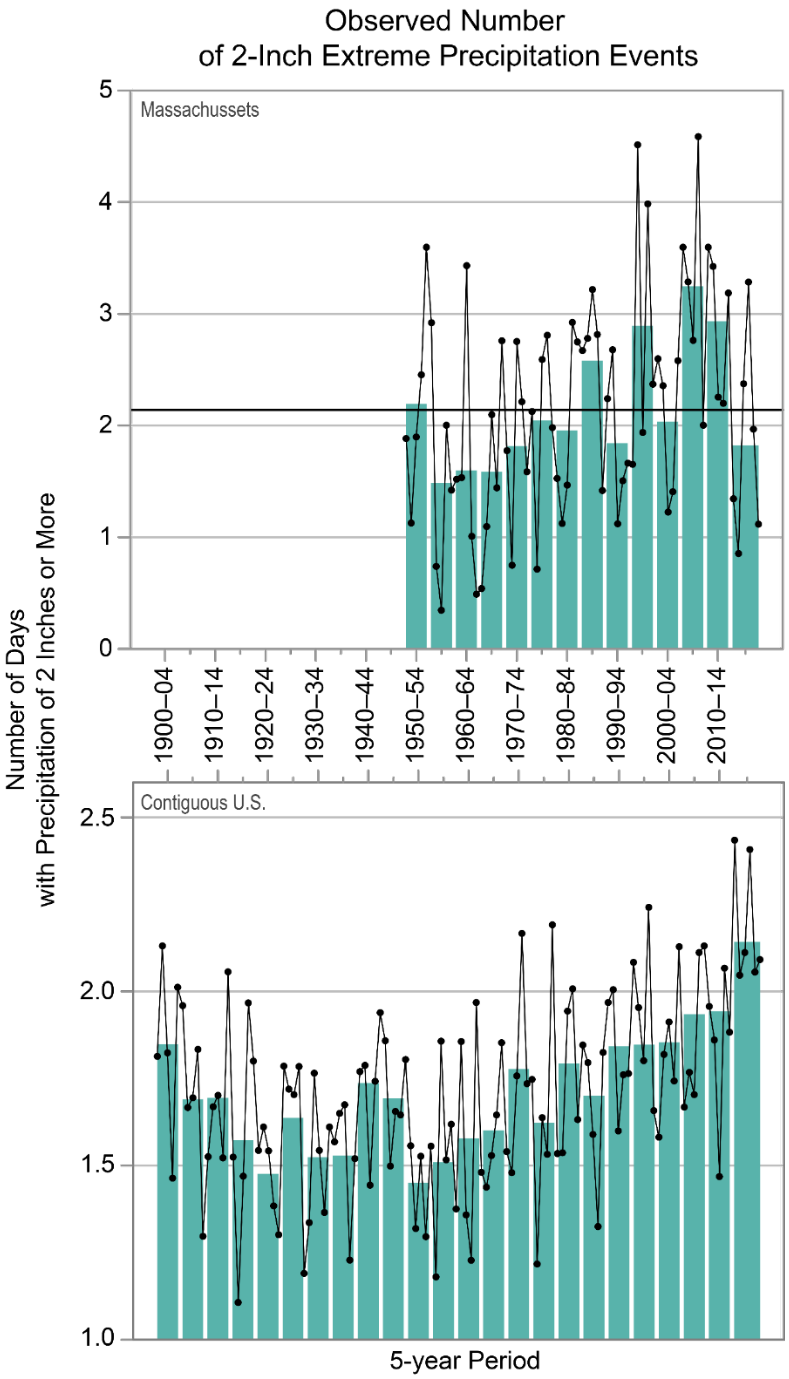

Figure 4. Annual number of 2-inch extreme precipitation events (days with precipitation of 2 inches or more). Dots show annual values. Bars show averages over 5-year periods. The horizontal black line shows the long-term (entire period) average for Massachusetts. Figure and caption from Runkle et al. (2022).

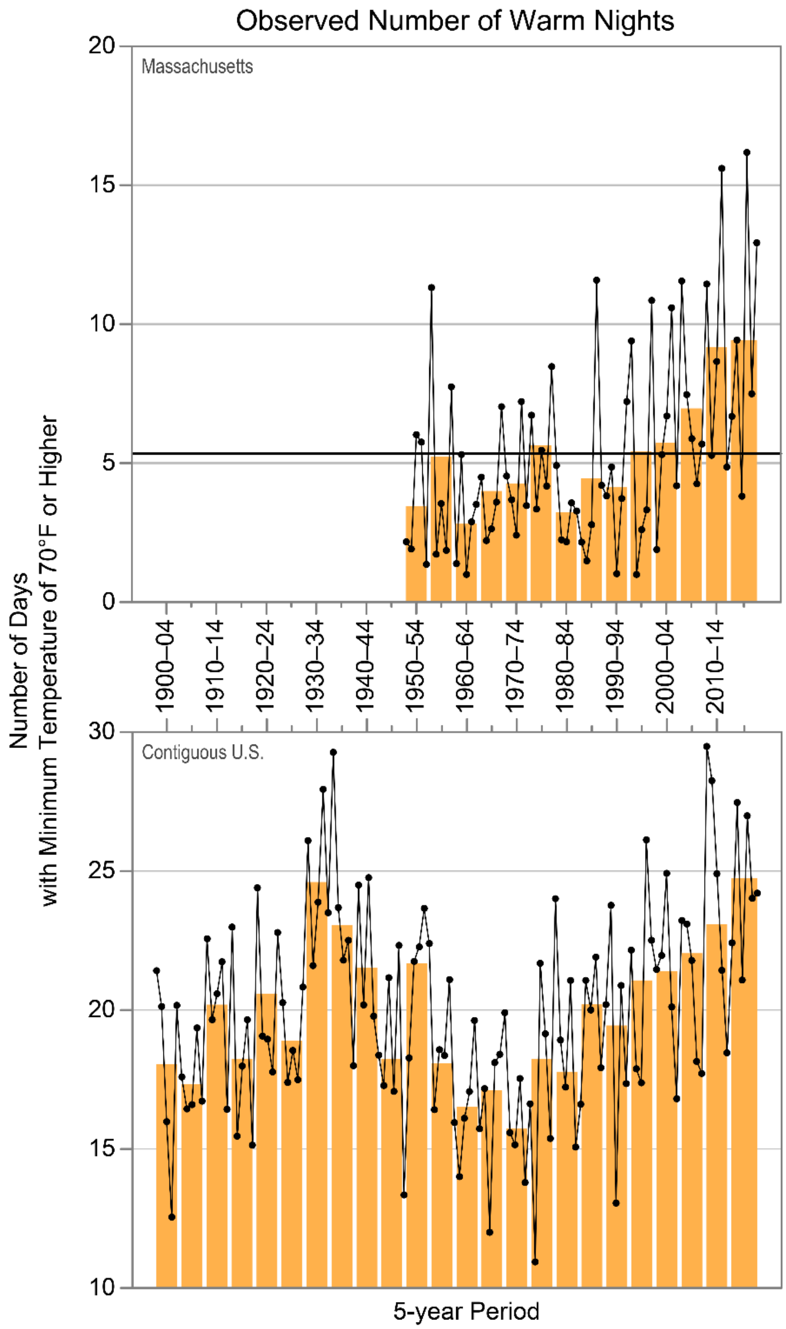

Figure 5. Observed annual number of warm nights (minimum temperature of 70 degrees Fahrenheit or higher) for Massachusetts from 1950 to 2020. Dots show annual values. Bars show averages over 5-year periods. The horizontal black line shows the long-term (entire period) average for Massachusetts. Figure and caption from Runkle et al. (2022).

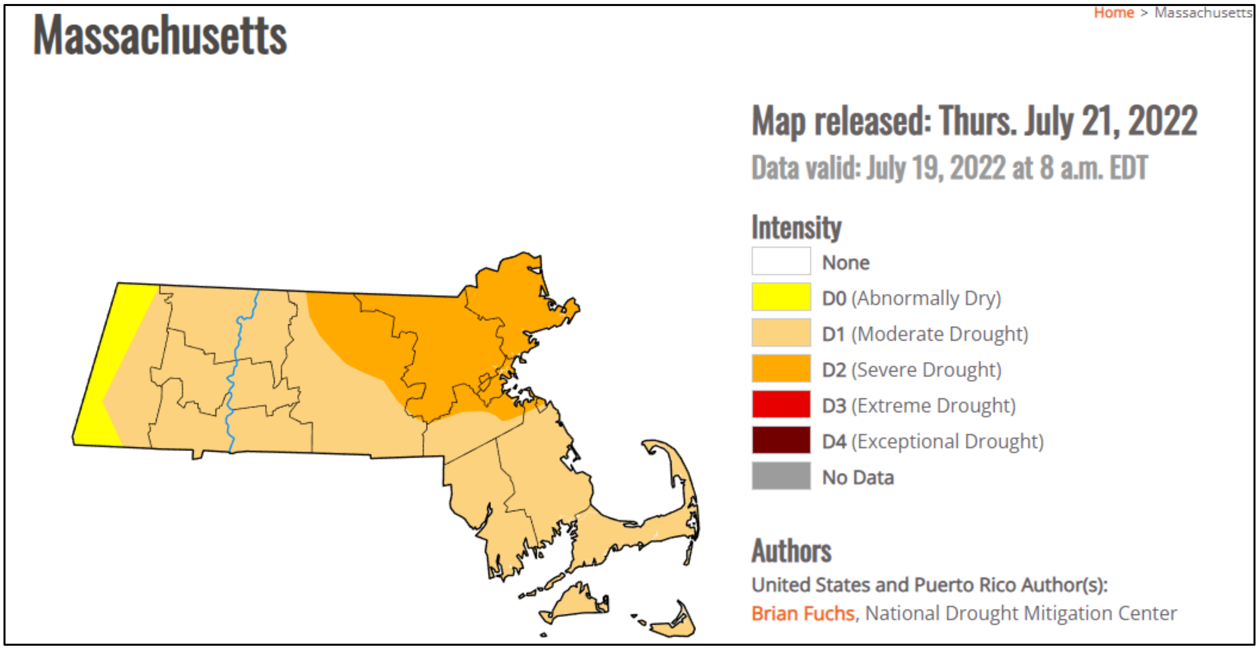

Figure 6. US Drought Monitor Map for Massachusetts, released July 21, 2022. The study area is currently in a Severe Drought.

WETLANDS

The wetlands adjacent to Alewife Brook within the study area are mapped by the Massachusetts Department of Environmental Protection (MassDEP) as wooded swamp (Figure 7). There are no Natural Heritage and Endangered Species Program (NHESP) areas present.

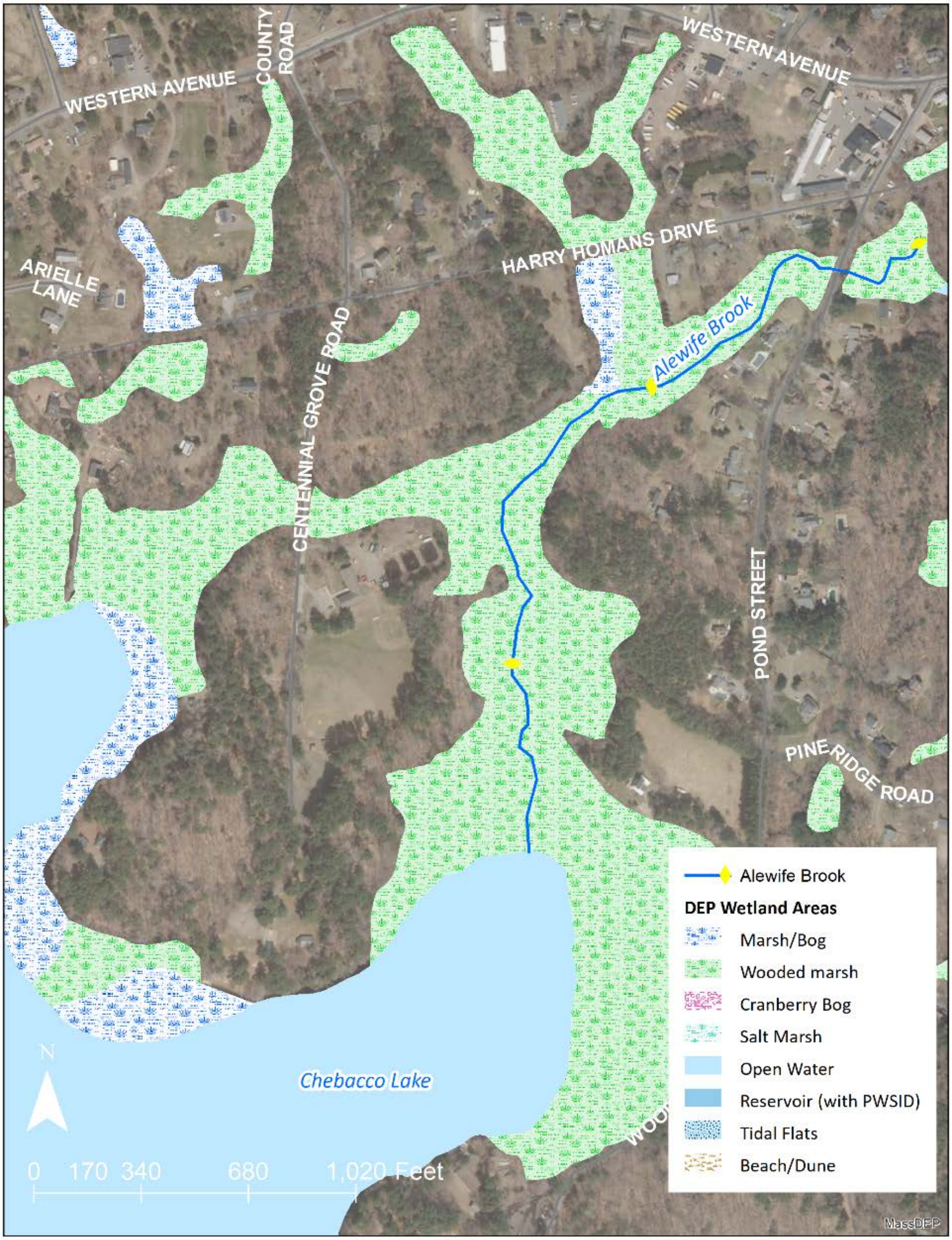

Figure 7. MassDEP wetlands map layer for the study area

WELL EXTRACTION

There are three Town of Essex wells tapping the medium-yield (100-300 gallons per minute) aquifer in glacial deposits underlying the study area (Figure 8). Wells 2 and 3 have historically been the most relied upon wells, though Well 1 is increasingly used more recently. A sketch of Well 1 obtained for this study shows that the well taps into the aquifer at a depth of approximately 31 to 39 feet below the surface.

We reviewed the well data from Wells 1 through 3 from April 20 to July 12 (Figure 9, Figure 10, and Figure 11) and discussed operations with the Town[10]. The well pumps are generally operated starting in the morning until day-time demand is met and two underground storage tanks at the filtration plant are filled. The storage tanks serve as the supply through the night until pumps are started again the next morning. Run times and pump rates are lowest during wet periods and highest during hot, dry conditions when demand for watering lawns and other needs are greatest.

Well extraction data show exactly this trend. The data show that well extraction rates increased between April and July from approximately 457 gallons per minute (GPM) on April 20 to 580 GPM on July 12, with dynamic drawdown water levels[11] decreasing over this time. According to the Town, run times also increase as the weather warms such that total extraction volumes increase into the summer. The static water levels in the wells dropped 4.2 feet in Well 1, 4.3 feet in Well 2, and 1.1 feet in Well 3 over the same period, indicating a lowered water table through the study area with the greatest reduction nearest to Alewife Brook (i.e., at Wells 1 and 2). The data suggest that well withdrawals contribute to low flows in Alewife Brook in warm summer months; however, additional long-term groundwater and surface water monitoring and water budget analyses are necessary to determine what portion of the low water period in Alewife Brook is due to groundwater extraction versus seasonal hydrologic fluctuations, drought conditions, or other climatic factors.

[10] Meeting held with Superintendent Michael Galli on June 20, 2022

[11] Dynamic drawdown water level is the water level in a well when the pump is running and the local water table is drawn down. Static water level is the water level in a well when the pump is not operating.

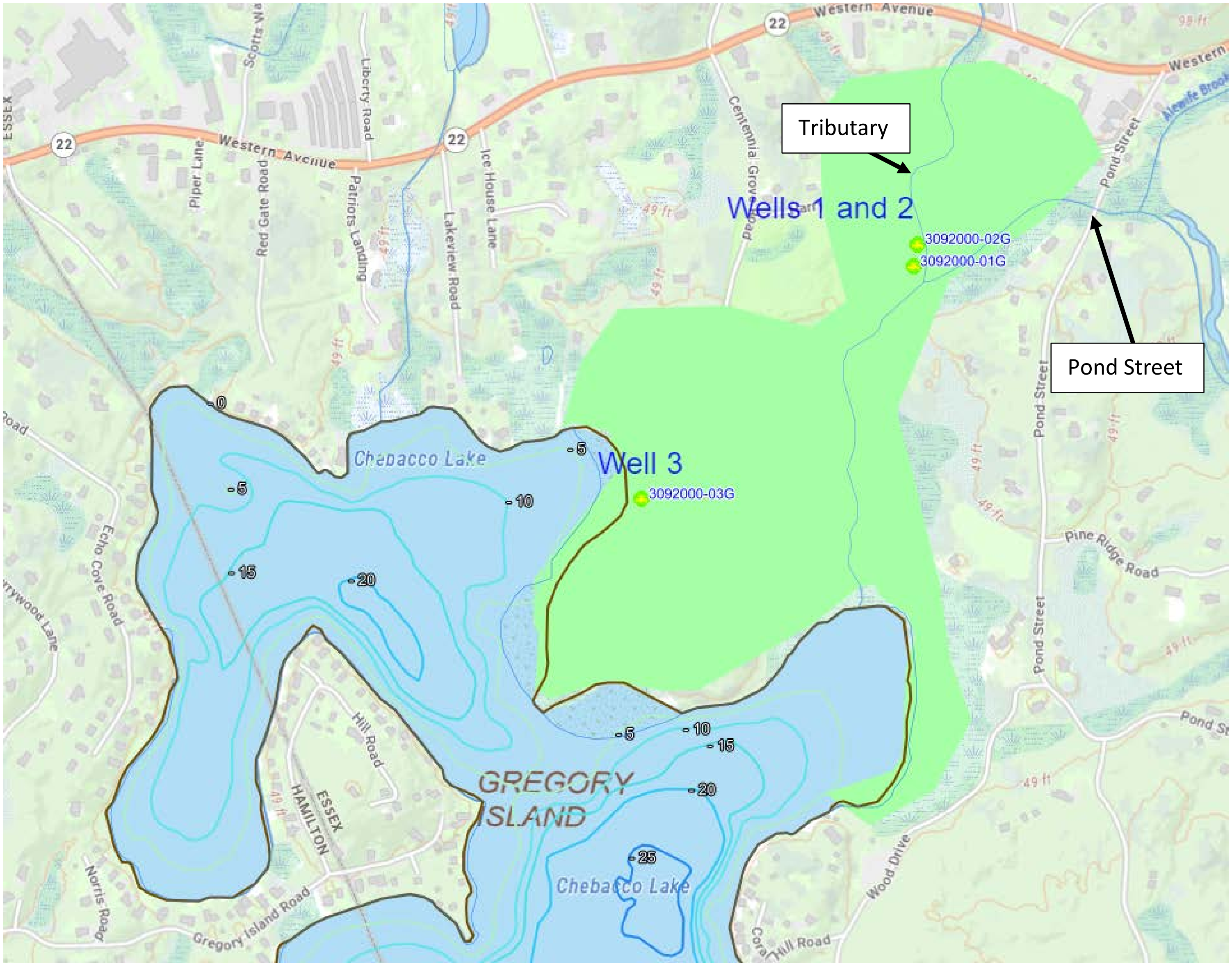

Figure 8. Locations of Town of Essex wells in relation to Chebacco Lake and the study area. Medium-yield aquifer shown in green polygon. Chebacco Lake depth contours shown with blue lines.

Figure 9. Pumping rates (GPM = gallons per minute) and water elevations for Essex town Well 1 from April 20 to July 12, 2022

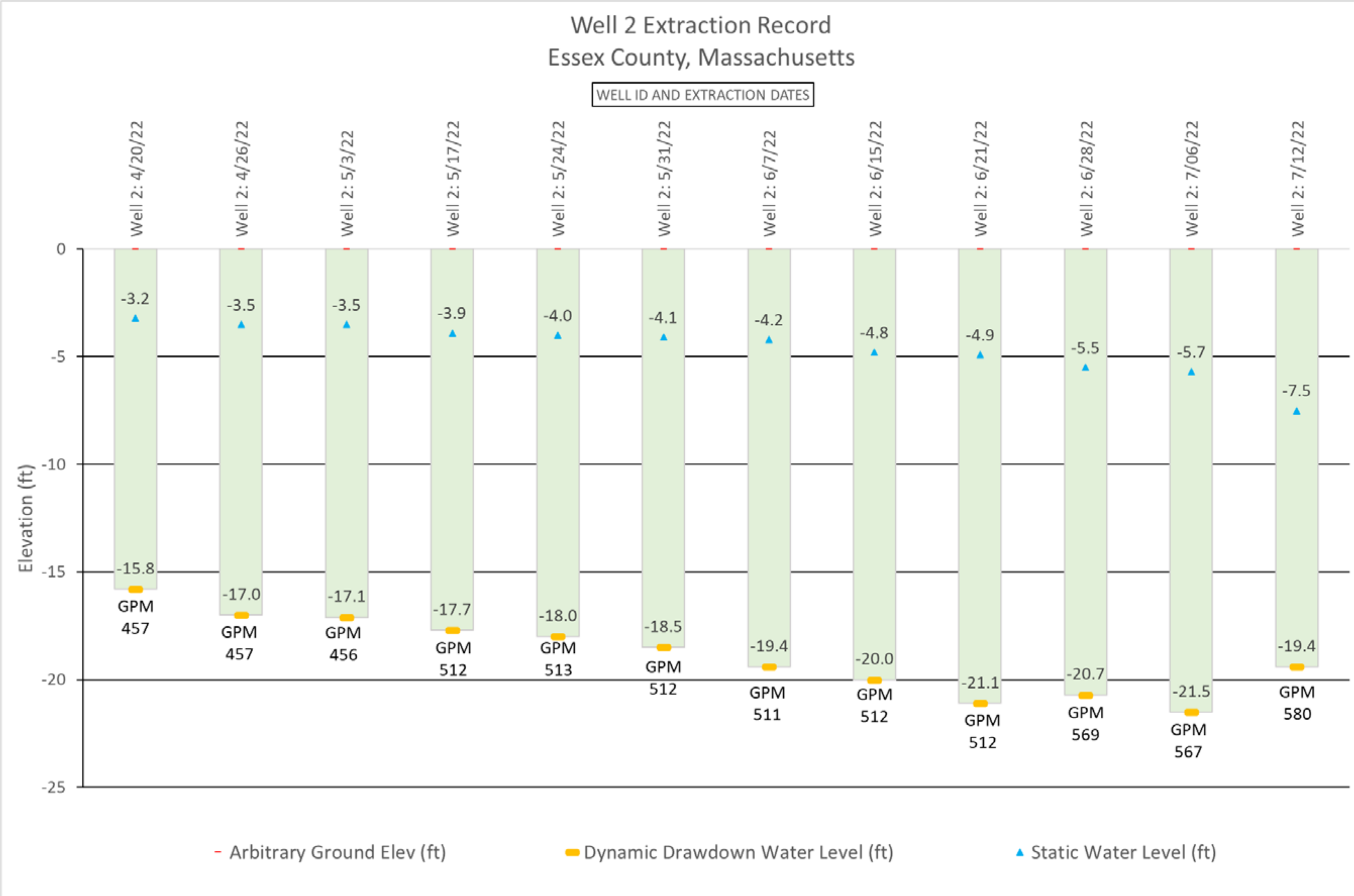

Figure 10. Pumping rates (GPM = gallons per minute) and water elevations for Essex town Well 2 from April 20 to July 12, 2022

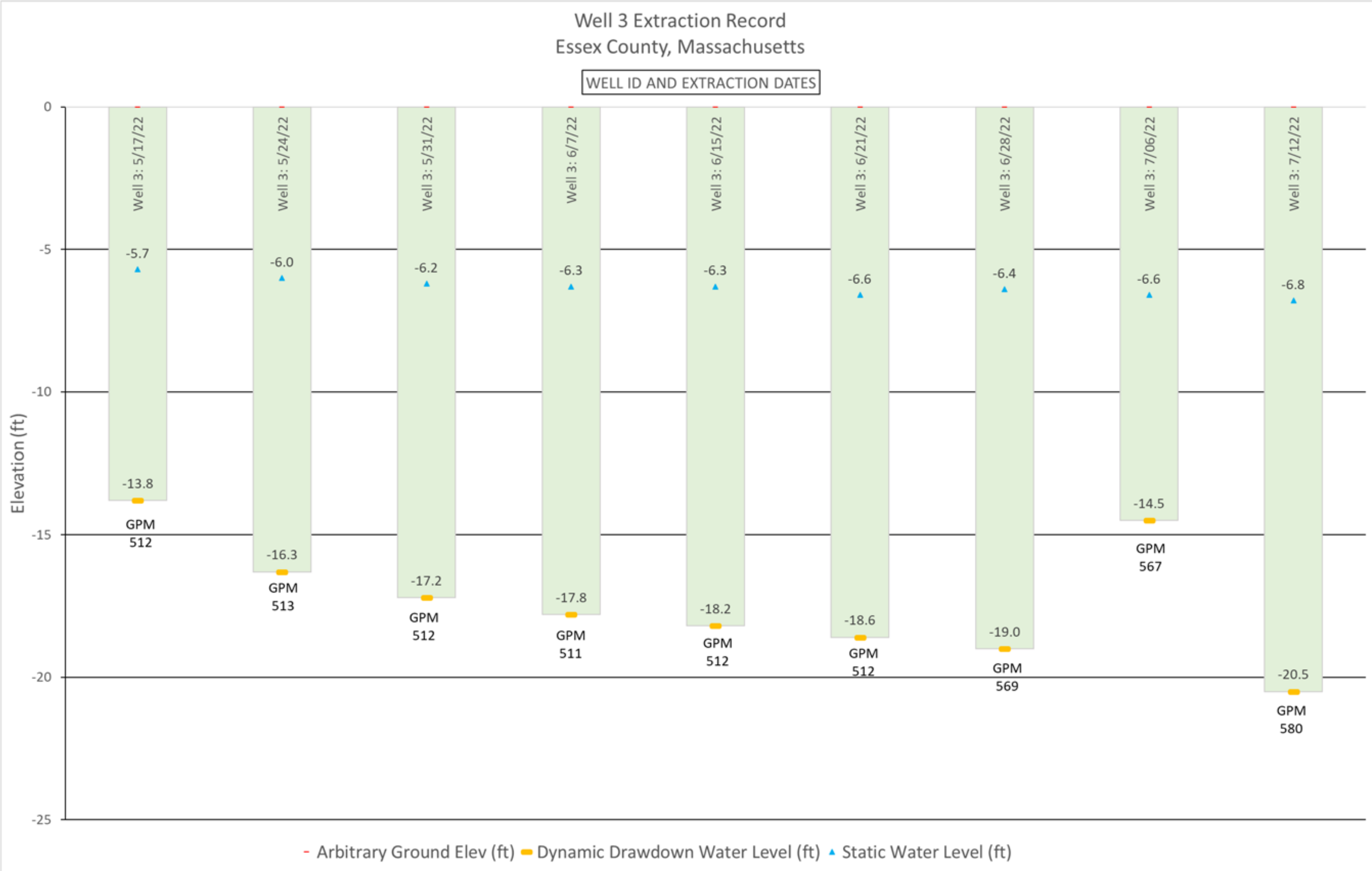

Figure 11. Pumping rates (GPM = gallons per minute) and water elevations for Essex town Well 2 from April 20 to July 12, 2022

Field Assessment

Inter-Fluve visited the site on March 23, April 6, and July 7, 2022 to conduct a geomorphic assessment, collect topographic survey data, take discharge measurements, and install and remove HOBO loggers used to monitor water surface elevations in Chebacco Lake and Alewife Brook. This section of the memo summarizes our findings.

GEOMORPHOLOGY

The study area is broken into three reaches: the Upper, Middle, and Lower (Figure 1). The reaches were delineated according to geomorphic characteristics, which will be discussed in the following sections.

Upper Reach

The Upper Reach of the Study area extends from the outlet of Chebacco Lake (the lake) to approximately 650 feet downstream and has a gradient of approximately 0.02%. At the time of the March 23, 2022 topographic survey, at the upstream reach, the channel was poorly defined within the center of a broad expanse of dense vegetation. The upstream end of the reach comprises a wetland fringe of the lake with dispersed flow and a barely-discernable primary flow path at the lake outlet (Figure 12). Alder, pepperbush, and other wetland plant species grow thickly across this area on hummocky terrain, with mounds interspersed over an otherwise inundated environment. In many places, roots or woody material grow across the various flow paths. Throughout the reach, a layer of fine sediment and organic material covers the channel. The thickness of this layer ranges from 0.6 to 2.8 feet. With distance downstream from the margin on Chebacco Lake, the channel gains more definition, though flow velocities remain barely perceptible. Some evidence of beaver activity was observed, including chewed shrubs and breached dams, which had been partially rebuilt by the July 7, 2022 field visit.

At the downstream end of the reach, a berm crosses the valley bottom Larger upland trees have colonized this raised feature. During wetter periods, the feature intercepts flow moving down the valley and directs it towards the central flow path. The feature is breached in the center, which concentrates flow as the channel exits the Upper Reach. No crossing or berm is depicted on historical topographic maps dating back to 1888, and the feature’s origin is unknown at this time.

At the time of our July 7, 2022 site visit, water levels were substantially lower than in March. Flow was limited to the small main channel that was surveyed in March with no overbank inundation. Flow appeared sufficient to support fish passage through the upper reach. Aside from the small incipient beaver dam (Figure 13), there were no apparent fish passage barriers in the reach.

Figure 12. Looking north from Chebacco Lake toward the lake outlet. Photo taken March 23, 2022.

Figure 13. Small beaver dam observed on July 7, 2022

Middle Reach

The Middle Reach begins at the berm feature described above. The reach is approximately 1,120 feet long with an average slope of approximately 0.02%. The channel is more well-defined than the Upper Reach, but maintains a high degree of connectivity with the adjacent floodplain, which was inundated during the March 2022 site visit. Midway through the reach, the channel bends to the northeast, before flowing past the municipal pumphouse (Wells 1 and 2 in Figure 8). The reach is flat, flow velocity was low, and no pronounced bedforms exist. The channel bed is generally covered with fine sediment and organic material, the thickness of which ranges from 0.3 to 3.0 feet. The reach ends approximately 225 feet downstream of the municipal wells, where a riffle forms a break in slope. No beaver activity was observed in the reach.

Figure 14. Looking upstream near Logger 3 on March 23, 2022 (left) and July 7, 2022 (right)

At the time of the July site visit, the wetted channel had shrunk from spanning nearly 125 feet across the floodplain, to a 1.5-foot-wide single-thread stream channel (Figure 14). In the upper portion of the reach, flow appeared to be sufficient to support fish passage, but it was increasingly marginal in the downstream end of the reach where flow was diminishing. At the downstream end of the reach, the surface flow had disappeared, leaving a dry riverbed downstream through the Pond Street bridge (Figure 15 and Figure 16).

Figure 15. Looking downstream near the break between the Middle and Lower Reach. The dry channel bed is visible beyond the surface water in the foreground. Photo taken July 7, 2022.

<u>Lower Reach</u>

The Lower Reach begins approximately 225 feet downstream of the municipal wells. The reach is 1,000 feet long with an average slope of 0.14%. At the time of the March 2022 site visit, the channel was well defined through most of the reach. As with the two upstream reaches, the channel was highly connected with floodplain, with flow spilling over the channel banks in some locations. The Lower Reach, which is notably steeper than the Upper and Middle Reaches, exhibits pool riffle morphology with coarser substrate and periodic gravel bars. A small tributary enters the channel from the west at the upstream end of the reach.

Historic stone walls are present along the channel throughout the reach. In two locations the walls appear to have crossed the channel historically, but have since been breached. In the downstream half of the reach, approximately 315 feet upstream of the Pond Street bridge, a gas line crosses beneath the channel.

The Lower Reach ends approximately 150 feet downstream of the Pond Street bridge. Substantial rock appears to have been added to the channel to act as a grade control to protect the bridge. No apparent fish passage barriers were observed in this reach. At the time of the July site visit, however, the stream was completely dry, with no surface flow observed (Figure 16). A landowner adjacent to the stream remarked that it was not atypical for the streambed to be dry in the summer.

Figure 16. The Pond Street crossing on July 7, 2022. No flow was present in the channel.

TOPOGRAPHIC SURVEY

During the March site visit, Inter-Fluve conducted a topographic survey using a Real Time Kinematic GPS system. The survey data were used to construct a longitudinal profile of Alewife Brook through the Study area. The longitudinal profile includes the elevations of the water surface, the channel bed, and the underlying refusal layer in areas where the channel bed was covered with soft fine sediment and organic material. The results of the survey are shown in Figure 17.

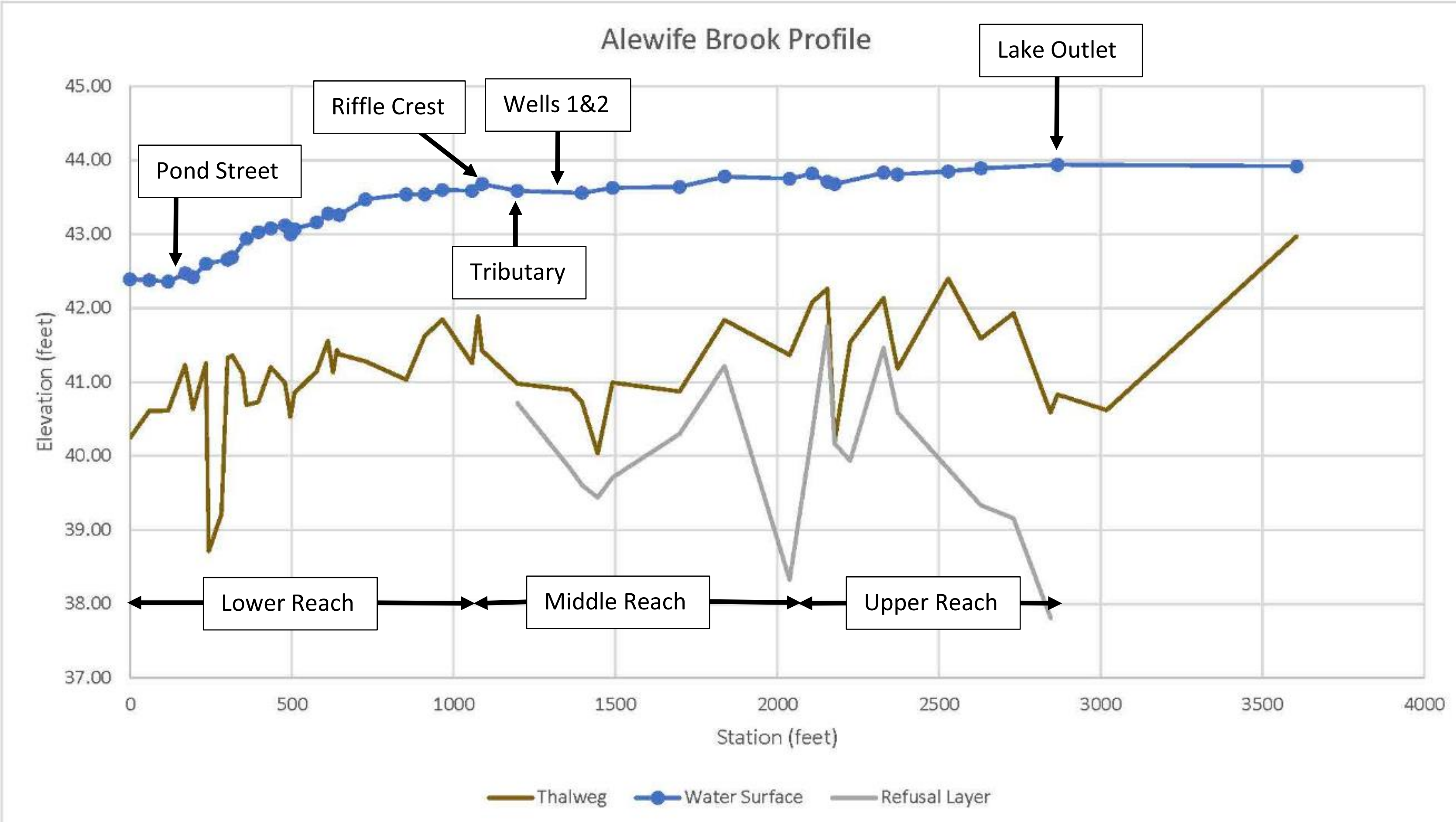

Figure 17. Alewife Brook profile through the study area. Data collected on March 23, 2022. Accumulated sediment is indicated by the difference between the gray 'Refusal Layer' and the brown 'Thalweg'.

The survey data indicate that the channel gradient is relatively flat through the Upper and Middle Reaches. Flow through this area was diffuse during the March and April site visits, though it became increasingly concentrated with downstream distance. Along these reaches, measurable (0.3 to 3.0 feet) fine sediment and organic material had accumulated over the bed surface. The Middle-Lower Reach transition is marked by an increase in slope and coarser bed material, with no accumulated fine sediment present on the bed.

DISCHARGE MEASUREMENTS

Discharge measurements were collected during the March and April field visits with a Hach flow meter. Locations of measurements are shown in Figure 18.

Figure 18. Locations of water level loggers and discharge measurements

The results from the discharge data collection indicate that tributary flows increased from late March to early April while Alewife Brook flows decreased. The decrease in Alewife Brook flows is more pronounced with upstream distance, with Logger 3 decreasing by approximately 60% (Table 3).

Table 3. Results of discharge measurements

	Discharge (cfs)	
Location	**3/23/2022**	**4/6/2022**
Pond Street/Logger 1	19.5	18.6
Logger 2	21.5	13.7
Logger 3	12.1	4.9
Tributary/Harry Homans Drive	7.0	11.5

Flow measurements were not taken during the July field visit because flow was negligible at the location of Logger 3 and not present at the other locations.

WATER DEPTH MONITORING

Hobo U20-L pressure transducer loggers made by Onset were deployed at four locations throughout the study area (Figure 18). The transducers were deployed inside perforated PVC stilling wells attached to t-posts driven into the channel bed (Figure 19). The water level was recorded every 15 minutes during the monitoring period, which ran from March 23 to July 7, 2022. A fifth logger was deployed to monitor atmospheric pressure during the monitoring period. This dataset was used to correct the water level data for atmospheric pressure fluctuations. Results of the water level monitoring are shown in Figure 20.

Results of the water level monitoring show a steady decrease in water level at all four locations throughout the monitoring period. This is to be expected as the monitoring period coincided with the transition from the wetter spring period to the dry summer period. The results also indicate that the water level in Alewife Brook is more sensitive to precipitation than is the level of Chebacco Lake, and that the sensitivity increases downstream. During the monitoring period, the maximum water surface elevation difference between Chebacco Lake and the Pond Street crossing was 1.42 feet on March 30, 2022. The minimum difference was 0.30 feet, which was observed on April 19, 2022 during a high flow event. This is a logical finding given that the inflows into Chebacco Lake are spread over the large surface area of the lake, and the flow becomes increasingly concentrated downstream. Another possibility is that upwelling through near-surface bedrock occurs near and feeds into the lake, while the downstream channel loses water through infiltration into the surficial glacial deposits. The bedrock in the area is highly jointed (Sablock, 1998), although we are unaware of any study that has investigated the bedrock influence on groundwater inflow into the lake.

At the time of retrieval, the water level had dropped below all four loggers, which was an unexpected outcome of the monitoring. The approximate point at which this occurred is indicated in the Figure 16 with color coded arrows. This point does not indicate when the channel bed went dry, but only when the water level dropped below the logger, which is dependent on how deep each logger was set relative to the water level. We can infer that in locations where the channel dried out, it occurred sometime after the water level dropped below the logger.

Figure 19. Water level monitoring well at the Pond Street crossing (Photo date: March 23, 2022).

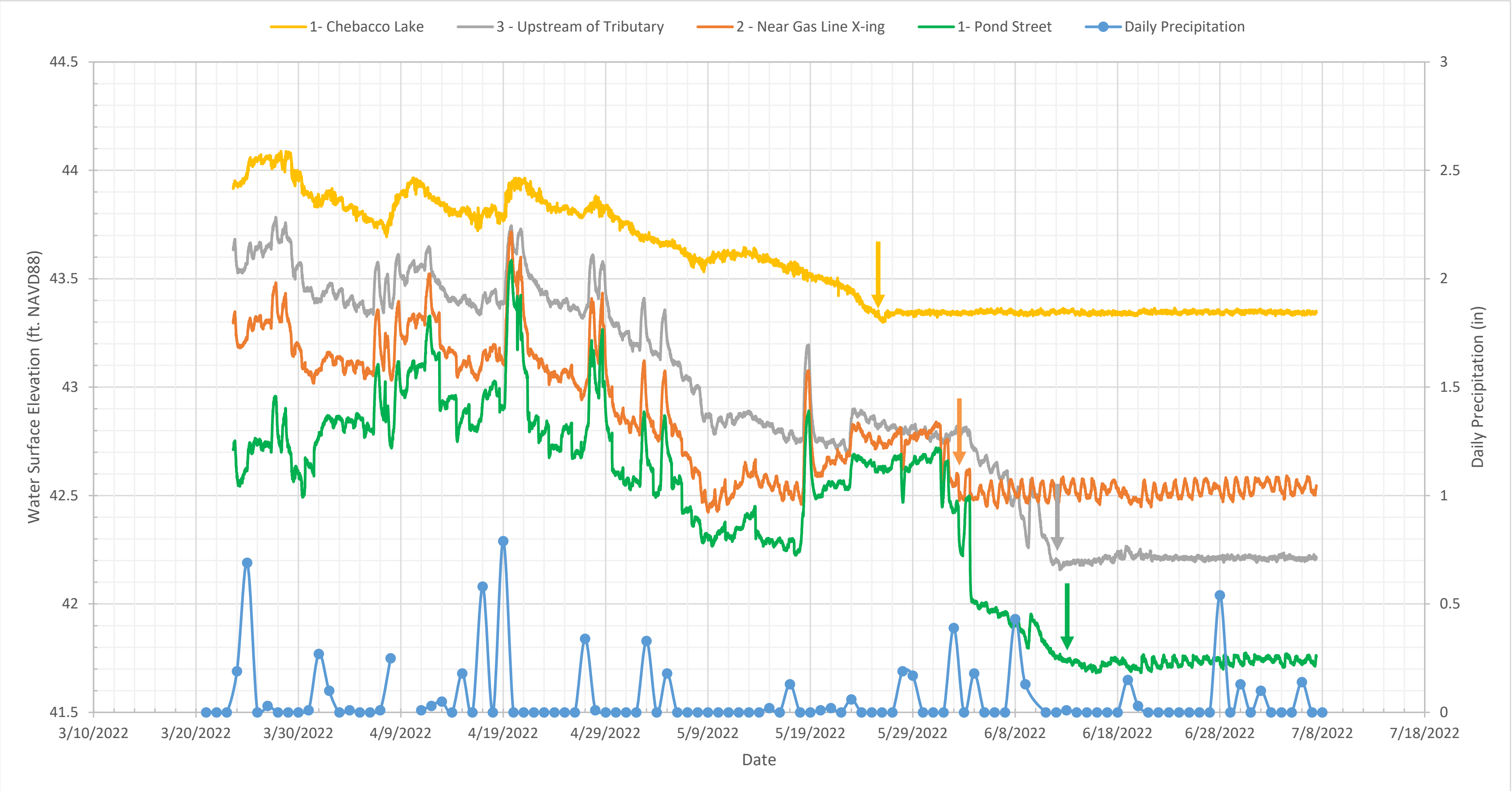

Figure 20. Results of water level monitoring at all four locations in the study area. Arrows indicate approximate dates at which the water levels dropped below the loggers. Precipitation data from NOAA climate station USC00190593 in Beverley, MA. A fish counting weir was installed approximately 10 feet downstream of the Pond Street water level logger on March 31, resulting in a slight increase in water elevation at Pond Street. The influence of the weir on water levels diminishes with distance upstream.

Summary

Alewife Brook is an important tributary to the Essex River, providing passage for migratory fish to access spawning grounds in Chebacco Lake. The lake outlet, or mouth of the brook, was historically relocated to its current position. Field conditions show no evidence of the once dredged channel, and instead, flow at the outlet is dispersed over a low-gradient floodplain wetland with dense vegetation. The result is a wooded wetland, currently consisting of shrubs that will likely evolve into a more forested wetland with the vegetation growing on hummocks. This type of wetland ecosystem is common at the margins of ponds at outlets where downstream elevation changes are subtle.

Flow conditions in Alewife Brook appear to be affected by precipitation, climate, surficial and bedrock geology, and local groundwater conditions. The various pressures on stream flow within the study area resulted in the channel running dry by July 2022. Similar conditions have been observed at least four additional times in the past decade with dry periods extending into the fall and rarely winter.

FISH PASSAGE

Alewives and other migratory fish are able to navigate Alewife Brook and make it to Chebacco Lake for spawning between early March and mid-May when water levels within the brook are deep enough to support passage. Water level monitoring during this study and observations made by landowners and project partners reveal that conditions are not always as favorable for the seaward migration in the summer or fall. Alewife Brook has run dry within the study area at least five times in the past decade. In the absence of historical data, we do not know the frequency, magnitude, and duration of similar events in the past. Observations do suggest, however, that the frequency at which the brook runs dry has increased in recent years due, at least in part, to direct (development and extraction) and indirect (climate change) human impacts.

With migratory fish populations in decline within the state and across the region, preserving fish runs is important ecologically, economically, and socially. Based on the existing data reviewed and the data we collected and analyzed, we believe a combination of factors may be resulting in the frequent low-water periods within Alewife Brook:

1. Climate change has resulted in more extreme precipitation events, but also more droughts. More frequent and more extended dry periods mean the aquifer under Alewife Brook is less able to recharge and under higher demand. During these periods, surface water delivered to Alewife Brook infiltrates into the underlying glacial material, causing the stream to run dry; and

2. Extraction appears to be a critical element associated with low-water periods as well. The aquifer that three municipal wells draw from is relatively small to support Town needs as well as support the lake, brook, and floodplain wetlands. As water demands and extraction rates increase in the summer, water levels within the aquifer are drawn down. In dry periods, the combination of low precipitation and higher extraction results in Alewife Brook running dry and fish being stranded in Chebacco Lake unable to migrate downstream.

LAKE FLOODING

We did not observe flooding along the margins of Chebacco Lake during the study period. We understand from lake residents, however, that flooding does occur periodically and is problematic for property owners. We reviewed the survey data to assess the potential impacts of fine sediment deposition on the channel bed elevation and thus water levels in the lake. Although we found up to approximately three feet of fine sediment deposited in some locations of the brook downstream of the lake, the sediment depth fell to zero close to municipal Wells 1 and 2. Downstream of the wells, or approximately 1,700 feet downstream of the lake outlet, the channel bed consists of gravel and small cobble that forms a riffle, or area of faster water that maintains the channel bed elevation. The elevation of the riffle crest is only approximately 0.5 feet lower than the top of the fine sediment at the lake outlet; therefore, removal of the fine sediment would not provide substantial flood relief at the lake, though small improvements may be observed.

Lake margin flooding could result from late winter/early spring runoff conditions. If the lake freezes over the winter, the ice breaking up in the spring could create blockages at the lake outlet with ice getting caught in the shallow water and in the vegetation at the lake margin. This could cause water to back up in the lake. Without direct observations and measurements of this phenomenon, it cannot be confirmed as a cause of lake margin flooding.

Finally, lake margin flooding may also be a result of the climate change factors discussed earlier. More frequent extreme precipitation events could result in the high lake levels that have caused some flooding concerns along the lake margins.

Within the scope of this initial study, it appears that significant manipulation of the lake outlet through sediment or vegetation removal would not provide complete flooding relief for lake residents.

Conclusions

A solution to the conflicting issues of fish passage in Alewife Brook and flooding in Chebacco Lake was not made immediately clear during the course of this study. We recognize the urgency in taking action on these issues in order to support migratory fish populations as well as the residents around the lake. Possible actions discussed with the project partners include dredging, removal of vegetation, and installing a flow control structure to concentrate and regulate flows. These actions would necessitate impact to the stream and wetlands with heavy construction equipment operating within these regulated resource areas. Dredging sediment and removing vegetation are maintenance actions that would need to be repeated according to a set schedule. Designing and building a flow control structure to concentrate flows at the outlet of the lake would significantly alter the wetland condition of the lake outlet. This structure would also require substantial regulatory oversight as it would likely be considered a dam necessitating maintenance, inspection, fish passage, and active regulation to achieve the desired flows and lake levels.

As described below, we recommend ongoing monitoring to better understand the causes of fish passage issues, the dry river bed in the summers, and high lake levels before committing to expensive engineering solutions that could have negative impacts on the ecology of the wetlands at the outlet of the lake and along Alewife Brook.

Recommendations

CONTINUING/ADDITIONAL STUDIES

A range of continuing or additional studies are recommended to improve the understanding of the conditions relative to fish passage and lake flooding in the study area.

- Install a fish monitoring site at the lake outlet – Determine how many fish pass Pond Street and what percentage enter the pond. We recognize this is extremely difficult due to the wide lake outlet and dispersed flow paths. However, if there were a way to monitor this, it would be useful in determining if the vegetation and sediment accumulation are contributing to poor passage during years in which sufficient water levels would otherwise allow fish to migrate. If developing this monitoring is possible, monitoring the out-migration should also be considered as the out-migration is often during periods of lower flow (i.e., summer and early fall).
- Continue water level logger deployments – Multi-year water level data would be useful in understanding water level changes in the broader context and identifying trends or issues over time. The data would help identify the length of time the brook is dry and what times of year the brook has enough water for fish to pass.
- Install groundwater piezometers – Groundwater piezometers placed in the areas of the channel that went dry in 2022 would provide water level data below the bottom of the channel bed. When the brook has no water in it, these piezometers would show the depth to groundwater below the channel bed, and groundwater fluctuations could be correlated with well extraction data.
- Mark the primary flow path of Alewife Brook – Stake out and survey and primary flow path of the brook in the Upper and Middle Reaches and identify specific locations, if any, where removal of aquatic vegetation or shrubs might benefit fish passage. During the initial study described in this memo, we did not observe locations we thought problematic, but another investigation during a different season would be beneficial to confirm.
- Begin discussions to address water extraction – Despite continued uncertainty regarding the impact of extraction, reducing extraction can only help maintain more water in the aquifer and thus in the brook. Specific actions include:
    - Identify ways to reduce demand, in particular during the low-flow periods; and
    - Locate alternative sources of water with a larger source that can support increased extraction.

FIELD WORK/ MAINTENANCE

- Remove the invasive aquatic *Cabomba caroliniana* (fanwort) from the margins of the lake – It is unknown whether this action will reduce flooding concerns by reducing blockages at the lake outlet; however, removing aquatic invasive plants is a good proactive effort to improve water quality and biodiversity. Water level monitoring before and after this work could determine the impacts of the plant on water levels in the lake.

- Design and implement lake outlet channel dredging – We recommend that this approach, if selected, come after sufficient monitoring of fish passage through the study area and efforts to reduce water extraction. This action is only useful if it is determined that fish are not able to navigate through the outlet even when sufficient water depths would otherwise allow. This step would include detailed survey, engineering design, permitting, bid support, construction, and construction administration/observation services. It should also be understood that dredging is a temporary solution that would need to be repeated in the future to continue to remove accumulated sediment and vegetation growth and maintain dredged open channel conditions. Design and construction considerations are included in Attachment 1.

References

MassGIS (Bureau of Geographic Information), Commonwealth of Massachusetts EOTSS online at https://maps.massgis.digital.mass.gov/MassMapper/MassMapper.html, accessed on May 16, 2022.

[USGS] U.S. Geological Survey. 2016. The StreamStats Program, online at http://streamstats.usgs.gov, accessed on March 3, 2022.

Collins, M. J. 2009. Evidence for changing flood risk in New England since the late 20th Century. JAWRA: Journal of the American Water Resources Association, 45 (2): 279-90.

Collins, M.J. Kirk, J. P., Pettit, J., DeGaetano, A. T., McCown, M. S., Peterson, T. C., Zhang, X. 2014. Annual floods in New England (USA) and Atlantic Canada: Synoptic climatology and generating mechanisms. Physical Geography, 35: 195–219. https://doi.org/10.1080/02723646.2014.888510

Collins, M.J. 2019. River flood seasonality in the Northeast United States: Characterization and trends. Hydrological Processes, 33 (5): 687-698. https://doi.org/10.1002/hyp.1335

Huang, H., J. M. Winter, E. C. Osterberg, R. M. Horton, Beckage, B. 2017. Total and extreme precipitation changes over the northeastern United States. J. of Hydrometeorology, 18: 1783-1798. https://doi.org/10.1175/JHM-D-16-0195.1

Runkle, J., Kunkel, K.E., Frankson, R., Easterling, D.R., Degaetano, A.T., Stewart, B.C., Sweet, W., Spaccio, J. 2022. Massachusetts State Climate Summary. NOAA National Centers for Environmental Information, State Climate Summaries 2022 150-MA. Available at: https://statesummaries.ncics.org/chapter/ma/

Sablock, J.M. (ed). 1998. Chebacco Lake Diagnostic Report. Department of Geological Sciences, Salem State College, Salem, MA.

Attachment 1

At this time, we do not recommend, or anticipate the need for, imminent engineering designs or construction activities. However, if the project partners are prepared to move ahead with design and implementation of construction activities, the following steps outline our typical approach.

- Data collection – A detailed survey to accurately reflect the existing ground topography and provide information sufficient to calculate cut and fill volumes for the contractor. This data collection task will likely also include a property line survey, wetland delineation, and continued water level monitoring if not already implemented.
- For this project, we recommend three phases of design to confirm that designs continue to align with project partner goals and also to provide updates to the public and stakeholders.
    - 30% Concept Design – This provides some engineering detail, but is mostly a plan set designed to provide a simplified, easy-to-read, visual of the conceptual plans to the partners and public.
    - 75% Designs – This design set has a lot more engineering detail with plan view maps of existing and proposed conditions, cross sections, typical designs, access and staging, planting plans, erosion and sediment control, and regulated resource area impacts.
    - 100% Designs – This is the final, stamped, and construction-ready design plan set that is ready for construction and is stamped by a MA-licensed engineer.
    - At each phase, additional detail is added to the designs from feedback or permits sought from project stakeholders as applicable. At each phase, a basis of design memo and engineer's opinion of probable cost (EOPC) will be created or updated along with the design plan set.
- Stakeholder engagement – This will be important throughout the project to keep residents informed, to gain agreements with landowners upon whose land construction needs to occur to achieve the project goals, and to identify and resolve questions or concerns prior to the permitting and construction phases.
- Permitting – Multiple permits are required for doing work within waterways and wetlands in Massachusetts. We typically begin permitting after the completion of the 75% designs, starting with the Massachusetts Environmental Policy Act (MEPA) Expanded Environmental Notification Form (EENF).
    - MEPA EENF – A general environmental review of project impacts. With new environmental justice regulations in place as of January 2022, the project may require an Environmental Impact Report (EIR).
    - MassDEP Chapter 91 dredge permit and 401 water quality certification – Restoration permits can receive a combined permit; depending on the proposed actions, this project may qualify as a restoration permit.
    - Wetland Protection Act Notice of Intent – MassDEP and Essex Conservation Commission
    - Army Corps of Engineers 404 Permit – Receipt of this permit will also require satisfying Section 7 endangered species review and Section 106 historical and archaeological review.

- Construction bid support – Following receipt of required permits and completion of final designs, the project is ready to be sent to contractors to begin the bidding process. This process includes advertisement, a site visit, response to questions, review of submissions, and a recommendation and selection of a contractor.
- Construction-period support – During construction, the engineering company responsible for designs is retained to provide construction observation services, review contractor submittals, and provide general support to the project owner throughout the process.