# Restoration and Revitalization Of the Sharon Great Cedar Swamp

## Progress Report

Requested by: Sharon Conservation Commission

Prepared by: Peter C. Fletcher, Aimlee D. Laderman, and Pamela T. Polloni

June 2012

# Table of Contents

# List of Figures

# I. Preface:

The Sharon Great Cedar Swamp (GCS) is vital to the health and sustainability of Sharon's independent water supply and Lake Massapoag, and it is imperative that Sharon moves now to correct the degradation and loss of this critical natural resource that has taken place since the 1960s. The GCS is the primary source of groundwater-derived base flow within the study area to the headwaters of Beaver Brook, Billings Brook, and the Canoe River, as well as Lake Massapoag (Figure 5).

As summarized by Horsley and Witten (June 2011), *"... the GCS and the immediate surrounding area is the primary source of groundwater recharge for the local area. This means that within the study area, the GCS and immediate surrounding area is the primary source of groundwater recharge to municipal well Stations 2, 3, and 4 along Beaver Brook; Stations 5 and 7 along Billings Brook; and Station 6 along the Canoe River. Due to its undeveloped nature, groundwater recharged at the GCS is of high quality and serves to dilute lesser quality groundwater recharged over more developed intervening areas between the GCS and the municipal wells. For the same reasons mentioned above, the GCS is also a primary source of groundwater-derived base flow within the study area to the headwaters of Beaver Brook, Billings Brook, and the Canoe River, as well as Lake Massapoag. While all of these water resources also receive some contributions from outside of the study area it should be noted that the areas outside of this study area north of Beaver Brook and east of Lake Massapoag consist primarily of till and/or bedrock uplands that likely contribute lesser amounts of groundwater recharge than do the permeable aquifer materials of the GCS and surrounding areas*." [1].

Other Massachusetts towns have spent millions on water purification and millions on flood control. Sharon's Great Cedar Swamp, an inland Atlantic White Cedar (AWC) wetland forest, supplies a free source of clean, abundant water that provides flood control and that can save millions of dollars per year for generations to come. All of these free services are seriously threatened with this wetland treasure in its current state. Our recommendation is to proceed with the restoration of the wetland forest so that it can continue to supply pure water for Sharon's residents, its lake, and the rest of its environment.

[1] Horsley Witten Group, 30 June 2011

## II. Introduction:

This project has been undertaken to examine existing conditions and make recommendations for restoration of the Sharon Great Cedar Swamp (GCS), a globally rare plant community and primary source of municipal water supply, which has been degraded over a period of more than fifty years. This wetland forest is a 250-acre gem of open space near the center of the town of Sharon, Massachusetts (Figure 1). It is a gem in desperate need of resuscitation. Thousands of its beautiful cedar trees are dead, many standing as a forlorn reminder of its past glory, many others lie crisscrossed on the surface of the peat.

Its waters supply six municipal wells in Sharon. In its pristine state, a cedar swamp functions to purify the groundwater with no artificial intervention. The groundwater reservoir protected beneath the wetland also feeds Lake Massapoag year-round, providing a wealth of recreation for its residents and excellent habitat for its fish. A healthy forested wetland reduces drought in times of low rainfall; stormwater percolates slowly through the complex sediments, moderating damaging floods for the entire region.

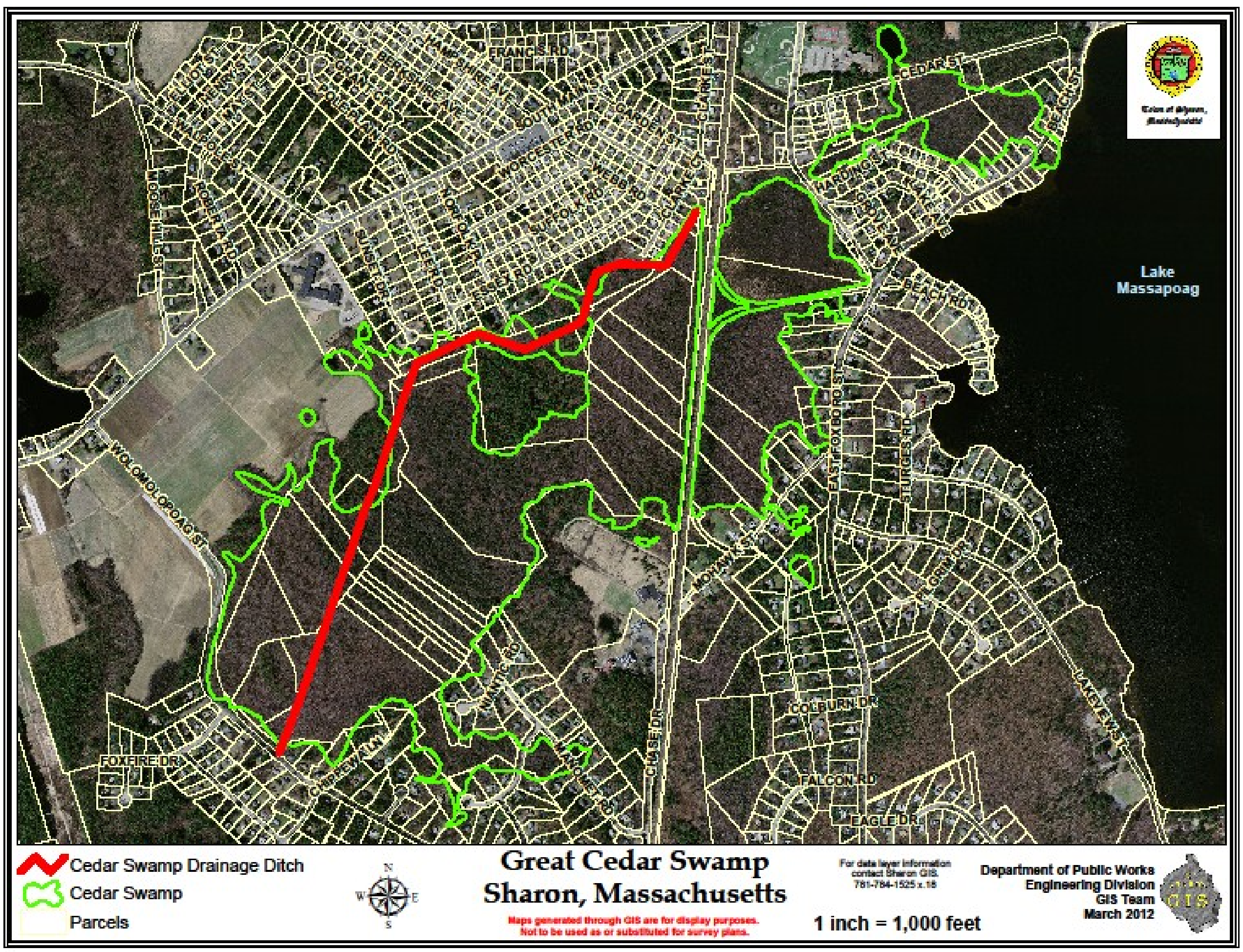


**Figure 1. Sharon Great Cedar Swamp and surrounding streets, aerial view. GCS outlined in green; drainage ditch in red.**

The situation deteriorated in the late 1950's when a residential subdivision, the Heights, was built right on the swamp's western border. These homes soon experienced localized flooding during storms: flooded basements, flooded streets, and poorly functioning septic systems. To eliminate excess water from the residential area, the town authorized construction of a ditch. This large drainage ditch extends about 1.25 miles through the western portion of the swamp (Figure 2). At its start just east of Garden Court, the ditch is about 2 feet deep by 8 feet wide. Where it exits the Swamp beneath Wolomolopoag Street the ditch is currently (2012) about 10 feet deep and 30 feet wide at its top.

**Figure 2. Ditch at the western edge of GCS, in the wooded area between the Heights and Wolomolopoag Street.**

**Figure 3. Healthy Atlantic White Cedar swamp (left); drained/degraded Atlantic White Cedar swamp (right).**

Unfortunately, this huge ditch has effectively drained a large area of the western portion of the Swamp. Large quantities of pristine groundwater, once held within the Swamp, now discharge into the ditch only to flow out of Town. This valuable supply of clean water is now lost to the citizens of Sharon. Lowering of the groundwater table has had major detrimental effects on the wetland ecosystem. Remains of the formerly vigorous stands of cedar now lie on the ground (Figure 3). The characteristic assemblage of wetland species is being replaced by more common plants, some of which are exotic and dangerously invasive. Extensive areas of formerly thick black organic soils are now dry. Rather than accumulating and sequestering organic matter to form peat, the organic matter now decomposes and volatilizes at an accelerated rate. The ground surface has subsided by several feet in much of the western portion of the Swamp. The oxidation of peat has global implications: the formerly sequestered carbon is released as greenhouse gases, contributing to global climate change.

# III. Personnel and Partnerships

## 1. Principal Sponsors:

Sharon Conservation Commission
Sharon Lake Management Study Committee: with critical assistance from the
Sharon Finance Committee

## 2. Principal Sponsor Contacts:

Gregory E. Meister, Conservation Administrator and Project Manager, Sharon GCS Restoration
Cliff Towner, Citizen Representative to the Project, Chairman of the Lake Management Study Committee
Irene Nasuti, Conservation Commission Clerk

## 3. Technical Team Members

Peter C. Fletcher, Soil Scientist
Aimlee D. Laderman, Ph.D., Limnologist/Ecologist
Pamela T. Polloni, Botanist

## 4. Critical Supporting Agencies/Participants

Massachusetts Department of Fish & Game, Division of Ecological Restoration, Franz Ingelfinger
Horsley Witten Group: Neal Price
Watershed Access Lab, Bridgewater State University: Kevin D. Curry, Director; Kim McCoy, Coordinator
Norfolk County Mosquito Control Project (NCMCP): John J. Smith, Director; David A. Lawson, Caroline E. Haviland, and Chan Suom.

## 5. Town of Sharon

Eric Hooper, Superintendent, Public Works Department
David Masciarelli, Supervisor, Water Division
April Forsman, GIS Coordinator, Engineering and GIS Division
Mary Tobin, Chairperson, Sharon Environmental Subcommittee,
Kurt Buermann and Paul Lauenstein, River Instream Flow Stewards

## 6. Other Project Advisors

Local and Regional:
Massachusetts Audubon Society, Christine Turnbull, Moose Hill Wildlife Sanctuary Director
Taunton River Watershed Project
Neponset River Watershed Association (NepRWA)
Ted Elliman, Invasives management, New England Wild Flower Society

State agencies:
Massachusetts Natural Heritage & Endangered Species Program, Division of Fisheries & Wildlife (MA-NHESP); Riverways Program, Massachusetts Dept. of Fish & Game (Riverways); Wetland Restoration Program (MA-WRP); Massachusetts Office of Coastal Zone Management (CZM); Massachusetts Department of Environmental Protection (MA-DEP) Southeast Region; Massachusetts Exec. Office of Energy & Environmental Affairs, Dept. of Conservation & Recreation (MA-DCR); University of Massachusetts, Dartmouth.

Federal agencies:
United States Army Corps of Engineers (USACOE); Partners for Fish & Wildlife Program, United States Fish & Wildlife Service, (USFWS) New England Field Office; United States Geological Survey (USGS), Water Resources Division (WRD), United States Environmental Protection Agency (EPA)

**Field Assistance**

Carolyn Danforth, Biologist

Adam Lazarus, Benjamin Polloni, Jonathan Polloni

**Current Members of Project Sponsors**

Sharon Conservation Commission:
Margaret D. Arguimbau, Chairperson
Hanford G. Langstroth, Stephen Cremer, Christine Turnbull, Elizabeth McGrath, Keevin Geller
Irene Nasuti, Secretary

Sharon Lake Management Study Committee:
Cliff Towner, Chairperson
Michael Baglino, Vice Chairman
Noah Siegel, Secretary
David Deitz, Todd Arnold, Michael Goldstein

**Figure 4. Federal, State and regional partners at a GCS site visit conducted by the Technical Team.**

# IV. Significance of this Project:

*The objective of this Project is to assess the current condition of the Sharon Great Cedar Swamp and recommend methods for restoring the functions and natural vitality of the Swamp while avoiding negative impacts on adjacent land.*

**Benefits to be derived from this project**:

- Conserving groundwater resources
- Purifying groundwater resources
- Stopping land subsidence
- Enhancing the treatment of stormwater runoff
- Reducing the threat of forest fires
- Restoring the plant community and wildlife habitat of a globally rare forested peatland
- Restoring the carbon sequestration function of the forested peatland

## A. Importance of the protected and restored Cedar Swamp to the Residents of Sharon

1. Located on the surface of the Town of Sharon's central, unconfined stratified drift aquifer and within a designated Zone II, the GCS is the primary recharge area for the Town's municipal drinking water supply.[2] Precipitation falling within this area percolates through the soil and is added to the underlying groundwater system.
2. The thick black organic soils within the GCS act as physical, biological, and chemical filters. Precipitation and stormwater runoff is purified as it passes through these soils. This natural filter that removes pollutants is worth thousands to millions of dollars per acre in purification services.[3]
3. During storm events the GCS acts as a large basin that stores water and moderates flooding. This water is then gradually released over a long period of time, mitigating the effects of summer droughts.
4. Groundwater mounded beneath the GCS gradually flows from the swamp in all directions (Figures 5 & 6).
5. Eastern portions of the GCS lie within the Town's Surface Water Protection District, implemented to preserve and protect the watershed of Lake Massapoag.
6. Groundwater from the GCS discharges as freshwater springs into the bottom of Lake Massapoag (Figure 7). This cool clean water helps to maintain the water quality within the Lake for bathing, boating, and fishing.[4]

[2] Horsley Witten Group, 30 June 2011
[3] Joyce and Mitchell, June 2007
[4] Buermann and Towner

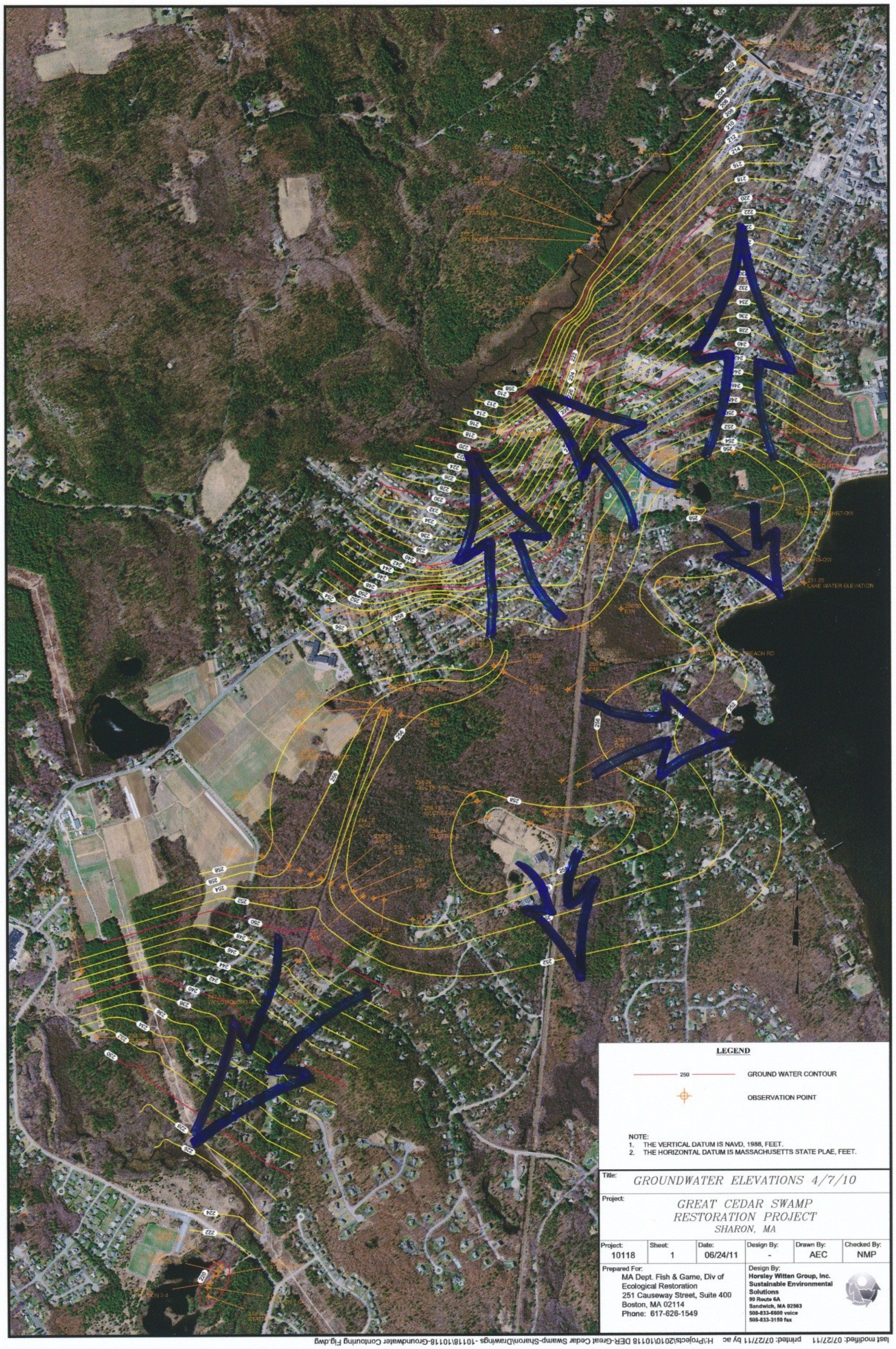


**Figure 5. April 7, 2010 Groundwater flow directions from Sharon GCS.**

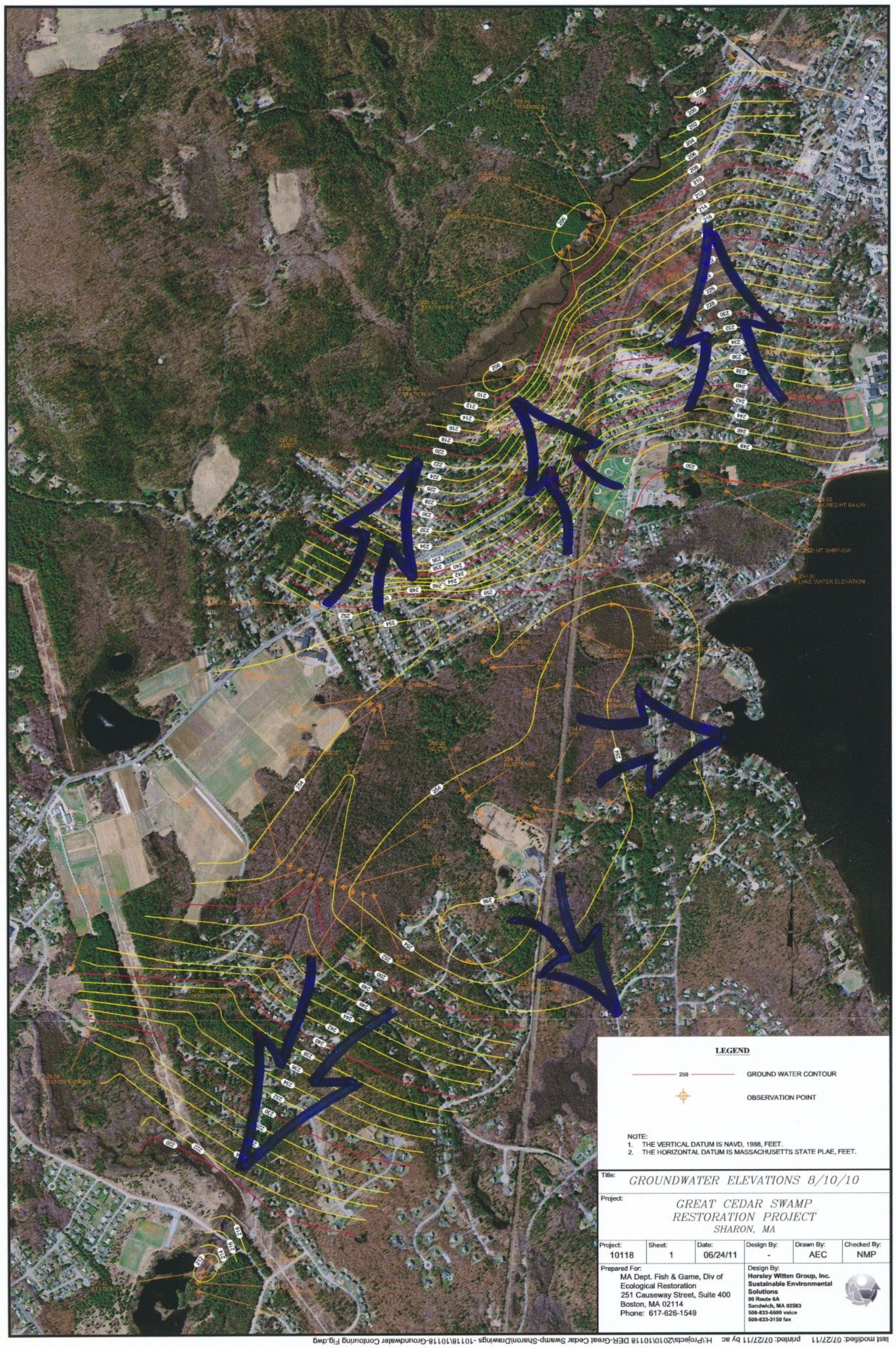


**Figure 6. August 10, 2010 Groundwater flow directions from Sharon GCS.** <u>Note two unusual factors</u>: **groundwater readings used to create this contour map took place: 1.) during a prolonged period when a total watering ban was imposed; and 2.) during a year (2010) with the wettest March, wettest month, wettest spring, fifth wettest August, and sixth wettest year on record (1891-2010).**

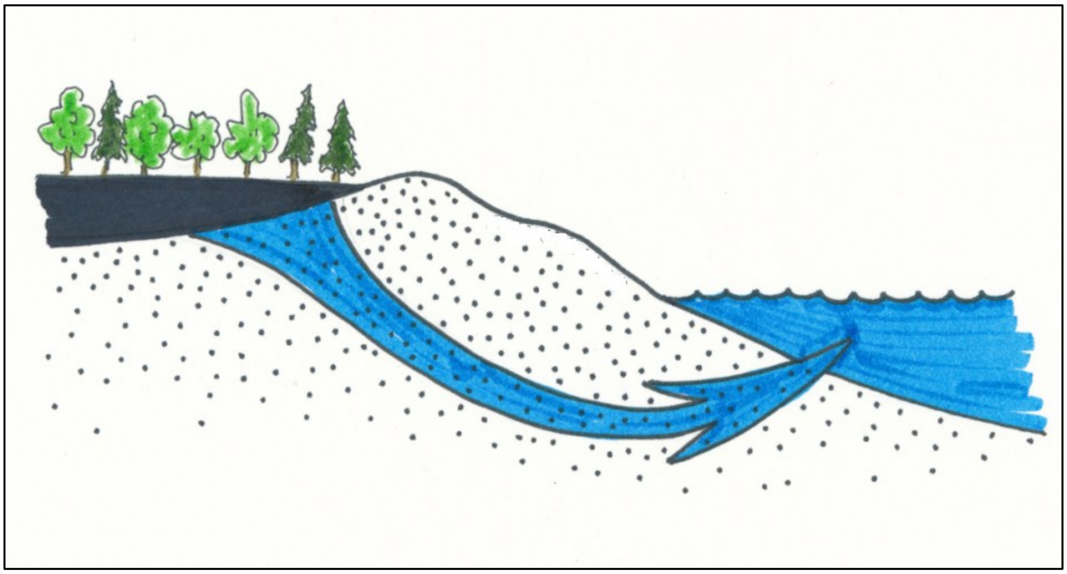

Figure 7. Groundwater flow from the Sharon GCS to Lake Massapoag

7. Wet peat is cooler than surrounding dry land in the summer, so it acts as a natural air conditioner, cooling while the tree canopy purifies the air by trapping aerial pollutants and, via photosynthesis, adds oxygen and sequesters carbon dioxide.
8. In addition to the potential for aesthetic enjoyment and recreation, these bio-geophysical attributes of a healthy cedar forest enhance the quality of life for the entire surrounding area.

## B. Importance of the GCS to neighboring towns and the State

1. The GCS contributes headwaters to two major watersheds in Southeastern Massachusetts, the Taunton River and Neponset River systems (Figure 8). Precipitation falling within the western and central portions of the Swamp exits as both stream and groundwater flow, and eventually flows into tributaries of the Taunton River. Waters from the eastern portion of the Swamp eventually flow into the Neponset River.

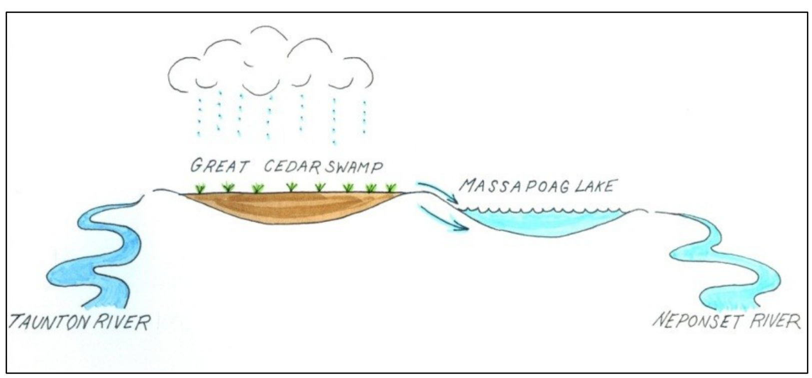


Figure 8. Groundwater flow from the Sharon Great Cedar Swamp to the Taunton River and Neponset River watersheds

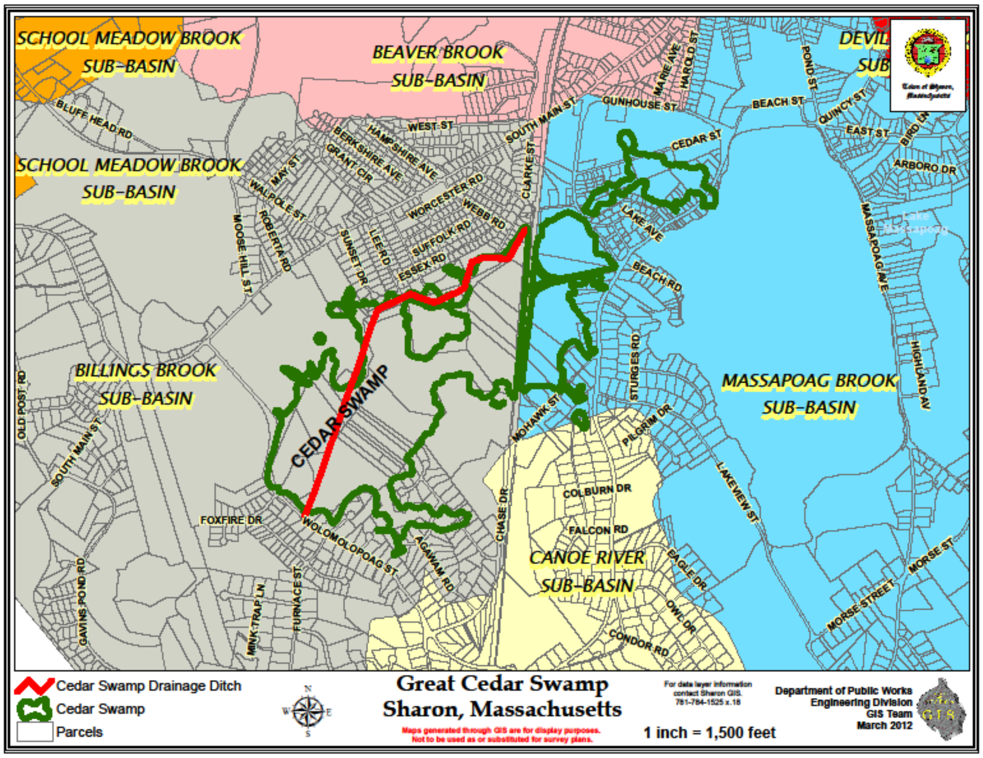


Figure 9. Sharon GCS and Sub-basins of the Taunton River (west) and Neponset River (east) watersheds.

2. Many neighboring towns have wells in areas fed by waters originating from the Swamp.
3. The thick black soils of the Swamp act as a carbon sink, holding organic matter and lessening the release of greenhouse gases (carbon sequestration).
4. Research and findings for this Project are transferable to other degraded wetlands within the State. The Sharon Great Cedar Swamp is unique in that it is divided into 3 distinct sections, each with a different hydrology. An active railroad line (Amtrak) and an old railroad spur pass through the Swamp (Figures 9, 10). The fill used for the railroad beds has compacted the underlying organic sediments creating a subsurface barrier that impedes groundwater flow between sections of the Swamp. Section 1 is in the western and central portions of the Swamp where the drainage ditch is located. The natural hydrology has been lowered in this area, degrading the entire Section. In Section 2 the hydrology is common to what one would expect to find in a healthy cedar swamp; this area has not been impacted by the ditch. In Section 3 the natural groundwater flow was once impeded; groundwater levels in this area were elevated flooding the wetland forest. Following the repair of a water control structure in 1994, AWC regeneration now occurs in this section although groundwater levels remain high.

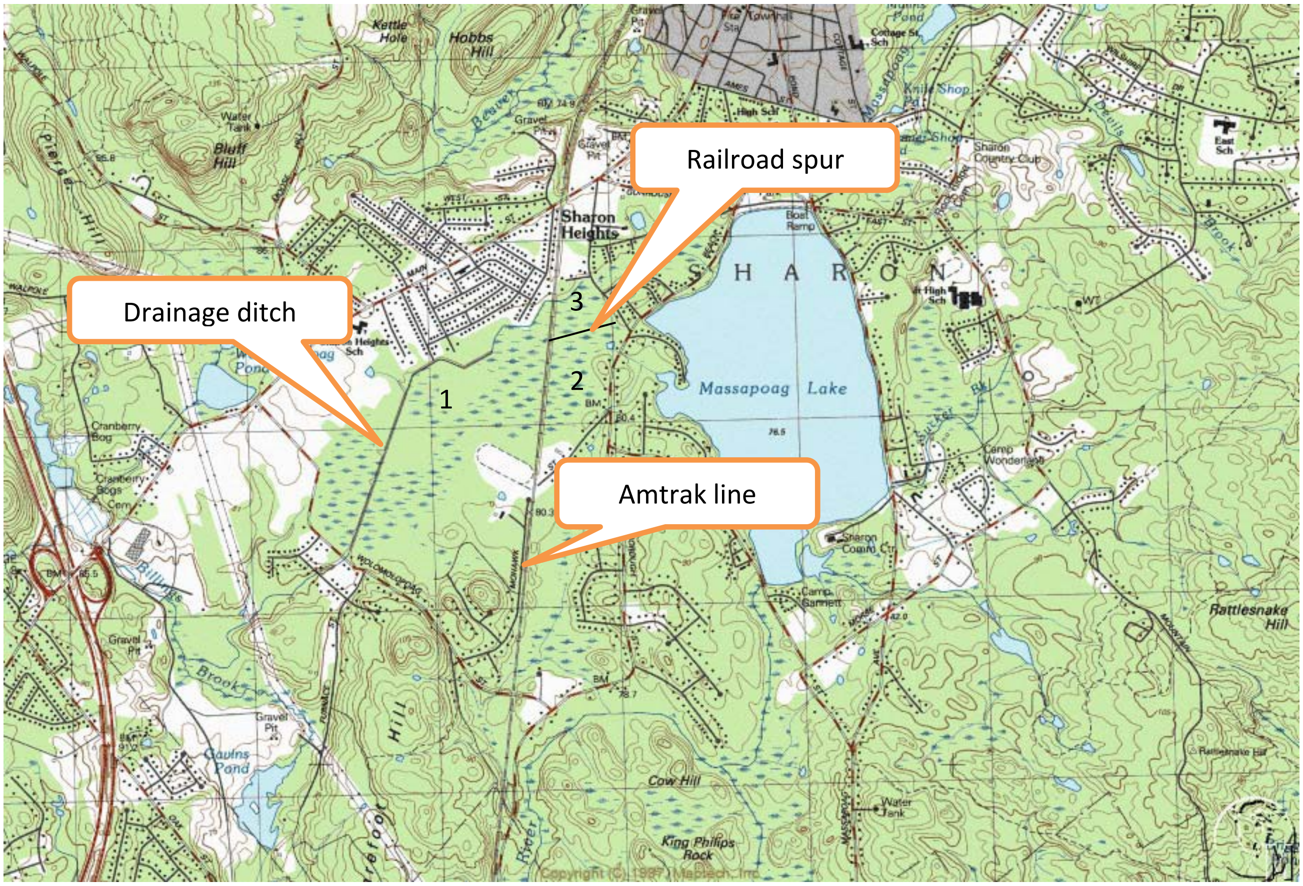


**Figure 10. Sharon Great Cedar Swamp and vicinity, USGS Topo. Brockton Quad (Maptech, Inc.) Section 1. West of Amtrak line, degraded by drainage ditch; Section 2. East of Amtrak line and south of railroad (RR) spur, has a healthy "reference" Atlantic White Cedar stand; Section 3. East of Amtrak line and north of RR spur has regenerating Atlantic White Cedars.**

# V. Overview of completed and ongoing projects

## A. Vegetation and wildlife studies[5]

**Section 1**. Plant community and wildlife descriptions are being recorded along two transects in this section where restoration of natural hydrologic conditions is a goal (Figure 11). Seven established study plots are being monitored.

**Figure 11. Fallen AWC in drained area east of Sunset Drive (Section 1).**

**Section 2.** Monitoring at Plot # D1E (Figure 12) continues, providing status information on the least disturbed portion of the Swamp. Here AWC trees averaging ~20 cm diameter at breast height (dbh) dominate the canopy.

**Figure 12. Late spring view of AWC swamp with normal groundwater elevation (Section 2).**

[5] Fletcher et al. April 2010. Note: Botanical field work has been conducted with the invaluable assistance of Carolyn Danforth, Biologist.

**Section 3.** This separate northeastern area, a portion formerly drowned by water retention, is important to the Swamp in that there are several stands of reproducing Atlantic White Cedar with both seedlings and saplings evident (Figure 13). Survival of these cedars is dependent on water level management and is threatened by the spread of rapidly growing invasive glossy buckthorn (*Frangula alnus*) and by browsing white-tailed deer. During 2009-11, unusually wet winters prevented easy access to study plots here where glossy buckthorn has taken hold. Site visits in 2007 through early 2011 have documented the rapid growth of this problem invasive. Using Plot #E1N as a control, we have initiated establishment of test plots nearby with selective cutting of glossy buckthorn.

Figure 13. Regenerating AWC with blossoming leatherleaf (*Chamaedaphne caliculata*) in foreground, (Section 3).

Continuing Action: to protect the regenerating AWC in Section 3 and determine feasibility of repopulating AWC within degraded areas of the GCS.

1. Establish glossy buckthorn control plots and construct deer exclosures if necessary.
2. Monitor seasonally to determine if AWC regeneration and sapling growth will be sustained and/or improved.
3. Monitor all vegetation plots seasonally to determine regeneration success in Section 3 relative to nearby areas in the degraded swamp of Section 1 west of the railroad, and the reference swamp of Section 2 south of the railroad spur.
4. Use the control structure to maintain suitable groundwater levels for AWC in Section 3.
5. Following restoration of Section 1 hydrology, begin test reintroduction planting to a suitable substrate within open canopy (e.g. at Test Plot established near monitoring well #A6E).

## B. Soil Investigations[6]

### 1. Soil Conditions within Section 1 of the GCS:

The large drainage ditch is located in Section 1 of the GCS. Within this section there are extensive areas with organic soils, and it is this area that has been most seriously impacted by the lowering of groundwater level. The most intensive soil investigations were conducted here.

The effects of soil subsidence are unique to this section of the Swamp. Organic soils (peats) form within areas that are very wet for long periods.. Organic litter (leaves, needles, and animal matter) falling within this wet anaerobic environment accumulates over time. In areas where the peat has been drained, gases replace the water in the soil pore spaces. Under these conditions the organic matter decomposes at an accelerated rate and the ground surface sinks. Evidence of significant soil subsidence can be verified by studying the exposed root systems at the base of trees (Figure 14). Soil subsidence weakens the support of the trees making them less stable and more susceptible to wind-throw. Within many areas of Section 1 of the Swamp, there are thousands of dead trees lying on the ground surface. Using the height of exposed root systems on standing trees as a gauge, the degree of subsidence within the organic soil areas can be determined. The amount of soil subsidence was estimated to range from 1 foot to greater than 3 feet. The degree of subsidence was greatest in the organic soils that are closest to the drainage ditch.

**Figure 14. Exposed AWC roots indicate severe soil subsidence near the ditch.**

Because groundwater has been lowered, especially in those areas closest to the drainage ditch, organic matter in the upper part of the soil is no longer saturated. In many of these areas the upper 1 to 1.5 feet of organic matter becomes very dry in summer. This makes these areas prone to forest fires that are notoriously difficult to control and extinguish.

[6] Fletcher et al. 2008

## 2. Soil Conditions within Sections 2 and 3 of the GCS

These investigations were conducted during the wet season of the year (spring and early summer) and there was standing water within the depressions. The general good health of the trees growing in this section of the Swamp, and the lack of evidence of subsidence suggest that the natural hydrology within Section 2 of the GCS has not been altered to any substantial degree.

In Section 3 there was standing (ponded) water on the surface that ranged in depth from 0.5 to 1 foot deep. Within this section of the Swamp it is interpreted that the groundwater elevations were raised in recent times.

## 3. Soil Transect Measuring the Depth of Organic Material

A soil transect was conducted along the eastern edge of the active railroad bed that passes north-south through the GCS (Figure 10). The purpose of these soil investigations was to measure the thickness of organic material within an area of the Swamp that was not impacted by the drainage ditch. The depth of organic material was determined by forcing a metal rod down into the soil. [The depth of the organic matter was determined when the metal rod met significant resistance and there was a gritty feel at the end of the probe.] The maximum length of the soil probe was 12.25 feet. Thickness of the organic matter overlying the mineral substrate was greater than 12.25 feet in some areas along this transect. Refer to the Soil Transect (Figure 15) for the range in thickness of the organic sediments and the depths to the underlying mineral substrate.

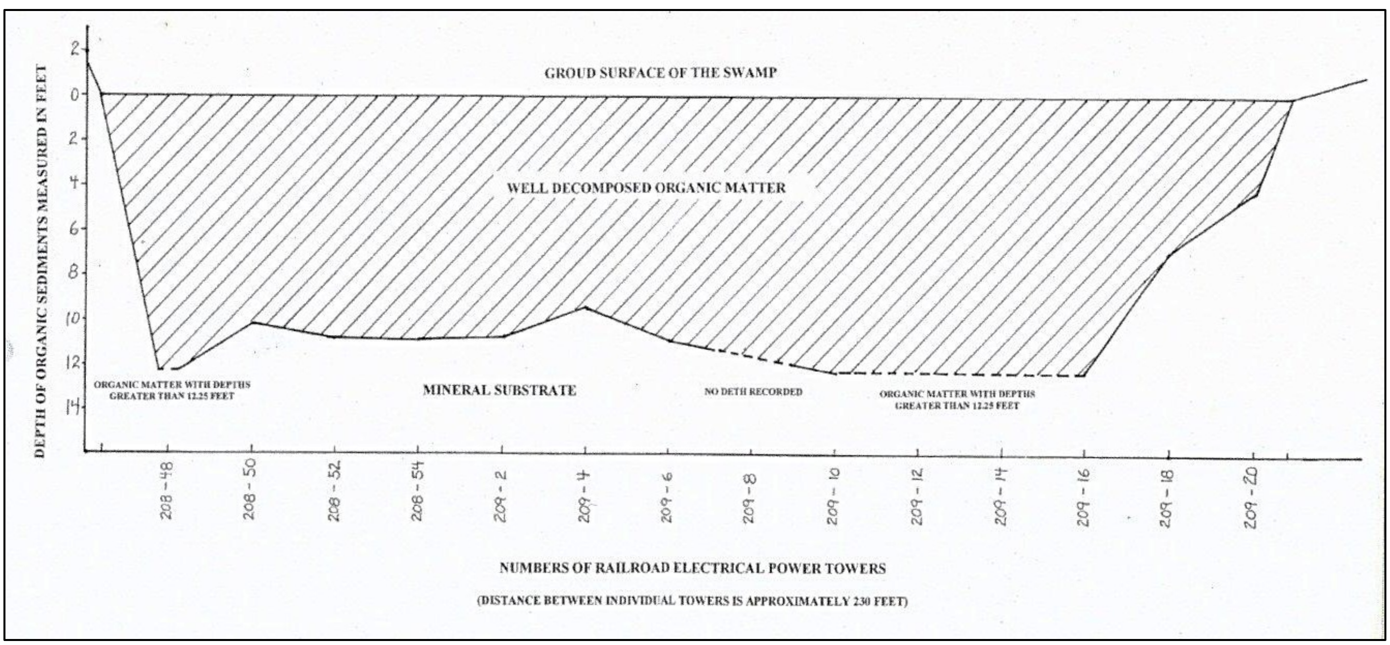


**Figure 15. Depth of organic matter in Sharon GCS on transect along east side of RR bed.**

## C. Groundwater Monitoring Program

An ongoing groundwater monitoring program has been put in place to assure the Town and its residents that this Project will create no negative impacts. The first phase was to install a groundwater monitoring well network. Thirty nine monitoring wells were installed within the Swamp and 7 wells in the Heights residential area (Figure 16). The purpose of these wells was to document the current groundwater conditions within the Swamp and the Heights, and to record seasonal fluctuations in the groundwater. Several years of monthly groundwater fluctuations have been recorded for this Project. At two wells (monitoring wells at Essex and Middlesex Roads) located in the Heights, electronic devices (data loggers) were installed to record hourly fluctuations in the groundwater. These data are being used to develop a baseline for the existing groundwater conditions; they will be used to assess the impacts of any actions taken for this Project.

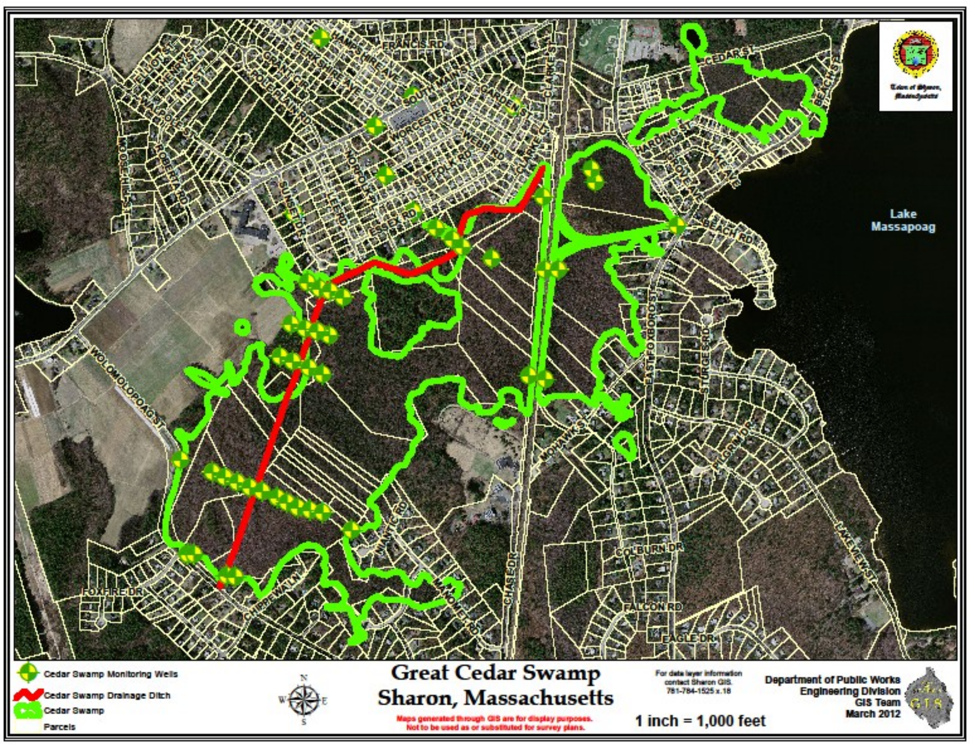


**Figure 16. Groundwater monitoring wells established in Sharon GCS and Sharon Heights.**

## D. Ongoing Groundwater Monitoring of Well Transects Along Ditch:

It is important to assess the impacts of any water control structures placed within the ditch. To assess the effects on groundwater elevations within these areas, four monitoring well transects have been positioned along the ditch (Figure 16). These are oriented perpendicular (east to west) to the direction of the ditch and are spaced at different intervals along the ditch. The first well transect is located north of where the ditch exits the Swamp beneath Wolomolopoag Street. The last transect is located just south of Sunset Drive where a stormwater culvert empties into the ditch.

### E. Monitoring of flows within the drainage ditch

Ongoing study measuring stream flow within the drainage ditch: a cooperative effort with the Sharon Friends of Conservation and the Sharon DPW.

Figure 17. Normal flow within the ditch.


Figure 18. Stormwater flow within the ditch, March 2010

### Stream Flow at Sharon's Wolomolopoag Street Gauge[7]

The Sharon Friends of Conservation have been monitoring a flow gauge in the ditch that drains Sharon's Atlantic White Cedar Swamp at Wolomolopoag Street (Figure 19) on a more or less daily basis since April, 2008. Kurt Buermann, President of the Sharon Friends of Conservation, collected the majority of the readings. The gauge was installed by the Massachusetts Department of Environmental Restoration, which also created a rating curve to convert depth readings into flow in cubic feet per second (cfs). Both the depth data and the flow data can be viewed along with photos of the site at the River Instream Flow Stewards (RIFLS) website, http://www.rifls.org.

Maximum flow of 46.7 cfs was recorded on March 31, 2010 following an unusually heavy rain event (Figure 18) when the ground was already saturated from previous rain. Minimum flow in the ditch approached zero during hot, dry weather in August, 2010.

Approximately 135 million gallons flows past the gauge in a typical year, but about 250 million gallons flowed past the gauge in 2009. The annual median of monthly median flows (i.e. typical flow) ranged from 0.23 cfs in 2010 to 1.18 cfs in 2009. Monthly median flows and estimates of the amount of water that flows past the gauge on an annual basis are shown in the attached spreadsheet.[8] Also attached are graphs of daily flows from 2008 through 2011 (Figure 20), showing both flow (blue line) and precipitation (gray bars). Note that the scale of the Y-axis varies from graph to graph, and the scale for precipitation is exponential.

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[7] Lauenstein, P. Stream Flow at Sharon's Wolomolopoag Street Gauge; http://www.rifls.org/detail.asp?siteId=86

[8] Ibid

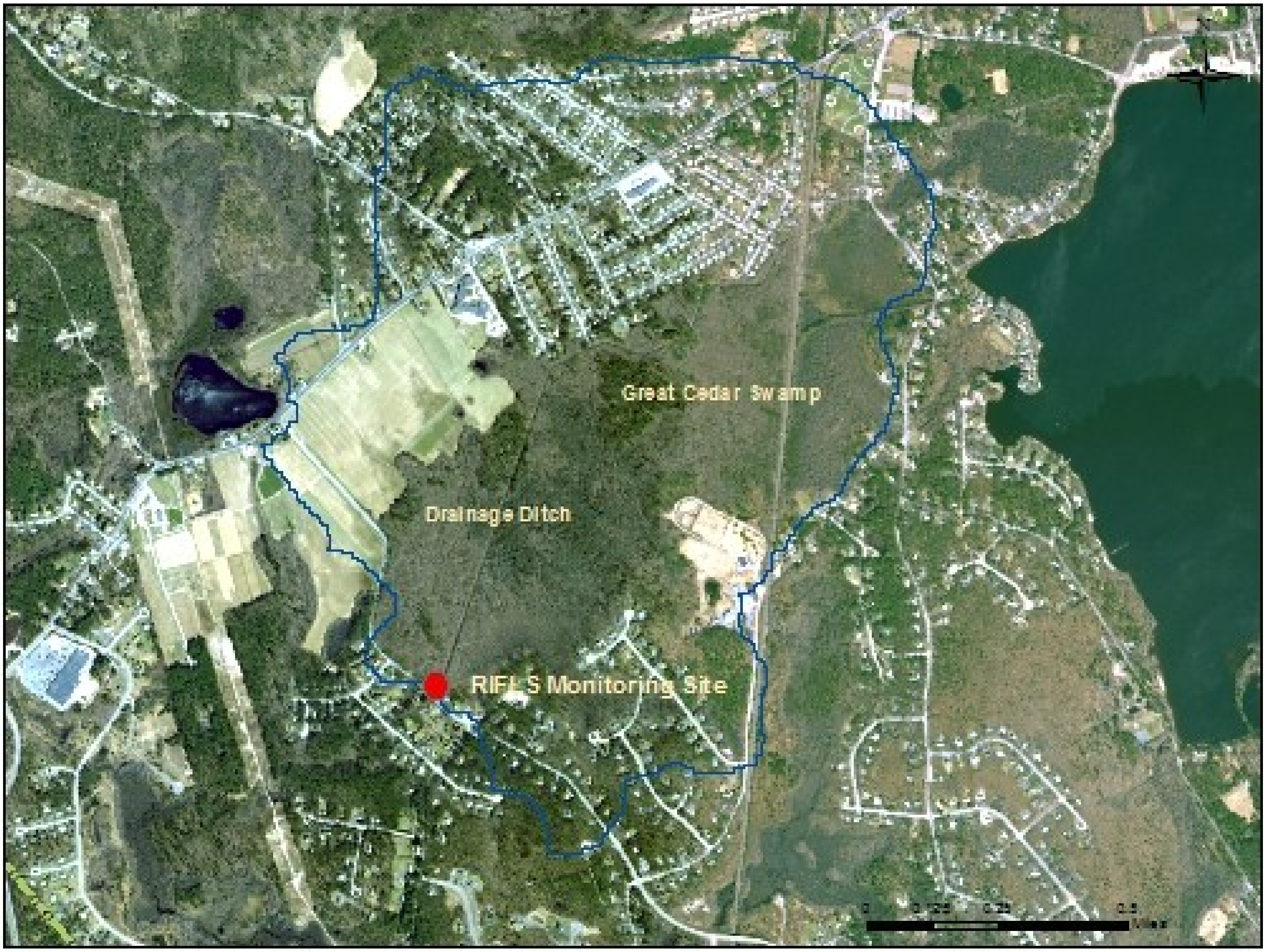
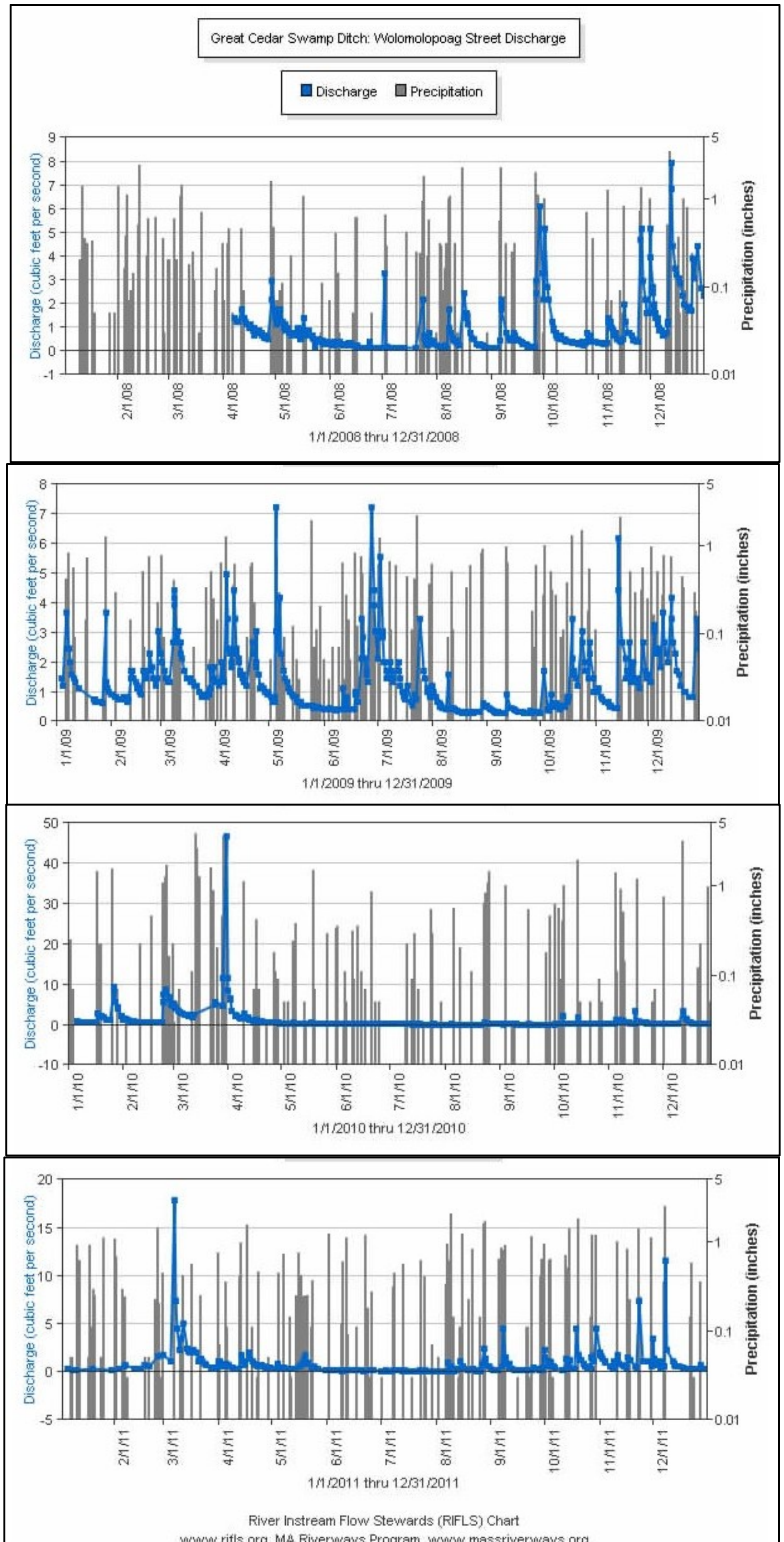



**Figure 19. Wolomolopoag Street RIFLS Monitoring Site.**




**Note**: Some extreme high or low flows may not plot with correct discharge values; if the staff gage is not calibrated for high or low water depths, the highest or lowest discharge within the range of calibration will be reported. To determine the range of stage heights that are calibrated, please consult the rating table.

**Figure 20. Precipitation and Wolomolopoag St. discharge measurements 2008 – 2011.**

## F. Ongoing mosquito monitoring and investigation[9]

Figure 21. Gravid Trap for adult mosquitoes.

The Sharon Conservation Commission and the Technical Team invited the Norfolk County Mosquito Control Project (NCMCP) to work with us at the inception of this project. The NCMCP has now been monitoring Sharon GCS mosquito populations for four years. Their work has provided a valuable service to the population of the Town, with vital information protecting the health of humans, their pets and Sharon's wildlife. Four traps for adult mosquitoes (Figure 21) were placed within the general area of the Swamp. Eastern Equine Encephalitis (EEE) virus was detected in 2011, in one of the NCMCP traps. Crypts, the cavities formed beneath trunks of Atlantic White Cedars, are breeding areas for *Culiseta melanura*, a species of mosquito that is a vector for EEE. NCMCP is monitoring populations of mosquito larvae in the GCS crypts (Figure 21).

"Since October of 2008, the NCMCD has been monitoring the Sharon Cedar Swamp for abundance of the EEE virus mosquito vector, *Culiseta melanura*. We've established 40 sampling sites along a portion of the swamp. Disregarding dry conditions in 2010, each site contained an average population of >6 mosquito larvae. Sampling for *Culiseta melanura* larvae is very involved and the results are often difficult to interpret. The larvae of this mosquito species inhabits what we call "crypts" formed from the roots of trees in the swamp. These recesses within the roots provide protection from the elements and predators. The quantity of larvae collected is often far and away less than what is hidden in these habitats. The 2011 sampling season saw our highest ever collection of *Culiseta melanura* due to wet conditions. More surveillance is needed to ascertain the relationship between cedar swamp water levels and *Culiseta melanura* abundance."

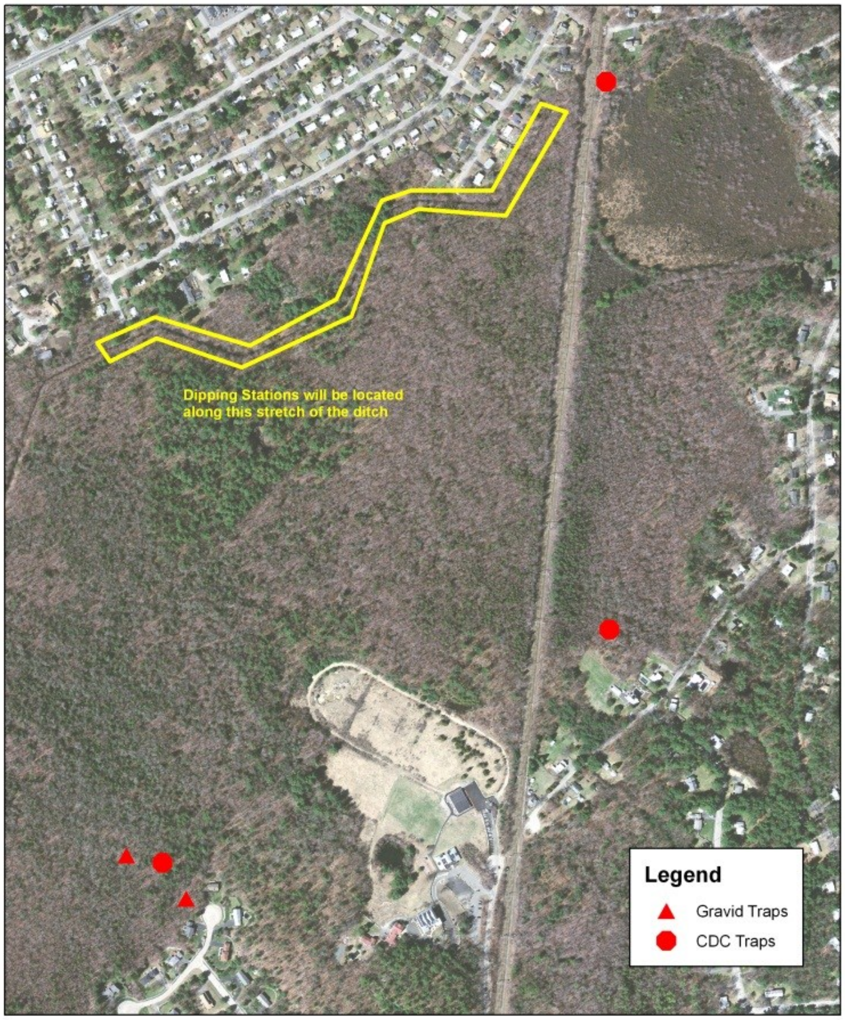
–Chan Suom, Entomologist, NCMCD

"A site inspection of the entire Great Ditch, from Garden Court to Wolomolopoag Street, was conducted by me, Brian Moore, & Bill Haviland on December 16, 2011. Areas of slower flow and moderate to severe blockages/debris were observed within the ditch. The District will assist the town/DPW in clearing such obstructions as needed/requested. Our Surveillance Technician, Nate Boonisar, will be conducting larval mosquito collections/counts this spring/summer (Figure 23). The site will be inspected again and larval data reviewed at the end of the 2012 mosquito season. We are able to share any related GIS shape files with the town as well." *Norfolk County Mosquito Control District (NCMCD)Sharon Cedar Swamp Revitalization Activity Update*

--Caroline E. Haviland, Water Management Project Coordinator, NCMCD

[9] NCMCD Sharon GCS Revitalization Activity Update March 13, 2011

**Sharon Cedar Swamp -- Trap Sites and Dipping Area**



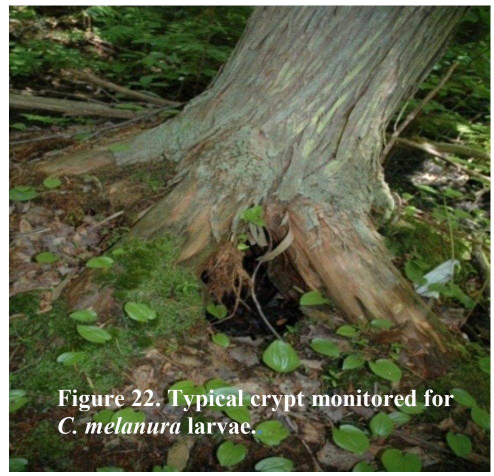



Figure 22. Typical crypt monitored for *C. melanura* larvae.

**Figure 23. Norfolk County Mosquito Control District (NCMCD) 2012 monitoring sites in GCS.**

### G. Horsley Witten Group Study/Report

The Massachusetts Division of Ecological Restoration (DER) collaborated with the Town of Sharon to investigate restoration opportunities for the GCS.[10] Their in-kind and direct services and contract with Horsley Witten, Inc. (HW) provided a ground elevation survey (Figure 25), groundwater contour maps (Figures 26 & 27), data compilation, and analysis. The topographic survey included "monitoring well elevations, ditch elevations, and other key hydrologic elements in the project area (such as a limited suite of subdivision infrastructure components). The survey was conducted using a combination of high-accuracy RTK GPS to collect as many points as possible and traditional land survey techniques to collect remaining points that were inaccessible due to GPS coverage limitations. The features surveyed included all GCS Technical Team monitoring wells in the Swamp and in the adjacent Sharon Heights subdivision along with representative neighboring ground shots. [11]

**"Background**

The Great Cedar Swamp (GCS) is located west of Lake Massapoag in Sharon, Massachusetts. Recent research conducted by the Great Cedar Swamp Technical Team (GCSTT) has determined that the swamp is threatened by lowered water levels. The GCSTT has previously installed more than 40 groundwater monitoring wells throughout the area, and collected significant hydrologic and ecologic data in support of an evaluation of potential wetland restoration options.

Factors that may potentially contribute to lowered GCS water levels, altered hydrology, and associated impacts to ecological function include:

- A drainage ditch that was installed in the 1960s to provide stormwater drainage for an adjacent neighborhood immediately to the west/northwest of the GCS (Sharon Heights). The neighborhood was reportedly constructed from the late 1950s to the early 1960s, and the drainage ditch itself was reportedly constructed during, or shortly following, the construction of the subdivision. The upper section of the ditch that runs immediately parallel to the subdivision appears to be at a relatively low gradient. Following its turn to the southeast, the ditch becomes more deeply incised, the gradient steepens, and both the flow and velocity appear to increase noticeably. It is likely that this lower reach of ditch has penetrated the GCS peat layer and is receiving significant groundwater inflow through the underlying sand and gravel deposits.

- The Sharon Heights stormwater drainage system consists of catch basins directly piped to outfalls to the drainage ditch. Portions of the drainage system are reportedly below the high groundwater level such that it may receive groundwater infiltration that could then be conveyed it to the drainage ditch in the GCS. The direct outfall stormwater management strategy for the neighborhood therefore likely quickly conveys aquifer recharge away from the study area, as well as intercepting previously recharged groundwater and conveying that away from the area thus further impacting local hydrology.

- The Town of Sharon operates six municipal drinking wells within glacial outwash deposits contiguous to the GCS. These wells service 98% of the Town's year-round residents plus the summertime population that concentrates around Lake Massapoag. Wells 2, 3, and 4, are located north of the swamp in the Beaver Brook Valley. Wells 5 and 7 are located to the south, adjacent to Billings Brook, and Well 6 is

[10] Purinton, Tim. 4 April 2012 Letter "Sharon Great Cedar Swamp, MA DER Project Participation" (Appendix A.)
[11] Price, Neal. 30 June 2011. Horsley & Witten report to DER (Appendix B.)

located to the southeast in the Canoe River sub-basin. Private wells service the reaming (remaining) 2%[12]. According to Cliff Towner, there are no private irrigation wells in the GCS area. The combined influences of groundwater withdrawals may lower the water table in the vicinity of the GCS.

**Scope of Work**

The current scope of work was undertaken with the intention of creating a framework within which to evaluate and utilize the hydrologic data previously collected by the GCSTT. It included the following primary elements.

1. A topographic survey was conducted of monitoring well elevations, ditch elevations, and other key hydrologic elements in the project area (such as a limited suite of subdivision infrastructure components). The survey was conducted using a combination of high-accuracy RTK GPS to collect as many points as possible, and traditional land survey techniques to collect remaining points that were inaccessible due to GPS coverage limitations. The features surveyed were:
    - All GCSTT monitoring wells in the GCS and the adjacent Sharon Heights area along with representative neighboring ground shots;
    - The two surface water gaging stations in the drainage ditch;
    - Ten representative transects crossing the drainage ditch and a longitudinal profile of the ditch bottom thalweg;
    - Town monitoring wells surrounding the three nearby public supply wells;
    - Inverts and other details of the stormwater outfalls that drain the Sharon Heights neighborhood northwest of the GCS to the drainage ditch, a representative sampling of catch basin rims and inverts on the cross streets between South Main Street and the drainage ditch, and a representative sampling of tops of foundations for approximately a dozen of the lowest elevation homes along Essex Road; and
    - The existing staff gage in Lake Massapoag.

2. All topographic survey data were digitally provided to DER, along with selected maps illustrating survey points on an aerial photographic base for the GCS and the Sharon Heights neighborhood.

3. Surveyed elevations of monitoring wells and staff gages were also provided to DER, who then converted previously collected GCSTT hydrology data into groundwater elevation data and conducted a quality control review.

4. Two groundwater contour maps were created for the project area based upon the surveyed well elevations and the historical water level data. One map represents average spring (or high water) conditions, and the other represents average late summer (or low water) conditions. HW selected April 7, 2010 and August 10, 2010 for the spring and summer mapping dates, respectively. Those decisions were based upon, first, maximizing the number of available data points for the selected mapping dates, and second, consulting the groundwater level records from the nearby USGS index well (NNW 27 in Norfolk) in order to find representative wet and dry times (within the GCSTT monitoring period). Groundwater contour maps were created through an iterative process whereby groundwater elevation data for all monitoring points were first contoured using the AutoCAD 2011 contouring tool, then those contours were adjusted by a hydrogeologist based upon knowledge of streams and other hydrologic features, and then the contours were digitized again in CAD. Those groundwater maps were previously supplied to DER in digital and paper formats, and are also attached here.

[12] Open Space and Recreation Plan, Town of Sharon, Massachusetts

**Discussion of Groundwater Contour Maps**

April 7, 2010

This map represents spring, high groundwater conditions. USGS Index Well NNW 27 in Norfolk exhibited a water level at this time that was 0.86 feet higher than the April mean. The following are the key hydrologic observations related to this map.

- There are two distinct peaks to the groundwater mound, each at approximately elevation 258 feet (NAVD, 1988), separated from each other by the GCS drainage ditch. The eastern peak is approximately located in the vicinity of the Islamic Center at the southeastern edge of the GCS, and the western peak is approximately located in the vicinity of the agricultural fields to the west of the GCS. Groundwater in the immediate vicinity of the drainage ditch is at elevation 254 feet at its highest, and drops to approximately elevation 246 feet by the time the ditch crosses Wolomolopoag Street at the southwestern edge of the GCS. It appears likely that, were it not for the hydraulic influence of the drainage ditch, the two distinct groundwater peaks would have previously been connected into a single larger peak (and potentially at higher maximum elevation than is currently exhibited), covering most of the GCS and adjacent agricultural and residential land.

- Groundwater flows (perpendicular to the contours) radially out from the groundwater peaks towards groundwater discharge areas. To the north, groundwater flows towards and enters Beaver Brook or one of the three municipal supply wells near the brook. To the south, groundwater discharges to the GCS drainage ditch and, eventually, Billings Brook. To the east, groundwater discharges to Lake Massapoag from which it appears to either exit along the north shore as groundwater, which eventually discharges to Beaver Brook, or to exit through a surface water outlet to Massapoag Brook at the northeastern corner. Western areas are outside of the mapped study area.

- The GCS drainage ditch exerts an obvious hydraulic influence with the 254 foot elevation groundwater contour tightly surrounding the majority of the ditch and the 256 foot elevation contour also encompassing the ditch. The ditch provides an easy conduit draining groundwater from the surrounding area and reducing the overall elevation of the water table beneath the GCS and the surrounding area. According to the GCSTT, and confirmed by field survey observations during this project, the southern portion of the ditch is incised through the GCS peat surface and intersects underlying permeable sand and gravel deposits capable of readily conveying water from the aquifer to the ditch. All of the GCS, except for the northern and eastern extents, appears to drain south to or towards the drainage ditch.

- Municipal drinking water well Stations 2, 3, and 4 along Beaver Brook and Station 7 along Billings Brook also exert an observed hydraulic influence. The spacing of groundwater contours grows tighter towards Beaver Brook and Stations 2, 3, and 4, indicating a steeper slope of the water table towards the combined hydraulic “draw’ of Beaver Brook and the pumping wells. With the area north of the brook consisting of glacial till and/or exposed bedrock highlands, most of the groundwater contribution to the brook and the municipal wells is likely drawn from the GCS and the surrounding areas south of the brook. The relative hydraulic importance of the brook versus the wells cannot be determined from this mapping exercise. The influence of Station 7 can be seen in the 220 foot elevation contour circling the lowered water table in the vicinity of that pumping well. Station 5 is at the edge of the study area and there are inadequate data points present to indicate the influence (or lack of) from that station on the local hydrology.

August 10, 2010

This map represents summer, low groundwater conditions. USGS Index Well NNW 27 in Norfolk exhibited a water level at this time 1.02 feet lower than the August mean. The following are the key hydrologic observations related to this map.

- Similar to the spring conditions map, there are two distinct peaks to the groundwater mound separated from each other by the GCS drainage ditch. Relative to the spring conditions map, the eastern peak over the GCS has been reduced in elevation by approximately 2 feet to elevation 256 feet, and the western peak has been reduced by approximately 4 feet to elevation 254 feet. Lower groundwater elevations are expected for summer conditions relative to spring conditions. One possible explanation for the greater decline on the western side is the greater proximity of the western mound peak to municipal supply well Stations 2, 3, 4, and 5. Groundwater withdrawals typically increase in the summer time and the proximity of the western peak to those increased withdrawals may contribute to a greater seasonal decline than is observed for the eastern mound peak.

- As was discussed for the spring conditions map, the GCS drainage ditch exerts an obvious hydraulic influence. What's different is that the overall lowered summer conditions water table has shifted the groundwater divide (location where groundwater changes from flowing south through the drainage ditch to flowing north towards Beaver Brook) to the south toward the bend in the drainage ditch adjacent to the Sharon Heights neighborhood. The southern portion of the GCS drainage ditch continues to drain to the south as it did on the spring conditions map, but groundwater around the northern portion of the ditch now appears to flow to the north. A high point within the ditch located just south of Linda Road may impound water upstream of it during low water time periods. During such drier periods, water impounded upstream of this high point may exit the system as groundwater flow to the north, rather than as surface water flow to the south through the drainage ditch. Increased summer season municipal water supply withdrawals from Stations 2, 3, and 4 to the north may also potentially contribute to the southward shift of the groundwater divide.

- Groundwater contours wrap around municipal drinking water well Stations 2, 3, and 7 to a greater degree than was observed on the spring conditions map. This is indicative of a lowered water table in the immediate vicinity of the pumping wells due to a normal increase in summer season pumping from those stations. Inadequate data points surround Stations 4 and 5 to indicate the influence (or lack of) increased summertime pumping.

**Discussion**

The groundwater mapping exercise indicates several important considerations. Many of the following discussion items are the same as those originally stated in a December 22, 2010 Technical Memorandum. Subsequent field work and analyses have allowed for a more refined discussion of those prior items, as well as the inclusion of some new items.

1. Because the peak of the local groundwater mound (currently two distinct peaks bisected by the GCS drainage ditch), the GCS and the immediate surrounding area is the primary source of groundwater recharge for the local area. This means that within the study area, the GCS and immediate surrounding area is the primary source of groundwater recharge to municipal well Stations 2, 3, and 4 along Beaver Brook; Stations 5 and 7 along Billings Brook; and Station 6 along the Canoe River. Due to its undeveloped nature, groundwater recharged at the GCS is of high quality and serves to dilute lesser quality groundwater recharged over more developed intervening areas between the GCS and the

municipal wells. For the same reasons mentioned above, the GCS is also a primary source of groundwater-derived baseflow within the study area to the headwaters of Beaver Brook, Billings Brook, and the Canoe River, as well as Lake Massapoag. While all of these water resources also receive some contributions from outside of the study area it should be noted that the areas outside of this study area north of Beaver Brook, and east of Lake Massapoag consist primarily of till and/or bedrock uplands that likely contribute lesser amounts of groundwater recharge than do the permeable aquifer materials of the GCS and surrounding areas.

2. The drainage ditch appears to be the primary anthropogenic factor impacting the hydrology of the GCS. While groundwater withdrawals from municipal wells undoubtedly have some influence, the wells are relatively distal in comparison to the ditch and do not dramatically affect the appearance of the groundwater contours in the GCS vicinity to the same extent as does the drainage ditch. The drainage ditch clearly bisects what was likely formerly a single groundwater mound peak, creating two separate peaks. The overall elevation of the two separate groundwater mound peaks are also likely lower than was a single peak that likely existed before the ditch was constructed. The closer you get to the ditch, the more significant its hydrologic influence.

3. The Sharon Heights neighborhood abutting the GCS to the northwest is the primary factor conflicting with restoration goals of increased groundwater elevations in the GCS. The neighborhood is served by onsite septic systems (many of which reportedly have depth to high groundwater concerns) and also reportedly has wet basement issues. Under current conditions, the depth to seasonal high groundwater for some areas of the neighborhood may be only approximately four feet. The neighborhood is therefore highly susceptible to any increases in groundwater level that might arise from a restoration of the GCS. This is not a surprise as the drainage ditch was likely constructed for the purpose of lowering groundwater elevations for the neighborhood.

4. If cost were not an issue, the best case restoration scenario for the GCS would incorporate integrated water resources management for the adjacent subdivision neighborhood in an effort to bring the local water budget more in balance, such that higher water levels in the GCS might be offset by lower anthropogenic groundwater additions in the neighborhood. This would include constructing a clustered wastewater treatment facility and low-impact development (LID) stormwater management facilities that would effectively transport water away from the subdivision to downgradient locations, where it could contribute to GCS hydrology while simultaneously reducing groundwater levels beneath the subdivision. After a quick review of available information, it was determined that topographic and open space limitations would be significant hurdles. Centralized wastewater treatment in particular would be quite expensive and potentially unpopular politically.

5. Some degree of LID stormwater management improvements that would benefit the GCS hydrology while mitigating residential impacts are likely still feasible.

6. Drainage ditch alterations that would reduce outflow through the ditch would, by necessary correlation, raise GCS groundwater levels. As such, they would likely be highly effective at raising groundwater elevations to the GCS. Potential ditch alterations include a series of check dams of various heights, infilling to different degrees, and the preceding augmented with a high water level under-drain for flood protection. While worth evaluating, all options for reducing flow through the drainage ditch would serve to raise groundwater levels beneath the Sharon Heights neighborhood to some extent. The amount of groundwater increase beneath the neighborhood would vary from negligible to significant depending upon the extent of increase in the neighboring GCS, and the proximity of specific neighborhood areas to

GCS areas with the greatest increase of groundwater elevation. Detailed analyses would be required to estimate the likely impact to specific neighborhood areas from different ditch alteration options.

**Conclusions**

This groundwater contouring efforts builds upon the extensive information gathered by the GCSTT and helps to advance our understanding of the swamp's hydrologic significance, and options for restoration.

The GCS is the primary recharge area for the Town of Sharon's municipal drinking supply. However recharge is greatly reduced by the drainage ditch and associated stormwater infrastructure which effectively circumvent this function. In addition, by intersecting the groundwater table, the ditch exerts a constant drain, further lowering groundwater levels. The resulting lowered groundwater table is evidenced by the vegetation changes throughout the Great Cedar Swamp and likely impacts groundwater availability and quality. However restoration options are complicated by the proximity of the Sharon Heights neighborhood to the GCS, and the neighborhood's demonstrated susceptibility to high groundwater concerns.

The followings items are potential next steps for consideration by the GCSTT to further inform restoration alternatives.

1. Use the topographic data and groundwater elevation data collected and compiled during this study in combination with existing Town topographic data, to create depth to water contour maps for the same two periods currently mapped for groundwater elevation. This would be a GIS and/or CAD exercise in data manipulation to create the maps. The maps would help to better inform where in the Sharon Heights neighborhood the greatest concerns for high groundwater exist.

2. Conduct supplemental surveying of key infrastructure components (e.g., basements, septic systems, and stormwater infrastructure) identified as susceptible from the depth to groundwater mapping. Research of Town data records for septic system and stormwater as-built drawings should also be conducted.

3. Create a numerical groundwater model based upon the water level data collected and compiled as part of this project, the geologic data from the 1987 IEP report, and any other readily available data from the Town, DER, or MassGIS. The areal extent of such a model would conceptually extend from the highlands above Beaver Dam Brook at the north to Billings Brook and the headwaters of the Canoe River to the south, and from Lake Massapoag at the east to the powerlines to the west. The model would be useful for evaluating the potential changes in groundwater elevation (and how they would affect key neighborhood infrastructure locations) that might result from different GCS restoration options.

   Numerical models vary widely in complexity and corresponding cost. The most prudent first step would be to create a model that is conceptual in nature - that is, it uses the available data to create a coherent hydrologic picture of the project area in general, but does not necessarily attempt to accurately portray the full extent of hydrogeologic spatial heterogeneity. Such a model will be an effective evaluation tool to compare the impacts of different restoration alternatives against each other but, however, its simulated predictions of groundwater elevations should not be considered absolutely accurate.

4. Evaluate the feasibility of LID stormwater management improvement upgrades for the Sharon Heights neighborhood that might have the potential to improve hydrology and water quality for the GCS while reducing the susceptibility of neighborhood stormwater infrastructure to high groundwater.

5. Evaluate the feasibility of community wastewater treatment options for the Sharon Heights neighborhood that might have the potential to improve hydrology and water quality for the GCS while reducing the susceptibility of neighborhood septic system infrastructure to high groundwater. Improved wastewater treatment from this neighborhood would also positively affect water quality for the municipal wells along Beaver Brook.

Use all of the above information and tools to holistically evaluate different restoration options relative to their potential impacts to the Sharon Heights neighborhood, as well as mitigation options to best maximize GCS restoration goals while minimizing infrastructure impacts. "[13]

Note: The Technical Team chose not to pursue the HW suggestion to develop a computerized groundwater model for the GCS due to the complexity of the model, the complexity of the site, and the costs of developing a model. As an alternative, the Team chose to install monitoring wells along transects (Figure 24) that would be used to monitor and detect any changes in groundwater elevation. Structures placed within the ditch to raise the groundwater levels and rehydrate portions of the Swamp would be designed to do this incrementally, so that impacts would be detected in the monitoring wells. This is discussed further in Section VI.D below. We recommend measuring rather than modeling.

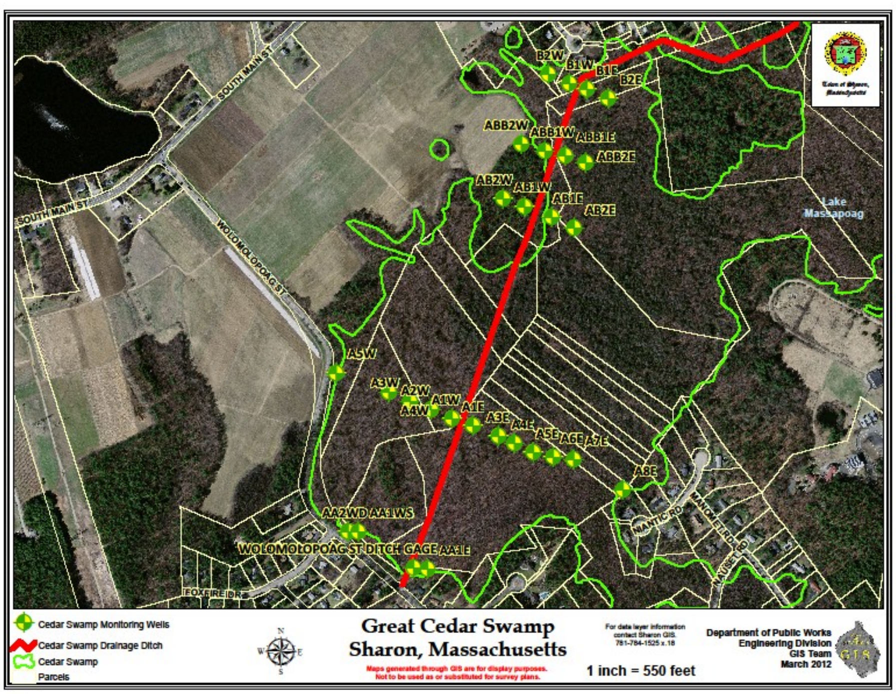



Figure 24. Monitoring Well locations in western Sharon Great Cedar Swamp.

[13] Price, Neal. 30 June 2011. Horsley & Witten report to DER (Appendix B.)

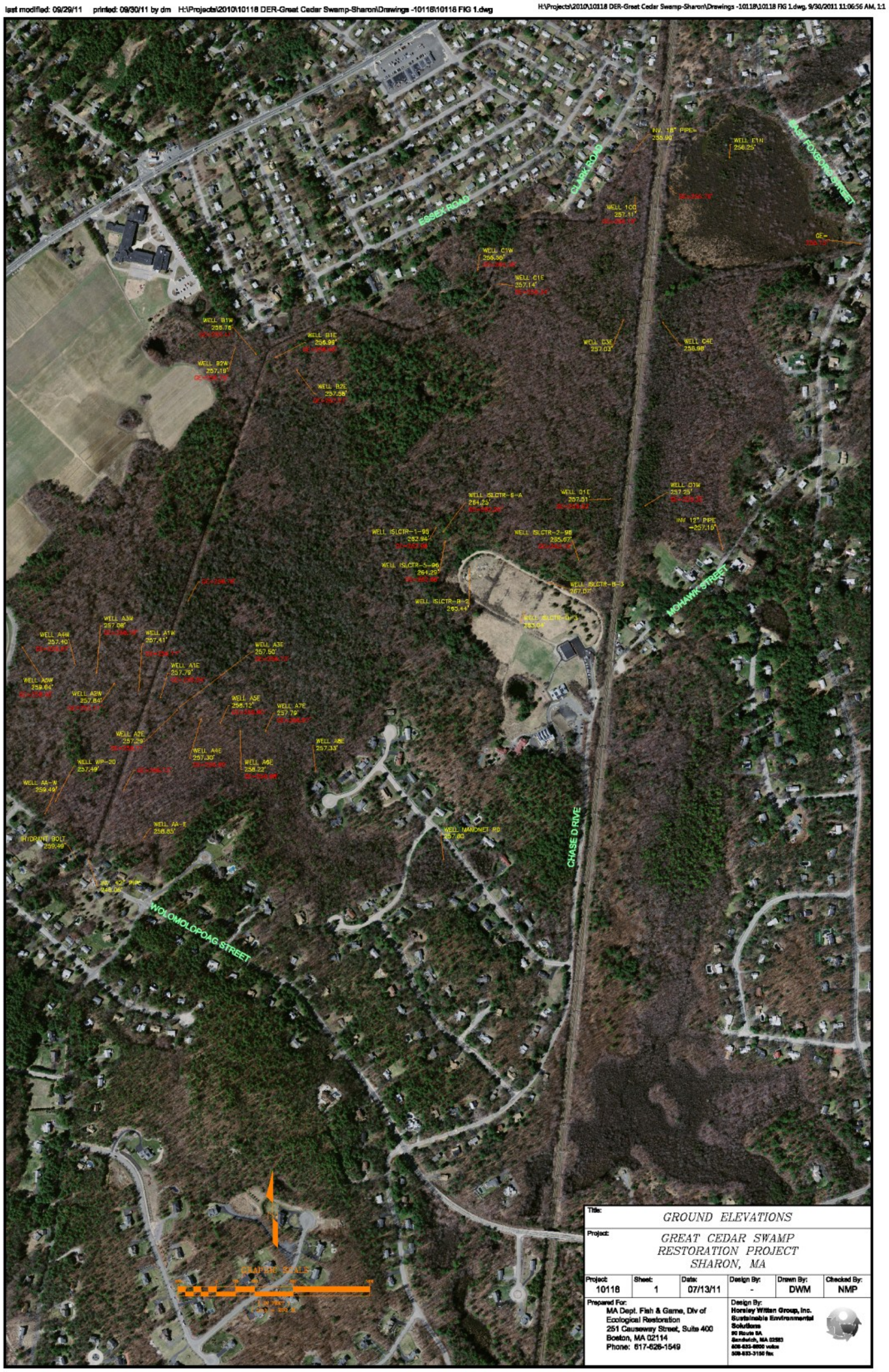



Figure 25. Ground elevations in Sharon GCS


**Figure 26. Groundwater elevations 7 April 2010.**

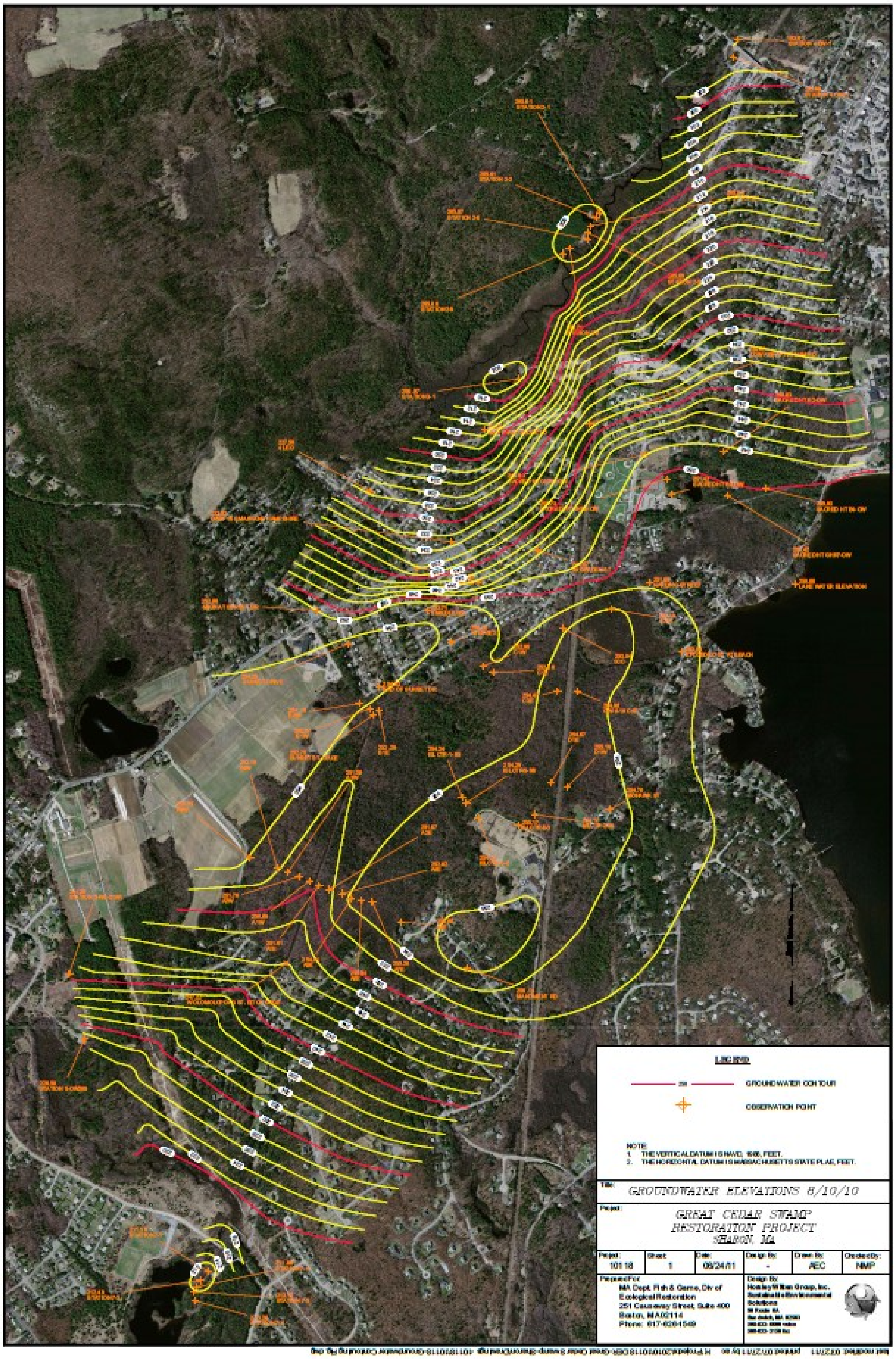



**Figure 27. Groundwater elevations 10 August 2010. <u>Note two unusual factors</u>: groundwater readings used to create this contour map took place: 1.) during a prolonged period when a total watering ban was imposed; 2.) during a year (2010) with the wettest March, wettest month, wettest spring, fifth wettest August, and sixth wettest year on record (1891-2010).**

When comparing the Groundwater Elevation Map for April 7, 2010 (Figure 26) with that of August 8, 2010 (Figure 27), notable on both maps is the steep groundwater gradient starting at the northwestern edge of the Swamp and extending beneath the Heights Area to the eastern edge of Beaver Brook. A major cause for this is the drawdown of groundwater by the municipal pumping wells along Beaver Brook.

There are several distinct differences between the April and August maps:

1. As would be expected the groundwater elevations are higher in April 2010 than August 2010, when the water table within the Swamp is approximately 2 feet lower.
2. In April 2010 groundwater is discharging into the ditch and flowing in a southerly direction exiting the swamp beneath Wolomolopoag Street. In August 2010 groundwater in the northern portion of the ditch is flowing in a northwesterly direction toward Beaver Brook.
3. Groundwater in the northeast portion of the Swamp discharges mostly into Massapoag Lake in April 2010, while in August it flows away from the Lake toward Beaver Brook.

It should be noted that the groundwater elevations in August 2010 were recorded during a time when there was a total water ban in Sharon. It is reasonable to expect that, if there had been no water ban, the differences between the April and August 2010 groundwater elevations would have been more dramatic.

### H. Groundwater Quality Analysis, Bridgewater State University[14]

Water Testing Pilot Project: Key trends from preliminary analysis of the nitrate-nitrogen, inorganic reactive phosphorus, and fecal coliform bacteria data.

The Bridgewater State University Watershed Access Laboratory analyzed groundwater samples collected in September 2011 (Figure 28). At five sites within the Sharon Heights neighborhood, levels were above the detection limit of 0.10 mg $N–NO_3$ /L, the highest being 19.11 mg/L at 18 Essex St., which is very high. Detection limit for phosphorus was 0.008 mg P/L. Only one sample, from well #A3W (Figure 23) between an agricultural field and the ditch, had slightly elevated levels of soluble inorganic phosphorus at 0.077mgP/L.

Key Trends from Preliminary Analysis of Data
Elevated levels of nitrate nitrogen were detected in the following sites:
PF SUNSET 092011
PF 392 S MAIN 092011
PF 18 ESSEX 092011
PF 4 LEO 092011
PF STORM DRAIN SUNSET 092111
PF 18 Essex is very high and should be a point of discussion.

Most wells had no fecal coliform bacteria, and those that did had levels below the contact recreation levels of 200 CFU per 100 ml. However, well C3E had some bacteria and may be a point of discussion. The storm drain also had some indication of fecal bacteria.

[14] Curry & McCoy, September 2011 Nutrient Data, Sharon Conservation Project

Elevated levels of nitrate nitrogen were detected in the groundwater underlying the Sharon Heights subdivision. Possible sources for these nitrates are on-site septic systems, lawn fertilizers, and storm drains. In the GCS monitoring wells, nitrate levels were extremely low or below detection level.

Initial Bridgewater Laboratory results suggest that the high quality groundwater flowing from the SGCS helps to dilute the nitrate levels in the groundwater beneath the surrounding residential areas. This is confirmed in the Horsley Witten Study "Due to the (Swamp's) undeveloped nature, groundwater recharged at the GCS is of high quality and serves to dilute lesser quality groundwater recharged over more developed intervening areas between the GCS and the municipal wells." Additional testing is needed to confirm this hypothesis and evaluate the magnitude of the nitrate problem.

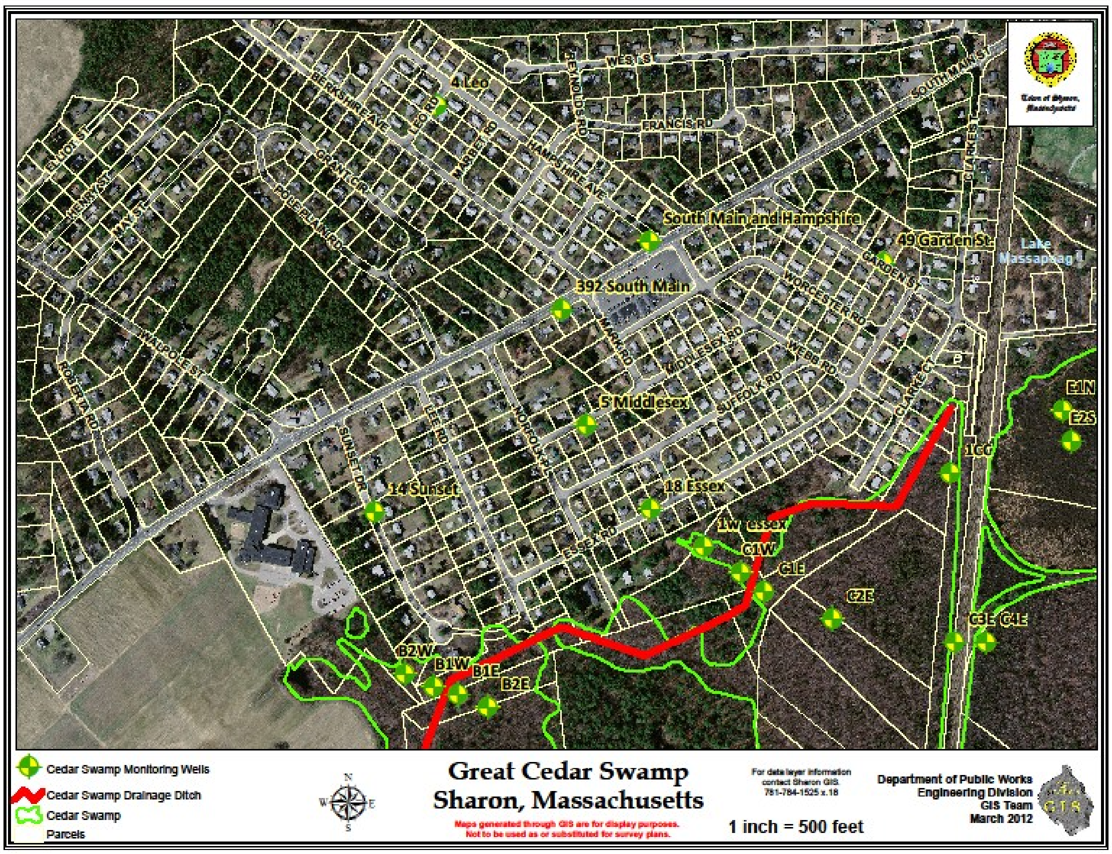



Figure 28. Monitoring wells sampled for groundwater analysis.

# VI. Recommended Actions Needed by the Town of Sharon

### A. Develop and implement a maintenance plan for the drainage ditch:

Figure 29. Undermined banks and trees collapsed into the ditch.

For ditches to function as they were originally designed, they require routine maintenance. If not regularly maintained there is a natural progression: the ditch gradually fills in with debris and sediment. Vegetation growing on the sides of a ditch deposits leaves and woody debris into the ditch. Strong flows during storm events and following snowmelt erode and undermine the banks causing the sides to slump. Erosion and strong winds cause trees to fall into the ditch (Figure 29). Street storm drains from subdivisions carry road sediments into the ditch. The combination of these processes results in the infilling of the ditch, reducing its effectiveness to convey water. During the five plus years that these studies were conducted significant changes were observed and documented within the ditch. Both natural sediments and foreign debris have accumulated.

The combined effects of these natural processes fill and restrict flows within the drainage ditch, reducing its capacity to direct water away from an area. If not maintained over a significant time period, groundwater levels within formerly drained areas will rise. This projected rise in the regional water table will have both positive and negative impacts: Beneficial effect: This would rehydrate portions of the Swamp that were drained by the ditch, restoring the natural wetland hydrology. Negative effect: In residential areas nearest the GCS ditch, groundwater elevation would rise and could have serious consequences for some home owners.

Potential negative effects include increased flooding of home basements and poor functioning of septic systems. Loose debris within the ditch could become dislodged during storm events and may clog storm drains causing localized flooding. .

Developing an annual maintenance plan for the ditch is strongly recommended. Included within the plan should be a) the removal of debris and sediment from the ditch and b) periodic cutting of vegetation growing on the banks of the ditch. State and Federal regulations only allow for maintaining the original dimensions of the ditch, and restrict deepening and widening the ditch. Before any water control structure can be placed within the ditch, there has to be a comprehensive ditch maintenance plan implemented, for all designs for water control structures tend to collect debris during storm events.

**B. Reduce groundwater discharge into the ditch and rehydrate portions of the Swamp:** Along the lower reaches of the ditch, starting south of the stormwater outlet at the eastern end of Sunset Drive and continuing down to where the ditch exits the Swamp beneath Wolomolopoag Street, the ditch has been significantly enlarged beyond its original design. Within this area the ditch passes through a large section of wetland forest where there are no homes. The ditch in this area varies from 8 to 10 feet deep and extends below the thickness of the black organic peat deposits into the underlying sands and gravel. Along these areas, groundwater discharges rapidly into the ditch through the coarse sands and gravels (Figure 30). Eventually groundwater exits the Swamp and Sharon via a tributary of Billings Brook. In addition to losing valuable groundwater, this has effectively drained a large portion of the Cedar Swamp. In the drained areas of the Swamp thousands of mature Atlantic White Cedars have died, the natural ecosystem has been degraded, and the ground surface is dramatically subsiding.

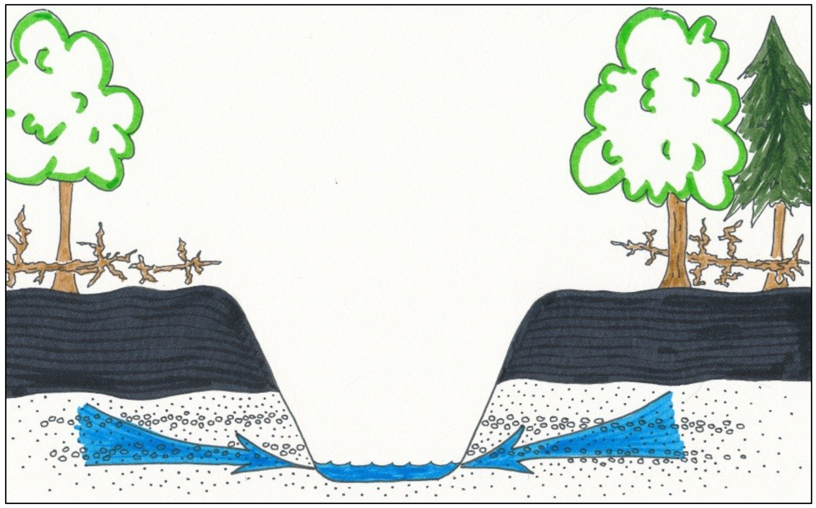


**Figure 30. Cross section of ditch showing direction of groundwater discharge through sands and gravels into the deepened drainage ditch.**

To reduce the negative impacts caused by the drainage ditch in these areas, the discharge of groundwater into the ditch through the coarse sands and gravels has to be reduced or eliminated. For this project, several options have been reviewed: 1. Construct a check-dam, 2. Install a water control structure, and 3. Divert ditch flow through a buried culvert.

**C. Evaluation of three options:**

**1. Stone rip rap check dam:**

Create a check dam by placing coarse stone rip rap in the ditch. The check dam would be located in the lower portion of the ditch close to where the ditch exits the Swamp through the culverts beneath Wolomolopoag Street. The purpose of the check dam would be to backup water within the ditch, reducing the rate of groundwater discharge into the ditch and subsequently allowing the groundwater within the adjacent wooded swamp to rise. Over time sediment will collect behind the check-dam, further reducing groundwater discharge into the ditch. Refer to the conceptual diagrams below that show the changes within the ditch over time (Figures 31-33).

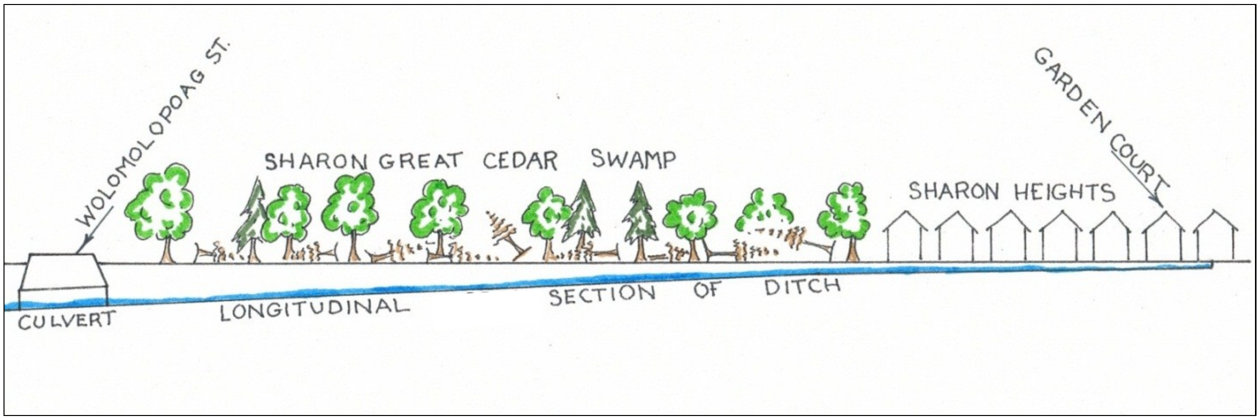



Figure 31. Drainage ditch as excavated and deepened.

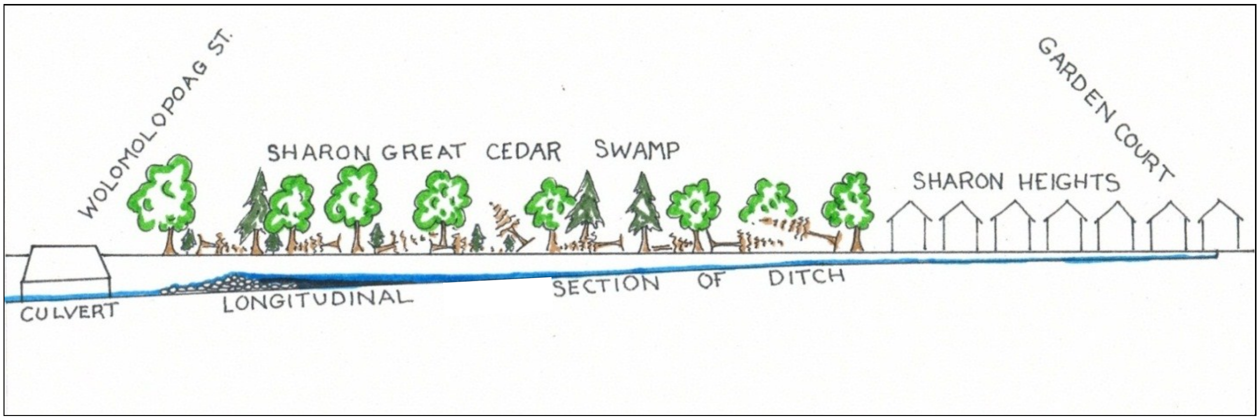



Figure 32. Stone rip rap check dam placed within the ditch

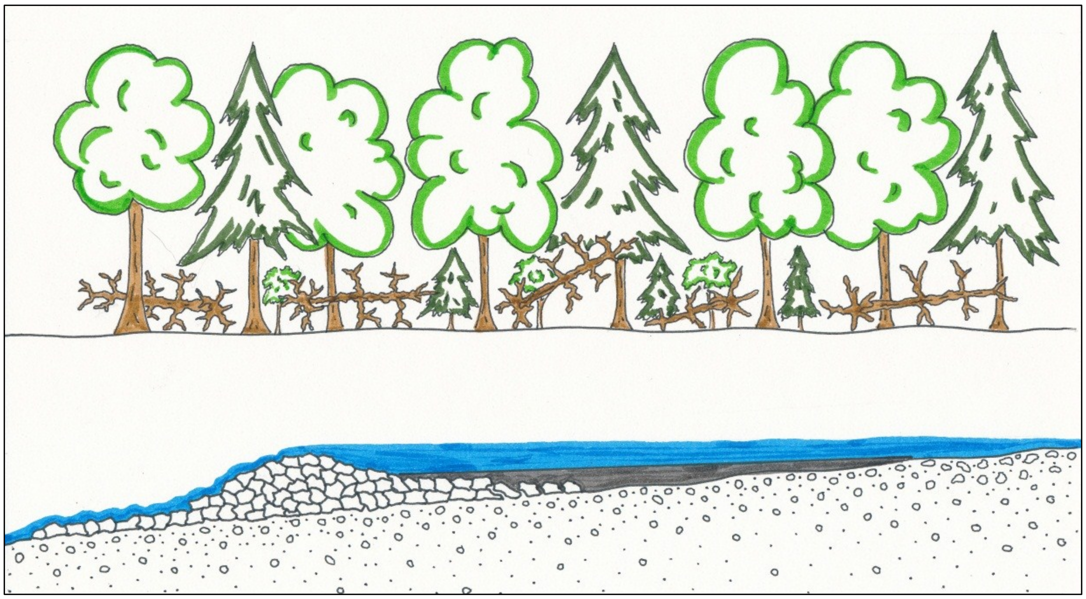


Figure 33. Close-up view showing effect of stone rip rap check dam.

With time sediment collects behind the check dam further reducing loss of groundwater via the ditch.

Evaluation of the check dam design:

- Least costly to implement.
- Easiest to install.
- The height of the check dam can be easily adjusted to optimize effects by either adding or removing stone rip rap.
- If there are any negative impacts detected, the rip rap can be removed.
- If at a later date, another kind of structure is thought to be more effective, the rip rap will most likely be needed for that structure and will not have to be removed.
- Requires continual maintenance of the upstream portions of the ditch to remove debris.

The height of a check dam determines the amount to which flow is backed up in the ditch as well as its effectiveness in reducing the rate of groundwater discharge into the ditch, thus rehydrating portions of the Swamp. Once a check dam is constructed in the ditch, its impact can be quantified by on-site groundwater monitoring. If it can be confirmed that additional flow can be restricted without negatively impacting homes in the Heights area, additional check dams could be constructed upstream creating a stepped effect (Figure 34).

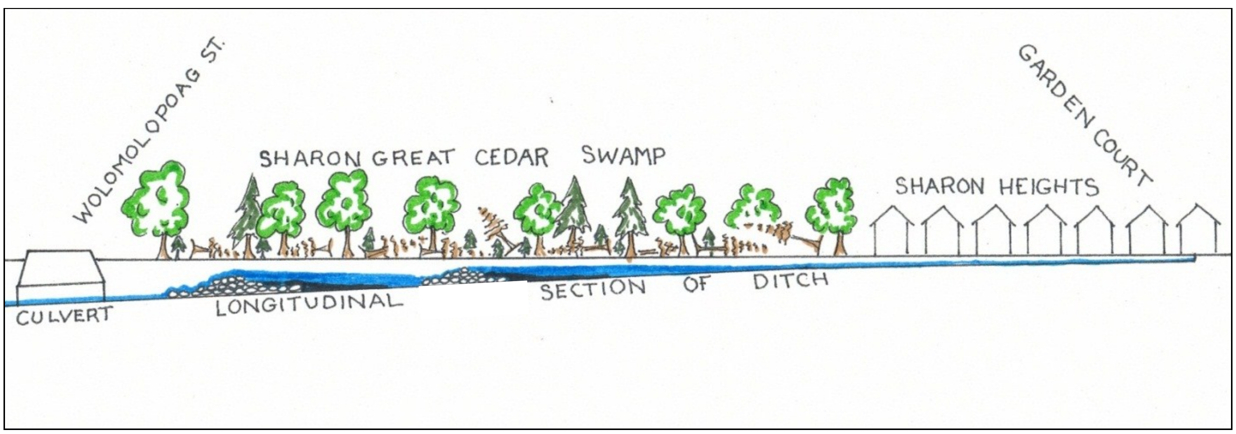



Figure 34. Series of check dams slowing flow with stepped effect.

Note: A check dam would create an area where debris floating down the ditch could collect. Continued maintenance of the ditch to remove debris is required. Inspections before, during and after storm events are recommended.

### 2. Water Control Structure:

Place a prefabricated aluminum water control structure within the ditch. The US Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) design is used by cranberry growers throughout Southern New England. The Stearns Irrigation, Inc. model

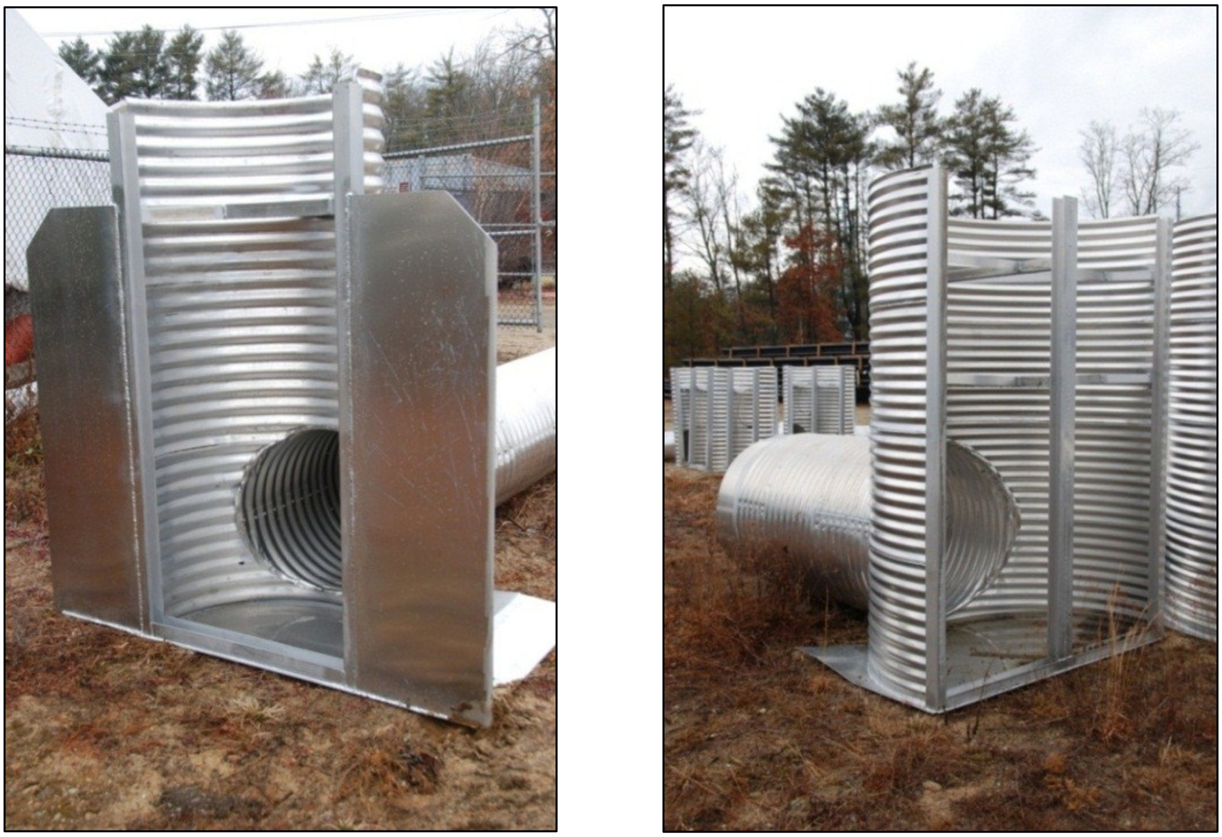


Figure 35. Aluminum water control structures manufactured by Stearn Irrigation, Inc. Wareham, MA, using Cakounas design specifications for USDA-NRCS water control structures.

(Figure 35) is used extensively by cranberry growers and is made locally. The structure would be located in the lower portion of the ditch close to where it exits the Swamp through culverts beneath Wolomolopoag Street. The purpose of the water control structure would be to back up flow within the ditch. This would reduce the rate of groundwater discharge into the ditch and subsequently raise groundwater elevation within the adjacent wooded swamp.

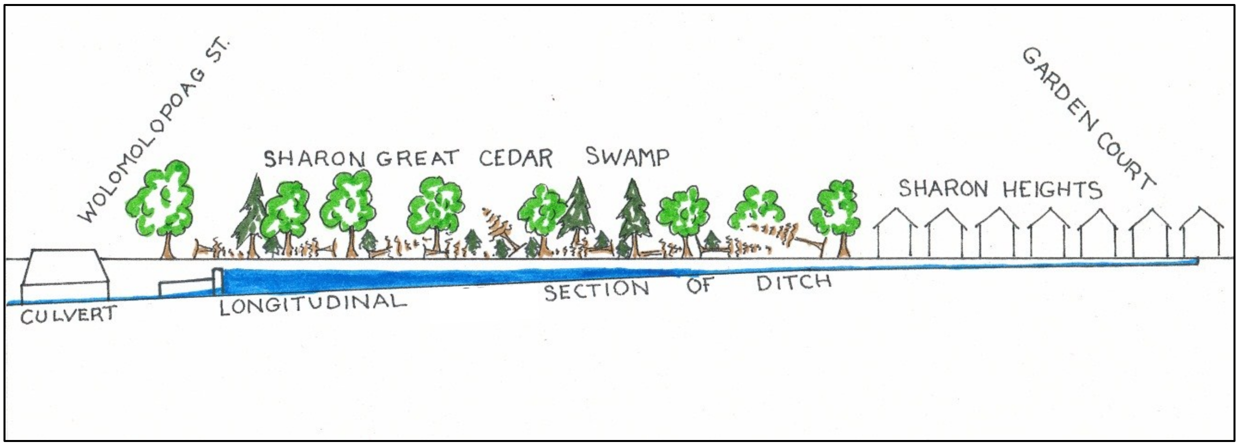



**Figure 36. Water control structure placed in the ditch.**

Evaluation of the water control structure design:

- Height can easily be adjusted simply by removing or adding flash-boards
- Flash-boards can be removed prior to large storm events
- If there are any negative impacts detected, the flash-boards can be adjusted
- Moderate cost to have constructed and then installed in the ditch
- Moderate ease of installation
- A water control structure would create an area where debris floating down the ditch could collect. Continued maintenance of the ditch to remove debris is required. Inspections before, during and after storm events are recommended.

3. **Buried Culvert:**

Bury a large water-tight culvert within a portion of the ditch. The buried culvert would start south of the last stormwater outlet (eastern end of Sunset Drive) that empties into the ditch from the Sharon Heights Subdivision, and extend southward ending north of the culverts at Wolomolopoag Street. Earthen spoil from the original ditch construction (berm at the top of the ditch) would be placed over the culvert. Along this stretch of the ditch, stormwater from the Heights would flow within the buried culvert. The purpose of the buried culvert would be to eliminate all groundwater discharge from entering into the culvert, subsequently restoring the original wetland hydrology to this portion of the GCS. The ground surface above the buried culvert would be re-vegetated (Figures 37 & 38).

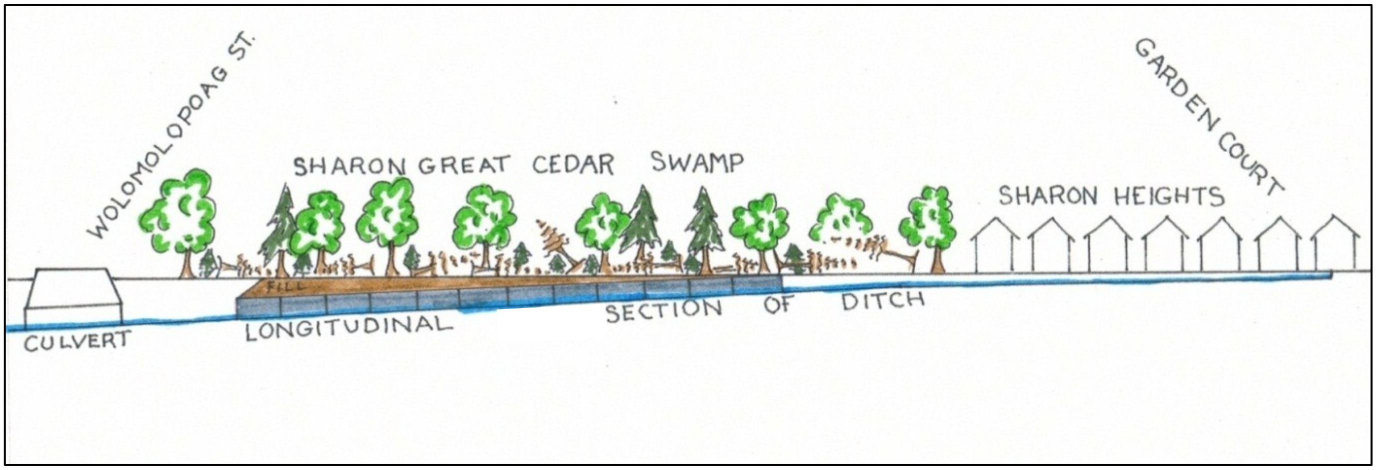



Figure 37. Buried water-tight culvert placed within deepened portion of the ditch.

Evaluation of buried culvert design:

- Eliminates all groundwater discharge from this area of the Swamp into the ditch
- Restores the original wetland hydrology in a large portion of the Swamp
- Most effective option for rehydrating portions of the Swamp
- Reclaims and re-vegetates portions of the Swamp
- Eliminates the need for ditch maintenance within the portion of the ditch that is buried.
- Requires continued maintenance of the upstream portions of the ditch to remove debris
- If there are any negative impacts detected, very difficult to make adjustments
- Costly to install
- Difficult installation
- Costly to remove this permanent installation if there are negative effects

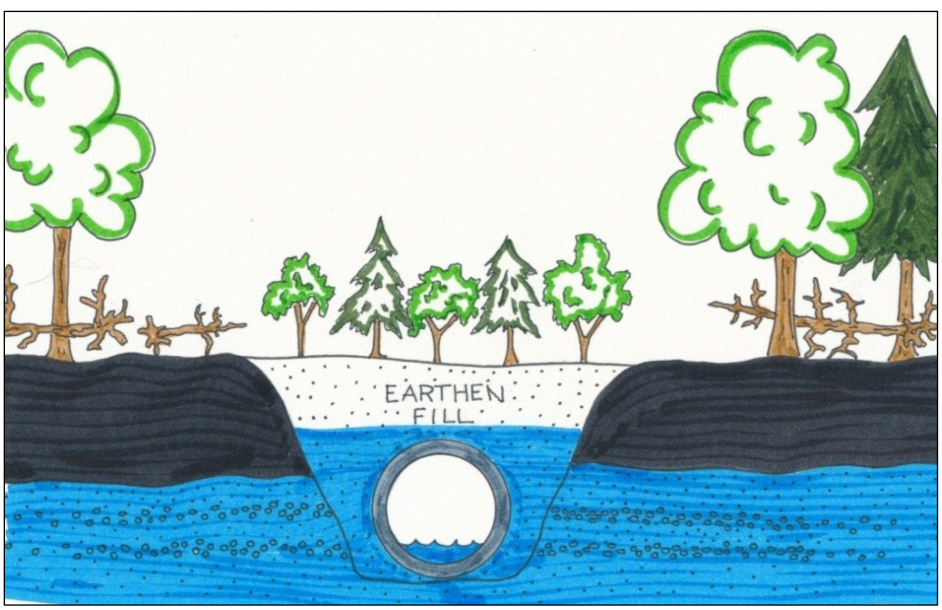



Figure 38. Cross section of culvert buried within the ditch. Water within the culvert originates from storm drains that empty into the ditch from the Heights subdivision that abuts the northwest section of the Swamp.

The inlet for the buried culvert would create an area where debris floating down the ditch could collect. Continued maintenance of the ditch to remove debris is required. Inspections before, during, and after storm events are recommended.

Caution: These are conceptual ideas, and before any construction begins at the Site, a construction plan has to be developed and approved by a qualified engineer.

**D. Collect Baseline Data and Continue Groundwater Monitoring:**

The Sharon Heights neighborhood abutting the GCS to the northwest presents a major complexity when we attempt to restore the cedar forest by raising the groundwater level in the drained portions of the GCS. This neighborhood is served by on-site septic systems. In low-lying areas close to the Swamp, there are some homes with poorly functioning septic systems and basements that flood after storm events. This is not a surprise as the drainage ditch was constructed to alleviate these problems when the Heights subdivision was constructed in the late 1950's. We quickly realized at the start of this Project that it would be impossible to rehydrate all of the drained portions of the GCS without negatively impacting some existing homes within the Sharon Heights area. To prevent such impact, groundwater is to be raised only in the southwestern portion of the Swamp where there are no houses.

An ongoing groundwater monitoring program has been put in place to assure the Town and its residents that this Project will create no negative impacts. The first phase was to install a groundwater monitoring well network. Thirty-nine monitoring wells were installed within the Swamp, and 7 wells in the Heights. The purpose of these wells was to document the current groundwater conditions within the Swamp and the Heights, and to record seasonal fluctuations in the groundwater. Several years of monthly groundwater fluctuations have been recorded for this Project. At two wells (monitoring wells at Essex and Middlesex Roads) located in the Heights, electronic devices (data loggers) have been installed that record hourly fluctuations in the groundwater. Data are being collected to develop a baseline for the existing groundwater conditions. This baseline will be used to assess the impacts of any actions taken for this Project.

It is important to assess the impacts of any water control structures placed within the ditch. To monitor the effects on groundwater elevations within these areas, four monitoring well transects have been positioned along the ditch (Figure 39). These wells are oriented perpendicular (east to west) to the direction of the ditch. Well Transect A (monitoring wells: A5W, A4W, A3W, A2W, A1W, A1E, A2E, A3E, A4E, A5E, A6E, A7E, and A8E) is located approximately 1,200 feet north (upstream) of Wolomolopoag Street. Well Transect AB (monitoring wells: AB2W, AB1W, AB1E, and AB2E) is located approximately 2,150 feet north of Wolomolopoag Street. Well Transect ABB (monitoring wells: ABB2W, ABB1W, ABB1E, and ABB2E) is approximately 3,050 feet north of Wolomolopoag Street. Well Transect B (monitoring wells: B2W, B1W, B1E, and B2E) is located approximately 3,475 feet north of Wolomolopoag Street and approximately 50 feet south (downstream) of the stormwater outlet at the eastern end of Sunset Drive.

These well transects are located upstream of where any future water control structures may be located. When a water control structure is placed in the ditch, these monitoring wells would document any changes in the groundwater elevations in areas adjacent to the ditch. Because the well transects are positioned at progressively greater distances from where a structure would be located, the well transect closest to it would be the first to record any changes. Having the four well transects in sequence along the ditch would allow for incrementally increasing the height of the water control structure and documenting its effects upstream. No structure would be designed to increase groundwater levels at Well Transect B because this could possibly have negative impacts on the Heights.

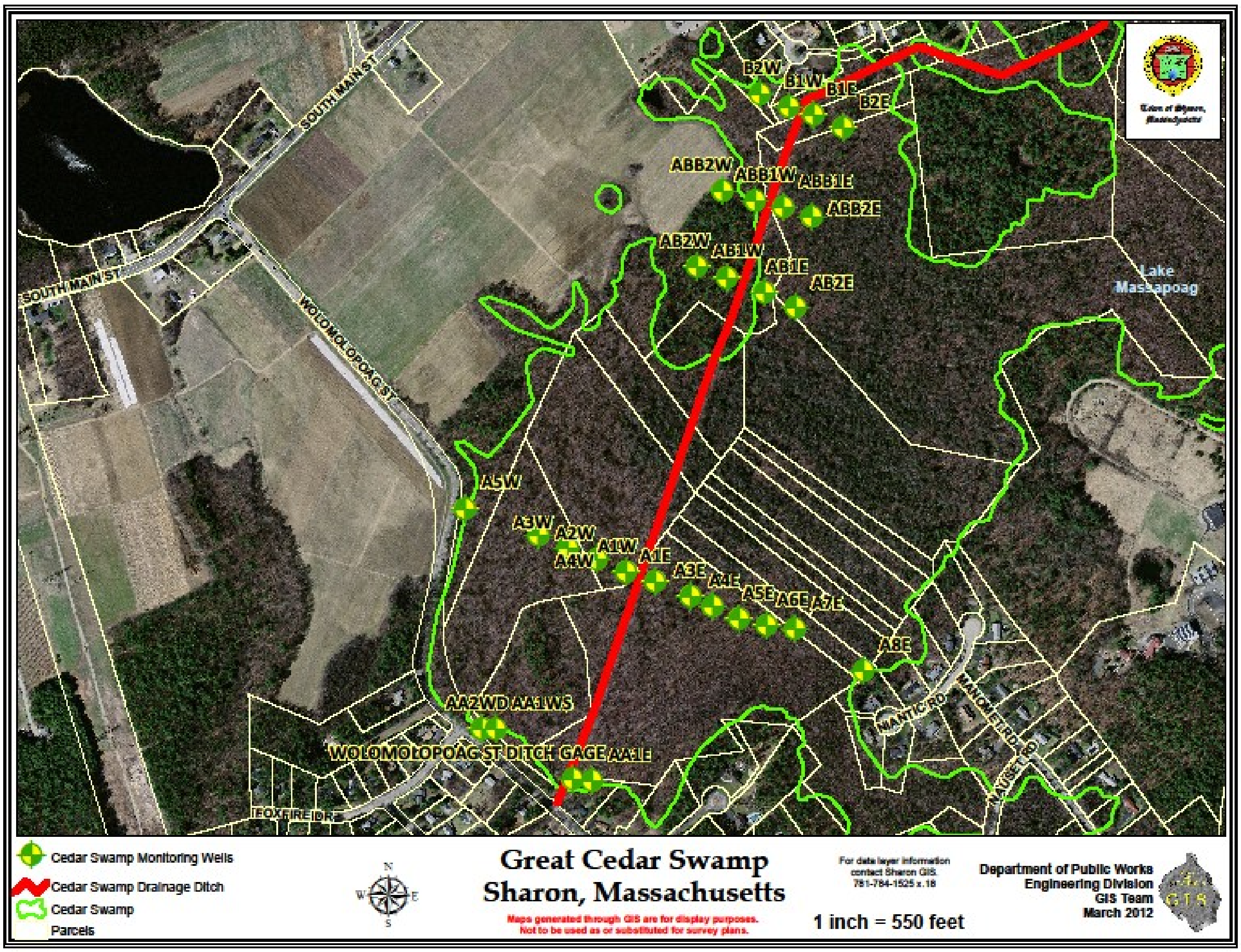



**Figure 39. Monitoring well transects in western Sharon GCS.**

# VII. References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# VIII. Appendix

## A. Purinton, T. MA Division of Ecological Restoration (DER) Project Participation

Department of Fish and Game
Division of Ecological Restoration
Tim Purinton, *Director*

**Deval Patrick**
*Governor*
**Timothy P. Murray**
*Lieutenant Governor*
**Richard K. Sullivan, Jr.**
*Secretary*
**Mary B. Griffin**
*Commissioner*

April 4, 2012

Greg Meister
Town of Sharron Conservation Commission
219 Massapoag Ave.
Sharon, MA 02067

RE: Sharon Great Cedar Swamp, MA DER Project Participation

Dear Greg:

Over the past twenty-four months the Massachusetts Division of Ecological Restoration (DER) has collaborated with the Town of Sharon to investigate restoration opportunities for the Sharon Great Cedar Swamp. DER has hired the Horsley Witten Group to develop groundwater contouring maps for the Great Cedar Swamp and assess project feasibility. DER staff has provided over 240 hours of staff time to assist with ground survey, and data compilation and analysis. It total, DER has contributed over $33,000 in direct and in-kind services to the project.

This letter is prepared to document the cash and in-kind contribution from our office to the Restoration and Revitalization of the Great Cedar Swamp, Sharon MA.

DER contributions to this project include:

- Hydrologic Consultation with Horsley Witten, Inc. = $2,337.50.
- Topographic Survey, Groundwater Contour Mapping, and Consultation with Horsley Witten = $20,808.33
- Estimate of in-kind staff time for Franz Ingelfinger: 200 hours x $40.12/hr = $8,024.
- Estimate of in-kind staff time for other DER Project Managers: 40 hours x $40.12/hr = $1,605.
- Estimate of in-kind travel costs incurred: 10 trips * 60 miles * $0.45/mile = $270.

Please do not hesitate to contact me with any questions or concerns at 617-626-1542 or Tim.Purinton@state.ma.us.

Sincerely,

Tim Purinton, Director

Department of Fish and Game, Division of Ecological Restoration, Riverways Program
251 Causeway Street • Suite 400 • Boston, Massachusetts 02114 • www.mass.gov/dfwele/der • (617) 626-1540

**B. Summary of Groundwater Mapping for the Sharon Great Cedar Swamp Restoration Project**

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Sandwich, MA • 02563
Tel: 508-833-6600 • Fax: 508-833-3150 • www.horsleywitten.com

June 30, 2011

VIA EMAIL

Mr. Franz Ingelfinger
Division of Ecological Restoration
Massachusetts Department of Fish & Game
251 Causeway Street, Suite 400
Boston, MA 02114

Re: Summary of Groundwater Mapping for the Sharon Great Cedar Swamp Restoration Project

Dear Franz:

The Horsley Witten Group (HW) is pleased to submit to the Department of Ecological Restoration (DER) the following summary of our field survey and groundwater mapping work regarding the potential for restoration of the Great Cedar Swamp.

**Background**
The Great Cedar Swamp (GCS) is located west of Lake Massapoag in Sharon, Massachusetts. Recent research conducted by the Great Cedar Swamp Technical Team (GCSTT) has determined that the swamp is threatened by lowered water levels. The GCSTT has previously installed more than 40 groundwater monitoring wells throughout the area, and collected significant hydrologic and ecologic data in support of an evaluation of potential wetland restoration options.

Factors that may potentially contribute to lowered GCS water levels, altered hydrology, and associated impacts to ecological function include:

- A drainage ditch that was installed in the 1960s to provide stormwater drainage for an adjacent neighborhood immediately to the west/northwest of the GCS (Sharon Heights). The neighborhood was reportedly constructed from the late 1950s to the early 1960s, and the drainage ditch itself was reportedly constructed during, or shortly following, the construction of the subdivision. The upper section of the ditch that runs immediately parallel to the subdivision appears to be at a relatively low gradient. Following its turn to the southeast, the ditch becomes more deeply incised, the gradient steepens, and both the flow and velocity appear to increase noticeably. It is likely that this lower reach of ditch has penetrated the GCS peat layer and is receiving significant groundwater inflow through the underlying sand and gravel deposits.

- The Sharon Heights stormwater drainage system consists of catch basins directly piped to outfalls to the drainage ditch. Portions of the drainage system are reportedly below the high groundwater level such that it may receive groundwater infiltration that could then be conveyed it to the drainage ditch in the GCS.

The direct outfall stormwater management strategy for the neighborhood therefore likely quickly conveys aquifer recharge away from the study area, as well as intercepting previously recharged groundwater and conveying that away from the area thus further impacting local hydrology.

- The Town of Sharon operates six municipal drinking wells within glacial outwash deposits contiguous to the GCS. These wells service 98% of the Town's year-round residents plus the summertime population that concentrates around Lake Massapoag. Wells 2, 3, and 4, are located north of the swamp in the Beaver Brook Valley. Wells 5 and 7 are located to the south, adjacent to Billings Brook, and Well 6 is located to the southeast in the Canoe River sub-basin. Private wells service the reaming 2%[15]. According to Cliff Towner, there are no private irrigation wells in the GCS area. The combined influences of groundwater withdrawals may lower the water table in the vicinity of the GCS.

**Scope of Work**

The current scope of work was undertaken with the intention of creating a framework within which to evaluate and utilize the hydrologic data previously collected by the GCSTT. It included the following primary elements.

5. A topographic survey was conducted of monitoring well elevations, ditch elevations, and other key hydrologic elements in the project area (such as a limited suite of subdivision infrastructure components). The survey was conducted using a combination of high-accuracy RTK GPS to collect as many points as possible, and traditional land survey techniques to collect remaining points that were inaccessible due to GPS coverage limitations. The features surveyed were:
    - All GCSTT monitoring wells in the GCS and the adjacent Sharon Heights area along with representative neighboring ground shots;
    - The two surface water gaging stations in the drainage ditch;
    - Ten representative transects crossing the drainage ditch and a longitudinal profile of the ditch bottom thalweg;
    - Town monitoring wells surrounding the three nearby public supply wells;
    - Inverts and other details of the stormwater outfalls that drain the Sharon Heights neighborhood northwest of the GCS to the drainage ditch, a representative sampling of catch basin rims and inverts on the cross streets between South Main Street and the drainage ditch, and a representative sampling of tops of foundations for approximately a dozen of the lowest elevation homes along Essex Road; and
    - The existing staff gage in Lake Massapoag.

6. All topographic survey data were digitally provided to DER, along with selected maps illustrating survey points on an aerial photographic base for the GCS and the Sharon Heights neighborhood.

7. Surveyed elevations of monitoring wells and staff gages were also provided to DER, who then converted previously collected GCSTT hydrology data into groundwater elevation data and conducted a quality control review.

8. Two groundwater contour maps were created for the project area based upon the surveyed well elevations and the historical water level data. One map represents average spring (or high water) conditions, and the other represents average late summer (or low water) conditions. HW selected April 7, 2010 and August 10, 2010 for the spring and summer mapping dates, respectively. Those decisions were based upon, first,

[15] Open Space and Recreation Plan, Town of Sharon, Massachusetts

maximizing the number of available data points for the selected mapping dates, and second, consulting the groundwater level records from the nearby USGS index well (NNW 27 in Norfolk) in order to find representative wet and dry times (within the GCSTT monitoring period). Groundwater contour maps were created through an iterative process whereby groundwater elevation data for all monitoring points were first contoured using the AutoCAD 2011 contouring tool, then those contours were adjusted by a hydrogeologist based upon knowledge of streams and other hydrologic features, and then the contours were digitized again in CAD. Those groundwater maps were previously supplied to DER in digital and paper formats, and are also attached here.

**Discussion of Groundwater Contour Maps**

April 7, 2010

This map represents spring, high groundwater conditions. USGS Index Well NNW 27 in Norfolk exhibited a water level at this time that was 0.86 feet higher than the April mean. The following are the key hydrologic observations related to this map.

- There are two distinct peaks to the groundwater mound, each at approximately elevation 258 feet (NAVD, 1988), separated from each other by the GCS drainage ditch. The eastern peak is approximately located in the vicinity of the Islamic Center at the southeastern edge of the GCS, and the western peak is approximately located in the vicinity of the agricultural fields to the west of the GCS. Groundwater in the immediate vicinity of the drainage ditch is at elevation 254 feet at its highest, and drops to approximately elevation 246 feet by the time the ditch crosses Wolomolopoag Street at the southwestern edge of the GCS. It appears likely that, were it not for the hydraulic influence of the drainage ditch, the two distinct groundwater peaks would have previously been connected into a single larger peak (and potentially at higher maximum elevation than is currently exhibited), covering most of the GCS and adjacent agricultural and residential land.

- Groundwater flows (perpendicular to the contours) radially out from the groundwater peaks towards groundwater discharge areas. To the north, groundwater flows towards and enters Beaver Brook or one of the three municipal supply wells near the brook. To the south, groundwater discharges to the GCS drainage ditch and, eventually, Billings Brook. To the east, groundwater discharges to Lake Massapoag from which it appears to either exit along the north shore as groundwater, which eventually discharges to Beaver Brook, or to exit through a surface water outlet to Massapoag Brook at the northeastern corner. Western areas are outside of the mapped study area.

- The GCS drainage ditch exerts an obvious hydraulic influence with the 254 foot elevation groundwater contour tightly surrounding the majority of the ditch and the 256 foot elevation contour also encompassing the ditch. The ditch provides an easy conduit draining groundwater from the surrounding area and reducing the overall elevation of the water table beneath the GCS and the surrounding area. According to the GCSTT, and confirmed by field survey observations during this project, the southern portion of the ditch is incised through the GCS peat surface and intersects underlying permeable sand and gravel deposits capable of readily conveying water from the aquifer to the ditch. All of the GCS, except for the northern and eastern extents, appears to drain south to or towards the drainage ditch.

- Municipal drinking water well Stations 2, 3, and 4 along Beaver Brook and Station 7 along Billings Brook also exert an observed hydraulic influence. The spacing of groundwater contours grows tighter towards Beaver Brook and Stations 2, 3, and 4, indicating a steeper slope of the water table towards the combined hydraulic "draw' of Beaver Brook and the pumping wells. With the area north of the brook consisting of glacial till and/or exposed bedrock highlands, most of the groundwater contribution to the brook and the municipal wells is likely drawn from the GCS and the surrounding areas south of the brook. The relative hydraulic importance of the brook versus the wells cannot be determined from this mapping exercise. The influence of Station 7 can be seen in the 220 foot elevation contour circling the lowered water table in the vicinity of that pumping well. Station 5 is at the edge of the study area and there are inadequate data points present to indicate the influence (or lack of) from that station on the local hydrology.

August 10, 2010

This map represents summer, low groundwater conditions. USGS Index Well NNW 27 in Norfolk exhibited a water level at this time 1.02 feet lower than the August mean. The following are the key hydrologic observations related to this map.

- Similar to the spring conditions map, there are two distinct peaks to the groundwater mound separated from each other by the GCS drainage ditch. Relative to the spring conditions map, the eastern peak over the GCS has been reduced in elevation by approximately 2 feet to elevation 256 feet, and the western peak has been reduced by approximately 4 feet to elevation 254 feet. Lower groundwater elevations are expected for summer conditions relative to spring conditions. One possible explanation for the greater decline on the western side is the greater proximity of the western mound peak to municipal supply well Stations 2, 3, 4, and 5. Groundwater withdrawals typically increase in the summer time and the proximity of the western peak to those increased withdrawals may contribute to a greater seasonal decline than is observed for the eastern mound peak.

- As was discussed for the spring conditions map, the GCS drainage ditch exerts an obvious hydraulic influence. What's different is that the overall lowered summer conditions water table has shifted the groundwater divide (location where groundwater changes from flowing south through the drainage ditch to flowing north towards Beaver Brook) to the south toward the bend in the drainage ditch adjacent to the Sharon Heights neighborhood. The southern portion of the GCS drainage ditch continues to drain to the south as it did on the spring conditions map, but groundwater around the northern portion of the ditch now appears to flow to the north. A high point within the ditch located just south of Linda Road may impound water upstream of it during low water time periods. During such drier periods, water impounded upstream of this high point may exit the system as groundwater flow to the north, rather than as surface water flow to the south through the drainage ditch. Increased summer season municipal water supply withdrawals from Stations 2, 3, and 4 to the north may also potentially contribute to the southward shift of the groundwater divide.

- Groundwater contours wrap around municipal drinking water well Stations 2, 3, and 7 to a greater degree than was observed on the spring conditions map. This is indicative of a lowered water table in the immediate vicinity of the pumping wells due to a normal increase in summer season pumping from those stations. Inadequate data points surround Stations 4 and 5 to indicate the influence (or lack of) increased summertime pumping.

**Discussion**

The groundwater mapping exercise indicates several important considerations. Many of the following discussion items are the same as those originally stated in a December 22, 2010 Technical Memorandum. Subsequent field work and analyses have allowed for a more refined discussion of those prior items, as well as the inclusion of some new items.

7. Because the peak of the local groundwater mound (currently two distinct peaks bisected by the GCS drainage ditch), the GCS and the immediate surrounding area is the primary source of groundwater recharge for the local area. This means that within the study area, the GCS and immediate surrounding area is the primary source of groundwater recharge to municipal well Stations 2, 3, and 4 along Beaver Brook; Stations 5 and 7 along Billings Brook; and Station 6 along the Canoe River. Due to its undeveloped nature, groundwater recharged at the GCS is of high quality and serves to dilute lesser quality groundwater recharged over more developed intervening areas between the GCS and the municipal wells. For the same reasons mentioned above, the GCS is also a primary source of groundwater-derived baseflow within the study area to the headwaters of Beaver Brook, Billings Brook, and the Canoe River, as well as Lake Massapoag. While all of these water resources also receive some contributions from outside of the study area it should be noted that the areas outside of this study area north of Beaver Brook, and east of Lake Massapoag consist primarily of till and/or bedrock uplands that likely contribute lesser amounts of groundwater recharge than do the permeable aquifer materials of the GCS and surrounding areas.

8. The drainage ditch appears to be the primary anthropogenic factor impacting the hydrology of the GCS. While groundwater withdrawals from municipal wells undoubtedly have some influence, the wells are relatively distal in comparison to the ditch and do not dramatically affect the appearance of the groundwater contours in the GCS vicinity to the same extent as does the drainage ditch. The drainage ditch clearly bisects what was likely formerly a single groundwater mound peak, creating two separate peaks. The overall elevation of the two separate groundwater mound peaks are also likely lower than was a single peak that likely existed before the ditch was constructed. The closer you get to the ditch, the more significant its hydrologic influence.

9. The Sharon Heights neighborhood abutting the GCS to the northwest is the primary factor conflicting with restoration goals of increased groundwater elevations in the GCS. The neighborhood is served by onsite septic systems (many of which reportedly have depth to high groundwater concerns) and also reportedly has wet basement issues. Under current conditions, the depth to seasonal high groundwater for some areas of the neighborhood may be only approximately four feet. The neighborhood is therefore highly susceptible to any increases in groundwater level that might arise from a restoration of the GCS. This is not a surprise as the drainage ditch was likely constructed for the purpose of lowering groundwater elevations for the neighborhood.

10. If cost were not an issue, the best case restoration scenario for the GCS would incorporate integrated water resources management for the adjacent subdivision neighborhood in an effort to bring the local water budget more in balance, such that higher water levels in the GCS might be offset by lower anthropogenic groundwater additions in the neighborhood. This would include constructing a clustered wastewater treatment facility and low-impact development (LID) stormwater management facilities that would effectively transport water away from the subdivision to downgradient locations, where it could contribute to GCS hydrology while simultaneously reducing groundwater levels beneath the subdivision. After a quick review of available information, it was determined that topographic and open space limitations would be significant hurdles. Centralized wastewater treatment in particular would be quite expensive and potentially unpopular politically.

11. Some degree of LID stormwater management improvements that would benefit the GCS hydrology while mitigating residential impacts are likely still feasible.

12. Drainage ditch alterations that would reduce outflow through the ditch would, by necessary correlation, raise GCS groundwater levels. As such, they would likely be highly effective at raising groundwater elevations to the GCS. Potential ditch alterations include a series of check dams of various heights, infilling to different degrees, and the preceding augmented with a high water level under-drain for flood protection. While worth evaluating, all options for reducing flow through the drainage ditch would serve to raise groundwater levels beneath the Sharon Heights neighborhood to some extent. The amount of groundwater increase beneath the neighborhood would vary from negligible to significant depending upon the extent of increase in the neighboring GCS, and the proximity of specific neighborhood areas to GCS areas with the greatest increase of groundwater elevation. Detailed analyses would be required to estimate the likely impact to specific neighborhood areas from different ditch alteration options.

**Conclusions**

This groundwater contouring efforts builds upon the extensive information gathered by the GCSTT and helps to advance our understanding of the swamp's hydrologic significance, and options for restoration.

The GCS is the primary recharge area for the Town of Sharon's municipal drinking supply. However recharge is greatly reduced by the drainage ditch and associated stormwater infrastructure which effectively circumvent this function. In addition, by intersecting the groundwater table, the ditch exerts a constant drain, further lowering groundwater levels. The resulting lowered groundwater table is evidenced by the vegetation changes throughout the Great Cedar Swamp and likely impacts groundwater availability and quality. However restoration options are complicated by the proximity of the Sharon Heights neighborhood to the GCS, and the neighborhood's demonstrated susceptibility to high groundwater concerns.

The followings items are potential next steps for consideration by the GCSTT to further inform restoration alternatives.

6. Use the topographic data and groundwater elevation data collected and compiled during this study in combination with existing Town topographic data, to create depth to water contour maps for the same two periods currently mapped for groundwater elevation. This would be a GIS and/or CAD exercise in data manipulation to create the maps. The maps would help to better inform where in the Sharon Heights neighborhood the greatest concerns for high groundwater exist.

7. Conduct supplemental surveying of key infrastructure components (e.g., basements, septic systems, and stormwater infrastructure) identified as susceptible from the depth to groundwater mapping. Research of Town data records for septic system and stormwater as-built drawings should also be conducted.

8. Create a numerical groundwater model based upon the water level data collected and compiled as part of this project, the geologic data from the 1987 IEP report, and any other readily available data from the Town, DER, or MassGIS. The areal extent of such a model would conceptually extend from the highlands above Beaver Dam Brook at the north to Billings Brook and the headwaters of the Canoe River to the south, and from Lake Massapoag at the east to the powerlines to the west. The model would be useful for evaluating the potential changes in groundwater elevation (and how they would affect key neighborhood infrastructure locations) that might result from different GCS restoration options.

Numerical models vary widely in complexity and corresponding cost. The most prudent first step would be to create a model that is conceptual in nature - that is, it uses the available data to create a coherent hydrologic picture of the project area in general, but does not necessarily attempt to accurately portray the full extent of hydrogeologic spatial heterogeneity. Such a model will be an effective evaluation tool to compare the impacts of different restoration alternatives against each other but, however, its simulated predictions of groundwater elevations should not be considered absolutely accurate.

9. Evaluate the feasibility of LID stormwater management improvement upgrades for the Sharon Heights neighborhood that might have the potential to improve hydrology and water quality for the GCS while reducing the susceptibility of neighborhood stormwater infrastructure to high groundwater.

10. Evaluate the feasibility of community wastewater treatment options for the Sharon Heights neighborhood that might have the potential to improve hydrology and water quality for the GCS while reducing the susceptibility of neighborhood septic system infrastructure to high groundwater. Improved wastewater treatment from this neighborhood would also positively affect water quality for the municipal wells along Beaver Brook.

11. Use all of the above information and tools to holistically evaluate different restoration options relative to their potential impacts to the Sharon Heights neighborhood, as well as mitigation options to best maximize GCS restoration goals while minimizing infrastructure impacts.

Thank you for the opportunity to assist with this project. Please feel free to contact me with any questions by phone (508) 833-6600 or email nprice@horsleywitten.com.

Sincerely,

HORSLEY WITTEN GROUP, INC.

Neal M. Price

Senior Hydrogeologist

Enclosures: Two Groundwater contour maps