Long Term Culvert Replacement Training Project

for

Spencer, Massachusetts
Clark Road
Unnamed Tributary to Stiles Reservoir

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Prepared For:
Division of Ecological Restoration
Massachusetts Department of Fish and Game
251 Causeway Street
Boston, MA 02114

Prepared By:
Comprehensive Environmental Inc.
225 Cedar Hill Street
Marlborough, Massachusetts 01752

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1. Introduction

The culvert replacement project site is located in Spencer, MA on Clark Road. This crossing is within the French River watershed in the southeast corner of town on an unnamed tributary west of the Stiles Reservoir. The project site is approximately 350 feet east of the intersection of Chickering Road and Clark Road. A project locus map is attached as **Figure 1**. A wooded wetland area exists upstream of the crossing with a small ponded area immediately upstream of the culvert inlet. The downstream end consists of a more defined stream channel flowing through an upland wooded area prior to conveyance through a box culvert beneath Wilson Avenue and discharge into the Stiles Reservoir.

The existing roadway-stream crossing consists of an 18-inch reinforced concrete pipe (RCP) culvert measuring 32 feet in length with an approximate 1% slope. Stone masonry headwalls upstream and downstream have deteriorated and stones have become displaced. A longitudinal crack within the pavement spans the roadway directly above the existing culvert pipe. Potential issues with settlement and roadway section loss caused by water flow piping along the side of the existing culvert may exist in this location. There are no water, sewer, or gas mains in the vicinity of the existing structure, no overhead wires are present in the immediate area.

The culvert replacement project will aim to replace the existing roadway-stream crossing with a cost effective structure that will better allow for wildlife and aquatic organism passage while providing passage of storm event flows, debris and flood resiliency.

2. Site Reconnaissance

Topographical and stream survey was performed at the site by a subcontracted survey field crew. The survey included typical relevant roadway, utility, property line, and landmark features for a distance of 50-feet in either direction along the road from the culvert. Topographical survey of existing contours is required, at a minimum, along the roadway embankments and in the immediate vicinity of the culvert. Stream survey was performed approximately 300-feet in each direction upstream and downstream from the culvert. The stream features surveyed and documented are further described below within this section.

Initial site reconnaissance and resource area delineation was performed at the site to document existing conditions. Wetland scientists examined and flagged the ordinary high water and bordering vegetated wetlands (BVW) resource areas. Stream bankfull width measurements at representative cross-sections outside of the influence of the existing culvert were also identified and flagged. The locations of these flags were subsequently surveyed by the subcontracted survey field crew for inclusion on the project base map.

Site reconnaissance included the documentation of the existing stream conditions upstream and downstream of the crossing. The type and integrity of stream grade controls were documented on field sketches to be used in determining the proper replacement structure placement, both horizontally and vertically. These stream features were surveyed to produce a longitudinal profile and representative cross-section views of the stream. The survey base map plan view, longitudinal profile and cross-sections with field notes are attached in **Appendix A**.

A reference reach was identified downstream of the existing culvert crossing outside of any influence by the existing structure. The reference reach was determined to be a representative section of the stream with similar slope characteristics to the replacement structure location. A streambed substrate analysis, known as a pebble count, was performed within the reference reach to understand the existing streambed material gradation which will be used to calculate and design the proposed streambed within the replacement structure. The pebble count information collected in the field and tabulated into graph format is attached in **Appendix B**.

Photographs of the representative site reconnaissance features are attached in **Appendix C**.

3. Geotechnical Evaluation

3.1. Subsurface Evaluation

CEI subcontracted Soil Exploration, Corp. of Leominster, MA to perform two borings within Clark Road; one on each side of the existing culvert. Soil Boring No. B-1 was completed approximately 30 feet east of the existing culvert within the eastbound travelled way of Clark Road. Soil Boring No. B-2 was completed approximately 20 feet west of the existing culvert footprint within the westbound travelled way of Clark Road. The information from these borings and laboratory analysis of soils samples will be utilized as the basis for the design of the proposed replacement structure foundation.

Each boring was intended to have a 40-feet depth beneath the roadway surface or to refusal, whichever was encountered first. Borings B-1 and B-2 were completed to depths of 22 feet and 22.5 feet below the surface of the roadway, respectively, with refusal at the bottom of each boring. Soil boring logs for borings B-1 and B-2 are attached in **Appendix D**.

Split spoon samples were taken every 10 feet or change in soil material type. Select soil samples were sent to a Massachusetts Certified lab, GeoTesting Express, Inc. of Acton, MA to perform analysis for: Atterberg Limits (ASTM D4318), USCS – Classification (ASTM D2487), Grain Size Sieve (ASTM D422), Density (ASTM D7263), and Moisture Content (ASTM D2216). These laboratory results are attached in **Appendix E**.

Based on the collected geotechnical information, there is a 6-inch thick layer of asphalt followed by 4-foot layer of medium dense, fine to coarse sand with gravel above and around the culvert pipe, likely a fill material used during the roadway construction. Immediately beneath the existing culvert pipe is an organic, peat layer which varies between 1.5 to 3-feet thick. The soils encountered immediately beneath the organics layer are generally loose to medium dense fine sand and silt. This is followed by a layer of dense to very dense silty gravel with sand and silty sand with gravel. Groundwater was encountered at 4.0 feet below the surface of the roadway in each boring at the top of the organic, peat layer.

3.2. Foundation System Alternatives

Three basic foundation types have been considered for this crossing replacement site. Those alternatives are: deep pile foundation – associated with bridges and large bottomless arch structures; shallow spread footing foundation – associated with three-sided bottomless structures; and mat or slab foundation - closed bottom structure or closed pipe. Additionally, several options are available for soil improvements at and below the foundation to increase soil bearing capacity and minimize vulnerability to scour, settlement and potential liquefaction. Soil improvement options include over excavation/ soil replacement, geogrid/ fabric installation, and chemical grouting/ soil mixing.

Preliminary foundation characteristics to consider during conceptual design include:

- Costs;
- Foundation design complexity;
- Construction & phasing feasibility;
- Roadway Type and Condition;
- Environmental concerns;
- Stability;
- Scour Protection;
- Soil Properties.

The deep pile foundation typically consists of a strip footing acting as a pile cap with piles of specific length, diameter, and material driven down to refusal or through adequate soils to act as friction piles. At this site, the deep foundation design would require further boring analysis to determine the bearing capacity at refusal. For piles that would extend down to refusal and be set on or be embedded into rock, additional rock core testing and analysis would be required to verify the capacity of the bedrock. This alternative would be the most costly in testing, design, and construction. This foundation would typically provide the highest stability and unsuitable soils above refusal would become less of a concern.

The shallow spread footing would provide an enlarged area for dead and live loads to be evenly distributed across the footprint and be dependent upon on the bearing capacity of the underlying soils. A shallow spread footing at this site would require the removal of the unsuitable organics, peat layer. The loose to medium dense fine sand and silt layer would require soil improvement techniques such as chemical grouting or fabric installation to be installed to aid against erodibility. Over excavation and soil replacement would not be recommended in this area due to the depths and total volume required. Based on preliminary review, the loose layer in boring B-1 is only marginally plastic with low clay properties, which would not create a large concern for settlement within this area. If the laboratory tests had shown a higher plasticity index a hydrometer lab test would be required to determine the silt and clay fractions of this soil layer. All other soil strata tested were confirmed as non-plastic. This alternative would require the largest excavation footprint creating the greatest cause for environmental concerns and cost implications. However, this foundation is a practical alternative for this site depending on the overall structure type selected.

A mat or slab footing consists of a closed bottom structure or closed pipe which acts to disperse the live and dead loads across bottom of the structure, avoiding any point load concentration concerns leading to settlement. As long as the structure type selected is compatible with this foundation type, this option poses the most cost effective solution at this site, with the greatest ease of constructability, and minimized environmental concerns. The organic, peat layer would need to be completely removed. Similar to the shallow spread footing, the marginally plastic material found in boring B-1 does not present a settlement concern. Soil improvements techniques such as chemical grouting or fabric installation over the loose material could be installed to aid against erodibility. This is the recommended foundation option if a closed bottom structure or closed pipe is the selected replacement culvert.

Consideration was given to the soil improvement options to prevent against scour and minimize vulnerability of the soils under highly saturated conditions including potential uplift of the culvert under surcharged conditions during very large storm events. Headwalls and wingwalls will be imperative in this area to act as anti-seep collars to prevent piping of groundwater through the material along the outside of the culvert walls.

3.3. Geotechnical Evaluation/Soil Properties

The laboratory dry density of soil encountered in boring B-1 from approx. 10'-12' was equivalent to 107.9 pcf. The dry density of soil encountered in boring B-2 from approx. 10'-12' was 103.3 pcf, however, from 15'-17' it was 124.2 pcf. The material sampled varied from loose to medium dense for the soil deposits encountered. Most of the deeper soil lenses were dense to very dense. The soil was generally classified as a medium dense fine sand with silt. The analyzed material had 56%-92% passing the #4 sieve and 15%-50% passing the #200 sieve. The Unified Soil Classification (ASTM D2487) for the materials was assumed to be somewhere between a SM – Silty Sand with Gravel and a GM – Silty Gravel with Sand. There were some lenses of peat material and others with more plasticity that were classified as CL-ML – Sandy silty clay. Atterberg Limits Testing (ASTM D4318) performed on the soils encountered in B-1 resulted in a Plasticity Index (PI) of 15 and in B-2 the soils were determined to be non-plastic. In accordance with IBC 2009 Chapter 16 Structural Design, Table 1613.5.2, and Massachusetts amendments, the encountered soils would be generally classified as Site Class D – Stiff Soils.

These classifications were used in conjunction with the laboratory bulk density to determine a representative unit weight of soil for design calculations and determination of design parameters. Encountered soils had moisture contents ranging between 7% and 18%. An in-situ unit weight of 115 pounds per cubic foot was assumed and a design wet unit weight of 125 pounds per cubic foot was used to represent all the encountered soils at the site. Those unit weights also fall within typical empirical values based on the average Standard Penetration Numbers (SPT N Values) for the soils encountered.

3.4. Soil Parameters for Foundation Design

Generally, soils were analyzed from 0 feet down to 14 feet below grade for foundation design based on an approximate foundation depth for the proposed culvert. This provided a more conservative estimate for soil design parameters since the deep material below the 11 to 15 foot depths became very dense. If the denser material located below 15 feet was included in the analysis, it could result in an over estimate of soil capacities for a shallow footing scenario. However, soil parameters should be re-evaluated during final design based on the selected alternative and associated foundation depth for the culvert. Especially if a deeper foundation alternative is located within the denser soil lenses.

Friction Angle

The internal friction angles for soils classified as medium dense, silty, clayey sand or gravel are at a minimum of 35 degrees and a maximum of 40 degrees. Using the assumed unit weights, boring depths and average SPT blow counts, CEI completed SPT corrections to represent the encountered soils for the analyzed depths. Corrected blow counts varied from 11 to in excess of 60 blows per foot between depths of 0 to 14 feet below the ground surface in two of the representative borings. Based on these correct blow counts, CEI selected an average friction angle of 36 degrees as a design parameter.

Please note that the friction angle of soil is used as a variable to select several soil strength properties and should not be confused with the angle of repose for the soil. The angle of repose would provide an estimate of the maximum stable slope angle for the soil to be used for grading and excavation purposes. This angle would likely be less than the friction angle selected for strength estimations. The angle of repose for soils is highly variable depending on depth of water table, soil type, cohesive vs. cohesionless properties, effective stresses and saturated vs. unsaturated conditions. Generally, a 3H:1V is the most stable slope for most soils encountered, but due to variability, it is recommended that a design consultant provide the proper angle of repose based on a detailed geotechnical analysis.

Allowable Bearing Capacity

An allowable bearing pressure range was identified based on the Unified Soil Classification of the encountered materials and a refined value was selected from that range based on corrected blow count data determined from the boring analysis. Based the boring data, the allowable bearing capacity could range between 1,500 and 2,000 psf.

3.5. Geotechnical Design Parameters

Based on the completed geotechnical analysis, the following design parameters are recommended for foundation designs for building and chamber footings, foundation walls and any required retaining walls that may be required in the design. As noted above, the following assumptions were made to select these design parameters:

- Average Corrected SPT N values (0-14 feet deep) = 30 - 50 bpf

- Assume ground water at an approximate depth of 4 feet
- Laboratory Dry Unit Weight = 110 pcf
- In-Situ Unit Weight = 115 pcf
- For design purposes, a wet unit weight of 125 pcf should be used.
- Internal Friction Angle = 36 degrees
- % Relative Dry Density = 70%-90%

Bearing Capacity Factors

Bearing capacity factors are provided below for informational purposes only. It is recommended that the allowable bearing capacity of 1,500 psf be used. Based on a selected internal friction angle of 36 degrees for the encountered material, the following bearing capacity design factors are provided for estimating bearing resistance of slabs on grade and footings:

- Cohesion bearing capacity factor - N_c = 50.6
- Surcharge bearing capacity factor - N_q = 37.8
- Unit Weight bearing capacity factor - N_γ = 56.3

Shape and depth factors should be adjusted accordingly based on the foundation design when determining soil bearing resistance of foundation elements.

Modulus of Subgrade Reaction

A typical modulus of subgrade reaction for fine grained soils with a relative density of approx. 70% - 80% is 160 to 220 lbs per cubic inch (140 - 190 tons per cubic feet).

Active, Passive & At-rest Earth Pressure Coefficients

Earth pressure coefficients for fine and coarse grained sands were calculated based on the assumed internal friction angle of soil. Based on the friction angle of 36 degrees, the Rankine earth pressure coefficients are as follows:

- At-rest Earth Pressure Coeff. (Ko) = 0.412
- Active Earth Pressure Coeff. (Ka) = 0.260
- Passive Earth Pressure Coeff. (Kp) = 3.852

Earth Pressures & Stresses

Effective stresses were calculated down to 15 feet based on the approximate extent of soil analysis. Based on subsurface exploration, ground water depths ranged between 4 to 5 feet below roadway level. However, for design purposes, it is recommended that an average groundwater depth of 4 feet be used for this site.

Assuming a design wet unit weight of 125 pcf and estimated groundwater depth of 4 feet, the effective stresses could range from 0 – 1,190 psf from 0-15 feet deep and 1,190 to 1,630 psf from 15 to 22 feet deep. Based on this scenario, maximum active lateral earth pressures could be up to

310 psf and maximum passive earth pressures could be in excess of 4,570 psf at the 15-foot depth.

Settlement Factors

Some immediate elastic settlement is expected for foundation elements. The material is somewhat compressible /expansive based on the silt/clay content, however, the settlement factors are low. Immediate settlement computations cannot be completed without foundation element depths, sizes and anticipated loads. The following are recommended design parameters that should be used to complete future anticipated settlement computations.

For a medium dense silty sand mixture, the range for Young's Modulus is 3.4 to 27.8 ksi. Based on the corrected SPT N values, Young's Modulus is estimated to be 3,490 psi (3.5 ksi). Poisson's Ratio is estimated at 0.30, but can be as high as 0.35. The void ratio for the encountered materials could range between 0.33 and 0.98 and for this material is assumed to be approximately 0.60. Foundation Shape Factors will vary based on foundation element type.

3.6. Seismic Considerations

Liquefaction Potential

Based on Hazard mapping, Spencer, MA is located within a Seismic Zone 2A and has relatively low hazard for seismic activity. Despite the low hazard, the encountered soils through the 15-foot depth had some loose silts and sand layers with low plasticity which would have a moderate susceptibility to liquefaction. The encountered groundwater tables were very shallow and based on observations during subsurface exploration, groundwater is estimated at only 4 feet. Based on boring samples, some of the encountered loose material was saturated (average moisture content near 20%) with corrected blow count (N1)60 values less than 20 blows/ft. There is a slight possibility that the soils could experience liquefaction during seismic activity. However, the loose soils do not extend deep down to bedrock and are confined by more dense material. The ten percent probability peak ground acceleration (PGA) for Spencer, MA is less than 0.15 g, therefore the potential for liquefaction is still low, but should be reviewed during final design depending on the type of foundation alternative that is selected.

Seismic Design Category Evaluation

Site Class Definition: D. Stiff Soils with SPT N Values between 15 and 50 in accordance with IBC 2009 Chapter 16 Structural Design, Table 1613.5.2 - Site Class Definitions and associated Massachusetts Amendments covered under 780 CMR Chapter 16.

Earthquake response accelerations for the maximum considered earthquake S_s= 0.230 g and S_i = 0.066 g for Spencer, MA according to 780 CMR Chapter 16, Table 1604.11.

Based on the USGS Earthquake Hazards Program, the Seismic Factors for Design (ASCE 7-05) are as follows: S_s= 0.176 g, S_i = 0.065 g.

3.7. Construction Considerations

Construction phasing, site restrictions and impacts to environmentally sensitive resource areas during construction will be a major factor in the foundation design and ultimately the structure type selection. Any changes in the roadway profile such as increased roadway elevation will affect the stress profile of the roadway and impact the structures and piping below. Typical expected traffic loadings have been considered at the site as well, the structure design and foundation design will provide for H-20 or higher loading.

Bypass piping may be required to divert the stream around the construction site. If construction is performed during low flow months (July-September) bypass pumping may be an option while utilizing the upstream ponded area as storm flow event retention. The contractor will be required to control groundwater elevations using an acceptable practice, such as well points and groundwater pumps, with discharge into sedimentation bags located on relatively level ground in vegetated, stabilized areas prior to entering the stream downstream of the project site.

4. Hydrologic and Hydraulic Evaluation

4.1. Hydrologic Study

CEI utilized Autodesk Storm and Sanitary Analysis (SSA) modelling software to perform TR-20 and TR-55 calculations to estimate peak discharge rates for the Clark Road roadway-stream crossing watershed. USGS StreamStats was used to delineate the watershed contributing to the unnamed tributary. StreamStats provided the estimated watershed area, percentage of area covered by forest, and estimated bankfull flow statistics. Additional input data included NRCS precipitation data (Cornell Study), NRCS soils survey, GIS land use information, and USGS topographical maps for estimating Time of Concentration.

The following peak flow flood discharges in cubic feet per second (cfs) were calculated from the SSA model:

- 1 year-24 hour Storm – 15.2 cfs
- 5 year-24 hour Storm – 40.8 cfs
- 10 year-24 hour Storm – 57.2 cfs
- 25 year-24 hour Storm – 85.9 cfs
- 50 year-24 hour Storm – 113.8 cfs
- 100 year-24 hour Storm – 148.8 cfs

Hydrologic computations are attached in **Appendix F**.

4.2. Hydraulic Study

Based on the hydrologic calculations, SSA hydraulic modeling was used to determine peak water surface elevations and velocities at several stream stations within the study area. Stream station data was input into the model using detailed survey information at cross-sections determined during the site reconnaissance. The existing culvert pipe inlet invert is at elevation 874.35 and the outlet invert is at elevation 874.00. The proposed alternatives have been modeled with a natural control structure, to be constructed of cobbles and boulders, at the upstream end to maintain the typical water level in the upstream ponded area, as to not drain the wetlands. The proposed alternatives have also been modeled with a proposed streambed elevation of 874.00 at the outlet end.

The existing conditions and several proposed structure alternatives were analyzed and compared for various flood return frequencies. The structure alternatives consist of: embedded circular metal pipe, embedded metal pipe arch, three-sided concrete box, and embedded concrete box. Peak water surface elevations at stream cross sections upstream and downstream of the structure, as well as peak flow velocities within the structure and immediately downstream, are provided for each alternative in **Appendix G**.

Table 4.1 – 10-Year Storm Event Hydraulic Summary

	Embedment	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
		Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
Ex. 18” RCP	None	878.17	874.67	11.79	1.92
Prop. 5’x2’ 3-sided Concrete Box	Open Bottom	876.83	874.88	5.39	2.37
Prop. 5’x4’ Concrete Box	2-feet	876.83	874.88	5.39	2.37
Prop. 5’ CMP	2.5-feet (½)	877.07	874.84	4.98	2.35
Prop. 6’ CMP	3-feet (½)	876.72	874.92	4.71	2.38
Prop.73”x55” CMP Arch	25-inches (to springline)	876.84	874.90	4.65	2.38
Prop.8’x2’ 3-Sided Metal Box	Open Bottom	876.16	874.93	4.89	2.39

Clark Road has a highway functional classification of local rural road as determined by MassDOT. This classification provides applicable guidelines for designing a new or replacement culvert. According to the MassDOT LRFD Bridge Manual the hydraulic design flood return frequency for a local rural roadway is the 10-year event. A stream crossing structure should provide ample clearance between the peak water surface elevations during the design storm event and the proposed structure low chord; MassDOT typically requires 2-feet. Ideally, the replacement structure should provide some freeboard during the design storm event to avoid pressurized flow conditions due to a submerged inlet. The scour design and scour check flood return frequencies are the 25-year and 50-year storm events, respectively, for structures requiring foundation designs.

Under proposed conditions in all scenarios, the culvert will be extended by 5-feet to increase the roadway shoulder at the crossing. This is in an effort to address traffic concerns and a history of automobile crashes in this area. The downstream plunge pool will be filled to accommodate the extension and proposed roadway embankment slopes. This proposal slightly affects the downstream output data as seen in the summary table. A more uniform shape and slope has been modeled at the downstream end, which results in a slight increase in the peak water surface elevation and peak flow velocity.

4.3. Construction Considerations

Roadway cover above the proposed structure will be a determining factor in the replacement alternative. The roadway shoulders are at elevation 878.00 at the crossing site. With proposed streambed inverts of 874.00 within the replacement structure, the overall top of pipe elevation must be considered. Allowable minimum cover over the proposed structure will control certain alternatives. Minimum cover over the concrete box culverts and corrugated metal pipe arches as recommended by the structure or pipe manufacturer must be maintained.

A wetland replication area may be required because of the proposed culvert extension and reshaping of the downstream end.

Bypass piping may be required to divert the stream around the construction site. If construction is performed during low flow months (July-September) bypass pumping may be an option while utilizing the upstream ponded area as storm flow event retention. The contractor will be required to control groundwater elevations using an acceptable practice, such as well points and groundwater pumps, with discharge into sedimentation bags located on relatively level ground in vegetated, stabilized areas prior to entering the stream downstream of the project site.

5. Structure Type Evaluation

The structure type selection considerations outlined below highlight the typical factors to be used during the initial decision making process.

5.1. Cost Considerations

Overall cost of the proposed replacement is one of the top factors in determining the structure type. Costs associated with engineering design and permitting, materials, and construction will be compared and weighed for each alternative. The following table highlights standard cost implication rankings.

Table 5.1 – Typical Cost Summary

Costs	Design & Permitting	Materials	Construction
Low	< $10,000	< $25,000	< $25,000
Medium	$10,000 - $35,000	$25,000 - $50,000	$25,000 - $100,000
High	> $35,000	> $50,000	> $100,000

Low cost options for materials and construction should be considered and prioritized as applicable to the replacement project. The life expectancy of the material will need to be considered and no aspects shall compromise safety.

Prioritize: replacement structures capable of being installed by local municipal forces; structures that can be designed and provided a structural engineering stamp by a manufacturer; and, structures that can be made available with the shortest lead time.

Structure types with materials that require excessive equipment, cranes, staging areas, traffic management, and the like, should be considered less desirable options. Engineering and design phase costs should not weigh as heavily in the structure type selection process.

Cost Factor: The costs associated with each proposed alternative will be weighed with the strongest consideration given to the least expensive options.

5.2. Site Considerations

Roadway Cover

At the Spencer site, available roadway cover prohibits the construction of a structure that will provide ample clearance between peak water surface elevations during storm events and the proposed structure low chord. The proposed alternative should provide freeboard during the design storm event to allow for non-pressurized flow conditions.

Roadway Cover Factor: Maximum available freeboard during the design storm event for each proposed structure will be a factor in the ultimate structure type selected.

Traffic

The existing bituminous concrete roadway pavement is approx. 21 feet wide, 10.5 feet per lane. No guardrail is provided on either side of the roadway. There is a history of automobile crashes at the downstream end of the culvert. Vehicles travelling north on Clark Road approach the project site down a steep hill prior to an abrupt 90-degree corner just east of the roadway-stream crossing. As part of this project the shoulder in the vicinity of the crossing will be extended to better match the overall roadway cross-section on both sides of the culvert. The addition of guardrails in the area will be examined further during final design efforts. Guardrail in this location has the potential for frequent minor damage and added maintenance requirements.

Preliminary meetings with the Town have determined that vehicle traffic cannot be detoured completely around the site during construction. Phasing of construction work is required for every alternative.

Traffic Factor: Proposed culvert crossing alternatives will include a 5-foot extension compared to the existing culvert length. Alternatives must be able to be constructed in phases due to traffic management requirements.

Utilities

There are no water, sewer, or gas mains in the vicinity of the existing structure, no overhead wires are present in the immediate area.

Utilities Factor: Utilities will not limit the proposed structure type alternative, or constructability.

Resource Areas

The existing culvert carries a stream/ wetland crossing beneath the roadway. Therefore, the structure is located within: the riverfront area, the inland bank buffer zone, bordering vegetated wetlands, and wetlands buffer zone. Wetland replication areas will need to be considered during the permitting phase due to this proposed shoulder widening which may impact wetlands in the vicinity. The culvert site is not located within Natural Heritage and Endangered Species Program (NHESP) rare or endangered species habitat. The culvert is not located in any known historic or cultural areas, and the site is not known to be located in any areas that would warrant the expectation of hazardous materials or contaminants.

Resource Areas Factor: All alternatives will require permitting. Overall extents of permitting and environmental impacts of each alternative will be considered.

Aquatic Organism Presence

Stiles Reservoir is approximately 750 feet downstream of the culvert and is known to have typical warm water fish species, including: largemouth bass, blue gill, pumpkinseeds, etc. It is possible those species use this stream as habitat, but do not reside in the stream. Macro invertebrates in the stream currently contribute to improving water quality and act as a food source for other aquatic organisms. Semi-Aquatic Organisms, such as turtle and frogs are able to cross the road, but are susceptible to traffic fatalities from the more than 500 cars that travel the road daily.

Aquatic Organism Presence Factor: Alternatives that can provide an ecological connection from the upstream end to downstream end of the roadway-stream crossing will receive priority consideration.

5.3. Hydraulic Considerations

Bankfull Width

There are discernable defined stream banks running through the upstream ponded area. The existing culvert pipe supports the stream crossing; however, the pipe is also contributing to the creation of the impoundment. The determination is whether to meet the 1.2 times bankfull width stream crossing requirement of the Massachusetts River and Stream Crossing Standards. There is streambed refusal for approximately 15-feet upstream of the existing culvert, which is assumed to be the historic channel grade. Meeting the bankfull width requirement may drain the high quality wetland and increase the design cost associated with determining the actual historic stream bottom with certainty. Maintaining the impoundment and the existing ecological benefits associated with it, and creating an ecological crossing that maintains the high quality wetland impoundment is the most cost effective and ecologically economic decision.

Average bankfull width measured along the downstream channel is 6.4-feet. Not all proposed alternatives will require a span length that will provide for 1.2 times the average bankfull width, a minimum structure width of 7.7-feet.

For replacement structures under 10-feet in width the municipality should use the services of a registered professional engineer to develop the design, but the design will not require review by MassDOT. Structures between 10-feet and 20-feet in width will require MassDOT review under MGL Chapter 85 Section 35 with a more involved design process. Structures over 20-feet in width will require the most stringent design process pertaining to full compliance with the MassDOT LRFD Bridge Manual. These scenarios should be carefully considered when selecting the proposed alternative as the additional review processes will increase costs.

Bankfull Width Factor: Based on the wetland crossing designation, it is not required that all alternatives meet a minimum span of 7.7-feet. The proposed alternative shall take into account the design review process cost implications.

<u>Embedment & Substrate</u>

Open-bottom structures are the preferred replacement type according to Massachusetts River and Stream Crossing Standards. Based on the Spencer geotechnical data, foundation types for open-bottom structures may become too expensive for a cost effective replacement project. Closed bottom pipes and box culverts act as their own mat or slab footing and require a minimum of 2-feet of embedment with matching stream substrate within the crossing.

All proposed crossings will need to be designed with pool-riffle bedforms within the structure to match the reference reach characteristics found in the field. A boulder and cobble grade control structure will need to be designed at the inlet of each proposed alternative to maintain the existing wetland water surface elevation.

Embedment & Substrate Factor: All proposed alternatives shall meet, at a minimum, embedment and substrate requirements. Proposed alternatives must allow for bedform material and large key pieces to be installed within the structures.

<u>Water Depth & Velocity</u>

Structure type alternatives have been modelled for a variety of typical storm events to examine the change in peak water surface elevation and velocity when compared to existing conditions.

Water Depth & Velocity Factor: Proposed conditions shall not create a rise in the peak water surface elevation, and shall not create abrupt changes in velocity at the upstream or downstream end which may cause aggradation and degradation.

FEMA

There have been no reported issues of historic flooding in the area of the existing structure. The roadway-stream crossing culvert is not located within the 100-year flood zone, no FEMA flood mapping concerns exist.

FEMA Factor: The stream is not located within the 100-year flood zone, potential changes in water surface elevation will not require map revisions.

5.4. Geotechnical Considerations

Foundation Design

Based on the geotechnical data collected from the site a foundation type has been considered for each alternative. The slab footing alternative will require little design, with foundation preparation and materials incidental to the crossing structure installation. Deep pile foundations and shallow spread footings present more costly alternatives which will require extensive foundation design and construction.

Foundation Design Factor: The cost, compatibility with underlying soils, construction effort, and permitting implications of each foundation alternative will affect the ultimate structure type selection.

Vertical Adjustment Potential

Short-term and long-term stream degradation and aggradation must be considered when proposing a replacement stream crossing structure. Potential degradation and scour are major concerns with open-bottom structures to ensure the foundations are protected and set at the appropriate elevation. Both open-bottom and closed structures must account for aggradation to ensure the hydraulic opening will remain sufficient for passage of flows and debris.

The anticipated variation in streambed elevation over time is known as the vertical adjustment potential (VAP). The VAP is estimated from field assessment of the stability of existing grade controls (such as existing boulder/cobble bed forms found at pool tail crests) upstream and downstream of the crossing. Using the survey of the "long profile," pool depths are measured from the elevations of these grade control features, and used to estimate the maximum expected stream degradation over the length of the profile.

VAP is not a large concern at this site due to the existing ponded area/wetland upstream of the crossing. However, VAP will still need to be accounted for. The stream channel is a convex shape based on the long profile which is susceptible to a possible headcut scenario. A grade control structure will be proposed at the inlet of the proposed replacement culvert constructed of boulders and cobbles to maintain the existing ponded area elevation as to not drain the existing wetland. This proposed grade control structure will aid in controlling any headcut potential.

The following table shows adjustment factors used to calculate the lower VAP by multiplying the maximum surveyed pool depth in the surveyed stream reach by the VAP Factor associated with the stream bedform classification. The stream bedform classification is determined during site reconnaissance.

Vertical Adjustment Potential Factor: Degradation and aggradation of the streambed elevation must be considered to ensure the crossing foundation is protected, and passage of flow does not become limited.

Table 5.2 –VAP Adjustment Factors

Stream Bedform Classification	VAP Factor
Step-pool channels, Slope > 5%, boulder-cobble boundaries	1.00 x Pool Max Depth
Step-pool channels, Slope < 5%, cobble-gravel boundaries	1.25 x Pool Max Depth
Steep riffles with ribs, cobble-gravel boundaries	1.50 x Pool Max Depth
Riffles, gravel-cobble boundaries	1.75 x Pool Max Depth
Riffles, sand-fine gravel boundaries	2.00 x Pool Max Depth
Bedrock	No adjustment

Source: USDA Forest Service - Eastern Region-R9, "Designing for Aquatic Organism Passage at Road-Stream Crossings (Stream Simulation)"

5.5. Alternatives Analysis

5.5.1. Concrete Box Culvert

Two concrete box culvert options have been examined as potential replacement alternatives. Proposed 5-foot wide by 2-foot high 3-sided concrete box culvert with open-bottom, and proposed 5-foot wide by 4-foot high concrete box culvert embedded 2-feet.

Site Consideration: Both options will have 1-foot of cover provided over the structure, which meets the manufacturer's requirements for H-25 loading. Both options could be constructed utilizing a traffic management plan of alternating one-way traffic with police detail. Both options will not have any utility issues or coordination required. Both options will require permitting, however the 3-sided box culvert may have slightly larger resource area impacts due to the footing installation.

Hydraulic Considerations: Both options will perform in the same manner hydraulically. The structures will appear identical within the stream, same geometry, material type, and streambed substrate. The 3-sided structure will make the placement of bedforms easier during the construction phase, as the stream bed can be constructed once footings are placed but before the culvert units are installed. There will be no rise in the upstream water surface elevation, velocities are closely comparable to existing conditions. However, both options will operate under pressure flow conditions due to a submerged inlet condition during the 10-year design storm. Neither option will meet 1.2 times the downstream bankfull width.

Geotechnical Considerations: The open-bottom option will require a more costly shallow spread footing foundation with soil improvements at the bearing layer. The closed box culvert would be considered a slab footing and act as its own spread footing foundation, this option would be the most cost effective. Each alternative will require the removal of the unsuitable organic, peat layer.

Cost Considerations: It is anticipated that the closed bottom box culvert will generate a lower cost than the 3-sided structure relative to the standard cost rankings. Design and permitting for the closed bottom box will be a medium ranking, while the 3-sided box requiring a foundation design will be a high ranking. Materials and construction will register in the high ranking for each concrete box alternative.

5.5.2. Corrugated Metal Pipe Culvert

Two corrugated metal pipe culvert options have been examined as potential replacement alternatives. Proposed 5-foot diameter corrugated metal pipe embedded half way to 2.5-feet, and proposed 6-foot diameter corrugated metal pipe embedded half way to 3-feet.

Site Consideration: Only the 5-foot diameter options will have the minimum 1-foot of cover provided over the structure, which meets the manufacturer's requirements for H-25 loading. The 6-foot diameter structure will only have 6-inches of cover above the pipe when embedded halfway. The roadway profile would need to be raised in the vicinity of the crossing in order to accommodate the 6-foot diameter pipe, which would have large cost and permitting implications. Both options could be constructed utilizing a traffic management plan of alternating one-way traffic with police detail. Both options will not have any utility issues or coordination required. Both options will require permitting, however the 6-foot diameter pipe will have slightly larger resource area impacts.

Hydraulic Considerations: As expected, the larger diameter alternative will provide lower peak water surface elevations upstream and lower peak velocities within and downstream of the crossing. The 6-foot diameter option will provide freeboard within the structure during the design storm, however the 5-foot diameter option will operate under pressure flow conditions during the 10-year design storm. For both options, there will be no rise in the upstream water surface elevation, velocities are closely comparable to existing conditions. The structures will both be embedded half of their respective diameters with streambed substrate and bedforms created within the crossing. The larger diameter structure will make the placement of bedforms easier during the construction phase. Neither option will meet 1.2 times the downstream bankfull width.

Geotechnical Considerations: Each of the two options would be considered a slab footing and act as its own spread footing foundation, this foundation type is the most cost effective. Each alternative will require the removal of the unsuitable organic, peat layer.

Cost Considerations: It is anticipated that the smaller diameter culvert will generate a lower overall cost than the larger diameter structure relative to the standard cost rankings. Design and permitting for the 5-foot diameter pipe will be a low ranking, while the 6-foot diameter pipe requiring roadway profile modification will be a high ranking. Materials will register in the low ranking for each metal pipe alternative. While construction for the 5-foot diameter pipe will be a medium ranking, the 6-foot diameter pipe requiring roadway profile modification will register in the high ranking.

5.5.3. Metal Arch Culvert

Two corrugated metal arch options have been examined as potential replacement alternatives. Proposed 73-inch wide by 55-inch high corrugated metal pipe arch embedded 25-inches, and proposed 8-foot wide by 2-foot high 3-sided metal box culvert with open-bottom.

Site Consideration: Both options will provide the manufacturer's recommended cover over the structure which meets the requirements for H-25 loading, with a minimum of 1-foot of cover. Both options could be constructed utilizing a traffic management plan of alternating one-way traffic with police detail. Both options will not have any utility issues or coordination required. Both options will require permitting, however the 3-sided metal box culvert may have slightly larger resource area impacts due to the footing installation.

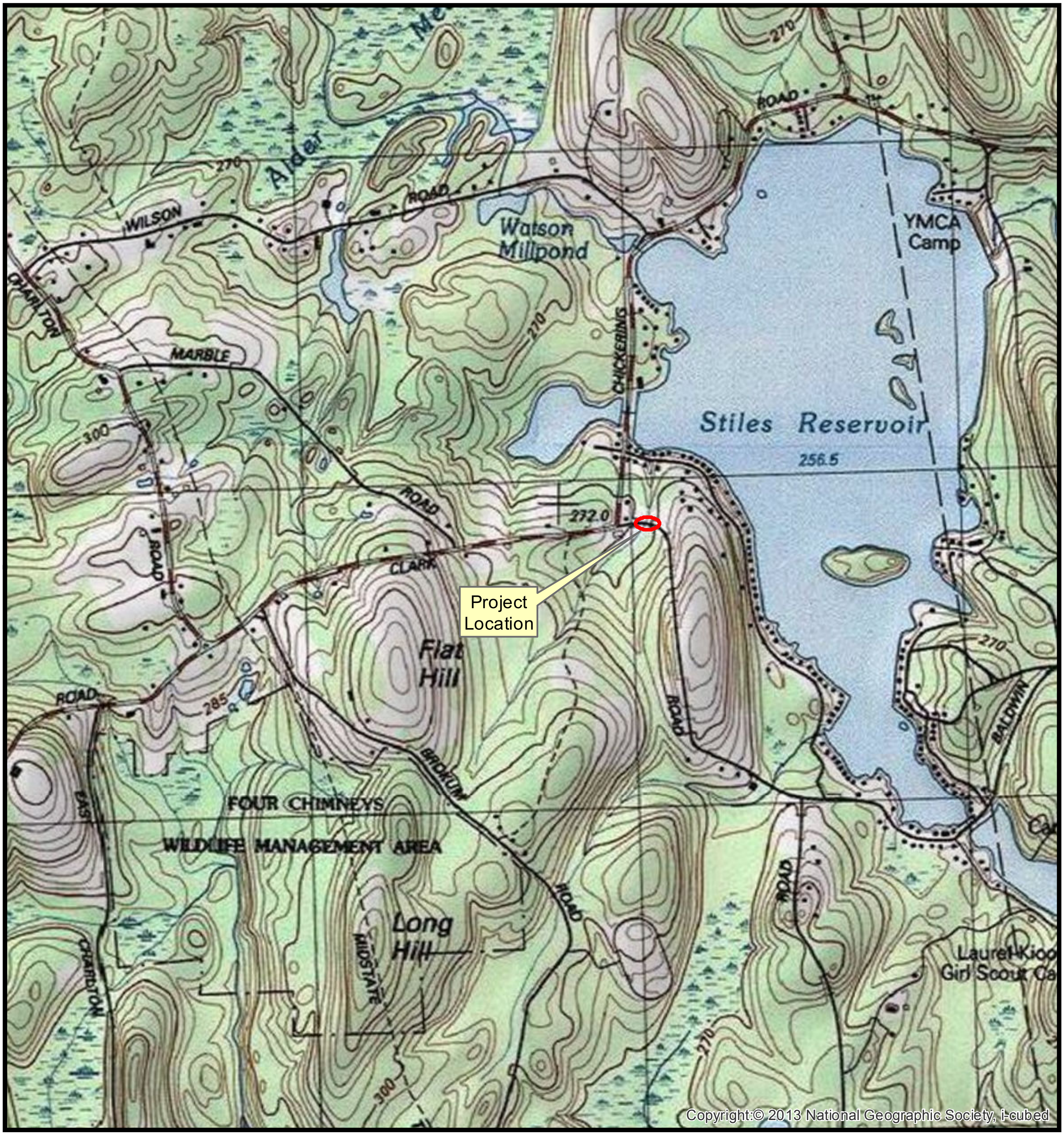
Hydraulic Considerations: Based on the geometry and shape of the different alternatives, the metal box will provide slightly lower peak water surface elevations upstream of the crossing, while the metal pipe arch will provide lower peak velocities within and downstream of the crossing. Both options will provide freeboard within the structure during the 10-year design storm. For both options, there will be no rise in the upstream water surface elevation, velocities are closely comparable to existing conditions. The structures will both be constructed with streambed substrate and bedforms created within the crossing. The 3-sided structure will make the placement of bedforms easier during the construction phase. The span of the pipe arch option will be slightly below bankfull width, while the 3-sided box option will meet 1.2 times the downstream bankfull width.

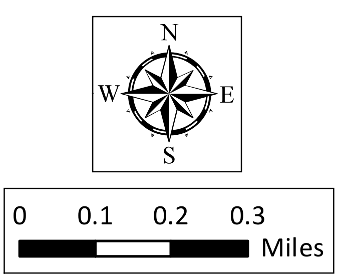
Geotechnical Considerations: The open-bottom option will require a more costly shallow spread footing foundation with soil improvements at the bearing layer. The closed pipe arch culvert would be considered a slab footing and act as its own spread footing foundation, this option would be the most cost effective. Each alternative will require the removal of the unsuitable organic, peat layer. *Cost Considerations:* It is anticipated that the closed bottom pipe arch culvert will generate a lower cost than the 3-sided structure relative to the standard cost rankings. Design and permitting for the closed bottom box will be a medium ranking, while the 3-sided box requiring a foundation design will be a high ranking. Materials will register in the low ranking for each metal pipe alternative. While construction for the closed bottom pipe arch will be a medium ranking, the 3-sided metal box requiring a spread footing installation will register in the high ranking.

5.6. Structure Type Selection

The recommended replacement structure for the Clark Road-Unnamed Tributary to Stiles Reservoir roadway-stream crossing culvert is the 73-inch wide by 55-inch high corrugated metal pipe arch embedded 25-inches to the pipe springline. This alternative offers the most compatible option for the site considering site constraints, hydraulic and geotechnical aspects, optimized with low total cost implications associated with design, permitting, materials, and construction.

Figures





Tributary to Stiles Reservoir,
Clark Rd., Spencer, MA

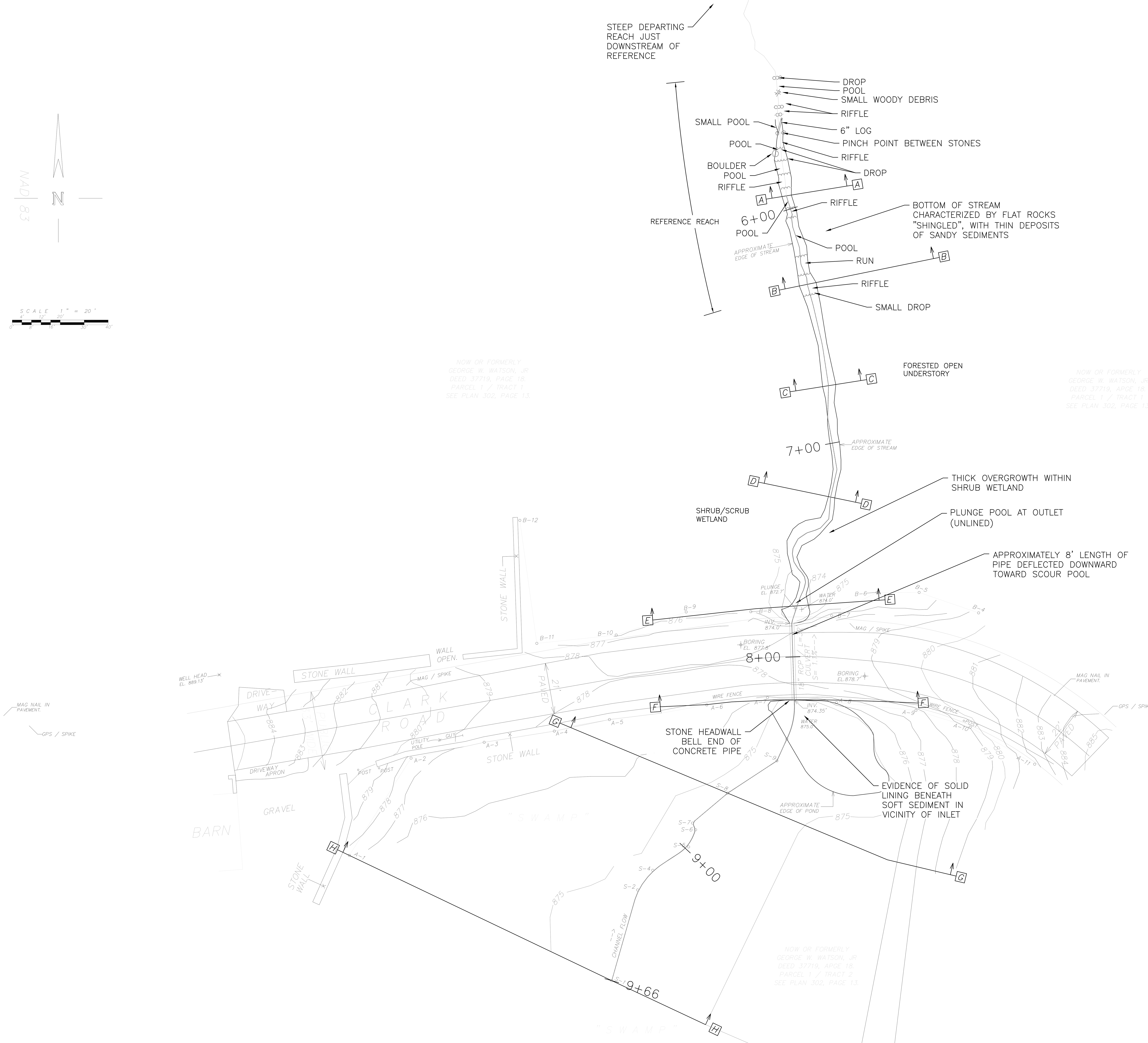
Data Source: USGS

Site Locus Map

Comprehensive
Environmental, Inc.

Appendix A

Stream Plan View, Longitudinal Profile, and Cross-Sections



GENERAL NOTES

No.	Revision/Issue	Date

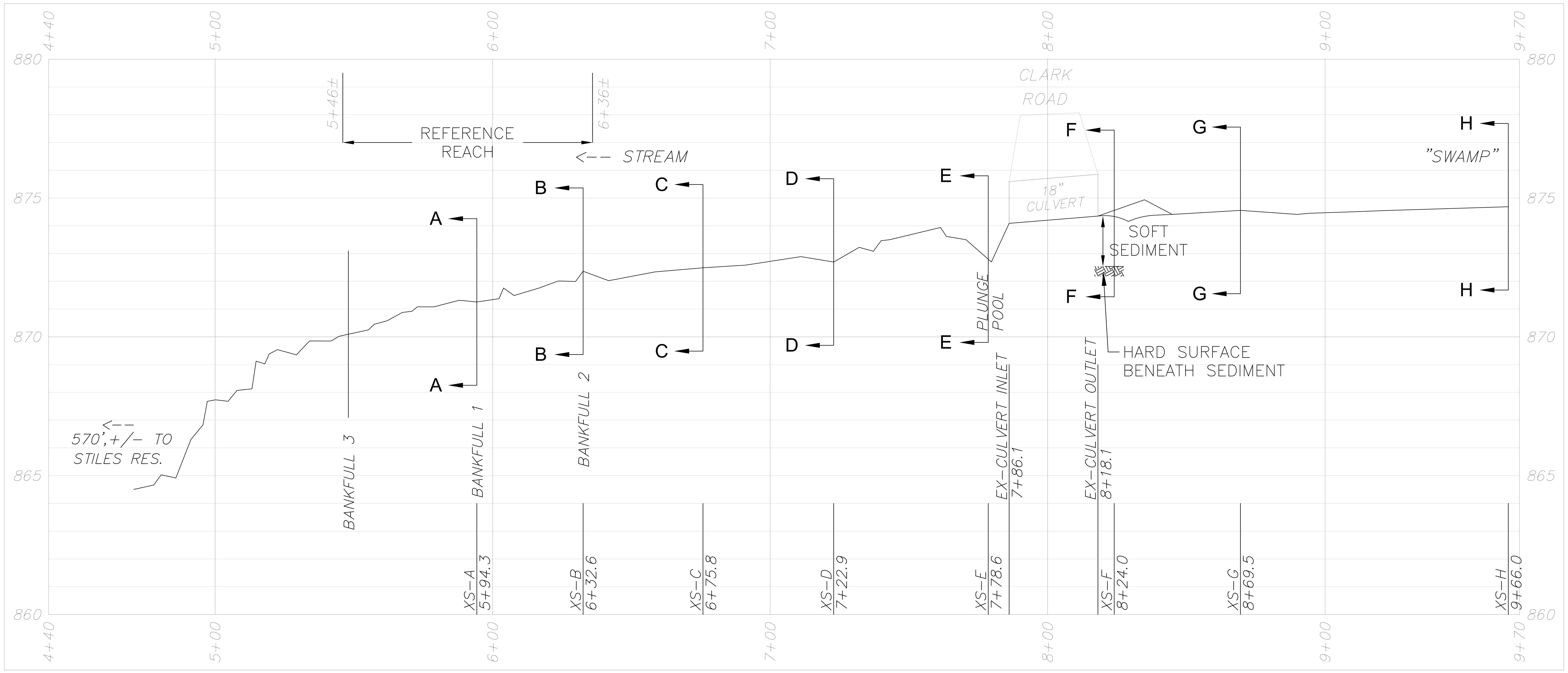
COMPREHENSIVE ENVIRONMENTAL INCORPORATED

225 CEDAR HILL ST.
MARLBOROUGH, MA 01752

CULVERT REPLACEMENT
CLARK ROAD
EXISTING STREAM FEATURES

Town of Spencer, MA

Contract No.: 2016-1 Date: JUNE 2016	Sheet
Drawn By: JJK Checked By: SS/DN Scale: AS SHOWN	C-1



STREAM PROFILE - CLARK ROAD

HORIZONTAL SCALE 1" = 20'
VERTICAL SCALE 1" = 2'

SCALE 1" = 20'

0' 10' 20' 30' 40' 60' 80'

GENERAL NOTES

No.	Revision/Issue	Date

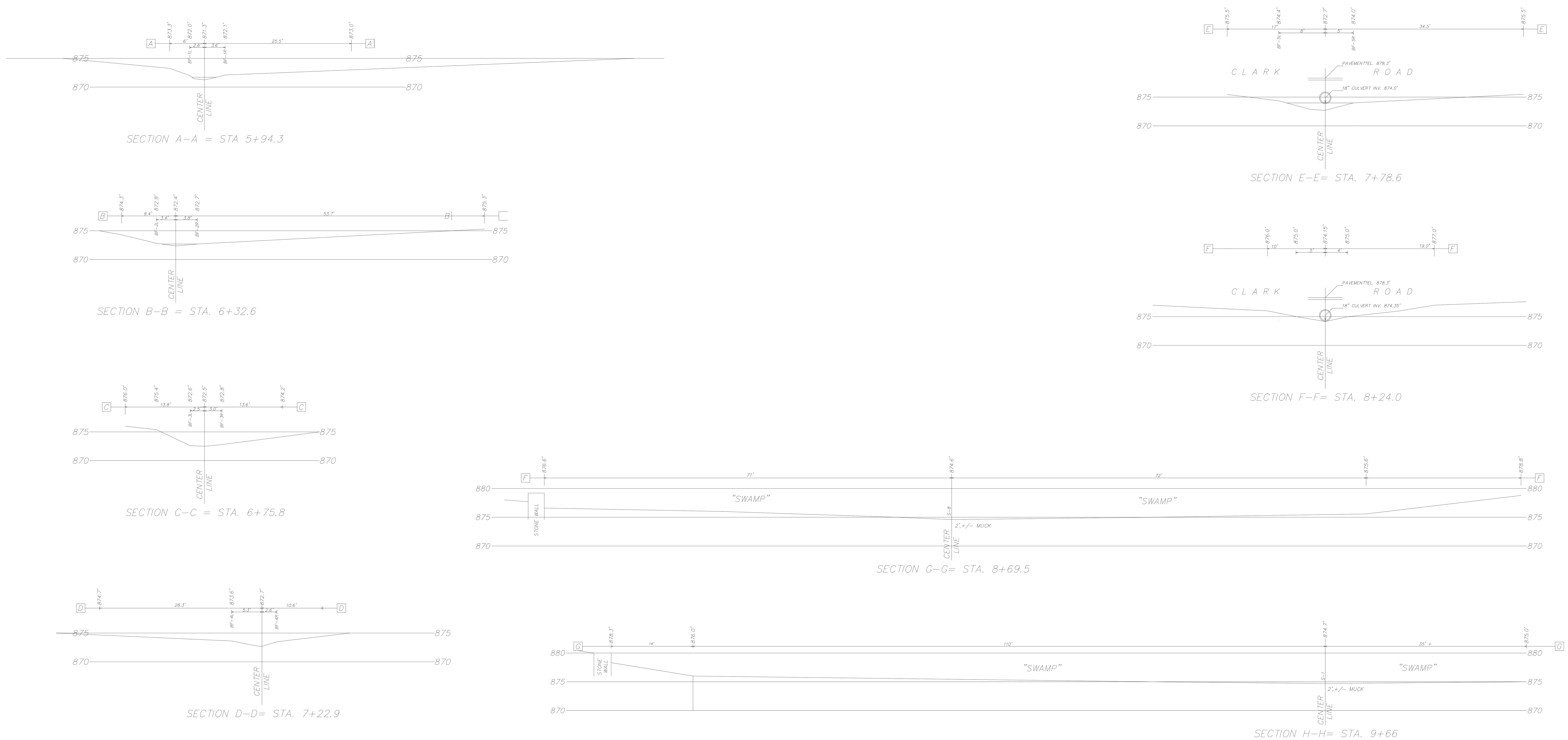
COMPREHENSIVE ENVIRONMENTAL INCORPORATED
225 CEDAR HILL ST.
MARLBOROUGH, MA 01752

CULVERT REPLACEMENT
CLARK ROAD
STREAM PROFILE

Town of Spencer, MA

Contract No.: 2016-1
Date: JUNE 2016
Drawn By: JJK
Checked By: SS/DN
Scale: AS SHOWN

Sheet C-2



STREAM CROSS SECTIONS
CLARK ROAD

SCALE 1" = 10'

GENERAL NOTES

No.	Revision/Issue	Date

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
225 CEDAR HILL ST.
MARLBOROUGH, MA 01752

CULVERT REPLACEMENT
CLARK ROAD
STREAM CROSS
SECTIONS

Town of Spencer, MA

Contract No.: 2016-1
Date: JUNE 2016
Drawn By: JJK
Checked By: SS/DN
Scale: AS SHOWN

Sheet
C-3

Appendix B

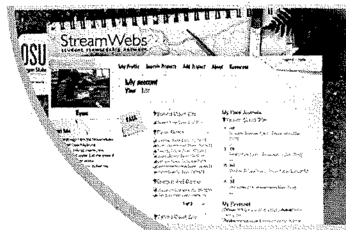
Pebble Count

OSU Oregon State University Extension Service

StreamWebs™

Student Stewardship Network

PEBBLE COUNT



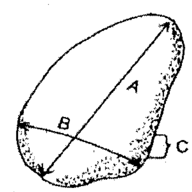
Name: Tim Charey, Scott Saluucci

School: ______________ Teacher: ______________

Date: 5/15/16 Time: 1PM

Stream/Site Name: Clark Road, Spencer, MA

Weather: Overcast 45°



(A) Long axis
(B) Intermediate axis
(C) Short axis

The intermediate axis is the pebble's diameter.

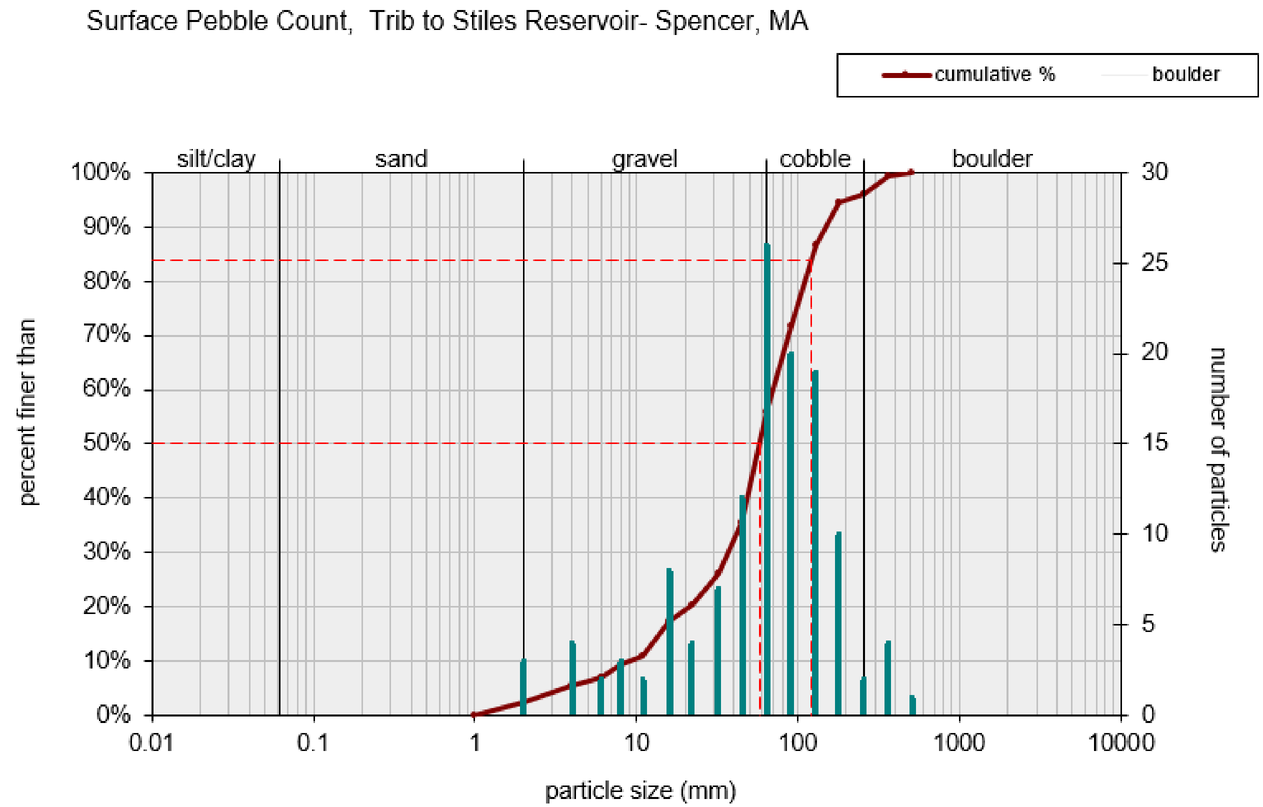
Pebble counts are an important component of analyzing stream characteristics. The distribution of sediment material on the streambed can inform you about a variety of different stream functions and hydrologic conditions, including erosion potential, woody debris, and aquatic species habitat.

Material	Size (mm)	Tally		#
silt/clay	0 - 0.062			
very fine sand	0.062 - 0.125			
fine sand	0.125 - 0.25			
medium sand	0.25 - 0.5			
coarse sand	0.5 - 1			
very coarse sand	1 - 2	III		3
very fine gravel	2 - 4	IIII		4
fine gravel	4 - 6	II		2
fine gravel	6 - 8	III		3
medium gravel	8 - 11	II		2
medium gravel	11 - 16	IIIII III		8
coarse gravel	16 - 22	IIII		4
coarse gravel	22 - 32	IIIII II		7
very coarse gravel	32 - 45	IIIII IIIII II		12
very coarse gravel	45 - 64	IIIII IIIII IIIII IIIII IIIII I		26
			STA 176 TO 179	
small cobble	64 - 90	IIIII IIIII IIIII IIIII	KCM PIECES 250 220	20
medium cobble	90 - 128	IIIII IIIII IIIII IIII	370 150 170	19
large cobble	128 - 180	IIIII IIIII	350 360 320	10
very large cobble	180 - 256	II	130 290 480	2
			STA 146 TO 153	
small boulder	256 - 362	IIII	KCM PIECES 260 280	4
small boulder	362 - 512	I	430 190 460	1
medium boulder	512 - 1024		150 230 390	
large boulder	1024 - 2048		310 350 300	
very large boulder	2048 - 4096		190 280	

Bankfull Channel

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	
very coarse sand	1 - 2	3
very fine gravel	2 - 4	4
fine gravel	4 - 6	2
fine gravel	6 - 8	3
medium gravel	8 - 11	2
medium gravel	11 - 16	8
coarse gravel	16 - 22	4
coarse gravel	22 - 32	7
very coarse gravel	32 - 45	12
very coarse gravel	45 - 64	26
small cobble	64 - 90	20
medium cobble	90 - 128	19
large cobble	128 - 180	10
very large cobble	180 - 256	2
small boulder	256 - 362	4
small boulder	362 - 512	1
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
total particle count:		127
bedrock	-------------	
clay hardpan	-------------	
detritus/wood	-------------	
artificial	-------------	
total count:		127

Note: Artificial = large chunk of asphalt (boulder)



Size (mm)	
D16	15
D35	44
D50	58
D65	78
D84	120
D95	200

Size Distribution	
mean	42.4
dispersion	3.0
skewness	-0.14

Type	
silt/clay	0%
sand	2%
gravel	54%
cobble	40%
boulder	4%

Appendix C

Site Photographs

Spencer, MA – Clark Road

View Upstream

View Downstream

Upstream Opening

Downstream Opening

Reference Reach

Reference Reach

Appendix D

Soil Boring Logs

TEST BORING LOG

SHEET 1

Soil Exploration Corp. Geotechnical Drilling Groundwater Monitor Well 148 Pioneer Drive Leominster, MA 01453 978 840-0391	**Comprehensive Environmental** **Site: Culvert** **Clark Road** **Spencer, MA**	BORING B-1 PROJECT NO. 16-0508 DATE: May 6, 2016

Ground Elevation:
Date Started: May 5, 2016
Date Finished: May 5, 2016
Driller: GG
Soil Engineer/Geologist:

GROUNDWATER OBSERVATIONS			
DATE	DEPTH	CASING	STABILIZATION

Depth Ft.	Casing bl/ft	Sample No.	Sample Pen/Rec	Sample Depth	Sample Blows/6”	Strata	Visual Identification of Soil and / or Rock Sample
							Asphalt.
						6”	
1		1	14”	6”-2’6”	5-11-11-11		Medium dense, dry, fine to coarse sand, trace fine to coarse gravel and silt.
						4’0”	
5		2	10”	5’0”-7’0”	7-4-4-4		Soft, wet organics, peat.
						7’0”	
							Fine to coarse sand.
						9’0”	
10		3	14”	10’0”-12’0”	4-3-3-3		Loose, wet, very fine sand and silt.
						14’0”	
15		4	12”	15’0”-16’4”	10-17-50/4”		Very dense, wet, fine to coarse sand and gravel, cobbles and silt.
20		5	0	20’0”-20’1”	50/1”		
						22’0”	
25							End of boring at 22’0”. Refusal with augers. Water encountered at 4’0” upon completion.
30							
35							
39							

Notes: Hollow Stem Auger Size - 4 1/4"

Cohesionless: 0 - 4 V. Loose, 4 - 10 Loose,	Trace 0 to 10%		CASING	SAMPLE	CORE TYPE
10 -30 M Dense, 30 -50 Dense, 50+ V Dense.	Little 10 to 20%	ID SIZE (IN)		SS	
Cohesive: 0 -2 V Soft, 2 -4 Soft, 4 -8 M Stiff	Some 20 to 35%	HAMMER WGT (LB)		140 lb.	
8 -15 Stiff, 15 -30 V. Stiff, 30 + Hard.	And 35% to 50%	HAMMER FALL (IN)		30"	

TEST BORING LOG

SHEET 2

Soil Exploration Corp. Geotechnical Drilling Groundwater Monitor Well 148 Pioneer Drive Leominster, MA 01453 978 840-0391	**Comprehensive Environmental** **Site: Culvert** **Clark Road** **Spencer, MA**	BORING B-2 PROJECT NO. 16-0508 DATE: May 6, 2016

Ground Elevation:
Date Started: May 5, 2016
Date Finished: May 5, 2016
Driller: GG
Soil Engineer/Geologist:

GROUNDWATER OBSERVATIONS

DATE	DEPTH	CASING	STABILIZATION

Depth Ft.	Casing bl/ft	Sample No.	Pen/Rec	Depth	Blows/6"	Strata	Visual Identification of Soil and / or Rock Sample
						6"	Asphalt.
1		1	13"	6"-2'6"	6-10-12-14		Medium dense, dry, fine to coarse sand and gravel, trace silt.
						4'0"	
5		2	3" 10"	5'0"-5'6" 5'6"-7'0"	4 5-6-6	5'6"	Soft, wet organics, peat Medium dense, wet, fine to medium sand and silt.
						9'0"	
10		3	10"	10'0"-12'0"	7-18-18-18		
15		4	13"	15'0"-17'0"	9-34-17-17		Dense to very dense, wet, fine to coarse sand and gravel, cobbles, some inorganic silt.
20		5	13"	20'0"-21'4"	40-55-60/4"		
		6	0	22'0"-22'1"	50/1"	22'6"	
25							End of boring at 22'6". Refusal with augers. Water encountered at 4'0" upon completion.
30							
35							
39							

Notes: Hollow Stem Auger Size - 4 1/4"

Cohesionless: 0 - 4 V. Loose, 4 - 10 Loose,	Trace 0 to 10%		CASING	SAMPLE	CORE TYPE
10 -30 M Dense, 30 -50 Dense, 50+ V Dense.	Little 10 to 20%	ID SIZE (IN)		SS	
Cohesive: 0 -2 V Soft, 2 -4 Soft, 4 -8 M Stiff	Some 20 to 35%	HAMMER WGT (LB)		140 lb.	
8 -15 Stiff, 15 -30 V. Stiff, 30 + Hard.	And 35% to 50%	HAMMER FALL (IN)		30"	

Appendix E

Soil Laboratory Test Results

Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	---	Sample Type:	---	Tested By:	jbr
Sample ID:	---	Test Date:	05/17/16	Checked By:	emm
Depth :	---	Test Id:	378263		

Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content,%
B-1	S- 3	10-12 ft	Moist, brown sandy silty clay	18.8
B-1	S- 4	15-16 ft 4 in	Moist, brown silty gravel with sand	7.2
B-2	S- 3	10-12 ft	Moist, reddish yellow silty gravel with sand	8.6
B-2	S- 4	15-17 ft	Moist, brown silty sand with gravel	12.0

Notes: Temperature of Drying : 110° Celsius

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Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	---	Sample Type:	---	Tested By:	cam
Sample ID:	---	Test Date:	05/20/16	Checked By:	emm
Depth :	---	Test Id:	378251		

USCS Classification - ASTM D2487

Boring ID	Sample ID	Depth	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
B-1	S-3	10-12 ft	Sandy Silty clay	CL-ML	8.3	41.3	50.4
B-1	S-4	15-16 ft 4 in	Silty gravel with sand	GM	39.4	38.3	22.3
B-2	S-3	10-12 ft	Silty gravel with sand	GM	44.0	39.4	16.6
B-2	S-4	15-17 ft	Silty sand with gravel	SM	38.8	46.3	14.9

Remarks: Grain Size analysis performed by ASTM D422 results enclosed
Atterberg Limits performed by ASTM D4318, results enclosed

Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	---	Sample Type:	---	Tested By:	jbr
Sample ID:	---	Test Date:	05/17/16	Checked By:	emm
Depth :	---	Test Id:	378255		

Laboratory Determination of Density (Unit Weight) of Soil Specimens by ASTM D7263

Boring ID	Sample ID	Depth	Visual Description	Bulk Density pcf	Moisture Content %	Dry Density pcf	*
B-1	S- 3	10-12 ft	Moist, brown sandy silty clay	128.2	18.75	107.9	(1)
B-2	S- 3	10-12 ft	Moist, reddish yellow silty gravel with sand	112.2	8.587	103.3	(2)
B-2	S- 4	15-17 ft	Moist, brown silty sand with gravel	139.2	12.04	124.2	(3)

* Sample Comments

(1): Method B-Volumetric, Reconstituted (compacted)

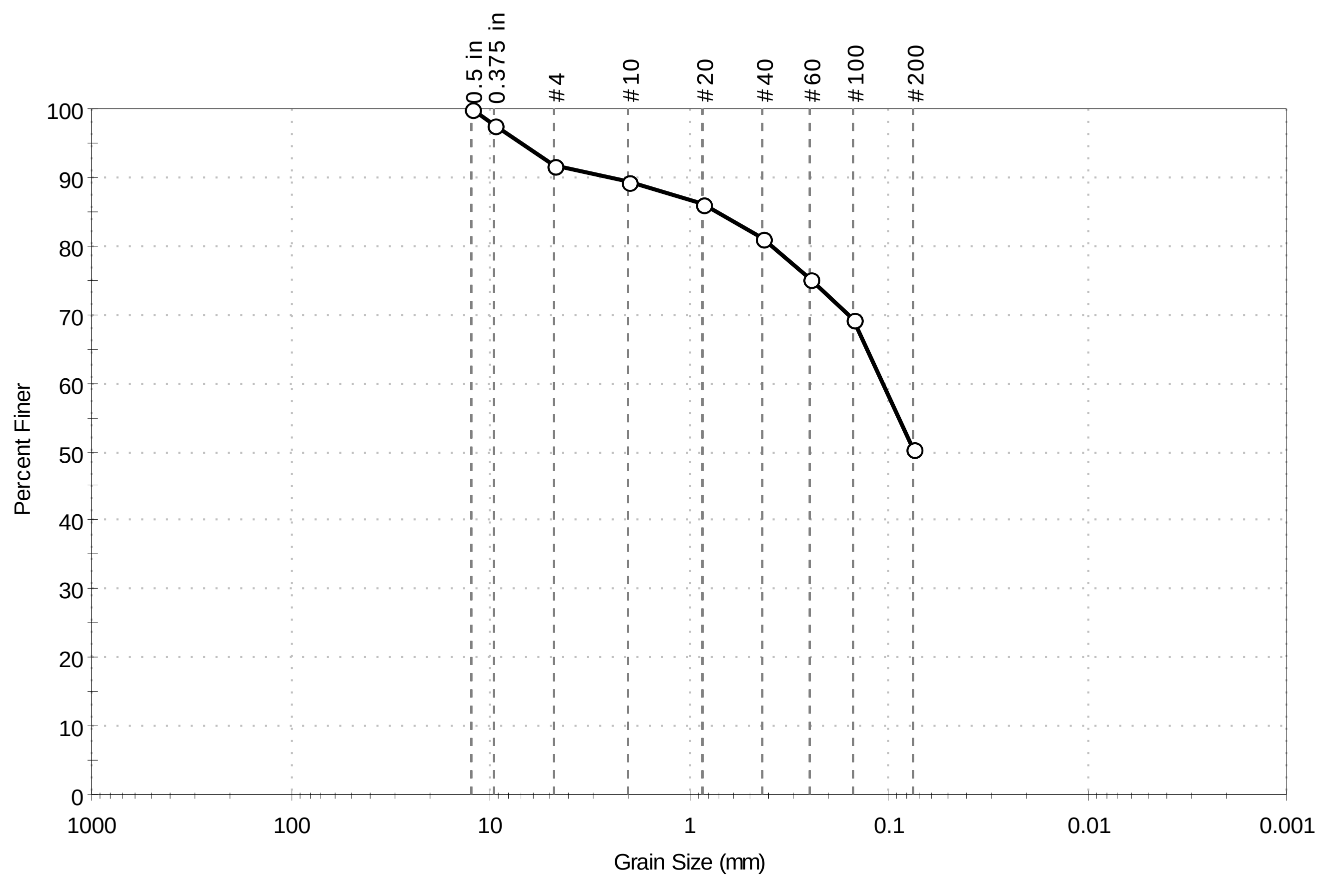
(2): Method B-Volumetric, Reconstituted (compacted)

(3): Method B-Volumetric, Reconstituted (compacted)

Notes: Moisture Content determined by ASTM D2216.

Client:	Comprehensive Environmental		
Project:	Spencer/Ashfield		
Location:	Spencer/Ashfield, MA	Project No:	GTX-304733
Boring ID: B-1	Sample Type: jar	Tested By:	jbr
Sample ID: S-3	Test Date: 05/18/16	Checked By:	emm
Depth : 10-12 ft	Test Id: 378256		
Test Comment:	---		
Visual Description:	Moist, brown sandy silty clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	8.3	41.3	50.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	98		
#4	4.75	92		
#10	2.00	89		
#20	0.85	86		
#40	0.42	81		
#60	0.25	75		
#100	0.15	69		
#200	0.075	50		

Coefficients

D_{85} = 0.7178 mm D_{30} = N/A

D_{60} = 0.1065 mm D_{15} = N/A

D_{50} = N/A D_{10} = N/A

C_u = N/A C_c = N/A

Classification

ASTM   Sandy Silty clay (CL-ML)

AASHTO   Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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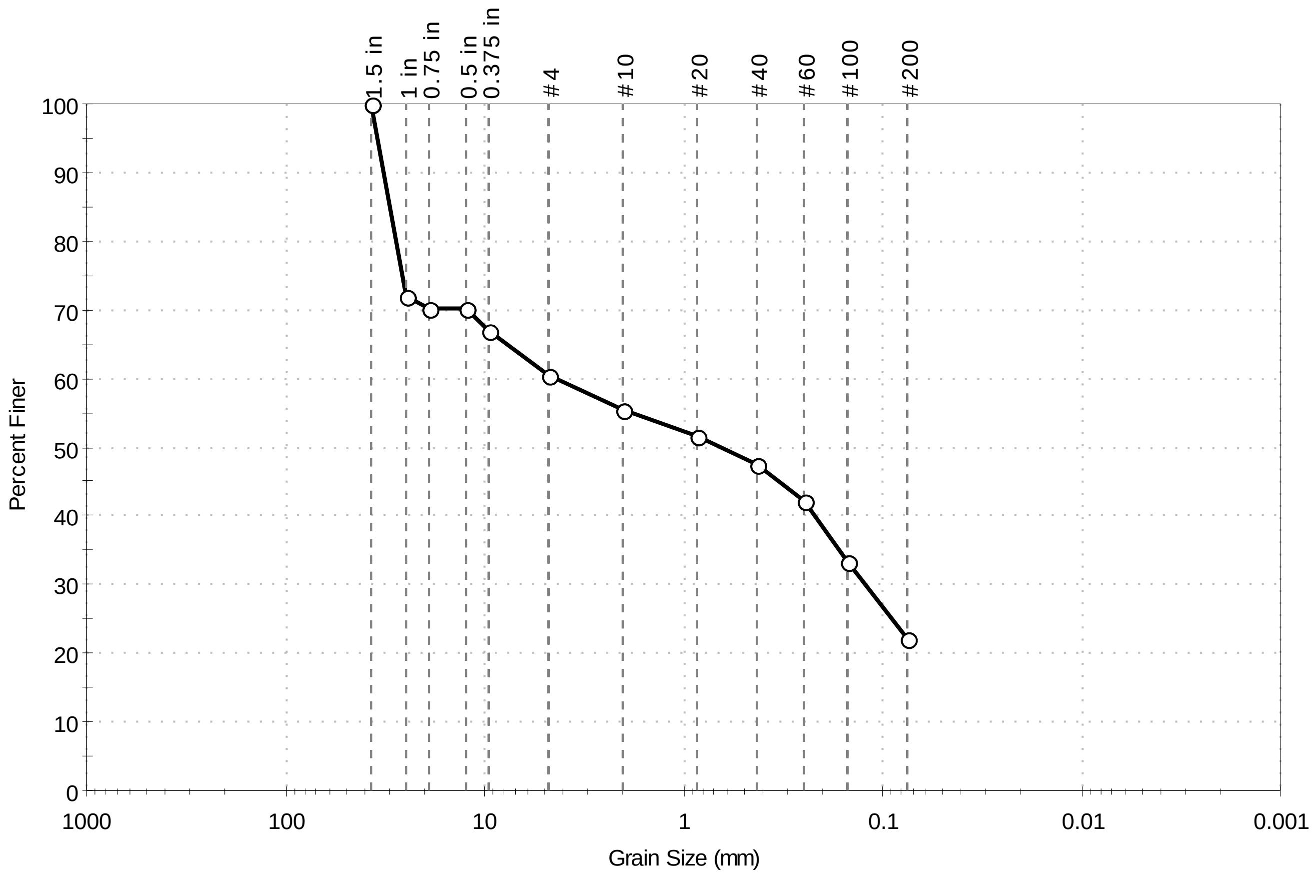
Client:	Comprehensive Environmental		
Project:	Spencer/Ashfield		
Location:	Spencer/Ashfield, MA	Project No:	GTX-304733

Boring ID:	B-1	Sample Type:	jar	Tested By:	jbr
Sample ID:	S-4	Test Date:	05/18/16	Checked By:	emm
Depth :	15-16 ft 4 in	Test Id:	378257		

Test Comment:	---
Visual Description:	Moist, brown silty gravel with sand
Sample Comment:	---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	39.4	38.3	22.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	72		
0.75 in	19.00	70		
0.5 in	12.50	70		
0.375 in	9.50	67		
#4	4.75	61		
#10	2.00	56		
#20	0.85	52		
#40	0.42	47		
#60	0.25	42		
#100	0.15	33		
#200	0.075	22		

Coefficients

D_{85} = 30.2132 mm	D_{30} = 0.1218 mm
D_{60} = 4.2861 mm	D_{15} = N/A
D_{50} = 0.6438 mm	D_{10} = N/A
C_u = N/A	C_c = N/A

Classification

ASTM: Silty gravel with sand (GM)

AASHTO: Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

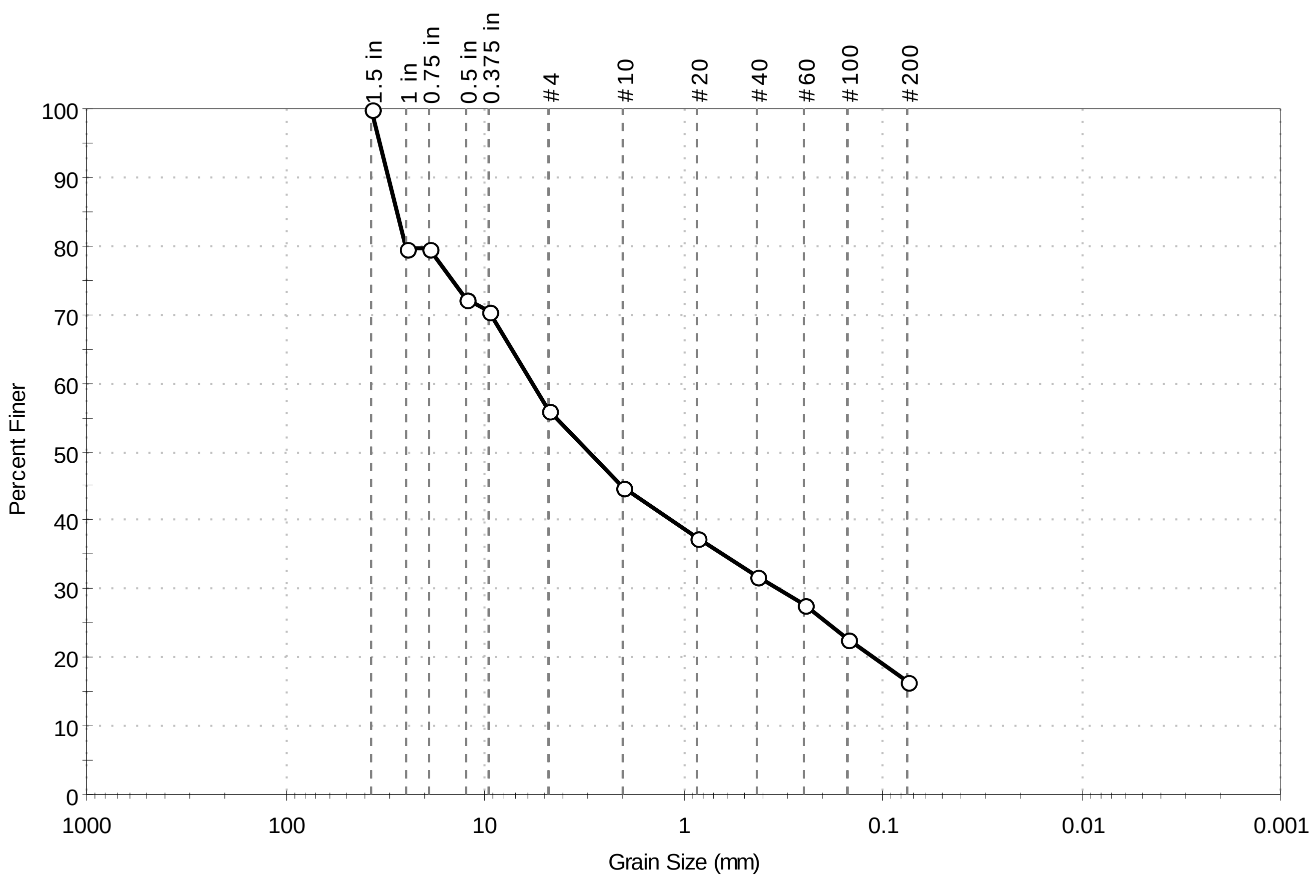
Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	B-2	Sample Type:	jar	Tested By:	jbr
Sample ID:	S-3	Test Date:	05/18/16	Checked By:	emm
Depth :	10-12 ft	Test Id:	378258		

Test Comment: ---
Visual Description: Moist, reddish yellow silty gravel with sand
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	44.0	39.4	16.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	80		
0.75 in	19.00	80		
0.5 in	12.50	72		
0.375 in	9.50	71		
#4	4.75	56		
#10	2.00	45		
#20	0.85	37		
#40	0.42	32		
#60	0.25	28		
#100	0.15	23		
#200	0.075	17		

Coefficients

D_{85} = 27.8528 mm
D_{30} = 0.3335 mm
D_{60} = 5.7491 mm
D_{15} = N/A
D_{50} = 2.9821 mm
D_{10} = N/A
C_u = N/A
C_c = N/A

Classification

ASTM Silty gravel with sand (GM)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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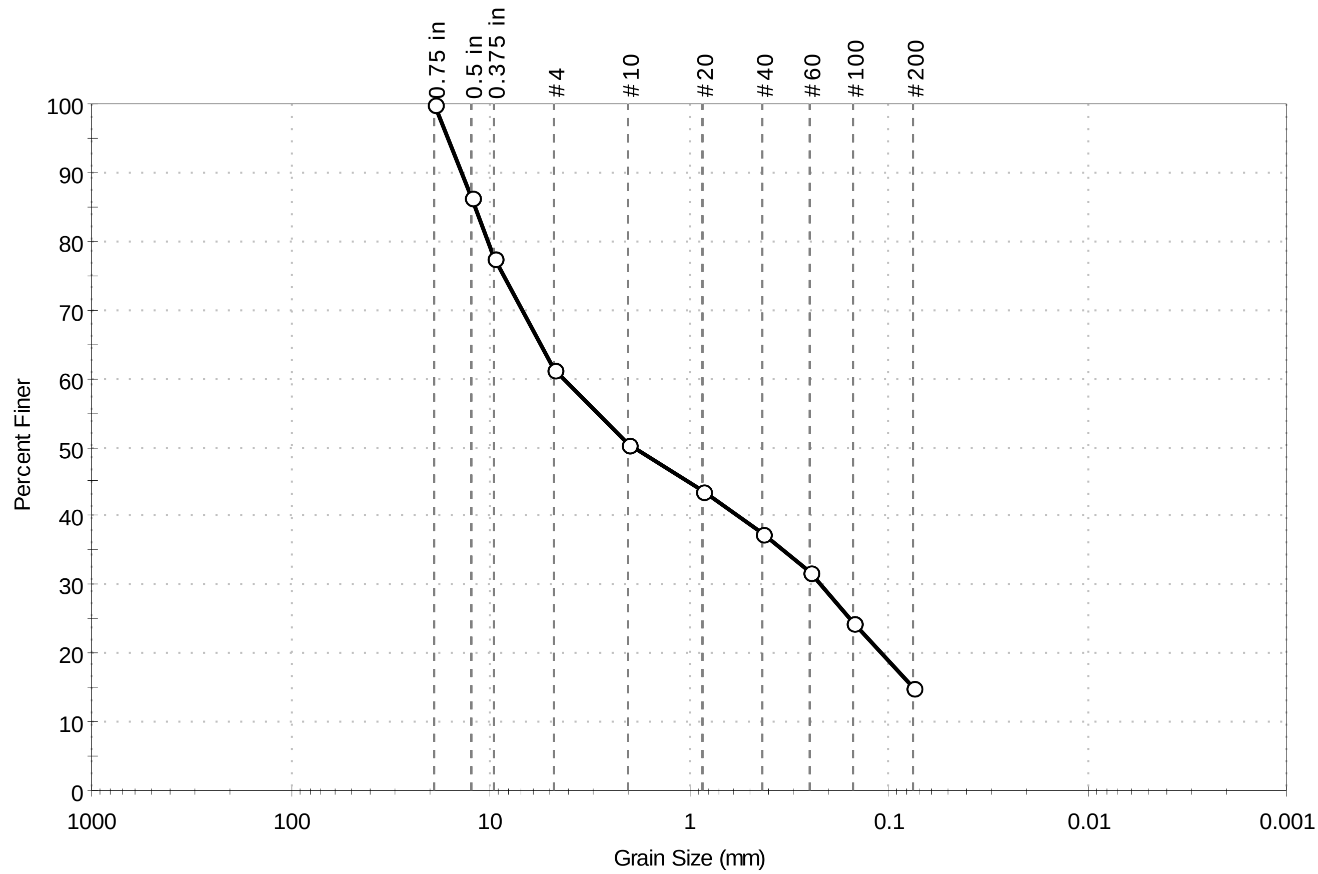
GeoTesting EXPRESS

Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	B-2	Sample Type:	jar	Tested By:	jbr
Sample ID:	S-4	Test Date:	05/18/16	Checked By:	emm
Depth :	15-17 ft	Test Id:	378259		

Test Comment: ---
Visual Description: Moist, brown silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	38.8	46.3	14.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	86		
0.375 in	9.50	78		
#4	4.75	61		
#10	2.00	50		
#20	0.85	44		
#40	0.42	38		
#60	0.25	32		
#100	0.15	24		
#200	0.075	15		

Coefficients

D_{85} = 11.9923 mm　　D_{30} = 0.2186 mm
D_{60} = 4.3002 mm　　D_{15} = 0.0755 mm
D_{50} = 1.9075 mm　　D_{10} = N/A
C_u = N/A　　C_c = N/A

Classification

ASTM　Silty sand with gravel (SM)

AASHTO　Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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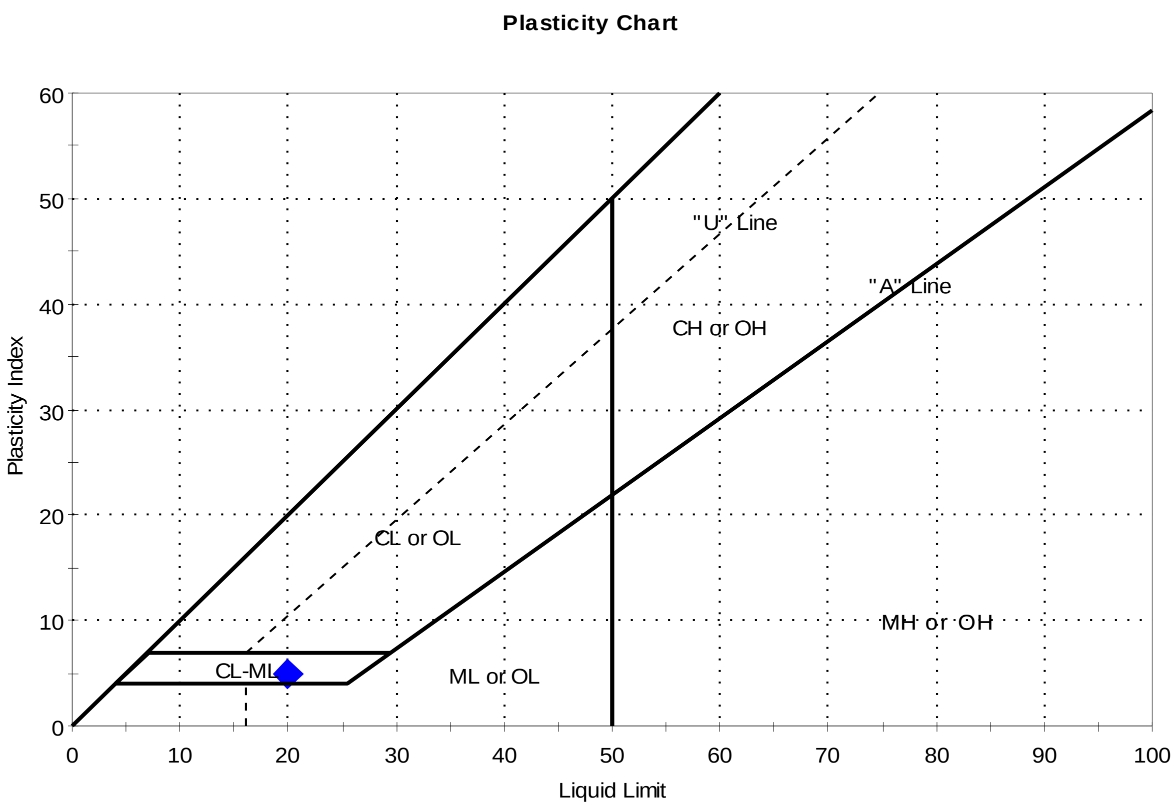
GeoTesting EXPRESS

Client: Comprehensive Environmental			
Project: Spencer/Ashfield			
Location: Spencer/Ashfield, MA		Project No:	GTX-304733
Boring ID: B-1	Sample Type: jar	Tested By:	cam
Sample ID: S-3	Test Date: 05/17/16	Checked By:	emm
Depth : 10-12 ft	Test Id: 378244		
Test Comment: ---			
Visual Description: Moist, brown sandy silty clay			
Sample Comment: ---			

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-3	B-1	10-12 ft	19	20	15	5	0.8	Sandy Silty clay (CL-ML)

Sample Prepared using the WET method

19% Retained on #40 Sieve

Dry Strength: HIGH

Dilatancy: SLOW

Toughness: LOW

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Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	B-1	Sample Type:	jar	Tested By:	cam
Sample ID:	S-4	Test Date:	05/17/16	Checked By:	emm
Depth :	15-16 ft 4 in	Test Id:	378245		

Test Comment: ---

Visual Description: Moist, brown silty gravel with sand

Sample Comment: ---

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-4	B-1	15-16 ft 4 in	7	n/a	n/a	n/a	n/a	Silty gravel with sand (GM)

53% Retained on #40 Sieve

Dry Strength: LOW

Dilatancy: RAPID

Toughness: n/a

The sample was determined to be Non-Plastic

Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	B-2	Sample Type:	jar	Tested By:	cam
Sample ID:	S-3	Test Date:	05/17/16	Checked By:	emm
Depth :	10-12 ft	Test Id:	378246		

Test Comment: ---
Visual Description: Moist, reddish yellow silty gravel with sand
Sample Comment: ---

Atterberg Limits - ASTM D4318

Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-3	B-2	10-12 ft	9	n/a	n/a	n/a	n/a	Silty gravel with sand (GM)

68% Retained on #40 Sieve
Dry Strength: LOW
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Client:	Comprehensive Environmental				
Project:	Spencer/Ashfield				
Location:	Spencer/Ashfield, MA			Project No:	GTX-304733
Boring ID:	B-2	Sample Type:	jar	Tested By:	cam
Sample ID:	S-4	Test Date:	05/18/16	Checked By:	emm
Depth :	15-17 ft	Test Id:	378247		

Test Comment: ---
Visual Description: Moist, brown silty sand with gravel
Sample Comment: ---

Atterberg Limits - ASTM D4318

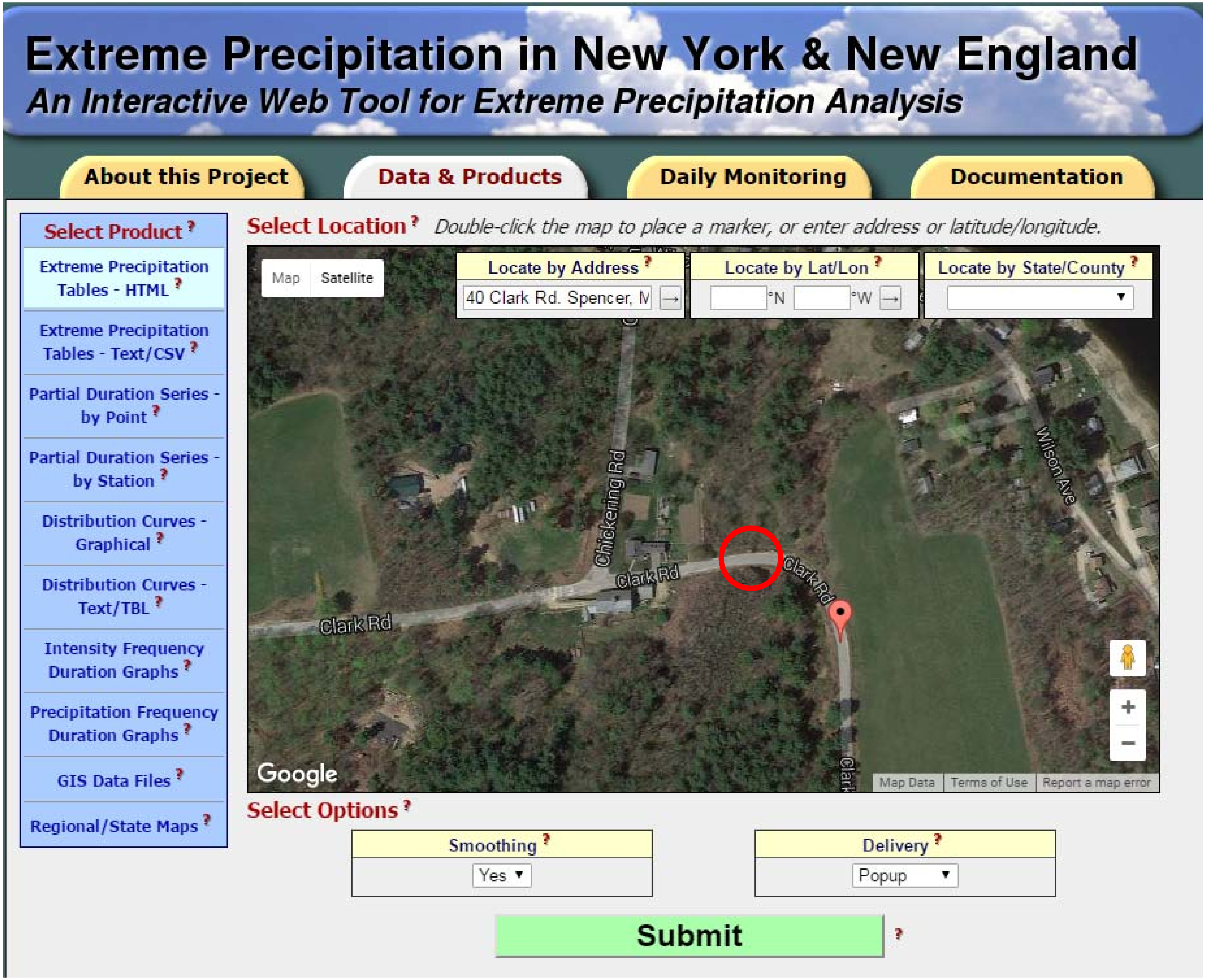
Sample Determined to be non-plastic

Symbol	Sample ID	Boring	Depth	Natural Moisture Content, %	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-4	B-2	15-17 ft	12	n/a	n/a	n/a	n/a	Silty sand with gravel (SM)

62% Retained on #40 Sieve
Dry Strength: LOW
Dilatancy: RAPID
Toughness: n/a
The sample was determined to be Non-Plastic

Appendix F

Hydrologic Computations


Extreme Precipitation in New York & New England
An Interactive Web Tool for Extreme Precipitation Analysis
About this Project
Data & Products
Daily Monitoring
Documentation
Select Product ?
Extreme Precipitation Tables - HTML ?
Extreme Precipitation Tables - Text/CSV ?
Partial Duration Series - by Point ?
Partial Duration Series - by Station ?
Distribution Curves - Graphical ?
Distribution Curves - Text/TBL ?
Intensity Frequency Duration Graphs ?
Precipitation Frequency Duration Graphs ?
GIS Data Files ?
Regional/State Maps ?
Select Location ? Double-click the map to place a marker, or enter address or latitude/longitude.
Map
Satellite
Locate by Address ?
40 Clark Rd. Spencer, M
Locate by Lat/Lon ?
°N
°W
Locate by State/County ?
Chickering Rd
Clark Rd
Clark Rd
Clark Rd
Wilson Ave
Google
Map Data
Terms of Use
Report a map error
Select Options ?
Smoothing ?
Yes
Delivery ?
Popup
Submit

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	Yes
State	Massachusetts
Location	
Longitude	71.954 degrees West
Latitude	42.207 degrees North
Elevation	Unknown/Unavailable
Date/Time	Tue, 31 May 2016 11:27:52 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.28	0.43	0.53	0.70	0.87	1.10	**1yr**	0.75	1.06	1.27	1.61	2.05	2.62	2.90	**1yr**	2.32	2.79	3.19	3.86	4.49	**1yr**
2yr	0.35	0.53	0.66	0.87	1.10	1.38	**2yr**	0.95	1.26	1.60	2.02	2.54	3.20	3.49	**2yr**	2.83	3.36	3.87	4.58	5.22	**2yr**
5yr	0.41	0.63	0.79	1.06	1.36	1.73	**5yr**	1.17	1.57	2.02	2.55	3.20	4.03	4.45	**5yr**	3.57	4.28	4.90	5.75	6.46	**5yr**
10yr	0.46	0.72	0.91	1.23	1.60	2.06	**10yr**	1.38	1.84	2.41	3.05	3.83	4.80	5.35	**10yr**	4.25	5.14	5.86	6.82	7.60	**10yr**
25yr	0.54	0.86	1.09	1.50	1.99	2.58	**25yr**	1.72	2.28	3.03	3.84	4.84	6.05	6.82	**25yr**	5.35	6.56	7.43	8.56	9.42	**25yr**
50yr	0.60	0.97	1.24	1.74	2.35	3.08	**50yr**	2.03	2.68	3.63	4.61	5.79	7.21	8.22	**50yr**	6.38	7.90	8.89	10.17	11.09	**50yr**
100yr	0.69	1.12	1.44	2.04	2.77	3.66	**100yr**	2.39	3.16	4.32	5.49	6.91	8.60	9.91	**100yr**	7.61	9.53	10.65	12.09	13.05	**100yr**
200yr	0.78	1.28	1.65	2.37	3.28	4.36	**200yr**	2.83	3.73	5.15	6.57	8.26	10.27	11.96	**200yr**	9.09	11.50	12.77	14.38	15.37	**200yr**
500yr	0.93	1.54	2.01	2.92	4.09	5.48	**500yr**	3.53	4.63	6.50	8.31	10.45	12.99	15.35	**500yr**	11.50	14.76	16.22	18.09	19.08	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.22	0.34	0.42	0.56	0.69	0.97	**1yr**	0.59	0.95	1.13	1.49	1.92	2.32	2.34	**1yr**	2.05	2.25	2.81	3.22	3.96	**1yr**
2yr	0.34	0.52	0.64	0.87	1.07	1.25	**2yr**	0.92	1.23	1.43	1.89	2.43	3.11	3.39	**2yr**	2.75	3.26	3.76	4.43	5.04	**2yr**
5yr	0.38	0.59	0.73	1.00	1.28	1.49	**5yr**	1.10	1.46	1.71	2.23	2.84	3.76	4.05	**5yr**	3.33	3.89	4.49	5.24	5.91	**5yr**
10yr	0.42	0.65	0.81	1.13	1.46	1.70	**10yr**	1.26	1.67	1.94	2.53	3.18	4.34	4.61	**10yr**	3.84	4.43	5.11	5.89	6.60	**10yr**
25yr	0.49	0.75	0.93	1.33	1.75	2.03	**25yr**	1.51	1.98	2.30	2.98	3.71	5.26	5.95	**25yr**	4.66	5.72	6.06	7.25	7.81	**25yr**
50yr	0.55	0.83	1.03	1.49	2.00	2.31	**50yr**	1.73	2.26	2.62	3.39	4.16	6.11	6.97	**50yr**	5.41	6.71	6.89	8.32	8.79	**50yr**
100yr	0.61	0.93	1.16	1.68	2.30	2.65	**100yr**	1.99	2.59	2.99	3.85	4.68	7.10	8.21	**100yr**	6.29	7.90	7.81	9.56	9.88	**100yr**
200yr	0.69	1.03	1.31	1.90	2.65	3.03	**200yr**	2.28	2.97	3.41	4.40	5.27	8.27	9.72	**200yr**	7.32	9.35	8.85	10.99	11.12	**200yr**
500yr	0.81	1.21	1.56	2.26	3.22	3.64	**500yr**	2.78	3.56	4.07	5.26	6.19	10.12	12.17	**500yr**	8.96	11.70	12.37	13.27	13.00	**500yr**

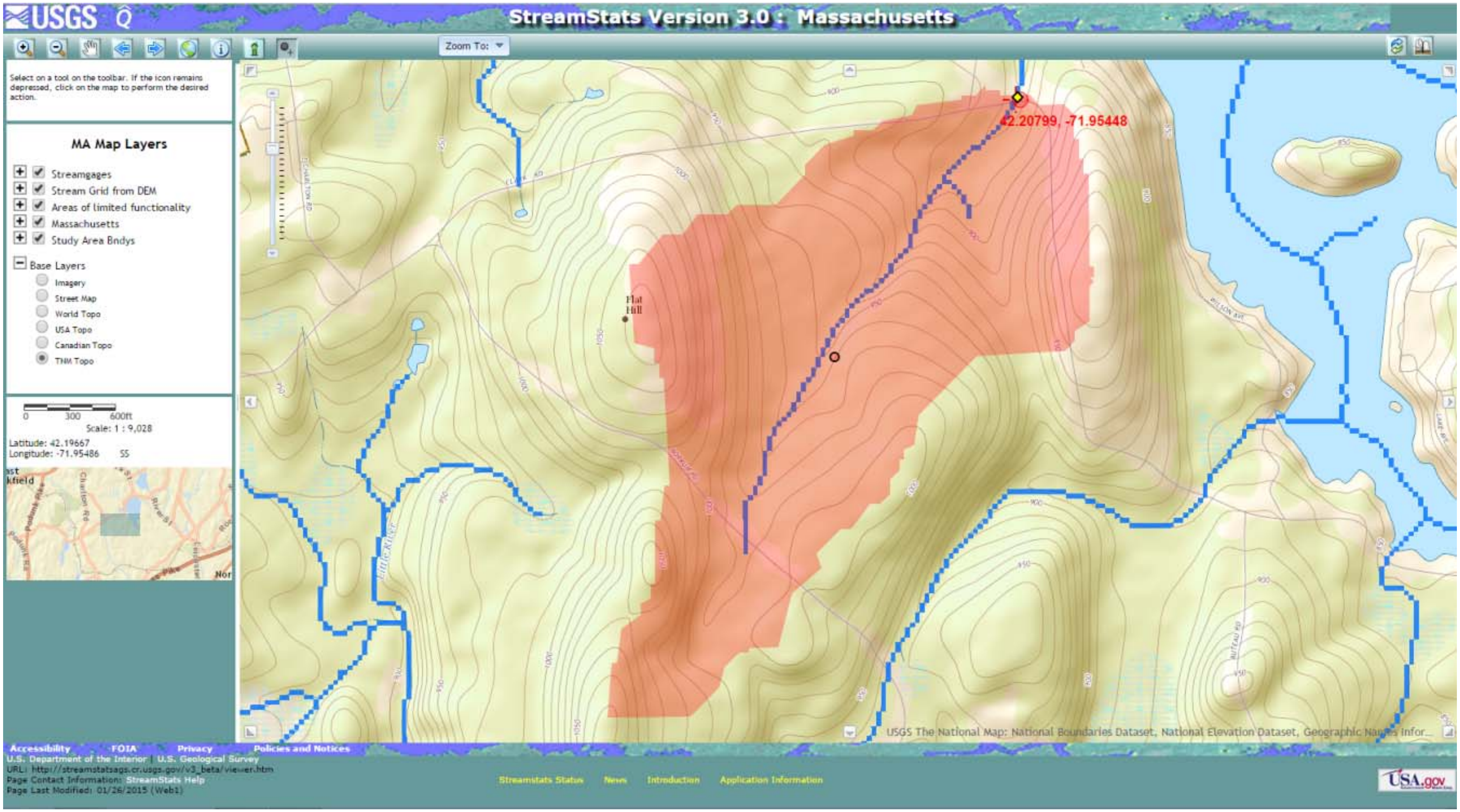
Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.31	0.48	0.58	0.78	0.96	1.18	**1yr**	0.83	1.15	1.37	1.75	2.33	2.85	3.22	**1yr**	2.52	3.10	3.52	4.17	4.91	**1yr**
2yr	0.36	0.55	0.68	0.92	1.13	1.33	**2yr**	0.98	1.30	1.54	2.00	2.58	3.32	3.63	**2yr**	2.94	3.49	4.03	4.76	5.51	**2yr**
5yr	0.43	0.67	0.83	1.13	1.44	1.71	**5yr**	1.25	1.67	1.97	2.54	3.21	4.33	4.86	**5yr**	3.83	4.68	5.33	6.30	7.07	**5yr**
10yr	0.50	0.77	0.96	1.34	1.73	2.07	**10yr**	1.50	2.03	2.40	3.05	3.80	5.30	5.99	**10yr**	4.69	5.76	6.61	7.80	8.68	**10yr**
25yr	0.62	0.95	1.18	1.68	2.21	2.67	**25yr**	1.91	2.61	3.10	3.87	4.77	6.93	7.85	**25yr**	6.14	7.55	8.82	9.96	11.01	**25yr**
50yr	0.73	1.11	1.38	1.98	2.67	3.24	**50yr**	2.30	3.16	3.78	4.64	5.65	8.49	9.69	**50yr**	7.52	9.32	10.99	12.21	13.40	**50yr**
100yr	0.86	1.30	1.63	2.35	3.22	3.92	**100yr**	2.78	3.83	4.60	5.57	6.70	10.38	11.98	**100yr**	9.19	11.52	13.68	14.94	16.31	**100yr**
200yr	1.01	1.52	1.93	2.79	3.89	4.75	**200yr**	3.36	4.64	5.60	6.66	7.95	12.71	14.81	**200yr**	11.25	14.24	17.05	18.29	19.85	**200yr**
500yr	1.27	1.89	2.43	3.53	5.02	6.13	**500yr**	4.33	5.99	7.26	8.47	9.95	16.59	19.56	**500yr**	14.68	18.80	20.98	23.86	25.73	**500yr**

Tributary to Stiles Reservoir

Clark Road

Spencer, MA



StreamStats Version 3.0

Basin Characteristics Ungaged Site Report

Date: Mon Apr 11, 2016 10:09:23 AM GMT-4
Study Area: Massachusetts
NAD 1983 Latitude: 42.208 (42 12 29)
NAD 1983 Longitude: -71.9544 (-71 57 16)

Label	Value	Units	Definition
DRNAREA	0.26	square miles	Area that drains to a point on a stream
STRMTOT	0.59	miles	Total length of mapped streams in basin
DRFTPERSTR	0	square mile per mile	Area of stratified drift per unit of stream length
MAREGION	0	dimensionless	Region of Massachusetts 0 for Eastern 1 for Western
FOREST	76.76	percent	Percentage of area covered by forest
CRSDFT	0	percent	Percentage of area of coarse-grained stratified drift
BSLDEM10M	7.655	percent	Mean basin slope computed from 10 m DEM
BSLDEM250	4.82	percent	Mean basin slope computed from 1:250K DEM
ACRSDFT	0	square miles	Area underlain by stratified drift
LC11IMP	0.61	percent	Average percentage of impervious area determined from NLCD 2011 impervious dataset
LC11DEV	5.11	percent	Percentage of land-use from NLCD 2011 classes 21-24
ELEV	967	feet	Mean Basin Elevation
PRECPRIS00	49.3	inches	Basin average mean annual precipitation for 1971 to 2000 from PRISM
LAKEAREA	0	percent	Percentage of Lakes and Ponds
OUTLETX	162465	State plane coordinates	Basin outlet horizontal (x) location in state plane coordinates
OUTLETY	884275	State plane coordinates	Basin outlet vertical (y) location in state plane coordinates
MAXTEMPC	13.5	degrees	Mean annual maximum air temperature over basin area, in degrees Centigrade
WETLAND	4.35	percent	Percentage of Wetlands
CENTROIDX	162088.9	State plane coordinates	Basin centroid horizontal (x) location in state plane coordinates
CENTROIDY	883749	State plane coordinates	Basin centroid vertical (y) location in state plane units

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Mon Apr 11, 2016 10:12:30 AM GMT-4
Study Area: Massachusetts
NAD 1983 Latitude: 42.208 (42 12 29)
NAD 1983 Longitude: -71.9544 (-71 57 16)
Drainage Area: 0.26 mi2

Low Flows Basin Characteristics			
100% Statewide Low Flow WRIR00 4135 (0.26 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.26 (below min value 1.61)	1.61	149
Mean Basin Slope from 250K DEM (percent)	4.820	0.32	24.6
Stratified Drift per Stream Length (square mile per mile)	0	0	1.29
Massachusetts Region (dimensionless)	0	0	1

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Probability of Perennial Flow Basin Characteristics			
100% Perennial Flow Probability (0.26 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.26	0.01	1.99
Percent Underlain By Sand And Gravel (percent)	0.00	0	100
Percent Forest (percent)	76.76	0	100
Massachusetts Region (dimensionless)	0	0	1

Bankfull Flows Basin Characteristics			
100% Bankfull Statewide SIR2013 5155 (0.26 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.26 (below min value 0.6)	0.6	329
Mean Basin Slope from 10m DEM (percent)	7.655	2.2	23.9

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Low Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
D50	0.24	ft3/s				
D60	0.14	ft3/s				
D70	0.0631	ft3/s				
D75	0.0439	ft3/s				
D80	0.0333	ft3/s				
D85	0.0228	ft3/s				
D90	0.0148	ft3/s				
D95	0.00778	ft3/s				
D98	0.00452	ft3/s				
D99	0.003	ft3/s				
M7D2Y	0.00803	ft3/s				
AUGD50	0.0231	ft3/s				
M7D10Y	0.00245	ft3/s				

http://pubs.usgs.gov/wri/wri004135/ (http://pubs.usgs.gov/wri/wri004135/)
Ries_ K.G._ III_ 2000_ Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135_ 81 p.

Probability of Perennial Flow Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PROBPEREN	0.42	dim	0.2		0.49	0.71

http://pubs.usgs.gov/sir/2006/5031/pdfs/SIR_2006-5031rev.pdf (http://pubs.usgs.gov/sir/2006/5031/pdfs/SIR_2006-5031rev.pdf)
Bent_ G.C._ and Steeves_ P.A._ 2006_ A revised logistic regression equation and an automated procedure for mapping the probability of a stream flowing perennially in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2006-5031_ 107 p.

Bankfull Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
BFWDTH	8.96	ft				
BFDPTH	0.65	ft				
BFAREA	5.74	ft2				
BFFLOW	14.2	ft3/s				

1-Year Storm Event

Project Description

File Name .... Spencer-Clark_Rd.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... SCS TR-55
Link Routing Method .... Hydrodynamic
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods ...... YES

Analysis Options

Start Analysis On	Jul 17, 2013	00:00:00
End Analysis On	Jul 18, 2013	00:00:00
Start Reporting On	Jul 17, 2013	00:00:00
Antecedent Dry Days	0	days
Runoff (Dry Weather) Time Step	0 01:00:00	days hh:mm:ss
Runoff (Wet Weather) Time Step	0 00:05:00	days hh:mm:ss
Reporting Time Step	0 00:05:00	days hh:mm:ss
Routing Time Step	30	seconds

Number of Elements

	Qty
Rain Gages	6
Subbasins...	1
Nodes...	1
Junctions	0
Outfalls	1
Flow Diversions	0
Inlets	0
Storage Nodes	0
Links..	0
Channels	0
Pipes	0
Pumps	0
Orifices	0
Weirs	0
Outlets	0
Pollutants	0
Land Uses	0

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	100-Year	Time Series	100-Year	Cumulative	inches	Massachusetts	Worcester	100	8.60	SCS Type III 24-hr
2	10-Year	Time Series	10-Year Storm	Cumulative	inches	Massachusetts	Worcester	10	4.80	SCS Type III 24-hr
3	1-Year	Time Series	1-Year	Cumulative	inches	Massachusetts	Worcester	1	2.62	SCS Type III 24-hr
4	25-Year	Time Series	25-Year Storm	Cumulative	inches	Massachusetts	Worcester	25	6.05	SCS Type III 24-hr
5	50-Year	Time Series	50-Year Storm	Cumulative	inches	Massachusetts	Worcester	50	7.21	SCS Type III 24-hr
6	5-Year	Time Series	5-Year Storm	Cumulative	inches	Massachusetts	Worcester	5	4.03	SCS Type III 24-hr

Subbasin Summary

SN	Subbasin ID	Area (ac)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	Time of Concentration (days hh:mm:ss)
1	Clark_Rd_Culvert	166.40	72.54	2.62	0.61	102.17	15.21	0 04:35:24

Subbasin Hydrology

Subbasin : Clark_Rd_Culvert

Input Data

Area (ac) 166.40
Weighted Curve Number 72.54
Rain Gage ID 1-Year

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
Pasture, grassland, or range, Good	24.96	C	74.00
Pasture, grassland, or range, Good	3.33	D	80.00
Woods, Good	102.34	C	70.00
Woods, Good	24.96	D	77.00
1 acre lots, 20% impervious	7.49	C	79.00
1 acre lots, 20% impervious	3.33	D	84.00
Composite Area & Weighted CN	166.41		72.54

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where :

Tc = Time of Concentration (hr)
n = Manning's roughness
Lf = Flow Length (ft)
P = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation :

V = 16.1345 * (Sf^0.5) (unpaved surface)
V = 20.3282 * (Sf^0.5) (paved surface)
V = 15.0 * (Sf^0.5) (grassed waterway surface)
V = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
V = 9.0 * (Sf^0.5) (cultivated straight rows surface)
V = 7.0 * (Sf^0.5) (short grass pasture surface)
V = 5.0 * (Sf^0.5) (woodland surface)
V = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
Tc = (Lf / V) / (3600 sec/hr)

Where:

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation :

V = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
R = Aq / Wp
Tc = (Lf / V) / (3600 sec/hr)

Where :

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

Sheet Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	.8	0.00	0.00
Flow Length (ft) :	100	0.00	0.00
Slope (%) :	0.5	0.00	0.00
2 yr, 24 hr Rainfall (in) :	3.20	0.00	0.00
Velocity (ft/sec) :	0.03	0.00	0.00
Computed Flow Time (min) :	65.10	0.00	0.00

Shallow Concentrated Flow Computations	Flowpath A	Flowpath B	Flowpath C
Flow Length (ft) :	2000	0.00	0.00
Slope (%) :	1.0	0.00	0.00
Surface Type :	Forest	Unpaved	Unpaved
Velocity (ft/sec) :	0.25	0.00	0.00
Computed Flow Time (min) :	133.33	0.00	0.00

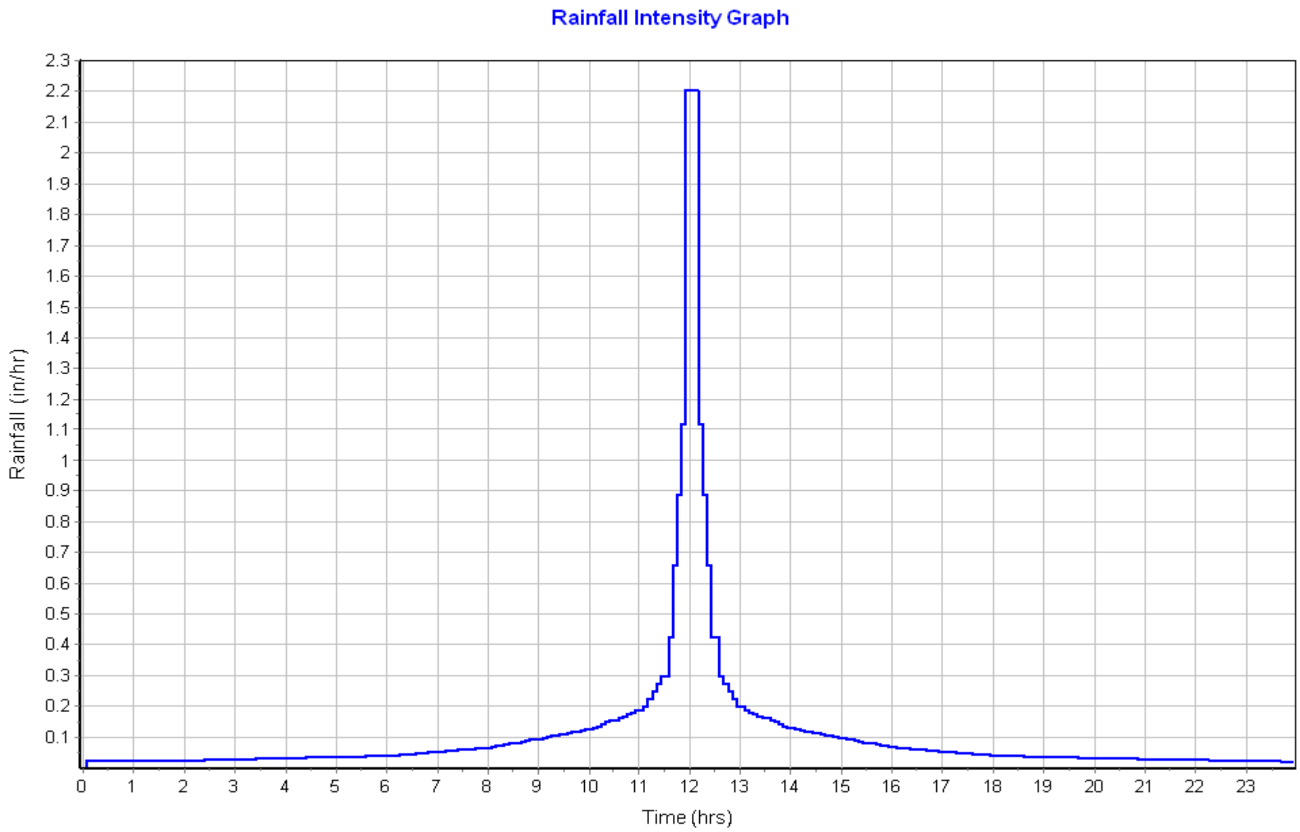
Channel Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	0.15	0.00	0.00
Flow Length (ft) :	3115	0.00	0.00
Channel Slope (%) :	1.0	0.00	0.00
Cross Section Area (ft²) :	5.74	0.00	0.00
Wetted Perimeter (ft) :	10.26	0.00	0.00
Velocity (ft/sec) :	0.67	0.00	0.00
Computed Flow Time (min) :	76.98	0.00	0.00

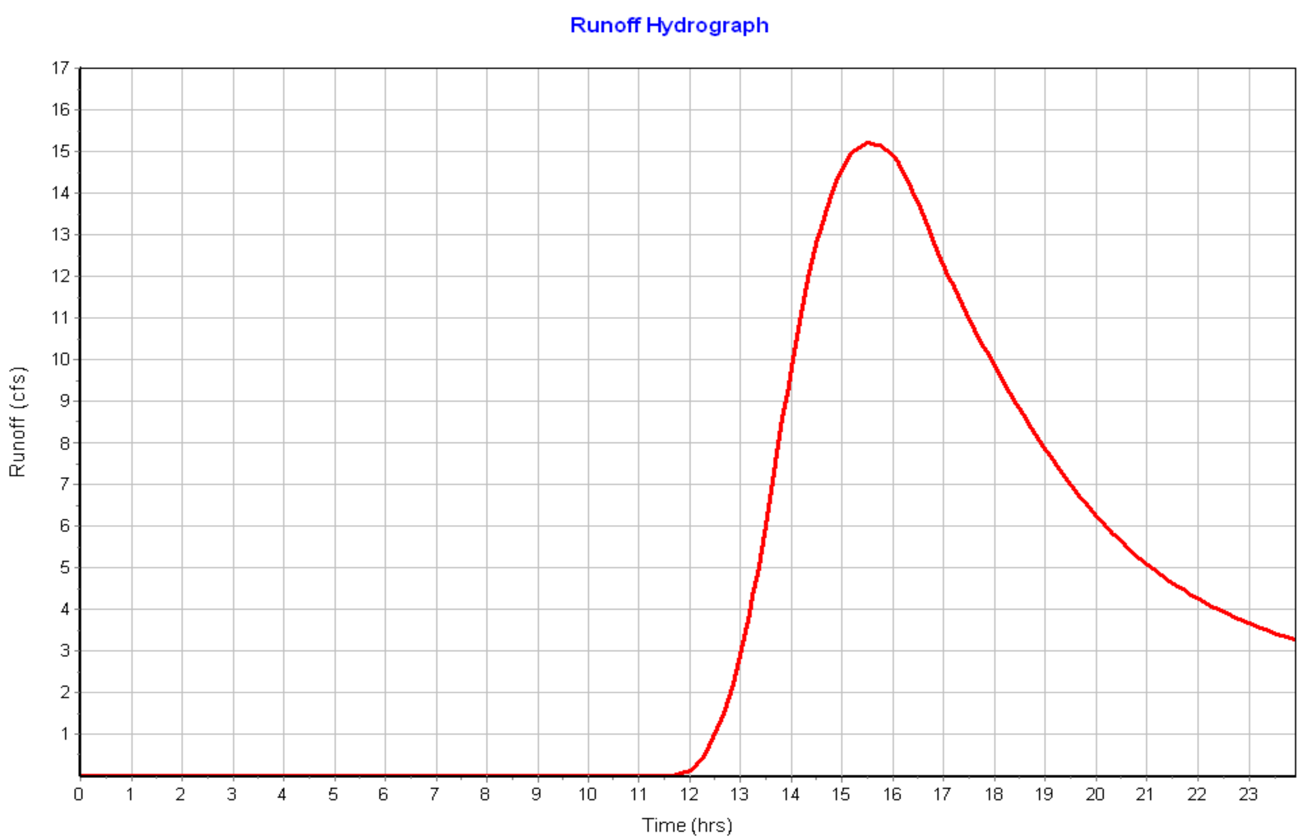
Total TOC (min) 275.41

Subbasin Runoff Results

Total Rainfall (in) 2.62
Total Runoff (in) 0.61
Peak Runoff (cfs) 15.21
Weighted Curve Number 72.54
Time of Concentration (days hh:mm:ss) 0 04:35:25

Subbasin : Clark_Rd_Culvert





5-Year Storm Event

Project Description

File Name .... Spencer-Clark_Rd.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... SCS TR-55
Link Routing Method .... Hydrodynamic
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods ...... YES

Analysis Options

Start Analysis On	Jul 17, 2013	00:00:00
End Analysis On	Jul 18, 2013	00:00:00
Start Reporting On	Jul 17, 2013	00:00:00
Antecedent Dry Days	0	days
Runoff (Dry Weather) Time Step	0 01:00:00	days hh:mm:ss
Runoff (Wet Weather) Time Step	0 00:05:00	days hh:mm:ss
Reporting Time Step	0 00:05:00	days hh:mm:ss
Routing Time Step	30	seconds

Number of Elements

	Qty
Rain Gages	6
Subbasins...	1
Nodes...	1
Junctions	0
Outfalls	1
Flow Diversions	0
Inlets	0
Storage Nodes	0
Links..	0
Channels	0
Pipes	0
Pumps	0
Orifices	0
Weirs	0
Outlets	0
Pollutants	0
Land Uses	0

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	100-Year	Time Series	100-Year	Cumulative	inches	Massachusetts	Worcester	100	8.60	SCS Type III 24-hr
2	10-Year	Time Series	10-Year Storm	Cumulative	inches	Massachusetts	Worcester	10	4.80	SCS Type III 24-hr
3	1-Year	Time Series	1-Year	Cumulative	inches	Massachusetts	Worcester	1	2.62	SCS Type III 24-hr
4	25-Year	Time Series	25-Year Storm	Cumulative	inches	Massachusetts	Worcester	25	6.05	SCS Type III 24-hr
5	50-Year	Time Series	50-Year Storm	Cumulative	inches	Massachusetts	Worcester	50	7.21	SCS Type III 24-hr
6	5-Year	Time Series	5-Year Storm	Cumulative	inches	Massachusetts	Worcester	5	4.03	SCS Type III 24-hr

Subbasin Summary

SN	Subbasin ID	Area (ac)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	Time of Concentration (days hh:mm:ss)
1	Clark_Rd_Culvert	166.40	72.54	4.03	1.52	252.60	40.76	0 04:35:24

Subbasin Hydrology

Subbasin : Clark_Rd_Culvert

Input Data

Area (ac) 166.40
Weighted Curve Number 72.54
Rain Gage ID 5-Year

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
Pasture, grassland, or range, Good	24.96	C	74.00
Pasture, grassland, or range, Good	3.33	D	80.00
Woods, Good	102.34	C	70.00
Woods, Good	24.96	D	77.00
1 acre lots, 20% impervious	7.49	C	79.00
1 acre lots, 20% impervious	3.33	D	84.00
Composite Area & Weighted CN	166.41		72.54

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where :

Tc = Time of Concentration (hr)
n = Manning's roughness
Lf = Flow Length (ft)
P = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation :

V = 16.1345 * (Sf^0.5) (unpaved surface)
V = 20.3282 * (Sf^0.5) (paved surface)
V = 15.0 * (Sf^0.5) (grassed waterway surface)
V = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
V = 9.0 * (Sf^0.5) (cultivated straight rows surface)
V = 7.0 * (Sf^0.5) (short grass pasture surface)
V = 5.0 * (Sf^0.5) (woodland surface)
V = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
Tc = (Lf / V) / (3600 sec/hr)

Where:

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation :

V = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
R = Aq / Wp
Tc = (Lf / V) / (3600 sec/hr)

Where :

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

Sheet Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	.8	0.00	0.00
Flow Length (ft) :	100	0.00	0.00
Slope (%) :	0.5	0.00	0.00
2 yr, 24 hr Rainfall (in) :	3.20	0.00	0.00
Velocity (ft/sec) :	0.03	0.00	0.00
Computed Flow Time (min) :	65.10	0.00	0.00

Shallow Concentrated Flow Computations	Flowpath A	Flowpath B	Flowpath C
Flow Length (ft) :	2000	0.00	0.00
Slope (%) :	1.0	0.00	0.00
Surface Type :	Forest	Unpaved	Unpaved
Velocity (ft/sec) :	0.25	0.00	0.00
Computed Flow Time (min) :	133.33	0.00	0.00

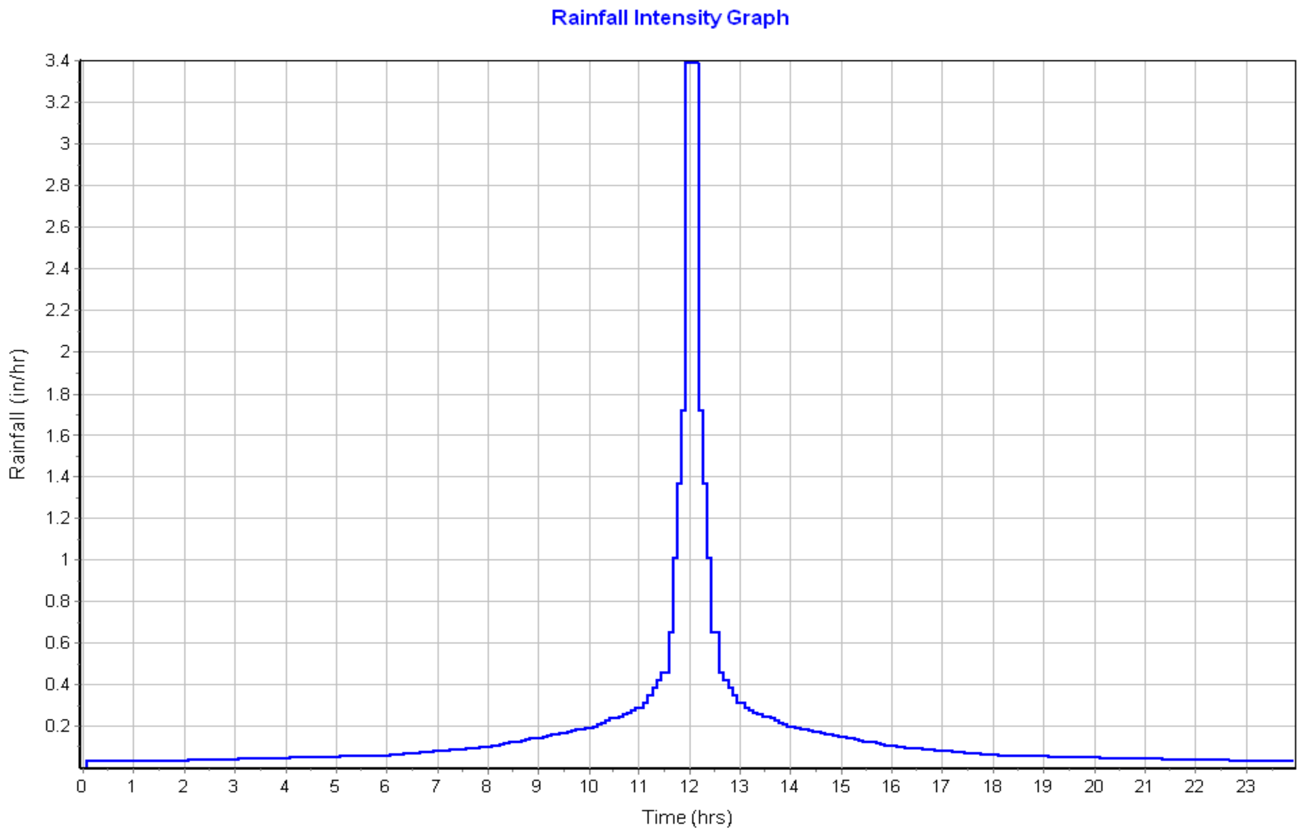
Channel Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	0.15	0.00	0.00
Flow Length (ft) :	3115	0.00	0.00
Channel Slope (%) :	1.0	0.00	0.00
Cross Section Area (ft²) :	5.74	0.00	0.00
Wetted Perimeter (ft) :	10.26	0.00	0.00
Velocity (ft/sec) :	0.67	0.00	0.00
Computed Flow Time (min) :	76.98	0.00	0.00

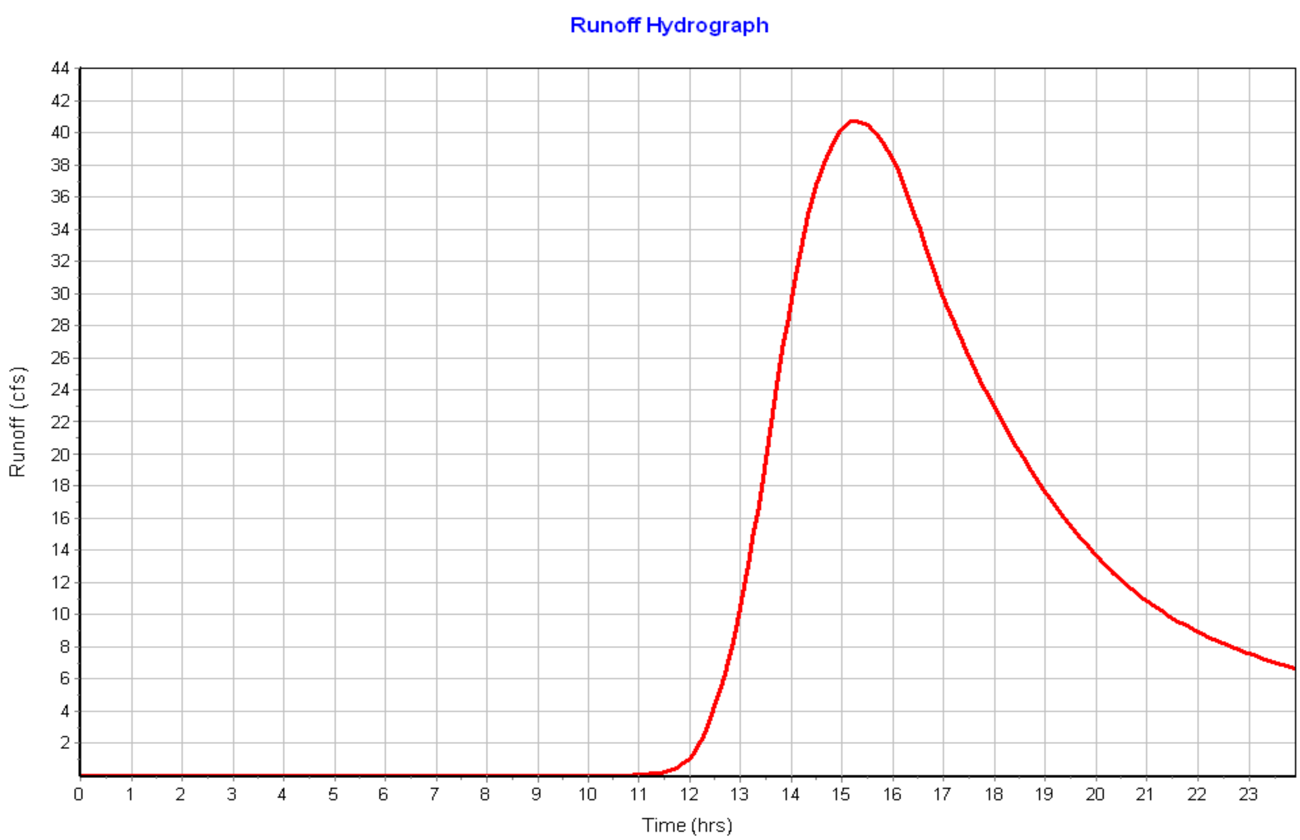
Total TOC (min) 275.41

Subbasin Runoff Results

Total Rainfall (in) 4.03
Total Runoff (in) 1.52
Peak Runoff (cfs) 40.76
Weighted Curve Number 72.54
Time of Concentration (days hh:mm:ss) 0 04:35:25

Subbasin : Clark_Rd_Culvert





10-Year Storm Event

Project Description

File Name .... Spencer-Clark_Rd.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... SCS TR-55
Link Routing Method .... Hydrodynamic
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods ...... YES

Analysis Options

Start Analysis On	Jul 17, 2013	00:00:00
End Analysis On	Jul 18, 2013	00:00:00
Start Reporting On	Jul 17, 2013	00:00:00
Antecedent Dry Days	0	days
Runoff (Dry Weather) Time Step	0 01:00:00	days hh:mm:ss
Runoff (Wet Weather) Time Step	0 00:05:00	days hh:mm:ss
Reporting Time Step	0 00:05:00	days hh:mm:ss
Routing Time Step	30	seconds

Number of Elements

	Qty
Rain Gages	6
Subbasins...	1
Nodes...	1
Junctions	0
Outfalls	1
Flow Diversions	0
Inlets	0
Storage Nodes	0
Links..	0
Channels	0
Pipes	0
Pumps	0
Orifices	0
Weirs	0
Outlets	0
Pollutants	0
Land Uses	0

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	100-Year	Time Series	100-Year	Cumulative	inches	Massachusetts	Worcester	100	8.60	SCS Type III 24-hr
2	10-Year	Time Series	10-Year Storm	Cumulative	inches	Massachusetts	Worcester	10	4.80	SCS Type III 24-hr
3	1-Year	Time Series	1-Year	Cumulative	inches	Massachusetts	Worcester	1	2.62	SCS Type III 24-hr
4	25-Year	Time Series	25-Year Storm	Cumulative	inches	Massachusetts	Worcester	25	6.05	SCS Type III 24-hr
5	50-Year	Time Series	50-Year Storm	Cumulative	inches	Massachusetts	Worcester	50	7.21	SCS Type III 24-hr
6	5-Year	Time Series	5-Year Storm	Cumulative	inches	Massachusetts	Worcester	5	4.03	SCS Type III 24-hr

Subbasin Summary

SN	Subbasin ID	Area (ac)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	Time of Concentration (days hh:mm:ss)
1	Clark_Rd_Culvert	166.40	72.54	4.80	2.09	347.44	57.17	0 04:35:24

Subbasin Hydrology

Subbasin : Clark_Rd_Culvert

Input Data

Area (ac) 166.40
Weighted Curve Number 72.54
Rain Gage ID 10-Year

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
Pasture, grassland, or range, Good	24.96	C	74.00
Pasture, grassland, or range, Good	3.33	D	80.00
Woods, Good	102.34	C	70.00
Woods, Good	24.96	D	77.00
1 acre lots, 20% impervious	7.49	C	79.00
1 acre lots, 20% impervious	3.33	D	84.00
Composite Area & Weighted CN	166.41		72.54

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where :

Tc = Time of Concentration (hr)
n = Manning's roughness
Lf = Flow Length (ft)
P = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation :

V = 16.1345 * (Sf^0.5) (unpaved surface)
V = 20.3282 * (Sf^0.5) (paved surface)
V = 15.0 * (Sf^0.5) (grassed waterway surface)
V = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
V = 9.0 * (Sf^0.5) (cultivated straight rows surface)
V = 7.0 * (Sf^0.5) (short grass pasture surface)
V = 5.0 * (Sf^0.5) (woodland surface)
V = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
Tc = (Lf / V) / (3600 sec/hr)

Where:

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation :

V = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
R = Aq / Wp
Tc = (Lf / V) / (3600 sec/hr)

Where :

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft^2)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

Sheet Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	.8	0.00	0.00
Flow Length (ft) :	100	0.00	0.00
Slope (%) :	0.5	0.00	0.00
2 yr, 24 hr Rainfall (in) :	3.20	0.00	0.00
Velocity (ft/sec) :	0.03	0.00	0.00
Computed Flow Time (min) :	65.10	0.00	0.00

Shallow Concentrated Flow Computations	Flowpath A	Flowpath B	Flowpath C
Flow Length (ft) :	2000	0.00	0.00
Slope (%) :	1.0	0.00	0.00
Surface Type :	Forest	Unpaved	Unpaved
Velocity (ft/sec) :	0.25	0.00	0.00
Computed Flow Time (min) :	133.33	0.00	0.00

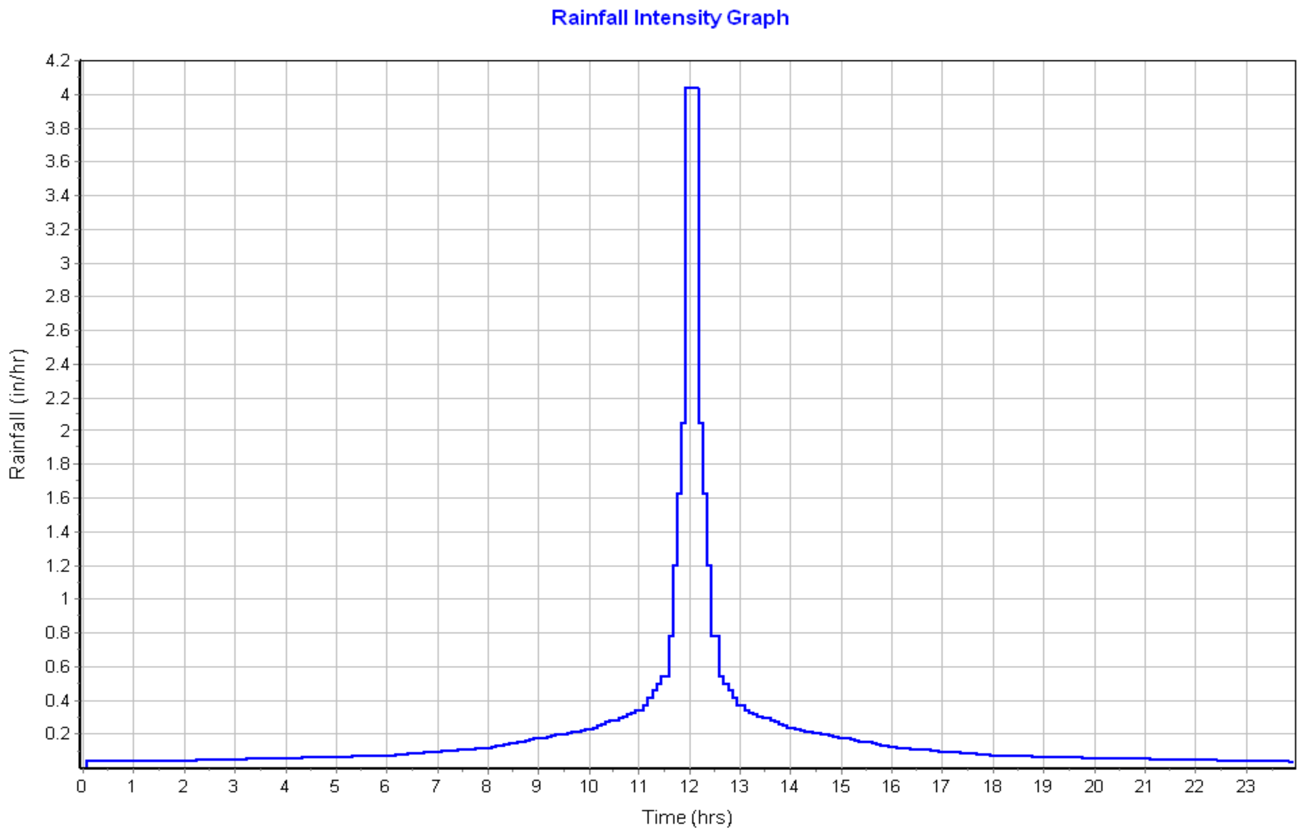
Channel Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	0.15	0.00	0.00
Flow Length (ft) :	3115	0.00	0.00
Channel Slope (%) :	1.0	0.00	0.00
Cross Section Area (ft²) :	5.74	0.00	0.00
Wetted Perimeter (ft) :	10.26	0.00	0.00
Velocity (ft/sec) :	0.67	0.00	0.00
Computed Flow Time (min) :	76.98	0.00	0.00

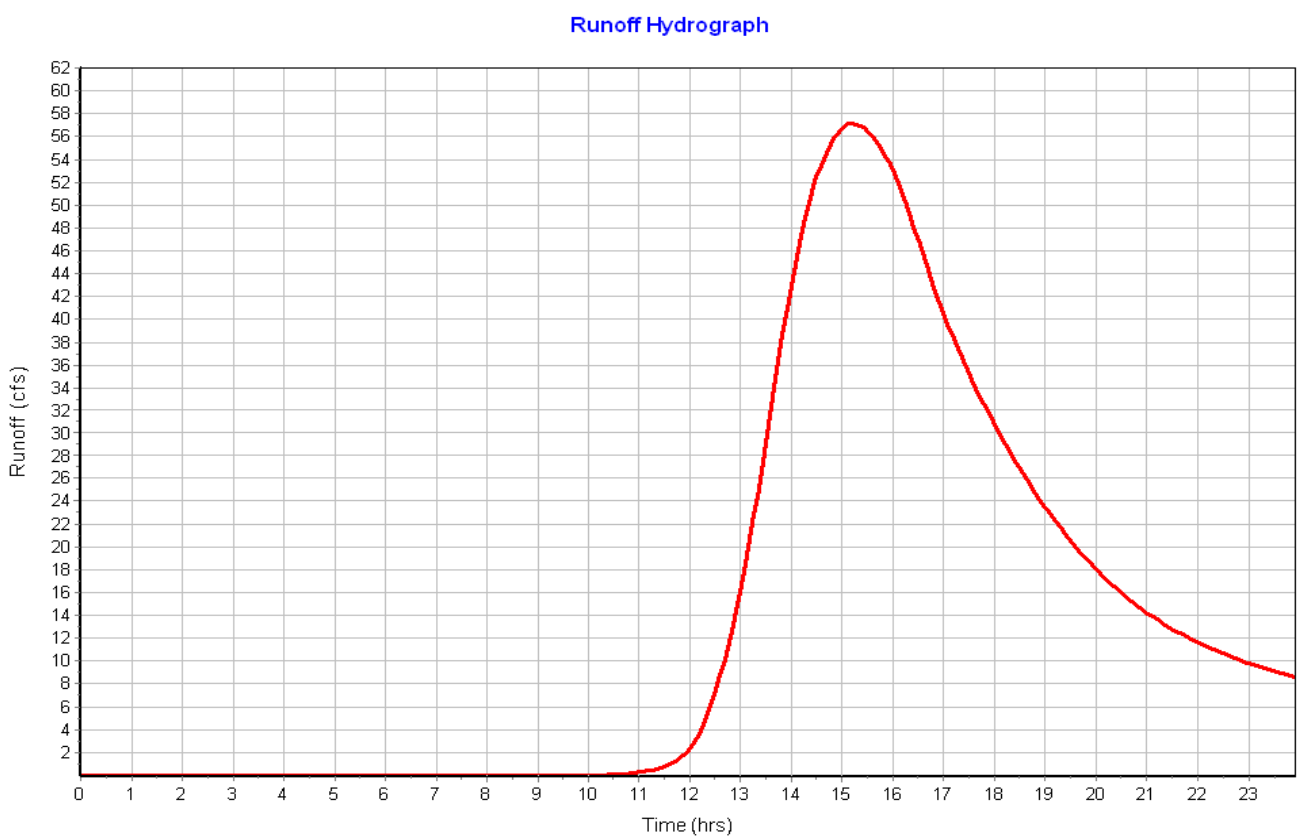
Total TOC (min) 275.41

Subbasin Runoff Results

Total Rainfall (in) 4.80
Total Runoff (in) 2.09
Peak Runoff (cfs) 57.17
Weighted Curve Number 72.54
Time of Concentration (days hh:mm:ss) 0 04:35:25

Subbasin : Clark_Rd_Culvert





25-Year Storm Event

Project Description

File Name .... Spencer-Clark_Rd.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... SCS TR-55
Link Routing Method .... Hydrodynamic
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods ...... YES

Analysis Options

Start Analysis On	Jul 17, 2013	00:00:00
End Analysis On	Jul 18, 2013	00:00:00
Start Reporting On	Jul 17, 2013	00:00:00
Antecedent Dry Days	0	days
Runoff (Dry Weather) Time Step	0 01:00:00	days hh:mm:ss
Runoff (Wet Weather) Time Step	0 00:05:00	days hh:mm:ss
Reporting Time Step	0 00:05:00	days hh:mm:ss
Routing Time Step	30	seconds

Number of Elements

	Qty
Rain Gages	6
Subbasins...	1
Nodes...	1
Junctions	0
Outfalls	1
Flow Diversions	0
Inlets	0
Storage Nodes	0
Links...	0
Channels	0
Pipes	0
Pumps	0
Orifices	0
Weirs	0
Outlets	0
Pollutants	0
Land Uses	0

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	100-Year	Time Series	100-Year	Cumulative	inches	Massachusetts	Worcester	100	8.60	SCS Type III 24-hr
2	10-Year	Time Series	10-Year Storm	Cumulative	inches	Massachusetts	Worcester	10	4.80	SCS Type III 24-hr
3	1-Year	Time Series	1-Year	Cumulative	inches	Massachusetts	Worcester	1	2.62	SCS Type III 24-hr
4	25-Year	Time Series	25-Year Storm	Cumulative	inches	Massachusetts	Worcester	25	6.05	SCS Type III 24-hr
5	50-Year	Time Series	50-Year Storm	Cumulative	inches	Massachusetts	Worcester	50	7.21	SCS Type III 24-hr
6	5-Year	Time Series	5-Year Storm	Cumulative	inches	Massachusetts	Worcester	5	4.03	SCS Type III 24-hr

Subbasin Summary

SN	Subbasin ID	Area (ac)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	Time of Concentration (days hh:mm:ss)
1	Clark_Rd_Culvert	166.40	72.54	6.05	3.09	513.51	85.91	0 04:35:24

Subbasin Hydrology

Subbasin : Clark_Rd_Culvert

Input Data

Area (ac) 166.40
Weighted Curve Number 72.54
Rain Gage ID 25-Year

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
Pasture, grassland, or range, Good	24.96	C	74.00
Pasture, grassland, or range, Good	3.33	D	80.00
Woods, Good	102.34	C	70.00
Woods, Good	24.96	D	77.00
1 acre lots, 20% impervious	7.49	C	79.00
1 acre lots, 20% impervious	3.33	D	84.00
Composite Area & Weighted CN	166.41		72.54

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where :

Tc = Time of Concentration (hr)
n = Manning's roughness
Lf = Flow Length (ft)
P = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation :

V = 16.1345 * (Sf^0.5) (unpaved surface)
V = 20.3282 * (Sf^0.5) (paved surface)
V = 15.0 * (Sf^0.5) (grassed waterway surface)
V = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
V = 9.0 * (Sf^0.5) (cultivated straight rows surface)
V = 7.0 * (Sf^0.5) (short grass pasture surface)
V = 5.0 * (Sf^0.5) (woodland surface)
V = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
Tc = (Lf / V) / (3600 sec/hr)

Where:

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation :

V = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
R = Aq / Wp
Tc = (Lf / V) / (3600 sec/hr)

Where :

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

Sheet Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	.8	0.00	0.00
Flow Length (ft) :	100	0.00	0.00
Slope (%) :	0.5	0.00	0.00
2 yr, 24 hr Rainfall (in) :	3.20	0.00	0.00
Velocity (ft/sec) :	0.03	0.00	0.00
Computed Flow Time (min) :	65.10	0.00	0.00

Shallow Concentrated Flow Computations	Flowpath A	Flowpath B	Flowpath C
Flow Length (ft) :	2000	0.00	0.00
Slope (%) :	1.0	0.00	0.00
Surface Type :	Forest	Unpaved	Unpaved
Velocity (ft/sec) :	0.25	0.00	0.00
Computed Flow Time (min) :	133.33	0.00	0.00

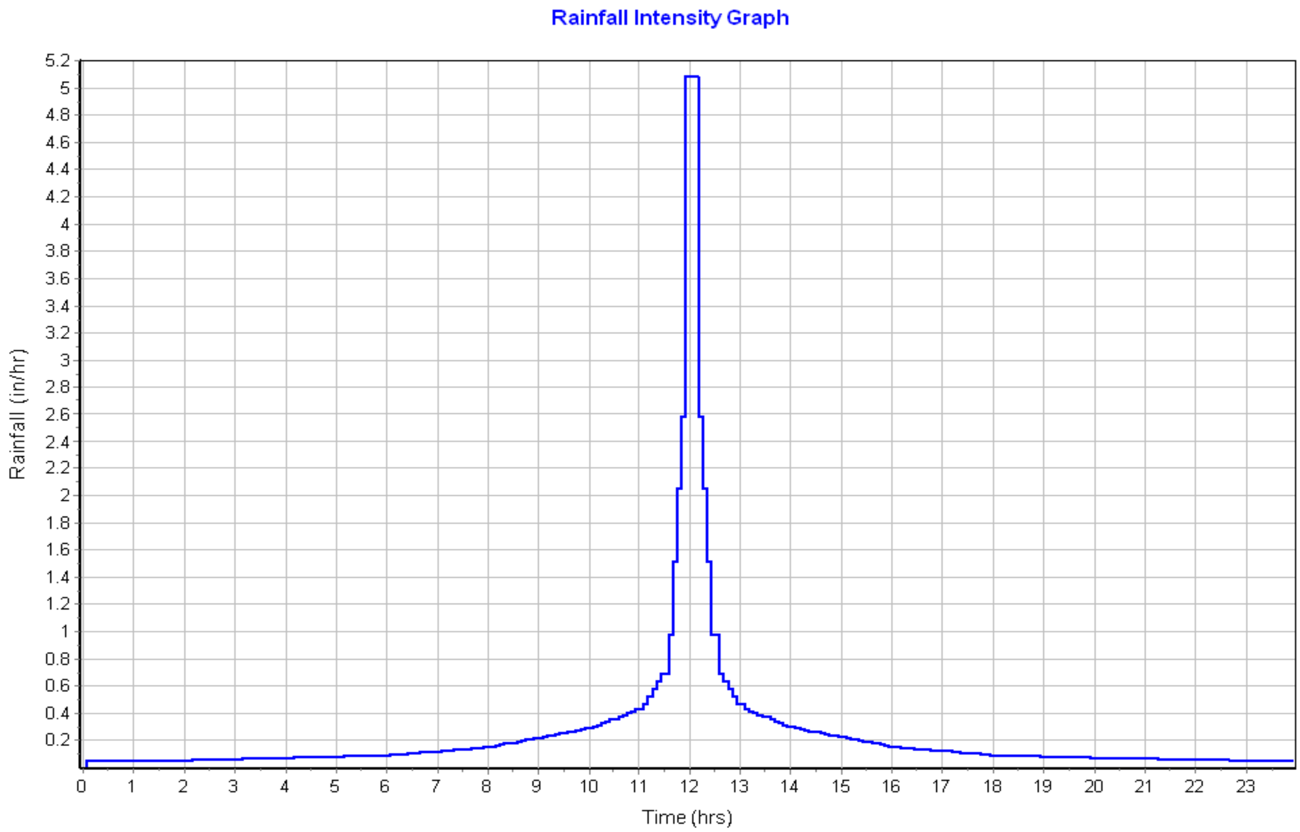
Channel Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	0.15	0.00	0.00
Flow Length (ft) :	3115	0.00	0.00
Channel Slope (%) :	1.0	0.00	0.00
Cross Section Area (ft^2) :	5.74	0.00	0.00
Wetted Perimeter (ft) :	10.26	0.00	0.00
Velocity (ft/sec) :	0.67	0.00	0.00
Computed Flow Time (min) :	76.98	0.00	0.00

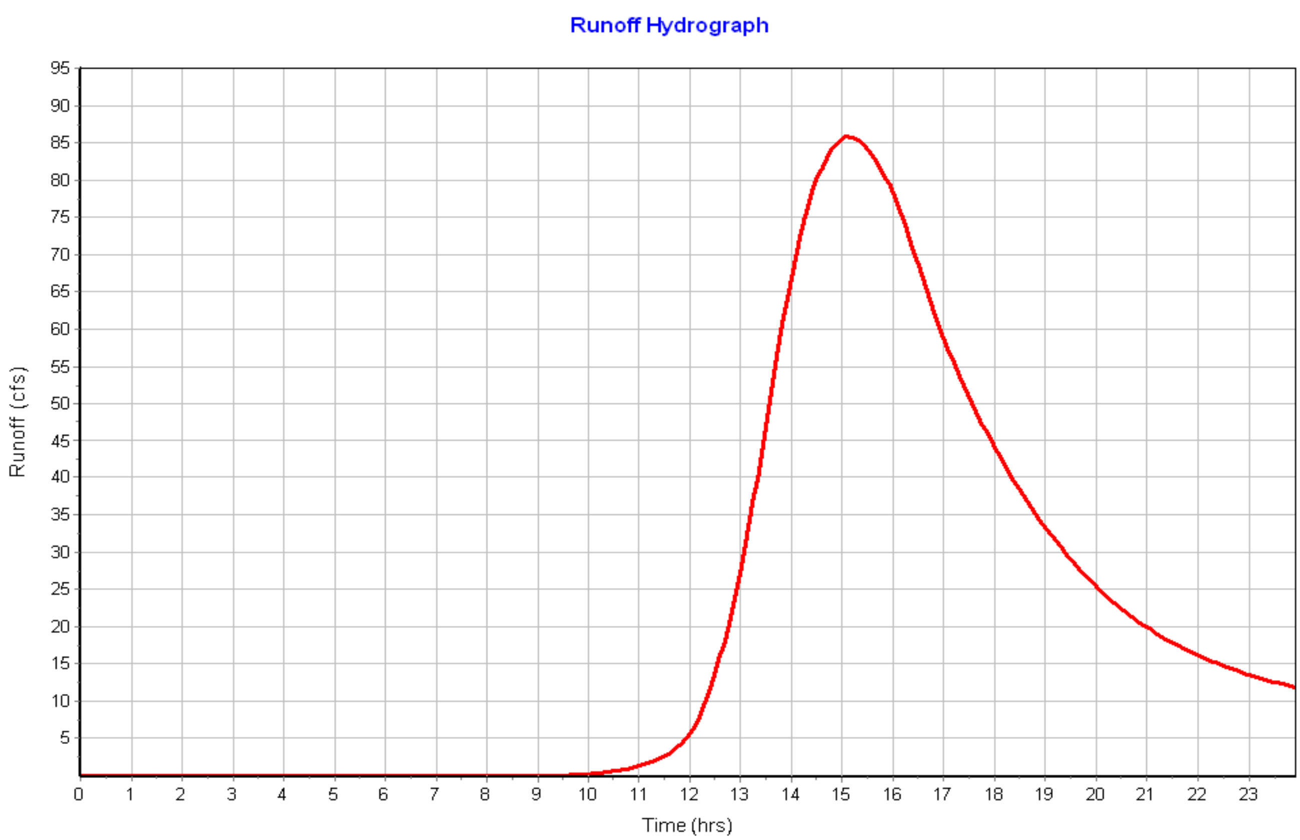
Total TOC (min) 275.41

Subbasin Runoff Results

Total Rainfall (in) 6.05
Total Runoff (in) 3.09
Peak Runoff (cfs) 85.91
Weighted Curve Number 72.54
Time of Concentration (days hh:mm:ss) 0 04:35:25

Subbasin : Clark_Rd_Culvert





50-Year Storm Event

Project Description

File Name .... Spencer-Clark_Rd.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... SCS TR-55
Link Routing Method .... Hydrodynamic
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods ...... YES

Analysis Options

Start Analysis On	Jul 17, 2013	00:00:00
End Analysis On	Jul 18, 2013	00:00:00
Start Reporting On	Jul 17, 2013	00:00:00
Antecedent Dry Days	0	days
Runoff (Dry Weather) Time Step	0 01:00:00	days hh:mm:ss
Runoff (Wet Weather) Time Step	0 00:05:00	days hh:mm:ss
Reporting Time Step	0 00:05:00	days hh:mm:ss
Routing Time Step	30	seconds

Number of Elements

	Qty
Rain Gages	6
Subbasins...	1
Nodes...	1
Junctions	0
Outfalls	1
Flow Diversions	0
Inlets	0
Storage Nodes	0
Links...	0
Channels	0
Pipes	0
Pumps	0
Orifices	0
Weirs	0
Outlets	0
Pollutants	0
Land Uses	0

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	100-Year	Time Series	100-Year	Cumulative	inches	Massachusetts	Worcester	100	8.60	SCS Type III 24-hr
2	10-Year	Time Series	10-Year Storm	Cumulative	inches	Massachusetts	Worcester	10	4.80	SCS Type III 24-hr
3	1-Year	Time Series	1-Year	Cumulative	inches	Massachusetts	Worcester	1	2.62	SCS Type III 24-hr
4	25-Year	Time Series	25-Year Storm	Cumulative	inches	Massachusetts	Worcester	25	6.05	SCS Type III 24-hr
5	50-Year	Time Series	50-Year Storm	Cumulative	inches	Massachusetts	Worcester	50	7.21	SCS Type III 24-hr
6	5-Year	Time Series	5-Year Storm	Cumulative	inches	Massachusetts	Worcester	5	4.03	SCS Type III 24-hr

Subbasin Summary

SN	Subbasin ID	Area (ac)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	Time of Concentration (days hh:mm:ss)
1	Clark_Rd_Culvert	166.40	72.54	7.21	4.07	676.75	113.81	0 04:35:24

Subbasin Hydrology

Subbasin : Clark_Rd_Culvert

Input Data

Area (ac) 166.40
Weighted Curve Number 72.54
Rain Gage ID 50-Year

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
Pasture, grassland, or range, Good	24.96	C	74.00
Pasture, grassland, or range, Good	3.33	D	80.00
Woods, Good	102.34	C	70.00
Woods, Good	24.96	D	77.00
1 acre lots, 20% impervious	7.49	C	79.00
1 acre lots, 20% impervious	3.33	D	84.00
Composite Area & Weighted CN	166.41		72.54

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where :

Tc = Time of Concentration (hr)
n = Manning's roughness
Lf = Flow Length (ft)
P = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation :

V = 16.1345 * (Sf^0.5) (unpaved surface)
V = 20.3282 * (Sf^0.5) (paved surface)
V = 15.0 * (Sf^0.5) (grassed waterway surface)
V = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
V = 9.0 * (Sf^0.5) (cultivated straight rows surface)
V = 7.0 * (Sf^0.5) (short grass pasture surface)
V = 5.0 * (Sf^0.5) (woodland surface)
V = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
Tc = (Lf / V) / (3600 sec/hr)

Where:

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation :

V = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
R = Aq / Wp
Tc = (Lf / V) / (3600 sec/hr)

Where :

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

Sheet Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	.8	0.00	0.00
Flow Length (ft) :	100	0.00	0.00
Slope (%) :	0.5	0.00	0.00
2 yr, 24 hr Rainfall (in) :	3.20	0.00	0.00
Velocity (ft/sec) :	0.03	0.00	0.00
Computed Flow Time (min) :	65.10	0.00	0.00

Shallow Concentrated Flow Computations	Flowpath A	Flowpath B	Flowpath C
Flow Length (ft) :	2000	0.00	0.00
Slope (%) :	1.0	0.00	0.00
Surface Type :	Forest	Unpaved	Unpaved
Velocity (ft/sec) :	0.25	0.00	0.00
Computed Flow Time (min) :	133.33	0.00	0.00

Channel Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	0.15	0.00	0.00
Flow Length (ft) :	3115	0.00	0.00
Channel Slope (%) :	1.0	0.00	0.00
Cross Section Area (ft^2) :	5.74	0.00	0.00
Wetted Perimeter (ft) :	10.26	0.00	0.00
Velocity (ft/sec) :	0.67	0.00	0.00
Computed Flow Time (min) :	76.98	0.00	0.00

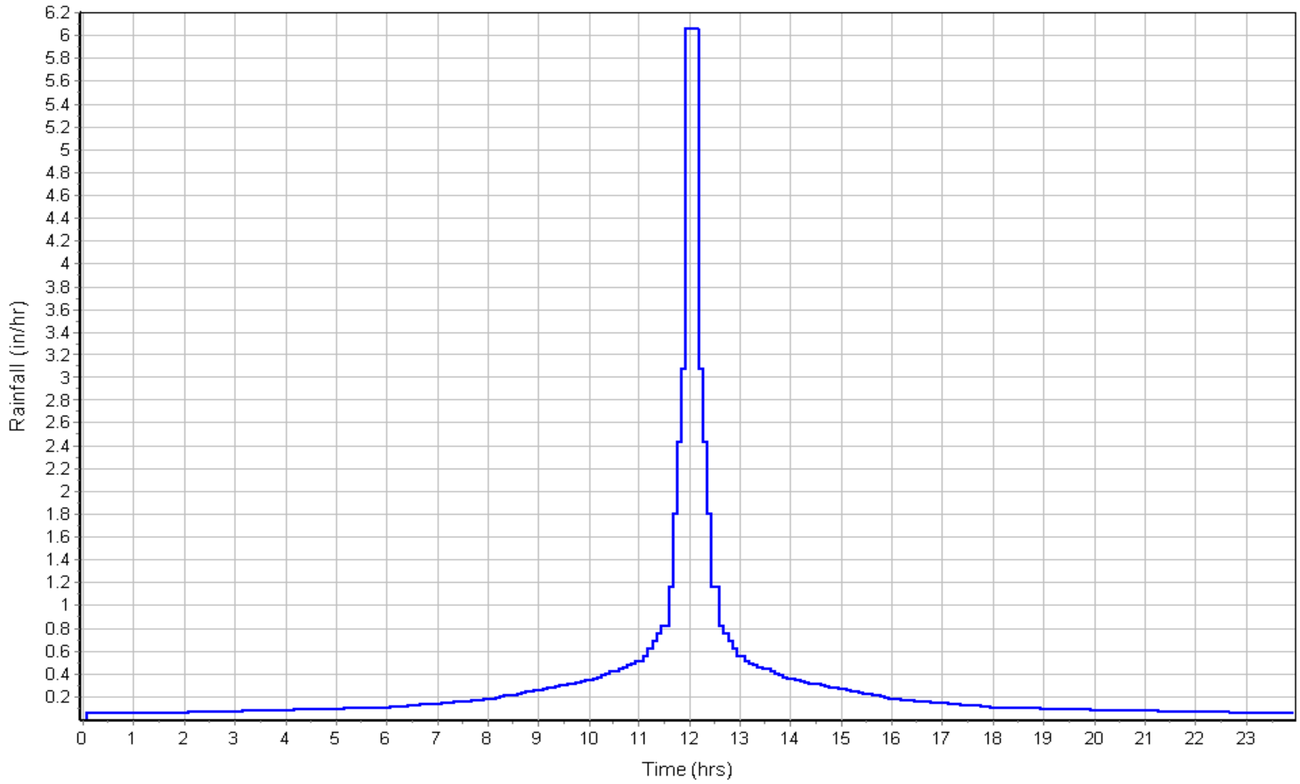
Total TOC (min) 275.41

Subbasin Runoff Results

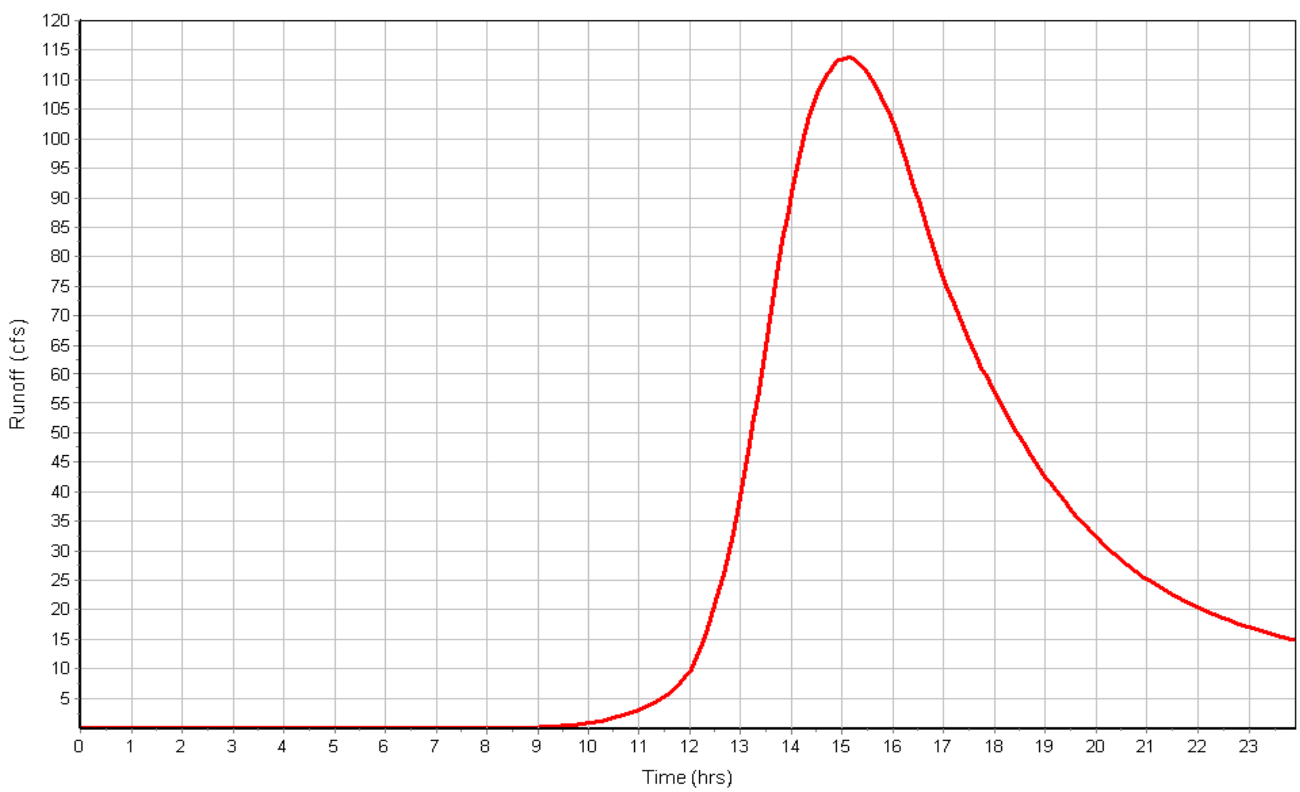
Total Rainfall (in) 7.21
Total Runoff (in) 4.07
Peak Runoff (cfs) 113.81
Weighted Curve Number 72.54
Time of Concentration (days hh:mm:ss) 0 04:35:25

Subbasin : Clark_Rd_Culvert

Rainfall Intensity Graph



Runoff Hydrograph



100-Year Storm Event

Project Description

File Name .... Spencer-Clark_Rd.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... SCS TR-55
Link Routing Method .... Hydrodynamic
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods ...... YES

Analysis Options

Start Analysis On	Jul 17, 2013	00:00:00
End Analysis On	Jul 18, 2013	00:00:00
Start Reporting On	Jul 17, 2013	00:00:00
Antecedent Dry Days	0	days
Runoff (Dry Weather) Time Step	0 01:00:00	days hh:mm:ss
Runoff (Wet Weather) Time Step	0 00:05:00	days hh:mm:ss
Reporting Time Step	0 00:05:00	days hh:mm:ss
Routing Time Step	30	seconds

Number of Elements

	Qty
Rain Gages	6
Subbasins..	1
Nodes..	1
Junctions	0
Outfalls	1
Flow Diversions	0
Inlets	0
Storage Nodes	0
Links...	0
Channels	0
Pipes	0
Pumps	0
Orifices	0
Weirs	0
Outlets	0
Pollutants	0
Land Uses	0

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	100-Year	Time Series	100-Year	Cumulative	inches	Massachusetts	Worcester	100	8.60	SCS Type III 24-hr
2	10-Year	Time Series	10-Year Storm	Cumulative	inches	Massachusetts	Worcester	10	4.80	SCS Type III 24-hr
3	1-Year	Time Series	1-Year	Cumulative	inches	Massachusetts	Worcester	1	2.62	SCS Type III 24-hr
4	25-Year	Time Series	25-Year Storm	Cumulative	inches	Massachusetts	Worcester	25	6.05	SCS Type III 24-hr
5	50-Year	Time Series	50-Year Storm	Cumulative	inches	Massachusetts	Worcester	50	7.21	SCS Type III 24-hr
6	5-Year	Time Series	5-Year Storm	Cumulative	inches	Massachusetts	Worcester	5	4.03	SCS Type III 24-hr

Subbasin Summary

SN	Subbasin ID	Area (ac)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	Time of Concentration (days hh:mm:ss)
1	Clark_Rd_Culvert	166.40	72.54	8.60	5.29	880.26	148.81	0 04:35:24

Subbasin Hydrology

Subbasin : Clark_Rd_Culvert

Input Data

Area (ac) 166.40
Weighted Curve Number 72.54
Rain Gage ID 100-Year

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
Pasture, grassland, or range, Good	24.96	C	74.00
Pasture, grassland, or range, Good	3.33	D	80.00
Woods, Good	102.34	C	70.00
Woods, Good	24.96	D	77.00
1 acre lots, 20% impervious	7.49	C	79.00
1 acre lots, 20% impervious	3.33	D	84.00
Composite Area & Weighted CN	166.41		72.54

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where :

Tc = Time of Concentration (hr)
n = Manning's roughness
Lf = Flow Length (ft)
P = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation :

V = 16.1345 * (Sf^0.5) (unpaved surface)
V = 20.3282 * (Sf^0.5) (paved surface)
V = 15.0 * (Sf^0.5) (grassed waterway surface)
V = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
V = 9.0 * (Sf^0.5) (cultivated straight rows surface)
V = 7.0 * (Sf^0.5) (short grass pasture surface)
V = 5.0 * (Sf^0.5) (woodland surface)
V = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
Tc = (Lf / V) / (3600 sec/hr)

Where:

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation :

V = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
R = Aq / Wp
Tc = (Lf / V) / (3600 sec/hr)

Where :

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

Sheet Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	.8	0.00	0.00
Flow Length (ft) :	100	0.00	0.00
Slope (%) :	0.5	0.00	0.00
2 yr, 24 hr Rainfall (in) :	3.20	0.00	0.00
Velocity (ft/sec) :	0.03	0.00	0.00
Computed Flow Time (min) :	65.10	0.00	0.00

Shallow Concentrated Flow Computations	Flowpath A	Flowpath B	Flowpath C
Flow Length (ft) :	2000	0.00	0.00
Slope (%) :	1.0	0.00	0.00
Surface Type :	Forest	Unpaved	Unpaved
Velocity (ft/sec) :	0.25	0.00	0.00
Computed Flow Time (min) :	133.33	0.00	0.00

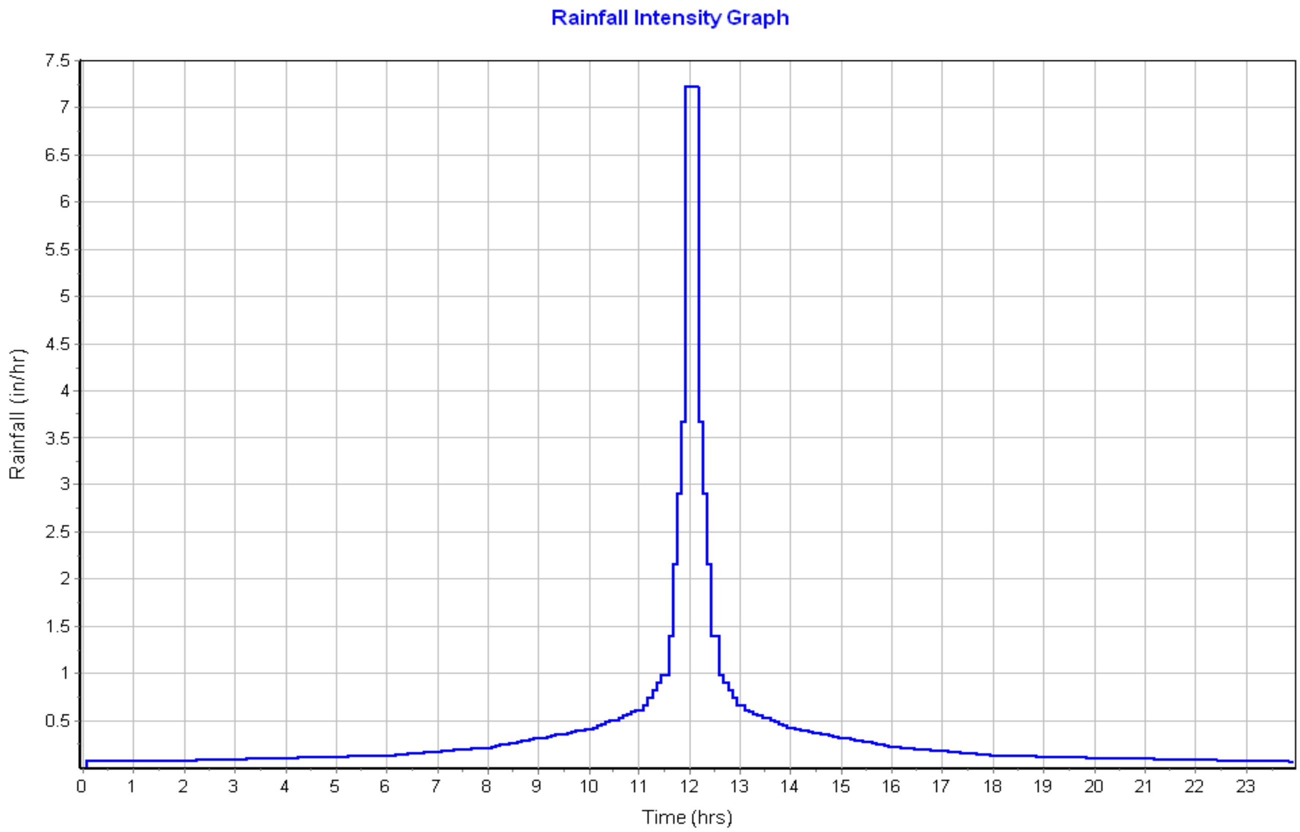
Channel Flow Computations	Flowpath A	Flowpath B	Flowpath C
Manning's Roughness :	0.15	0.00	0.00
Flow Length (ft) :	3115	0.00	0.00
Channel Slope (%) :	1.0	0.00	0.00
Cross Section Area (ft²) :	5.74	0.00	0.00
Wetted Perimeter (ft) :	10.26	0.00	0.00
Velocity (ft/sec) :	0.67	0.00	0.00
Computed Flow Time (min) :	76.98	0.00	0.00

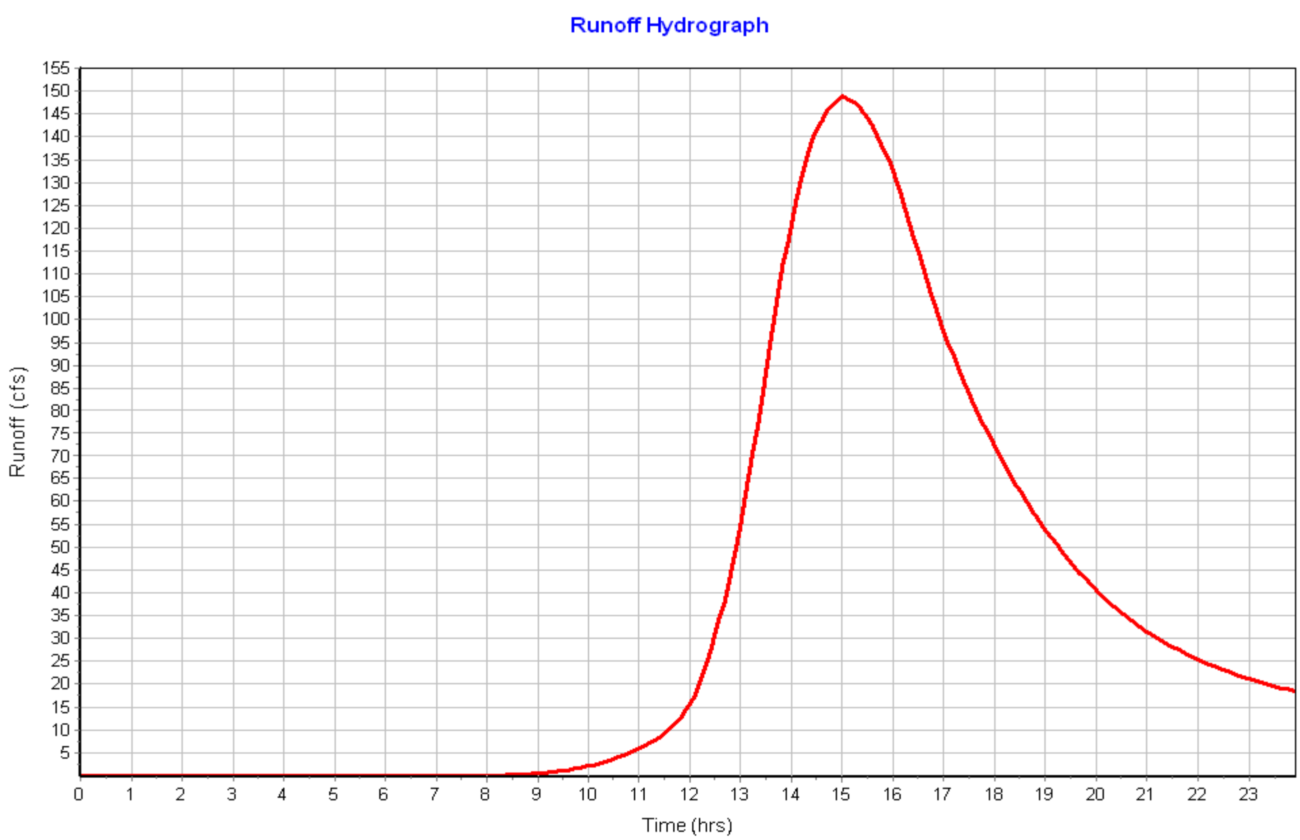
Total TOC (min) 275.41

Subbasin Runoff Results

Total Rainfall (in) 8.60
Total Runoff (in) 5.29
Peak Runoff (cfs) 148.81
Weighted Curve Number 72.54
Time of Concentration (days hh:mm:ss) 0 04:35:25

Subbasin : Clark_Rd_Culvert





Appendix G

Hydraulic Computations

Project: Spencer, MA - Clark Road
Culvert Analysis at Unnamed Tributary to Stiles Reservoir

Existing 18" Diameter RCP				
	Culvert Inlet Invert	Culvert Outlet Invert	Inlet Low Chord Elev.	Roadway Cover (ft)
	874.35	874.00	875.85	2.0
Storm Event	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
	Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
1-Year	875.86	873.96	6.27	1.34
5-Year	877.62	874.28	10.50	1.67
10-Year	878.17	874.67	11.79	1.92
25-Year	878.39	875.21	12.25	2.14
50-Year	878.51	875.52	12.49	2.24
100-Year	878.63	875.82	12.50	2.27

Proposed 5'W x 2'H 3-Sided Box Culvert (Open Bottom)				
	Culvert Inlet Invert	Culvert Outlet Invert	Inlet Low Chord Elev.	Roadway Cover (ft)
	874.35	874.00	876.35	1.0
Storm Event	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
	Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
1-Year	875.32	874.12	3.19	1.73
5-Year	876.20	874.70	4.60	2.27
10-Year	876.83	874.88	5.39	2.37
25-Year	878.03	875.10	6.80	2.52
50-Year	878.30	875.49	7.06	2.56
100-Year	878.47	875.81	7.19	2.61

Proposed 5'W x 4'H Box Culvert (Embedded 2')				
	Culvert Inlet Invert	Culvert Outlet Invert	Inlet Low Chord Elev.	Roadway Cover (ft)
	874.35	874.00	876.35	1.0
Storm Event	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
	Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
1-Year	875.32	874.12	3.19	1.73
5-Year	876.20	874.70	4.60	2.27
10-Year	876.83	874.88	5.39	2.37
25-Year	878.03	875.10	6.80	2.52
50-Year	878.30	875.49	7.06	2.56
100-Year	878.47	875.81	7.19	2.61

Proposed 5' Diameter CMP (Embedded Half-Way 2.5')				
	Culvert Inlet Invert	Culvert Outlet Invert	Inlet Low Chord Elev.	Roadway Cover (ft)
	874.35	874.00	876.85	1.0
Storm Event	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
	Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
1-Year	875.51	874.12	3.09	1.73
5-Year	876.51	874.67	4.30	2.25
10-Year	877.07	874.84	4.98	2.35
25-Year	878.11	875.12	6.29	2.49
50-Year	878.34	875.51	6.55	2.56
100-Year	878.49	875.81	6.66	2.61

Project: Spencer, MA - Clark Road
Culvert Analysis at Unnamed Tributary to Stiles Reservoir

Proposed 6' Diameter CMP (Embedded Half-Way 3')				
	Culvert Inlet Invert	Culvert Outlet Invert	Inlet Low Chord Elev.	Roadway Cover (ft)
	874.35	874.00	877.35	0.5
Storm Event	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
	Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
1-Year	875.41	874.13	2.98	1.75
5-Year	876.27	874.71	4.24	2.28
10-Year	876.72	874.92	4.71	2.38
25-Year	877.83	875.24	5.96	2.59
50-Year	878.18	875.47	6.48	2.60
100-Year	878.39	875.80	6.73	2.60

Proposed 73"W x 55"H CMP Arch (Embedded to Springline 25")				
	Culvert Inlet Invert	Culvert Outlet Invert	Inlet Low Chord Elev.	Roadway Cover (ft)
	874.35	874.00	876.85	1.0
Storm Event	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
	Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
1-Year	875.42	874.13	2.94	1.75
5-Year	876.34	874.71	4.14	2.27
10-Year	876.84	874.90	4.65	2.38
25-Year	878.02	875.13	6.14	2.56
50-Year	878.28	875.48	6.48	2.56
100-Year	878.45	875.80	6.61	2.61

Proposed 8'W x 2'H 3-Sided Metal Box Culvert (Open Bottom)				
	Culvert Inlet Invert	Culvert Outlet Invert	Inlet Low Chord Elev.	Roadway Cover (ft)
	874.35	874.00	876.35	1.5
Storm Event	Peak Water Surface Elevation (feet)		Peak Flow Velocity (ft/sec)	
	Upstream of Culvert	Downstream of Culvert	Within Culvert	Downstream of Culvert
1-Year	875.14	874.13	3.66	1.77
5-Year	875.80	874.72	4.60	2.28
10-Year	876.16	874.93	4.89	2.39
25-Year	876.90	875.19	6.12	2.48
50-Year	878.29	875.55	8.43	2.96
100-Year	878.31	875.80	8.38	2.99