Great Marsh Barriers Assessment

Regional Inventory and Assessment of Risk and Impact of

Barriers to Flow in Coastal Watersheds of the North Shore of Massachusetts

February 2018

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Great Marsh Barriers Assessment available online at http://pie-rivers.org/barriers

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Acknowledgments

This report is the culmination of a multi-year process that would not have been possible without the support of an excellent team of funders, partners, staff and volunteers. The National Fish and Wildlife Foundation (NFWF) provided generous funding to support the project through the Hurricane Sandy Coastal Resilience Grant Program. We are grateful to our project partners including the National Wildlife Federation (NWF), Trout Unlimited, Meridian Associates, the Great Marsh Resiliency Partnership and members of the broader Parker-Ipswich-Essex-Rivers Partnership (PIE-Rivers).

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Report Overview

This report summarizes work conducted as part of the *Great Marsh Barriers Assessment* (Barriers Assessment). The Barriers Assessment is a component of a multifaceted project led by the National Wildlife Federation (NWF) called *Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts* (Resiliency Project). The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and included five separate sub-projects aimed to increase the resiliency of the Great Marsh and the Parker-Ipswich-Essex Rivers Restoration Partnership (PIE-Rivers) region.

The term “barriers” in this report refers to human-made structures that may impede flow, fluvial and coastal processes (dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures). The interruption of important physical, chemical and ecological processes can reduce the overall resilience of our coastal watersheds, making our communities more vulnerable to extreme weather events and our ecological resources less sustainable.

As our region has become more developed, waterways and coastlines have been dotted with more infrastructure and more aquatic barriers. Many of these structures have aged past their design life and are in need of replacement or removal, while others were not designed to effectively pass wildlife or to manage high flows associated with extreme weather. New England has experienced more frequent floods since 1970 (Armstrong et al. 2011), increasing the risk of failure for aging and/or undersized structures. The extreme damage caused by recent large storms, including the Mother’s Day Storm (2006), Hurricane Irene (2011) and Hurricane Sandy (2012) has highlighted these risks. These weather events have also drawn attention to the importance of some of the ecosystem services provided by naturally functioning aquatic systems, including flood attenuation and protection against storm surge. The presence of aquatic barriers limits the ability of the system to serve some of these functions.

The Ipswich River Watershed Association (IRWA) inventoried and assessed 1,026 potential barriers across the 280 square mile region as part of the most comprehensive such effort in this portion of New England. The inventory included an extensive desktop GIS analysis, thorough review of information from previous reports and on-the-ground surveys of more than 500 road-stream crossings to supplement existing IRWA data sets. The structures were then assessed and prioritized using screening tools that considered both ecological impact and infrastructure risk. This comprehensive approach provides a novel, regional assessment of barriers in the Great Marsh and its contributing watersheds. This report and the combined results of the screening analyses are intended to be used as tools for local governments, private owners and restoration practitioners to identify sites that warrant further investigation, especially where infrastructure and ecological risk appear to overlap. We hope this will identify opportunities for projects to be initiated and implemented that achieve dual benefits with respect to community resilience and ecological integrity. This framework will allow municipal officials, restoration practitioners and others to identify and further pursue work at sites while considering the position of the site and relative importance within the landscape and watershed.

The Region

The geographic scope of this project includes the watersheds of the Parker, Ipswich and Essex Rivers (PIE-Rivers) as well as some additional areas in the coastal municipalities of Newburyport and Salisbury, MA. The PIE-Rivers watersheds are the principal contributing watersheds to the Great Marsh Area of Critical Environmental Concern (ACEC) and include much of the city of Newburyport. The study also includes the portion of Newburyport that is within the Merrimack River watershed and the Town of Salisbury in its entirety. These additional areas were incorporated so that the study region includes all of the municipalities included in the Great Marsh Coastal Adaptation Planning effort associated with our work. In total, the project area includes approximately 280 square miles and all or parts of 29 towns (Figure 1).

Portions of seven of the municipalities fall within tidally influenced coastal areas of the Great Marsh study region. These are the Towns of Essex, Ipswich, Newbury, Rowley, and Salisbury as well as the Cities of Gloucester and Newburyport (Table 1). These coastal municipalities may have all four of the barrier types assessed in this report. The remaining 21 municipalities are in the non-coastal portion of the study region and therefore by definition have no tidal crossings or coastal stabilization structures (Table 2). A number of municipalities (e.g. Manchester, Beverly) are located on the coast, but do not have coastal zones within the study region. These are considered inland municipalities in this report, as our analysis of them does not include coastal areas.

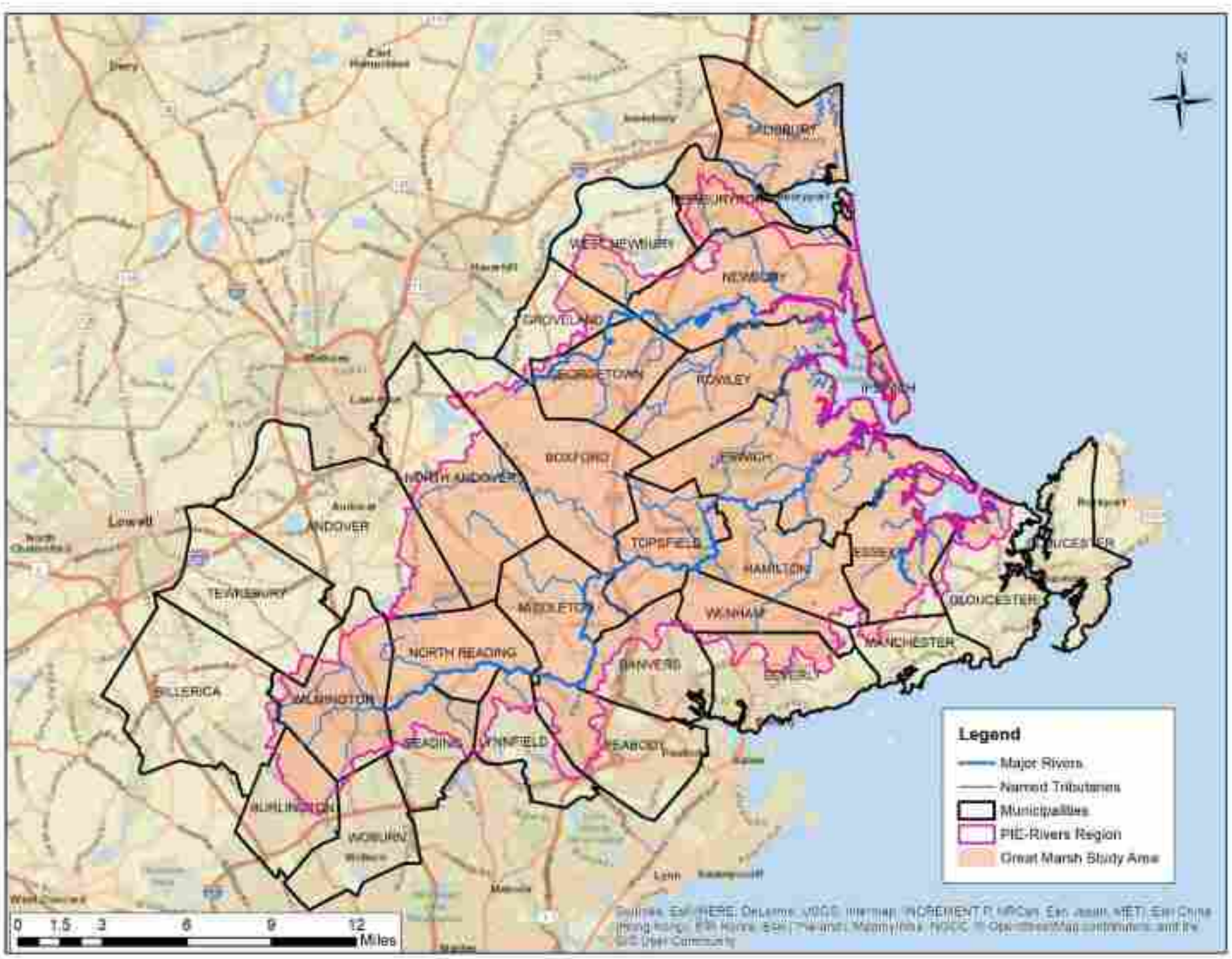

Figure 1. Map showing the region covered by the Great Marsh Barriers Study.

Table 1. List of coastal municipalities in the Great Marsh study region showing total land area falling within the study region and number of barriers of each barrier type expected to exist based on existing data sets and GIS analysis.

Town	Area (square miles)	Dams	Non-Tidal Stream Crossings	Tidal Crossings	Shoreline Stabilization
Essex	13.0		38	12	
Gloucester	2.9		3	3	1
Ipswich	32.4	6	87	17	25
Newbury	23.4	9	80	26	21
Newburyport	8.8	4	34	4	31
Rowley	18.6	6	76	9	
Salisbury	16.0		20	15	9

Table 2. List of inland municipalities in the Great Marsh study region showing total land area falling within the study region and number of barriers of each barrier type expected to exist based on existing data sets and GIS analysis. Numbers of road-stream crossings and dams located within the surveyed portions of each municipality. The area column represents the land area of the municipality that falls within the study region.

Town	Area (square miles)	Non-Tidal Crossings	Dams
Andover	5.4	28	7
Beverly	3.7	16	1
Billerica	0.6	1	
Boxford	21.2	158	11
Burlington	3.5	9	3
Danvers	3.9	21	3
Georgetown	12.9	90	1
Groveland	3.4	10	
Hamilton	14.4	61	
Lynnfield	3.4	5	1
Manchester	0.4	3	
Middleton	14.5	62	10
North Andover	16.6	83	7
North Reading	13.5	50	2
Peabody	4.6	30	6
Reading	4.8	9	
Tewksbury	0.5		
Topsfield	12.8	83	11
Wenham	7.4	34	1
West Newbury	3.6	11	
Wilmington	14.2	62	
Woburn	0.1	1	

Project Description

The *Great Marsh Barriers Assessment* (Barriers Assessment) was conducted by the Ipswich River Watershed Association (IRWA) as a component of a multifaceted project called *Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts* (Resiliency Project). The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and the Parker-Ipswich-Essex Rivers Restoration Partnership (PIE-Rivers) region.

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report, include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. This report and the combined results of the screening analyses are tools for local governments, private owners and restoration practitioners to identify sites warranting further investigation, especially where infrastructure and ecological risk overlap. This report identifies opportunities for projects to be initiated and implemented that achieve the dual benefits of improved community resilience and ecological integrity.

Municipal jurisdictions end at town boundaries, despite clear hydrologic and ecological links across those boundary lines. Since a primary focus of this project was to provide useful and easily accessible information for municipal partners, we have summarized the results and available information for each municipality in separate sections appended to this report. The town-specific summaries go into greater detail and are intended to give local officials, staff and residents maps, study results and other information specific to the town in which they are working as a supplement to this regional analysis. The summaries for individual towns can be found in the Appendix of this report.

This project also provides assistance to communities and infrastructure owners with efforts to remove or mitigate ecological and infrastructure risk at sites where it is feasible and cost effective. This project developed conceptual design plans for the replacement of 103 of the high priority road crossings in the region (101 non-tidal crossings plus two tidal sites in Salisbury) to improve storm resilience and ecological connectivity. These sites were chosen based on preliminary results from the screening analysis and conversations with staff at many of the region's municipalities. The conceptual design plans and supporting materials are available and appended to this report.

Structure Types

Our analysis considers four basic categories of structures that intercept or redirect water; dams, non-tidal road-stream/river crossings, tidal crossings and coastal stabilization structures. These structures all have limited life spans and, depending on their design, location and maintenance history, their failure may present significant risk to people and other infrastructure. This risk is elevated during extreme storm and high tide events, which are becoming more common in northeastern Massachusetts.

These structures also often severely alter natural flow, flooding and sediment transport regimes of rivers and coastal areas that can result in significant negative impacts to the ecology and resilience of those systems. For example, the downstream transport of sediments and nutrients from the watershed provides important nourishment to coastal food webs and helps salt marshes keep pace with erosion and sea level rise. Also, downstream transport of wood and other material helps build and re-shape river and stream habitat, providing important complexity and habitat niches to support a wide range of aquatic and semi-aquatic species.

The biological and ecological impacts of these changes to the river system can be profound. For example, sea-run migratory (diadromous) fishes such as river herring can have their entire life cycle interrupted. If aquatic barriers keep adult river herring from returning from the ocean to access their freshwater spawning grounds, the fish stocks are quickly depleted. River herring are an important forage fish in the estuary and ocean, providing food for species such as striped bass, cod and tuna. Thus, low river herring abundance can have a negative effect on these prized game and food fishes. The exclusion or reduction of river herring from the freshwater system also removes an important annual source of marine-derived food and nutrients, in the form of adult fish and their eggs, to the coastal rivers and ponds. This change greatly alters the food web and nutrient cycle, with impacts on everything from bugs to birds that live in or frequent these freshwater habitats.

The risk to roads and other infrastructure associated with barriers are also significant. This has been highlighted quite frequently over the last decade or so during large rain events such as Hurricane Sandy (2012), Hurricane Irene (2011) and the 2006 Mother's Day Storm which is the storm of record in the study area. Flooding events such as these test aging and undersized infrastructure with sometimes dangerous and often costly results as roads, railways and other infrastructure is damaged and destroyed as structure fail or underperform.

In light of aging infrastructure, increasing storm severity and shrinking budgets municipalities and other government entities have an increased need to prioritize the riskiest structures for upgrade and replacement. At the same time, in recent decades, ecological restoration practitioners have given greater attention to the impact some of these structures have on valuable ecosystems and ecosystem services. Restoration practitioners too have identified the need to prioritize the structures with the highest cost-benefit ratios for improvements. In many cases, there is considerable overlap between ecosystem impact and infrastructure risk, but rarely are these two concerns considered together. This study utilizes a variety of data sets and screening analyses to summarize and assess the relative effects of these structures on infrastructure and aquatic ecology in the region. This study integrates prioritization efforts for infrastructure and ecological concerns to identify sites where both can be addressed, benefitting communities by promoting more resilient infrastructure and ecosystems.

This comprehensive approach provides a novel, regional assessment of barriers in the Great Marsh and its contributing watersheds. This framework will allow municipal officials, restoration practitioners and others to identify and further pursue work at sites while considering their position and relative impact within the landscape and watershed.

Dams

Massachusetts has nearly 3,000 known dams, most of which have roots as power sources for small mills built in the 18th and 19th centuries. On average, there are more than 10 dams per 100 stream miles across New England and New York (Anderson & Olivero Sheldon 2011). There are currently 84 dams within the Great Marsh study region, the majority of which are relatively small structures that have long since outlived the purpose for which they were built. As a result of their age, many of these dams are also in some level of disrepair, increasing the risk of an eventual structure failure.

Dams have a profound impact on river processes and ecology. They interrupt natural downstream sediment transport, alter nutrient cycles and temperature regimes, block fish and wildlife migration corridors and change free flowing (lotic) habitat to more pond-like (lentic) habitat altering the species the system can support. The combination of these and other factors associated with dams has resulted in a drastic change in species composition and abundance throughout the region. Removing a dam can quickly remove many of the negative effects and begin to restore a river to a more natural state. For this reason, river restoration experts have become more and more focused on removing dams when they are no longer needed or when their costs outweighs their benefits.

In recent decades, more and more dam owners in Massachusetts and across the country are reevaluating the risk, cost and ecological impact of outdated dams. Forty-five dams have been removed in Massachusetts since 2000[1], including two in the Great Marsh study region. In many cases they are choosing to remove rather than maintain dams they no longer need. In cases where dams are still actively used there are sometimes options to reduce risk and ecological impact during maintenance and renovation. With such a large number of dams it is important for both dam owners and restoration practitioners to have a way to prioritize structures for further consideration.

Non-Tidal Road-Stream Crossings

“Road-stream crossing” is a general term that includes structures that carry roads or railways over streams or rivers. Most often these crossings are either culverts or bridges. When crossings are undersized, improperly installed (e.g. too high relative to the stream bed), or in disrepair, they can cause serious problems for the roadway, the waterway, or both. As the name implies, non-tidal crossings are those bridges and culverts that span waterways that are not influenced by ocean tides. Public works departments are often dealing with maintenance and replacement of these structures which are ubiquitous throughout the temperate northeast. In

[1] Rivers, American (2017): American Rivers Dam Removal Database. figshare. https://doi.org/10.6084/m9.figshare.5234068.v2, Retrieved: 4:00 pm, 11/17/2017.

recent years, restoration practitioners have been giving increased attention to the impact of improper crossing design on river function and aquatic ecology.

The Massachusetts Stream Crossing Standards (Jackson et al. 2011) were developed to guide design of new and upgraded stream crossings that allow natural fluvial processes to take place through a crossing, thus allowing for better habitat connectivity. Crossings designed to meet these standards have also proven more resilient to high storm flows, reducing failure risk and increasing structure life.

Tidal Crossings

Tidal crossings are bridges and culverts located within the tidally influenced portion of streams and rivers as well as tidal creeks. The tidal water flowing through these structures may be saltwater, brackish or freshwater depending on its position in the watershed and streamflow rates, but all sites are subject to two-way water flow at regular tidal intervals. Undersized tidal crossings can impact aquatic and salt marsh systems in many ways, including alteration of natural tidal inundation cycles, salinity gradients and species movement. In some cases, historic presence of an undersized tidal crossing can have long-term (potentially permanent) repercussions that negatively affect salt marsh health.

Tidal crossings are analogous to non-tidal crossings in many ways; however the twice daily fluctuation of water level, bi-directional flow, and exposure to coastal storm surges makes them a special case for both prioritization and design. Because of these rapid and extreme fluctuations in variables including velocity, water depth and salinity, it is very challenging to make judgments about both the ecological impact and the flooding or failure risk based on site visits and rapid assessment. Due to these factors, acceptable rapid assessment methods have not yet been developed for this type of structure.

Coastal Stabilization Structures

Like the other three structure types, coastal stabilization structures can have deleterious effects on aquatic systems. While these structures differ from the first three in that they do not block or constrict the flow-through of water in the same way, they can and do have large impacts on energy and sediment transport regimes in the nearshore and estuarine environments of the Great Marsh. Hardened coastal structures[2] often increase the risk of storm impacts on adjacent sites, scour important shallow water and intertidal habitat, and alter natural tidal flooding cycles on salt marsh and beach ecosystems. The physics governing these impacts are complex and highly site specific, but in general it can be assumed that the more armored a coastline is the more impacted the coastal ecosystem. In places where infrastructure needs to be protected, the proper design and maintenance of the structures is extremely important to ensure minimal impacts on ecosystem function and storm protection associated with natural dune, beach and marsh features.

Methods

Below is a summary of the methods the Ipswich River Watershed Association (IRWA) team used to identify and prioritize potential barriers throughout the study region. The methods are organized by the four barrier types listed above. This study leverages a variety of existing data sets and prioritization efforts for the various structure types and attempts to integrate them into a more comprehensive, screening level assessment of these structures. We used unique methodologies to assess and prioritize each structure type because of the inherent differences among the structure types and the variation in available data and screening tools. Structures were prioritized across the region as well as within each individual municipality. The priority scores produced in this report, while often presented as numerical values, should not be considered a comprehensive quantitative assessment of importance. Important considerations including cost, ownership and historic value were not systematically evaluated. In addition, the screening analysis was not able to consider many site-specific factors including specific species presence, rare species habitat and existing utilities. These priority scores are intended to be used as a tool to identify sites that warrant further investigation and to provide a decision support tool to assist municipal managers and other structure owners.

In addition to the inventory and prioritization effort described above, this project developed conceptual plans for the replacement and upgrade of a subset of structures that we identified as high priority. We identified a subset of high priority road-stream crossings for potential design based on our initial prioritization effort, meetings with municipal representatives, and position relative to other structures. For example, some structures that had moderate priority scores were included for design if they either opened up a large portion of river to upstream access or were among a series of related high priority structures located along the same stretch of

[2] Human-made structures consisting of material such as rock, concrete or steel that are designed to resist shoreline erosion and movement of coastal sand and sediment.

waterway. Similarly, some high-scoring structures were removed from consideration if their upgrade would not reconnect a large segment of habitat and were not on an important roadway.

Dams

We identified dam locations in the region using the Massachusetts Office of Dam Safety (ODS) Dams layer[3] as our base data set. The ODS Dams layer was checked against our local knowledge of dam locations and dam removals that had taken place since the last update of the database in February, 2012. Records of dam locations that we knew to be incorrect or redundant, or where dams had been removed, were withdrawn from the data set prior to our final analysis.

We then assessed dams in ESRI ArcGIS using a prioritization system that considered screening indices for both infrastructure risk (RI) and ecological impact (EI) to derive a numeric dam priority (DP) score for each dam in the region. The generalized process for deriving these DP scores is outlined in Figure 2. More detail on how the DP score and its various components were calculated is discussed below. Dams across the whole region were sorted and ranked according to their calculated DP scores to provide an initial priority list.

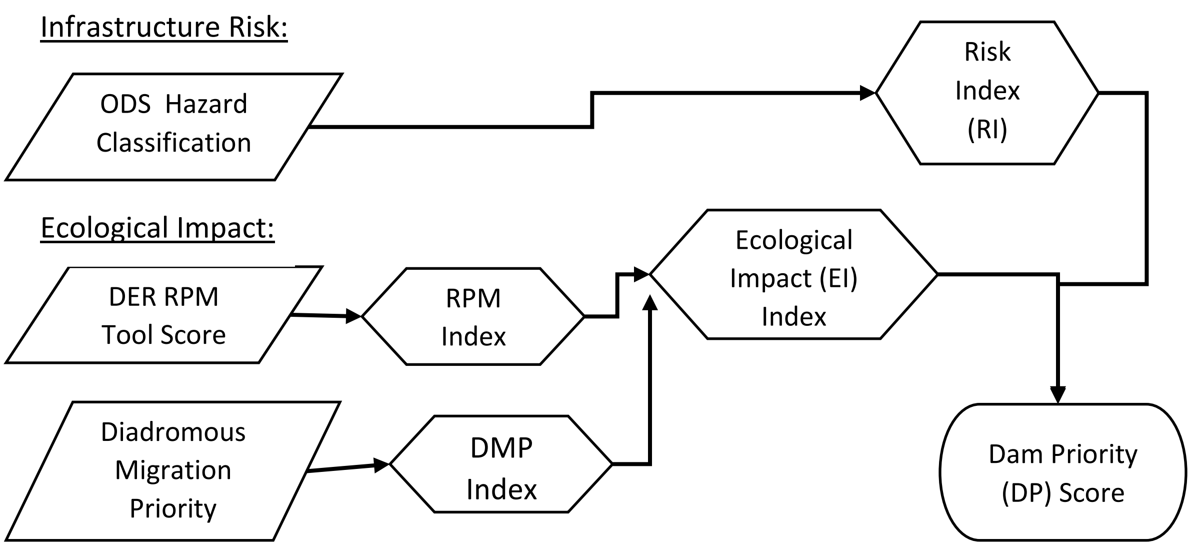

Figure 2. Generalized barrier prioritization scoring process for dams[4]. Explanations of model inputs and sub-components are more fully explained in the Infrastructure Risk, Ecological Impact and Dam Priority Score sections below.

A number of dams in the region are directly associated with reservoirs that provide drinking water to local communities through surface water withdrawals. While it is conceivable that a municipality or water provider may decide to decommission and remove one of these structures, we assumed it was quite unlikely in most cases due to the ongoing, important function these dams are providing. We conducted a second round of prioritization using the same process as above, but removing dams that are known to be associated with active municipal surface water reservoirs.

[3] http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/dams.html
[4] Explanation of abbreviations in Figure 2: ODS (Massachusetts Office of Dam Safety), DER RPM (Massachusetts Division of Ecological Restoration – Dam Restoration Potential Model)

The final step in prioritizing dams was consideration of any available local information on factors including community priority, safety concerns and restoration interest that we were able to obtain from conversations with residents, ecological experts or municipal officials. Dams with active or planned restoration projects, specific community concerns, or those that are known to be in poor condition were flagged and added to the priority list. While this step is inherently more subjective than calculating numerical priority scores, it can provide critically important information affecting restoration potential of a site.

Infrastructure Risk (RI)

The ODS assigns hazard codes to dams under its regulatory jurisdiction based on the severity of hazards presented to communities in the event of dam failure. Jurisdictional dam owners are responsible for periodic inspection of their dams on a schedule set by the hazard code. Hazard codes do not relate in any way to probability of failure since these codes are not tied to the maintenance condition of the dam.

For our analysis, we chose to use the hazard code for the dams as our screening metric for infrastructure risk. We considered all dams to be in similar condition and focused solely on the risk in the event of failure according to the ODS categorization. Each dam in the study region was assigned a risk index value based on its ODS hazard code as shown in Table 3.

Table 3. Dam Infrastructure Risk Index (RI) scoring system.

Office of Dam Safety Hazard Class	Risk Index Score
Non-Jurisdictional	0
Low Hazard	0.5
Significant Hazard	1
High Hazard	2

Ecological Impact (EI)

To screen for the ecological impact of dams, we used the Massachusetts Division of Ecological Restoration's (DER) Restoration Potential Model (RPM) Tool[5] and priority restoration paths for anadromous fish identified by the Massachusetts Division of Marine Fisheries (DMF) (Reback et al. 2004) and the Ipswich River Watershed Association.

The RPM Tool displays information that can be used to evaluate the relative ecological benefit of removing a dam based on a scoring system that considers a variety of dam and watershed characteristics including indicators of watershed position, ecological integrity and aquatic habitat connectivity. It does not account for many other variables that must be considered when assessing the priority and potential impacts of dam removal.

While the RPM tool does give some priority to head of tide dams and structures that have fewer downstream barriers to the ocean, it does not specifically prioritize structures that are important migration paths for diadromous fish. Diadromous fish are important to ecosystem processes in coastal rivers and restoration of diadromous fish stocks (especially river herring) is a major regional priority. For these reasons, we chose to give extra weight to dams that block migration paths to critical spawning and rearing habitats. We began to identify high priority restoration paths using an analysis of anadromous fish passage conducted by DMF which discussed

[5] Restoration Potential Model Tool and description available at: https://www.mass.gov/service-details/ders-restoration-potential-model-tool-description

anadromous fish restoration potential for all major streams in the study region and provided information on the presence/absence of fish passage structures at various dams (Reback et al. 2004). Ipswich River Watershed Association staff reviewed these paths and added additional priority routes leading to some historical alewife spawning ponds that we deemed to have restoration potential based on recent habitat surveys and conversations with DMF staff. The final network of priority migration corridors is shown in magenta in Figure 3. All dams located along these priority migration corridors were categorized as migration priorities and further split based on whether they have existing fish passage structures.

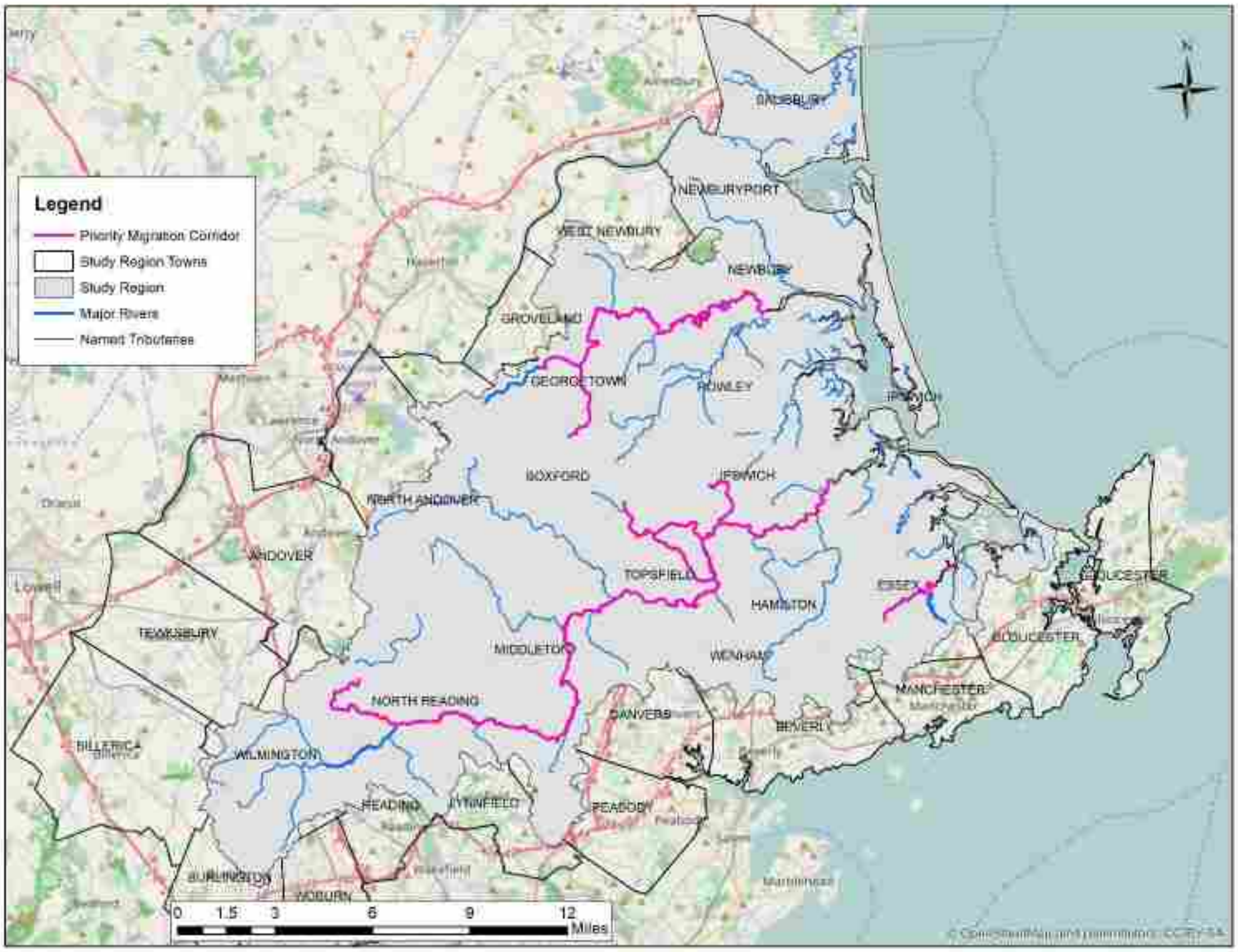

Figure 3. Map of Great Marsh Barriers Assessment study region showing priority migration corridors for anadromous fish.

We combined the information from the RPM tool score and the DMP categories into an Index of Ecological Impact (EI). The EI Index is a score ranging from 0 to 2 with lower scores indicating structures that are likely causing less negative ecological impact to their watersheds (i.e. are lower priority for removal or other restoration) and higher scores being structures that should be higher restoration priorities based on ecological criteria. It is important to note that this is just a screening tool that does not consider many factors that might increase or decrease a dam's impact on its watershed. Removal of dams with EI Index scores of 0 may still provide significant ecological benefits.

The EI Index score is calculated as:

$$\text{EI Index} = \ (RPM\ Index + \ DMP\ Index\ )/2 \qquad (1)$$

where:

The RPM Index is derived from Table 4 and the DMP Index is derived from Table 5.

Table 4. RPM Index scoring system

RPM Score Range	RPM Index Score
0-20	0
21-35	1
36-65	2

Table 5. DMP Index scoring system

DMP Category	DMP Index Score
No Priority	0
Priority - Existing Passage	1
Priority - No Passage	2

Dam Priority Score (DP)

The DP Score, as outline in Figure 2, is the final numeric value we calculated to prioritize dams based on the infrastructure and ecological indices were used as inputs. The DP Score is calculated using the following equation:

$$\mathrm{DP} = (\mathrm{EI} + \mathrm{RI}) + 0.01(\mathrm{RI} - \mathrm{EI}) \qquad (2)$$

The DP score ranges from 0 to 4 with higher numbers representing dams that are higher priority for removal based on our screening methods. The DP score gives near equal weight to both the ecological (EI) and risk (RI) scores. In cases where the sum of the two scores is equal, it gives priority to dams that derive more of their score from the RI index score.

Non-Tidal Road-Stream Crossings

We identified expected stream crossing locations using GIS data downloaded from the North Atlantic Aquatic Connectivity Collaborative (NAACC) stream crossing database[6]. This data set includes stream crossings predicted by GIS desktop analysis (intersecting stream networks with road and rail networks across the state) and known locations verified by previous field studies. Because this data set is based on a state-wide desktop GIS analysis some crossings were not in their originally expected place and some did not exist at all. Additionally, some crossings were identified during field visits and added to the data set by our field crews. Our goal was to conduct a complete survey of the crossings in the watershed, knowing that a considerable number of sites would be

[6] www.streamcontinuity.org/cdb2

inaccessible for a variety of reasons including private property and crew safety (e.g. Interstate highway, active railroad).

A large number of the crossings included in our analysis had been previously verified, surveyed and scored based on ecological criteria in an earlier study conducted by IRWA as part of the NAACC program (Kelder 2014). We conducted a secondary desktop analysis to remove incorrect, redundant, or removed structures and also added some structures that were not in the original data set. We also flagged and removed known tidal stream crossings from this analysis because the prioritization system described below is designed for non-tidal stream crossings only[7].

As part of this study, we collected additional field measurements of elevation and geomorphology variables at road stream crossings using a protocol developed by Trout Unlimited (TU). This included an extensive field effort over the course of three years where teams conducted one or more site visits to more than 500 road-stream crossings, an effort that required well over 3,000 hours of staff and volunteer time. Using the information collected during this survey as well as information from the NAACC surveys noted above, TU conducted a screening-level analysis of each crossing's expected ability to pass peak flows generated by five storm scenarios (50%, 10%, 4%, 2% and 1% likelihood storms)[8]. The full results of the TU analysis are summarized in the appended report (Trout Unlimited 2017).

We prioritized field efforts using our best professional judgment regarding the relative importance of getting results for a crossing based upon factors including watershed position, proximity to known barriers and relationship to critical migration habitat. For example, a crossing located on private property immediately downstream from a water supply dam high in the watershed and without a fish ladder would likely not warrant further investigation if it was not easily accessible. On the other hand, a crossing on private property, but along a priority migration corridor would be flagged for follow up and we would make extra effort to gain access to conduct a survey at a later date. As a result of the logistical challenges of a study of this scope, the percentage of sites visited may appear low, but this effort represents a far more complete understanding of road-stream crossings than in almost any other watershed system in the Commonwealth.

We assessed non-tidal road-stream crossings using a prioritization system that considered screening indices for both infrastructure risk and ecological impact to derive a numeric Crossing Priority (CP) score for each crossing. The generalized process for deriving the CP scores is outlined in Figure 4. More detail on how the CP score and its components were calculated is outlined in the sections below. Crossings across the whole study region were mapped in ESRI ArcGIS and ranked according to their calculated CP scores to allow for visual assessment of their potential impact on watershed and municipal scales. We also produced maps showing the distribution of crossings based on their component infrastructure risk (CRI) and ecological impact (CEI) scores.

[7] Field data was collected at a number of tidal crossings, but any results from the screening tools would be of questionable value since both the NAACC and Hydraulic Capacity tools do not consider two-way flow.

[8] Storm likelihood is the calculated percent chance of at least one 24-hour rainfall event of that size or larger occurring on any given year. This concept is sometimes presented as a return interval where the return interval is the number of times, on average, this magnitude of rainfall is expected to happen over a fixed time period (e.g. 1% likelihood storm = 100 year return interval storm). – 1% = 100 yr, 2% = 50 yr, 4% = 25 yr, 10% = 10 yr, and 50% = 2 yr.

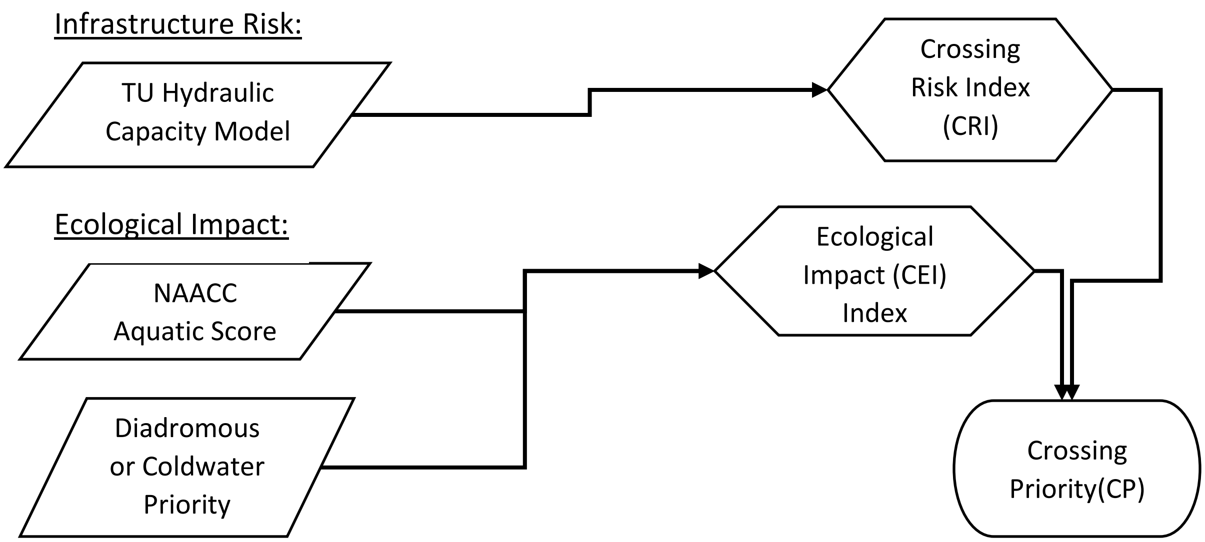

Figure 4. Generalized barrier prioritization scoring process for non-tidal road-stream crossings. Explanations of model inputs and sub-components are fully explained in the Infrastructure Risk, Ecological Impact and Crossing Priority Score sections below.

The CP score is an index value we calculated for prioritizing non-tidal road-stream crossings for upgrade based on our screening of infrastructure risk and ecological impact. The CP score ranges from 0 to 10 with larger numbers representing higher priority structures for replacement. It is important to point out that these priorities are based on our screening tools and don't consider all aspects of an eventual decision to prioritize a structure for replacement, including local priority, cost and other site-specific concerns.

Using preliminary results from the above analysis, we produced maps and tables showing high priority crossings for each municipality with ten or more scored crossings. We approached officials from each municipality to solicit their feedback on the results and inquire about any other sites that they deemed high priority (especially due to flooding or failure history). We used feedback from the municipalities to ground-truth our results and to adjust town-specific priority design lists as appropriate. Consistent with our approach to local knowledge regarding dams, sites prioritized based solely on local knowledge were included as priorities, but not explicitly ranked.

Infrastructure Risk (CRI)

The TU Hydraulic Capacity (HC) screening model calculates expected flow at the 2-yr, 10-yr, 25-yr, 50-yr, and 100-yr return interval storms at each crossing site based on its upstream watershed characteristics and tests whether the structure has the capacity to accommodate the peak flow. The inability of crossings to pass storm flows can result in water ponding on the upstream side of the road embankment and increased velocities and erosive forces at the downstream outlet. In general, we expect the roadway in areas around these crossings to be more likely to flood and fail over time and chose to use the results of the HC model to generate our Crossing Infrastructure Risk Index (CRI).

For each return interval, the HC screening model generates a value of Pass (enough capacity), Fail (not enough capacity) or Transitional (near capacity 85% - 115% of capacity). We used these results to generate a numeric CRI value scaled from 0-5 with 0 passing at all and 5 at none of the return intervals tested using the following formula:

$$\mathrm{CRI} = 1\mathrm{F} + .6\mathrm{T} \quad (3)$$

where:

F = the number of return intervals where the crossing fails

T = the number of return intervals where the crossing is transitional

Ecological Impact (CEI)

The NAACC program assesses non-tidal road-stream crossings based on their design with respect to ecological connectivity. Specifically the protocol measures a crossing's level of compliance with the MA Stream Crossing Standards which were developed to promote stream continuity, aquatic organism passage and wildlife passage at crossings (Jackson et al. 2011). Field collected data is submitted by trained individuals to the NAACC database which, among other things, calculates an NAACC Aquatic Score for each crossing. This Aquatic Score (AQ) is a value ranging from 0 to 1 with 0 representing no connectivity and 1 representing full connectivity at the crossing. We used this score as the primary component in our Crossing Ecological Impact Index (CEI).

As we did with dams, we wanted to incorporate some level of added importance to crossings located along high value stream reaches. In particular, we were interested in prioritizing crossings along priority migration paths for diadromous fishes and for coldwater stream habitat which is rare in the study region. For diadromous fish, we used the priority migration corridors described in the Dam Ecological Impact Index section above and shown in Figure 3. We then retrieved the MA DFW Coldwater Fisheries Resources[9] layer from MassGIS and attempted to add any coldwater habitat to our priority corridors. All of the mapped coldwater resources within the study region were already included in the stream reaches shown in Figure 3 so that was kept as the priority region. All crossings located along the priority migration corridors were categorized as migration priorities (MP) and assigned an MP value of 1. All other crossings were assigned a MP value of 0.

Using the above information, we calculated the CEI Index as described below.

If AQ is greater than 0.5:

$$\mathrm{CEI} = 5 - 5\mathrm{AQ} \quad (4)$$

If AQ is less than or equal to 0.5:

$$\mathrm{CEI} = 5 - 5\mathrm{AQ} + \mathrm{MP} \quad (5)$$

where:

AQ = NAACC Aquatic Score

MP = migration priority value described above (0 or 1)

[9] http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/dfwcfr.html

If CEI calculations returned a value of greater than 5 the score was rounded down to 5. The CEI score ranges from 0 to 5 with larger numbers indicating structures that are expected to have higher negative ecological impact based on this screening assessment and thus higher priority for improvement.

Crossing Priority Score (CP)

The CP score, as outlined in Figure 4, is the final numeric value we calculated for prioritizing non-tidal road-stream crossings for upgrade based on our screening of infrastructure risk and ecological impact. The CP score ranges from 0 to 10 with larger numbers representing higher priority structures for replacement. The score is obtained by summing the CRI and CEI scores as follows:

$$\mathrm{CP} = \mathrm{CRI} + \mathrm{CEI} \tag{6}$$

In cases where only CRI or CEI scores were available, CP was equivalent to the available component score.

Tidal Crossings

Because of the highly variable and complex conditions at tidal crossings and tidally restricted areas, no one has yet developed assessment methodologies comparable to those for non-tidal crossings. These structures are subject to two-way water flow as well as the variable effects from both upstream (e.g. river flow, stormwater) and downstream (e.g. tidal inundation, storm surge) directions. For example, a large rainfall event would have different impact when occurring at low tide versus high tide. Similarly, the ecological effects of crossings that create tidal restrictions are harder to identify as tidal stage has a substantial impact on whether these structures are barriers to animal movement. Due to these complexities, the vulnerability and ecological impact of individual tidal crossings is difficult to quantify as part of a rapid assessment protocol. For these tidal structures, we relied on results from the Draft Great Marsh Coastal Wetlands Restoration Plan (see below) as well as locations and information regarding tidal crossings obtained through the NAACC surveys, desktop GIS analysis, review of aerial imagery, site visits and local knowledge.

The Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration), together with numerous partners, completed the Draft Great Marsh Coastal Wetlands Restoration Plan (Draft GMP)[10] as a tool to help communities in the Great Marsh region identify and restore degraded and former coastal wetland habitats. The Draft GMP was initially developed in 2006 and is currently (2017) being updated and revised. It presents maps and descriptions of 121 potential and completed salt marsh restoration sites in the Great Marsh. The Draft GMP also included more detailed “rapid technical assessments” of a subset of the sites it considered. These reports include more detail on the degree of tidal restriction, including information such as measurements of tidal range over month-long periods, that may be of use if these sites are further explored.

Our analysis focused on tidal road crossings as well as some off-road structures (such as berms and water control structures) that may be acting as barriers to natural tidal exchange. We built our data set of tidal crossings by conducting a detailed review of the 121 records in the Draft GMP as well as 23 surveys from our NAACC field work that identified tidal conditions. Using these two data sets in conjunction with desktop GIS analysis of aerial photos and local knowledge, we identified a total of 89 tidal crossings within the study region.

[10] Developed by Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration) - 2006

These sites are all located within the seven coastal municipalities in the study (Essex, Gloucester, Ipswich, Newbury, Newburyport, Rowley and Salisbury).

We characterized each tidal crossing as to whether it was under a public way and whether it was associated with a marsh that was classified as tidally restricted in the Draft GMP. The Draft GMP prioritized tidally restricted marshes from low to high priority based on a subjective (best professional judgment) assessment of ecological restoration potential and feasibility at the site. Our analysis defined priority tidal crossings by combining the above criteria as shown in Table 6. Structures identified as high priority or problem areas for flooding by municipal staff or in the Great Marsh Regional Coastal Adaptation Plan were considered to be high priority tidal crossings if not already included through the above screening approach.

Table 6. Prioritization categories for tidal crossings in the Great Marsh Barriers Assessment.

<table>
<tr><th>On Public Way</th><th>Restoration Priority in 2006 Draft Great Marsh Plan (Draft GMP)</th><th>Tidal Crossing Priority</th></tr>
<tr><td rowspan="4">No</td><td>Not in Draft GMP</td><td rowspan="2">Low</td></tr>
<tr><td>Low</td></tr>
<tr><td>Med</td><td>Med</td></tr>
<tr><td>High</td><td>High</td></tr>
<tr><td rowspan="4">Yes</td><td>Not in Draft GMP</td><td>Low</td></tr>
<tr><td>Low</td><td>Med</td></tr>
<tr><td>Med</td><td rowspan="2">High</td></tr>
<tr><td>High</td></tr>
</table>

Coastal Stabilization Structures

To identify priority coastal stabilization structures, we relied on data from the Massachusetts Coastal Structure Inventory and Assessment Project[11] which inventoried both public and private shoreline stabilization structures throughout the Commonwealth. For this analysis, we considered hard, human-made structures including seawalls, revetments, bulkheads, groins, jetties, breakwaters, and dikes or levees. The available information on these structures allowed us to identify location, structure type, length of shoreline impacted and, in some cases physical condition of the structures. We were unable to assess ecological impacts of individual shoreline stabilization structures with the available data and screening tools.

Publicly Owned Structures

Publicly owned shoreline stabilization structures were inventoried and assessed in a report prepared for Massachusetts Departments of Coastal Zone Management (CZM) and Conservation and Recreation (DCR) from 2006 to 2009 (Bourne Consulting Engineering 2009). The data and reports include condition ratings and estimated repair or reconstruction costs for publicly-owned coastal structures. These structures were characterized through on-site evaluation that focused primarily on shoreline stabilization structures and their ability to resist major coastal storms and prevent damage due to flooding and erosion.

[11] Massachusetts Coastal Structure Inventory and Assessment Project available at: http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/seawall-inventory/

The inventory rated structures based on a condition scoring system that ranged from excellent (A) to critical (F). For our analysis we used the condition structures from this assessment as a proxy for infrastructure risk under the assumption that structures in poorer condition are more likely to fail during storms. These publicly owned structures were separated into priority categories based on the condition scores as follows: low priority (A, B), moderate priority (C), high priority (D, F). This prioritization assumed that poor condition makes structures more vulnerable to failure during storms, increasing the risk of damage to both property and ecosystem services.

Privately Owned Structures

Privately owned coastal stabilization structures were inventoried and summarized in a 2013 report prepared for the Massachusetts Office of Coastal Zone Management (CZM) by Applied Science Associates, Inc. (Fontenault et al. 2013). This 2013 effort identified location and type of coastal structures, such as seawalls and revetments, not included in previous phases of the Massachusetts Coastal Infrastructure Inventory and Assessment Project. These structures were identified using remote sensing techniques and are presumed to be privately owned. The data and report provide a comprehensive assessment of shoreline armoring coast-wide.

This inventory of privately owned coastal stabilization structures does not include an assessment of structure condition. For our analysis, we included information on number of structures, location and length of altered shoreline, but did not assess risk or prioritize the structures.

Crossing Replacement Designs

As the final component of this project, Meridian Associates, Inc. (MAI) was contracted to develop conceptual designs for the replacement of a subset of selected high priority crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures. This task was focused almost exclusively on non-tidal crossings, but tidal crossings could be designed where site-specific conditions allowed the engineering team to do so.

The designs were developed using available site data including measurements, photos and field notes collected by IRWA as well as results from the NAACC database[12] and the Trout Unlimited Hydraulic Conductivity screening tool. Modeling effort field measurements collected by IRWA for the NAACC and screening tools. The proposed designs focused on improving hydraulic capacity and ecological connectivity and were intended to conform to the Massachusetts Stream Crossing Standards where applicable (Jackson et al. 2011). The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

[12] NAACC Crossing database available at: www.streamcontinuity.org/cdb2

Results

A total of 1,026 barrier structures were assessed as part of this analysis. The following sections provide a broad summary of prioritization results for each barrier type for the whole study region. Those interested in results, discussion and complete data sets specific to individual municipalities should refer to the town specific packages in the appendices of this report.

Dams

There are 91 dam records in the Office of Dam Safety (ODS) Database that fall within the limits of the study region and were considered as part of our analysis. After review, we identified 84 records that represent existing dams and retained those for prioritization and analysis. The design purpose and active use of these dams is varied, however a considerable number (14) are currently used to impound water for municipal surface water supply reservoirs. No dams in the region produce hydroelectric power or are designed to provide flood control.

The geography, geology and hydrology of the Great Marsh region are generally not compatible with the construction of large dams. As a result, the study region is dominated by relatively small dams with small impoundments. Of the 81 dams in the region, 35 are not under the jurisdiction of the Office of Dam Safety (non-jurisdictional)[13] because of relatively low risk of downstream damage based largely on height and impoundment size. While small dams generally present lower risk to life and property in the event of failure, non-jurisdictional dam owners are not required by ODS to conduct regular safety inspections of their structures. Due to the age of many of these structures as well as the absence of inspection requirements, many of these small structures are in considerable disrepair increasing the likelihood of eventual failure.

The results of our regional prioritization of dams based on DP score are summarized below in Table 7 (without water supply dams) and Table 8 (with water supply dams). Water supply dams occupy the top 4 priority spots and 8 of the top 12 (Table 8). This appears to largely be a function of the tendency for these to be larger structures and thus higher hazard. Many of the high-ranking water supply dams also represent parts of impoundments that are formed by multiple dams, so are somewhat redundant to consider separately. For example, three of the top four structures are components of the dam system that forms the Putnamville Reservoir.

When water supply dams are removed from the priority ranking, the list of high priority dams is dominated by structures that are old mill dams and, for the most part, no longer serve the purpose they were designed for. Some of these structures have active projects underway to remove or improve conditions at them and others have been identified as possible restoration sites pending owner interest and funding availability (Table 7). The locations of the 11 highest priority dams identified in this analysis are highlighted in Figure 6. Water supply dams that had high DP scores, but were removed from the final analysis, are also highlighted on the map.

A look at the infrastructure risk and ecological impact components of our screening approach can also provide some insight as to what is driving the DP score. The 46 dams that are regulated by the ODS are primarily classified as low risk (22) or significant risk (17) structures with only 6 dams classified as high risk. All 6 of the high risk dams are part of surface water supply reservoir systems. A map of the study region showing dams by ODS hazard class can be seen in Figure 7. Figure 5 shows a graphical representation of dams summarized by

[13] The MA Office of Dam Safety (ODS) data set included 34 non-jurisdictional dams. One dam (MA00181) was changed from significant hazard to non-jurisdictional for our analysis based on information from the City of Beverly indicating that it was mis-identified in the ODS database.

Restoration Potential Model (RPM) score and diadromous migration priority, the two sets of data that are used to determine the Ecological Impact Index (EI). There are 5 dams with RPM scores of >40 that are also along priority migration corridors. The region-wide results of the EI Index analsis are shown in Figure 8. The higher priority dams are concentrated lower down in the watersheds and along the mainstems of the major rivers, largely as a function of location relative to diadromous migration corridors.

Table 7. Top ranked dams in Great Marsh study region. List includes top 11 dams based on Dam Priority (DP) score and additional dams with active restoration projects or specific local priority. List excludes water supply dams. *Adjusted Priority Rank is the ranking with water supply dams excluded.

Adjusted Priority Rank*	Dam ID	Dam Name	Town	Risk Index (RI)	Eco Index (EI)	Dam Priority (DP)	Active Project or Local Priority
1	MA01137	Ipswich River Dam (South Middleton)	Middleton	1	1.5	2.5	Active
2	MA00159	Howe Pond Dam	Boxford	1	1	2.0	
2	MA00261	Pentucket Pond Outlet Dam	Georgetown	1	1	2.0	
2	MA01604	Jewel Mill Dam	Rowley	1	1	2.0	
5	MA01198	Baldpate Pond Dam	Boxford	0.5	1.5	2.0	
5	MA00231	Ipswich Mills Dam	Ipswich	0.5	1.5	2.0	Active
5	MA00241	Parker River Dam #1 (Central Street)	Newbury	0.5	1.5	2.0	
8	MA01610	Howletts Brook Dam	Topsfield	0	2	2.0	
9	MA00158	Stiles Pond Outlet Dam	Boxford	1	0.5	1.5	
9	MA03006	Mill Pond Dam	Middleton	1	0.5	1.5	
9	MA01613	Bethune Pond Dam	Topsfield	1	0.5	1.5	
20	MA00276	Willowdale Dam	Ipswich	1.5	1.5	1.5	Active
45	MA00240	Parker River Dam #2 (Larkin Road)	Newbury	0	0.5	0.5	Priority

Table 8. Top 16 dams in Great Marsh study region ranked by Dam Priority (DP) score.

Priority Rank	Dam ID	Dam Name	Town	Water Supply
1	MA00745	Putnamville Reservoir Dam	Danvers	Yes
2	MA00744	Putnamville Reservoir West Dike	Danvers	Yes
2	MA00726	Winona Pond Dam	Peabody	Yes
2	MA01297	Putnamville Reservoir East Dike	Danvers	Yes
5	MA01137	Ipswich River Dam (South Middleton)	Middleton	
6	MA01121	Mill Pond Dam	Burlington	Yes
6	MA01123	Mill Pond South Dike	Burlington	Yes
8	MA00182	Longham Reservoir Dam	Wenham	Yes
8	MA00165	Dow Brook Reservoir Dam	Ipswich	Yes
8	MA00159	Howe Pond Dam	Boxford	
8	MA00261	Pentucket Pond Outlet Dam	Georgetown	
8	MA01604	Jewel Mill Dam	Rowley	
13	MA01198	Baldpate Pond Dam	Boxford	
13	MA00231	Ipswich Mills Dam	Ipswich	
13	MA00241	Parker River Dam #1 (Central Street)	Newbury	
16	MA01610	Howletts Brook Dam	Topsfield	

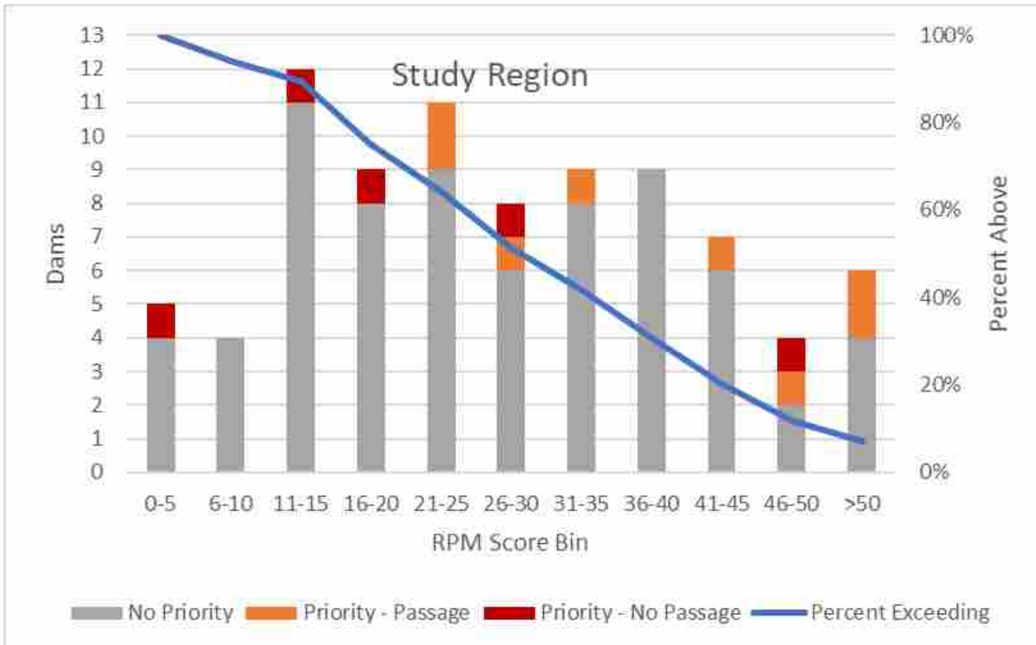

Figure 5. Summary of Dams in the Great Marsh study region summarized by RPM score and diadromous migration priority. The blue line shows the percentage of dams in the region that meet or exceed the RPM score.

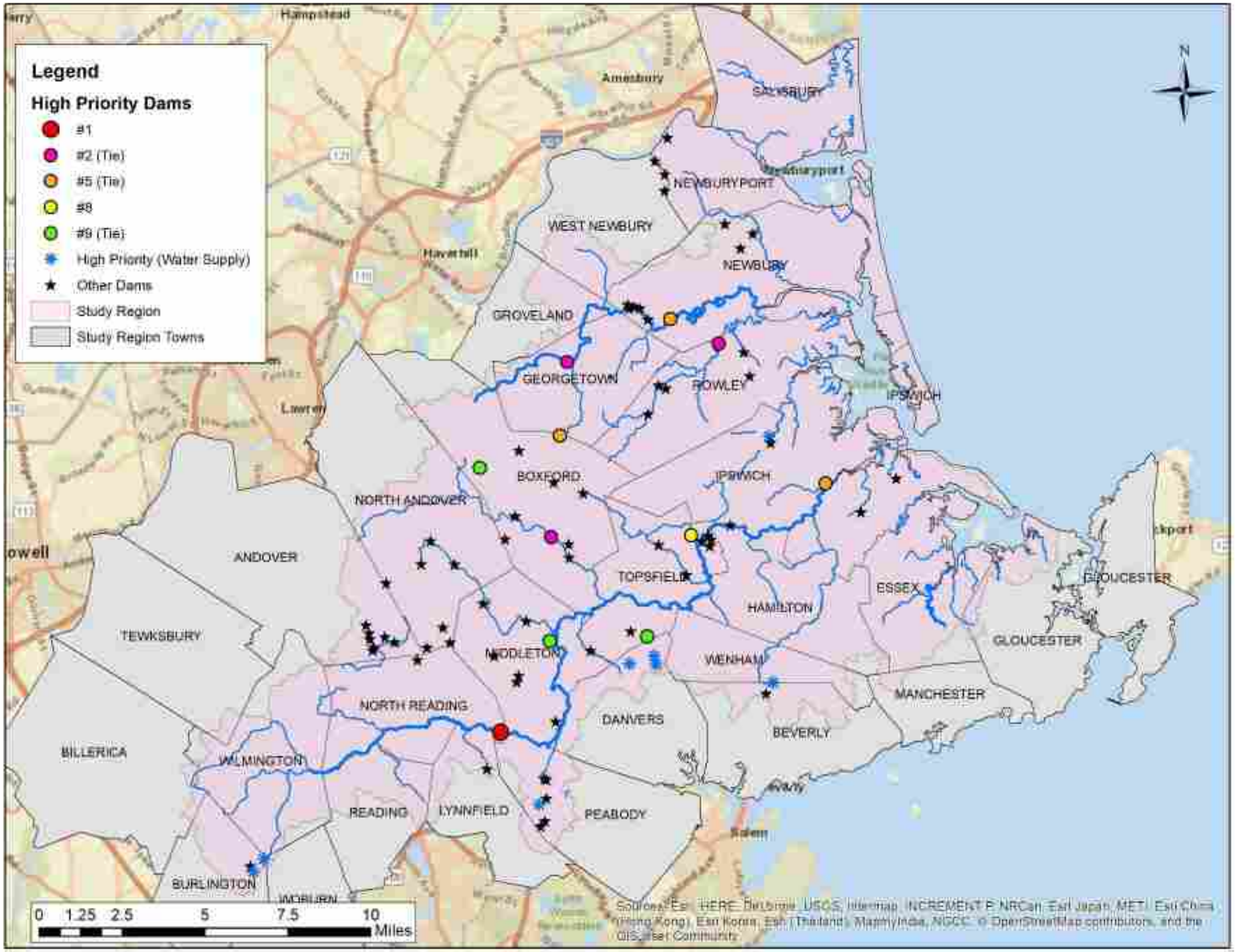

Figure 6. Map of Great Marsh study region showing highest priority dams based on DP Score analysis. Water supply dams were removed from the final ranking.

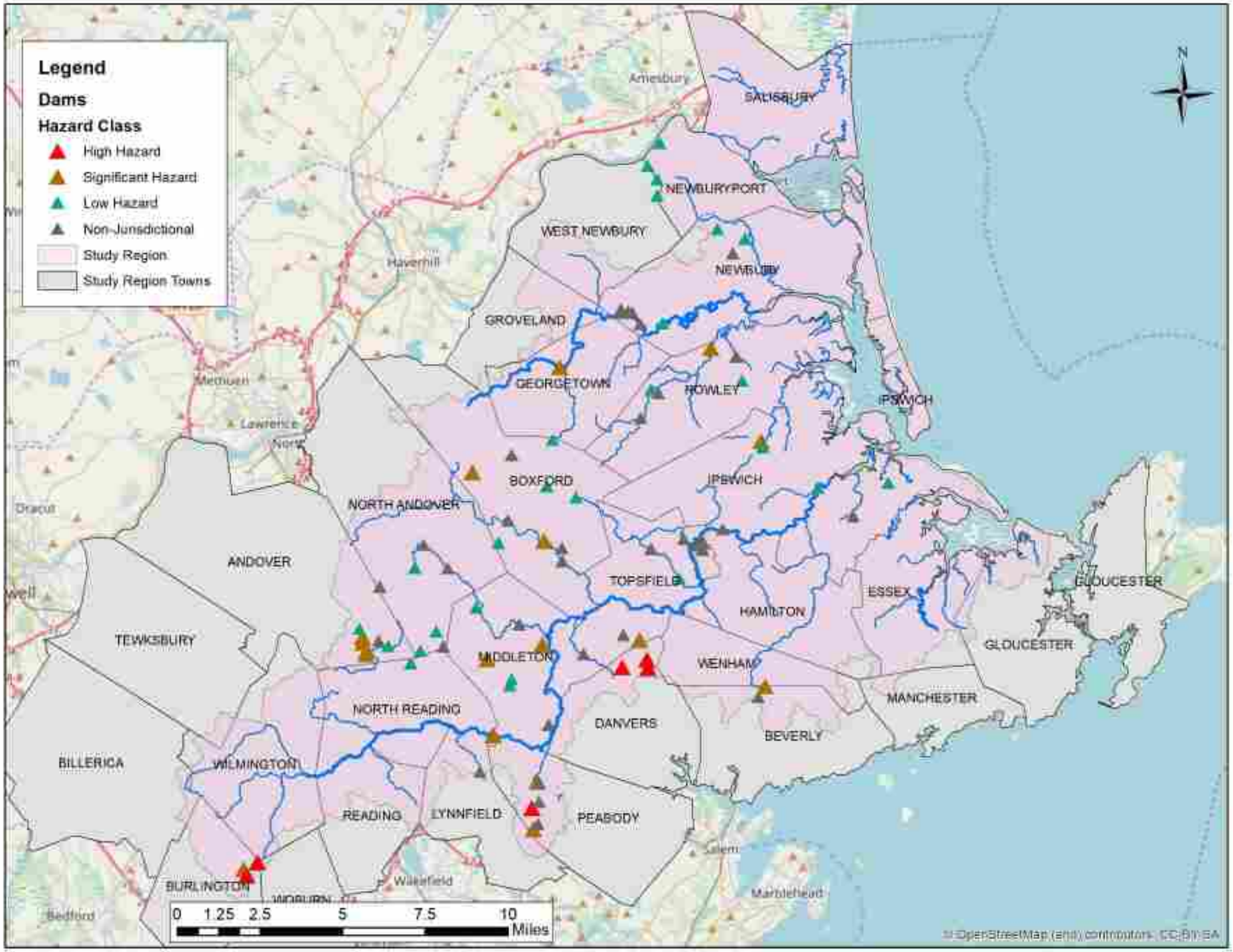

Figure 7. Map of the Great Marsh study region showing dams classified by MA Office of Dam Safety hazard class.

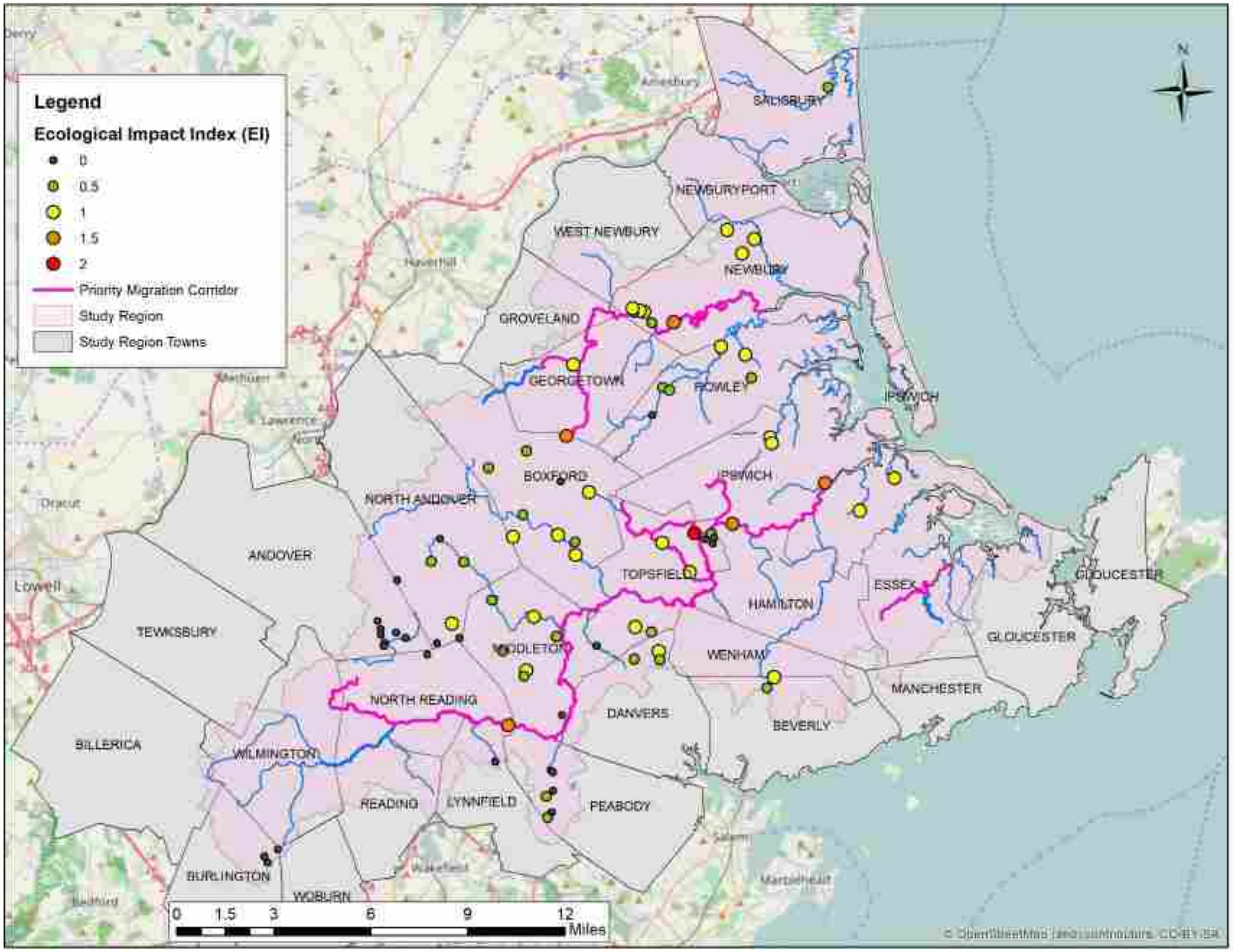

Figure 8. Map of Great Marsh study region showing dams prioritized by Ecological Impact Index scores.

Non-Tidal Road Stream Crossings

The North Atlantic Aquatic Connectivity Collaborative (NAACC) database predicted a total of 1,176 road-stream crossings within the 280 square mile study region. Over the course of this project, a total of 704 (60%) of the predicted structures were inventoried by IRWA-trained survey teams. Within the higher priority portions of the region, percent coverage was higher with 76% (292) of the crossings along rivers/major tributaries and 79% (92) of the crossings along priority migration corridors inventoried. These numbers are an underrepresentation of the number of sites that crews visited since a considerable number of sites were deemed inaccessible by crews in the field. Ninety three of the 704 inventoried sites either had no crossing or the crossing had been removed prior to the survey; this left 611 sites where we were able to collect survey data to run screening analyses. We assigned Crossing Priority (CP) index scores and ranked each of these 611 crossings[14].

The CP scores calculated ranged from 0 to 9.94 on the 10-point scale. Most of the crossings scored in the lower part of the range with a median CP score for all scored crossings of 2. A histogram displays two separate peaks in score frequency with high numbers of crossings scoring either around 1 or around 6.5 (Figure 9). These distinct frequency peaks of CP scores helps distinguish between groups of structures with relatively low combined priority and those that are more problematic from both infrastructure and ecological perspectives.

The 35 highest priority structures had CP scores greater than 7 (Table 9). Thirty-two of these structures were single culvert crossings and the remaining three were multiple culvert crossings, highlighting that bridges tend to be more effective at passing both flood waters and aquatic organisms. Figure 10 shows a map of crossings throughout the study region by CP score. We did not detect a strong distribution pattern for high CP scores; however it appears that the density of higher priority crossings is lower in the upper portions of the Ipswich, Parker, Essex and Miles River watersheds than in much of the rest of the Great Marsh study region.

Maps showing results for the infrastructure (CRI) and ecological (CEI) components of the CP score are included below in Figure 11 and Figure 12. Sites with the highest infrastructure risk are predicted to fail to pass flows associated with the 2-year return interval storm. Structures in this high risk CRI category appear to be slightly more highly concentrated in portions of the study region east of North Andover and Middleton and less common in the headwaters of the Ipswich River (Figure 11). Structures with higher ecological impact (CEI) scores appear to be somewhat more concentrated on small, low order tributaries where it is more likely that crossings structures are small culverts (Figure 12).

[14] Crossing Priority (CP) scores for 488 sites were calculated using both infrastructure risk (CRI) and ecological impact (CEI) values. For 123 crossings, we lacked usable results for the infrastructure risk (CRI) screening tool, mainly because the more detailed survey data need to run that model could not be collected for those sites. Sites lacking CRI scores were assigned CP scores and ranked using results from CEI scores only.

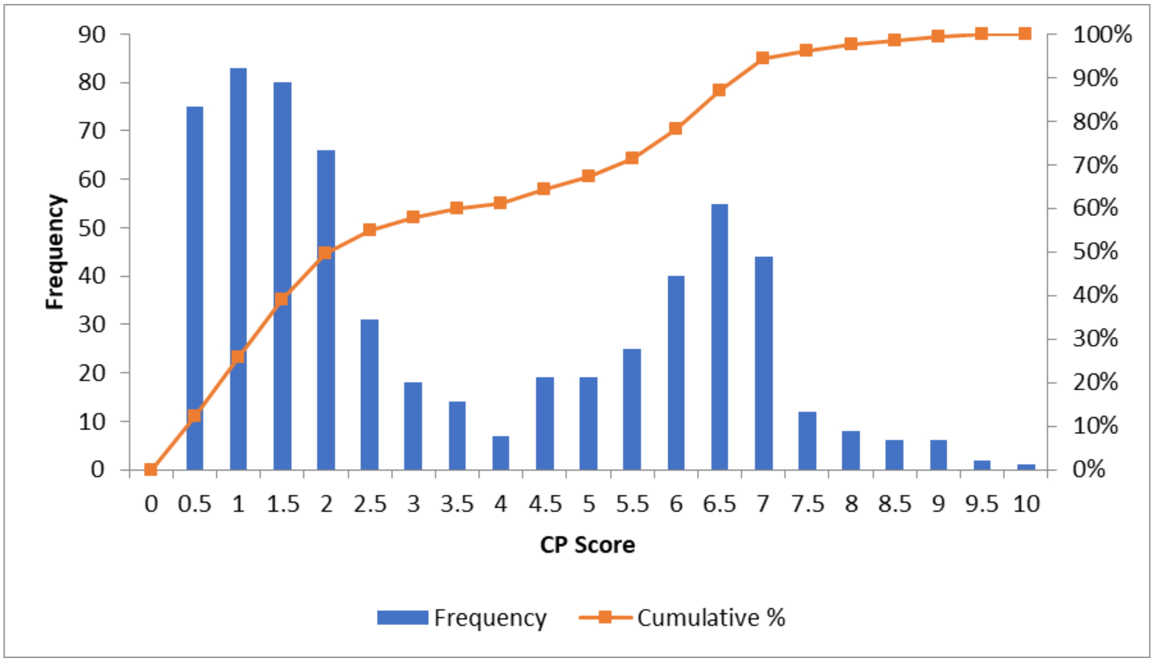

Figure 9. Frequency histogram showing Crossing Priority (CP) scores for non-tidal road-stream crossings in the Great Marsh study region.

Table 9. Non-tidal road-stream crossings with Crossing Priority (CP) scores of greater than 7 in the Great Marsh Barriers Assessment. This represents the 35 highest priority structures in the region based on screening model results.

Regional CP Rank	Crossing ID	Town	Road	Structure Type	CRI Score	CEI Score	CP Score
1	188	Wenham	Dodges Row	Single Culvert	5.0	4.9	9.9
2	9011	Topsfield	Meetinghouse Lane	Single Culvert	5.0	4.3	9.3
3	472	North Andover	Liberty Street	Single Culvert	4.6	4.4	9.0
4	670	Topsfield	Pond Street	Single Culvert	5.0	3.9	8.9
5	1054	Newbury	Coleman Road	Single Culvert	5.0	3.9	8.9
6	151	Wilmington	Ainsworth Road	Single Culvert	5.0	3.7	8.7
7	879	Boxford	Washington Street	Single Culvert	5.0	3.7	8.7
8	421	Andover	Gray Road	Single Culvert	4.0	4.6	8.6
9	408	Andover	Salem Street	Single Culvert	4.0	4.6	8.6
10	862	Georgetown	Nelson Street	Single Culvert	5.0	3.5	8.5
11	435	Topsfield	River Rd	Single Culvert	4.6	3.7	8.3
12	84	North Reading	Concord Street	Single Culvert	5.0	3.3	8.3
13	859	Boxford	Main Street	Multiple Culvert	5.0	3.3	8.3
14	990	Rowley	Main Street	Single Culvert	3.6	4.7	8.3
15	517	Hamilton	Winthrop Sreet	Single Culvert	3.6	4.4	8.0
16	753	Ipswich	Pine Swamp Road	Single Culvert	5.0	2.9	7.9
17	681	Boxford	Main Street	Single Culvert	3.0	4.8	7.8
18	755	Boxford	Kelsey Road	Single Culvert	5.0	2.7	7.7
19	439	Essex	Story Street	Single Culvert	4.0	3.7	7.7
20	413	Hamilton	Moulton Street	Single Culvert	5.0	2.7	7.7
21	1162	Newbury	Off Middle Road	Single Culvert	4.6	3.0	7.6
22	1094	Newbury	Orchard Street	Single Culvert	2.6	5.0	7.6
23	765	Boxford	Off Styles Pond Road	Single Culvert	2.6	5.0	7.6
24	898	Rowley	Daniels Road	Single Culvert	5.0	2.5	7.5
25	860	Georgetown	Central Street	Single Culvert	5.0	2.5	7.5
26	639	Ipswich	Essex Road	Single Culvert	5.0	2.4	7.4
27	587	North Andover	Carlton Lane	Single Culvert	3.6	3.6	7.2
28	462	Topsfield	Summer Street	Single Culvert	5.0	2.1	7.1
29	878	Rowley	Haverhill Street	Single Culvert	5.0	2.1	7.1
30	1231	Newburyport	Pheasant Run Drive	Multiple Culvert	5.0	2.1	7.1
31	788	Rowley	Boxford Road	Single Culvert	5.0	2.1	7.1
32	9017	Newbury	Off Middle Road	Single Culvert	5.0	2.0	7.0
33	1155	West Newbury	Georgetown Road	Multiple Culvert	5.0	2.0	7.0
34	292	Hamilton	Alan Road	Single Culvert	5.0	2.0	7.0
35	484	Boxford	Middleton Road	Single Culvert	4.0	3.0	7.0

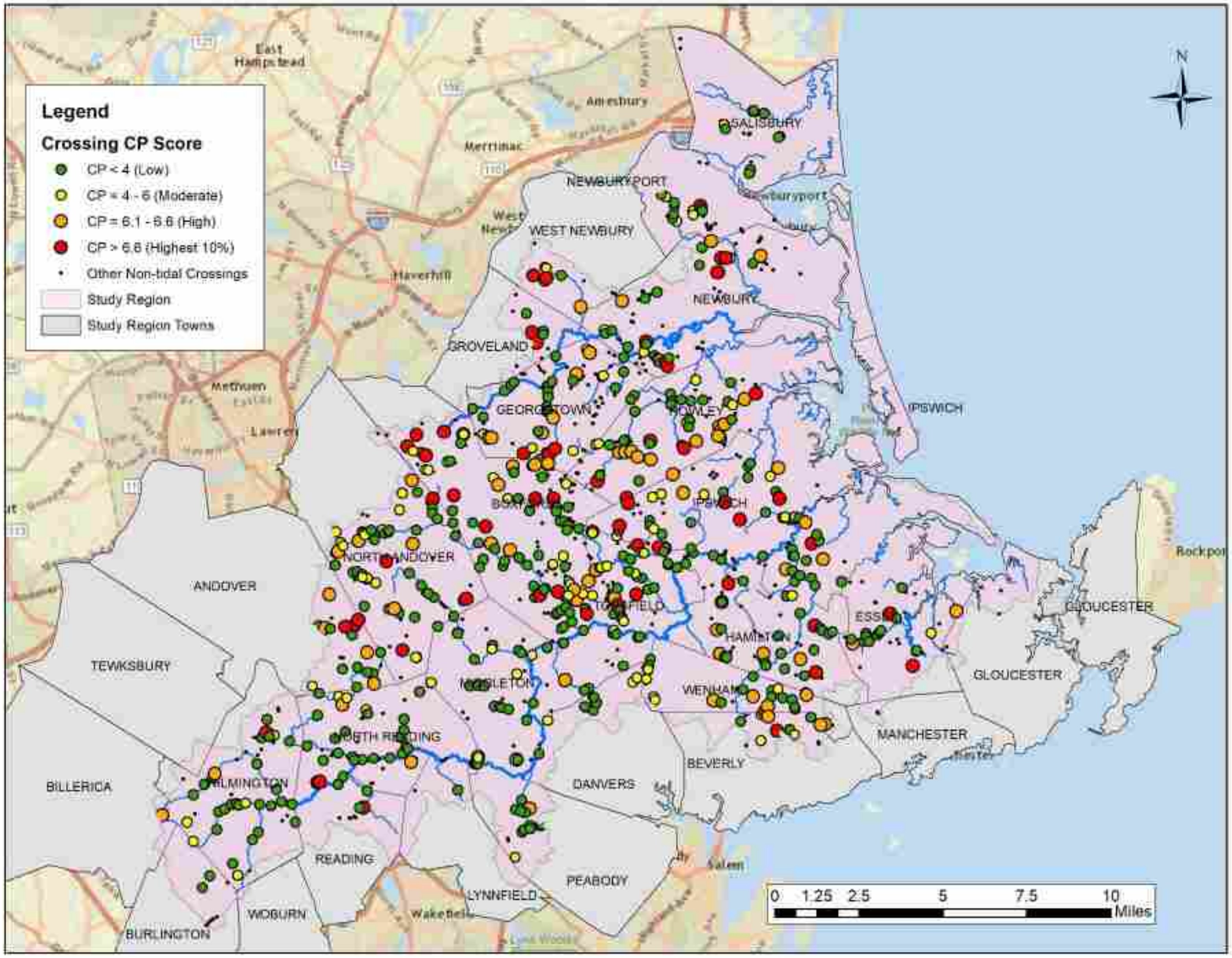

Figure 10. Map of the Great Marsh study region showing non-tidal road-stream crossings prioritized by Crossing Priority (CP) score.

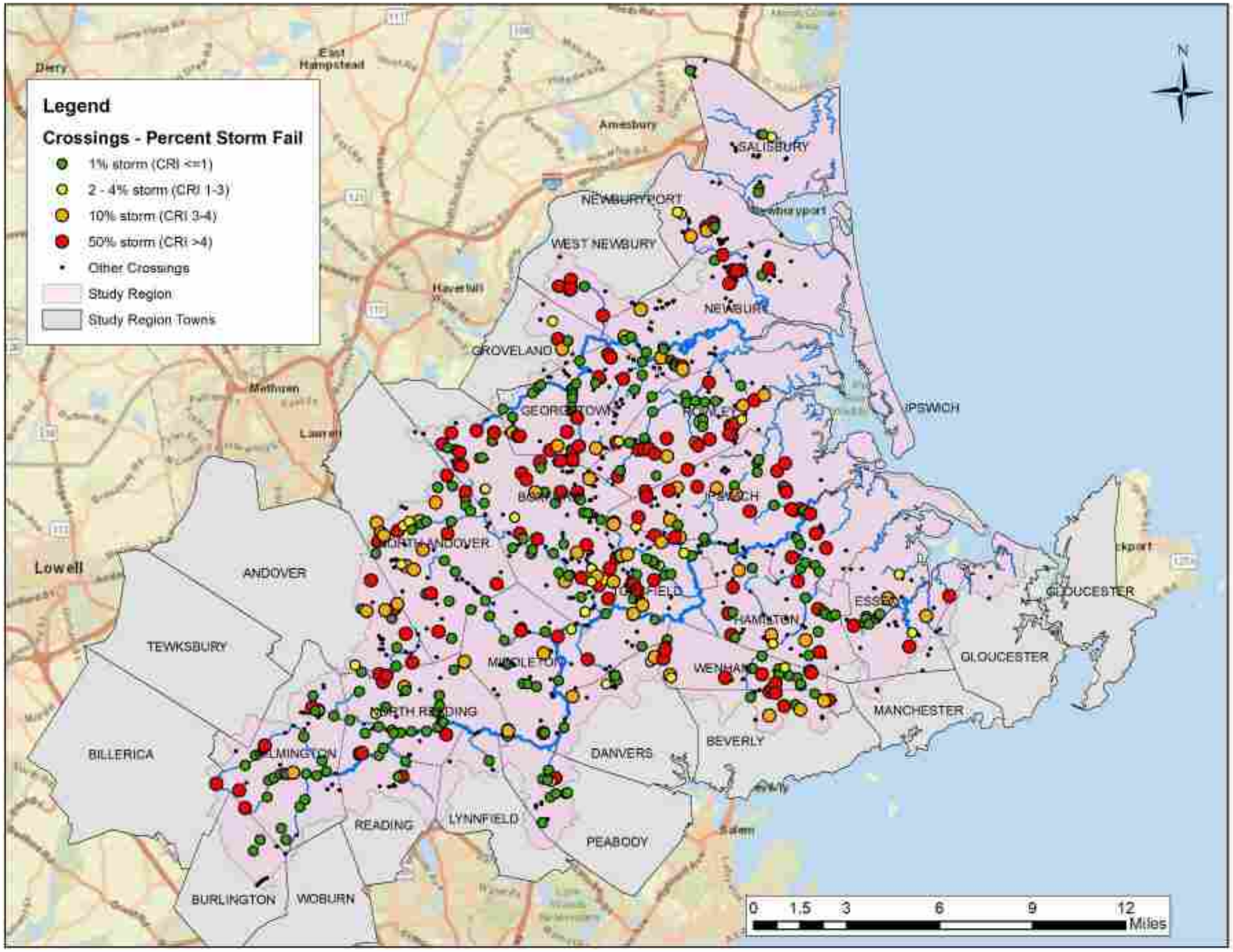

Figure 11. Map of the Great Marsh study region showing non-tidal road-stream prioritized by Crossing Infrastructure Risk Index (CRI) and the percent storm at which it is expected to fail to adequately pass flows.

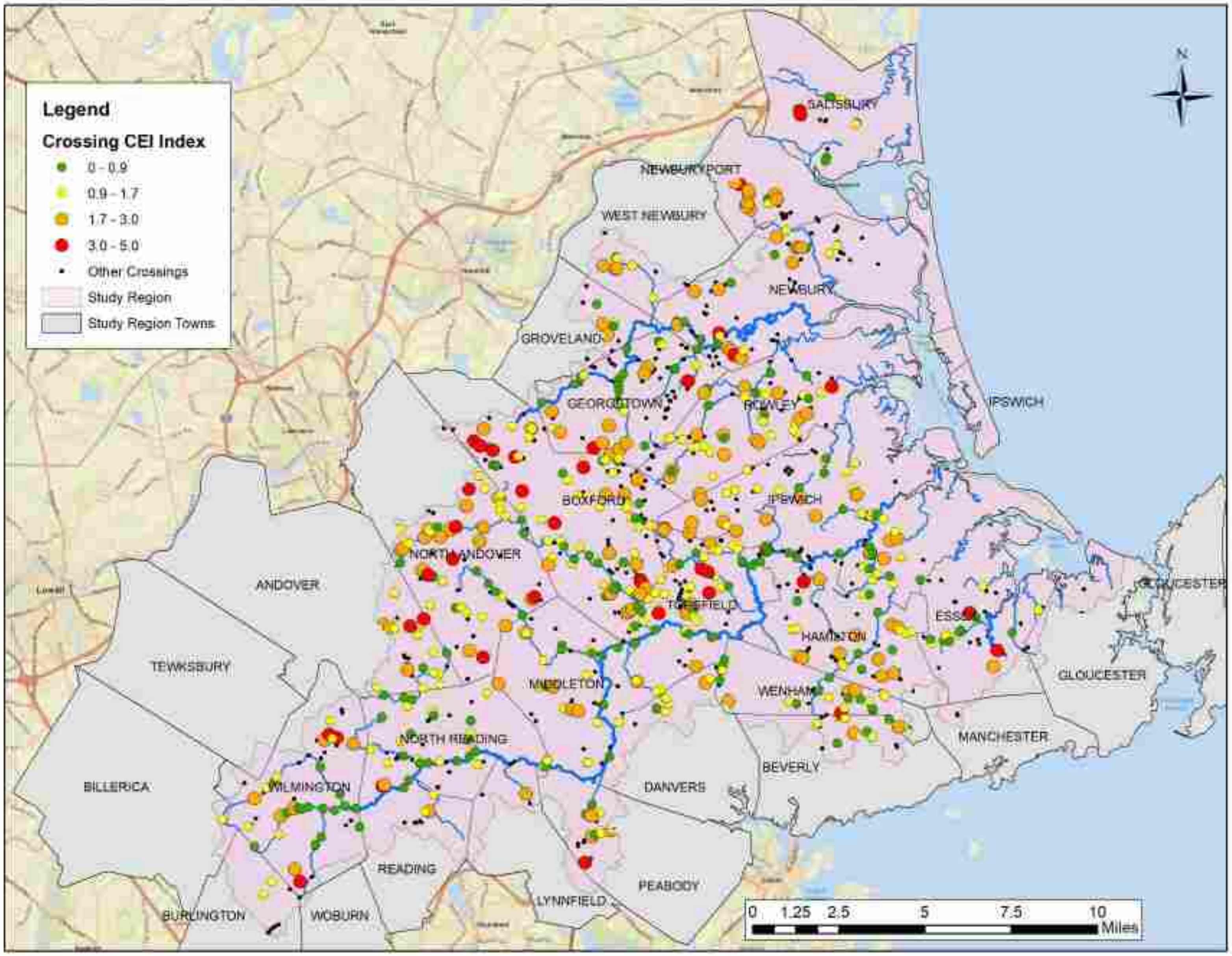

Figure 12. Map of the Great Marsh study region showing non-tidal road-stream crossings prioritized by Crossing Ecological Impact Index (CEI).

Tidal Crossings

Based on a detailed review of 23 tidal crossings encountered during our field surveys and 121 site records in the Draft Great Marsh Plan, we identified a total of 86 tidal crossings in the study region. Sixty-nine (80%) of those 86 crossings were located under a public way and more than half (44) were associated with a tidally restricted salt marsh identified in the Draft GMP. As noted in the methods section, prioritizing tidal crossings with rapid screening techniques is a challenge. A group of partners led by UMass Amherst is currently developing and testing a rapid assessment technique for ecological connectivity at tidal crossings which we tested in our study region in the summer of 2017. Once the protocol is finalized and available for use, these sites can be assessed using the new protocol which will be adopted as a formal module in the NAACC assessment framework.

Based on our tidal crossing screening criteria 37% (32) are high, 12% (10) medium and 51% (44) low priority for further investigation. The spatial distribution of the prioritized tidal crossings is mapped in Figure 13. Salisbury has the most (12) high priority tidal crossings in the study region followed by Newbury (9) and Ipswich (7) as shown in Table 10. The cities of Gloucester and Newburyport don't have any high priority tidal crossings that were part of this study.

Table 10. High priority tidal crossings in the Great Marsh study region.

Town	Crossing ID	Road/Site	Public Way	GMP Priority Marsh	Local Priority
Essex	17107	Route 133	Yes	Medium	
	17108	Old Essex Road	Yes	Medium	
	17109	Behind Town Hall	No	High	
	436	Eastern Ave	Yes	Low	Yes
	406	Landing Road	Yes	NIP	Yes
Ipswich	660	Argilla Road (Labor in Vain Creek)	Yes	Medium	
	6864	Labor in Vain Road (Labor in Vain Creek)	Yes	Medium	
	17240	MBTA Marsh West of Rowley River (N)	Yes	Medium	
	17241	MBTA Marsh West of Rowley River (S)	Yes	Medium	
	17242	Town Farm Road North	Yes	Medium	
	17243	Town Farm Road South	Yes	Medium	
	17246	Trustees East side of Castle Hill	No	High	
Newbury	17329	Route 1A - 500 ft N of Rowley Line	Yes	High	
	17330	Route 1A - Rowley Town Line	Yes	High	
	17343	Newman Road East of Little River	Yes	High	
	17331	River Front	Yes	Medium	
	17344	Kents Island Road	No	Medium	Yes
	1192	Hanover Street	Yes	Low	Yes
	17334	Boston Road	Yes	Low	Yes
	1196	Newburyport Turnpike (Little River)	Yes	NIP	Yes
	17336	MBTA - Little River S of Boston Road	Yes	NIP	Yes
Rowley	17462	Red Gate Road	Yes	Medium	
Salisbury	10104	Ferry Road	Yes	High	
	10107	Route 1 (Town Creek)	Yes	High	
	10108	State Reservation Road	Yes	Medium	
	10117	State Reservation Road	Yes	Medium	
	10118	State Reservation Road	Yes	Medium	
	17471	Rail Trail	No	High	
	17472	Rail Trail	No	High	
	17473	Route 1	Yes	High	
	17474	Old County Road	Yes	Medium	
	17475	Old County Road	Yes	Medium	
	17477	March Road	Yes	High	
	17478	1st Street	Yes	High	

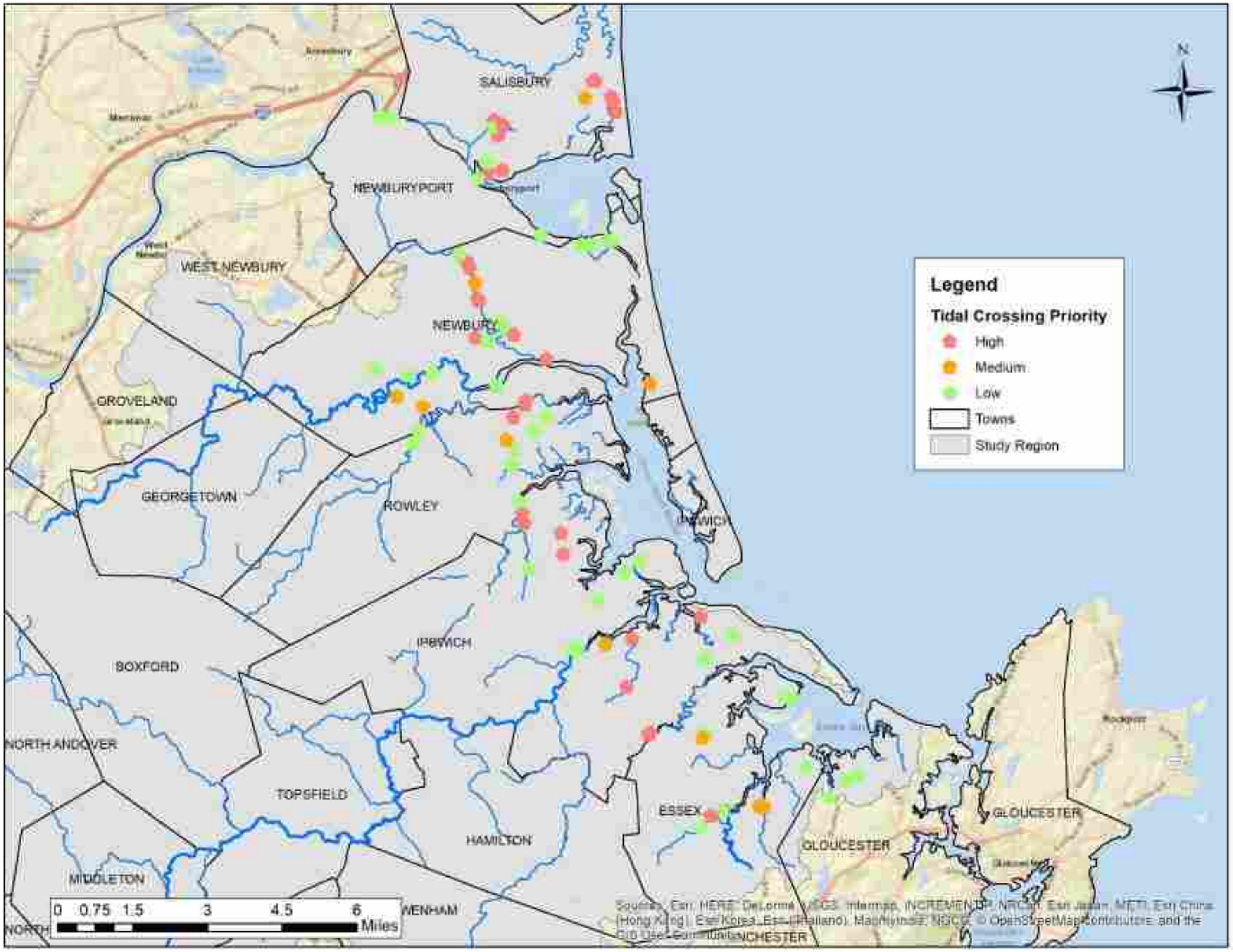

Figure 13. Map of the Great Marsh study region showing prioritized tidal crossings.

Coastal Stabilization Structures

We evaluated a total of 87 coastal stabilization structures as part of this study using the existing data sets from MA Office of Coastal Zone Management (CZM) on public and private shoreline stabilization structures. Within the study region there are 27 public structures and 60 private structures covering almost 6,000 linear meters (3.7 miles) of shoreline (Table 11). Since the CZM inventory of private stabilization structures was conducted by remote sensing methods, the condition of the private structures was not available.

Of the 27 public structures, 1 was identified as high priority and 9 were moderate priority with the remaining 17 (63%) in good condition and therefore low priority (Table 11). Ninety five percent (57) of the private shoreline stabilization structures are located in the municipalities of Ipswich, Newbury and Newburyport. Newburyport (17 structures) and Salisbury (7 structures) together have more than half (63%) of the public structures. Across the region, the vast majority of stabilization structures are located around the mouths of the Merrimack and Ipswich rivers (Figure 14). The areas associated with Salisbury Beach, the Parker River National Wildlife Refuge, Crane Beach and Essex Bay show few signs of hardened shorelines within these data sets.

Table 11. Summary of coastal stabilization structures in the Great Marsh study region. Structure totals include structure count and cumulative length.

Structure Category	Structure Priority	Count	Length (meters)
Public	High	1	32
	Moderate	9	458
	Low	17	2223
Private	NA	60	3259
Total		**87**	**5972**

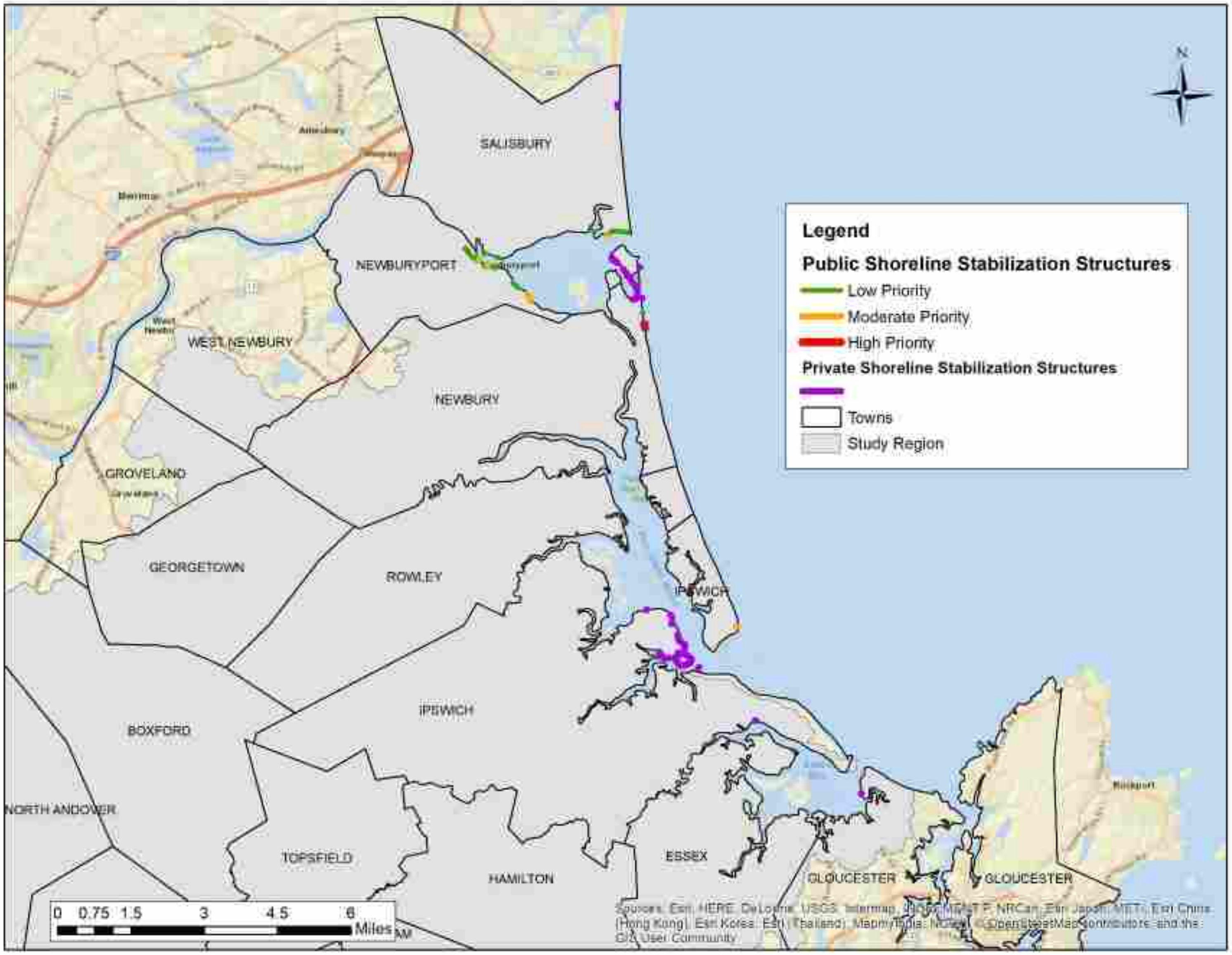

Figure 14. Map of the Great Marsh study region showing prioritized coastal stabilization structures.

Crossing Replacement Designs

Meridian Associates, Inc. (MAI) developed conceptual designs for 103 high priority crossings in the region. The structures designed were almost exclusively non-tidal crossings (101), but two sites were tidal crossings for which the engineering team felt comfortable proposing conceptual designs. These designs can provide a starting point for municipalities and other crossing owners to more easily incorporate more resilient and long-lived structures into their bridge and culvert maintenance schedules. We hope the plans are useful tools to help with scoping, budgeting and fundraising associated with crossing upgrades. A summary of the number of crossings designed by municipality is shown below (Table 12). Figure 15 shows the distribution of designed crossings throughout the Great Marsh study region. Please refer to Appendix 3 for the full package of designs and recommendations prepared by MAI and IRWA.

Table 12. Summary of conceptual designs for crossing replacement by municipality.

Municipality	Number of Crossings Designed
Andover	5
Boxford	15
Essex	3
Georgetown	4
Hamilton	3
Ipswich	4
Middleton	3
Newbury	12
Newburyport	2
North Andover	10
Reading	1
Rowley	6
Salisbury	5
Topsfield	14
Wenham	3
West Newbury	2
Wilmington	11
Total	**103**

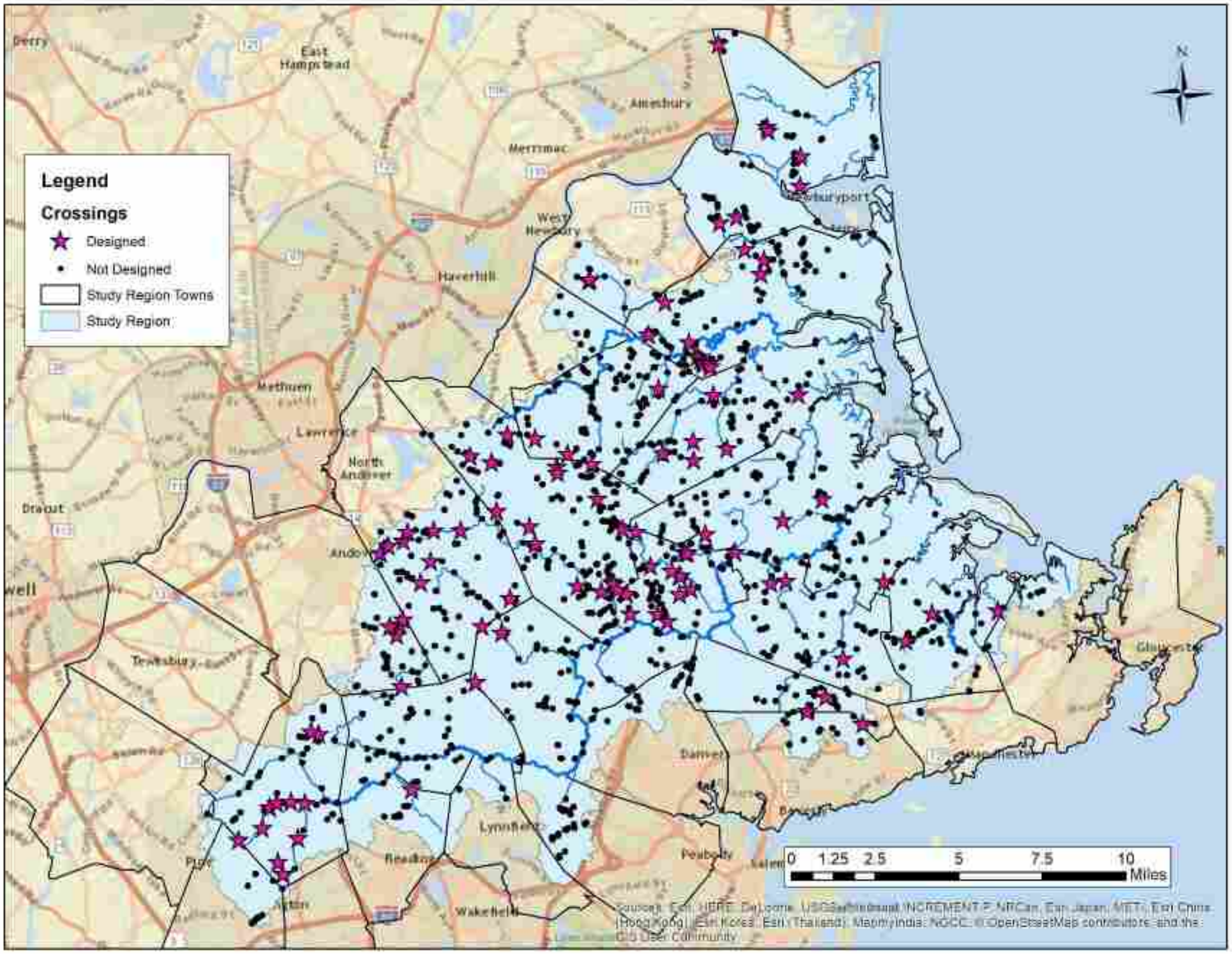

Figure 15. Map of the Great Marsh study region showing crossing sites for which conceptual designs were developed as part of the project.

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Appendix 1 – Coastal Municipality Summary Reports

This appendix contains town-specific summary reports for the coastal municipalities in the Great Marsh study region. These seven municipalities contain areas within the tidally influenced portion of the study region and therefore may have all four barrier types considered in our analysis. The municipalities are listed in Table 1 and the summary reports follow in alphabetical order. No report was produced for the City of Gloucester because only a very small portion of the city and few barriers fell within the study region.

Table 1. Alphabetical list of coastal towns in the Great Marsh study region showing the total number of each barrier type assessed within the surveyed portions of each municipality. The area column represents the land area of the municipality that falls within the study region. **No report was produced for the City of Gloucester because only a very small portion of the city and few barriers fell within the study region.*

Town	Area (square miles)	Dams	Non-Tidal Stream Crossings	Tidal Crossings	Shoreline Stabilization Structures	Structures Designed
Essex	13.0		38	12		3
*Gloucester	2.9		3	3	1	
Ipswich	32.4	6	87	17	25	4
Newbury	23.4	9	80	26	21	12
Newburyport	8.8	4	34	4	31	2
Rowley	18.6	6	76	9		6
Salisbury	16.0		20	15	9	5

Table of Contents (Appendix 1)

Essex

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Essex. This project was conducted by the Ipswich River Watershed Association (IRWA) as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and the PIE-Rivers Region[1].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. Here we provide detailed results from the prioritization of the four barrier types. For more detail on prioritization methods as well as region-wide priorities see the main report[2].

Figure 1. Outlet of non-tidal crossing at Andrews Street in Essex (Site #308).

The majority of Essex is located in the study region, covering an area of approximately 13.0 square miles. Essex is one of seven municipalities with land within the coastal portion of the Great Marsh study region and two of the four structure types are present (Figure 3). Our analysis considered a total of 29 structures including 17 non-tidal crossings (Table 2) and 12 tidal crossings (Table 3). This study did not identify any dams or coastal stabilization structures in the Town of Essex.

We were able to inventory and prioritize a total of 17 of the 38 known non-tidal crossings in the Town of Essex[3]. Our screening tools suggest that a number of these structures warrant a closer look for possible upgrade. Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (Ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The two highest priority based on combined ecological and infrastructure risk were also among the top 50 sites region-wide (Table 2). The four crossings that scored the poorest are single culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance. Any crossing with infrastructure

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[1] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[2] Full report document available at http://www.pie-rivers.org/barriers/

[3] The overall percentage of the total non-tidal crossings prioritized is relatively low due to a combination of factors. Most of the sites not surveyed were high in the watershed on very small tributaries. Additionally some sites were skipped due to site-specific access and safety issues. Regardless, this regional effort represents a far more complete understanding of road-stream crossings than in almost any other watershed system in the Commonwealth.

risk index (CRI) scores above 4 is showing possible inability to pass flow from storms that have a 50% chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms.

Our screening evaluation identified five high priority tidal crossings (Table 3). High priority tidal crossings were identified based on the combination of their association with a public road (public way), whether they were listed as priority sites in the Draft Great Marsh Coastal Wetlands Restoration Plan[4] and whether they had been identified as a priority by municipal other partners. Our methodology for assessing tidal crossing structures was less quantitative than the ones we used to assess non-tidal crossings, but given increasing sea level and storm intensities any structure already subject to tidal exchange is at risk. The tidal crossing on Landing Road (Site #406) was identified as a high priority crossing by the Town of Essex based on its location and history of storm-related flooding. This crossing provides the only point of access for the Essex Transfer Station and other Department of Public Works assets that would be needed during a large storm event. We would suggest that the structures that we have identified as high priority are worth a closer, more rigorous analysis where and when possible.

Figure 2. Outlet of tidal road-stream crossing at Eastern Avenue in Essex (Site #436).

As part of this study, Meridian Associates, Inc. (MAI) developed sketch conceptual sketch designs for the replacement of 3 non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[5]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Essex Designs begin on page 213

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[4] Developed by Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration) - 2006

[5] A design was prepared for a crossing on Harry Homans Drive (Site #361) that was not flagged as a high priority by the screening tools. The site was identified as a high priority in the preliminary results used to choose crossings and was later significantly downgraded in priority during a quality control review of the model results. While this structure does not appear to be a high priority for replacement, we have included the designs which would provide some improvement for both wildlife passage and flood conveyance.

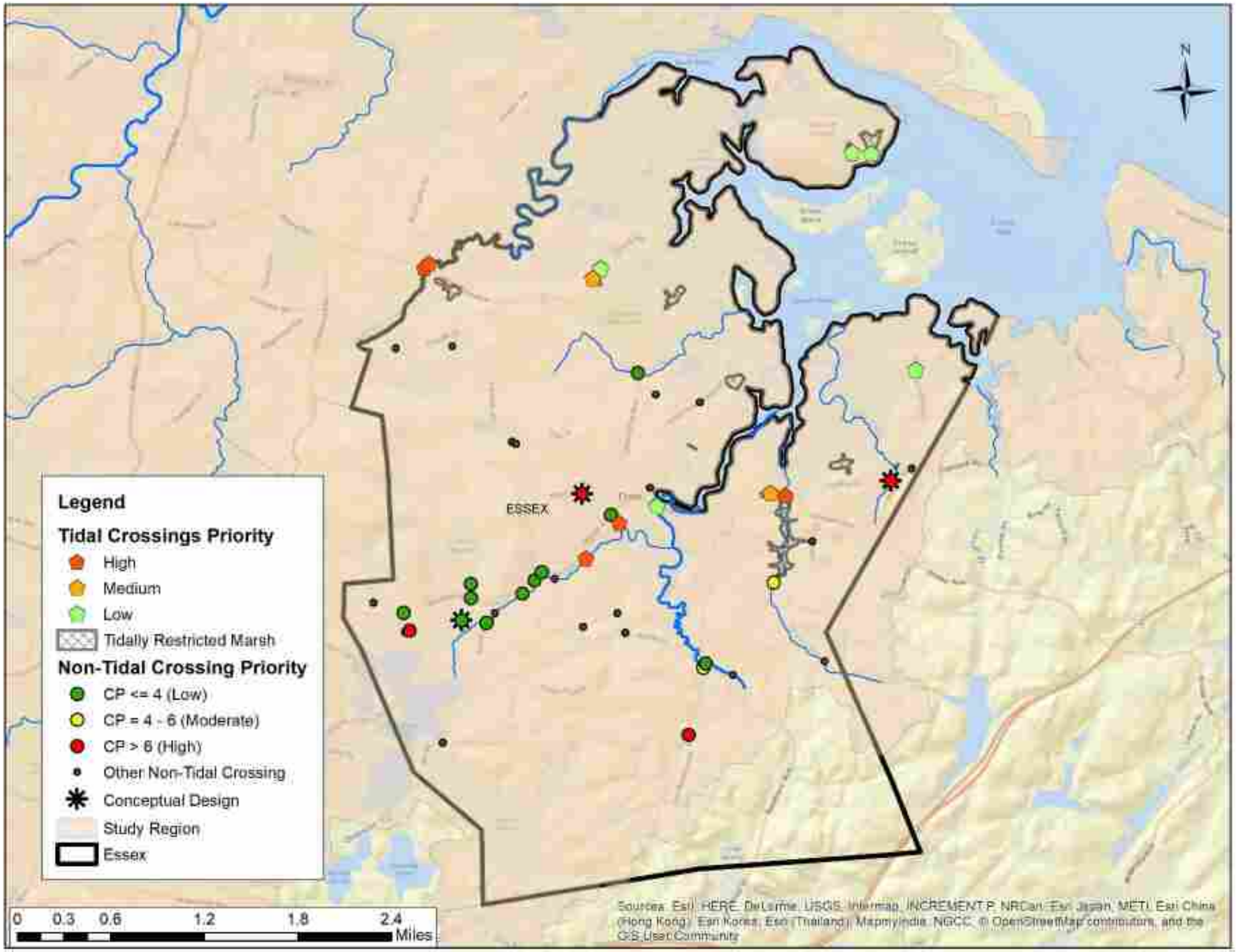

Figure 3. Map showing locations and prioritization scores for non-tidal and tidal crossings for the portion of the Great Marsh Study region within the Town of Essex, MA. Locations of crossings with available conceptual designs as well as suspected tidally restricted marshes are also noted.

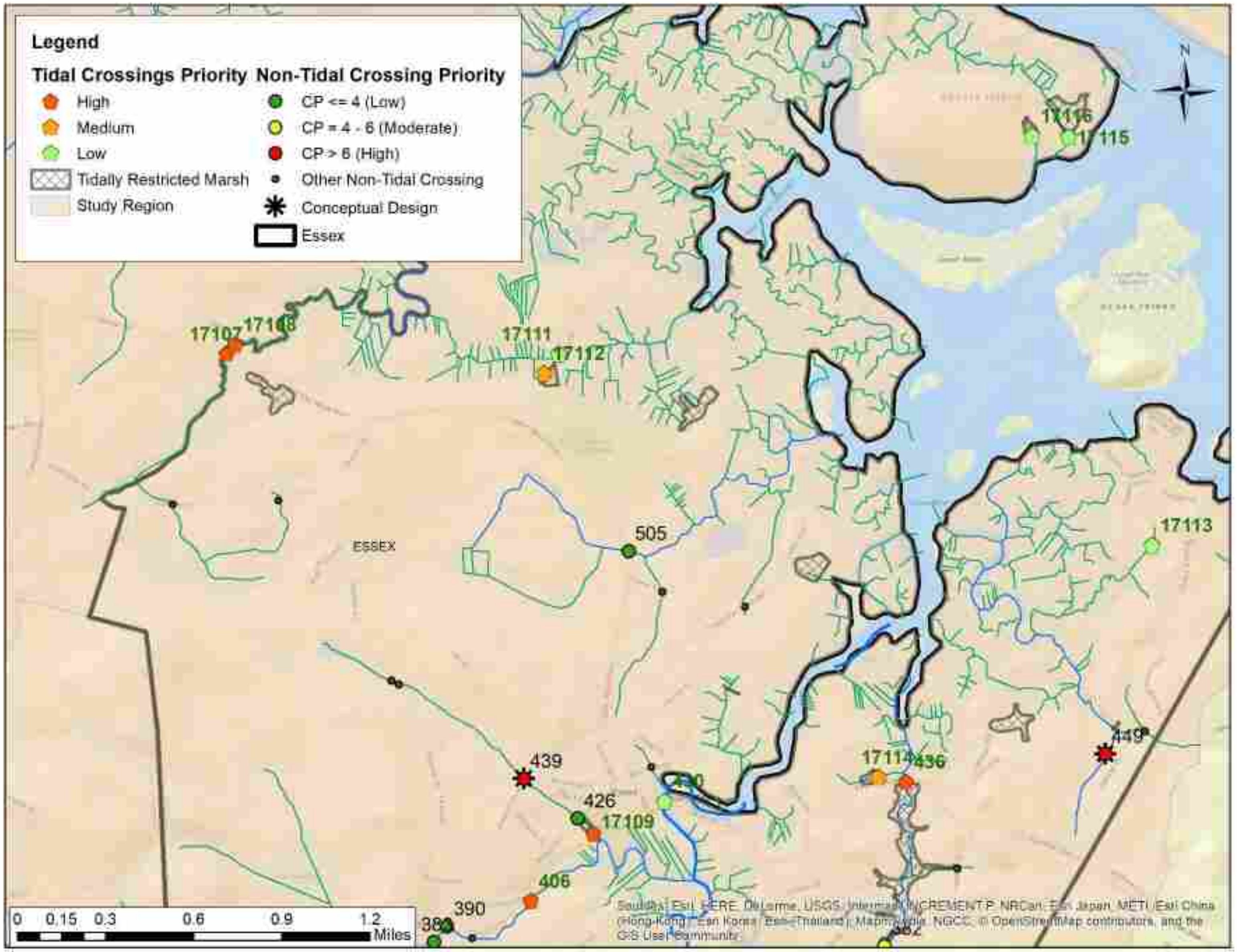

Figure 4. Prioritized non-tidal and tidal crossings in the Great Marsh Study region within the northern portion of the Town of Essex, MA. Non-tidal crossing ID shown in black and tidal crossing ID shown in green.

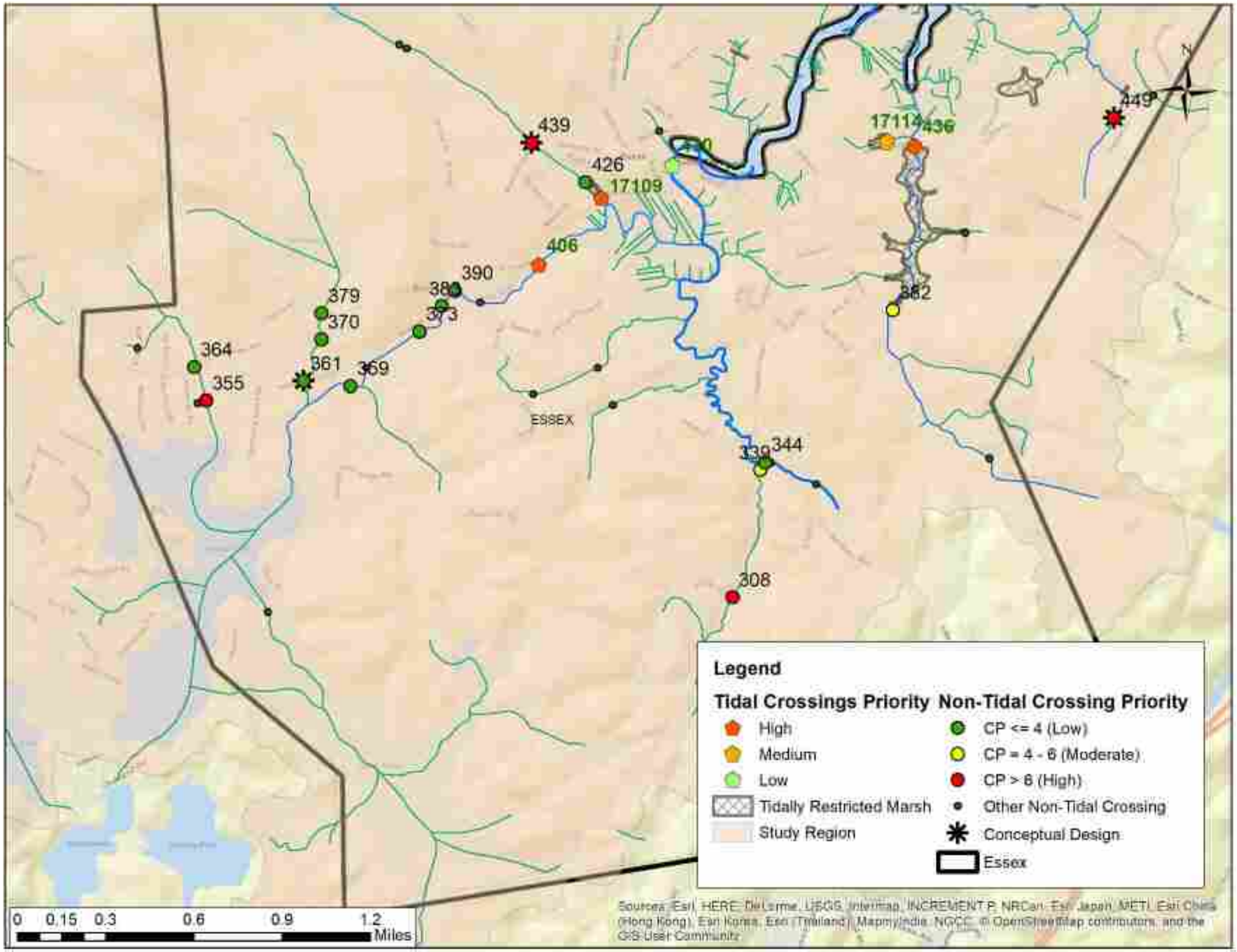

Figure 5. Prioritized non-tidal and tidal crossings in the Great Marsh Study region within the southern portion of the Town of Essex, MA. Non-tidal crossing ID shown in black and tidal crossing ID shown in green.

Table 2. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Essex, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
439	1	19	Story Street	Single Culvert	4.0	3.7	7.7	Yes
308	2	48	Andrews Street	Single Culvert	5.0	1.8	6.8	
449	3	71	Lufkin Road	Single Culvert	5.0	1.6	6.6	Yes
355	4	75	Icehouse Lane	Single Culvert	5.0	1.6	6.6	
382	5	214	Grove Street	Bridge	4.0	0.7	4.7	
339	6	229	Apple Street	Single Culvert	2.6	1.7	4.3	
505	7	239	John Wise Avenue	Bridge	2.6	1.3	3.9	
344	8	240	Southern Avenue	Single Culvert	NA	3.9	3.9	
426	9	249	Martin Street	Single Culvert	2.6	0.8	3.4	
370	10	340	Western Ave	Single Culvert	0.0	1.7	1.7	
379	11	382	County Rd	Single Culvert	0.0	1.4	1.4	
373	12	424	Essex Park Road	Single Culvert	0.0	1.2	1.2	
361	13	514	Harry Homans Drive	Open Bottom Arch	0.0	0.6	0.6	Yes
364	14	530	Western ave	Open Bottom Arch	NA	0.5	0.5	
359	15	559	Pond Street	Bridge	0.0	0.3	0.3	
390	16	583	Apple Street	Open Bottom Arch	0.0	0.2	0.2	
383	17	596	Off Park Road	Bridge	0.0	0.1	0.1	

Table 3. Prioritized tidal crossings in the portion of the Great Marsh study region within the Town of Essex, MA. Sites with available conceptual designs and/or associated rapid technical assessments (RTA) from the Draft Great Marsh Coastal Wetlands Restoration Plan are noted.

Crossing ID	Road/Site	Public Way	GMP Priority Marsh	Local Priority	Tidal Crossing Priority	Design or RTA
17107	Route 133	Yes	Medium		High	
17108	Old Essex Road	Yes	Medium		High	
17109	Behind Town Hall	No	High		High	
436	Eastern Ave	Yes	Low	Yes	High	RTA
406	Landing Road	Yes	NIP	Yes	High	
17112	Island Road	Yes	Low		Medium	RTA
17114	North of Eastern Ave	Yes	Low		Medium	RTA
430	Main Street	Yes	NIP		Low	
17111	Island Road	Yes	NIP		Low	
17113	Conomo Point Road	Yes	NIP		Low	
17115	East side of Choate Island - marsh behind Long Island	No	Low		Low	
17116	East side of Choate Island - southwest of white cottage	No	Low		Low	

Ipswich

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Ipswich. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[6].

Figure 6. Ipswich Mills Dam (MA00231)

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. Here we provide detailed results from the prioritization of the four barrier types. For more detail on prioritization methods as well as region-wide priorities see the main report[7]. The entire town of Ipswich is located in the study region, covering an area of approximately 32.4 square miles. Ipswich is one of seven municipalities with land within the coastal portion of the Great Marsh study region and all four structure types are present (Figure 8). Our analysis considered a total of 103 structures including 5 dams (Table 4), 56 non-tidal crossings (Table 5), 17 tidal crossings (Table 6), and 25 coastal stabilization structures (Table 7).

The Ipswich Mills Dam is the highest priority dam in Ipswich and is the 5th ranked dam across the study region as a whole (Table 4). The Ipswich Mills Dam is owned by the Town and has been a high priority of river restoration advocates for a number of years. A dam removal feasibility study is underway as of 2017, but no decision has been made to remove the structure. The active project at the Willowdale Dam is a planned fishway replacement being led by the private dam owner (Foote Brothers Canoe & Kayak Rentals) and the MA Division of Marine Fisheries.

We were able to inventory and prioritize a total of 56 non-tidal crossings in the Town of Ipswich. While none of these seem to stand alone as highest priority for immediately investigating replacement and upgrade, our screening tools suggest that a number of them warrant a closer look. Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The six highest priority based on combined ecological and infrastructure risk were also among the top 50 sites region-wide (Table 5). Most of the poorly scored crossings are single

[6] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[7] Full report document available at http://www.pie-rivers.org/barriers/

culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance. Any crossing with an infrastructure risk index (CRI) score above 4 is showing possible inability to pass flow from storms that have a 50% chance of occurring on any given year. While this does not indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms.

Figure 7. Outlet of tidal crossing at Argilla Road and Labor in Vain Creek (Site #660).

Our evaluation identified seven high priority tidal crossings (Table 6). High priority tidal crossings were identified based on the combination of their association with a public road (public way), whether they were listed as priority sites in the Draft Great Marsh Coastal Wetlands Restoration Plan[8] and whether they had been identified as a priority by municipal other partners. Our methodology for assessing tidal crossing structures was less quantitative than the ones we used to assess non-tidal crossings, but given increasing sea level and storm intensities any structure already subject to tidal exchange is at risk. We would suggest that the structures that we have identified as high priority are worth a closer, more rigorous analysis where and when possible.

There are 25 coastal stabilization structures identified in the Town of Ipswich all but one of which are private structures (Table 7). The only public structure is located on Plum Island and is flagged as a moderate priority in our screening based on its condition score. There is a total of more than two kilometers of hardened shoreline in Ipswich with by far the heaviest concentration being on the shores of Little Neck and Great Neck (Figure 8).

As part of this study, Meridian Associates, Inc. (MAI) developed sketch conceptual sketch designs for the replacement of 4 high priority non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[9]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Ipswich designs begin on page 226

[8] Developed by Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration) - 2006

[9] The Gravelly Brook crossing of Topsfield Road (Site #616) was selected for design based on its ecological priority and maintenance condition. The crossing designed on Chebacco Road (Site #6610) was selected based on flooding issues flagged by the Ipswich Department of Public Works.

Table 4. Dams in the portion of the Great Marsh study region within the Town of Ipswich, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank		Dam Name	Priority Scoring			Active/ Priority Project
	Town	Region		Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA00231	1	5	Ipswich Mills Dam	0.5	1.5	2	Active
MA01207	2	12	Rantoul Pond Dam	0.5	1	1.5	
MA00276	3	20	Willowdale Dam	0	1.5	1.5	Active
MA02989	4	30	Argilla Farm Pond Dam	0	1	1	
MA00165	NA	NA	Dow Brook Reservoir Dam	1	1	2	
MA00230	NA	NA	Bull Brook Reservoir Dam	0.5	1	1.5	

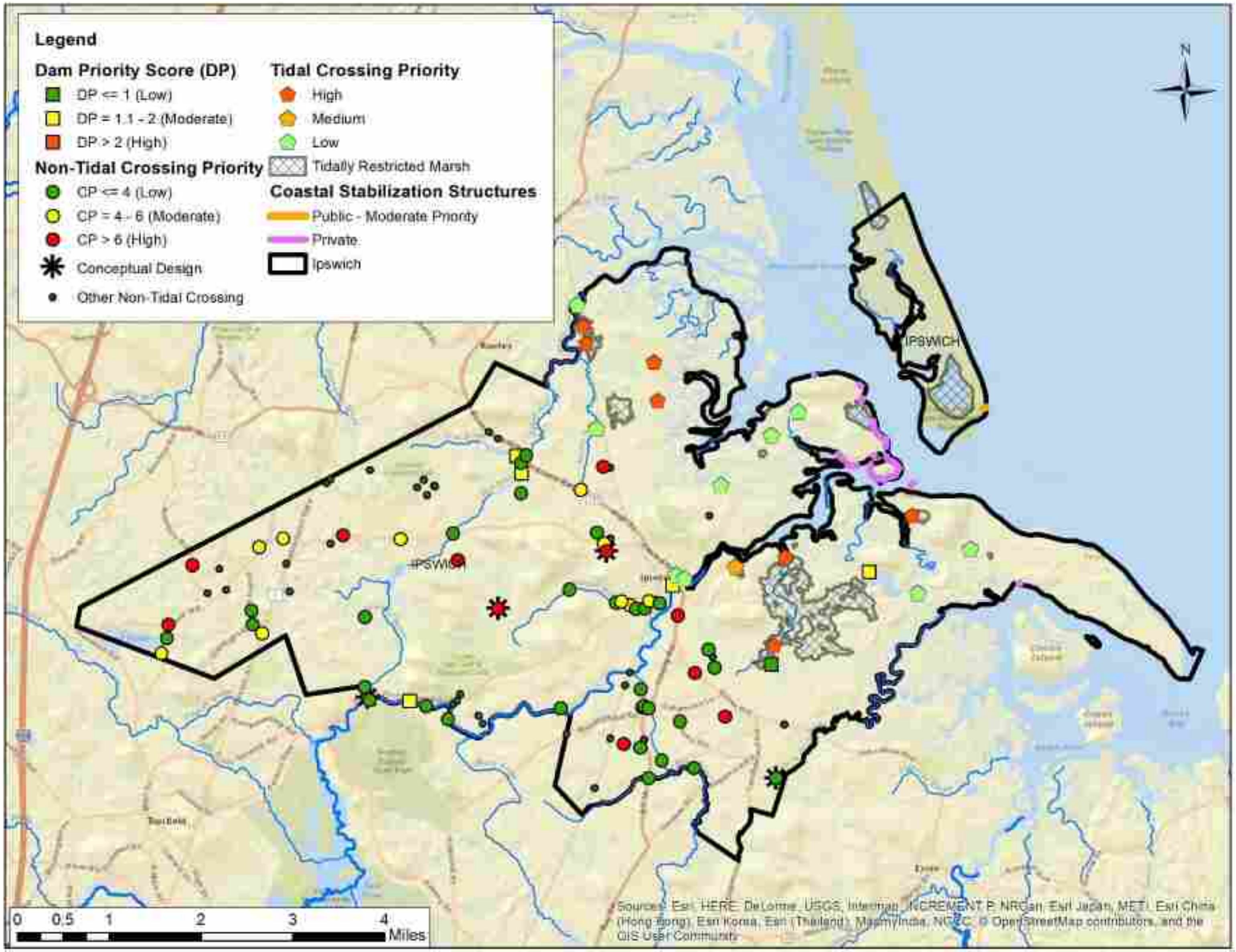

Figure 8. Map showing locations and prioritization scores for dams, non-tidal crossings, tidal restrictions and coastal stabilization structures for the Great Marsh Study region within the Town of Ipswich, MA. Crossings with available conceptual designs and suspected tidally restricted marshes are also noted.

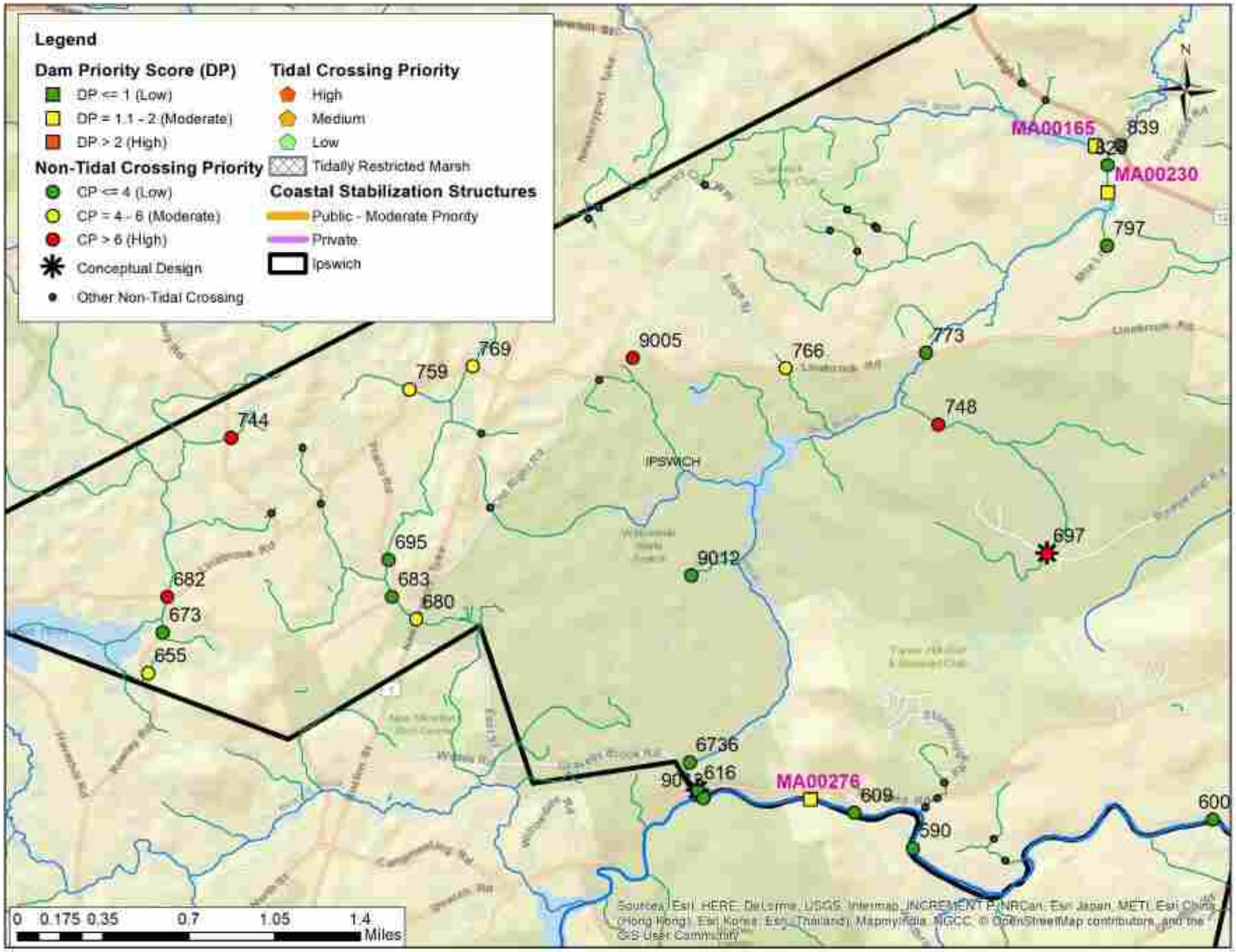

Figure 9. Prioritized structures in the Great Marsh Study region within the western portion of the Town of Ipswich, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

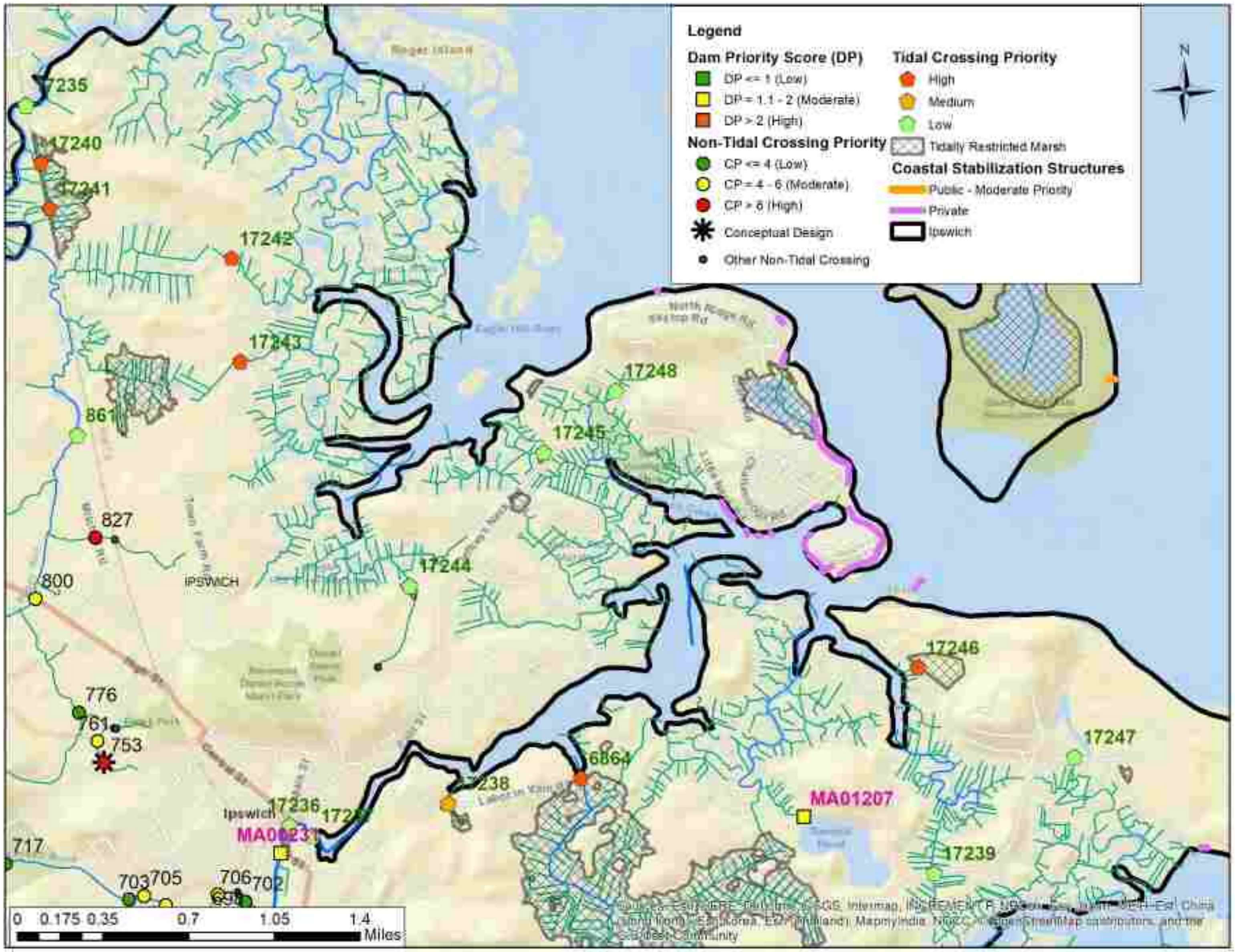

Figure 10. Prioritized structures in the Great Marsh Study region within the northeastern portion of the Town of Ipswich, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

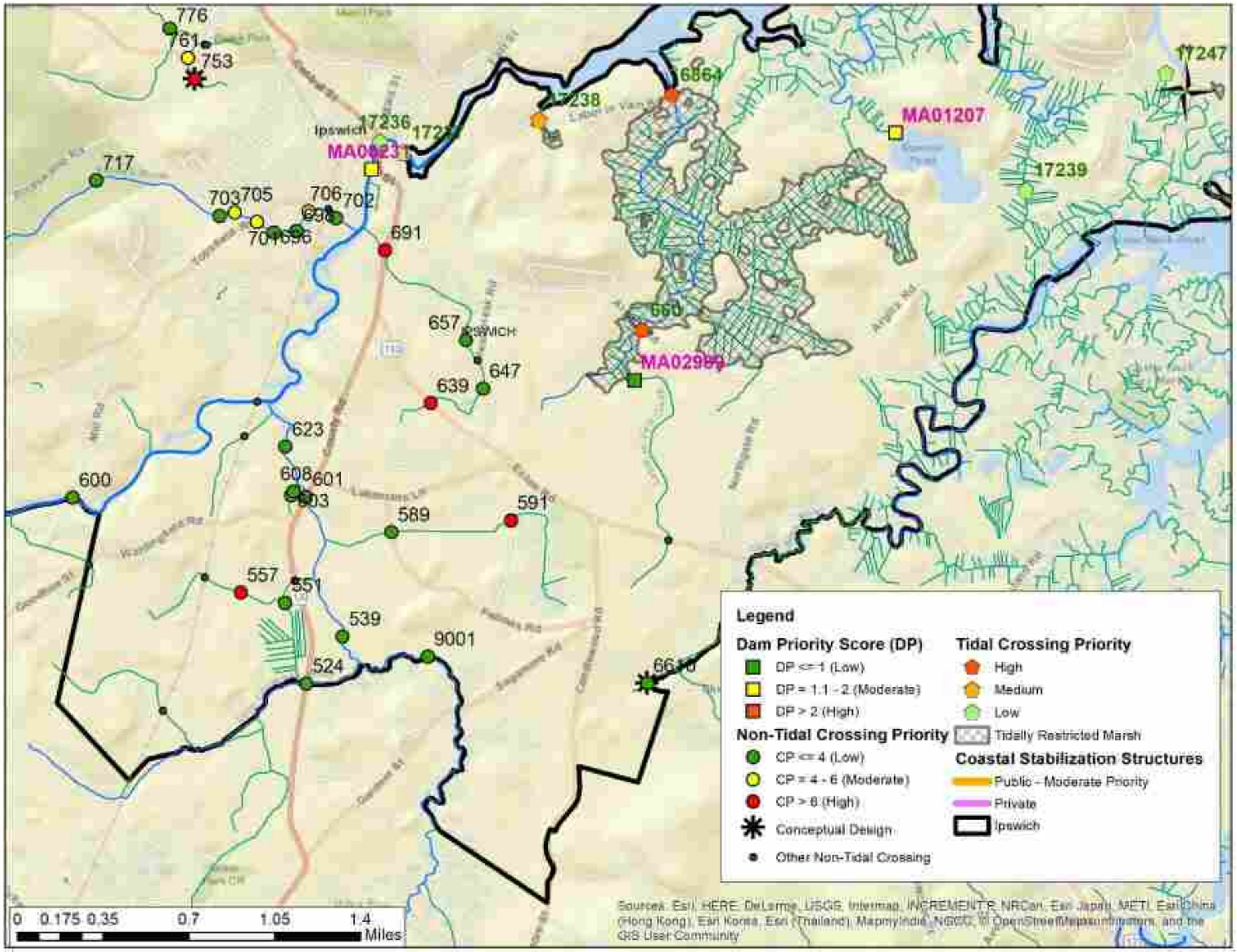

Figure 11. Prioritized structures in the Great Marsh Study region within the southeastern portion of the Town of Ipswich, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

Table 5. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Ipswich, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 1 of 2)

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
753	1	16	Pineswamp Road	Single Culvert	5.0	2.9	7.9	Yes
639	2	26	Essex Road	Single Culvert	5.0	2.4	7.4	
697	3	43	Pineswamp Road	Single Culvert	5.0	1.8	6.8	Yes
748	4	44	Pineswamp Road	Single Culvert	4.0	2.8	6.8	
744	5	45	Newbury Road	Single Culvert	5.0	1.8	6.8	
682	6	49	Boxford Road	Single Culvert	5.0	1.8	6.8	
591	7	90	Heatherside Lane	Single Culvert	5.0	1.4	6.4	
9005	8	93	Linebrook Road	Single Culvert	5.0	1.4	6.4	
827	9	114	Mitchell Road	Multiple Culvert	5.0	1.2	6.2	
691	10	123	County Rd	Bridge	5.0	1.1	6.1	
557	11	126	Off Waldingfield Road	Single Culvert	5.0	1.1	6.1	
759	12	135	Linebrook Road	Open Bottom Arch	5.0	1.0	6.0	
705	13	146	Hodgkins	Single Culvert	4.6	1.2	5.8	
706	14	148	Hayward Street	Bridge	4.6	1.2	5.8	
769	15	163	Linebrook Road	Single Culvert	4.0	1.6	5.6	
800	16	172	High Street	Single Culvert	4.6	0.9	5.5	
761	17	185	Linebrook Rd	Single Culvert	4.0	1.3	5.3	
680	18	186	Newburyport Turnpike	Single Culvert	4.0	1.3	5.3	
766	19	198	Linebrook Road	Single Culvert	4.0	1.1	5.1	
701	20	199	Topsfield Road	Bridge	4.6	0.4	5.0	
655	21	211	Linebrook Road	Single Culvert	3.0	1.8	4.8	
616	22	248	Topsfield Road	Single Culvert	0.0	3.4	3.4	Yes
776	23	256	School Street	Single Culvert	1.6	1.5	3.1	
647	24	287	Heartbreak Road	Single Culvert	NA	2.4	2.4	
683	25	290	Old Right Road	Single Culvert	NA	2.3	2.3	
608	26	296	County Rd	Single Culvert	NA	2.2	2.2	
589	27	309	Fellows Road	Multiple Culvert	NA	2.0	2.0	
603	28	311	County Rd	Single Culvert	NA	1.9	1.9	
9012	29	318	Off Road	Single Culvert	NA	1.9	1.9	

Table 5 (continued). Non-tidal crossings in the portion of the Great Marsh study region within the Town of Ipswich, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 2 of 2)

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
828	30	351	High Street	Single Culvert	0.0	1.6	1.6	
657	31	353	Off Heartbreak Road	Single Culvert	NA	1.6	1.6	
673	32	374	Linebrook Road	Single Culvert	NA	1.5	1.5	
797	33	379	Mile Lane	Multiple Culvert	0.6	0.9	1.5	
698	34	410	Peabody Street	Multiple Culvert	NA	1.3	1.3	
703	35	431	Heard Drive	Single Culvert	NA	1.1	1.1	
539	36	436	Unnamed Road	Multiple Culvert	0.0	1.1	1.1	
524	37	437	Route 1A	Single Culvert	0.0	1.1	1.1	
695	38	453	Plains Road	Single Culvert	NA	1.0	1.0	
6610	39	469	Chebacco Road	Culvert	NA	0.9	0.9	Yes
551	40	482	Off Route 1A	Single Culvert	NA	0.8	0.8	
696	41	483	Safford Street	Single Culvert	NA	0.8	0.8	
773	42	485	Linebrook Road	Single Culvert	0.0	0.8	0.8	
717	43	496	Pineswamp Road	Bridge	0.6	0.1	0.7	
590	44	504	Off Winthrop Street	Bridge	0.0	0.7	0.7	
609	45	508	Willowdale Road	Bridge	NA	0.7	0.7	
839	46	515	High Street	Bridge	0.0	0.6	0.6	
702	47	517	Kimball Street	Bridge	0.0	0.6	0.6	
623	48	543	Unnamed Road	Bridge	0.0	0.5	0.5	
601	49	546	Route 1A	Bridge	0.0	0.4	0.4	
6736	50	557	Off Road	Bridge	0.0	0.3	0.3	
9001	51	571	Unnamed Road	Bridge	0.0	0.3	0.3	
9013	52	597	Off Topsfield Road	Bridge	NA	0.1	0.1	
600	53	607	Mill Road	Open Bottom Arch	NA	0.0	0.0	

Table 6. Prioritized tidal crossings in the portion of the Great Marsh study region within the Town of Ipswich, MA. Sites with available conceptual designs and/or associated rapid technical assessments (RTA) from the Draft Great Marsh Coastal Wetlands Restoration Plan are noted.

Crossing ID	Road/Site	Public Way	GMP Priority Marsh	Local Priority	Tidal Crossing Priority	Design or RTA
660	Argilla Road (Labor in Vain Creek)	Yes	Medium		High	RTA
6864	Labor in Vain Road (Labor in Vain Creek)	Yes	Medium		High	RTA
17240	MBTA Marsh West of Rowley River (N)	Yes	Medium		High	
17241	MBTA Marsh West of Rowley River (S)	Yes	Medium		High	
17242	Town Farm Road North	Yes	Medium		High	
17243	Town Farm Road South	Yes	Medium		High	
17246	Trustees East side of Castle Hill	No	High		High	
17238	Labor in Vain Road West of Riverside Drive	Yes	Low		Medium	
861	Muddy Run East of Paradise Road	No	NIP		Low	
17235	MBTA (Rowley River)	Yes	NIP		Low	
17236	Choate Bridge (Ipswich River)	Yes	NIP		Low	
17237	County Street Bridge (Ipswich River)	Yes	NIP		Low	
17239	Argilla Road (Fox Creek)	Yes	NIP		Low	
17244	West of Jeffrey's Neck Road South of Greenwod Farm Road	No	NIP		Low	
17245	West of Jeffrey's Neck Road North of Island Park	No	NIP		Low	
17247	Argilla Road (Castle Neck Creek)	Yes	NIP		Low	
17248	Little Neck Road West of Mulholland Dr	Yes	NIP		Low	

Table 7. Coastal stabilization structures in in the portion of the Great Marsh study region within the Town of Ipswich, MA.

Structure Category	Structure Priority	Structure Type	Structure ID	Location Note	Length (meters)
Public	Moderate	Groin/ Jetty	036-016-000-002-100	Plum Island	39
Private	NA	Revetment	144-024C-069-000-001		601
		Revetment	144-024A-097-000-002		304
		Revetment	144-024A-106-000-001		146
		Revetment	144-023D-052K-000-001		139
		Bulkhead/Seawall	144-024C-069-011-001		110
		Revetment	144-024C-069-000-002		89
		Groin/Jetty	144-000-000-000-001		80
		Revetment	144-024C-069-000-007		70
		Bulkhead/Seawall	144-024C-069-000-006		55
		Revetment	144-034-002-000-001		52
		Bulkhead/Seawall	144-015D-029-000-001		49
		Revetment	144-015D-014-000-001		44
		Bulkhead/Seawall	144-024A-112-000-001		40
		Revetment	144-023D-086-000-001		33
		Bulkhead/Seawall	144-024C-195-000-001		30
		Bulkhead/Seawall	144-024C-069-000-004		28
		Revetment	144-024C-069-000-003		24
		Bulkhead/Seawall	144-024A-111-000-001		21
		Bulkhead/Seawall	144-024A-097-000-001		20
		Bulkhead/Seawall	144-024A-102-000-001		20
		Groin/Jetty	144-015A-013-000-001		19
		Revetment	144-024C-069-000-005		18
		Revetment	144-023D-052D-000-001		18
		Groin/Jetty	144-023D-052C-000-001		14
Total					**2063**

Newbury

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Newbury. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation and included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[10].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. Here we provide detailed results from the prioritization of the four barrier types. For more detail on prioritization methods as well as region-wide priorities see the main report[11].

The majority of Newbury is located in the study region, covering an area of approximately 23.4 square miles. Newbury is one of seven municipalities with land within the coastal portion of the Great Marsh study region and all four structure types are present (Figure 14). Our analysis considered a total of 86 structures including 9 dams (Table 8), 30 non-tidal crossings (Table 9), 26 tidal crossings (Table 10), and 21 coastal stabilization structures (Table 11).

Figure 12. Parker River Dam #2 (Larkin Road Dam) in Newbury (MA00240)

The Parker River Dam #1 (a.k.a. Central Street Dam) is the highest priority dam in Ipswich and is tied for 5th ranked dam across the study region based on our numeric screening system (Table 8). This dam has an actively managed fishway that is closely monitored and maintained during the annual river herring migration and has been passing alewife and blueback herring quite effectively in recent years. The Parker River Dam #2 (a.k.a. Larkin Road Dam) farther upstream appears to present more of a migration barrier and failure risk based on professional judgment. The Larkin Dam and fishway are both in need of significant maintenance and the fishway seems to be less effective at passing river herring. The Larkin Dam was the subject of a dam removal feasibility study which found the cost of removal would be less than the cost of repair. Since the dam no longer serves its design purpose, the Town of Newbury has been seeking funds to remove the structure and restore the river at that site.

We inventoried and prioritized a total of 30 non-tidal crossings in the Town of Newbury. The screening results identify several high priority crossings including six crossings that are among the 50 poorest scoring sites in the

[10] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[11] Full report document available at http://www.pie-rivers.org/barriers/

region based on combined ecological and infrastructure risk (Table 9). The crossing on Parker Street/Scotland Road (Site #1203) at the Newburyport city line has been identified as a local priority for replacement due to flooding and maintenance concerns. This 2-cell culvert spans the town boundary and the two municipalities share ownership of it. It is the second highest priority non-tidal crossing in the City of Newburyport. Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (Ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The five crossings that scored the poorest are all single culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance. Any crossing with infrastructure risk index (CRI) scores above 4 is showing possible inability to pass flow from storms that have a 50% chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms.

Figure 13. Perched outlet of non-tidal crossing at Coleman Road in Newbury (Site #1054)

Our evaluation identified nine high priority tidal crossings (Table 10). Four high priority crossings (1192, 17334, 1196 and 17336) along the Little River were identified by town representatives as areas of concern due to flow restriction. These sites have shown visible restriction of outgoing flow (i.e. hydraulic head loss from upstream to downstream) during past large storm events and may contribute to upstream flooding[12]. High priority tidal crossings were identified based on the combination of their association with a public road (public way), whether they were listed as priority sites in the Draft Great Marsh Coastal Wetlands Restoration Plan[13] and whether they had been identified as a priority by municipal other partners. Our methodology for assessing tidal crossing structures was less quantitative than the ones we used to assess non-tidal crossings, but given increasing sea level and storm intensities any structure already subject to tidal exchange is at risk. We would suggest that the structures that we have identified as high priority are worth a closer, more rigorous analysis where and when possible. The Great Marsh Plan provides rapid technical assessments of three of the high priority tidal crossings identified in this analysis.

There is a total of 21 coastal stabilization structures identified in the Town of Newbury all but two of which are private structures (Table 11). One of the public structures, located east of the Dartmouth Way/Southern Boulevard intersection, is flagged as high priority in our screening. There is an estimated total of 719 meters of hardened shoreline in Newbury, mainly concentrated on the eastern shore of the Plum Island inlet known as The Basin (Figure 14).

As part of this study, Meridian Associates, Inc. (MAI) developed sketch conceptual sketch designs for the replacement of 12 high priority non-tidal crossings with structures designed to increase aquatic connectivity and

[12] John O'Connell, personal communication, January 22, 2018
[13] Developed by Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration) - 2006

resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[14]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Newbury designs begin on page 235

[14] Sites #1053, #1056, #1058 and #1069 are in succession on one stream and sites #1049 and #1054 are in succession on a neighboring stream both of which are tributaries to the Parker River.

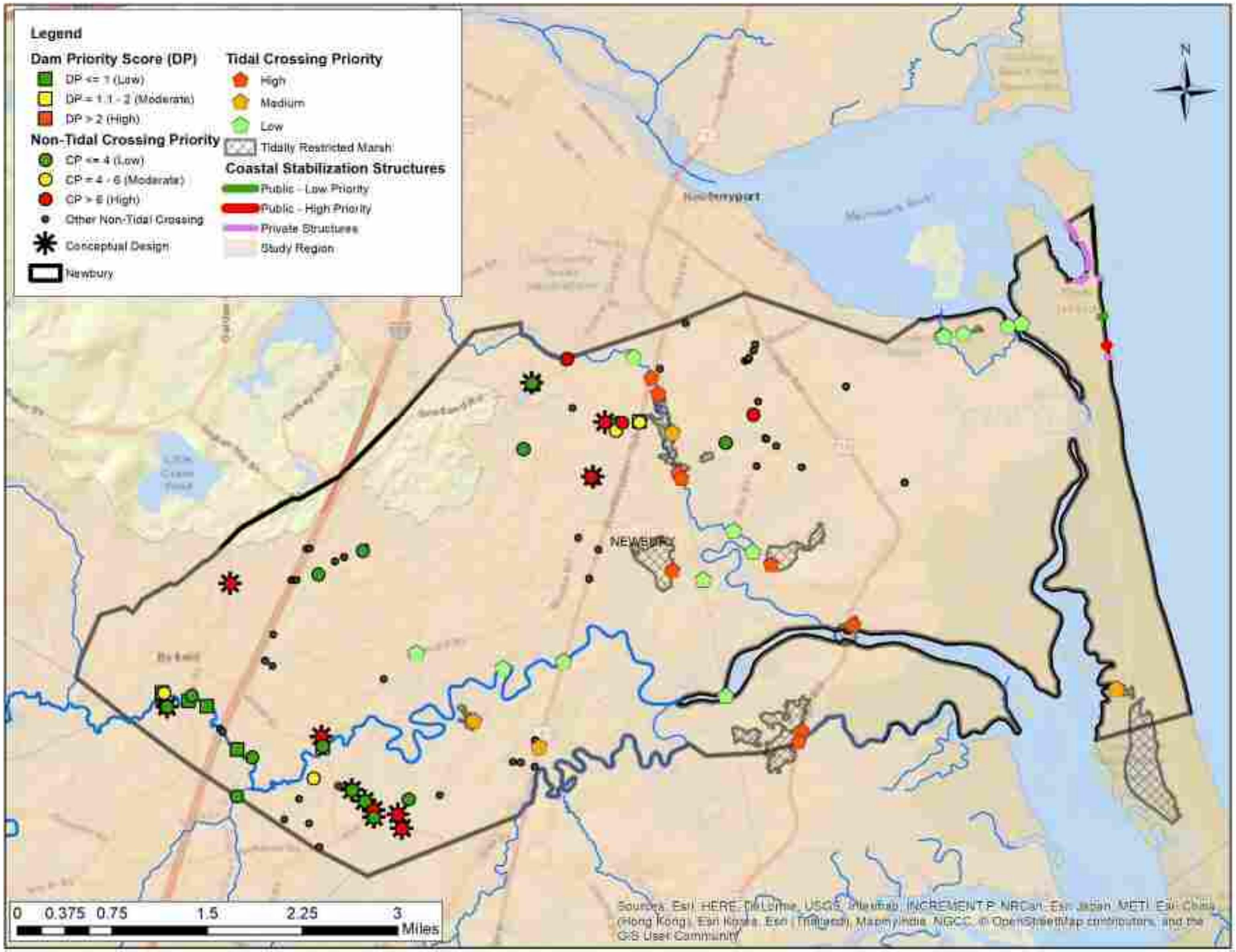

Figure 14. Map showing locations and prioritization scores for dams, non-tidal crossings, tidal restrictions and coastal stabilization structures for the Great Marsh Study region within the Town of Newbury, MA. Crossings with available conceptual designs and suspected tidally restricted marshes are also noted.

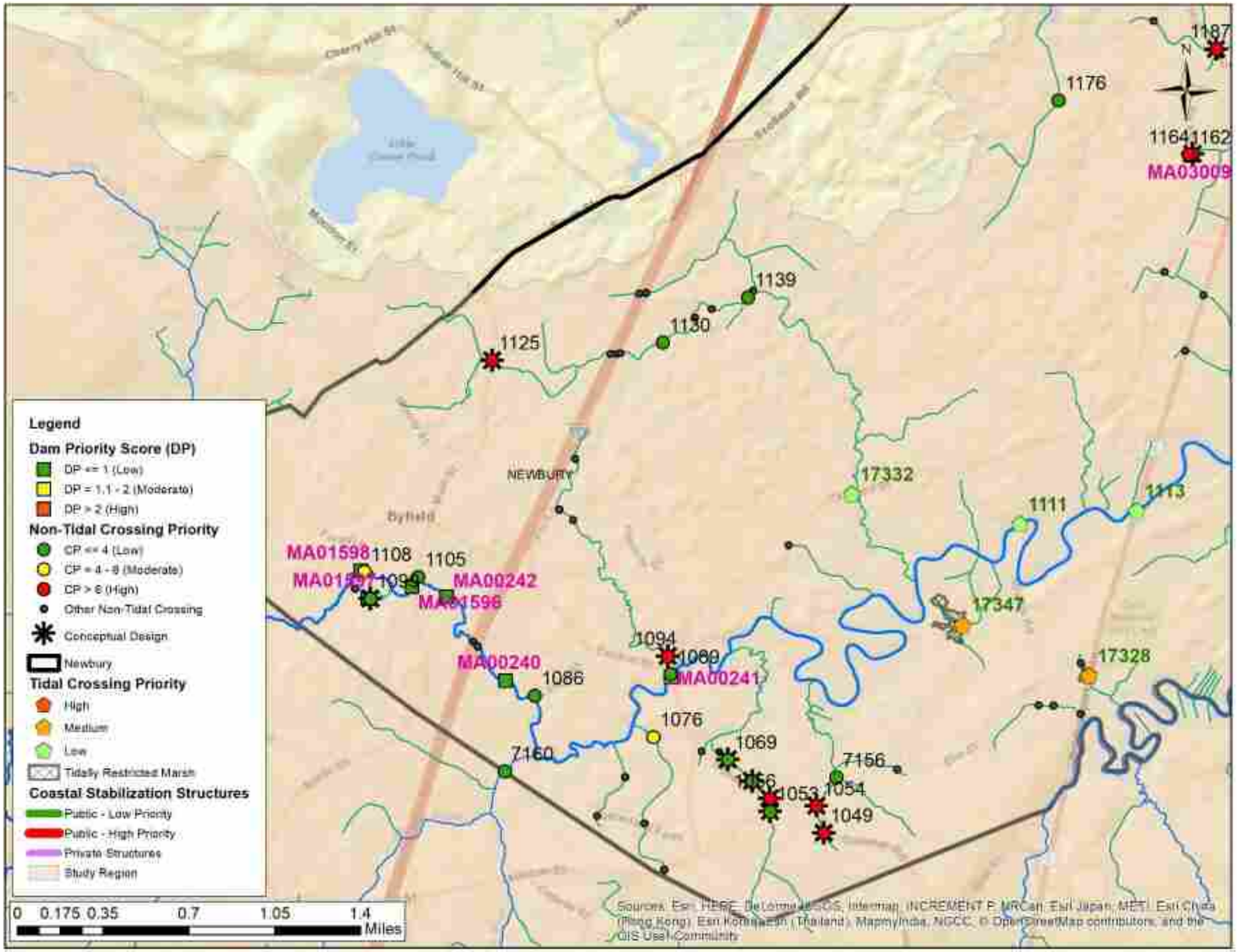

Figure 15. Prioritized structures in the Great Marsh Study region within the western portion of the Town of Newbury, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

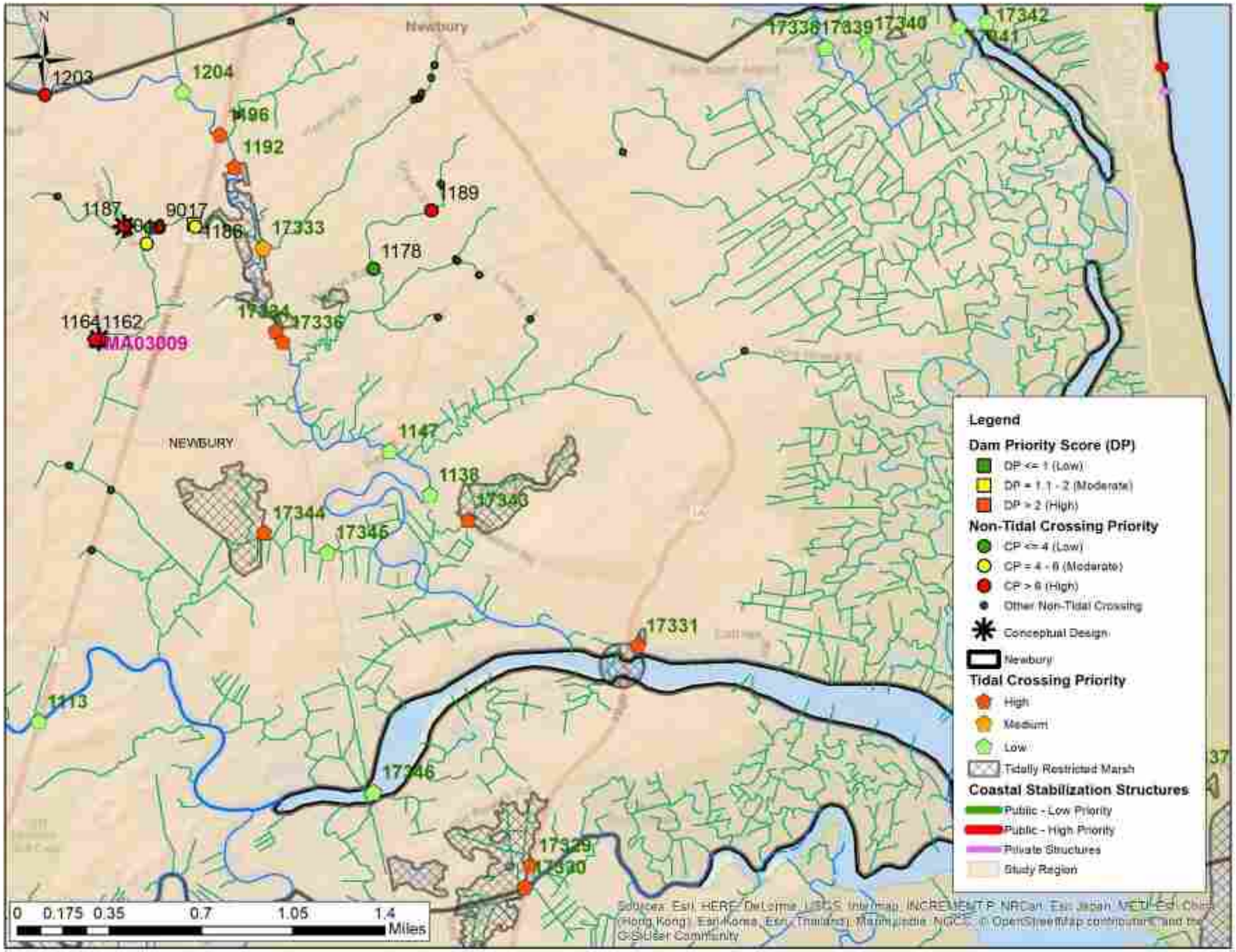

Figure 16. Prioritized structures in the Great Marsh Study region within the central portion of the Town of Newbury, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

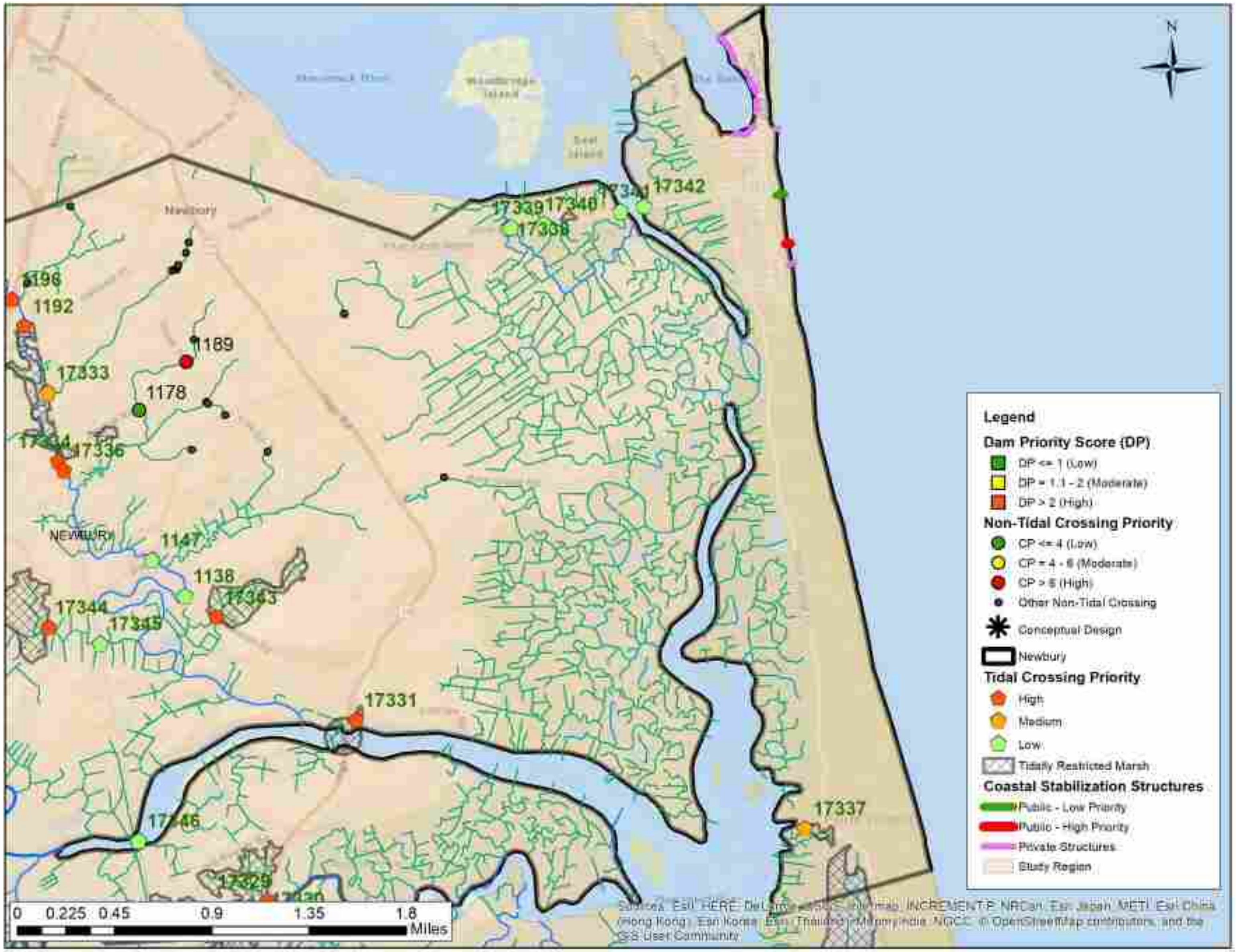

Figure 17. Prioritized structures in the Great Marsh Study region within the eastern portion of the Town of Newbury, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

Table 8. Dams in the portion of the Great Marsh study region within the Town of Newbury, MA prioritized by Dam Priority Score (DP). The Parker River Dam #2 (Larkin Dam) is flagged as a priority due to poor condition needed fishway maintenance.

	Priority Rank			Priority Scoring			Active/ Priority Project
Dam ID	Town	Region	Dam Name	Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA00241	1	5	Parker River Dam #1 (Central Street)	0.5	1.5	2	
MA01211	2	12	Mill Pond Dam	0.5	1	1.5	
MA03008	2	12	Blackwell Dam	0.5	1	1.5	
MA00240	4	30	Parker River Dam #2 (Larkin)	0	1	1	Priority
MA00242	4	30	Parker River Dam #4 (Blacksmith Shop)	0	1	1	
MA01596	4	30	Parker River Dam #3 (Snuff Mill)	0	1	1	
MA01598	4	30	Parker River Dam #5 (River Street)	0	1	1	
MA03009	4	45	Highfield Road Dam	0	1	1	
MA01597	9	45	Parker River Dam South At River St.	0	0.5	0.5	

Table 9. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Newbury, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. *Site #1203 is on the town line and ownership is shared with the City of Newburyport.

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
1054	1	5	Coleman Road	Single Culvert	5.0	3.9	8.9	Yes
1162	2	21	Off Middle Road	Single Culvert	4.6	3.0	7.6	
1094	3	22	Orchard Street	Single Culvert	2.6	5.0	7.6	Yes
9017	4	32	Off Middle Road	Single Culvert	5.0	2.0	7.0	
1049	5	40	Off Coleman Road	Single Culvert	4.0	2.9	6.9	Yes
1187	6	46	Highfield Road	Multiple Culvert	5.0	1.8	6.8	Yes
1125	7	74	Main Street	Multiple Culvert	4.0	2.6	6.6	Yes
1189	8	99	Green Street	Single Culvert	5.0	1.3	6.3	
1203	9*	103	Parker Street/Scotland Road	Multiple Culvert	5.0	1.3	6.3	
1056	10	106	School Street	Single Culvert	5.0	1.3	6.3	Yes
1164	11	133	Middle Road	Multiple Culvert	5.0	1.0	6.0	Yes
1186	12	167	Newburyport turnpike	Single Culvert	5.0	0.6	5.6	
9016	13	187	Off Middle Road	Bridge	4.0	1.3	5.3	
1076	14	205	Fatherland Drive	Multiple Culvert	4.0	0.9	4.9	
1108	15	221	River Road	Open Bottom Arch	3.6	0.8	4.4	
1053	16	255	Elm Street	Single Culvert	0.0	3.1	3.1	Yes
1069	17	274	Off School Street	Single Culvert	0.0	2.5	2.5	Yes
1130	18	291	Burns WMA West Road	Single Culvert	NA	2.2	2.2	
1058	19	293	Off School Street	Single Culvert	0.0	2.2	2.2	Yes
1185	20	300	Middle Road	Single Culvert	0.0	2.1	2.1	
1194	21	328	Scotland Road	Single Culvert	0.0	1.8	1.8	Yes
1099	22	337	River Street	Single Culvert	0.0	1.8	1.8	Yes
1089	23	361	Central Street	Open Bottom Arch	0.0	1.6	1.6	
7156	24	405	Elm Street	Multiple Culvert	NA	1.3	1.3	
1178	25	440	Boston Road	Single Culvert	0.0	1.1	1.1	
7160	26	481	Parish Road	Bridge	0.0	0.8	0.8	
1105	27	512	Main Street	Bridge	0.0	0.6	0.6	
1139	28	535	WMA power line and trail	Ford	NA	0.5	0.5	
1176	29	554	Off Highfield Road	Bridge	NA	0.4	0.4	
1086	30	585	Larkin Street	Bridge	0.0	0.2	0.2	

Table 10. Prioritized tidal crossings in the portion of the Great Marsh study region within the Town of Newbury, MA. Sites with available conceptual designs and/or associated rapid technical assessments (RTA) from the Draft Great Marsh Coastal Wetlands Restoration Plan are noted.

Crossing ID	Road/Site	Public Way	GMP Priority Marsh	Local Priority	Tidal Crossing Priority	Design or RTA
17329	Route 1A - 500 ft N of Rowley Line	Yes	High		High	RTA
17330	Route 1A - Rowley Town Line	Yes	High		High	RTA
17343	Newman Road East of Little River	Yes	High		High	RTA
17331	River Front	Yes	Medium		High	
17344	Kents Island Road	No	Medium	Yes	High	RTA
1192	Hanover Street	Yes	Low	Yes	High	
17334	Boston Road	Yes	Low	Yes	High	
1196	Newburyport Turnpike (Little River)	Yes	NIP	Yes	High	
17336	MBTA - Little River S of Boston Road	Yes	NIP	Yes	High	
17328	Newburyport Turnpike South End Newbury Golf Club	Yes	Low		Medium	
17333	MBTA West Bank Little River	Yes	Low		Medium	
17337	West of Plum Island Drive	No	Medium		Medium	
17347	West of Middle Road	No	Medium		Medium	
1111	Middle Road	Yes	NIP		Low	
1113	Newburyport Turnpike (Parker River)	Yes	NIP		Low	
1138	Newman Road (Little River)	Yes	NIP		Low	
1147	Hay Street	Yes	NIP		Low	
1204	Power Line Off Highfield Road	No	NIP		Low	
17332	Orchard Street	Yes	NIP		Low	
17338	Plum Island Turnpike (Plumbush Creek - West)	Yes	NIP		Low	
17339	Plum Island Turnpike (Plumbush Creek)	Yes	NIP		Low	
17340	Plum Island Turnpike West of Plum Bush Downs	Yes	NIP		Low	
17341	Plum Island Turnpike Bridge West	Yes	NIP		Low	
17342	Plum Island Turnpike Bridge East	Yes	NIP		Low	
17345	MBTA South of Hay Street	Yes	NIP		Low	
17346	MBTA (Parker River)	Yes	NIP		Low	

Table 11. Coastal stabilization structures in the portion of the Great Marsh study region within the Town of Newbury, MA.

Structure Category	Structure Priority	Structure Type	Structure ID	Location Note	Length (meters)
Public	Low	Groin/ Jetty	050-002U-000-029-100	Plum Island Boulevard	59
	High	Groin/ Jetty	050-002U-000-044-100	Plum Island - Dartmouth Way	32
Private	NA	Bulkhead/Seawall	205-U04-000-078-001		29
		Revetment	205-U04-000-077-001		17
		Bulkhead/Seawall	205-U04-000-074-001		71
		Bulkhead/Seawall	205-U04-000-072-001		32
		Bulkhead/Seawall	205-U04-000-070-001		21
		Bulkhead/Seawall	205-U04-000-069-001		23
		Revetment	205-U04-000-067-001		34
		Bulkhead/Seawall	205-U04-000-066-001		10
		Revetment	205-U04-000-009-001		12
		Revetment	205-U04-000-003-001		113
		Revetment	205-U03-000-166-001		43
		Revetment	205-U03-000-133-001		42
		Revetment	205-U03-000-123-001		38
		Groin/Jetty	205-U03-000-187-001		19
		Bulkhead/Seawall	205-U03-000-163-001		26
		Bulkhead/Seawall	205-U03-000-162-001		15
		Revetment	205-U03-000-128-001		19
		Bulkhead/Seawall	205-U03-000-129-001		18
		Groin/Jetty	205-U01-000-010-001		45
Total					**719**

Newburyport

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the City of Newburyport. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and the PIE-Rivers Region[15].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. Here we provide detailed results from the prioritization of the four barrier types. For more detail on prioritization methods as well as region-wide priorities see the main report[16].

The entire City of Newburyport is located in the study region, covering an area of approximately 8.8 square miles. Newburyport is one of seven municipalities with land within the coastal portion of the Great Marsh study region and all four structure types are present (Figure 19). Our analysis considered a total of 52 structures including; 4 dams (Table 12), 14 non-tidal crossings (Table 13), 4 tidal crossings (Table 14), and 31 coastal stabilization structures (Table 15).

Figure 18. Inlet of non-tidal crossing under Parker Street/Scotland Road at Newbury town line in Newburyport (Site #1203)

Three of the four dams in Newburyport are water supply dams located along the Artichoke River on the western edge of the city. The Fred Maudslay Dam, located within Maudslay State Park is not associated with a water supply and is tied for 13th in priority rank across the study region based on our screening system (Table 12). While this structure ranks fairly high, it does not appear to offer a large restoration opportunity based on a best professional judgment assessment of potential upstream habitat and downstream property risk in the event of dam failure.

We inventoried and prioritized a total of 14 non-tidal crossings in the City of Newburyport[17]. A culvert on Pheasant Run Drive (Site # 1231) ranked the poorest in the city (30th poorest in the region) based on combined ecological and infrastructure risk (Table 13). The second highest priority non-tidal crossing in the city is located on Parker Street/Scotland Road (Site #1203) at the Newbury town line. The two municipalities share ownership of this 2-cell culvert, which has been identified as a local priority for replacement due to flooding and maintenance concerns. Poor scores in the screening tool generally indicate that structures are less likely to

[15] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[16] Full report document available at http://www.pie-rivers.org/barriers/

[17] One crossing (site #1203) is on the town line and ownership is shared with the Town of Newbury. This structure is included in data sets for both municipalities.

function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (Ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. Four of the five crossings that scored the poorest are single or multiple culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance. Any crossing with infrastructure risk index (CRI) scores of higher than 4 is showing possible inability to pass flow from storms that have a 50% chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms.

High priority tidal crossings were identified based on the combination of their association with a public road (public way), whether they were listed as priority sites in the Draft Great Marsh Coastal Wetlands Restoration Plan[18] and whether they had been identified as a priority by municipal other partners. The four tidal crossings considered as part of our analysis all rank as low priority (Table 14). Three of the four structures are all major bridge crossings of the Merrimack River. The City of Newburyport has few roads within the tidal zone and, as a result few tidal crossings.

There are 31 coastal stabilization structures identified in the City of Newburyport of which 14 are private and 17 are public structures (Table 15). Six of the public structures were categorized as moderate priority and none were high priority. There is an estimated total of more than 2 kilometers of hardened shoreline in Newburyport, mainly concentrated on the lower Merrimack River and the eastern shore of the Plum Island inlet known as The Basin (Figure 19).

As part of this study, Meridian Associates, Inc. (MAI) developed sketch conceptual sketch designs for the replacement of 2 high priority non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[19]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Newburyport designs begin on page 248

[18] Developed by Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration) - 2006

[19] The two crossings on Hale Street (Sites #1218 and #1225) were selected for design in part because they were identified as significant concern for flooding by staff from the City of Newburyport

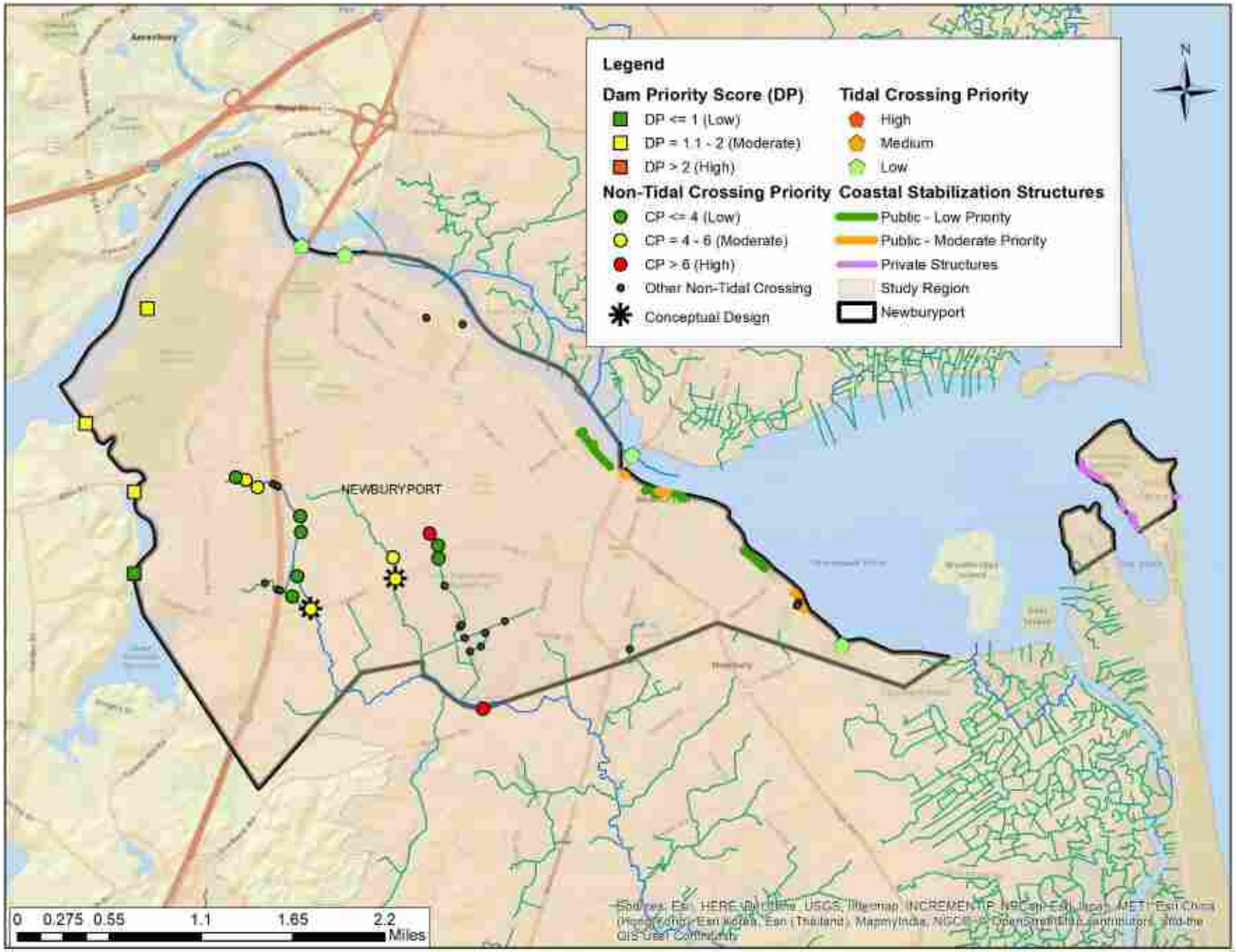

Figure 19. Map showing locations and prioritization scores for dams, non-tidal crossings, tidal crossings and coastal stabilization structures for the Great Marsh Study region within the City of Newburyport, MA. Crossings with available conceptual designs are also noted.

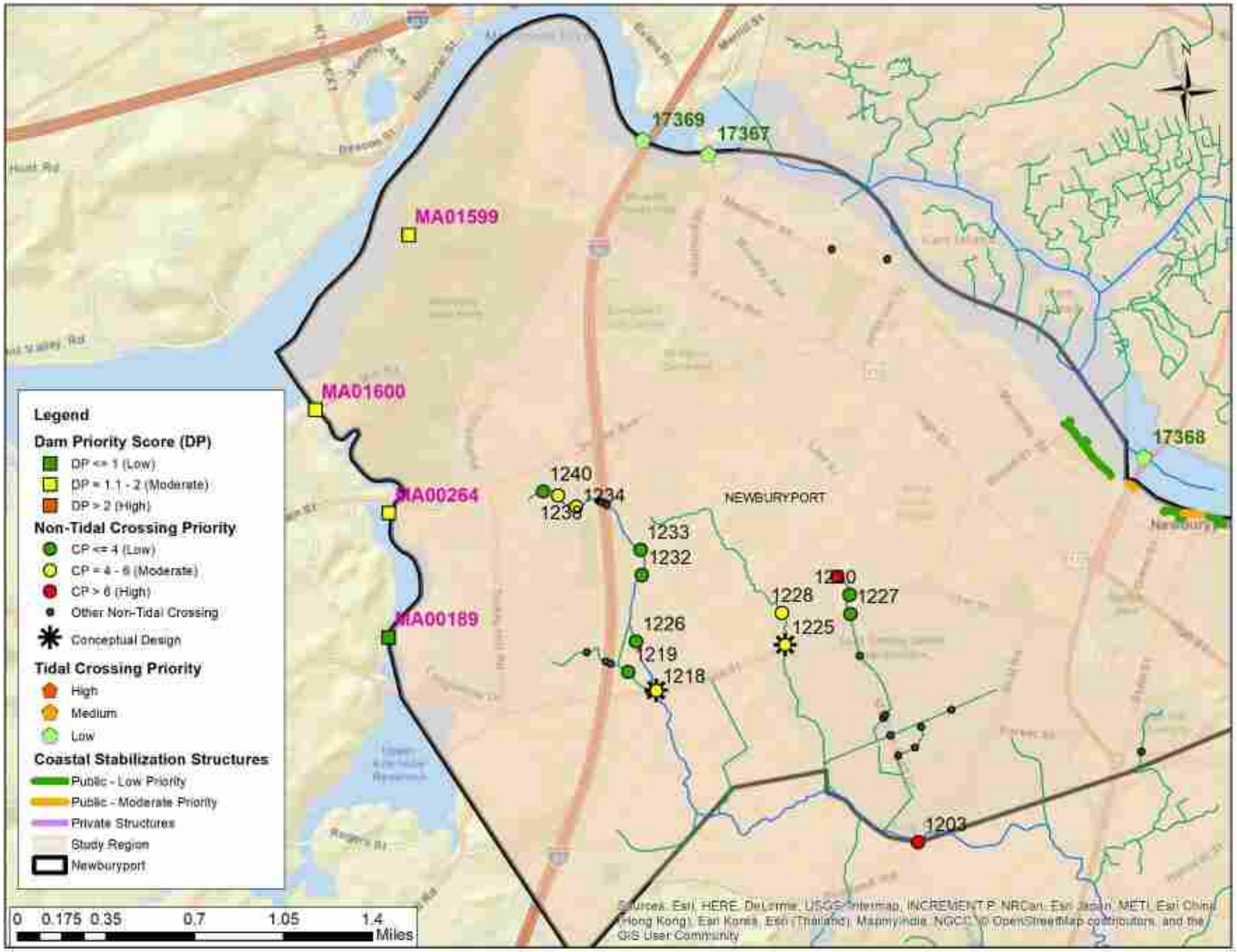

Figure 20. Prioritized structures in the Great Marsh Study region within the western portion of the City of Newburyport, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

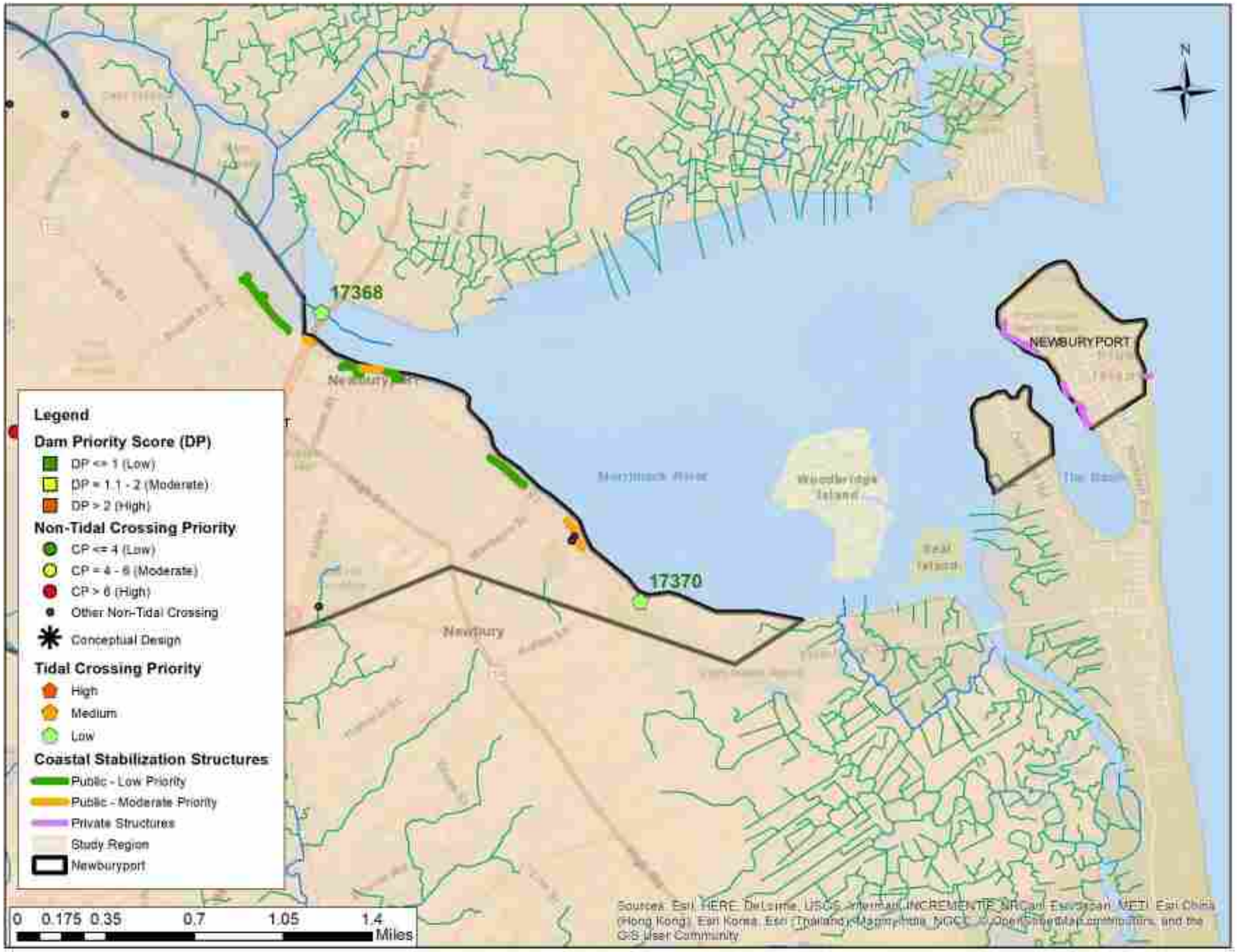

Figure 21. Prioritized structures in the Great Marsh Study region within the eastern portion of the City of Newburyport, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

Table 12. Dams in the portion of the Great Marsh study region within the City of Newburyport, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank Town	Priority Rank Region	Dam Name	Priority Scoring Infrastructure Risk (RI)	Priority Scoring Ecological Impact (EI)	Priority Scoring Priority Score (DP)	Active Project
MA01599	1	12	Fred Maudslay Dam	0.5	1	1.5	
MA01600	NA	NA	Artichoke River Dam	0.5	1	1.5	
MA00264	NA	NA	Lower Artichoke Reservoir Dam	0.5	1	1.5	
MA00189	NA	NA	Upper Artichoke Reservoir Dam	0.5	0.5	1	

Table 13. Non-tidal crossings in the portion of the Great Marsh study region within the City of Newburyport, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. *Site #1203 is on the town line and ownership is shared with the Town of Newbury.

Crossing ID	Priority Rank Town	Priority Rank Region	Road	Structure Type	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Crossing Priority (CP)	Concept Designs
1231	1	30	Pheasant Run Drive	Multiple Culvert	5.0	2.1	7.1	
1203	2*	103	Parker Street/Scotland Road	Multiple Culvert	5.0	1.3	6.3	
1234	3	151	Storeybrook Drive	Single Culvert	2.6	3.1	5.7	
1218	4	154	Hale Street	Multiple Culvert	4.0	1.7	5.7	Yes
1228	5	156	Doe Run Drive	Bridge	5.0	0.7	5.7	
1225	6	179	Hale Street	Multiple Culvert	4.0	1.4	5.4	Yes
1238	7	194	Virginia Lane	Single Culvert	2.6	2.6	5.2	
1240	8	246	Lt Leary Drive	Single Culvert	1.6	1.9	3.5	
1233	9	286	Little River Bike Trail	Single Culvert	NA	2.4	2.4	
1230	10	288	Fox Run Drive	Multiple Culvert	0.6	1.7	2.3	
1226	11	289	Little River Bike Trail	Single Culvert	NA	2.3	2.3	
1219	12	295	Off I 95	Single Culvert	NA	2.2	2.2	
1232	13	299	Newburyport bike path	Single Culvert	NA	2.1	2.1	
1227	14	301	Hale Street	Single Culvert	0.0	2.1	2.1	

Table 14. Prioritized tidal crossings in the portion of the Great Marsh study region within the City of Newburyport, MA. Sites with available conceptual designs and/or associated rapid technical assessments (RTA) from the Draft Great Marsh Coastal Wetlands Restoration Plan are noted.

Crossing ID	Road/Site	Public Way	GMP Priority Marsh	Local Priority	Tidal Crossing Priority	Design or RTA
17367	Spofford Street over Merrimack	Yes	NIP		Low	
17368	Route 1 over Merrimack	Yes	NIP		Low	
17369	Interstate 95 over Merrimack	Yes	NIP		Low	
17370	Plum Island Turnpike near Rolfes Lane	Yes	NIP		Low	

Table 15. Coastal stabilization structures in the portion of the Great Marsh study region within the City of Newburyport, MA.

Structure Category	Structure Priority	Structure Type	Structure ID	Location Note	Length (meters)
Public	Low	Bulkhead/ Seawall	051-011-000-001B-400	Railroad Avenue	37
	Low	Revetment	051-054-000-003-200	Cashman Park	134
	Low	Revetment	051-054-000-003-100	Cashman Park	178
	Low	Bulkhead/ Seawall	051-011-000-001B-300	Railroad Avenue	72
	Low	Bulkhead/ Seawall	051-011-000-001B-200	Railroad Avenue	97
	Low	Bulkhead/ Seawall	051-012-000-009-100	Fish Coop	86
	Low	Bulkhead/ Seawall	051-026-000-028-100	Harrison Street Joppa Park	276
	Low	Bulkhead/ Seawall	051-012-000-009-200	Harbor Master Office Area	24
	Low	Revetment	051-012-000-009-300	Harbor Master Building	18
	Low	Revetment	051-054-000-003-300	Cashman Park	263
	Moderate	Bulkhead/ Seawall	051-011-000-001B-100	Railroad Avenue	163
	Moderate	Bulkhead/ Seawall	051-030-000-009-100	Water Street	27
	Moderate	Revetment	051-030-000-013-200	Simons Beach	60
	Moderate	Bulkhead/ Seawall	051-030-000-013-100	Simons Beach	41
	Moderate	Bulkhead/ Seawall	051-011-000-002-100	Gillis Bridge	54
	Moderate	Bulkhead/ Seawall	051-030-000-013-300	Simons Beach	28
	Moderate	Groin/ Jetty	051-054-000-003-400	Cashman Park	7
Private	NA	Bulkhead/Seawall	206-077-000-018-001		60
		Revetment	206-077-000-015-001		18
		Bulkhead/Seawall	206-077-000-011-001		53
		Revetment	206-077-000-010-001		25
		Bulkhead/Seawall	206-077-000-006-001		39
		Bulkhead/Seawall	206-077-000-021-001		55
		Revetment	206-076-000-085-001		69
		Bulkhead/Seawall	206-076-000-052-001		40
		Bulkhead/Seawall	206-076-000-036-001		41
		Revetment	206-076-000-035-001		25
		Bulkhead/Seawall	206-076-000-019-001		27
		Revetment	206-076-000-018-001		27
		Groin/Jetty	206-077-000-125-001		24
		Bulkhead/Seawall	206-077-000-076-001		54
Total					**2121**

Rowley

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Essex. This project was conducted by the Ipswich River Watershed Association (IRWA) as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and the PIE-Rivers Region[20].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. Here we provide detailed results from the prioritization of the four barrier types. For more detail on prioritization methods as well as region-wide priorities see the main report[21].

Figure 22. Outlet of non-tidal crossing at Independence Street in Rowley (Site #926)

The entire Town of Rowley is located in the study region, covering an area of approximately 18.6 square miles. Rowley is one of seven municipalities with land within the coastal portion of the Great Marsh study region and three of the four structure types are present (Figure 23). Our analysis considered a total of 58 structures including 6 dams (Table 16), 43 non-tidal crossings (Table 17), and 9 tidal crossings (Table 18). This study did not identify any coastal stabilization structures in Rowley.

Rowley's highest priority dam, the Jewel Mill Dam on the Mill River, is tied for 2nd in priority rank regionally (Table 16). This structure is at the head of tide, is a significant hazard structure and may present an opportunity for removal or improved fish passage in the future. As of the writing of this report, conservation partners including the Nor East Chapter of Trout Unlimited and the Parker River Clean Water Association are investigating the habitat potential upstream of this dam for migratory river herring and other anadromous fishes. The dam is privately owned so any restoration effort would need to be done in cooperation with the owner. The other five dams in Rowley do not rank among the higher priority dams in the region. It is worth noting that the Ox Pasture Brook Dam (MA01603) is now the closest barrier to the ocean on Ox Pasture Brook following the removal of the former Lower Ox Pasture Brook Dam that was demolished in 2009 as part of an ecological restoration project.

We inventoried and prioritized a total of 43 non-tidal crossings in the Town of Rowley. The screening results identify several high priority crossings including five crossings that are among the 50 poorest scoring sites in the

[20] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[21] Full report document available at http://www.pie-rivers.org/barriers/

region based on combined ecological and infrastructure risk (Table 17). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The 11 poorest scoring crossings are single or multiple culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance. Any crossing with infrastructure risk index (CRI) scores of higher than 4 is showing possible inability to pass flow from storms that have a 50% chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms.

High priority tidal crossings were identified based on the combination of their association with a public road (public way), whether they were listed as priority sites in the Draft Great Marsh Coastal Wetlands Restoration Plan[22] and whether they had been identified as a priority by municipal other partners. Our evaluation identified one of the nine tidal crossings as high priority (Table 18). This crossing, located on Red Gate Road appears to restrict tidal exchange to a large section of salt marsh near the Newbury town line (Figure 23). This structure was also the subject of a Rapid Technical Assessment as part of the Great Marsh Plan. Our methodology for assessing tidal crossing structures was less quantitative than the ones we used to assess non-tidal crossings, but given increasing sea level and storm intensities any structure already subject to tidal exchange is at risk. We would suggest that this high priority structure is worth a closer, more rigorous analysis when possible.

As part of this study, Meridian Associates, Inc. (MAI) developed sketch conceptual sketch designs for the replacement of 6 non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Rowley designs begin on page 264

[22] Developed by Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration) - 2006

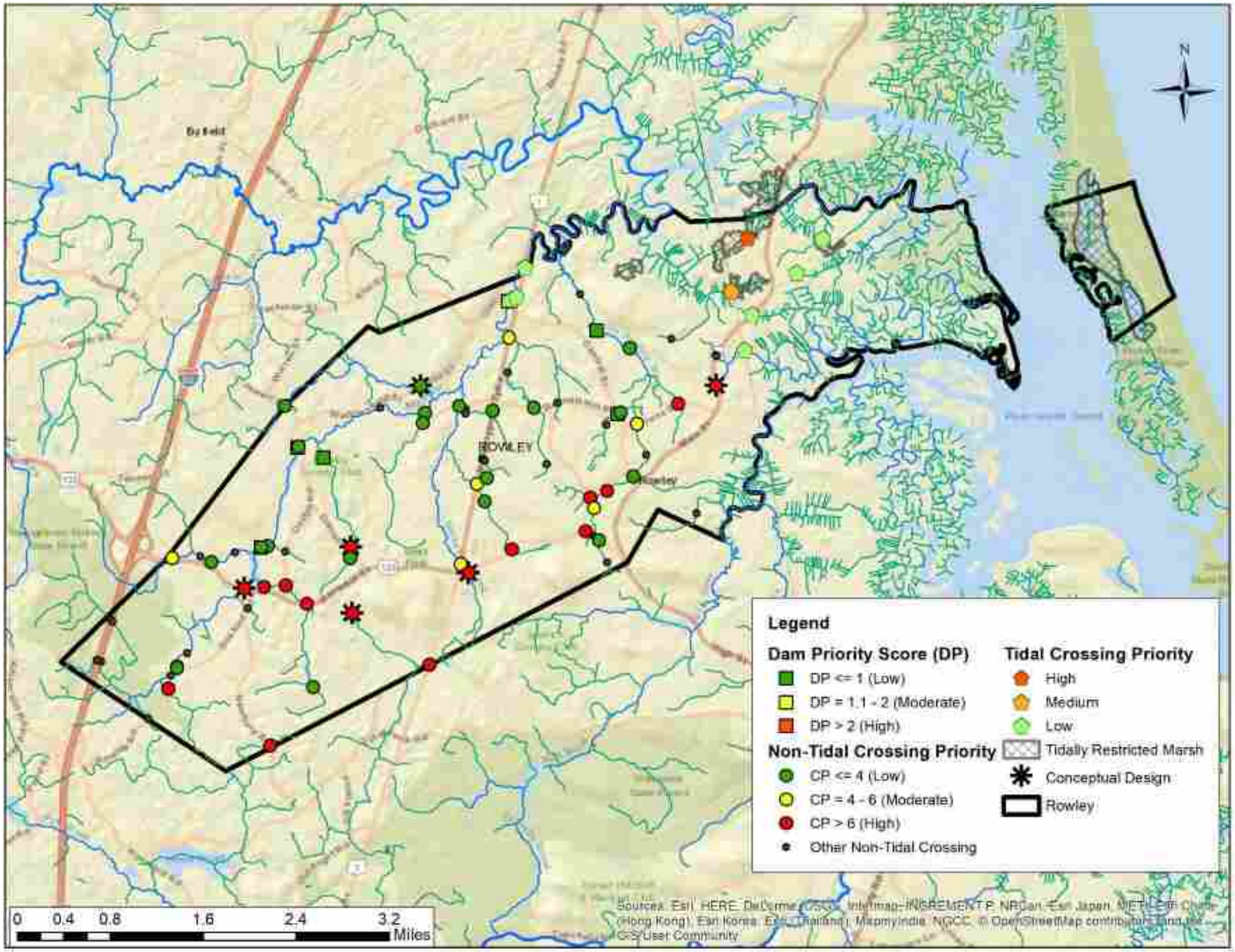

Figure 23. Map showing locations and prioritization scores for dams, non-tidal crossings and tidal restrictions for the Great Marsh Study region within the Town of Rowley, MA. Crossings with available conceptual designs and suspected tidally restricted marshes are also noted.

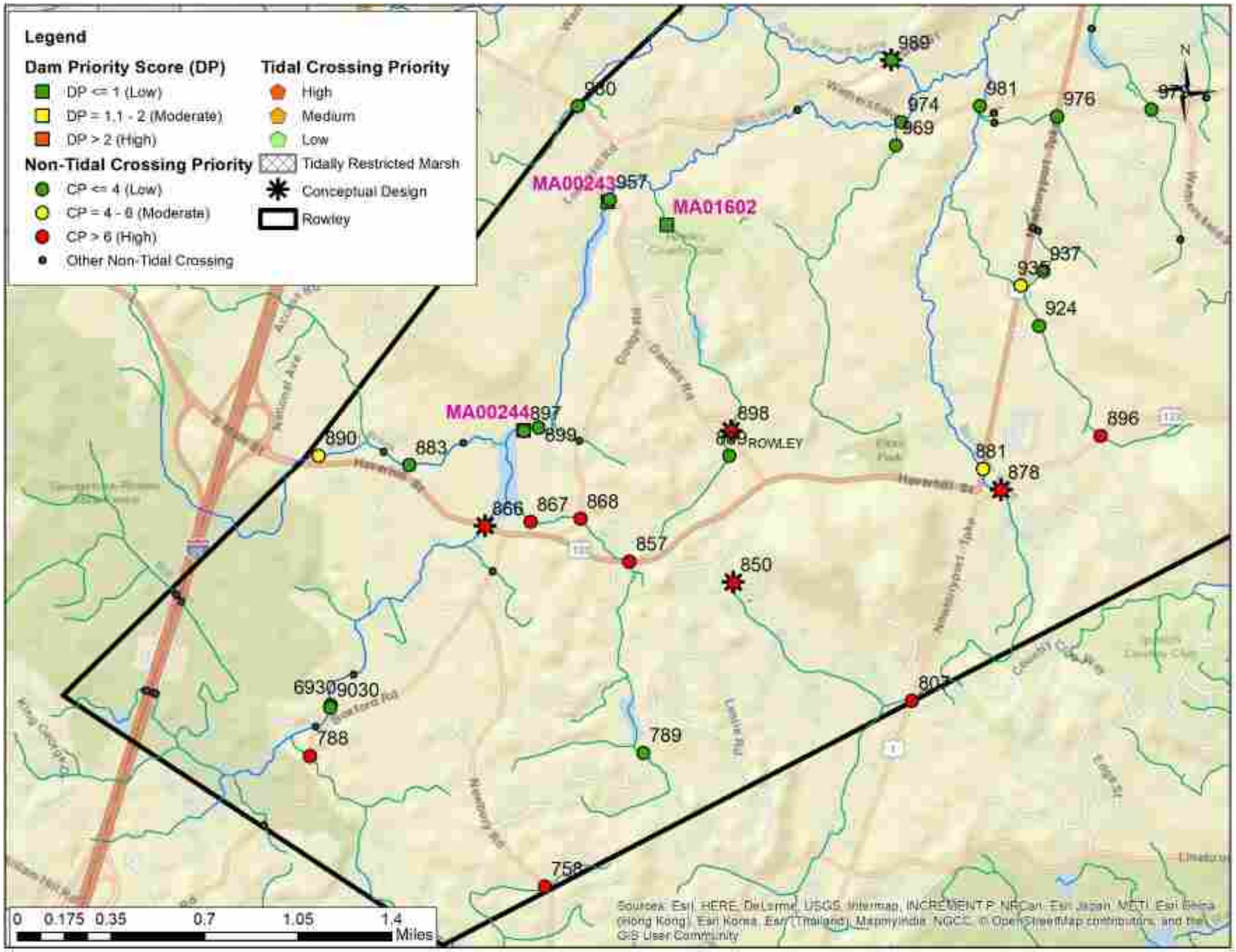

Figure 24. Prioritized structures in the Great Marsh Study region within the western portion of the Town of Rowley, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

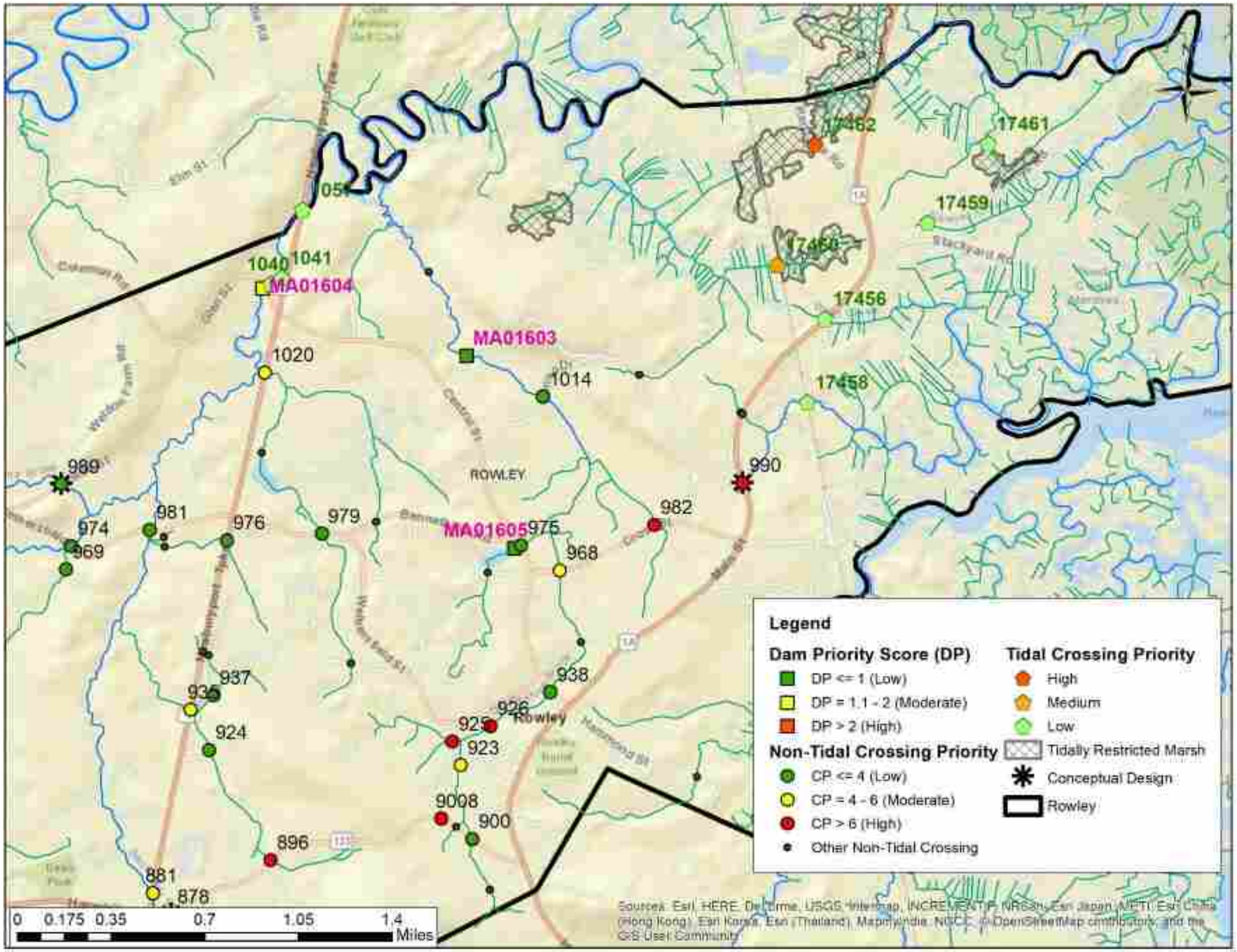

Figure 25. Prioritized structures in the Great Marsh Study region within the eastern portion of the Town of Rowley, MA. Dam ID shown in pink, non-tidal crossing ID shown in black and tidal crossing ID shown in green.

Table 16. Dams in the portion of the Great Marsh study region within the Town of Rowley, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank		Dam Name	Priority Scoring			Active/ Priority Project
	Town	Region		Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA01604	1	2	Jewel Mill Dam	1	1	2	Priority
MA00243	2	26	Lower Millpond Dam	0.5	0.5	1	
MA01605	2	26	Central Street Dam	0.5	0.5	1	
MA01603	4	30	Ox Pasture Brook Dam	0	1	1	
MA01602	5	45	Country Club Pond Dam	0	0.5	0.5	
MA00244	6	54	Upper Millpond Dam	0	0	0	

Table 17. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Rowley, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (page 1 of 2)

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
990	1	14	Main Street	Single Culvert	3.6	4.7	8.3	Yes
898	2	24	Daniels Rd	Single Culvert	5.0	2.5	7.5	Yes
878	3	29	Haverhill Street	Single Culvert	5.0	2.1	7.1	Yes
788	4	31	Boxford Road	Single Culvert	5.0	2.1	7.1	
758	5	41	Newbury Road	Single Culvert	5.0	1.9	6.9	
868	6	63	Dodge Road	Single Culvert	5.0	1.7	6.7	
896	7	68	Haverhill Street	Single Culvert	5.0	1.6	6.6	
850	8	80	Kathleen Circle	Single Culvert	4.0	2.5	6.5	Yes
866	9	87	Haverhill St	Single Culvert	5.0	1.4	6.4	Yes
867	10	89	Haverhill	Multiple Culvert	5.0	1.4	6.4	
9008	11	91	Haverhill Street	Single Culvert	5.0	1.4	6.4	
926	12	94	Independence St	Open Bottom Arch	4.6	1.8	6.4	
982	13	100	Cross St	Single Culvert	5.0	1.3	6.3	
857	14	108	Haverhill St	Single Culvert	5.0	1.3	6.3	
807	15	127	Turnpike Road	Bridge	5.0	1.1	6.1	
925	16	128	Bradford Street	Single Culvert	5.0	1.1	6.1	
881	17	139	Newburyport Turnpike	Single Culvert	4.0	1.9	5.9	
1020	18	145	Newburyport Turnpike	Single Culvert	5.0	0.8	5.8	
923	19	173	Summer Street	Single Culvert	4.0	1.5	5.5	
935	20	176	Newburyport Turnpike	Single Culvert	4.0	1.5	5.5	
968	21	223	Cross St	Bridge	4.0	0.3	4.3	
890	22	225	HaverhillSt	Single Culvert	2.6	1.7	4.3	
938	23	244	Church St	Single Culvert	1.6	1.9	3.5	
6930	24	281	Off_Boxford Road	Multiple Culvert	0.0	2.4	2.4	
979	25	298	Wethersfield Street	Single Culvert	0.0	2.2	2.2	
989	26	304	Hillside Street	Single Culvert	0.0	2.0	2.0	Yes
897	27	315	Mill Rd	Single Culvert	NA	1.9	1.9	
980	28	331	Weathersfield Road	Culvert	NA	1.8	1.8	
969	29	346	Taylors Lane	Single Culvert	NA	1.7	1.7	

Table 17. (Continued) Non-tidal crossings in the portion of the Great Marsh study region within the Town of Rowley, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (page 2 of 2)

Crossing ID	Priority Rank Town	Priority Rank Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
924	30	357	Victory Lane	Single Culvert	0.0	1.6	1.6	
883	31	375	Haverhill St	Single Culvert	0.0	1.5	1.5	
975	32	377	Central St	Single Culvert	NA	1.5	1.5	
789	33	381	Cindy Lane	Multiple Culvert	0.0	1.4	1.4	
976	34	387	Newburyport Turnpike	Single Culvert	0.0	1.4	1.4	
974	35	408	Wethersfield Street	Bridge	0.0	1.3	1.3	
900	36	444	Haverhill Street	Single Culvert	0.0	1.1	1.1	
981	37	519	Wethersfield Street	Bridge	0.0	0.6	0.6	
957	38	533	Dodge St	Bridge	0.0	0.5	0.5	
937	39	534	Turcotte Drive	Multiple Culvert	0.0	0.5	0.5	
889	40	538	Powerhouse Lane	Open Bottom Arch	NA	0.5	0.5	
9030	41	564	Off_Boxford Road	Bridge	0.0	0.3	0.3	
1014	42	569	Fenno Drive	Bridge	0.0	0.3	0.3	
899	43	592	Mill Rd	Bridge	0.0	0.1	0.1	

Table 18. Prioritized tidal crossings in the portion of the Great Marsh study region within the Town of Rowley, MA. Sites with available conceptual designs and/or associated rapid technical assessments (RTA) from the Draft Great Marsh Coastal Wetlands Restoration Plan are noted.

Crossing ID	Road/Site	Public Way	GMP Priority Marsh	Local Priority	Tidal Crossing Priority	Design or RTA
17462	Red Gate Road	Yes	Medium		High	RTA
17460	MBTA	Yes	Low		Medium	
1040	Glen Street	Yes	NIP		Low	
1041	Fullingmill Road	Yes	NIP		Low	
1057	Newburyport Turnpike (Mill River)	Yes	NIP		Low	
17456	Route 1A (West Creek)	Yes	NIP		Low	
17458	MBTA (Sand Creek)	Yes	NIP		Low	
17459	Patmos Road	Yes	NIP		Low	
17461	North of Patmos Road	No	Low		Low	

Salisbury

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Salisbury. This project was conducted by the Ipswich River Watershed Association (IRWA) as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and the PIE-Rivers Region[23].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. Here we provide detailed results from the prioritization of the four barrier types. For more detail on prioritization methods as well as region-wide priorities see the main report[24].

Figure 26. Outlet of non-tidal crossing at Elmwood Street in Salisbury (Site #10109)

The entire town of Salisbury is located in the study region, covering an area of approximately 16.0 square miles. Salisbury is one of seven municipalities with land within the coastal portion of the Great Marsh study region and three of four structure types are present (Figure 28). Our analysis considered a total of 36 structures including 12 non-tidal crossings (Table 19), 15 tidal crossings (Table 20), and 9 coastal stabilization structures (Table 21). This study did not identify and dams in Salisbury.

We inventoried and prioritized a total of 12 non-tidal crossings in the Town of Salisbury (Table 19). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (Ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. None of the crossings in Salisbury are among the higher priority sites in the region, but there are a number of single culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance. In all, the non-tidal crossings in Salisbury appear to be of less overall concern than the tidal crossings.

Our evaluation categorized 12 of the 15 tidal crossings in Salisbury as high priority (Table 20). High priority tidal crossings were identified based on the combination of their association with a public road (public way), whether they were listed as priority sites in the Draft Great Marsh Coastal Wetlands Restoration Plan[25] and whether they had been identified as a priority by municipal other partners. Our methodology for assessing tidal crossing

[23] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[24] Full report document available at http://www.pie-rivers.org/barriers/
[25] Developed by Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP), (now part of the MA Division of Ecological Restoration) - 2006

structures was less quantitative than the ones we used to assess non-tidal crossings, but given increasing sea level and storm intensities any structure already subject to tidal exchange is at risk. We would suggest that all structures that we have identified as high priority are worth a closer, more rigorous analysis where and when possible.

There are 9 coastal stabilization structures identified in the Town of Salisbury of which 7 are public and 2 are private structures (Table 21). Of the publicly owned structures, 6 are rated as low priority and 1 is rated as a moderate priority in our screening. There is a total of more than one kilometer of hardened shoreline in Salisbury with the heaviest concentration being along the mouth of the Merrimack River at the Salisbury Beach State Reservation (Figure 28).

Figure 27. Outlet of tidal crossing on Town Creek at Route 1 in Salisbury (Site #10107)

As part of this study, Meridian Associates, Inc. (MAI) developed sketch conceptual sketch designs for the replacement of 5 crossings (3 non-tidal and 2 tidal) with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Salisbury designs begin on page 271

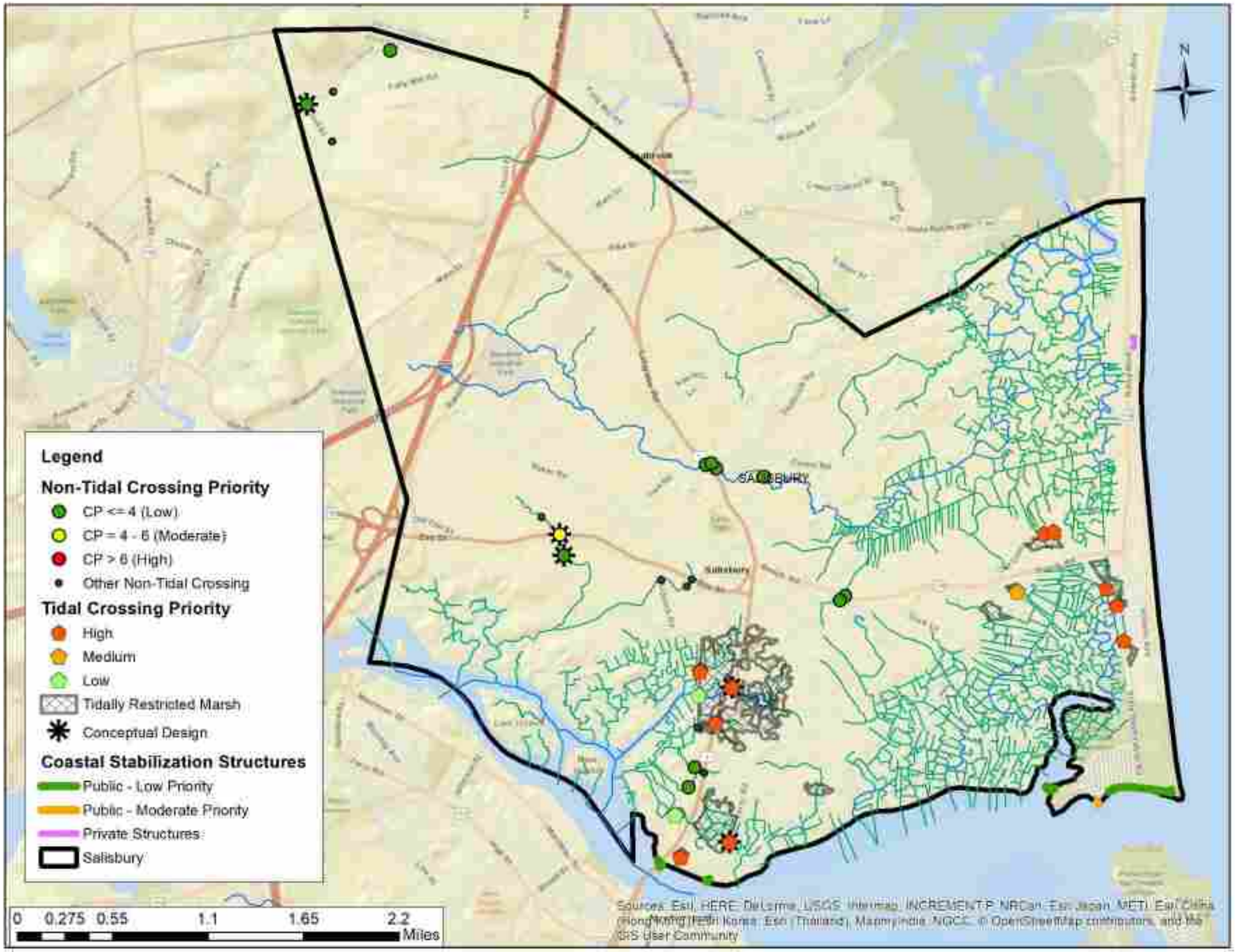

Figure 28. Map showing locations and prioritization scores for dams, non-tidal crossings, tidal restrictions and coastal stabilization structures for the Great Marsh Study region within the Town of Salisbury, MA. Crossings with available conceptual designs and suspected tidally restricted marshes are also noted.

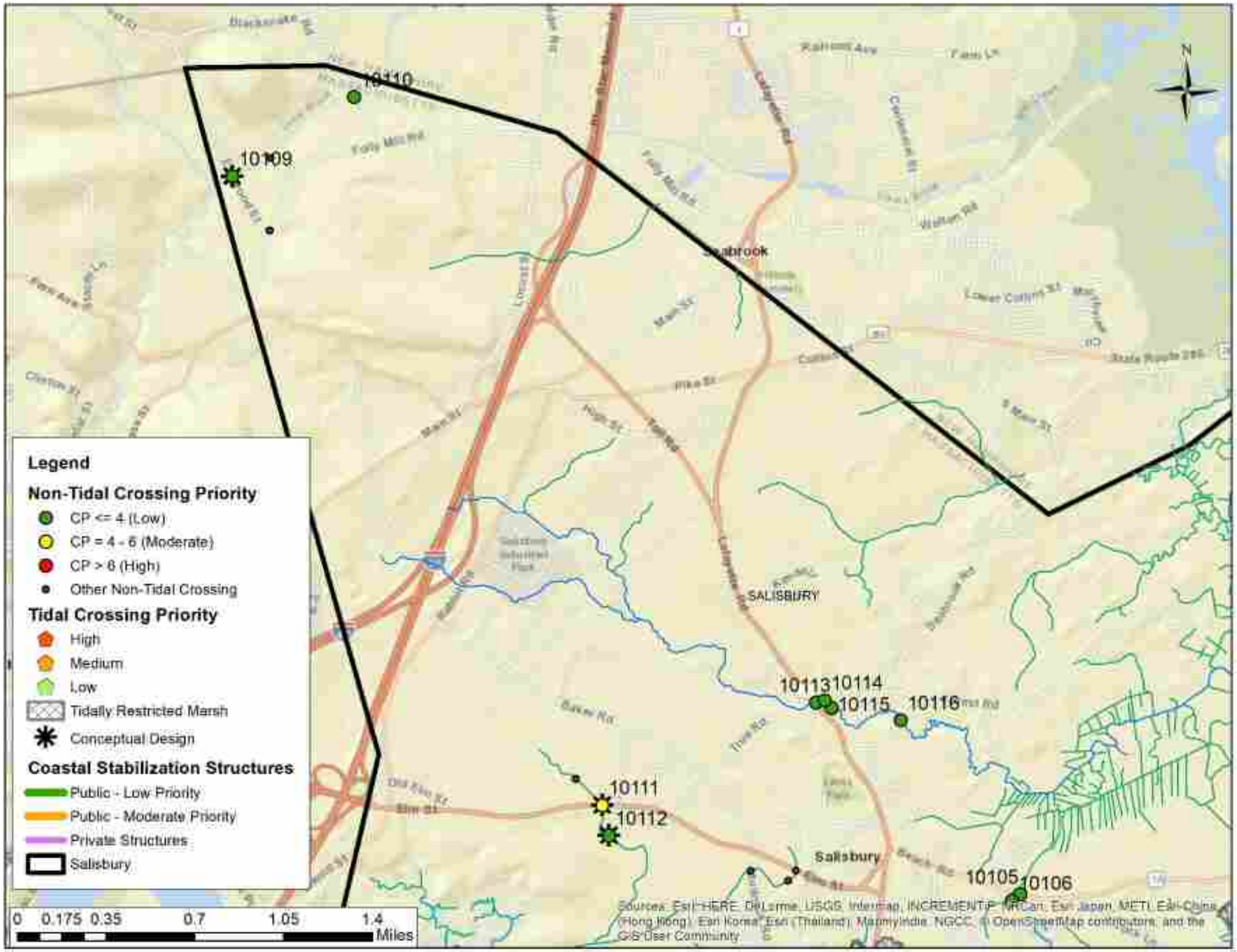

Figure 29. Prioritized structures in the Great Marsh Study region within the northern portion of the Town of Salisbury, MA. Non-tidal crossing ID shown in black and tidal crossing ID shown in maroon.

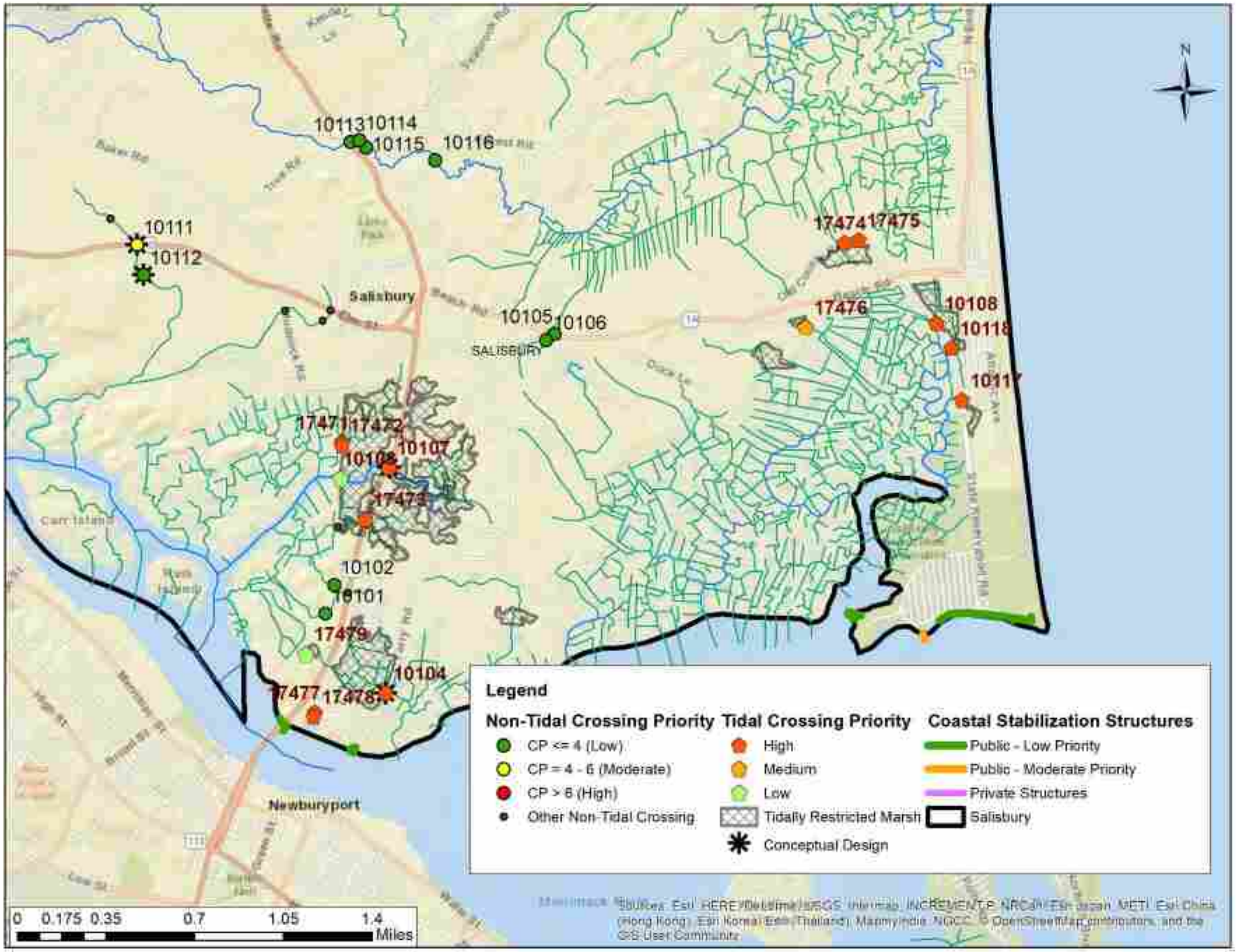

Figure 30. Prioritized structures in the Great Marsh Study region within the southern portion of the Town of Salisbury, MA. Non-tidal crossing ID shown in black and tidal crossing ID shown in maroon.

Table 19. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Salisbury, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
10111	1	237	Route 110	Culvert	NA	4.1	4.1	Yes
10109	2	241	Elmwood Street	Culvert	0.0	3.9	3.9	Yes
10112	3	250	unnamed	Culvert	NA	3.4	3.4	Yes
10116	4	251	Forest Road	Multiple Culvert	2.2	1.1	3.3	
10110	5	366	Black Snake Road	Culvert	NA	1.6	1.6	
10106	6	412	Beach Road	Culvert	NA	1.3	1.3	
10102	7	468	bike path	Culvert	0.0	0.9	0.9	
10105	8	499	Beach Road	Culvert	NA	0.7	0.7	
10113	9	513	Lafayette Road (Rt 1)	Bridge	0.0	0.6	0.6	
10115	10	526	Gerrish Road	Bridge	NA	0.6	0.6	
10101	11	553	Steven	Bridge	0.0	0.4	0.4	
10114	12	579	unnamed	Bridge	0.0	0.2	0.2	

Table 20. Prioritized tidal crossings in the portion of the Great Marsh study region within the Town of Salisbury, MA. Sites with available conceptual designs and/or associated rapid technical assessments (RTA) from the Draft Great Marsh Coastal Wetlands Restoration Plan are noted.

Crossing ID	Road/Site	Public Way	GMP Priority Marsh		Tidal Crossing Priority	Design or RTA
10104	Ferry Road	Yes	High		High	Design, RTA
10107	Route 1 (Town Creek)	Yes	High		High	Design
10108	State Reservation Road	Yes	Medium		High	RTA
10117	State Reservation Road	Yes	Medium		High	
10118	State Reservation Road	Yes	Medium		High	RTA
17471	Rail Trail	No	High		High	
17472	Rail Trail	No	High		High	
17473	Route 1	Yes	High		High	
17474	Old County Road	Yes	Medium		High	RTA
17475	Old County Road	Yes	Medium		High	RTA
17477	March Road	Yes	High		High	RTA
17478	1st Street	Yes	High		High	RTA
17476	East of Hayes Street	No	Medium		Medium	RTA
10103	Rail Trail (Town Creek)	No	Other_AB		Low	
17479	Rail Trail	No	Low		Low	

Table 21. Man-made coastal stabilization structures in the portion of the Great Marsh study region within the Town of Salisbury, MA.

Structure Category	Structure Priority	Structure Type	Structure ID	Location Note	Length (meters)
Public	Low	Groin/ Jetty	065-007-000-015-200	Gillis Bridge	38
	Low	Bulkhead/ Seawall	065-007-000-010-100	First Street	77
	Low	Groin/ Jetty	065-030-000-001-400	State Park	12
	Low	Bulkhead/ Seawall	065-030-000-001-300	State Park	628
	Low	Revetment	065-030-000-001-100	Merrimack River	159
	Low	Revetment	065-007-000-015-100	Gillis Bridge	64
	Moderate	Groin/ Jetty	065-030-000-001-200	State Park	39
Private	NA	Revetment	259-035-000-224-001		21
		Bulkhead/Seawall	259-035-000-234-001		20
Total					**1059**

Appendix 2 - Inland Municipality Summary Reports

This appendix contains town-specific summary reports for the inland municipalities in the Great Marsh study region. There are 22 municipalities that fall all or completely within the study region and are outside of the coastal zone (i.e. outside of tidal influence). These municipalities are categorized as inland municipalities in our analysis and, by definition, cannot contain any tidal crossings or coastal stabilization structures.

All 22 municipalities are listed in Table 22 and summary reports for 15 towns follow in alphabetical order. We did not produce summary reports for municipalities where we assessed fewer than 10 structures unless a conceptual design was developed for one of the structures.

Table 22. Alphabetical list of inland municipalities in the Great Marsh study region showing the total number of each barrier type located within the surveyed portions of each municipality. The area column represents the land area of the municipality that falls within the study region.

Town	Area (square miles)	Non-Tidal Crossings	Dams	Structures Designed	Report in Appendix
Andover	5.4	20	7	5	Yes
Beverly	3.7	10	1		Yes
Billerica	0.6	1			No
Boxford	21.2	102	11	15	Yes
Burlington	3.5	3	3		No
Danvers	3.9	15	3		Yes
Georgetown	12.9	43	1	4	Yes
Groveland	3.4	5			No
Hamilton	14.4	34		3	Yes
Lynnfield	3.4	2	1		No
Manchester	0.4				No
Middleton	14.5	35	10	3	Yes
North Andover	16.6	59	7	10	Yes
North Reading	13.5	33	2		Yes
Peabody	4.6	21	6		Yes
Reading	4.8	4		1	Yes
Tewksbury	0.5				No
Topsfield	12.8	57	11	14	Yes
Wenham	7.4	29	1	3	Yes
West Newbury	3.6	7		2	Yes
Wilmington	14.2	35		11	Yes
Woburn	0.1	1			No

Table of Contents (Appendix 2)

Andover

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Andover. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[26].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[27].

Approximately 5.4 square miles of the Town of Andover is located within the Great Marsh study region. This portion of the study watershed, located in the southeastern portion of Andover, is outside of the coastal zone (Figure 32). As an inland municipality, Andover does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 27 potential barrier sites with structures confirmed and prioritized at 23 of those locations including 7 dams (Table 23) and 16 non-tidal crossings (Table 24).

Figure 31. Outlet of road-stream crossing at Gray Road in Andover (Site #421)

None of the dams stood out as particularly high priority for combined risk and ecological impact with a four-way tie for first between Brackett Pond Dam, Field Pond Dam, Collins Pond Dam and Field Pond Dike–all located in close proximity to one another within the Harold Parker State Forest. These dams ranked 22nd in the region.

We inventoried and prioritized 16 non-tidal crossings in the Town of Andover. The screening results identify two crossings that were among the 10 highest priority crossings region-wide (Table 24). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (Ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The seven highest priority sites all had infrastructure risk (CRI) scores of 4 or greater indicating that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that

[26] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[27] Full report document available at http://www.pie-rivers.org/barriers/

those crossings might be worth taking a closer look at to see how they are performing during storms. All seven of these crossings were single culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 5 high priority non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[28]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Andover designs begin on page 191

[28] Sites #260 (Mohawk Road) and #374 (Salem Street) were identified as high priority crossings for infrastructure risk in the preliminary results used to choose sites for design and were later significantly downgraded in priority during a quality control review of the model results. We have included designs here and believe both sites are good candidates for replacement based on ecological impact and best professional judgement.

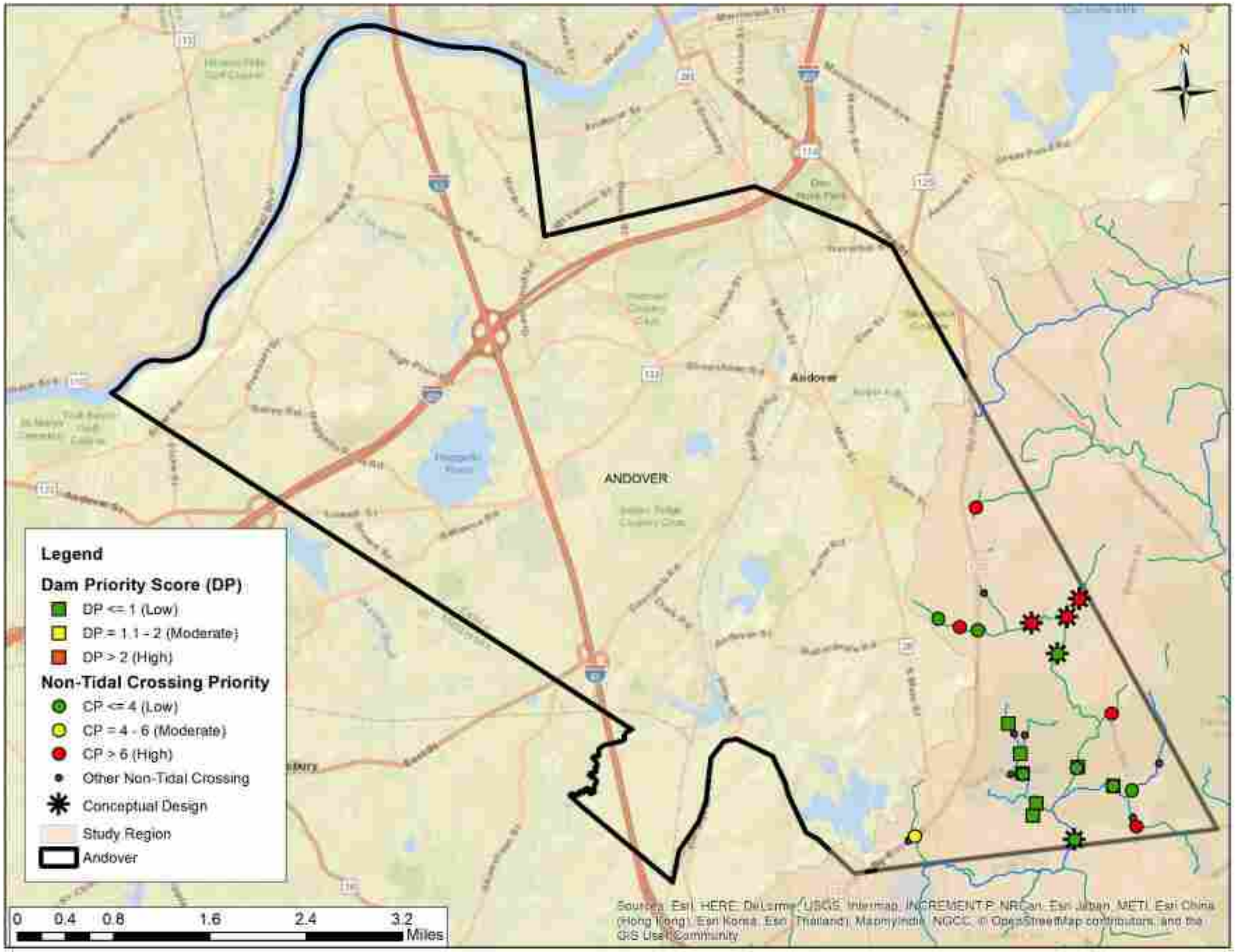

Figure 32. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of Andover, MA. Crossings with available conceptual designs are also noted.

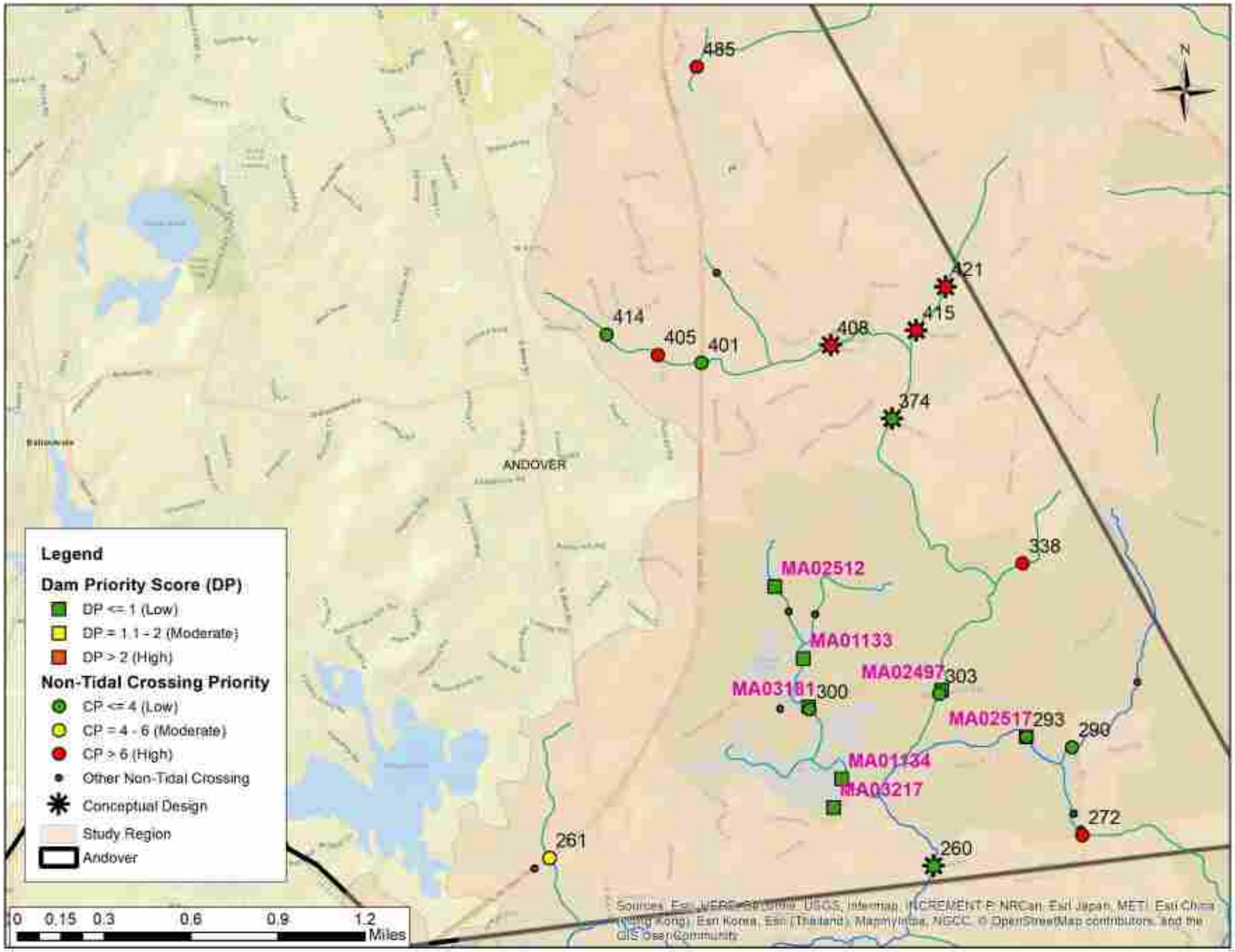

Figure 33. Closeup view of prioritized dams and non-tidal crossings in the Great Marsh Study region within Town of Andover. Dam ID shown in pink and crossing ID shown in black.

Table 23. Dams in the portion of the Great Marsh study region within the Town of Andover, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank: Town	Priority Rank: Region	Dam Name	Priority Scoring: Infrastructure Risk (RI)	Priority Scoring: Ecological Impact (EI)	Priority Scoring: Priority Score (DP)	Active/ Priority Project
MA01133	1	21	Brackett Pond Dam	1	0	1	
MA01134	1	21	Field Pond Dam	1	0	1	
MA03181	1	21	Collins Pond Dam	1	0	1	
MA03217	1	21	Field Pond Dike	1	0	1	
MA02512	5	40	Deleano Pond Dam	0.5	0	0.5	
MA02517	5	40	Frye Pond Dam	0.5	0	0.5	
MA02497	7	54	Skug River Dam	0	0	0	

Table 24. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Andover, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
421	1	8	Gray Road	Single Culvert	4	4.6	8.6	Yes
408	2	9	Salem Street	Single Culvert	4	4.6	8.6	Yes
415	3	56	Korinthian Way	Single Culvert	5	1.7	6.7	Yes
272	4	65	Jenkins Road	Single Culvert	5	1.6	6.6	
485	5	85	Prospect Road	Single Culvert	5	1.5	6.5	
338	6	104	Jenkins Road	Single Culvert	4.6	1.7	6.3	
405	7	117	Ivy Lane	Single Culvert	4	2.2	6.2	
261	8	230	Route 125/Andover Bypass	Single Culvert	2.6	1.6	4.2	
414	9	258	Holt Road	Multiple Culvert	0.6	2.4	3.0	
300	10	279	Harold Parker Road	Single Culvert	NA	2.4	0.0	
260	11	355	Mohawk Road	Multiple Culvert	0	1.6	1.6	Yes
290	12	359	Jenkins Road	Single Culvert	NA	1.6	0.0	
293	13	397	Harold Parker Campground Road	Single Culvert	NA	1.3	0.0	
374	14	413	Salem Street	Multiple Culvert	0	1.3	1.3	Yes
401	15	417	Andover Bypass	Single Culvert	NA	1.2	0.0	
303	16	551	Harold Parker Road	Bridge	0	0.4	0.4	

Beverly

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the City of Beverly. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[29].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[30].

Approximately 3.7 square miles of the City of Beverly is located within the Great Marsh study region. This portion of the study watershed, located in the northern portion of Beverly, is outside of the coastal zone so Beverly is considered an inland municipality in our analysis (Figure 34). As an inland municipality, Beverly does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 11 potential barrier sites with structures confirmed and prioritized at 9 of those locations including 1 dam (Table 25) and 8 non-tidal crossings (Table 26).

The Norwood Pond Dam (MA00181) is the only dam we identified in the City of Beverly. This dam is located in the headwaters of the Miles River. The MA Office of Dam Safety (ODS) database lists this dam as a significant hazard structure, which would have ranked it as a high priority. The City of Beverly has informed us that they were told by ODS that the dam is classified as a non-jurisdictional structure due to its small size (<6 feet tall)[31]. We have adjusted the data set accordingly and the Norwood Pond Dam now ranks as a low priority structure (tied for 45th in the region) in our analysis (Table 25). While this dam is not ranked as a high priory, it is still important that they be properly monitored and maintained. If dam structures are no longer needed, removal may be considered as an option to remove risk and enhance ecological integrity.

Of the 8 non-tidal crossings inventoried and prioritized based on combined ecological and infrastructure risk, the highest priority crossing ranked 50th across the entire study region (Table 26). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. While none of the crossings in Beverly stood out on a region-wide scale, most of them appear to present considerable infrastructure risk. The five highest priority sites all had infrastructure risk (CRI) scores of 4 or greater indicating that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. Four of the five high CRI crossings were single or multiple culverts that could likely be

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[29] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[30] Full report document available at http://www.pie-rivers.org/barriers/

[31] Michael P. Collins, Commissioner of Public Services and Engineering, email communication, 12/27/2017

replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

We did not develop conceptual designs for upgrade of any crossings located in the City of Beverly.

Table 25. Dams in the portion of the Great Marsh study region within the City of Beverly, MA prioritized by Dam Priority Score (DP).

	Priority Rank			Priority Scoring			
Dam ID	Town	Region	Dam Name	Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	Active/ Priority Project
MA00181	1	45	Norwood Pond Dam	0	0.5	0.5	

Table 26. Non-tidal crossings in the portion of the Great Marsh study region within the City of Beverly, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

	Priority Rank				Priority Scoring			
Crossing ID	Town	Region	Road	Structure Type	Infrastructure Risk (CRI)	Ecological Impact (CEI)	Crossing Priority (CP)	Concept Designs
153	1	50	Landers Drive	Multiple Culvert	5.0	1.8	6.8	
176	2	78	Grover Road	Culvert	5.0	1.5	6.5	
181	3	142	Dodge Street	Single Culvert	4.6	1.3	5.9	
149	4	193	Essex Street	Open Bottom Arch	4.0	1.2	5.2	
136	5	209	Beaver Pond Road	Single Culvert	4.0	0.8	4.8	
165	6	441	Dodge St	Open Bottom Arch	0.0	1.1	1.1	
175	7	549	Morgan's Island Rd	Open Bottom Arch	0.0	0.4	0.4	
155	8	552	Fern Street	Multiple Culvert	0.0	0.4	0.4	

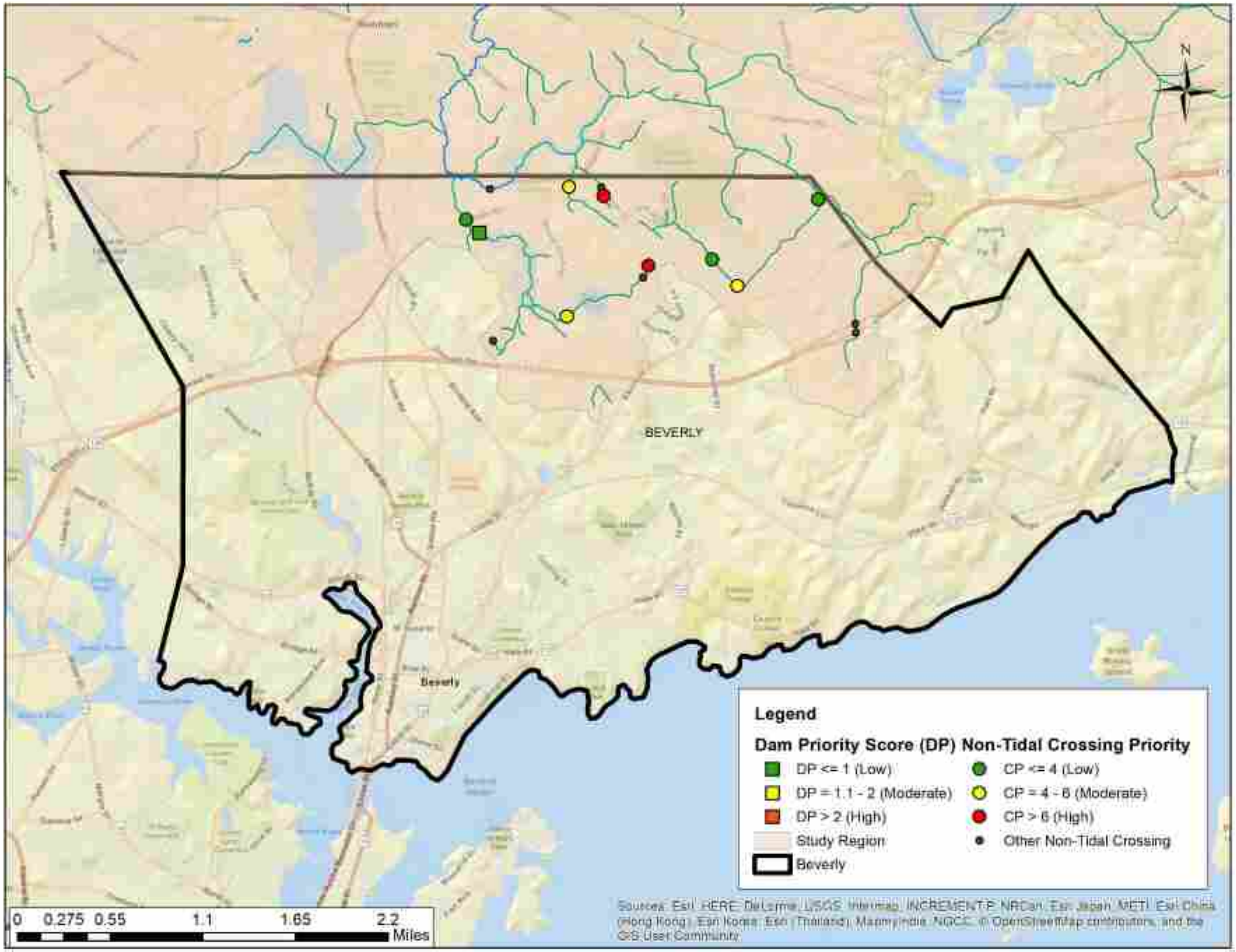

Figure 34. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the City of Beverly, MA.

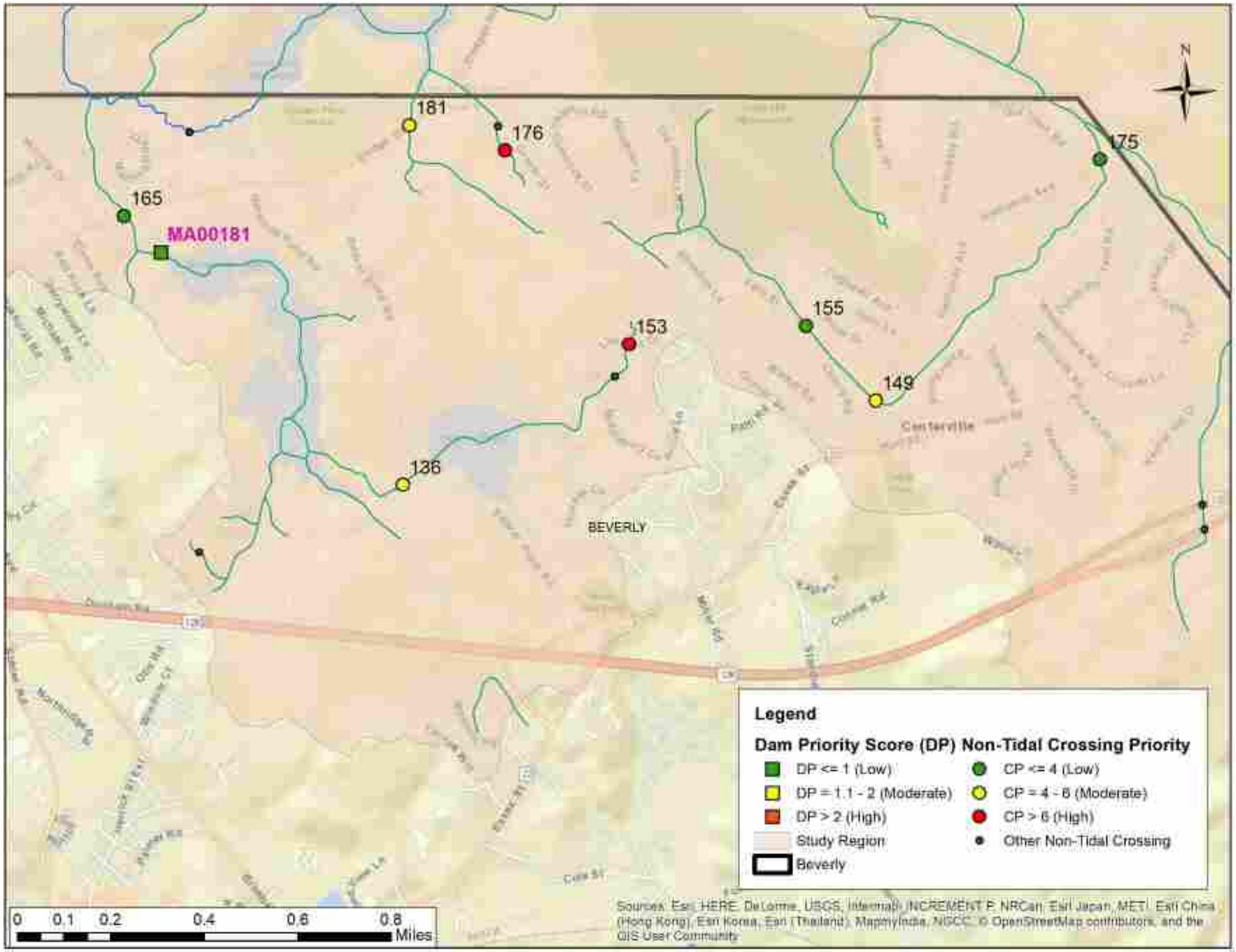

Figure 35. Closeup view of prioritized dams and non-tidal crossings in the Great Marsh Study region within the City of Beverly, MA. Dam ID shown in pink and crossing ID shown in black.

Boxford

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Boxford. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[32].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[33].

Figure 36. Howe Pond Dam, Boxford (MA00159)

The Town of Boxford is the municipality with the largest land area (21.2 square miles) and containing the most structures in the Barriers Assessment. All but the northern tip of Boxford is within the study region and the town is outside of the coastal zone (Figure 38). As an inland municipality, Boxford does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 113 potential barrier sites with structures confirmed and prioritized at 92 of those locations including 10 dams (Table 27) and 82 non-tidal crossings (Table 28).

Three dams ranked among the 10 highest priority dams in the region with the Howe Pond Dam (MA00159) on Fish Brook tied for 2nd in ranking based on a combination of risk and ecological impact (Table 27). Fish Brook and its tributaries have been the focus of recent restoration efforts by Trout Unlimited, the Town of Boxford, Ipswich River Watershed Association and partners based on its potential as cold water and fluvial (flowing) habitat. To maximize the potential ecological benefit of any efforts to improve connectivity at the Howe Pond Dam, it would be beneficial to explore options to remove or improve passage at Lockwood Dam 1 (MA01525) located downstream. The Baldpate Pond Dam (MA01198) and Stiles Pond Outlet Dam (MA00158) are also among the highest priority dams in the region ranking tied for 5th and 9th, respectively.

We inventoried and prioritized 82 non-tidal crossings in the Town of Boxford based on combined ecological and infrastructure risk. The screening results identified seven crossings that were among the 50 highest priority crossings region-wide (Table 28). Poor scores in the screening tool generally indicate that structures are less

[32] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[33] Full report document available at http://www.pie-rivers.org/barriers/

likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. More than one quarter (22) of the sites scored including 8 of the 10 highest priority sites had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. The vast majority of the crossings in Boxford were single or multiple culverts that could likely be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.


Figure 37. Outlet of road-stream crossing at Main Street, Boxford (Site #859)

The Nor'East Chapter of Trout Unlimited has been working closely with the Town of Boxford and other partners to restore aquatic connectivity in Crooked Pond Brook, a tributary to Fish Brook, to increase habitat quality for river dependent fish including brook trout. This included a culvert upgrade on a crossing near Lockwood Lane in 2013[34]. The Town, with support from Trout Unlimited, is currently planning to replace the next culvert upstream at the brook's crossing under Middleton Road (Site #484). This site ranks as a high priority in the screening analysis and the upgraded crossing will significantly improve habitat connectivity in Crooked Pond Brook.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 15 high priority non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[35]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

[34] https://www.ipswichriver.org/projects-2/crooked-pond-brook/

[35] A crossing on Baldpate Road (Site #814) was chosen for design based on its ecological score. Site #720 (Main Street) was selected based on ecological score and best professional judgment as it is located along a migration path from Fish Brook to Stiles Pond. The crossings designed on Middleton Road (Site #511) and Pye Brook Lane (Site #679) were identified as high priority for infrastructure risk in the preliminary results used to choose crossings for design and were later significantly downgraded in priority during a quality control review of the model results.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Boxford designs begin on page 197

Table 27. Dams in the portion of the Great Marsh study region within the Town of Boxford, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank		Dam Name	Priority Scoring			Active/ Priority Project
	Town	Region		Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA00159	1	2	Howe Pond Dam	1	1	2	
MA01198	2	5	Baldpate Pond Dam	0.5	1.5	2	
MA00158	3	9	Stiles Pond Outlet Dam	1	0.5	1.5	
MA00160	4	12	Lowe Pond Outlet Dam	0.5	1	1.5	
MA01202	4	12	Towne Pond Dam	0.5	1	1.5	
MA01525	6	30	Lockwood Dam 1	0	1	1	
MA01201	7	40	Fourmile Pond Dam	0.5	0	0.5	
MA01199	8	45	Lockwood Dam 3	0	0.5	0.5	
MA03227	8	45	Spofford Pond Outlet Dam	0	0.5	0.5	
MA03229	8	45	Fish Brook Dam	0	0.5	0.5	

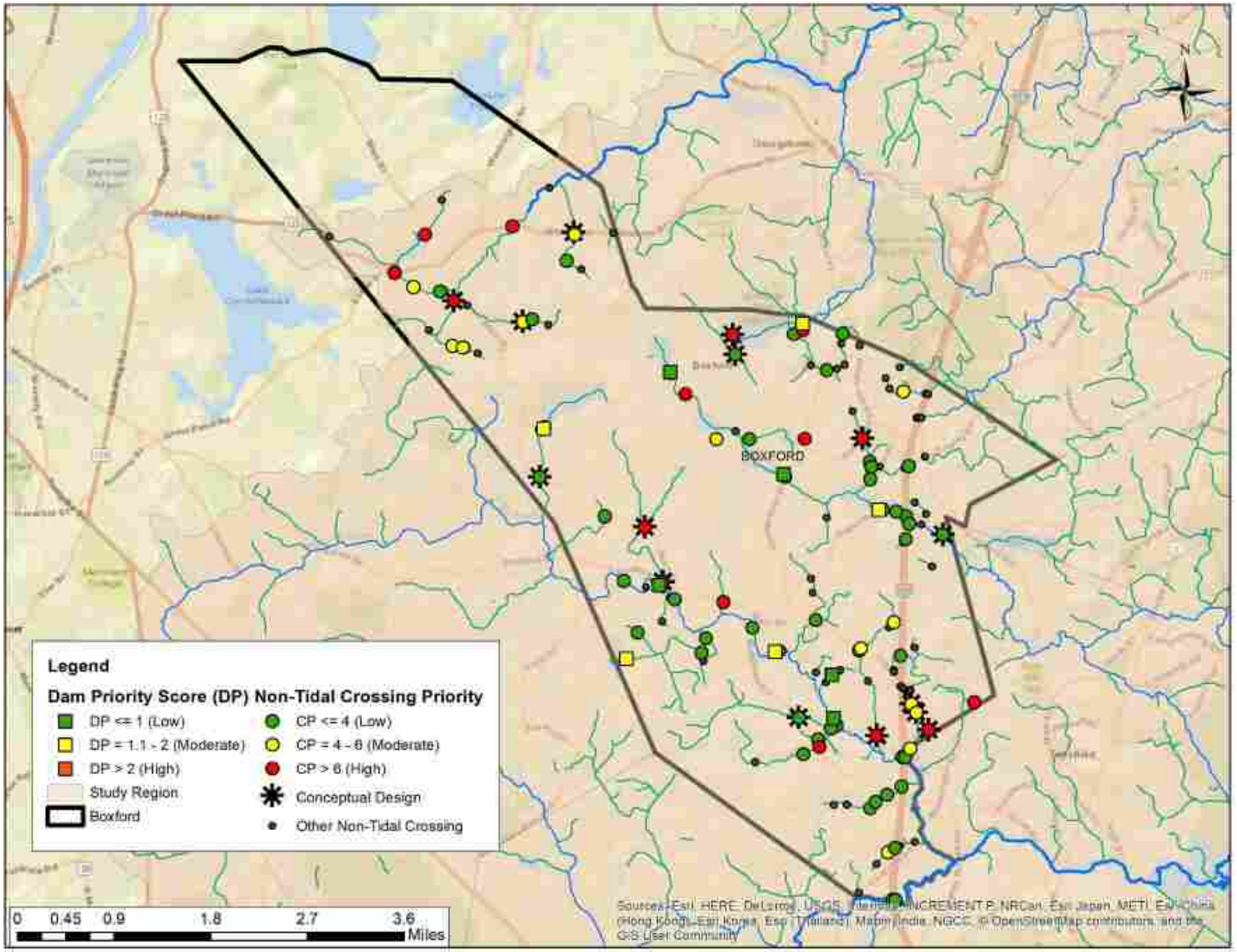

Figure 38. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of Boxford, MA. Crossings with available conceptual designs are also noted.

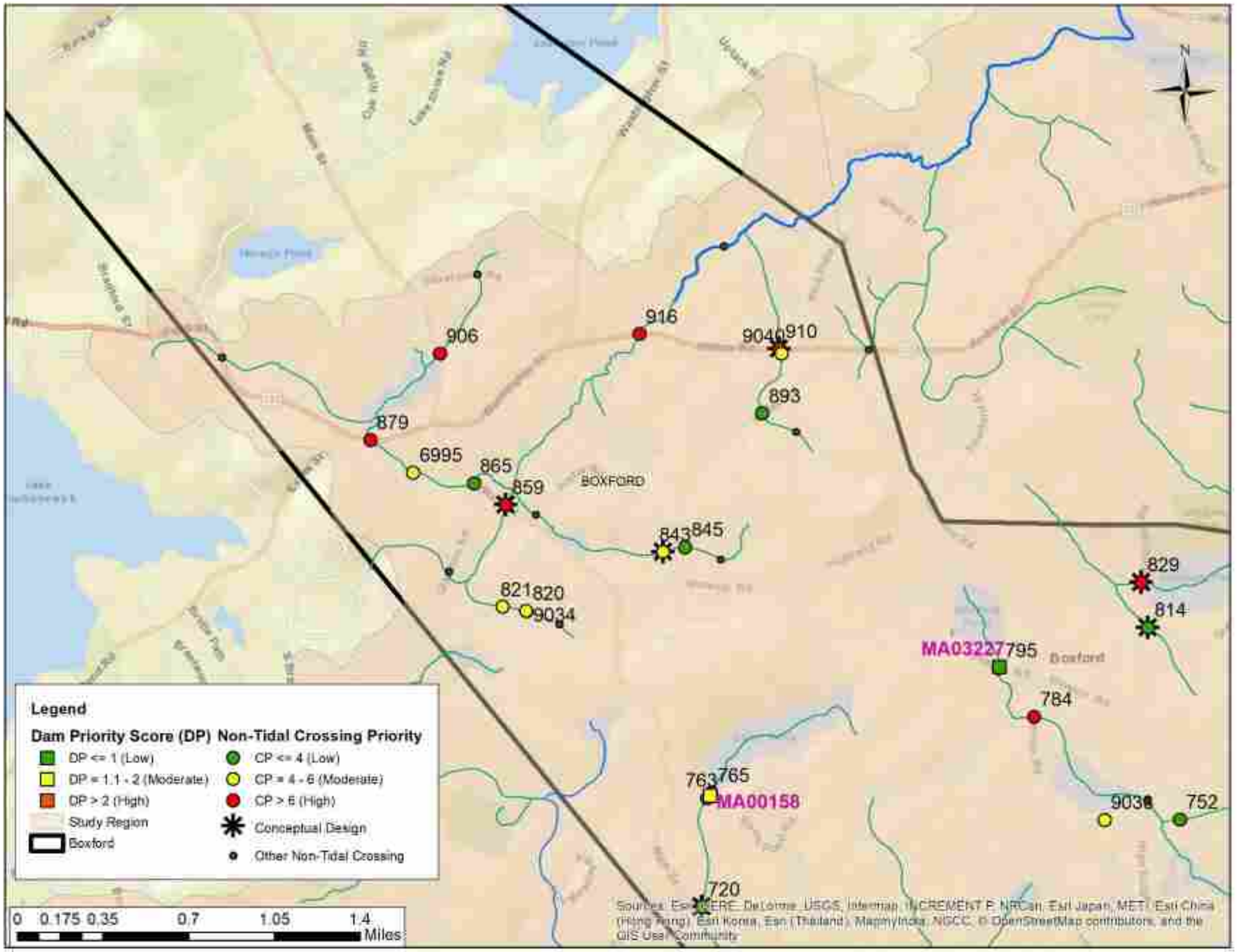

Figure 39. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the northern portion of the Town of Boxford, MA. Dam ID shown in pink and crossing ID shown in black.

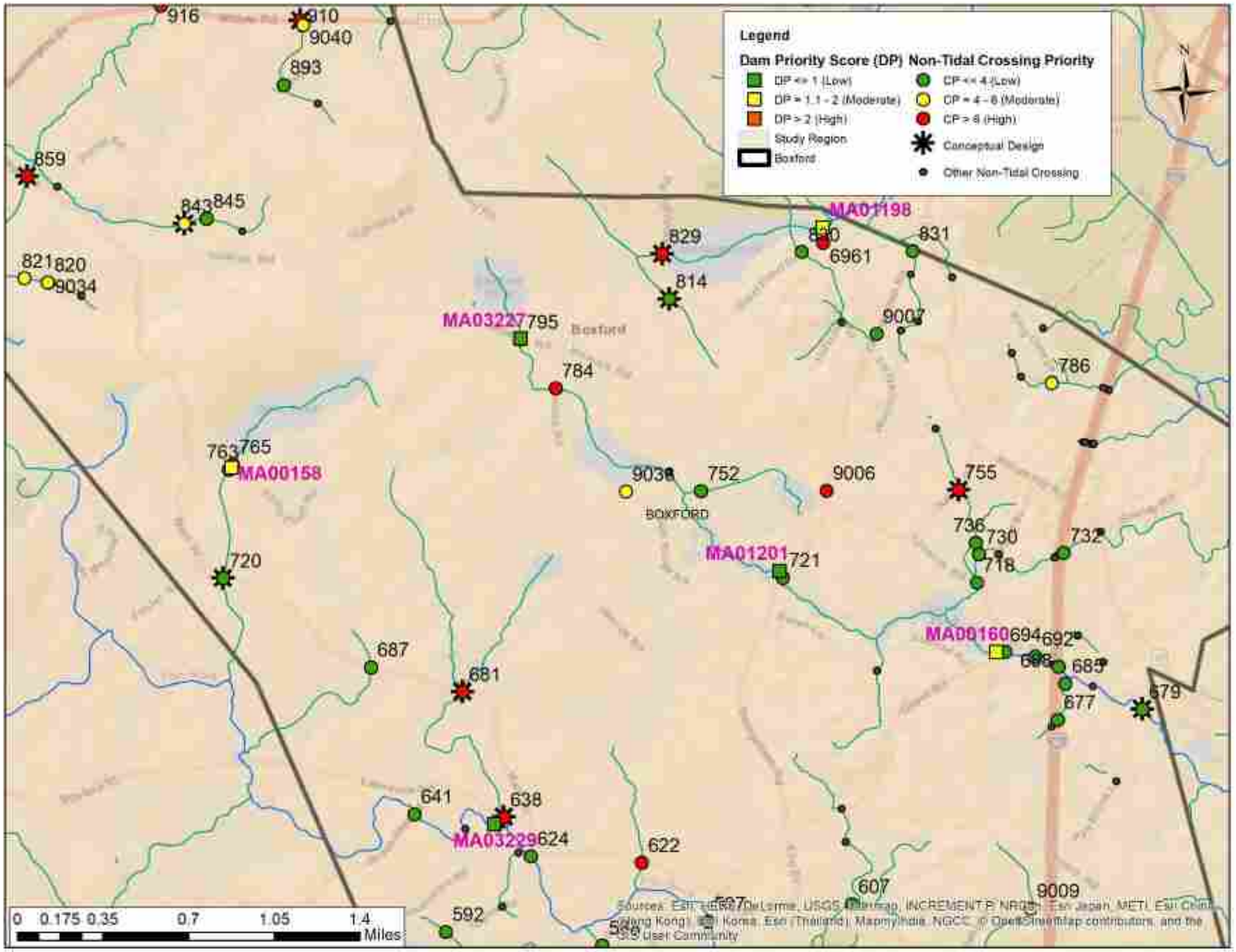

Figure 40. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the central portion of the Town of Boxford, MA. Dam ID shown in pink and crossing ID shown in black.

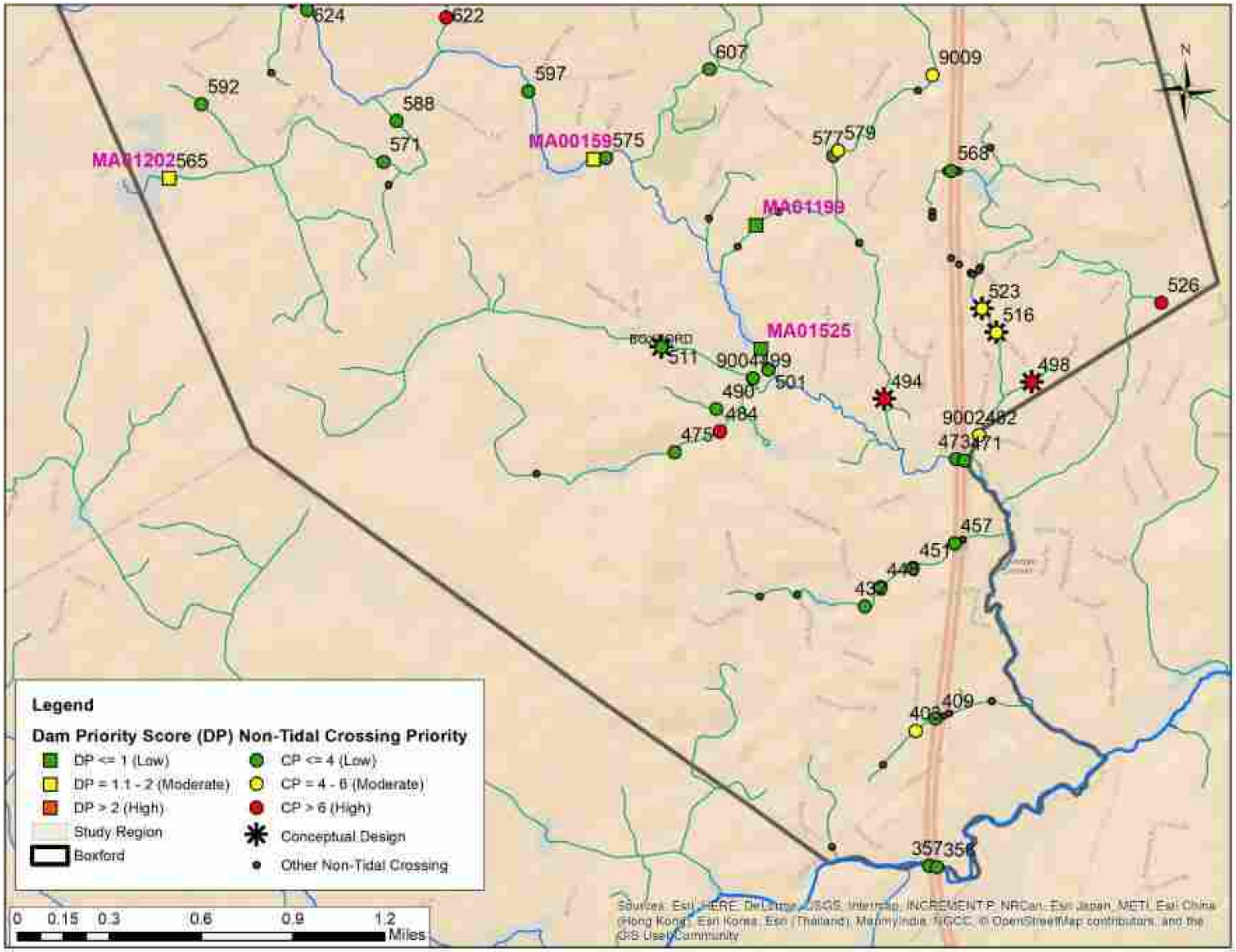

Figure 41. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the southern portion of the Town of Boxford, MA. Dam ID shown in pink and crossing ID shown in black.

Table 28. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Boxford, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (page 1 of 3)

Crossing ID	Priority Rank Town	Priority Rank Region	Road	Structure Type	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Crossing Priority (CP)	Concept Designs
879	1	7	Washington Street	Single Culvert	5.0	3.7	8.7	
859	2	13	Main Street	Multiple Culvert	5.0	3.3	8.3	Yes
681	3	17	Main Street	Single Culvert	3.0	4.8	7.8	Yes
755	4	18	Kelsey Road	Single Culvert	5.0	2.7	7.7	Yes
765	5	23	Off Styles Pond Road	Single Culvert	2.6	5.0	7.6	
484	6	35	Middleton Road	Single Culvert	4.0	3.0	7.0	
9006	7	36	Georgetown Road	Single Culvert	5.0	2.0	7.0	
906	8	52	Main Street	Single Culvert	4.6	2.1	6.7	
916	9	57	Willow Road	Single Culvert	5.0	1.7	6.7	
494	10	60	Lockwood Lane	Single Culvert	5.0	1.7	6.7	Yes
638	11	61	Lawrence Road	Single Culvert	5.0	1.7	6.7	Yes
910	12	69	Willow Road	Single Culvert	3.6	3.0	6.6	Yes
784	13	76	Herrick Road	Culvert	5.0	1.6	6.6	
622	14	86	Main Street	Single Culvert	5.0	1.4	6.4	
526	15	97	Surrey Lane	Single Culvert	5.0	1.3	6.3	
6961	16	102	Great Pond Drive	Single Culvert	5.0	1.3	6.3	
498	17	109	Silverbrook Road	Single Culvert	4.0	2.2	6.2	Yes
829	18	113	Baldpate Road	Single Culvert	5.0	1.2	6.2	Yes
9009	19	136	Off Pinehurst Drive	Single Culvert	5.0	1.0	6.0	
820	20	140	Off Ipswich Road	Single Culvert	5.0	0.9	5.9	
786	21	149	King George Drive	Single Culvert	3.6	2.2	5.8	
795	22	150	Ipswich Road	Single Culvert	5.0	0.8	5.8	
9040	23	164	Off Willow Road	Bridge	4.6	1.0	5.6	
843	24	168	Porter Road	Single Culvert	0.6	5.0	5.6	Yes
821	25	175	Ipswich Road	Single Culvert	4.6	0.9	5.5	
9033	26	182	High Ridge Road	Single Culvert	4.0	1.4	5.4	
523	27	190	Silver Brook Road	Single Culvert	2.0	3.2	5.2	Yes
516	28	203	Silverbrook Road	Single Culvert	NA	4.9	4.9	Yes
579	29	204	Topsfield Road	Single Culvert	4.0	0.9	4.9	

Table 28 (Continued). Non-tidal crossings in the portion of the Great Marsh study region within the Town of Boxford, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (page 2 of 3)

Crossing ID	Priority Rank Town	Priority Rank Region	Road	Structure Type	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Crossing Priority (CP)	Concept Designs
482	30	208	Lockwood Lane	Single Culvert	3.0	1.8	4.8	
403	31	224	Middleton Road	Single Culvert	3.0	1.3	4.3	
6995	32	236	Brook Road	Culvert	0.0	4.1	4.1	
814	33	254	Baldpate Road	Single Culvert	0.0	3.2	3.2	Yes
577	34	270	Cahoon Road	Single Culvert	1.6	1.0	2.6	
565	35	278	Off Winding Oaks Way	Single Culvert	NA	2.5	2.5	
607	36	282	Topsfield Road	Single Culvert	0.0	2.4	2.4	
694	37	306	Depot Road	Single Culvert	0.6	1.4	2.0	
432	38	307	Wildmeadow Road	Single Culvert	NA	2.0	2.0	
568	39	312	I-95 SB	Single Culvert	NA	1.9	1.9	
448	40	314	Holmes Rd	Single Culvert	0.0	1.9	1.9	
451	41	319	Middleton Road	Single Culvert	NA	1.9	1.9	
9004	42	322	Off Lockwood Lane	Multiple Culvert	NA	1.9	1.9	
687	43	339	Main Street	Single Culvert	NA	1.7	1.7	
893	44	348	Valley Road	Single Culvert	0.0	1.7	1.7	
511	45	356	Middleton Road	Single Culvert	0.0	1.6	1.6	Yes
571	46	364	Townsend Farm Road	Multiple Culvert	0.0	1.6	1.6	
592	47	371	Towne Road	Single Culvert	0.0	1.5	1.5	
588	48	378	Townsend Farm Road	Single Culvert	0.6	0.9	1.5	
677	49	383	I-95 NB	Single Culvert	NA	1.4	1.4	
763	50	384	Stiles Pond Road	Multiple Culvert	0.0	1.4	1.4	
752	51	385	Batchelder Road	Multiple Culvert	0.0	1.4	1.4	
9002	52	386	Andrew's Farm Road	Open Bottom Arch	0.6	0.8	1.4	
730	53	390	Service Road off Pond Street	Single Culvert	0.0	1.4	1.4	
9007	54	392	Off Georgetown Road	Single Culvert	NA	1.4	1.4	
720	55	403	Main Street	Multiple Culvert	0.0	1.3	1.3	Yes
490	56	420	Middleton Road	Single Culvert	NA	1.2	1.2	
718	57	429	Ipswich Road	Single Culvert	NA	1.2	1.2	
641	58	430	Brookview Road	Bridge	NA	1.1	1.1	

Table 28. (Continued). Non-tidal crossings in the portion of the Great Marsh study region within the Town of Boxford, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (page 3 of 3)

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
9034	59	442	Off Topsfield Road	Bridge	NA	1.1	1.1	
721	60	443	Georgetown Road	Bridge	0.0	1.1	1.1	
845	61	460	Anna's Way	Single Culvert	0.0	1.0	1.0	
679	62	463	Pye Brook Lane	Multiple Culvert	0.0	0.9	0.9	Yes
624	63	466	Towne Road	Multiple Culvert	0.0	0.9	0.9	
736	64	471	Service Road off Pond Street	Bridge	0.0	0.9	0.9	
732	65	473	I-95 NB	Single Culvert	NA	0.9	0.9	
597	66	474	Middleton Road	Bridge	NA	0.8	0.8	
409	67	479	Interstate 95	Single Culvert	NA	0.8	0.8	
499	68	480	Lockwood Lane	Multiple Culvert	0.0	0.8	0.8	
688	69	516	I-95 NB	Single Culvert	NA	0.6	0.6	
831	70	520	Georgetown Road	Single Culvert	0.0	0.6	0.6	
457	71	524	I-95 SB	Single Culvert	NA	0.6	0.6	
692	72	525	I-95 NB	Open Bottom Arch	0.0	0.6	0.6	
501	73	527	Lockwood Lane	Bridge	0.0	0.6	0.6	
830	74	544	Great Pond Ave	Bridge	0.0	0.5	0.5	
685	75	577	Power Lines East of I-95 NB	Bridge	NA	0.2	0.2	
475	76	582	Off Middleton Road	Ford	NA	0.2	0.2	
865	77	589	Main Street	Single Culvert	0.0	0.1	0.1	
471	78	600	I-95 NB	Bridge	NA	0.1	0.1	
473	79	601	I-95 SB	Bridge	NA	0.0	0.0	
357	80	604	Interstate 95	Bridge	NA	0.0	0.0	
356	81	605	Interstate 95	Bridge	NA	0.0	0.0	
575	82	611	Mill Road	Bridge	0.0	0.0	0.0	

Danvers

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Danvers. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[36].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[37].

Approximately 3.9 square miles of the Town of Danvers is located within the Great Marsh study region. This portion of the study watershed, located on the northern and western edges of Danvers, is outside of the coastal zone so Danvers is considered an inland municipality in our analysis (Figure 42). As an inland municipality, Danvers does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 18 potential barrier sites with structures confirmed and prioritized at 13 of those locations including 3 dams (Table 29) and 10 non-tidal crossings (Table 30).

None of the dams in Danvers were ranked for priority. All three of the dams in the Danvers portion of the study region are high hazard structures that have high priority scores (Table 29). All three structures are associated with the Putnamville Reservoir and are critical components of the Salem-Beverly water supply system.

We inventoried and prioritized 10 non-tidal crossings in the Town of Danvers based on combined ecological and infrastructure risk. Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. None of the crossings were identified as high priorities for on a regional level. The highest priority crossing, located on Valley Road, ranked 180th across the entire study region (Table 31). With a CRI score of 4, this was also the only structure that was identified as a significant infrastructure risk by our screening tool. Sites with infrastructure risk (CRI) scores of 4 or greater indicating that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. We recommend further investigation at this site as it is a single culvert that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time for replacement or maintenance.

We did not develop conceptual designs for upgrade of any crossings located in the Town of Danvers.

[36] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[37] Full report document available at http://www.pie-rivers.org/barriers/

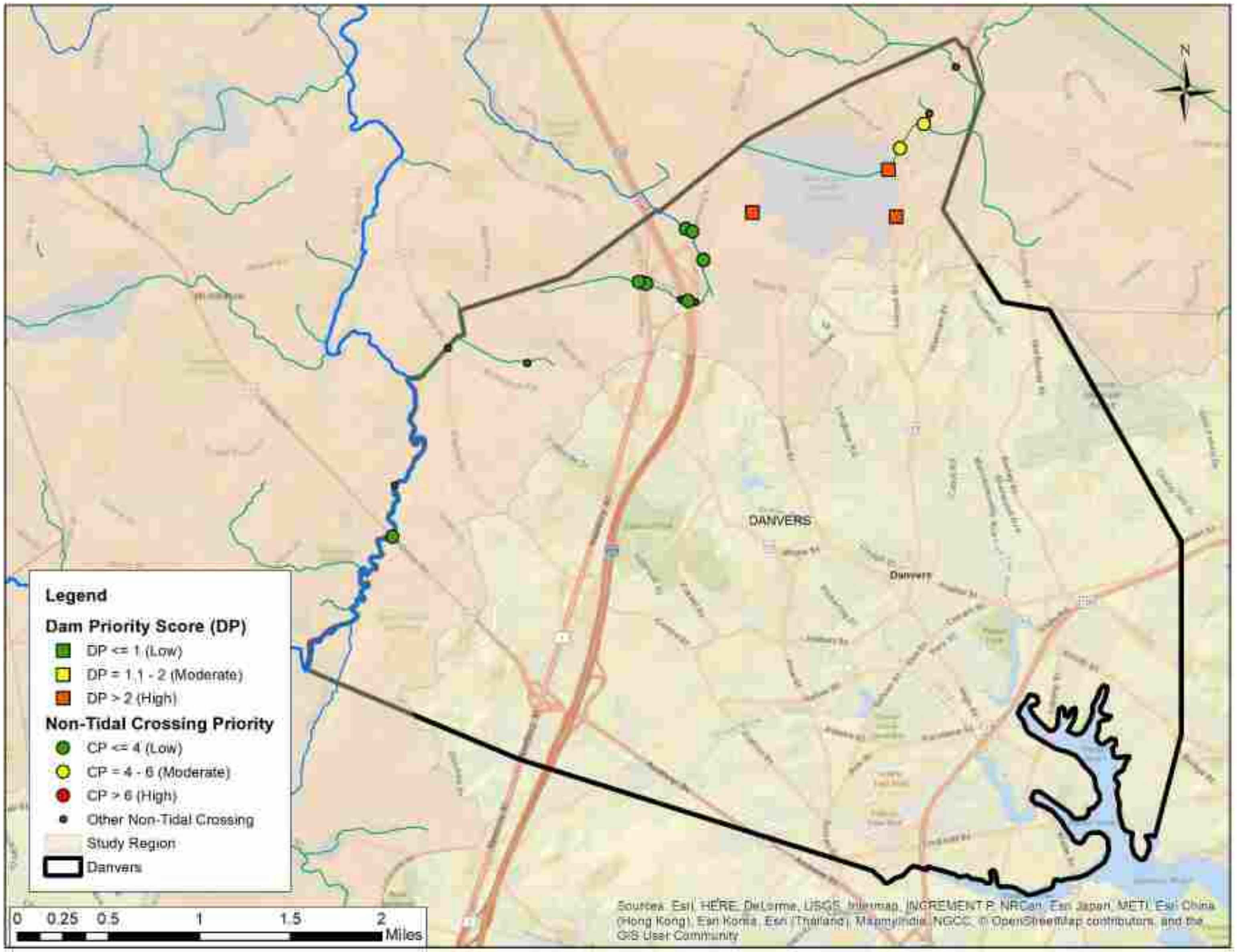

Figure 42. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of Danvers, MA.

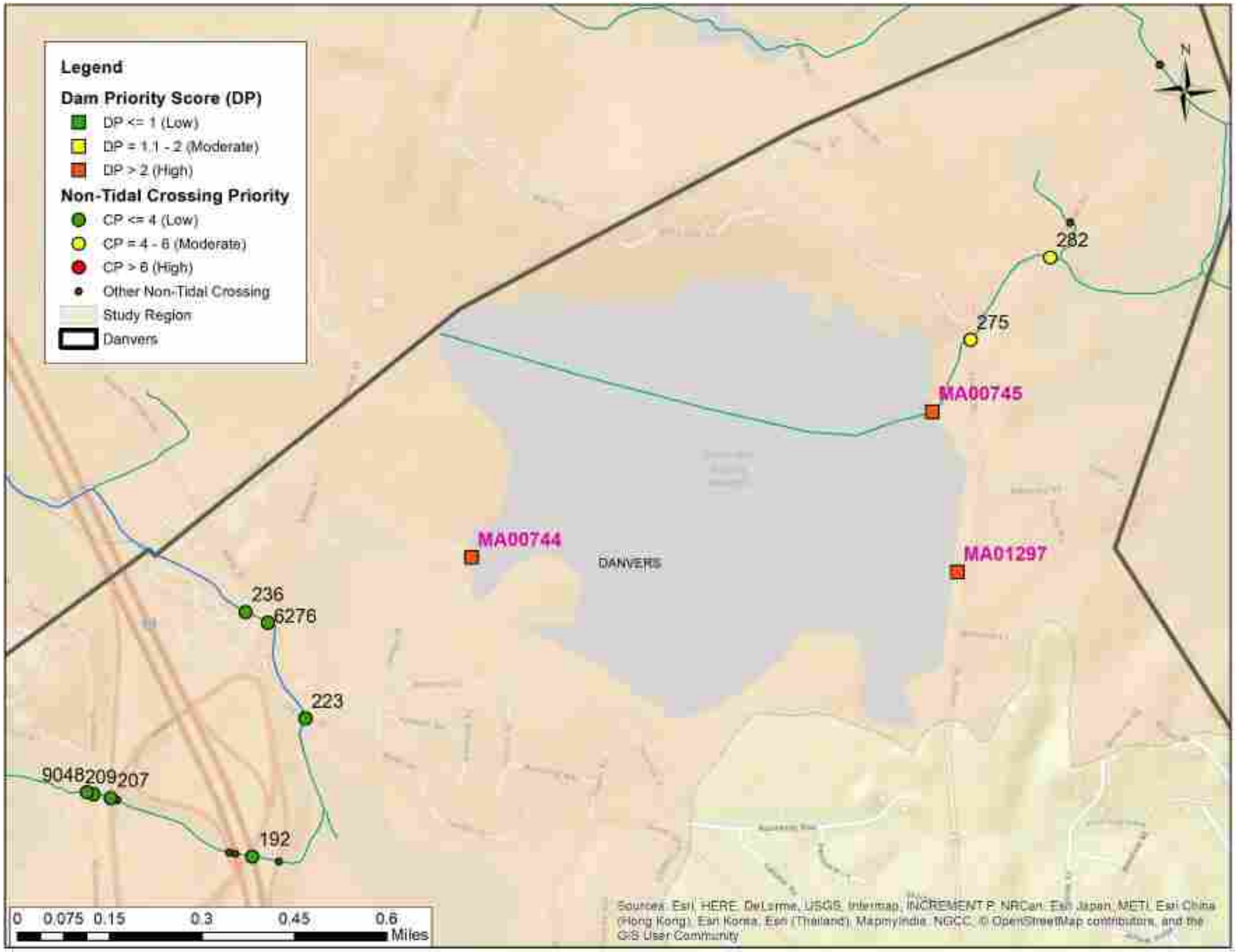

Figure 43. Closeup view of dams and non-tidal crossings in the Great Marsh Study region within the Town of Danvers, MA. Dam ID shown in pink and crossing ID shown in black.

Table 29. Dams in the portion of the Great Marsh study region within the Town of Danvers, MA. All dams in Danvers are associated with the Putnamville Reservoir and were not prioritized due to their importance as part of a drinking water supply system.

Dam ID	Priority Rank Town	Priority Rank Region	Dam Name	Priority Scoring Infrastructure Risk (RI)	Priority Scoring Ecological Impact (EI)	Priority Scoring Priority Score (DP)	Active/ Priority Project
MA00745	NA	NA	Putnamville Reservoir Dam	2	1	3	
MA00744	NA	NA	Putnamville Reservoir West Dike	2	0.5	2.5	
MA01297	NA	NA	Putnamville Reservoir East Dike	2	0.5	2.5	

Table 30. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Danvers, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank Town	Priority Rank Region	Road	Structure Type	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Crossing Priority (CP)	Concept Designs
282	1	180	Valley Road	Single Culvert	4.0	1.4	5.4	
275	2	206	Locust Street	Multiple Culvert	2.6	2.2	4.8	
209	3	245	Ferncroft Road	Single Culvert	2.2	1.3	3.5	
9048	4	262	Off Ferncroft Road	Bridge	2.6	0.2	2.8	
236	5	268	Old North Street	Single Culvert	1.2	1.4	2.6	
6276	6	350	Route 1	Culvert	0.0	1.7	1.7	
207	7	388	Us 1/I95 Interchange	Single Culvert	NA	1.4	1.4	
223	8	398	Old North Street	Multiple Culvert	0.0	1.3	1.3	
192	9	423	I-95 NB	Multiple Culvert	NA	1.2	1.2	
118	10	581	Andover Street Route 114	Bridge	0.0	0.2	0.2	

Georgetown

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Georgetown. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[38].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[39].

Almost all of the Town of Georgetown is located within the Great Marsh study region covering an area of approximately 12.9 square miles. All but the northwestern corner of Georgetown is within the study region and the town is outside of the coastal zone (Figure 45). As an inland municipality, Georgetown does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 44 potential barrier sites with structures confirmed and prioritized at 40 of those locations including 1 dam (Table 32) and 39 non-tidal crossings (Table 31).

Figure 44. Outlet of road-stream crossing at Nelson Street, Georgetown (Site #862)

The Pentucket Pond Outlet Dam (MA00261) is the only dam located within the Town of Georgetown. This dam is a high priority, tied for 2nd highest priority in the region based on a combination of risk and ecological impact (Table 32). The Pentucket Pond Outlet Dam is the sixth and final dam on the Parker River between the ocean and Pentucket Pond, the primary alewife spawning pond in the Parker watershed. In addition to its impact on fish and wildlife migration, it is also rated as a significant hazard dam by the MA Office of Dam Safety, causing it to have a higher priority rating than the other Parker River dams.

We inventoried and prioritized 39 non-tidal crossings in the Town of Georgetown based on combined ecological and infrastructure risk. The screening results identified three crossings that were among the 50 highest priority crossings region-wide (Table 31). The highest priority crossing in town is a single culvert on Nelson Street (Site #862) which ranked 10th regionally. Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are

[38] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[39] Full report document available at http://www.pie-rivers.org/barriers/

undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. Fourteen of the 15 highest priority sites had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. The vast majority (13) of the 15 highest priority crossings in Georgetown are single or multiple culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 4 high priority non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[40]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Georgetown designs begin on page 217

[40] The crossing designed on Jewett Street (Site #1003) was chosen based on its ecological score.

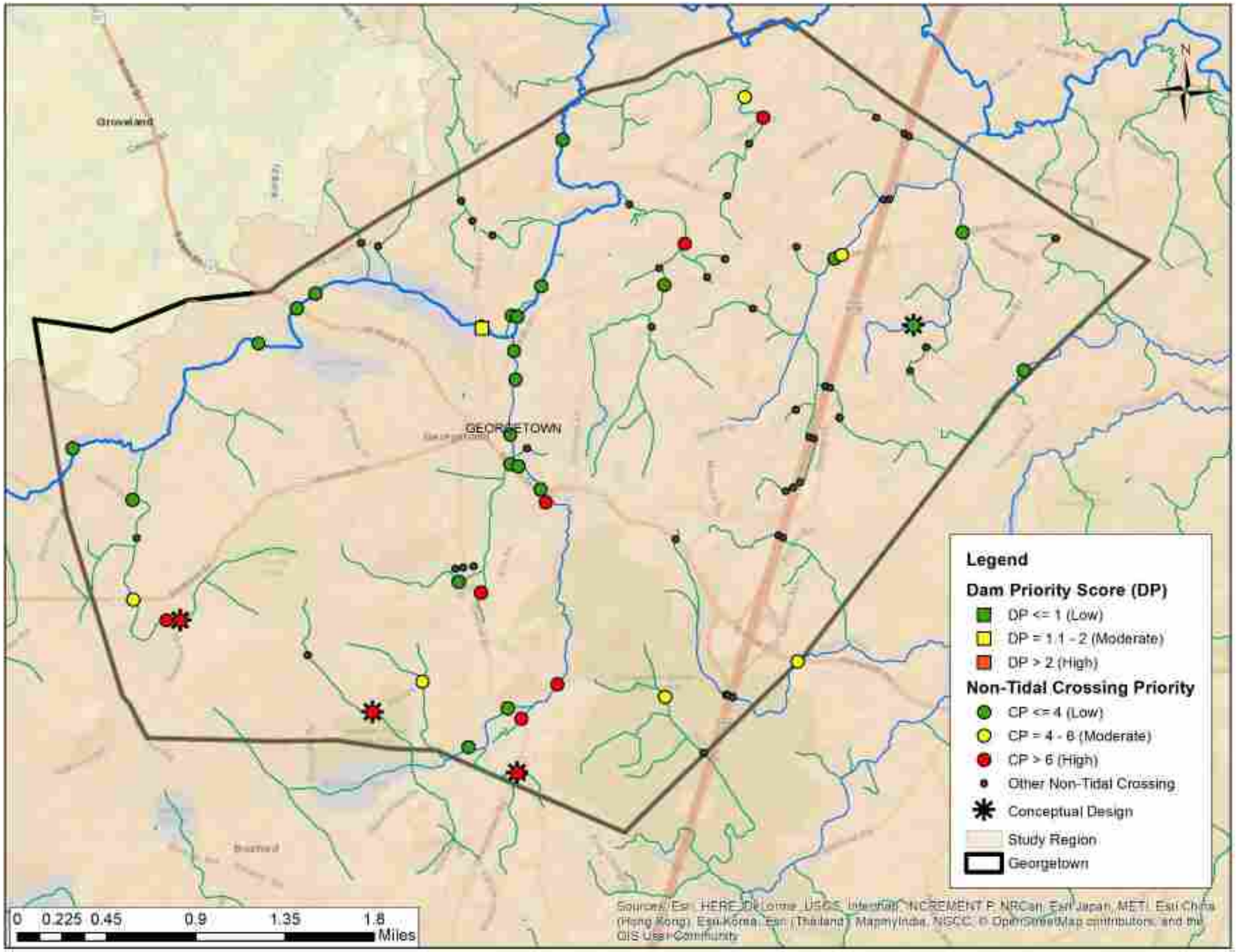

Figure 45. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of Georgetown, MA. Crossings with available conceptual designs are also noted.

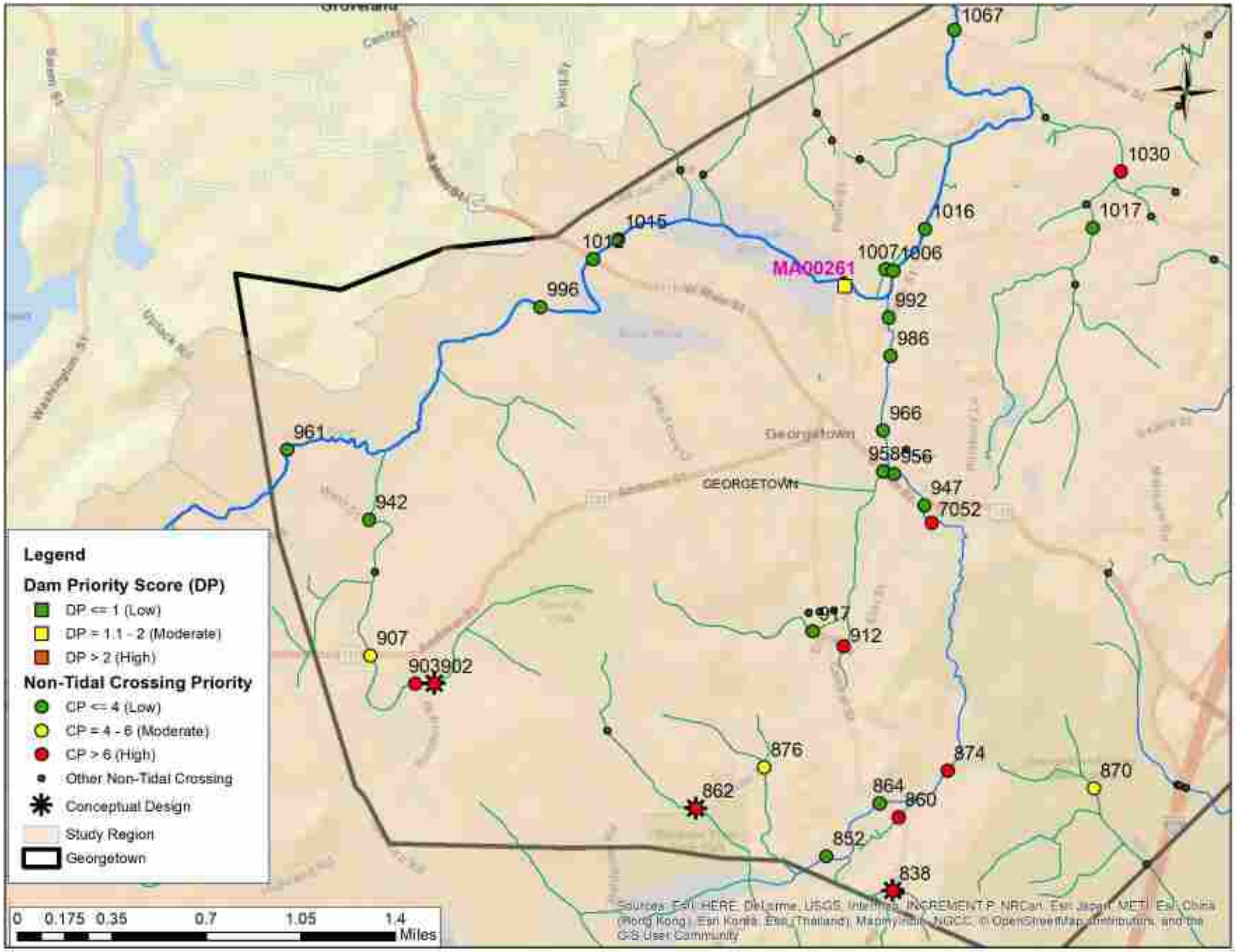

Figure 46. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the western portion of the Town of Georgetown, MA. Dam ID shown in pink and crossing ID shown in black.

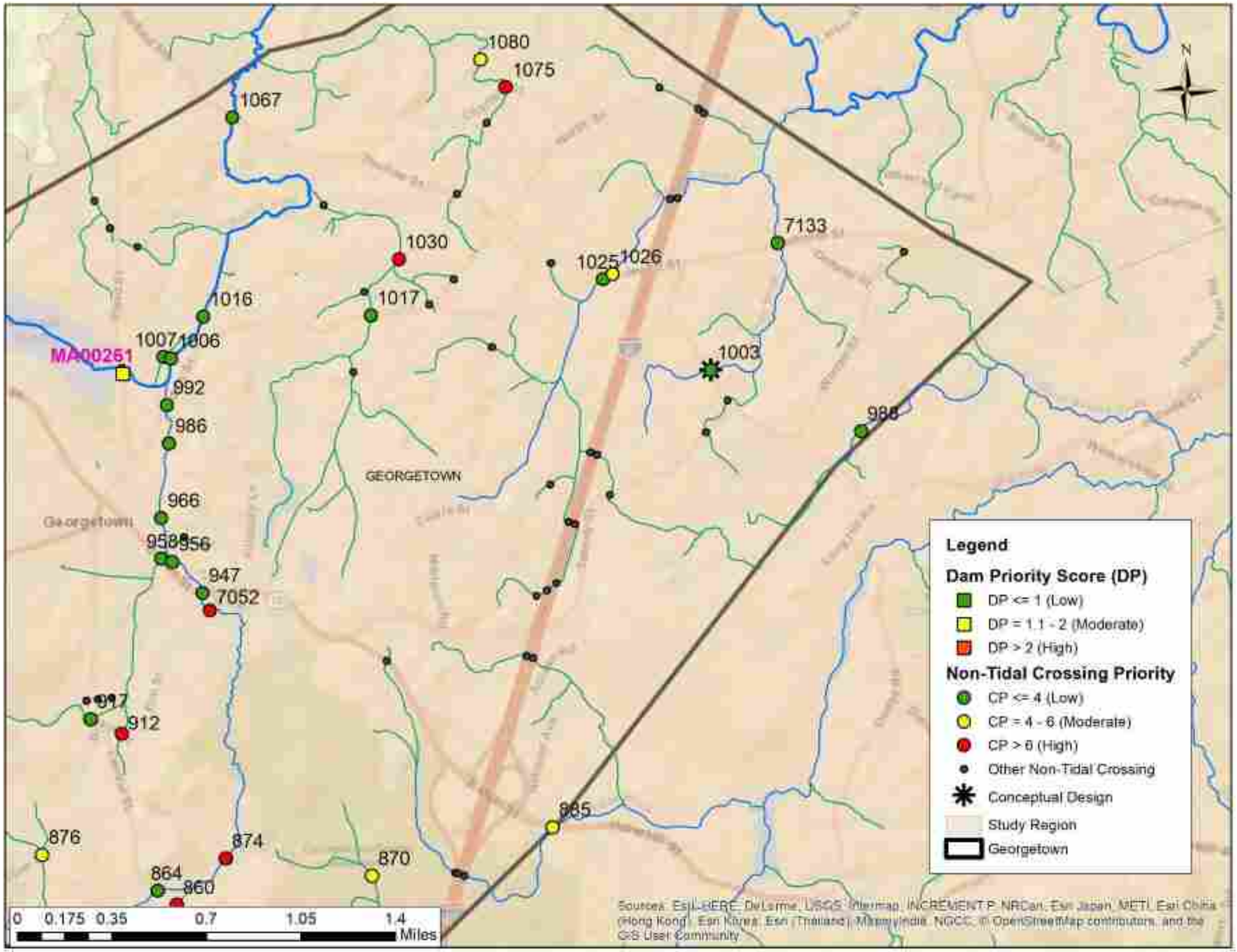

Figure 47. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the eastern portion of the Town of Georgetown, MA. Dam ID shown in pink and crossing ID shown in black.

Table 31. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Georgetown, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 1 of 2)

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
862	1	10	Nelson Street	Single Culvert	5.0	3.5	8.5	Yes
860	2	25	Central Street	Single Culvert	5.0	2.5	7.5	
874	3	37	East Street	Single Culvert	5.0	2.0	7.0	
902	4	64	Spofford Street	Single Culvert	4.6	2.0	6.6	Yes
7052	5	77	Church Street	Multiple Culvert	5.0	1.5	6.5	
1030	6	88	Brookmeadow Lane	Multiple Culvert	4.6	1.8	6.4	
838	7	96	Georgetown Road	Open Bottom Arch	5.0	1.4	6.4	Yes
912	8	107	Brook Street	Multiple Culvert	5.0	1.3	6.3	
903	9	111	Hardy Terrace	Single Culvert	4.6	1.6	6.2	
1075	10	124	Charles Street	Multiple Culvert	5.0	1.1	6.1	
885	11	138	East Main Street	Single Culvert	5.0	0.9	5.9	
1026	12	143	Jewett Street	Multiple Culvert	5.0	0.8	5.8	
876	13	155	Nelson Street	Multiple Culvert	3.6	2.1	5.7	
1080	14	157	Off Dereck Circle	Bridge	5.0	0.7	5.7	
907	15	165	Andover Street	Single Culvert	4.0	1.6	5.6	
870	16	234	Pingree Farm Road	Ford	3.6	0.5	4.1	
1003	17	247	Jewett Street	Single Culvert	0.0	3.5	3.5	Yes
1017	18	260	North Street	Single Culvert	0.0	2.9	2.9	
917	19	264	Rail Bed off Brook Street	Single Culvert	NA	2.7	2.7	
852	20	329	Hiking Trail	Single Culvert	NA	1.8	1.8	
942	21	335	West Street	Single Culvert	0.0	1.8	1.8	
864	22	349	Central Street	Single Culvert	0.0	1.7	1.7	
7133	23	389	Jackman Road	Culvert	0.0	1.4	1.4	
958	24	391	East Main Street	Bridge	0.0	1.4	1.4	
956	25	399	Penn Brook Avenue	Bridge	0.0	1.3	1.3	
1015	26	445	Off West Main Street	Bridge	0.0	1.1	1.1	
947	27	449	East Main Street	Bridge	0.6	0.4	1.0	
1007	28	461	Mill Street	Bridge	0.0	0.9	0.9	
1067	29	486	Thurlow Street	Bridge	0.0	0.8	0.8	

Table 31 (Continued). Non-tidal crossings in the portion of the Great Marsh study region within the Town of Georgetown, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 2 of 2)

Crossing ID	Priority Rank		Road	Structure Type	Priority Scoring			Concept Designs
	Town	Region			Infrastructure Risk (CRI)	Ecological Impact (CEI)	Crossing Priority (CP)	
988	30	497	Farnham Road	Single Culvert	0.0	0.7	0.7	
1012	31	522	West Main Street	Single Culvert	0.0	0.6	0.6	
961	32	539	West Street	Bridge	0.0	0.5	0.5	
1016	33	545	Off North Street	Bridge	0.0	0.4	0.4	
996	34	548	Bailey Lane	Bridge	0.0	0.4	0.4	
986	35	558	Summer Street	Bridge	0.0	0.3	0.3	
992	36	562	North Street	Bridge	0.0	0.3	0.3	
966	37	563	Winter Street	Single Culvert	0.0	0.3	0.3	
1006	38	570	Mill Street	Bridge	0.0	0.3	0.3	
1025	39	587	Hazan Court	Bridge	0.0	0.2	0.2	

Table 32. Dams in the portion of the Great Marsh study region within the Town of Georgetown, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank		Dam Name	Priority Scoring			Active/ Priority Project
	Town	Region		Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA00261	1	2	Pentucket Pond Outlet Dam	1	1	2	

Hamilton

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Hamilton. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[41].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[42].

Almost all of the Town of Hamilton is located within the Great Marsh study region covering an area of approximately 14.4 square miles. All but a small area in the southeastern part of the town is within the study region and the Hamilton is outside of the coastal zone (Figure 49). As an inland municipality, Hamilton does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 34 potential barrier sites with structures confirmed and prioritized at 28 of those locations including all of which were non-tidal crossings (Table 33). Our analysis did not identify any dams in the Town of Hamilton.

We inventoried and prioritized 28 non-tidal crossings in the Town of Hamilton based on combined ecological and infrastructure risk. The screening results identify three crossings that were among the 50 highest priority crossings region-wide (Table 33). The highest priority crossing in town is a single culvert on Winthrop Street (Sinte #517) which ranked 15th regionally. Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. Eight of the 10 highest priority sites in town had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year.

Figure 48. Outlet of road-stream at Winthrop Street (Site #517). This perched crossing was the highest priority crossing identified by screening tools in the Town of Hamilton.

[41] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[42] Full report document available at http://www.pie-rivers.org/barriers/

While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. Nine of the 10 highest priority crossings in Hamilton are single or multiple culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of three high priority non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding[43]. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Hamilton designs begin on page 222

[43] The crossing of Black Brook on Highland Street (Site #527) that was designed was chosen based on its ecological score.

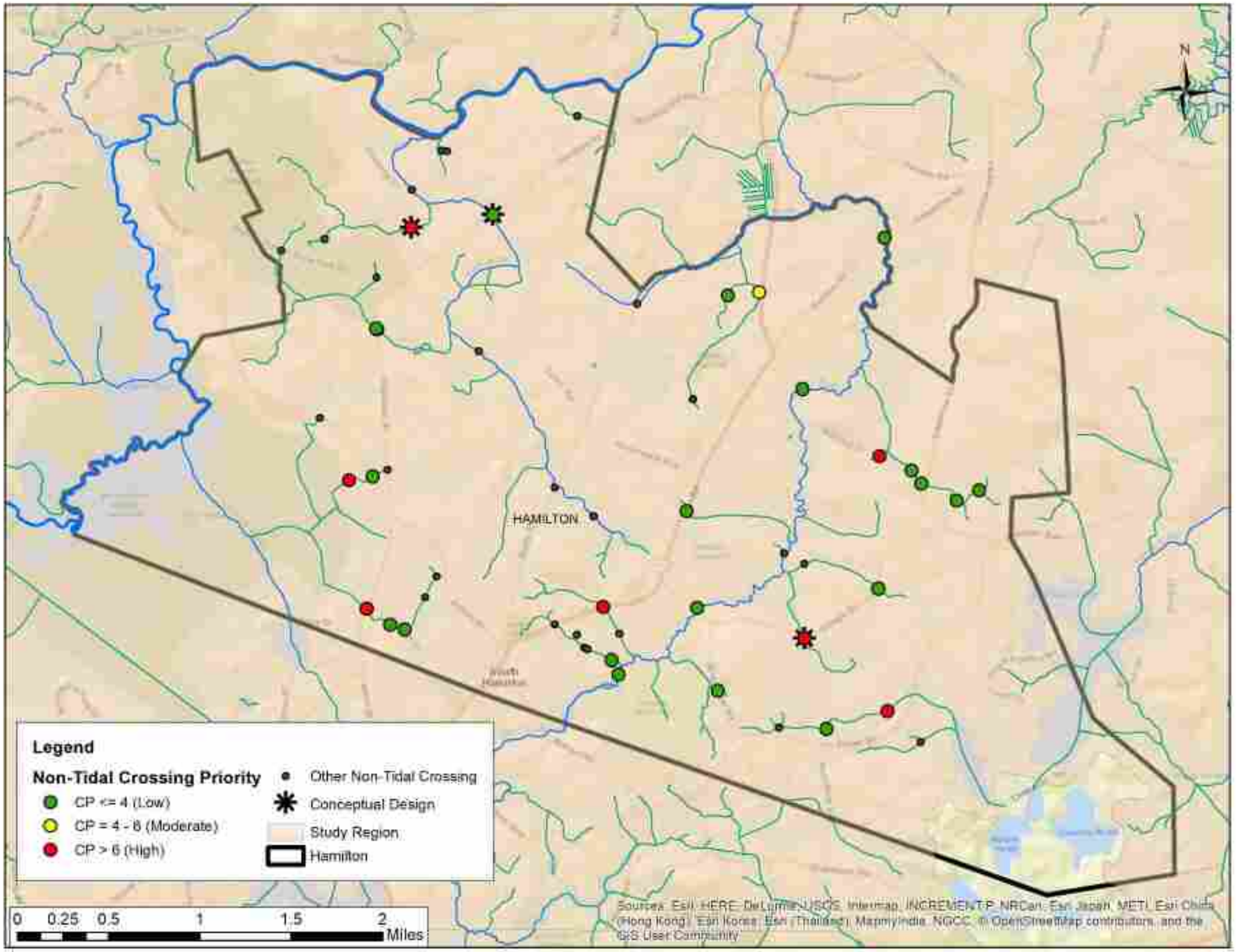

Figure 49. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of Hamilton, MA. Crossings with available conceptual designs are also noted.

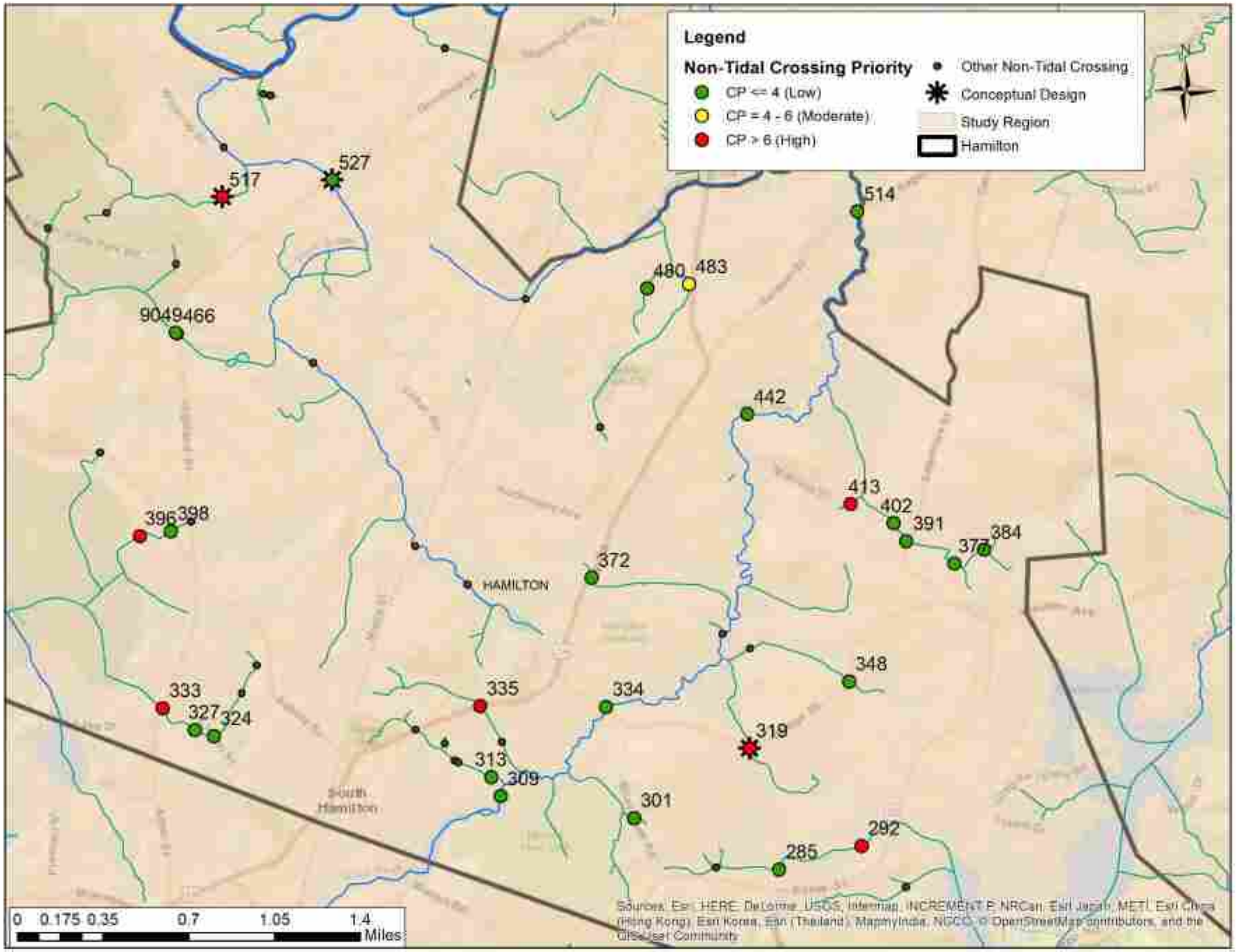

Figure 50. Closeup view of non-tidal crossings in the Great Marsh Study region within the Town of Hamilton, MA. Crossings with available conceptual designs are also noted.

Table 33. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Hamilton, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
517	1	15	Winthrop Sreet	Single Culvert	3.6	4.4	8.0	Yes
413	2	20	Moulton Street	Single Culvert	5.0	2.7	7.7	
292	3	34	Alan Road	Single Culvert	5.0	2.0	7.0	
319	4	62	bridge street	Single Culvert	4.0	2.7	6.7	Yes
396	5	66	Morris Avenue	Multiple Culvert	5.0	1.6	6.6	
335	6	82	Bay Road	Single Culvert	4.0	2.5	6.5	
466	7	101	Highland Street	Single Culvert	5.0	1.3	6.3	
333	8	132	Highland Street	Single Culvert	5.0	1.0	6.0	
483	9	169	Bay Road	Open Bottom Arch	5.0	0.6	5.6	
402	10	252	Moulton Street	Single Culvert	1.0	2.3	3.3	
285	11	266	Woodbury Rd	Multiple Culvert	0.6	2.1	2.7	
527	12	267	Highland Street	Single Culvert	0.0	2.7	2.7	Yes
313	13	276	Myopia Hunt Club access Road	Single Culvert	1.2	1.3	2.5	
324	14	310	Linden Street	Single Culvert	NA	2.0	2.0	
391	15	317	Sagamore Street	Single Culvert	0.6	1.3	1.9	
372	16	333	Bay Road	Single Culvert	NA	1.8	1.8	
327	17	336	Howard Street	Multiple Culvert	0.0	1.8	1.8	
309	18	354	Myopia Hunt Club access Road	Open Bottom Arch	NA	1.6	1.6	
398	19	415	Asbury Street	Single Culvert	0.0	1.2	1.2	
384	20	419	Blueberry Lane	Single Culvert	0.0	1.2	1.2	
514	21	434	Gardner Street	Culvert	0.0	1.1	1.1	
377	22	439	Juniper Road	Single Culvert	0.0	1.1	1.1	
480	23	447	Bay Road	Single Culvert	NA	1.0	1.0	
348	24	467	Bridge Street	Single Culvert	0.0	0.9	0.9	
301	25	498	Miles River Road	Single Culvert	NA	0.7	0.7	
334	26	506	Bridge Street	Bridge	NA	0.7	0.7	
442	27	523	Moulton Street	Bridge	0.0	0.6	0.6	
9049	28	588	Off Highland Street	Bridge	NA	0.1	0.1	

Middleton

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Andover. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[44].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[45].

The Town of Middleton is located outside of the coastal zone and the entire town is located within the Great Marsh study region covering approximately 14.5 square miles (Figure 53). As an inland municipality, Middleton does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 45 potential barrier sites with structures confirmed and prioritized at 44 of those locations including 9 dams (Table 34) and 35 non-tidal crossings (Table 35).

Figure 51. South Middleton Dam on the Ipswich River (MA01137).

The Ipswich River Dam (a.k.a. South Middleton Dam, MA01137), located on the Ipswich River in the southwest corner of the town, is the highest priority dam in the study region based on a combination of risk and ecological impact (Table 34). The dam is a significant hazard structure that currently blocks migratory fish access to the upper portion of the Ipswich River watershed including Martins Pond and other historic spawning ponds for alewife. The dam owner (Bostik, Inc.) is working with a group of partners to remove the outdated dam and restore a free flowing river at the site. The Mill Pond Dam (MA03006) also ranks among the higher priority dams in the region, tied for 9th. The Emerson Brook Dam at Lake Street (MA00273), Middleton Pond Outlet Dam (MA00295) and Middleton Pond Southeast Dike (MA02277) are all part of active water supply systems and were scored, but not priority ranked in our analysis.

We inventoried and prioritized 31 non-tidal crossings in the Town of Middleton based on ecological and infrastructure risk. Our screening analysis identified a single culvert on River Street (ID# 100) as the highest priority crossing in Middleton which ranked 58th in the region (Table 35). Poor scores in the screening tool

[44] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[45] Full report document available at http://www.pie-rivers.org/barriers/

generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. Seven of the 10 highest priority sites had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. Eight of the 10 highest priority crossings in Middleton are single or multiple culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

Figure 52. Outlet of road-stream crossing at Forest Street, Middleton (Site #274).

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 3 non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[46]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. The designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- Middleton designs begin on page 231

[46] The crossing under Essex Street (Site #380) immediately down of the Creighton Pond Dam was selected for design in error. The design is included here as it would be a considerable upgrade over the current structure, but we do not feel this should be a priority for replacement ahead of its regular maintenance schedule. Improved aquatic passage would offer little benefit absent of improvements to fish passage into Creighton Pond. The proposed structure would improve conditions for semi-aquatic animals that may be currently moving over the road surface. It would also improve hydraulic capacity and reduce failure risk during large storm events.

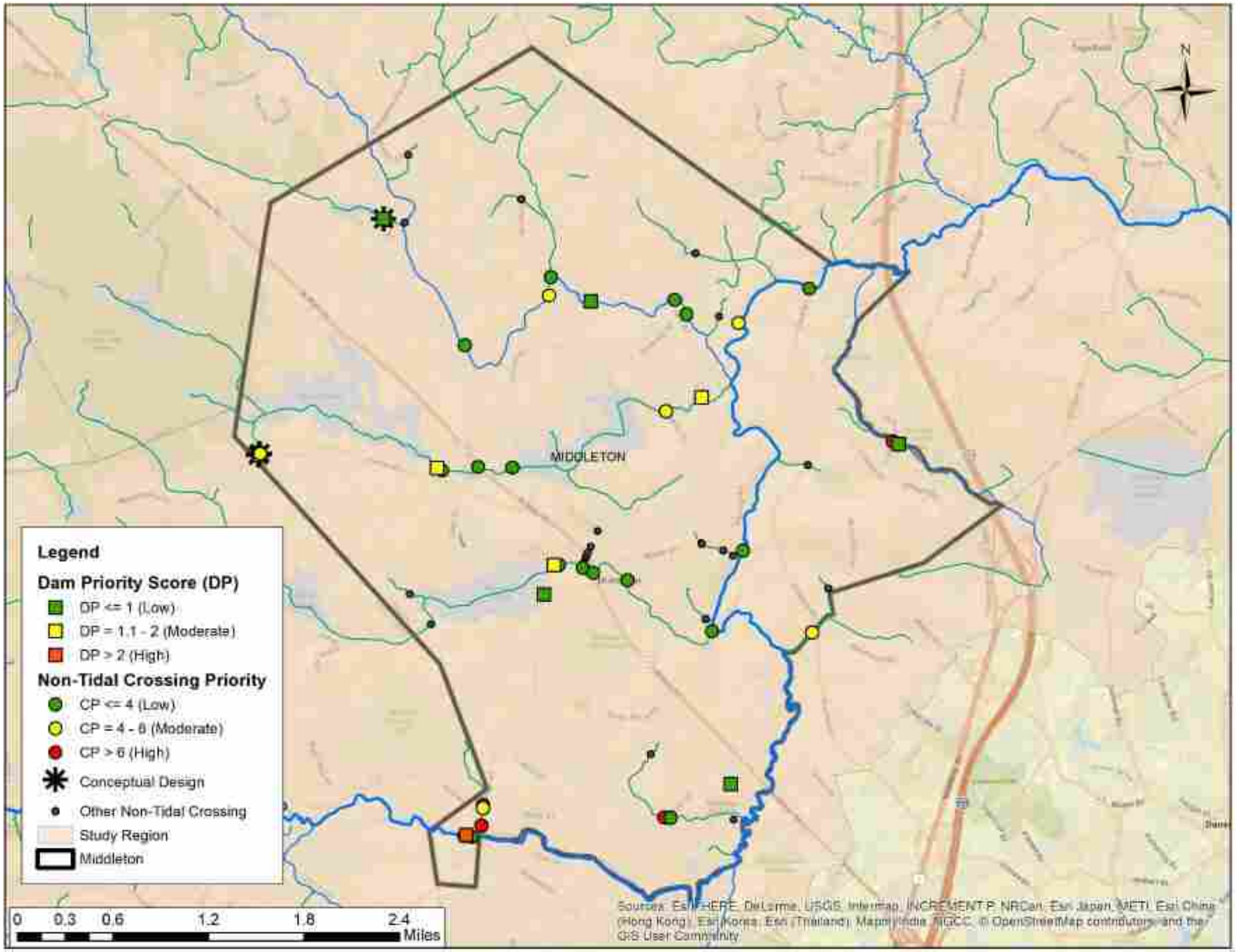

Figure 53. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region in the Town of Middleton, MA.

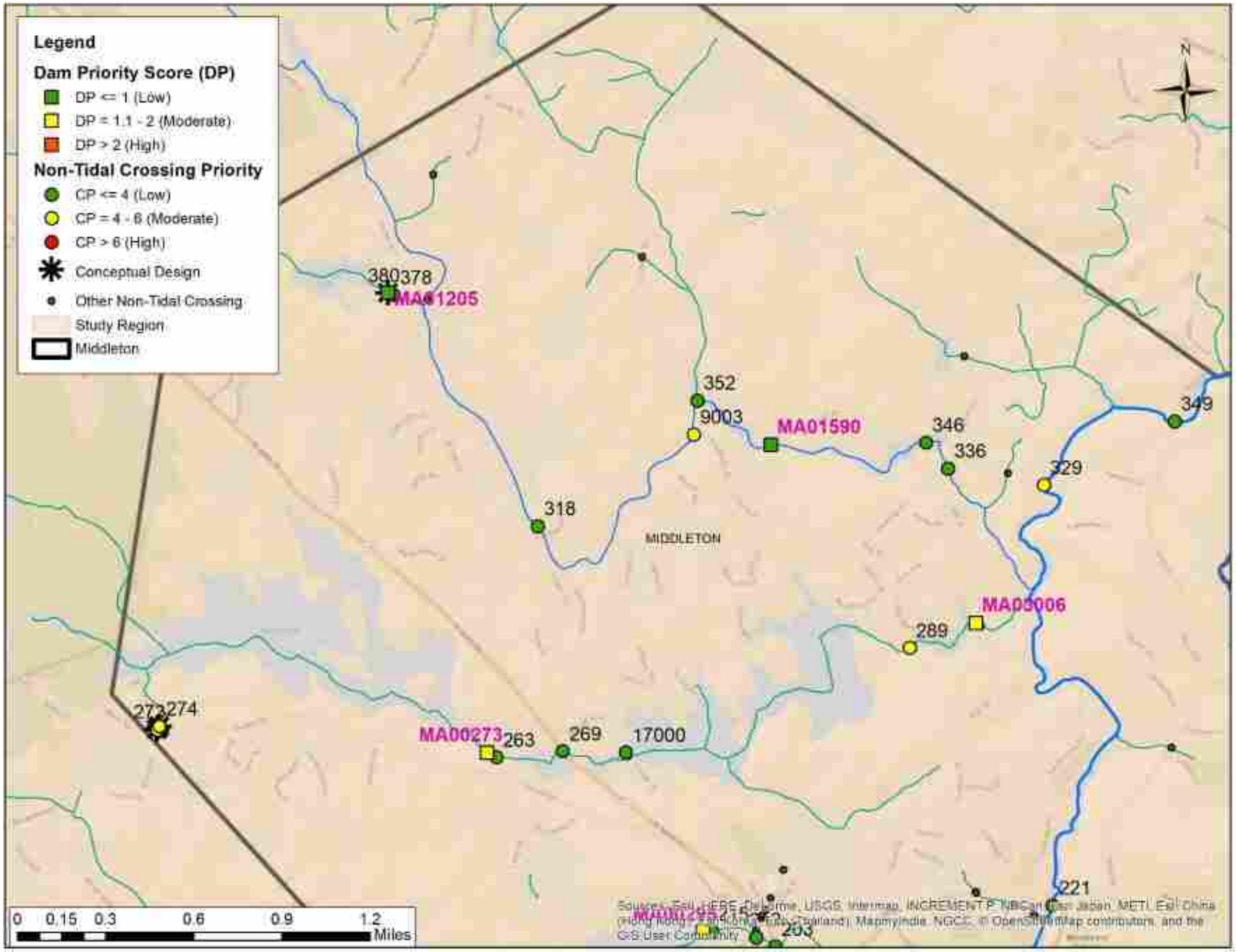

Figure 54. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the northern portion of the Town of Middleton, MA. Dam ID shown in pink and crossing ID shown in black.

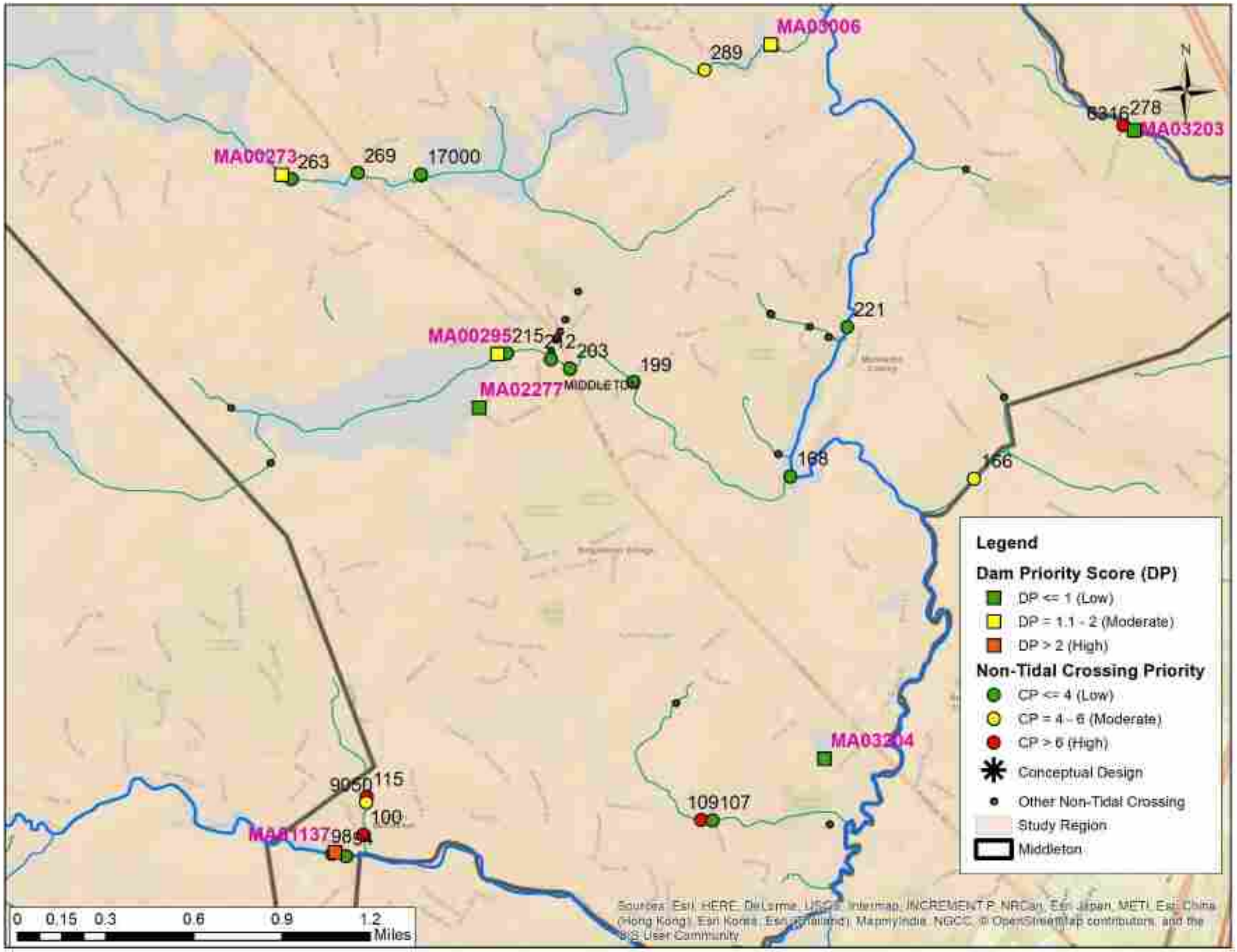

Figure 55. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the southern portion of the Town of Middleton, MA. Dam ID shown in pink and crossing ID shown in black.

Table 34. Dams in the portion of the Great Marsh study region within the Town of Middleton, MA prioritized by Dam Priority Score (DP).

	Priority Rank			Priority Scoring			Active/
Dam ID	Town	Region	Dam Name	Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	Priority Project
MA01137	1	1	Ipswich River Dam (South Middleton)	1	1.5	2.5	Active
MA03006	2	9	Mill Pond Dam	1	0.5	1.5	
MA01205	3	26	Creighton Pond Dam	0.5	0.5	1	
MA01590	4	30	Prichard Pond Dam	0	1	1	
MA03203	5	54	Coppermine Road Dam	0	0	0	
MA03204	5	54	Paradise Park Dam	0	0	0	
MA00273	NA	NA	Emerson Brook Dam At Lake Street	1	0.5	1.5	
MA00295	NA	NA	Middleton Pond Outlet Dam	0.5	1	1.5	
MA02277	NA	NA	Middleton Pond Southeast Dike	0.5	0.5	1	

Table 35. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Middleton, MA prioritized by Crossing Priority Score (CP).

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
100	1	58	River Street	Single Culvert	5.0	1.7	6.7	
115	2	81	Boston Street	Single Culvert	5.0	1.5	6.5	
109	3	118	River Street	Single Culvert	4.6	1.6	6.2	
278	4	120	Coppermine Road	Culvert	5.0	1.1	6.1	
273	5	147	Forest Street (South Loop)	Single Culvert	4.6	1.2	5.8	Yes
274	6	153	Forest Street	Single Culvert	3.6	2.1	5.7	Yes
329	7	191	Peabody Street	Bridge	5.0	0.2	5.2	
166	8	201	Middleton Street	Single Culvert	3.6	1.3	4.9	
9003	9	207	Off N Liberty Street	Bridge	4.6	0.2	4.8	
289	10	216	Liberty Street	Multiple Culvert	3.2	1.4	4.6	
9050	11	217	Driveway off Boston Street	Single Culvert	3.6	1.0	4.6	
349	12	265	East Street	Bridge	1.8	0.9	2.7	
380	13	272	Essex Street	Single Culvert	NA	2.6	2.6	Yes
203	14	285	South Main Street Rt 114	Single Culvert	NA	2.4	2.4	
6316	15	305	Ferncroft Golf Cart Path	Single Culvert	NA	2.0	2.0	
199	16	325	Mount Vernon	Single Culvert	0.0	1.8	1.8	
17000	17	327	Essex Street	Single Culvert	NA	1.8	1.8	
94	18	341	Boston Street	Single Culvert	NA	1.7	1.7	
263	19	347	Lake Street	Single Culvert	NA	1.7	1.7	
168	20	363	Off South Main Street	Single Culvert	NA	1.6	1.6	
378	21	365	Essex Street	Culvert	0.0	1.6	1.6	
215	22	401	Lake Street	Multiple Culvert	0.0	1.3	1.3	
212	23	409	Pleasant Street	Single Culvert	0.0	1.3	1.3	
98	24	411	Boston Road	Single Culvert	NA	1.3	1.3	
318	25	426	Essex Street	Bridge	0.0	1.2	1.2	
107	26	451	Natsue Way	Single Culvert	0.0	1.0	1.0	
346	27	462	Mill Street	Single Culvert	0.0	0.9	0.9	
352	28	465	North Liberty Street	Multiple Culvert	0.0	0.9	0.9	
336	29	555	Peabody Street	Bridge	NA	0.3	0.3	
221	30	572	Maple Street	Bridge	0.0	0.3	0.3	
269	31	609	North Main Street	Bridge	0.0	0.0	0.0	

North Andover

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of North Andover. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[47].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[48].

Figure 56. Outlet of road-stream crossing at Liberty Street, North Andover (Site #472).

The Town of North Andover is located outside of the coastal zone and the southern half of the town is located within the Great Marsh study region covering approximately 16.6 square miles (Figure 57). As an inland municipality, North Andover does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 66 potential barrier sites with structures confirmed and prioritized at 64 of those locations including 7 dams (Table 36) and 57 non-tidal crossings (Table 37).

The Stearns Pond Dam (MA01143) is the highest priority dam in North Andover based on our combined screens for risk and ecological impact, tied for ranking 13th in the region (Table 36). None of the rest of the dams in the town rank as particularly high priority in our screening. Three of the 7 dams in North Andover, including the Stearns Pond Dam, are owned and operated by the Massachusetts Department of Conservation and Recreation.

We inventoried and prioritized 57 non-tidal crossings in the Town of North Andover based on ecological and infrastructure risk. The screening results identify three crossings that were among the top 50 region-wide. A single culvert on Liberty Street (Site #472) is the highest priority crossing in North Andover, ranking 3rd poorest in the region (Table 37). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized

[47] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[48] Full report document available at http://www.pie-rivers.org/barriers/

relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. Eight of the 10 highest priority sites had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. The 10 highest priority crossings in North Andover are single or multiple culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 10 non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[49]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- North Andover designs begin on page 251

[49] Replacement designs were developed for crossings on Blue Ridge Road (Site #675), Abbott Street (#668), Sharpners Pond road (#411) and Foster Street (#674) based on ecological scores and potential for habitat improvement.

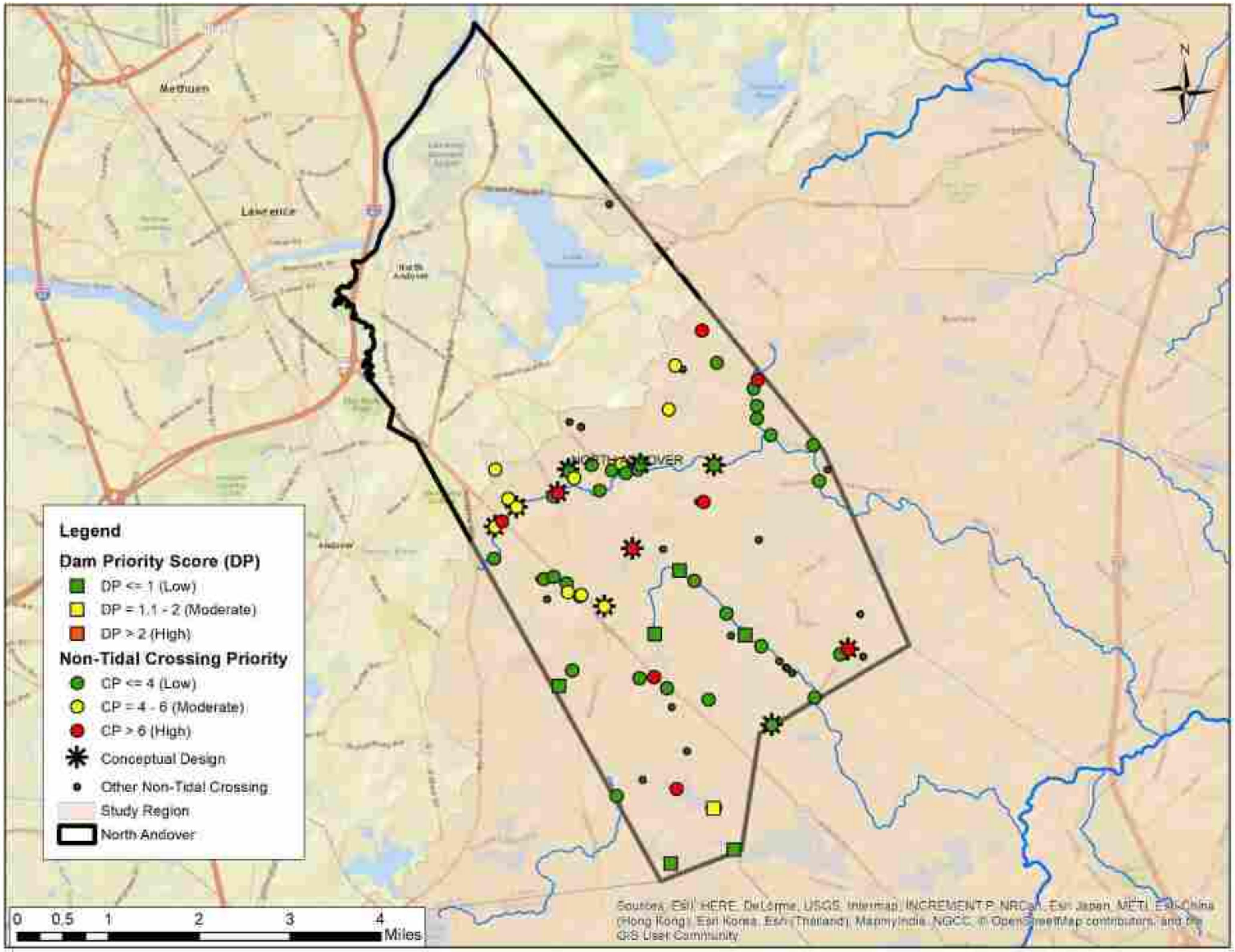

Figure 57. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of North Andover, MA. Crossings with available conceptual designs are also noted.

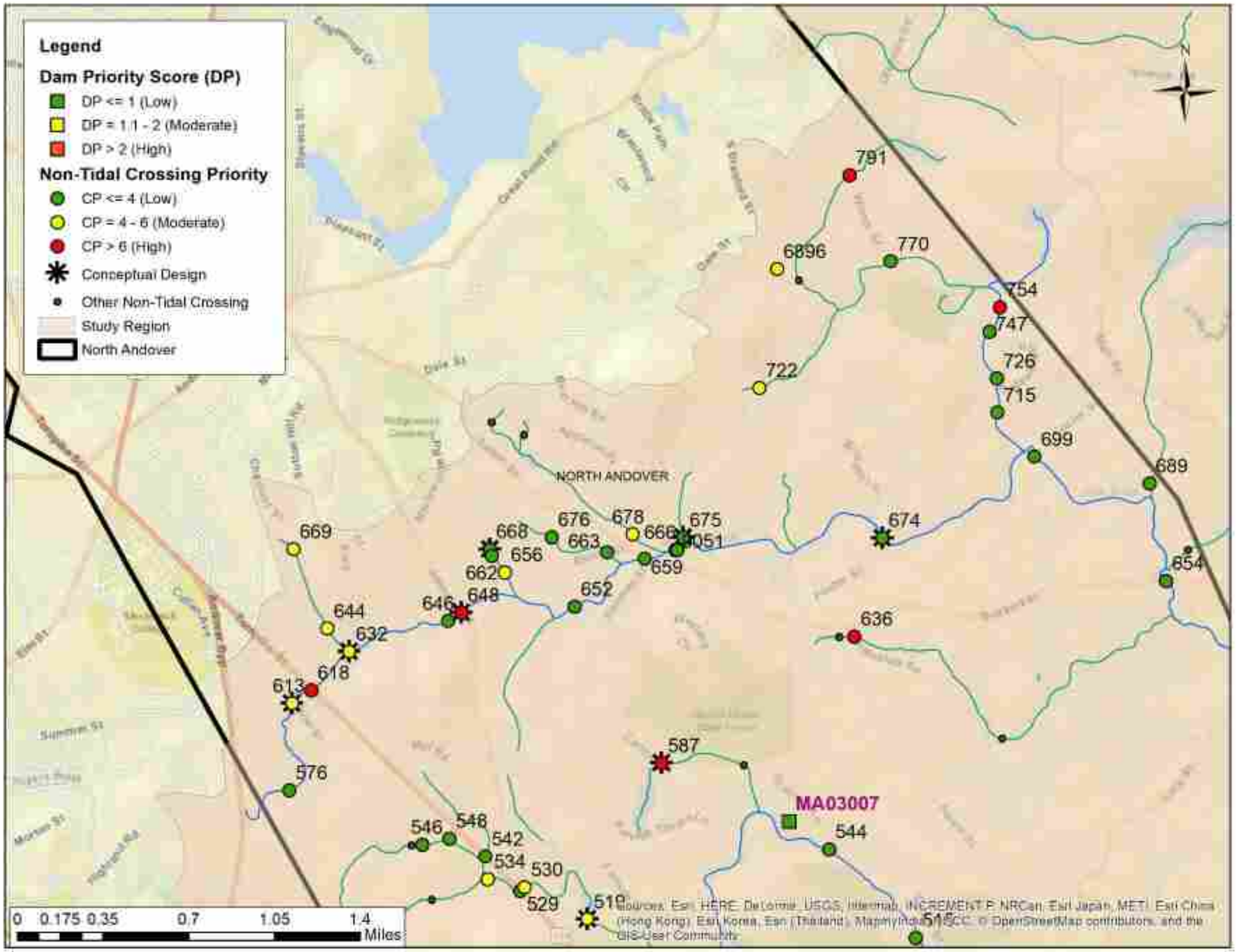

Figure 58. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the northern portion of the Town of North Andover, MA. Dam ID shown in pink and crossing ID shown in black.

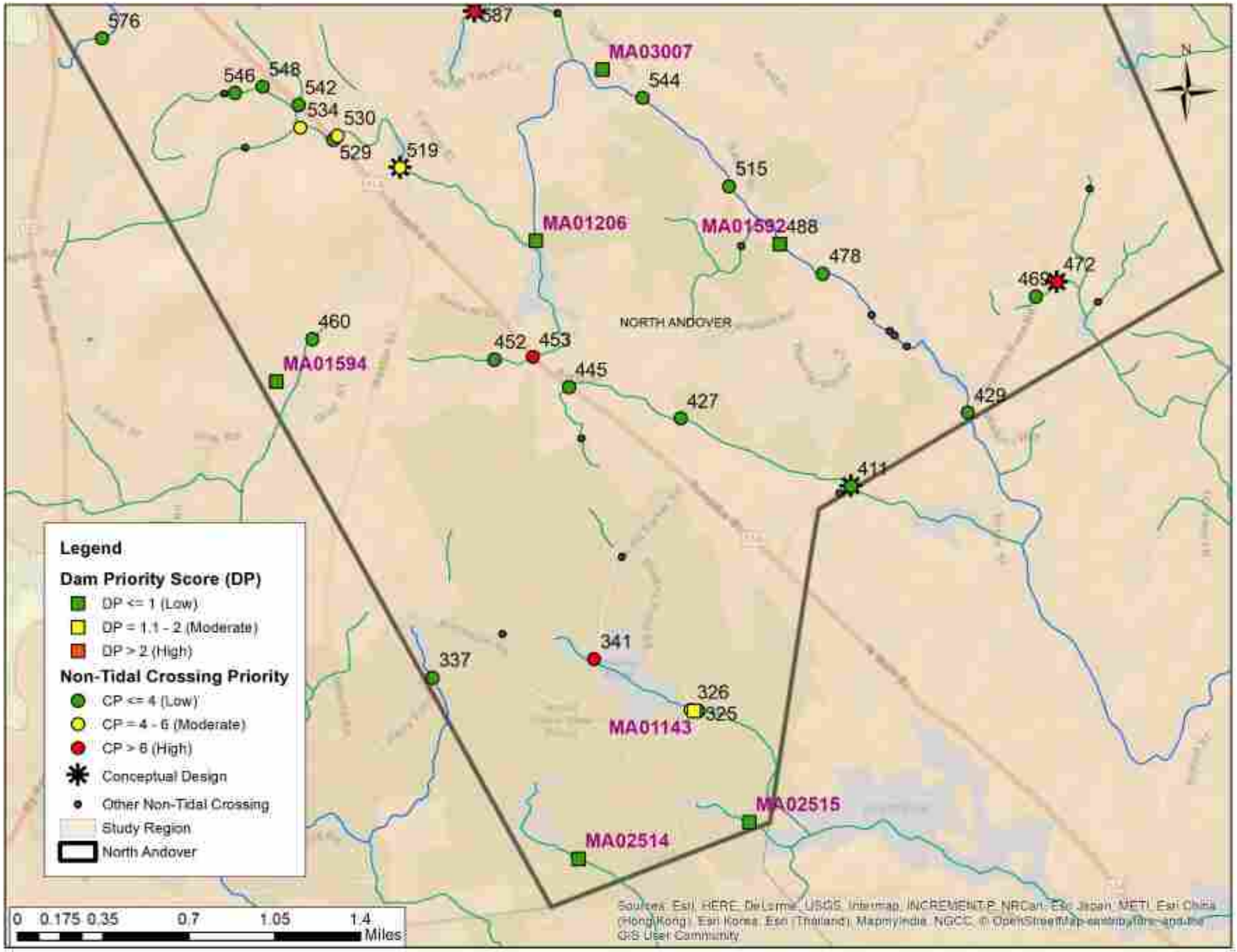

Figure 59. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the southern portion of the Town of North Andover, MA. Dam ID shown in pink and crossing ID shown in black.

Table 36. Dams in the portion of the Great Marsh study region within the Town of North Andover, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank		Dam Name	Priority Scoring			Active/ Priority Project
	Town	Region		Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA01143	1	12	Stearns Pond Dam	0.5	1	1.5	
MA01206	2	26	Farnums Mill Pond Dam	0.5	0.5	1	
MA02514	3	40	Salem Pond Dam	0.5	0	0.5	
MA01592	4	45	Boston Brook Dam	0	0.5	0.5	
MA01594	5	54	Farm Pond - On Skug River D #10	0	0	0	
MA02515	5	54	Sudden Pond Dam	0	0	0	
MA03007	5	54	Farr Pond Dam	0	0	0	

Table 37. Non-tidal crossings in the portion of the Great Marsh study region within the Town of North Andover, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 1 of 2)

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
472	1	3	Liberty Street	Single Culvert	4.6	4.4	9.0	Yes
587	2	27	Carlton Lane	Single Culvert	3.6	3.6	7.2	Yes
341	3	39	Harold Parker Road	Single Culvert	5.0	1.9	6.9	
754	4	59	Saw Mill Road	Single Culvert	5.0	1.7	6.7	
636	5	67	Candlestick Rd	Single Culvert	4.6	2.0	6.6	
648	6	84	Johnson Street	Single Culvert	4.6	1.9	6.5	Yes
618	7	98	Route 114/ Turnpike Street	Single Culvert	4.6	1.7	6.3	
791	8	131	Winter Street	Single Culvert	5.0	1.0	6.0	
453	9	134	Turnpike Street	Single Culvert	5.0	1.0	6.0	
534	10	144	Rt 114/Turnpike Street	Multiple Culvert	2.2	3.6	5.8	
632	11	162	Chestnut Street	Single Culvert	4.0	1.6	5.6	Yes
722	12	170	South Bradford Street	Multiple Culvert	3.6	2.0	5.6	
613	13	171	Willow Road	Single Culvert	3.0	2.6	5.6	Yes
519	14	184	Brook Strete	Multiple Culvert	4.0	1.3	5.3	Yes
678	15	202	Keyes Way	Single Culvert	3.6	1.3	4.9	
644	16	213	Woodlea Road	Single Culvert	3.6	1.1	4.7	
530	17	220	Johnson Street	Single Culvert	3.6	0.8	4.4	
6896	18	222	Cortland Drive	Multiple Culvert	0.0	4.4	4.4	
669	19	226	Blueberry Hill Lane	Multiple Culvert	3.2	1.1	4.3	
656	20	227	Rea Street	Single Culvert	3.0	1.3	4.3	
326	21	231	Stearns Pond Rd	Single Culvert	NA	4.2	4.2	
675	22	243	Blue Ridge Road	Single Culvert	0.0	3.7	3.7	Yes
548	23	257	Rt 114/Turnpike Street	Single Culvert	NA	3.0	3.0	
668	24	263	Abbott St	Single Culvert	NA	2.8	2.8	Yes
676	25	271	Nutmeg Lane	Open Bottom Arch	2.6	0.0	2.6	
411	26	273	Sharpners Pond Road	Single Culvert	0.0	2.6	2.6	Yes
663	27	275	Abbott Street	Single Culvert	1.6	0.9	2.5	
469	28	277	Sharpners Pond Road	Single Culvert	NA	2.5	2.5	
652	29	297	South Cross Road	Multiple Culvert	0.0	2.2	2.2	

Table 37 (continued). Non-tidal crossings in the portion of the Great Marsh study region within the Town of North Andover, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 2 of 2)

Crossing ID	Priority Rank Town	Priority Rank Region	Road	Structure Type	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Crossing Priority (CP)	Concept Designs
747	30	302	Hay Meadow Road	Single Culvert	0.0	2.0	2.0	
659	31	313	Salem Street	Multiple Culvert	0.0	1.9	1.9	
674	32	330	Foster Street	Multiple Culvert	0.0	1.8	1.8	Yes
715	33	342	Foster Street	Multiple Culvert	0.0	1.7	1.7	
546	34	362	Rt 114/Turnpike Street	Single Culvert	NA	1.6	1.6	
478	35	367	Salem Street	Multiple Culvert	NA	1.5	1.5	
662	36	369	Abbott Street	Single Culvert	NA	1.5	1.5	
646	37	372	Holly Ridge Road	Multiple Culvert	0.6	0.9	1.5	
325	38	376	Stearns Pond Road	Bridge	0.0	1.5	1.5	
726	39	394	Haymeadow Road	Single Culvert	0.0	1.3	1.3	
427	40	395	Berry Street	Single Culvert	0.0	1.3	1.3	
460	41	400	Stiles Street	Single Culvert	NA	1.3	1.3	
445	42	416	Turnpike Street/ Route 114	Single Culvert	NA	1.2	1.2	
770	43	418	Winter Street	Multiple Culvert	0.0	1.2	1.2	
699	44	421	Lost Pond Lane	Single Culvert	0.0	1.2	1.2	
542	45	452	Rt 114/ Turnpike Street	Single Culvert	NA	1.0	1.0	
576	46	470	Willow Street	Multiple Culvert	0.0	0.9	0.9	
9051	47	487	Off Blue Ridge Road	Bridge	NA	0.8	0.8	
488	48	491	Off Salem Street	Bridge	NA	0.7	0.7	
544	49	494	Hawkins Lane	Bridge	0.0	0.7	0.7	
429	50	501	Sharpners Pond Rd	Multiple Culvert	0.0	0.7	0.7	
654	51	518	Boxford Street	Single Culvert	NA	0.6	0.6	
529	52	556	Route 114/Turnpike Street	Single Culvert	0.0	0.3	0.3	
666	53	567	Blue Ridge Road	Multiple Culvert	NA	0.3	0.3	
337	54	573	Off Harold Parker Road	Bridge	NA	0.3	0.3	
452	55	584	Colonial Avenue	Open Bottom Arch	0.0	0.2	0.2	
689	56	593	Ogunquit Road	Bridge	NA	0.1	0.1	
515	57	595	Pheasant Brook Road	Open Bottom Arch	0.0	0.1	0.1	

North Reading

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of North Reading. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[50].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[51].

The Town of North Reading is outside of the coastal zone and almost the entire town is located within the Great Marsh study region, covering approximately 13.5 square miles (Figure 61). As an inland municipality, North Reading does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 35 potential barrier sites with structures confirmed and prioritized at 30 of those locations including 1 dam (Table 38) and 29 non-tidal crossings (Table 39).

Figure 60. Road-stream crossing at Park Street, North Reading (Site #99).

The Bradford Pond Dam (MA02504) is the only dam in North Reading. This dam was not identified as a high priority, tied for 41st in ranking among all of the dams in the region (Table 38). While this structure is not ranked as a high priority, it is still important that it be properly monitored and maintained per dam safety requirements as a low hazard dam[52]. If the structure is no longer needed, removal may be an option that could enhance ecological integrity in this portion of the watershed.

We inventoried and prioritized 29 non-tidal crossings in North Reading based on ecological and infrastructure risk. The three highest priority crossings are all located in close proximity to one another near Concord Street. Our screening analysis identified a single culvert off or Concord Street (Site #84) as the highest priority crossing in North Reading, ranking 12th in the region (

Table 39). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The 8 highest priority

[50] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[51] Full report document available at http://www.pie-rivers.org/barriers/
[52] https://www.mass.gov/service-details/dam-safety-inspection-requirements

sites had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. Five of those structures are not expected to pass flows that have a 50% chance of occurring (CRI=5). While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. All 8 of the highest priority crossings in North Reading are single culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

We did not develop conceptual designs for upgrade of any crossings located in the Town of North Reading.

Table 38. Dams in the portion of the Great Marsh study region within the Town of North Reading, MA prioritized by Dam Priority Score (DP).

	Priority Rank			Priority Scoring			Active/ Priority Project
Dam ID	Town	Region	Dam Name	Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA02504	1	40	Bradford Pond Dam	0.5	0	0.5	

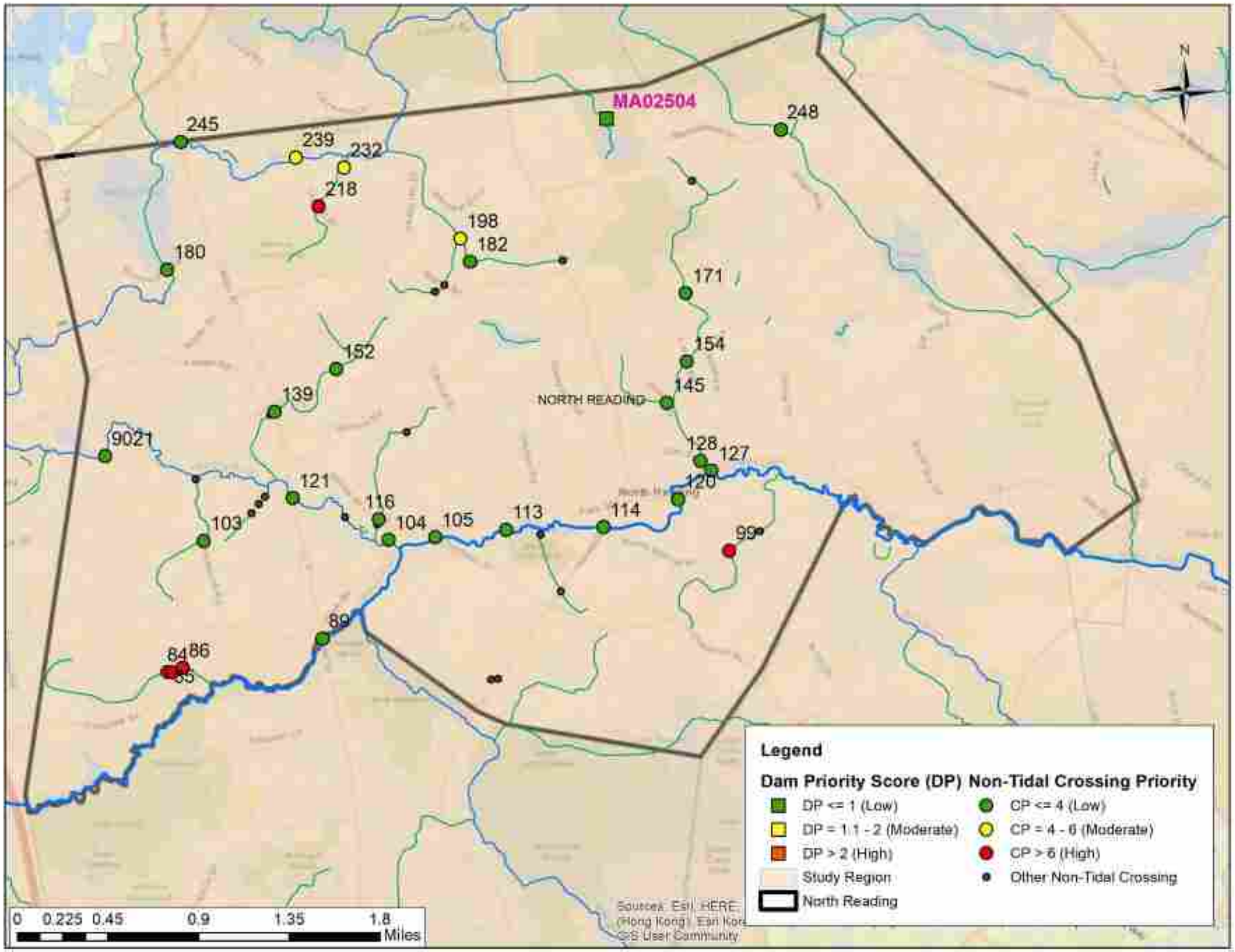

Figure 61. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of North Reading, MA. Dam ID shown in pink and crossing ID shown in black.

Table 39. Non-tidal crossings in the portion of the Great Marsh study region within the Town of North Reading, MA prioritized by Crossing Priority Score (CP).

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
84	1	12	Off of Concord Street	Single Culvert	5.0	3.3	8.3	
86	2	42	Concord Street	Single Culvert	5.0	1.9	6.9	
85	3	110	Off of Concord Street	Single Culvert	4.6	1.6	6.2	
218	4	112	Central Street	Single Culvert	5.0	1.2	6.2	
99	5	122	Park Street	Single Culvert	5.0	1.1	6.1	
232	6	158	Hillview Road	Single Culvert	5.0	0.7	5.7	
239	7	189	Central Street	Single Culvert	4.6	0.6	5.2	
198	8	192	Wagon Drive	Single Culvert	4.0	1.2	5.2	
139	9	261	Lowell Rd (Rt 62) & Main St (Rt 28)	Single Culvert	1.6	1.2	2.8	
154	10	343	Lindor Road	Single Culvert	0.0	1.7	1.7	
128	11	380	Elm Street	Multiple Culvert	0.0	1.5	1.5	
116	12	404	Winter Street/Rt 62	Multiple Culvert	0.0	1.3	1.3	
103	13	414	Southwick Road	Bridge	0.0	1.3	1.3	
248	14	432	Marblehead Street	Single Culvert	0.0	1.1	1.1	
113	15	454	Central Street	Bridge	0.0	1.0	1.0	
9021	16	464	Salem and Lowell Railroad	Bridge	0.0	0.9	0.9	
171	17	477	Darrel Drive	Bridge	0.6	0.2	0.8	
152	18	492	Country Club Road	Multiple Culvert	0.0	0.7	0.7	
145	19	495	Duane Drive	Open Bottom Arch	0.6	0.1	0.7	
180	20	503	Burrough Road	Multiple Culvert	0.0	0.7	0.7	
105	21	507	Chestnut Street	Multiple Culvert	0.0	0.7	0.7	
120	22	537	Washington Street	Bridge	0.0	0.5	0.5	
121	23	542	Route 28, Main Street	Bridge	0.0	0.5	0.5	
245	24	550	Route 28/Main Street	Bridge	0.0	0.4	0.4	
104	25	561	Park Street	Bridge	0.0	0.3	0.3	
182	26	590	Barbie Lane	Bridge	0.0	0.1	0.1	
127	27	599	Washington Street	Bridge	0.0	0.1	0.1	
114	28	603	Haverhill Street	Bridge	0.0	0.0	0.0	
89	29	610	Main Street/Rt. 28	Bridge	0.0	0.0	0.0	

Peabody

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the City of Peabody. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[53].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[54].

Approximately 4.6 square miles of the City of Peabody is located within the Great Marsh study region. This portion of the study watershed, located primarily west of Route 1 (Newbury Street), is outside of the coastal zone so Peabody is considered an inland municipality in our analysis (Figure 62). As an inland municipality, Peabody does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 27 potential barrier sites with structures confirmed and prioritized at 19 of those locations including 6 dams (Table 40) and 13 non-tidal crossings (Table 41).

None of the dams in Peabody stood out as regional priorities based on our combined screens for risk and ecological impact. The Winona Pond Dam (MA00726) and Suntaug Lake Dam (MA01139) are the two dams with the highest priority scores, but were not ranked because they are actively used as part of the Peabody water supply system (Table 40). The Elginwood Pond Dam (MA01141) was the highest priority dam in Peabody, but only ranked in a tie for 22nd regionally. The other three dams were all tied for 54th (lowest priority) in the regional ranking. While none of these dams ranked as high priorities, it is still important that they be properly monitored and maintained per dam safety requirements[55]. If structures are no longer needed, removal may be considered as an option to remove risk and enhance ecological integrity.

We inventoried and prioritized 13 non-tidal crossings in the City of Peabody based on combined ecological and infrastructure risk. The highest priority crossing was a single culvert on Lowell Street (Site #56) that ranked 116th in the region (Table 41). Poor scores in the combined screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. Site #56 was the only structure in Peabody which ranked as a significant infrastructure-only risk. The culvert had an infrastructure risk (CRI) score of 5 indicating that it is not expected to pass flows associated with storms that have a 50% chance of occurring on any given year. While this does not indicate that the culvert will fail, it is an indicator that the crossing might be worth taking a closer look at to see how it performs during storms. We recommend further investigation at this site as it is a single culvert that could potentially be replaced with larger

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[53] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[54] Full report document available at http://www.pie-rivers.org/barriers/

[55] https://www.mass.gov/service-details/dam-safety-inspection-requirements

and more storm resilient/fish friendly crossings when it comes time for replacement or maintenance. We did not develop conceptual designs for upgrade of any crossings located in the City of Peabody.

Table 40. Dams in the portion of the Great Marsh study region within the City of Peabody, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank		Dam Name	Priority Scoring			Active/ Priority Project
	Town	Region		Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA01141	1	21	Elginwood Pond Dam	1	0	1	
MA01138	2	54	Devils Dishfull Pond Dam	0	0	0	
MA03218	2	54	Elginwood Pond Dam #2	0	0	0	
MA03221	2	54	Puritan Lawn Pond Dam	0	0	0	
MA00726	NA	NA	Winona Pond Dam	2	0.5	2.5	
MA01139	NA	NA	Suntaug Lake Dam	1	0.5	1.5	

Table 41. Non-tidal crossings in the portion of the Great Marsh study region within the City of Peabody, MA prioritized by Crossing Priority Score (CP).

Crossing ID	Priority Rank		Road	Structure Type	Priority Scoring			Concept Designs
	Town	Region			Infrastructure Risk (CRI)	Ecological Impact (CEI)	Crossing Priority (CP)	
56	1	116	Lowell Street	Single Culvert	5.0	1.2	6.2	
11	2	235	Lake Street	Multiple Culvert	0.0	4.1	4.1	
48	3	253	Crystal Drive	Bridge	1.6	1.6	3.2	
51	4	269	Cobb Ave	Multiple Culvert	0.0	2.6	2.6	
32	5	303	Pine Street	Single Culvert	0.0	2.0	2.0	
23	6	308	Lake Street	Single Culvert	NA	2.0	2.0	
33	7	358	Pine Street	Single Culvert	0.0	1.6	1.6	
31	8	373	Pine Brook Lane	Single Culvert	NA	1.5	1.5	
34	9	455	Off Pine Street	Single Culvert	0.0	1.0	1.0	
27	10	505	Winona Street	Bridge	0.0	0.7	0.7	
71	11	531	Russell Street	Bridge	0.0	0.5	0.5	
53	12	536	Lowell Street	Bridge	0.0	0.5	0.5	
97	13	591	Boston Street	Bridge	0.0	0.1	0.1	

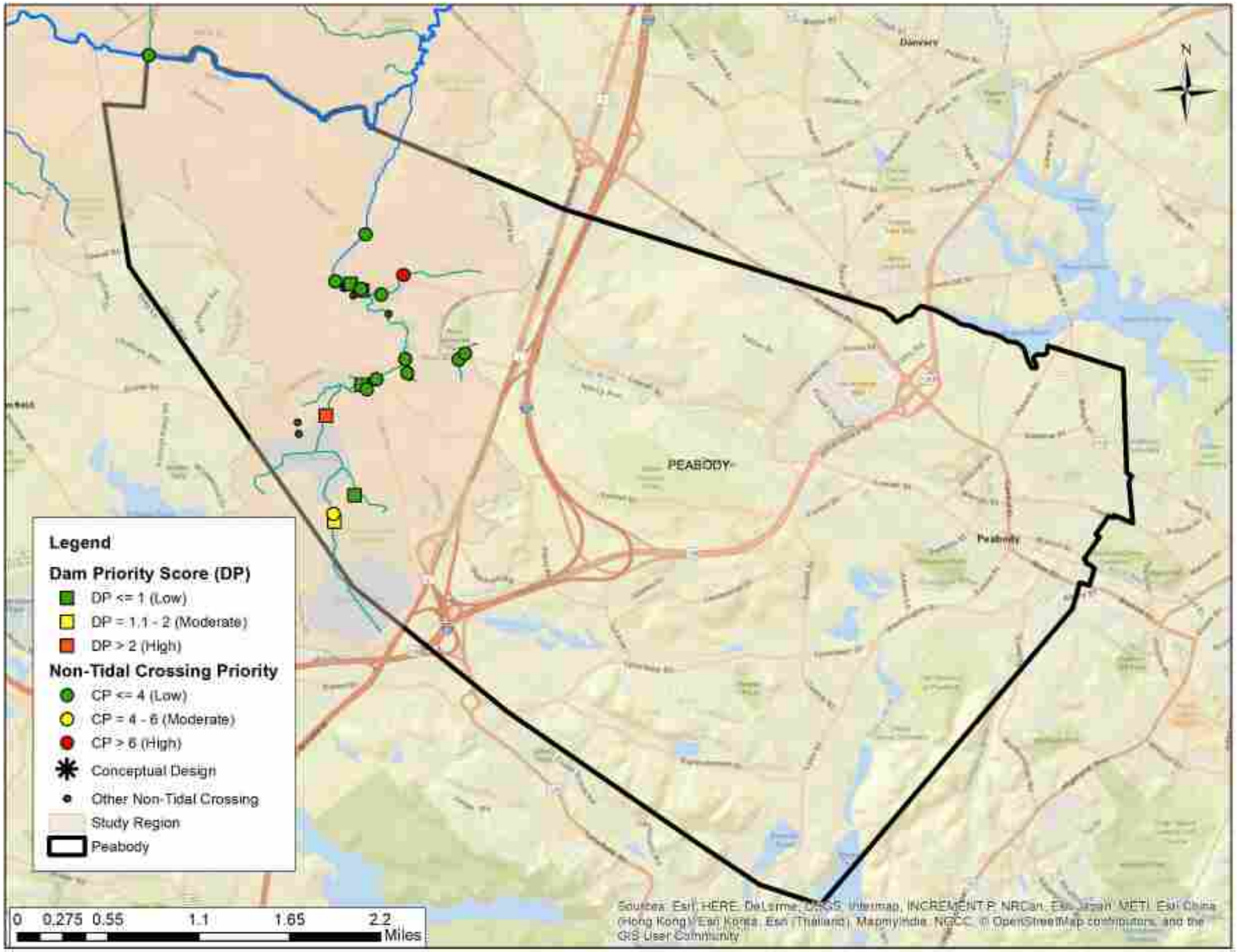

Figure 62. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the City of Peabody, MA.

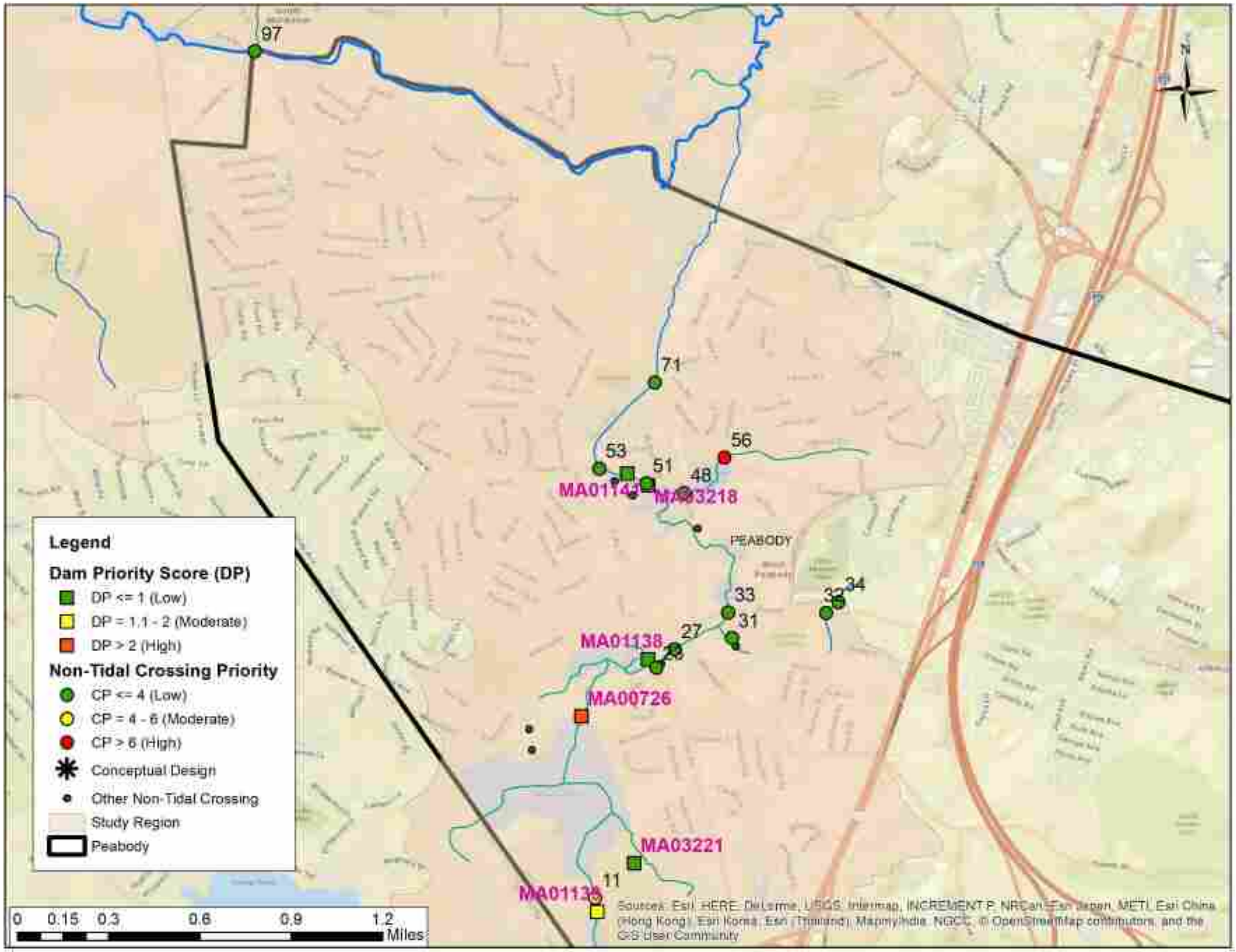

Figure 63. Closeup map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the City of Peabody, MA. Dam ID shown in pink and crossing ID shown in black.

Reading

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Reading. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[56].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[57].

The Town of Reading is outside of the coastal zone and approximately 4.8 square miles of the northern portion of the town is located within the Great Marsh study region (Figure 65). As an inland municipality, Reading does not have any tidal crossings or coastal stabilization structures. The portion of the study watershed within the Reading town limits does not have many potential barrier sites, but we are including a town summary because we developed a conceptual design for one structure. Our analysis considered a total of 4 potential barrier sites (all non-tidal crossings), with structures confirmed and prioritized at all 4 of those locations (Table 42). Our analysis did not identify any dams in the Town of Reading.

Figure 64. Inlet of road-stream crossing at Haverhill Street, Reading (Site #60).

None of the four non-tidal crossings inventoried and prioritized based on combined ecological and infrastructure risk were identified as high priorities on a regional level. Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The crossing with the highest combined priority score was a single culvert on Haverhill Street (Site #60) that ranked 55th in the region (Table 42). This was also the only crossing structure that was identified as a significant infrastructure risk by our screening tool. The crossing had an infrastructure risk (CRI) score of 4.6 indicating that it is not expected to reliably pass flows associated with storms that have a 50% chance of occurring on any given year. While this does not indicate that the culvert will fail, it is an indicator that the crossing might be worth taking a closer look at to see how it performs during storms. We recommend

[56] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[57] Full report document available at http://www.pie-rivers.org/barriers/

further investigation at this site as it is a single culvert that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time for replacement or maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of one non-tidal crossing (ID# 76) with a structure designed to increase aquatic connectivity and resilience to flooding[58]. The design was developed using available site data including field measurements collected by IRWA during the screening analyses. The design provides a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at the site. This design can provide a starting point to more easily incorporate a resilient and long-lived structure into maintenance and replacement schedules. This plan can help with scoping, budgeting and fundraising associated with upgrading the crossing.

Meridian design materials are located in Appendix 3

- Supporting materials begin on page 180
- The Reading design is on page 262

[58] Site #76 was identified as a high combined priority in preliminary screening results and selected for design. The site was later significantly downgraded in priority during a quality control review of the model results. While it is not flagged as a high priority crossing in the final results, the design is included as it would be a significant improvement over the existing structure.

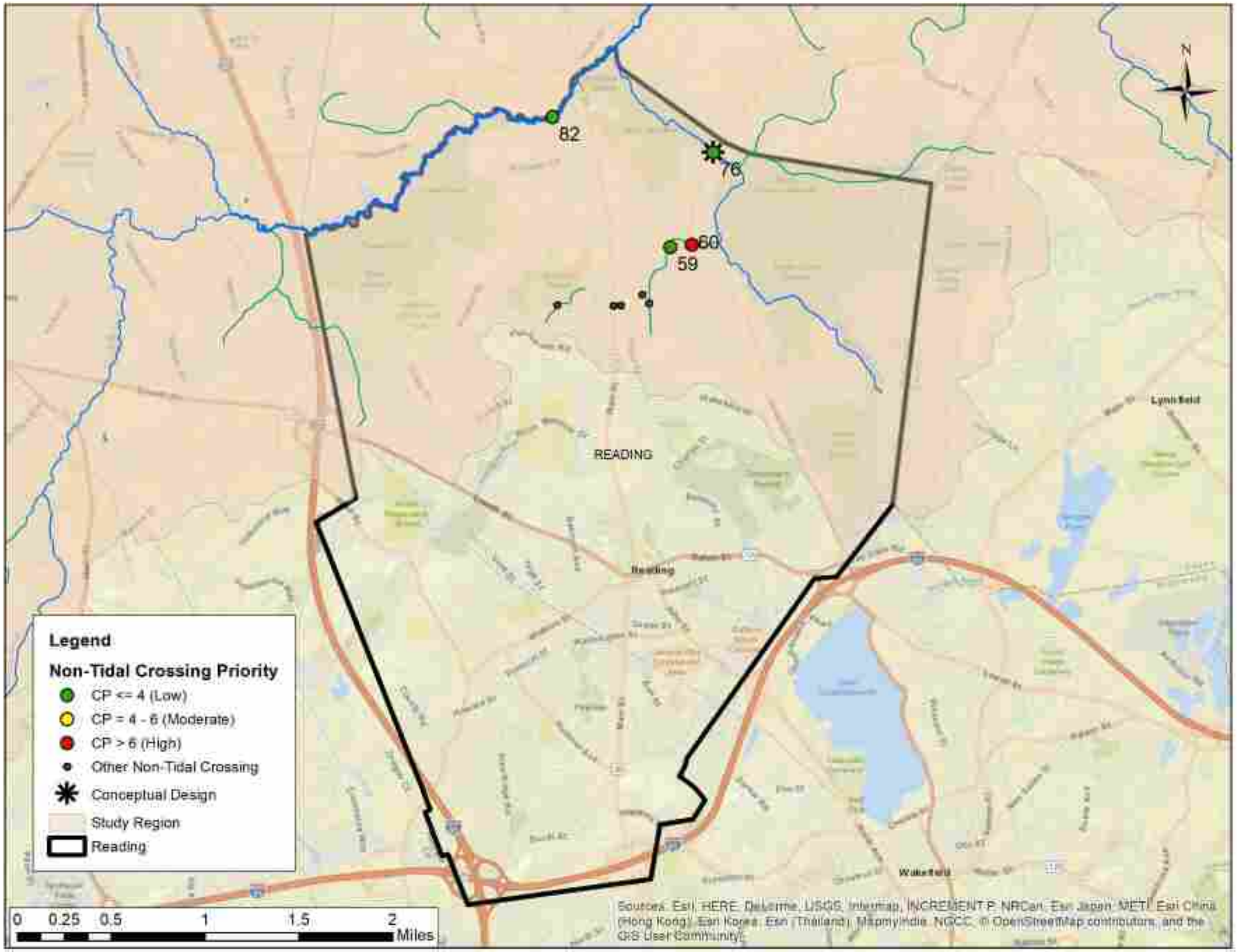

Figure 65. Map showing locations and prioritization scores for non-tidal crossings in the Great Marsh Study region within the Town of Reading, MA. Crossings with available conceptual designs are also noted.

Table 42. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Reading, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank		Road	Structure Type	Priority Scoring			Concept Designs
	Town	Region			Infrastructure Risk (CRI)	Ecological Impact (CEI)	Crossing Priority (CP)	
60	1	55	Haverhill Street	Single Culvert	4.6	2.1	6.7	
76	2	422	Haverhill Street	Open Bottom Arch	0.0	1.2	1.2	Yes
59	3	459	Eastway	Multiple Culvert	0.0	1.0	1.0	
82	4	608	Mill Street	Bridge	0.0	0.0	0.0	

Topsfield

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Topsfield. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[59].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[60].

Figure 66. Howletts Brook Dam, Topsfield (MA01610).

The Town of Topsfield is located outside of the coastal zone and the entire town is located within the Great Marsh study region covering approximately 12.8 square miles (Figure 67). As an inland municipality, Topsfield does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 68 potential barrier sites with structures confirmed and prioritized at 63 of those locations including 9 dams (Table 43) and 54 non-tidal crossings (Table 44).

The Howletts Brook Dam (MA01610), located just north of Ipswich Road between the intersections of Campmeeting and Willowdale Roads, is the highest priority dam in Topsfield (8th in region) based on a combination of risk and ecological impact (Table 43). The dam is a privately owned non-jurisdictional structure that currently blocks migratory fish access to Howlett Brook and Hood Pond. The Bethune Pond Dam (MA01613) also ranks among the higher priority dams in the region, tied for 9th. Regardless of priority ranking, it is important that all dam structures be properly monitored and maintained per dam safety requirements[61]. If structures are no longer needed, removal may be considered as an option to remove risk and enhance ecological integrity.

We inventoried and prioritized 54 non-tidal crossings in the Town of Topsfield based on combined ecological and infrastructure risk. The screening results identified five crossings that were among the top 50 priorities region-wide. Single culverts on Meetinghouse Lane (Site #9011) and Pond Street (Site #670) were the two highest priority for immediate attention, respectively ranking 2nd and 4th in the region (Table 44). Poor scores in

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[59] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[60] Full report document available at http://www.pie-rivers.org/barriers/
[61] https://www.mass.gov/service-details/dam-safety-inspection-requirements

the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The 14 highest priority sites had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. The eight highest priority crossings in Topsfield are single culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 14 non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[62]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. They can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. The plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

Figure 1. Outlet of road-stream crossing at River Road in Topsfield (Site #435).

The Meridian design materials are located in Appendix 3.

- Supporting materials begin on page 180
- Topsfield designs begin on page 277

[62] Three of the crossings on Mile Brook (Sites #550, #537, and #536) were chosen for design, in part, because of their proximity to one another along one migration path to Hood Pond. The Howlett Brook crossing of North Street (Site #615) was similarly prioritized based on its importance along the migration path to Hood Pond. A crossing on East Street (Site #658) was designed primarily based on a combination of ecological connectivity and locally identified flooding issues. Crossings on South Main Street (Site #433) and Perkins Row (Site #500) were identified as high priority for infrastructure risk in the preliminary results used to choose crossings for design and were later significantly downgraded in priority during a quality control review of the model results.

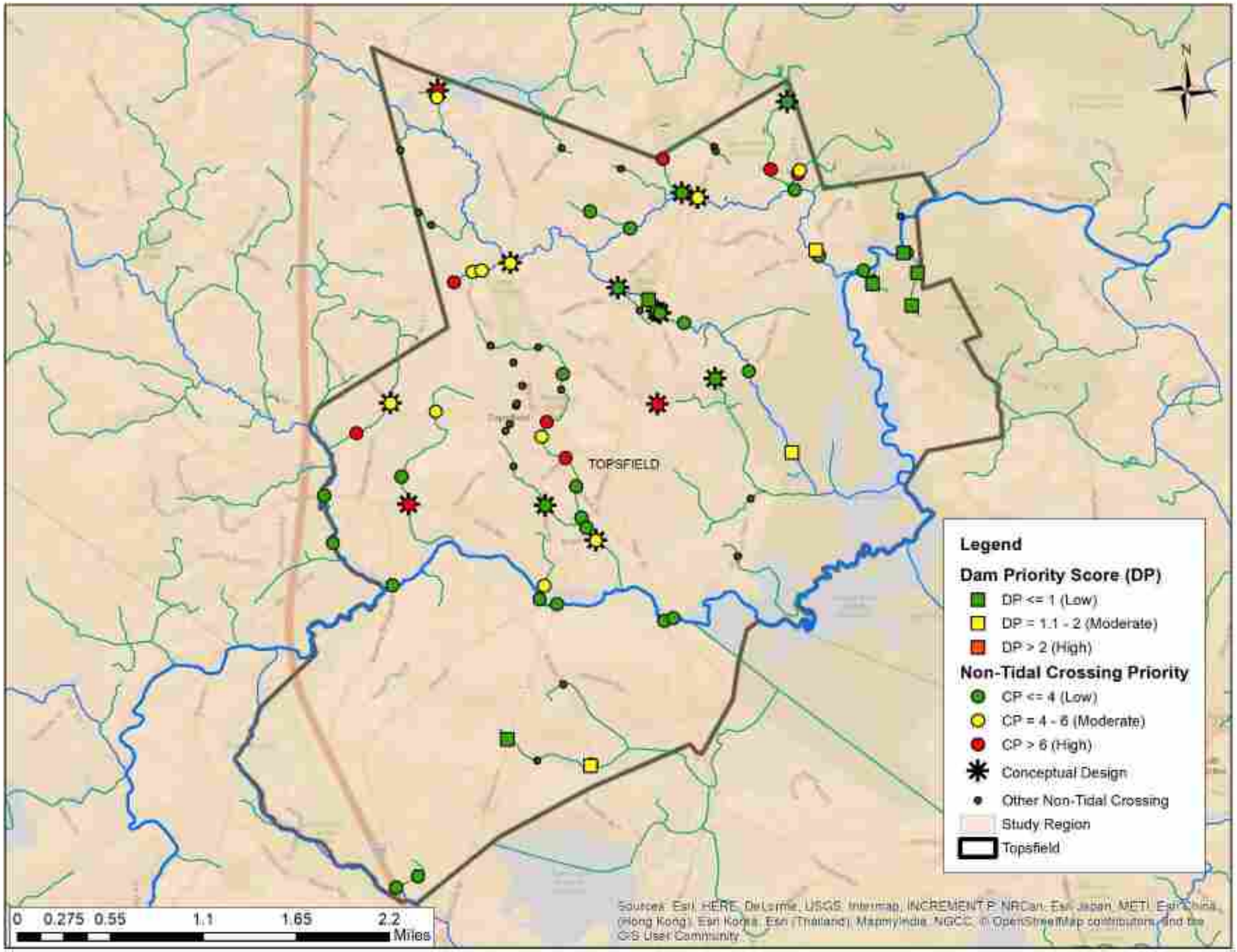

Figure 67. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of Topsfield, MA. Crossings with available conceptual designs are also noted.

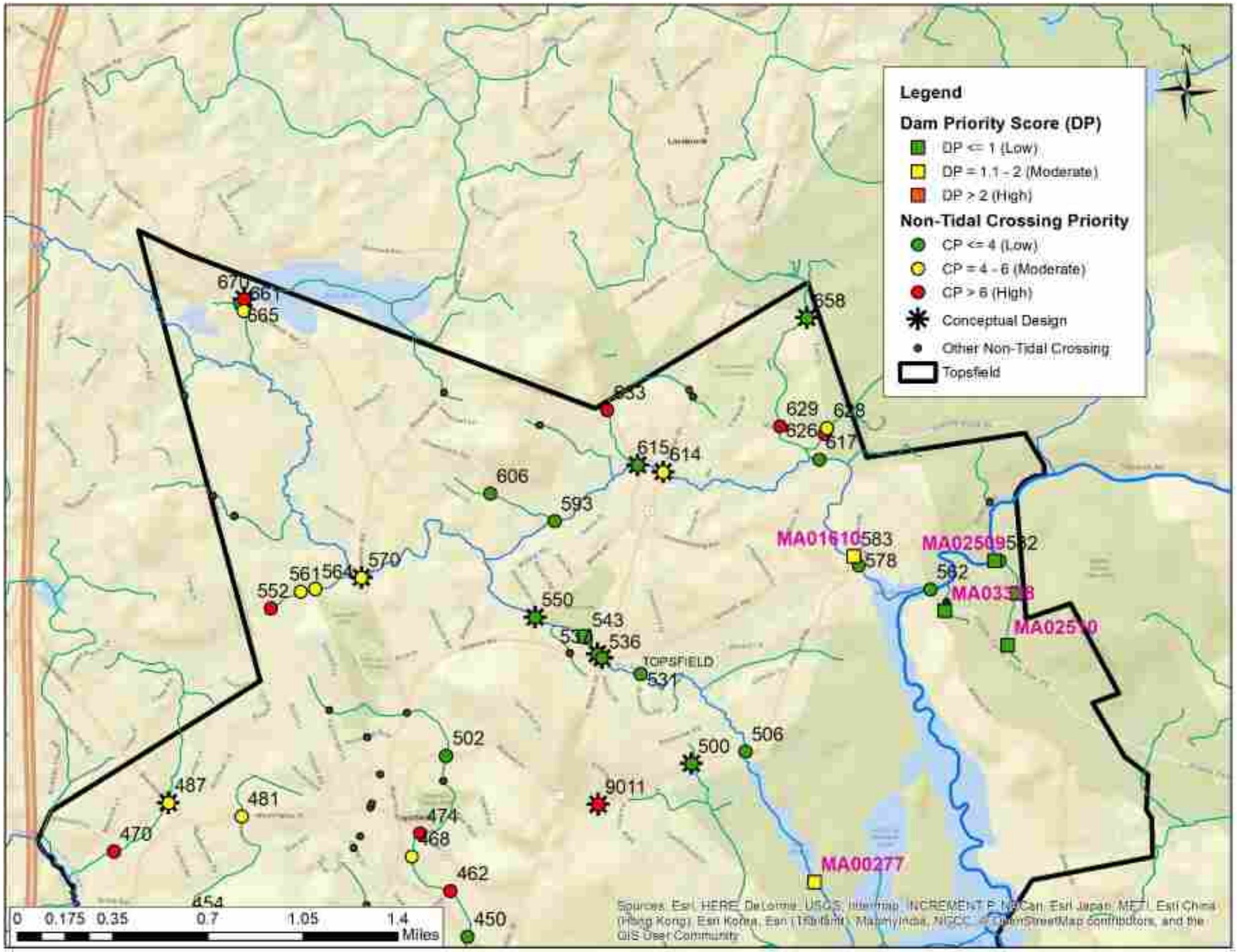

Figure 68. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the northern portion of the Town of Topsfield, MA. Dam ID shown in pink and crossing ID shown in black.

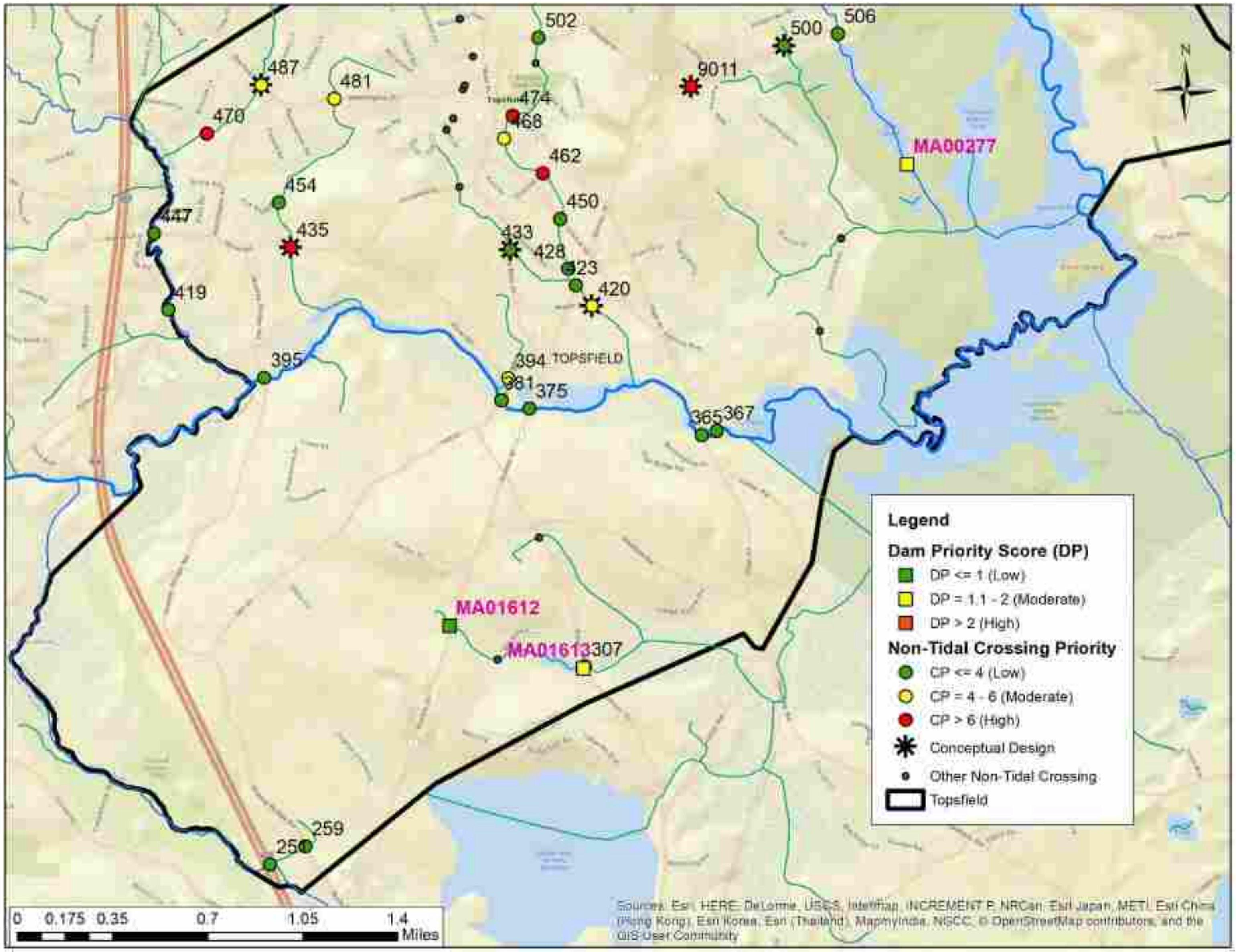

Figure 69. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the southern portion of the Town of Topsfield, MA. Dam ID shown in pink and crossing ID shown in black.

Table 43. Dams in the portion of the Great Marsh study region within the Town of Topsfield, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank		Dam Name	Priority Scoring			Active/ Priority Project
	Town	Region		Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)	
MA01610	1	8	Howletts Brook Dam	0	2	2	Priority
MA01613	2	9	Bethune Pond Dam	1	0.5	1.5	
MA00277	3	12	Mile Brook Dam	0.5	1	1.5	
MA01611	4	30	Pleasure Pond Dam	0	1	1	
MA01612	4	30	Peirce Pond Dam	0	1	1	
MA02509	6	45	Ipswich Pond Dam	0	0.5	0.5	
MA02510	7	54	Farm Trail Pond	0	0	0	
MA02511	7	54	Otter Pond Dam	0	0	0	
MA03338	7	54	Bradley Palmer Entrance Dam	0	0	0	

Table 44. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Topsfield, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 1 of 2)

Crossing ID	Priority Rank Town	Priority Rank Region	Road	Structure Type	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Crossing Priority (CP)	Concept Designs
9011	1	2	Meetinghouse Lane	Single Culvert	5.0	4.3	9.3	Yes
670	2	4	Pond Street	Single Culvert	5.0	3.9	8.9	Yes
435	3	11	River Road	Single Culvert	4.6	3.7	8.3	Yes
462	4	28	Summer Street	Single Culvert	5.0	2.1	7.1	
633	5	38	North Street	Single Culvert	5.0	2.0	7.0	
629	6	53	Wildes Road	Single Culvert	5.0	1.7	6.7	
626	7	70	Wildes Road	Single Culvert	5.0	1.6	6.6	
470	8	92	Lockwood Lane	Single Culvert	5.0	1.4	6.4	
552	9	119	Thompson Lane	Bridge	4.6	1.5	6.1	
474	10	121	High Street	Single Culvert	5.0	1.1	6.1	
564	11	141	Bare Hill Road	Single Culvert	4.0	1.9	5.9	
468	12	174	School Street	Single Culvert	5.0	0.5	5.5	
628	13	178	East St	Single Culvert	4.0	1.4	5.4	
481	14	181	Washington Street	Single Culvert	4.0	1.4	5.4	
661	15	183	Off Haverhill Street	Single Culvert	3.6	1.8	5.4	
614	16	195	Route 1	Culvert	4.0	1.2	5.2	Yes
561	17	196	Parsonage Lane	Single Culvert	4.0	1.1	5.1	
394	18	197	River Road	Single Culvert	3.6	1.5	5.1	
543	19	200	North Street	Multiple Culvert	0.0	5.0	5.0	
420	20	210	Maple Street	Multiple Culvert	3.6	1.2	4.8	Yes
570	21	228	Haverill Road	Bridge	3.6	0.7	4.3	Yes
487	22	233	Boxford Road	Single Culvert	2.6	1.6	4.2	Yes
550	23	238	North St	Single Culvert	0.6	3.4	4.0	Yes
307	24	283	Salem Road	Multiple Culvert	0.0	2.4	2.4	
531	25	292	Brookside Road	Multiple Culvert	1.2	1.0	2.2	
502	26	316	Howlett St	Multiple Culvert	0.6	1.3	1.9	
433	27	320	South Main St	Bridge	0.0	1.9	1.9	Yes
658	28	338	East Street	Single Culvert	0.0	1.7	1.7	Yes
578	29	360	Ipswich Road	Bridge	1.2	0.4	1.6	

Table 44 (continued) Non-tidal crossings in the portion of the Great Marsh study region within the Town of Topsfield, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted. (Page 2 of 2)

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
423	30	368	Newburyport Turnpike	Single Culvert	0.0	1.5	1.5	
500	31	370	Perkins Row	Single Culvert	0.0	1.5	1.5	Yes
428	32	393	Topsfield Linear Common	Single Culvert	0.0	1.4	1.4	
251	33	396	I-95 NB	Multiple Culvert	NA	1.3	1.3	
617	34	402	East Street	Single Culvert	NA	1.3	1.3	
537	35	406	Ipswich Road	Multiple Culvert	0.0	1.3	1.3	Yes
593	36	407	Aaron Drive	Multiple Culvert	NA	1.3	1.3	
454	37	425	Fox Run Extension	Single Culvert	NA	1.2	1.2	
259	38	427	Rowley Bridge Road	Bridge	NA	1.2	1.2	
615	39	428	North Street	Culvert	NA	1.2	1.2	Yes
665	40	450	Haverhill Road	Single Culvert	0.0	1.0	1.0	
419	41	456	Washington Street	Bridge	NA	1.0	1.0	
450	42	472	Central Street	Multiple Culvert	NA	0.9	0.9	
447	43	476	River Road	Bridge	NA	0.8	0.8	
583	44	500	Unnamed Path	Bridge	NA	0.7	0.7	
606	45	502	Off Timber Lane	Single Culvert	NA	0.7	0.7	
562	46	510	Asbury Street	Bridge	0.0	0.6	0.6	
506	47	540	Perkins Row	Open Bottom Arch	0.0	0.5	0.5	
536	48	541	Newburyport Turnpike	Bridge	0.0	0.5	0.5	Yes
367	49	576	Railroad	Bridge	NA	0.2	0.2	
582	50	586	Bradley Palmer Trail	Bridge	NA	0.2	0.2	
365	51	594	Route 97	Bridge	0.0	0.1	0.1	
381	52	598	Salem Road	Bridge	0.0	0.1	0.1	
395	53	602	Rowley Bridge Road	Bridge	0.0	0.0	0.0	
375	54	606	Newburyport Turnpike (Rt. 1)	Open Bottom Arch	NA	0.0	0.0	

Wenham

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Wenham. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[63].

Figure 70. Inlet of road-stream crossing at Hull Street in Wenham (Site #161).

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[64].

The Town of Wenham is located outside of the coastal zone and almost the entire town is located within the Great Marsh study region covering approximately 7.4 square miles (Figure 71). As an inland municipality, Wenham does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 30 potential barrier sites with structures confirmed and prioritized at 26 of those locations including 1 dam (Table 45) and 25 non-tidal crossings (Table 46).

The Longham Reservoir Dam (MA00182) is the only dam we identified in the Town of Wenham (Table 45). This dam is a significant hazard structure located in the headwaters of the Miles River. This dam had a fairly high priority score based on a combination of risk and ecological impact screening, but was not priority ranked because of it is an actively used component of the Salem-Beverly water supply system.

We inventoried and prioritized 25 non-tidal crossings in the Town of Wenham based on combined ecological and infrastructure risk. The highest priority structure identified by the screening analysis was a single culvert located on Dodge Row (Site #188). This culvert, on a tributary feeding into Longham Reservoir, was also the highest ranking non-tidal crossing in the entire region (Table 46). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The 10 highest priority sites had infrastructure risk (CRI) scores of 4 or greater. This

[63] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[64] Full report document available at http://www.pie-rivers.org/barriers/

indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. Eight of the 10 highest priority crossings in Wenham are culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 3 non-tidal crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[65]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

The Meridian design materials are located in Appendix 3.

- Supporting materials begin on page 180
- Wenham designs begin on page 292

[65] Site #233 on Grapevine Road was selected for design largely due to structure condition and municipal interest in replacement at this crossing.

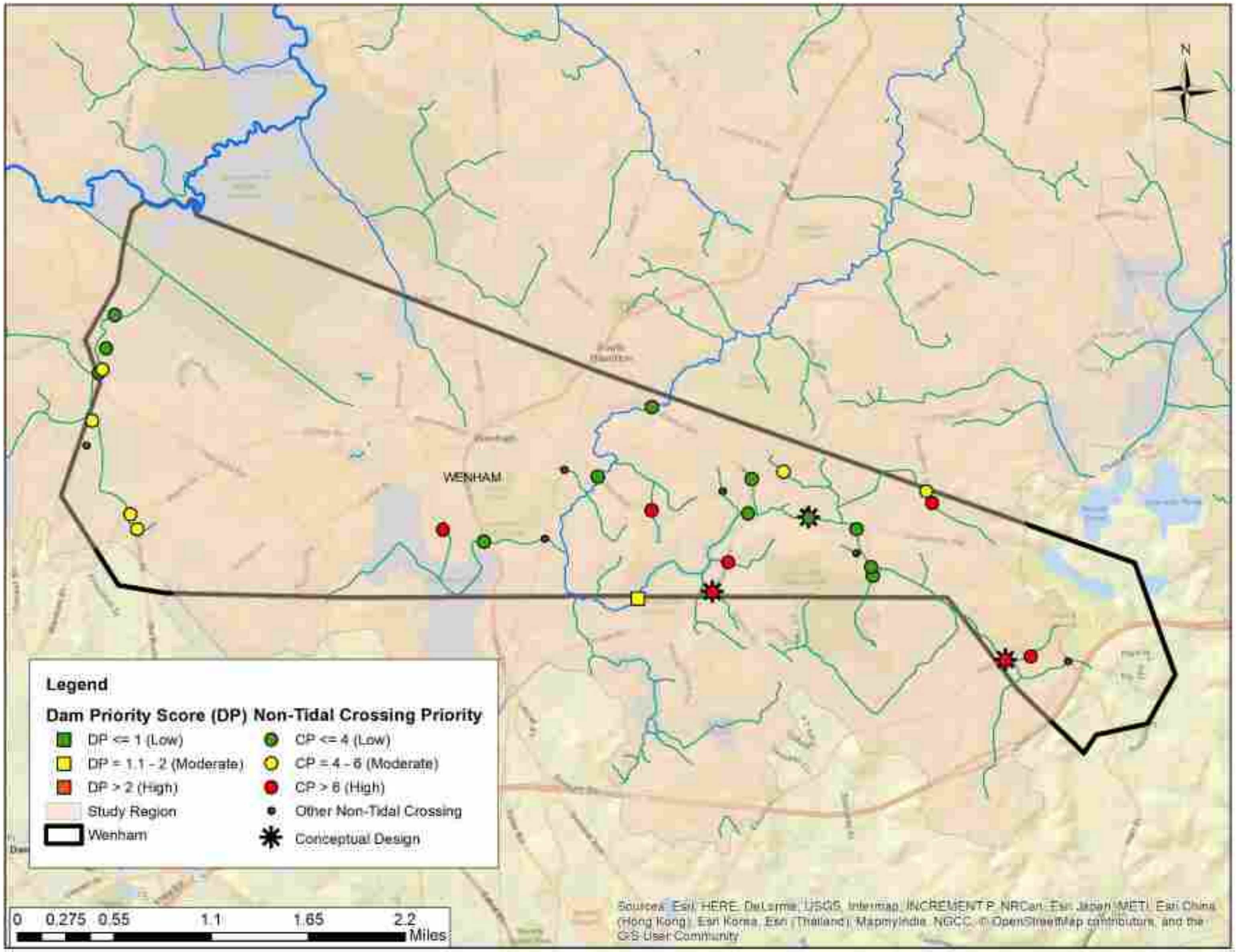

Figure 71. Map showing locations and prioritization scores for dams and non-tidal crossings in the Great Marsh Study region within the Town of Wenham, MA. Crossings with available conceptual designs are also noted.

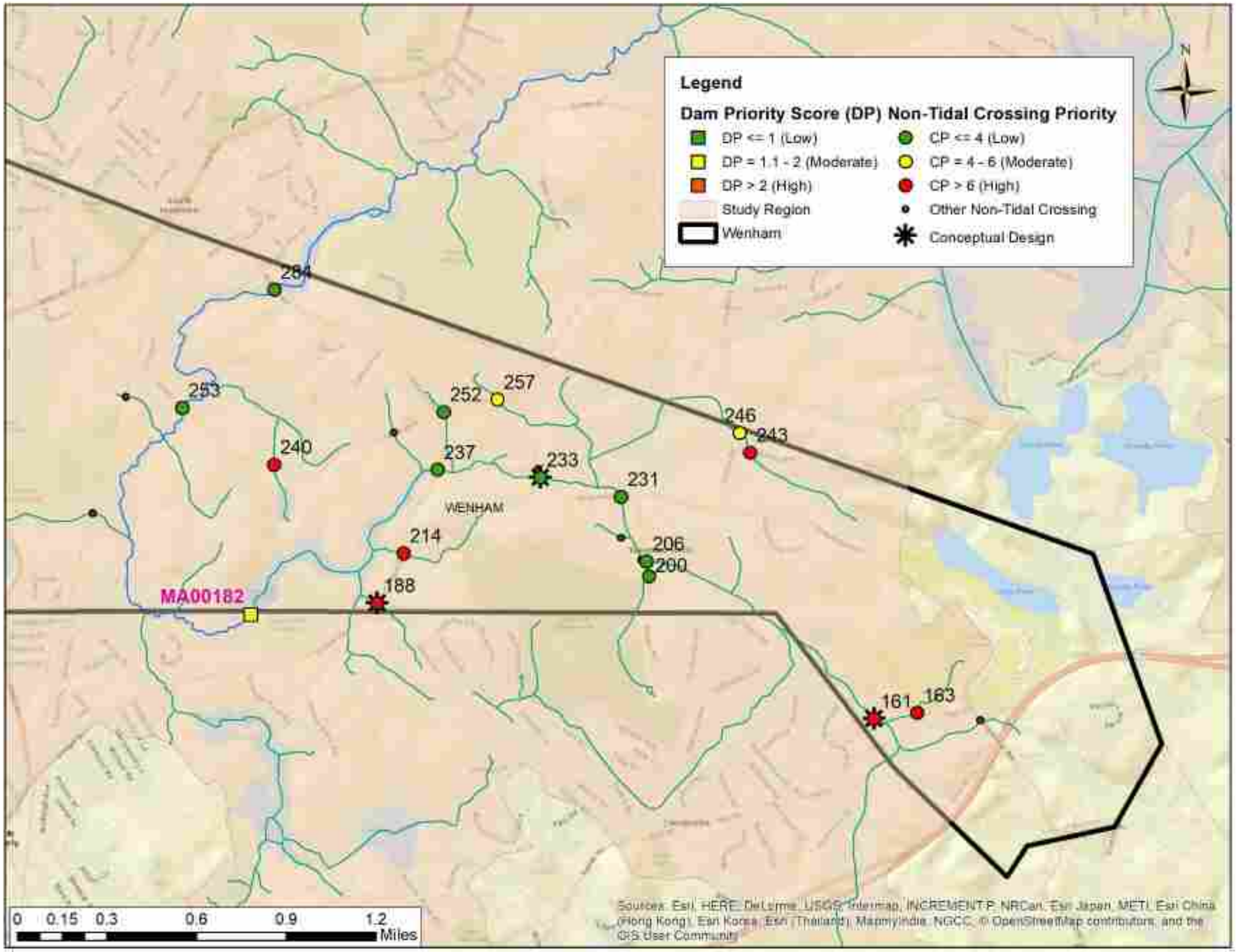

Figure 72. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the eastern portion of the Town of Wenham, MA. Dam ID shown in pink and crossing ID shown in black.

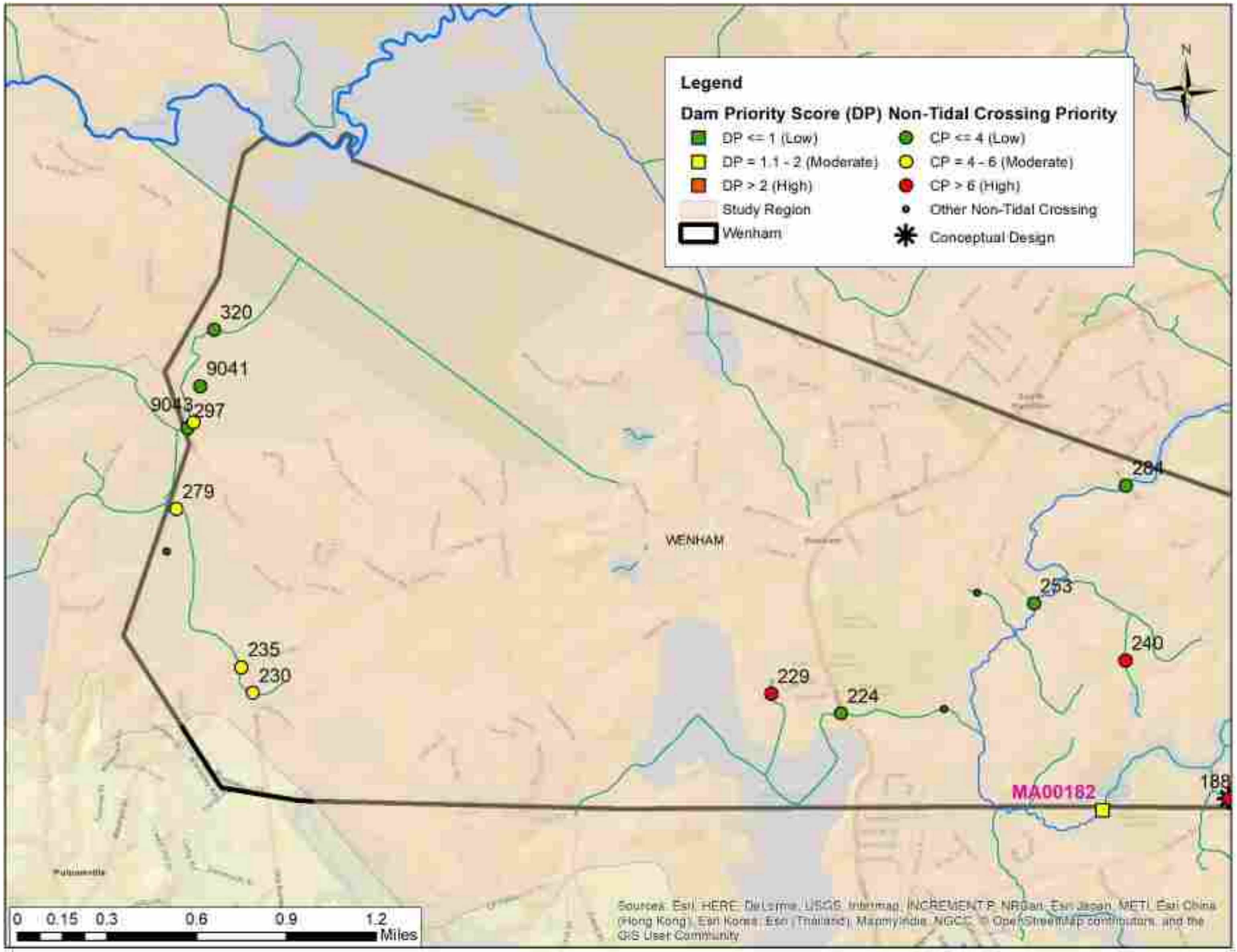

Figure 73. Prioritized dams and non-tidal crossings in the Great Marsh Study region within the western portion of the Town of Wenham, MA. Dam ID shown in pink and crossing ID shown in black.

Table 45. Dams in the portion of the Great Marsh study region within the Town of Wenham, MA prioritized by Dam Priority Score (DP).

Dam ID	Priority Rank: Town	Priority Rank: Region	Dam Name	Priority Scoring: Infrastructure Risk (RI)	Priority Scoring: Ecological Impact (EI)	Priority Scoring: Priority Score (DP)	Active/ Priority Project
MA00182	NA	NA	Longham Reservoir Dam	1	1	2	

Table 46. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Wenham, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
188	1	1	Dodge Row	Single Culvert	5.0	4.9	9.9	Yes
240	2	72	Larch Row	Single Culvert	5.0	1.6	6.6	
214	3	79	Dodges Row	Culvert	5.0	1.5	6.5	
163	4	83	Hull Street	Single Culvert	5.0	1.5	6.5	
229	5	125	Lake Avenue	Single Culvert	5.0	1.1	6.1	
161	6	129	Hull Street	Culvert	4.0	2.1	6.1	Yes
243	7	130	Danes Way	Single Culvert	4.6	1.5	6.1	
9043	8	160	Topsfield Nature Trail	Bridge	4.6	1.1	5.7	
279	9	161	Danvers Rail Trail	Bridge	5.0	0.6	5.6	
246	10	166	Rubbly Road	Single Culvert	4.0	1.6	5.6	
235	11	212	Maple Street	Multiple Culvert	3.6	1.2	4.8	
257	12	218	Larch Row	Single Culvert	2.6	2.0	4.6	
230	13	219	Burley	Multiple Culvert	2.6	1.8	4.4	
200	14	294	Essex street	Bridge	1.6	0.6	2.2	
252	15	321	Larch Row	Single Culvert	0.0	1.9	1.9	
231	16	433	Grapevine Road	Single Culvert	0.0	1.1	1.1	
233	17	475	Grapevine Road	Multiple Culvert	0.0	0.8	0.8	Yes
284	18	478	Walnut Street	Bridge	0.0	0.8	0.8	
9041	19	484	Topsfield Nature Trail	Multiple Culvert	0.0	0.8	0.8	
206	20	490	Essex Street	Bridge	0.0	0.7	0.7	
320	21	493	Topsfield Linear common	Single Culvert	0.0	0.7	0.7	
224	22	509	Main St	Open Bottom Arch	NA	0.7	0.7	
237	23	521	Dodges Rowe	Open Bottom Arch	0.0	0.6	0.6	
253	24	532	Larch Row	Bridge	0.0	0.5	0.5	
297	25	580	Topsfield Road	Open Bottom Arch	0.0	0.2	0.2	

West Newbury

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of West Newbury. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[66].

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[67].

Approximately 3.6 square miles of the Town of West Newbury is located within the Great Marsh study region. This portion of the study watershed, located in the southern portion of West Newbury, is outside of the coastal zone so West Newbury is considered an inland municipality in our analysis (Figure 75). As an inland municipality, West Newbury does not have any tidal crossings or coastal stabilization structures. The portion of the study watershed within the West Newbury town limits has relatively few potential barrier sites, but we are including a town summary because we developed conceptual designs for two structures. Our analysis considered a total of 11 potential barrier sites (all non-tidal crossings), with structures confirmed and prioritized at 7 of those locations (Table 47). Our analysis did not identify any dams in the Town of West Newbury.

Figure 74. Outlet of road-stream crossing at Crane Neck Street, West Newbury (Site #1153).

The highest priority non-tidal crossing in the Town of West Newbury based on our screening analysis of ecological and infrastructure risk is a multiple culvert on Georgetown Road (Site #1155) that ranked the 33rd poorest in the region (Table 47). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. The five highest priority sites all had an infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given

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[66] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/

[67] Full report document available at http://www.pie-rivers.org/barriers/

year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. The five highest priority crossings in West Newbury are single or multiple culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 2 non-tidal crossings with a structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

The Meridian design materials are located in Appendix 3.

- Supporting materials begin on page 180
- West Newbury designs begin on page 296

Table 47. Non-tidal crossings in the portion of the Great Marsh study region within the Town of West Newbury, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank		Road	Structure Type	Priority Scoring			Concept Designs
	Town	Region			Infrastructure Risk (CRI)	Ecological Impact (CEI)	Crossing Priority (CP)	
1155	1	33	Georgetown Road	Multiple Culvert	5.0	2.0	7.0	Yes
1158	2	51	Hilltop Circle	Single Culvert	5.0	1.7	6.7	
1124	3	105	Crane Neck Street	Single Culvert	5.0	1.3	6.3	
1153	4	115	Crane Neck Street	Multiple Culvert	4.0	2.2	6.2	Yes
1171	5	137	Georgetown Road	Multiple Culvert	5.0	0.9	5.9	
1173	6	242	Tewksbury Lane	Bridge	3.0	0.8	3.8	
1159	7	438	Middle Street	Open Bottom Arch	0.0	1.1	1.1	

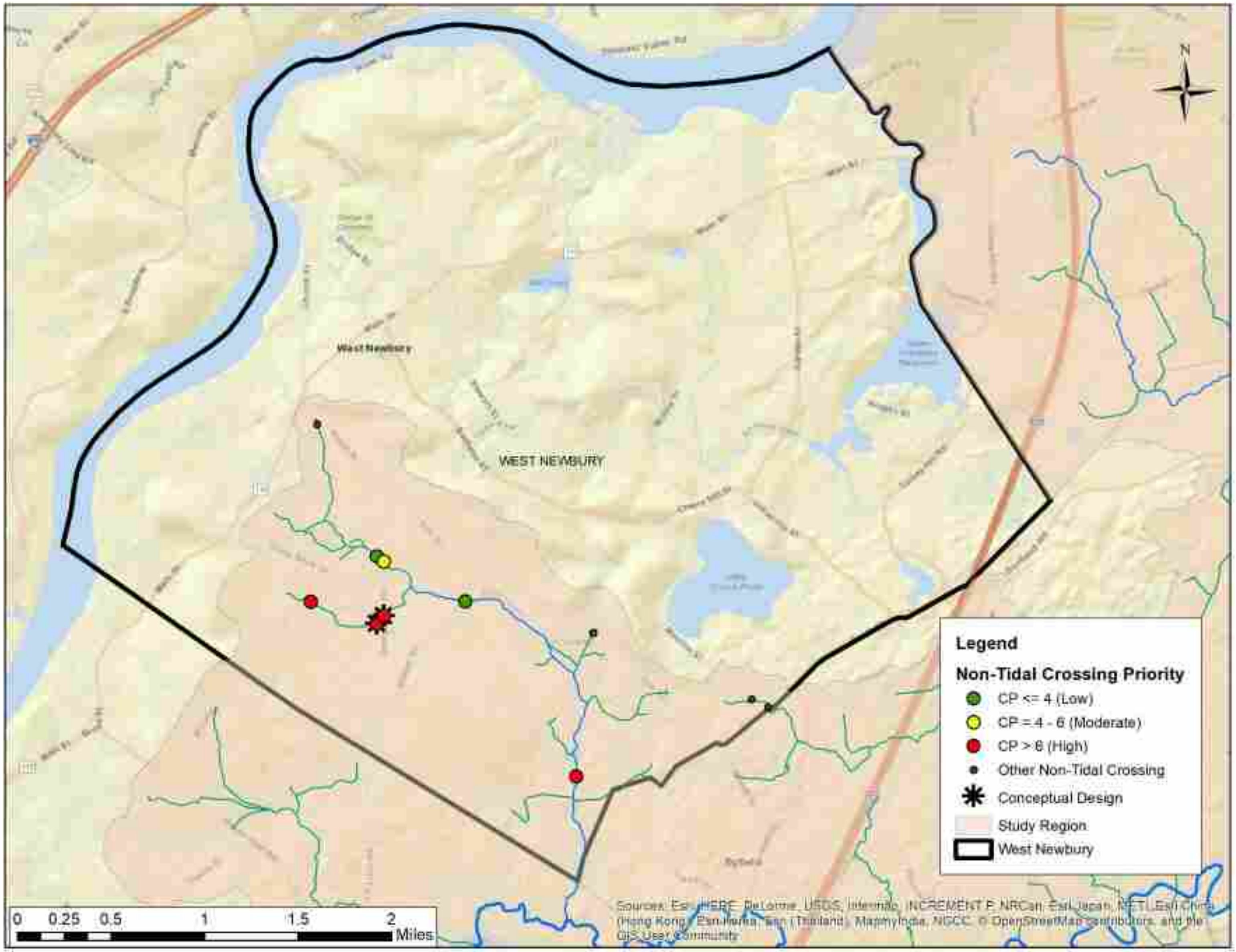

Figure 75. Map showing locations and prioritization scores for non-tidal crossings in the Great Marsh Study region within the Town of West Newbury, MA. Crossings with available conceptual designs are also noted.

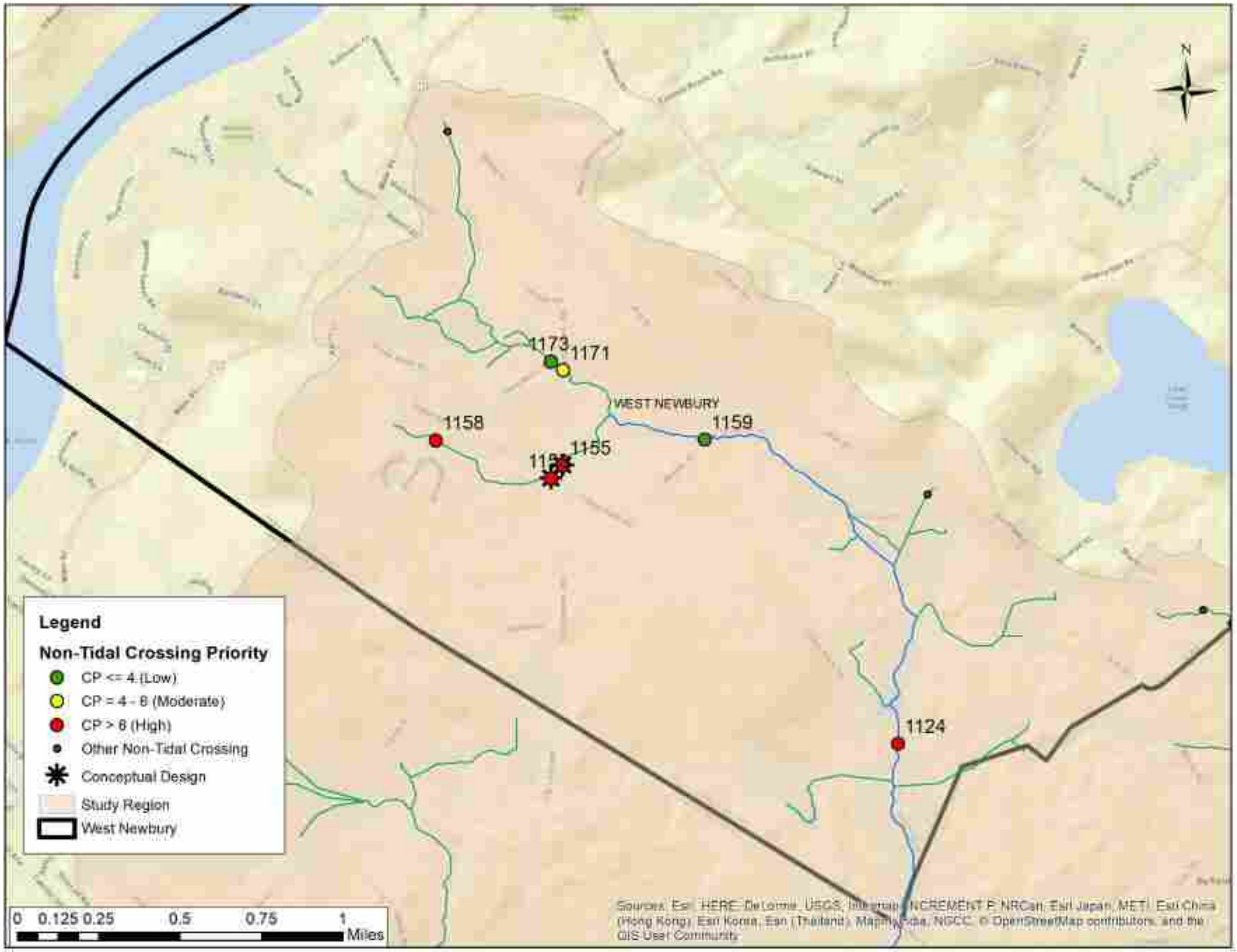

Figure 76. Closeup view of non-tidal crossings in the Great Marsh Study region within the Town of West Newbury, MA. Crossings with available conceptual designs are also noted.

Wilmington

This section summarizes results of the Great Marsh Barriers Assessment (Barriers Assessment) analysis for the Town of Wilmington. This project was conducted by the Ipswich River Watershed Association as a component of the Great Marsh Resiliency Project. The Resiliency Project was funded by the National Fish and Wildlife Foundation through the Hurricane Sandy Coastal Resiliency Competitive Grant Program and led by the National Wildlife Federation. The project included five separate sub-projects aimed at increasing the resiliency of the Great Marsh and PIE-Rivers Region[68].

Figure 77. Outlet of road-stream crossing at Ainsworth Road, Wilmington (Site #151).

The Barriers Assessment inventoried, assessed, and prioritized human made structures that may impede flow, fluvial and coastal processes. These structures, collectively called barriers in the report include dams, non-tidal stream/river crossings, tidal crossings, and coastal stabilization structures. We assessed these structures based on both ecological impact and infrastructure risk using a combination of existing analyses, newly applied screening tools and local knowledge. For more detail on prioritization methods as well as region-wide priorities see the main report[69].

Figure 78. Outlet of road-stream crossing at Chestnut Street, Wilmington (Site #9).

The Town of Wilmington is located outside of the coastal zone and almost the entire town is located within the Great Marsh study region covering approximately 14.2 square miles (Figure 79). Wilmington includes the majority of the watersheds for the three principle headwater streams that give rise to the main stem of the Ipswich River. As an inland municipality, Wilmington does not have any tidal crossings or coastal stabilization structures. Our analysis considered a total of 35 potential barrier sites (all non-tidal crossings) with structures confirmed and prioritized at 31 of those locations (Table 48). Our analysis did not identify any dams in the Town of Wilmington.

The highest priority non-tidal crossing in the Town of Wilmington based on our analysis of ecological and infrastructure risk is a single culvert on Ainsworth Road (Site #151) that also ranked 6th in the region (Table

[68] The PIE-Rivers Region includes the 280 square mile combined watersheds of the Parker, Ipswich and Essex Rivers in northeastern Massachusetts. http://www.pie-rivers.org/
[69] Full report document available at http://www.pie-rivers.org/barriers/

48). Poor scores in the screening tool generally indicate that structures are less likely to function properly during high flows (infrastructure risk) and may present significant barriers to wildlife migration and river function (ecological impact). Very often these dual impacts stem from crossings that are undersized relative to their upstream watershed and/or mismatched to the natural grade of the stream bed. Six of the 8 highest priority sites had infrastructure risk (CRI) scores of 4 or greater. This indicates that they were not expected to pass flows associated with storms that have a 10% or higher chance of occurring on any given year. While this doesn't indicate they will fail, it is an indicator that those crossings might be worth taking a closer look at to see how they are performing during storms. The four highest priority crossings in Wilmington are single culverts that could potentially be replaced with larger and more storm resilient/fish friendly crossings when it comes time to do routine maintenance.

As part of this study, Meridian Associates, Inc. (MAI) developed conceptual design plans for the replacement of 11 non-tidal crossings with a structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures[70]. The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

The Meridian design materials are located in Appendix 3.

- Supporting materials begin on page 180
- Wilmington designs begin on page 299

[70] Sites #9 (Chestnut Street) and #28 (Burlington Avenue) were selected for design based on ecological score and best professional judgement regarding their likelihood to plug with debris. Sites #18 (Andover Street), #55 (Main Street) and #65 (Wildwood Street) were selected based on municipal input regarding maintenance and flooding concerns.

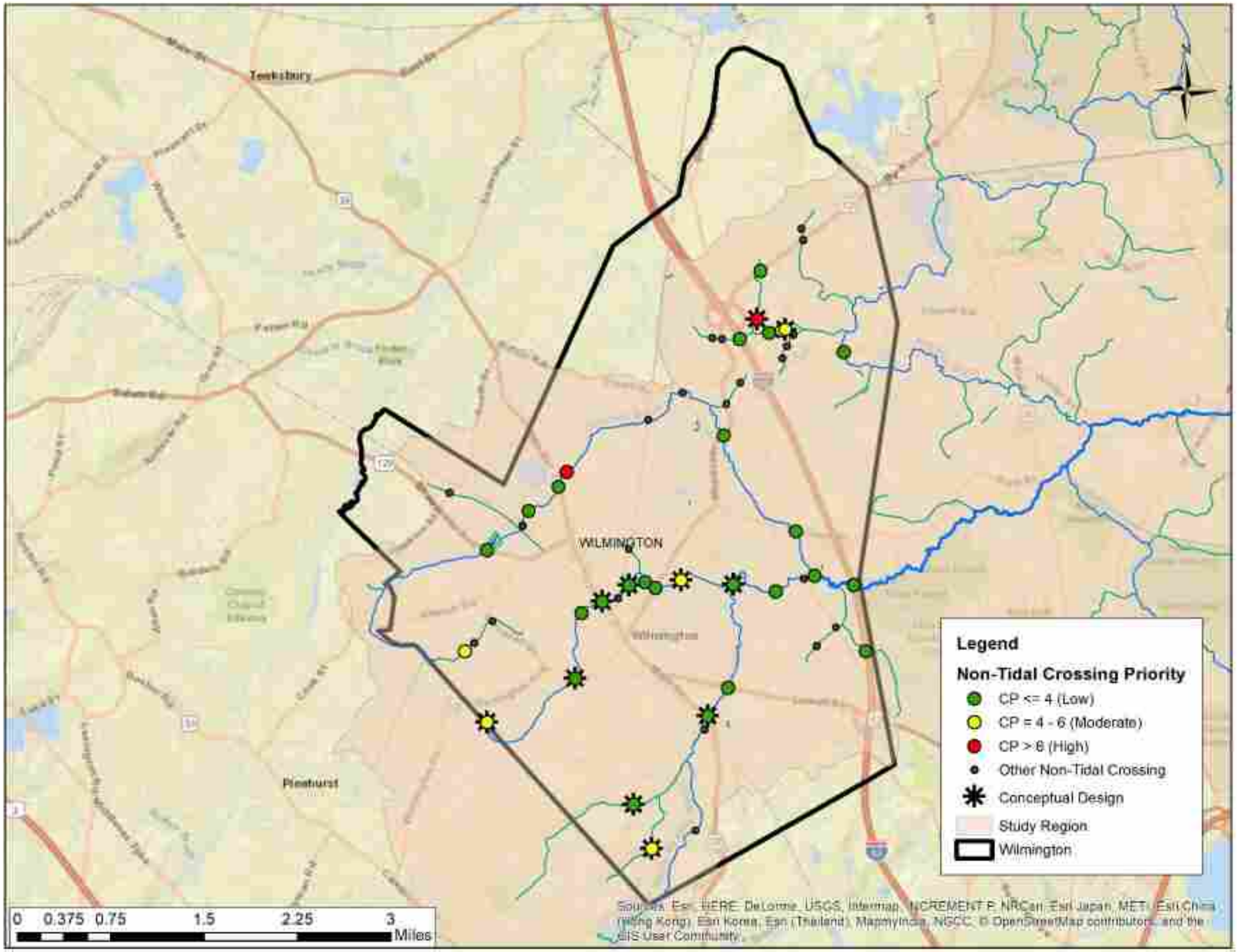

Figure 79. Map showing locations and prioritization scores for non-tidal crossings in the Great Marsh Study region within the Town of Wilmington, MA. Crossings with available conceptual designs are also noted.

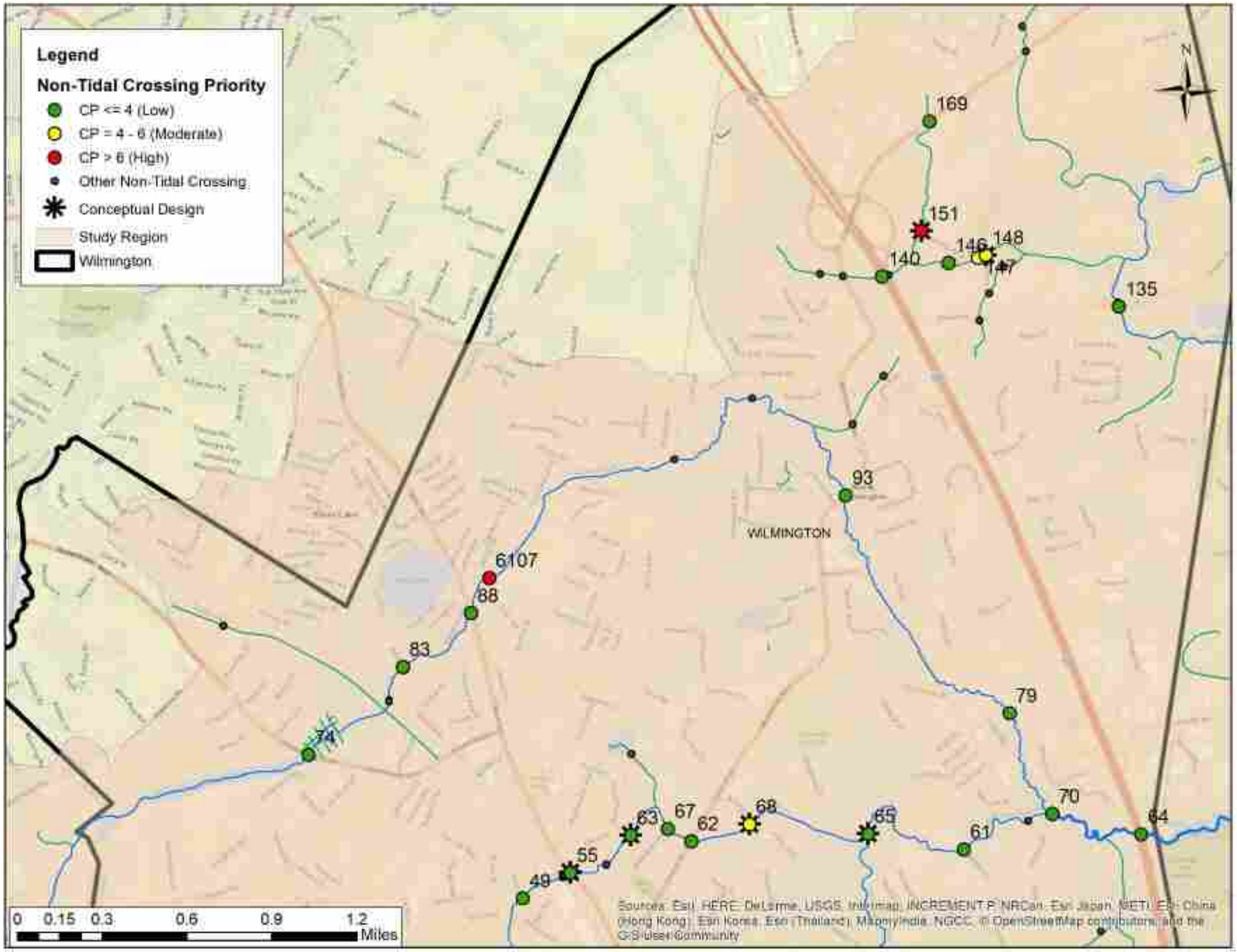

Figure 80. Non-tidal crossings in the Great Marsh Study region within the northern portion of the Town of Wilmington, MA. Crossings with available conceptual designs are also noted.

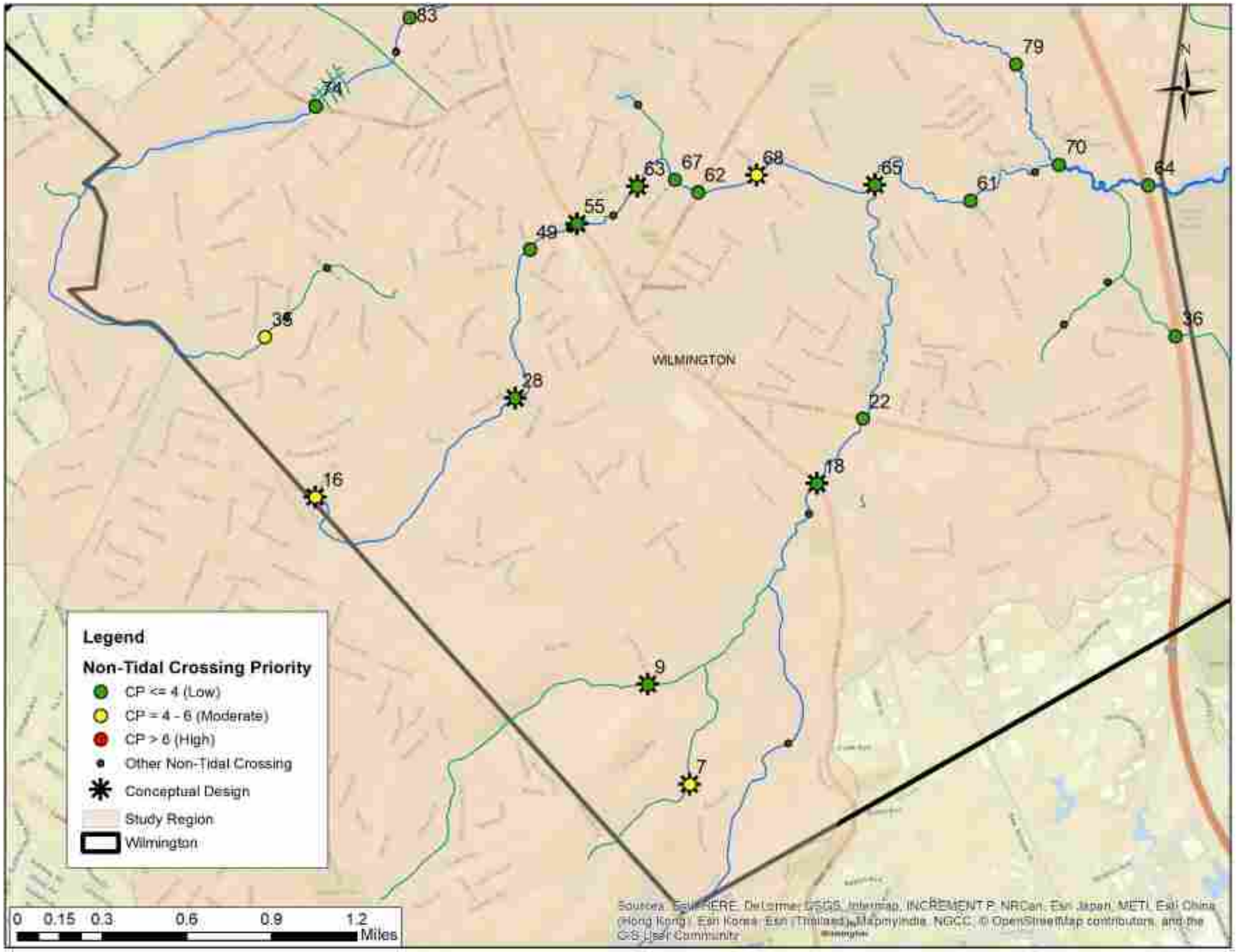

Figure 81. Non-tidal crossings in the Great Marsh Study region within the southern portion of the Town of Wilmington, MA. Crossings with available conceptual designs are also noted.

Table 48. Non-tidal crossings in the portion of the Great Marsh study region within the Town of Wilmington, MA prioritized by Crossing Priority Score (CP). Sites with available conceptual designs as part of this project are noted.

Crossing ID	Priority Rank: Town	Priority Rank: Region	Road	Structure Type	Priority Scoring: Infrastructure Risk (CRI)	Priority Scoring: Ecological Impact (CEI)	Priority Scoring: Crossing Priority (CP)	Concept Designs
151	1	6	Ainsworth Road	Single Culvert	5.0	3.7	8.7	Yes
6107	2	73	Glen Road	Single Culvert	5.0	1.6	6.6	
35	3	152	Forest Street	Single Culvert	4.6	1.1	5.7	
16	4	159	Beech Street	Single Culvert	5.0	0.7	5.7	Yes
148	5	177	Woburn Street	Multiple Culvert	2.2	3.2	5.4	Yes
147	6	188	Ainsworth Road	Open Bottom Arch	4.0	1.3	5.3	
7	7	215	Chestnut Street	Single Culvert	0.0	4.6	4.6	Yes
68	8	232	Adams Street	Single Culvert	4.0	0.2	4.2	Yes
63	9	259	Clark Street	Multiple Culvert	0.0	2.9	2.9	Yes
49	10	323	Canal Street	Multiple Culvert	0.0	1.8	1.8	
135	11	324	Salem Street/Rt 62	Bridge	0.0	1.8	1.8	
74	12	326	Shawsheen Avenue	Multiple Culvert	0.0	1.8	1.8	
140	13	332	I-93	Single Culvert	NA	1.8	1.8	
9	14	334	Chestnut Street	Multiple Culvert	0.0	1.8	1.8	Yes
169	15	344	Route 125	Multiple Culvert	0.0	1.7	1.7	
83	16	345	Wild Avenue	Multiple Culvert	0.0	1.7	1.7	
28	17	352	Burlington Avenue	Multiple Culvert	0.0	1.6	1.6	Yes
146	18	457	Andover Street	Multiple Culvert	0.0	1.0	1.0	
36	19	488	I-93 SB	Single Culvert	NA	0.8	0.8	
55	20	489	Main Street/Route 38	Bridge	0.0	0.8	0.8	Yes
79	21	511	Concord Street	Multiple Culvert	0.0	0.6	0.6	
18	22	528	Main Street/Route 38	Bridge	0.0	0.6	0.6	Yes
22	23	529	Lowell Street	Bridge	0.0	0.5	0.5	
62	24	547	Church Street	Bridge	0.0	0.4	0.4	
93	25	560	Middlesex Avenue	Multiple Culvert	0.0	0.3	0.3	
65	26	565	Wildwood Street	Bridge	0.0	0.3	0.3	Yes
61	27	566	Federal Street	Open Bottom Arch	0.0	0.3	0.3	
70	28	568	Woburn Street	Multiple Culvert	0.0	0.3	0.3	
64	29	574	I-93	Single Culvert	NA	0.3	0.3	
67	30	575	Middlesex Avenue	Bridge	0.0	0.2	0.2	
88	31	578	Main Street/Route 38	Bridge	0.0	0.2	0.2	

Appendix 3 – Road-Stream Crossing Designs

Properly sized, designed and installed crossings can reduce flooding and failure risk, extend structure longevity and improve river and stream conditions. As the final component of this project, Meridian Associates, Inc. (MAI) was contracted to develop conceptual designs for the replacement of a subset of selected high priority crossings with structures designed to increase aquatic connectivity and resilience to flooding. These structures were identified as high priorities based on a combination of their numeric priority scores, municipal input, structural condition and proximity to other priority structures. This task was focused almost exclusively on non-tidal crossings, but tidal crossings could be designed where site-specific conditions allowed the engineering team to do so.

The designs were developed using available site data including measurements, photos and field notes collected by IRWA as well as results from the NAACC database[71] and the Trout Unlimited Hydraulic Conductivity screening tool. Modeling effort field measurements collected by IRWA for the NAACC and screening tools. The proposed designs focused on improving hydraulic capacity and ecological connectivity and were intended to conform to the Massachusetts Stream Crossing Standards where applicable (Jackson et al., 2011). The designs were developed using available site data including field measurements collected by IRWA during the screening analyses. The designs provide a visual representation of the size and scale of a potential replacement structure that would better convey storm flows and meet ecological stream crossing standards at each site. These designs can provide a starting point to more easily incorporate resilient and long-lived structures into maintenance and replacement schedules. These plans can help with scoping, budgeting and fundraising associated with crossing upgrades.

In the following pages, please find materials provided by MAI explaining the methods they used to develop the designs as well as the purpose and limitations of these preliminary drawings. Also included is some information on additional tasks that would be included in the design process and photos and general pros and cons of some typical crossing types. The 103 preliminary designs are organized by municipality and Crossing ID#.

Structures designed to meet the Massachusetts Stream Crossing Standards meet requirements under the MA Wetlands Protection Act. The Massachusetts Division of Ecological Restoration (DER) has launched a program designed to provide technical and financial assistance to municipalities looking to replace road-stream crossings with structures that meet these standards. DER is building a library of technical assistance resources on their web page. They are also funding demonstration restoration projects around the commonwealth and will be holding training sessions beginning in 2018.

- DER Culvert Replacement Website: https://www.mass.gov/service-details/replace-a-culvert

[71] NAACC Crossing database available at: www.streamcontinuity.org/cdb2

Table of Contents (Appendix 3)

Meridian Supporting Materials

Supporting materials for preliminary designs provided by Meridian Associates, Inc. (8 pages)

MERIDIAN ASSOCIATES
100% employee owned

July 17, 2017

Ipswich River Watershed Association
143 County Road, Ipswich, MA 01938
Attn.: Brian Kelder
Restoration Program Manager

Dear Mr. Kelder,

The following materials were created by Meridian Associates, Inc. (MAI) in cooperation with the Ipswich River Watershed Association (IRWA). This package includes initial conceptual design sketches developed by MAI for replacement of existing culverts, with structures designed to meet the Massachusetts Stream Crossing Standards. The locations were identified by IRWA as high priority for upgrade based on their regional analysis of ecological connectivity and infrastructure risk at road-stream crossings. In addition, MAI has provided a list of possible next steps that can be taken to continue the culvert replacement process from initial land surveying through final design and permitting, as well as a brief list of “pros and cons” of the different culvert types that have been proposed.

The concept sketches are intended for use by municipalities and their Public Works departments as tools for evaluating the feasibility of replacing the existing culverts highlighted herein, as well as for prioritizing any possible stream crossing upgrades in municipalities where multiple crossings have been chosen. The sketches included here are initial concepts based on available information only, and any final crossing designs may vary greatly based on the results of further analysis, design, permitting and cost considerations. These sketches are intended to serve as a starting point to begin the process of scoping project scale, developing cost estimates and evaluating other considerations prior to entering a more intensive design phase.

Criteria used by MAI in selection of proposed crossing structures include the Massachusetts Stream Crossing Standards, specific site constraints including the obvious presence of existing utilities, location of crossing, available bankfull width (upstream and downstream), any vertical dimensions provided by IRWA during field surveys, overall location of crossing, and surrounding topography in the area of the crossing.

Data used in creation of the concept sketches includes, but was not limited to, information provided by IRWA to MAI. This information included field notes, photos, bankfull width estimates (upstream and downstream), vertical measurements on both ends of culvert from existing road surface, field notes describing any existing structures, and geographical location information in the form of an interactive ArcGIS map. MAI took this information, combined with base plans derived from local GIS resources (when available) and Google Earth, to construct these concepts. No formal land surveying was performed in the field by MAI. These sketches are therefore approximate in nature.

These plans, as stated above, are to be used as tools for evaluating possible crossing upgrades. They are not intended in any way to be substituted for design plans, and are not to be used for construction. As stated in the 'Next Steps" document included, any crossing replacement will need a formal design and hydrologic analysis performed by a registered professional Engineer.

Sincerely,

MERIDIAN ASSOCIATES, INC.

Christopher A. Ryan
Senior Project Engineer

P:\5900\ADMIN\Letters_Memos\Cover Letter.doc

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100% employee owned

IRWA Stream Crossing Project

Possible Next Steps

Distribute concept sketches and report with cover letters to DPW Directors, Town Planners, Conservation Agents, City Council members, or other decision makers in the affected towns to create awareness and possible opportunities for linkage with projects that may be in the pipeline already. A good example would be, say, a subdivision or other large site design being proposed near one of the crossings, and the Planning Board could use the opportunity to link a stream crossing upgrade as a condition for granting a Special Permit for the project, etc.

Collect land survey data in area of crossing to be upgraded. May also require survey of roadway approaches if determined that roadway vertical alignment will be affected by crossing design. Survey data needing collection would include detail of existing stream bed and crossing components, roadway approaches on both sides of crossing area, as well as areas directly adjacent to stream in both upstream and downstream directions. Research on existing utilities would need to be performed, and any surface utility components and markings would need to be located. Exact limits of ground survey would need to be determined in field prior to start, since each site varies.

Research any subsurface utilities in the area of crossing that could potentially impact a proposed design. Engage all utility providers if any relocation is being proposed, since major utility relocations may pose significant issues with a proposed crossing being able to meet the stream crossing standards. Any known utility lines would need to be marked on the ground to allow for collection during land survey process.

If a crossing is being proposed under a state road, MassDOT would need to be engaged during the planning process to determine any agency requirements. This will affect the entire process from land survey, to design and permitting.

Determine any local permitting requirements for a new crossing. Local Public Works department would need to be engaged, along with Conservation, Fire, Water and Public Safety departments to assess any impacts and possible special requirements required, depending on location.

Conduct formal analysis of contributing hydrology to evaluate any potential negative downstream impacts.

Full design of new crossing with design plans and specifications. If MassDOT is involved, design and specifications must conform to agency standards. Again, this may or may not include design changes to existing roadway. New crossing design should meet stream crossing standards. If all standards cannot be met due to site constraints, the standards should be met to the greatest extent possible.

Pros and Cons of Crossing Types

- 3 sided concrete box
  - Good longevity with low maintenance
  - Can be custom fabricated for specific location requirements
  - Allows for wider span than elliptical metal arch in most locations
  - Can incorporate wing walls for slope retention, and guard rails/sidewalk when needed
  - Good for crossings under roadway
  - Relatively quick installation once components are on site
  - Stream bed can be left relatively untouched during installation
  - More expensive than elliptical metal arch
  - Requires more excavation and longer potential road closure time
  - Relocated utilities would have to be placed on top of structure
- 4 sided concrete box
  - Good longevity with lower maintenance requirements than elliptical metal arch
  - Allows for wider spans in most locations
  - Can incorporate wing walls into structure and guard rail/sidewalk on top of structure
  - Relocated utilities can be placed over or under structure
  - Might choose over 3 sided in cases with poor substrate for footings
  - Higher cost than metal arch solution
  - Existing stream bed would need to be eliminated along length of structure
- Elliptical arch
  - Inexpensive relative to concrete structures
  - Less overall excavation required
  - Good for smaller crossings in areas of tight site restrictions
  - Shorter road closure time required during installation
  - Custom fabrication available
  - Various standard sizes available should allow faster delivery to site
  - Shorter life span than most concrete structures
  - If longer crossing length required, concrete may be preferable due to height requirement of arch, and may affect ability to meet crossing standards
- Open bottom Arch
  - Can consider using stem footings to keep metal out of abrasion zone
  - Less expensive compared to precast concrete arch structure
  - Allows stream bed to remain mostly undisturbed
  - Good in areas of high vertical clearance to allow for wildlife passage
  - Possible shorter lifespan
  - More frequent maintenance may be required

- Bridge span (metal)
    - In situations where road can be closed for a period of time, can consider using GRS abutments to reduce cost
    - Can be more aesthetically pleasing than concrete structure in locations of high visibility
    - Various design types available
    - Can provide wide crossing area for various types of wildlife passage
    - Sidewalks, guard rails and street lighting can be incorporated into structure
    - More likely to have higher maintenance costs vs precast span over time
    - High purchase and installation costs
    - More excavation and longer road closure time required for installation

Example Crossing Photos

Figure 1. 3-sided Box culvert

Figure 2. 4-sided box culvert.

Figure 3. Elliptical arch culvert

Figure 4. Open bottom arch culvert (metal)

Figure 5. Open bottom arch culvert (concrete)

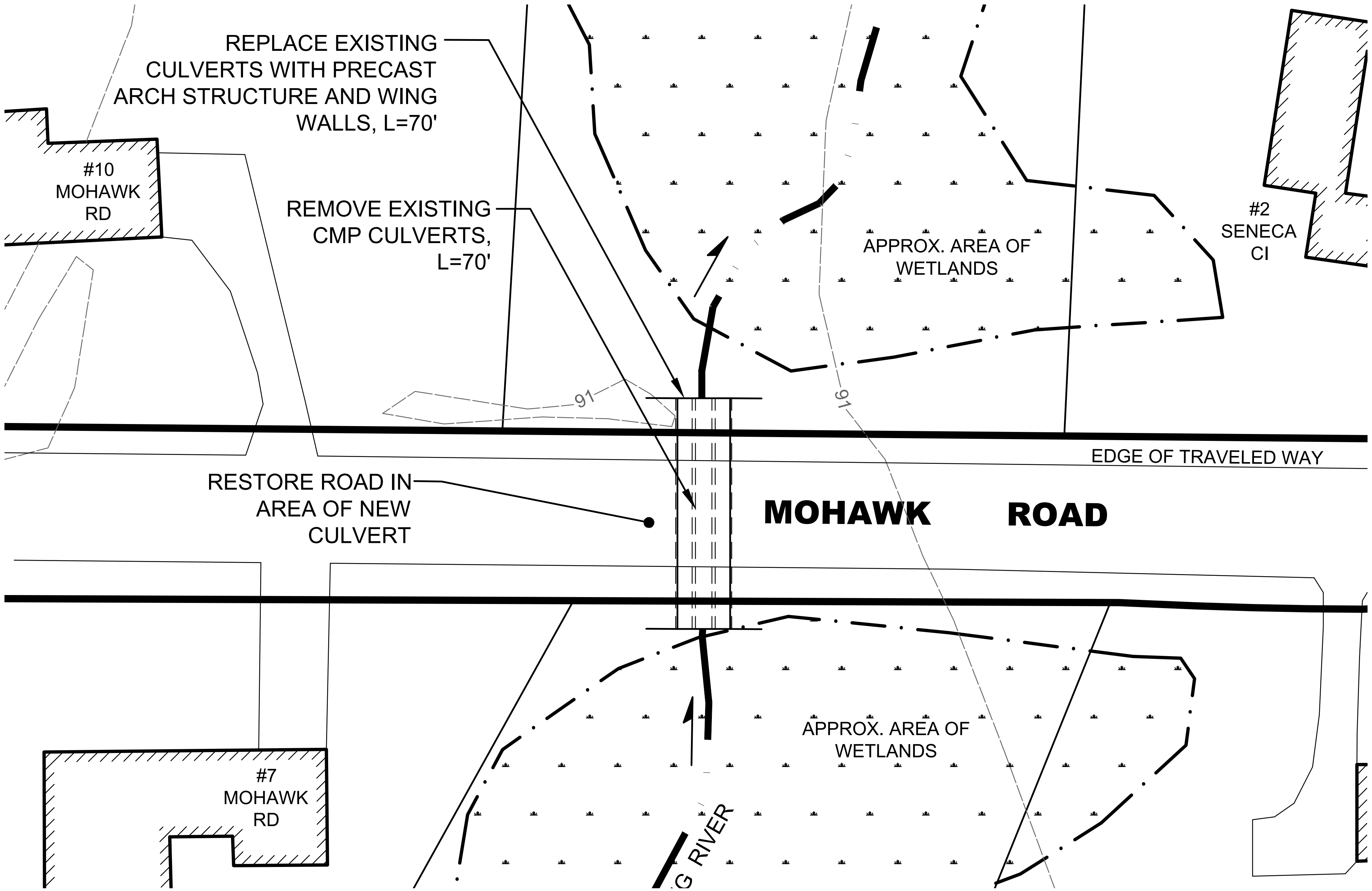
Figure 6. Steel bridge span

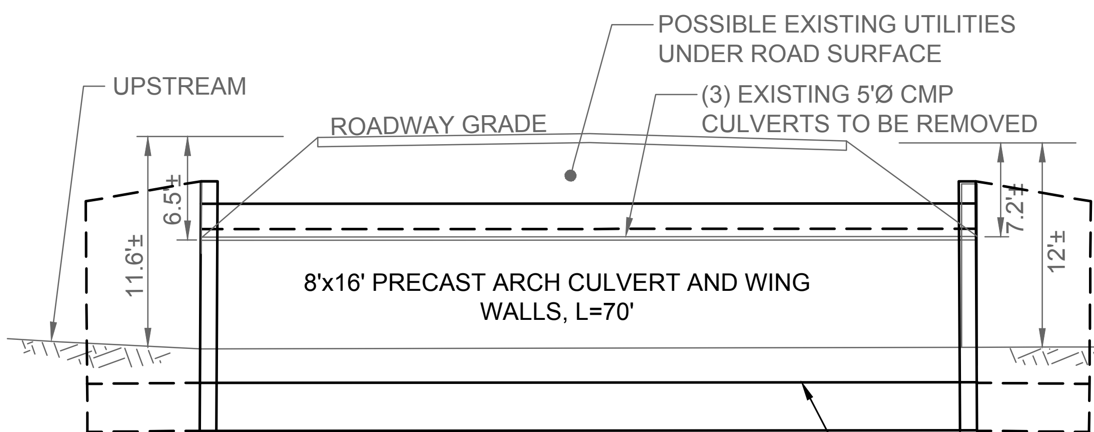
P:\5900\ADMIN\Letters_Memos\IRWA next steps rev4.doc

Andover Designs

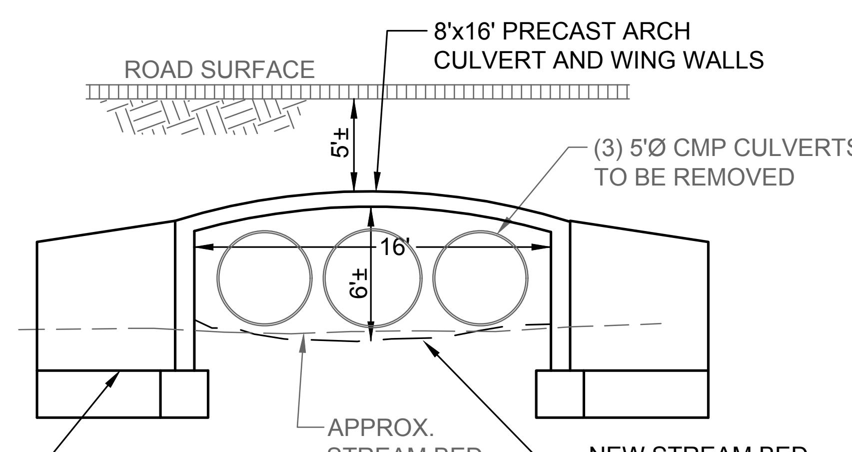
Conceptual designs for the replacement of select road-stream crossings in the Town of Andover, MA

5 pages





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=13 FEET. PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.14
10. NAACC CROSSING CODE: xy4260298371099415
11. NAACC SURVEY ID: 5079

IRWA CROSSING #260 SKETCH PLAN

LOCATED IN

ANDOVER, MASSACHUSETTS

(MIDDLESEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: NOV. 1, 2016

15 0 15 30 60

MERIDIAN ASSOCIATES

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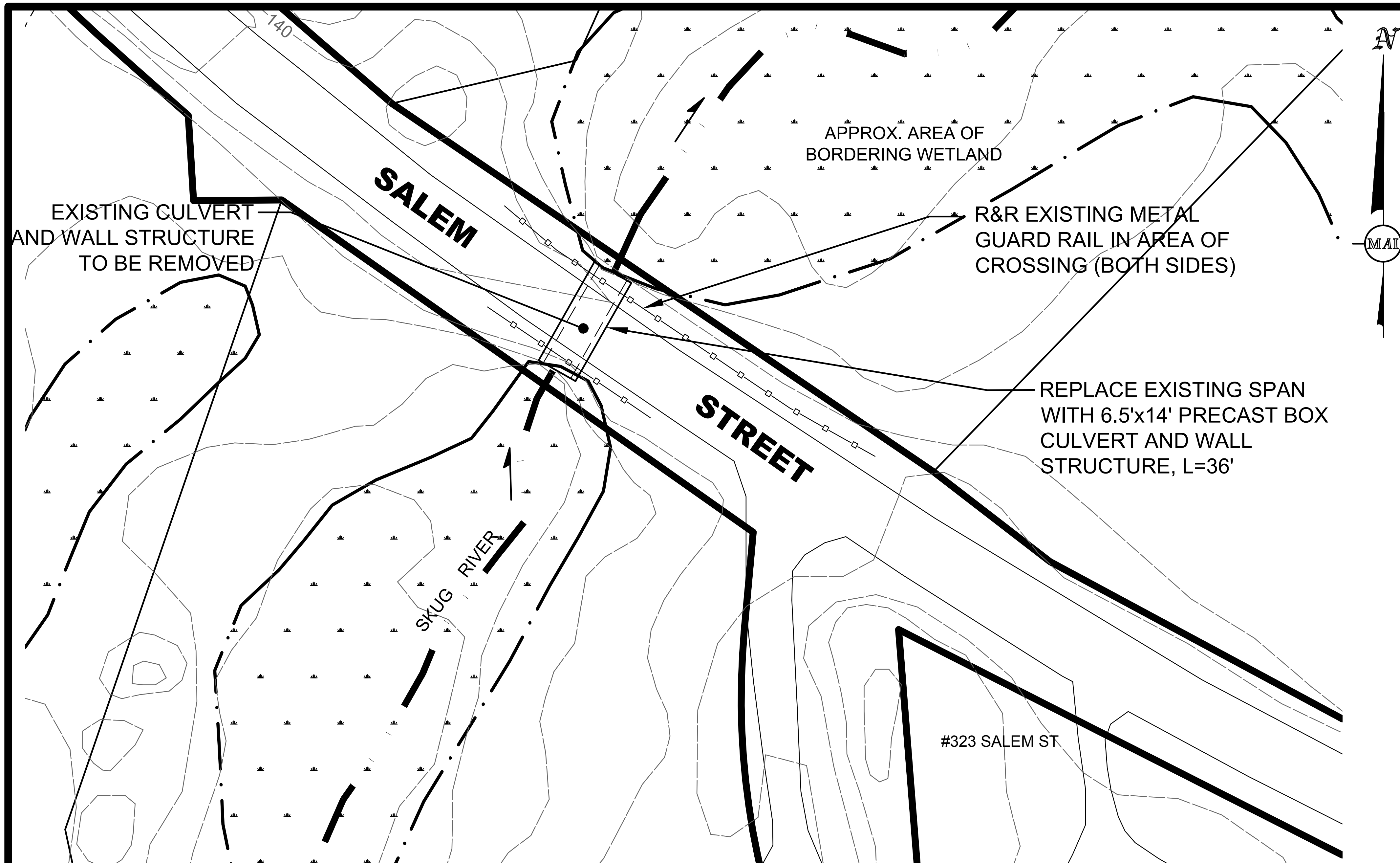
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 260.dwg

MAI Project: 5900



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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=11 FEET. PROPOSED CULVERT WIDTH=14 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.75
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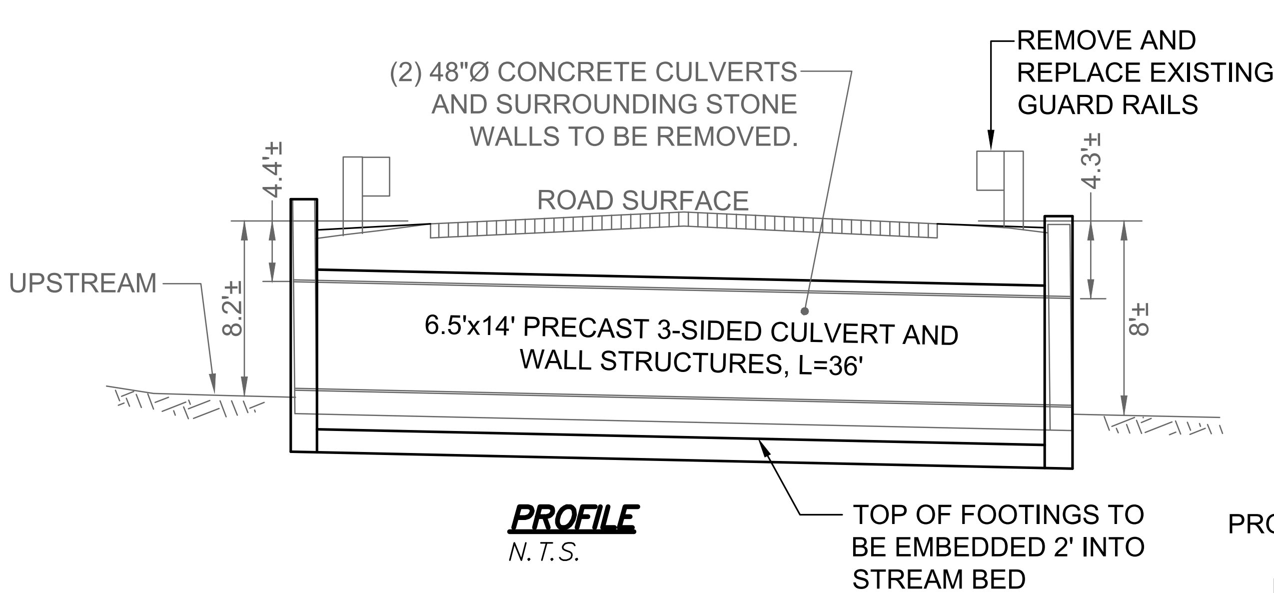
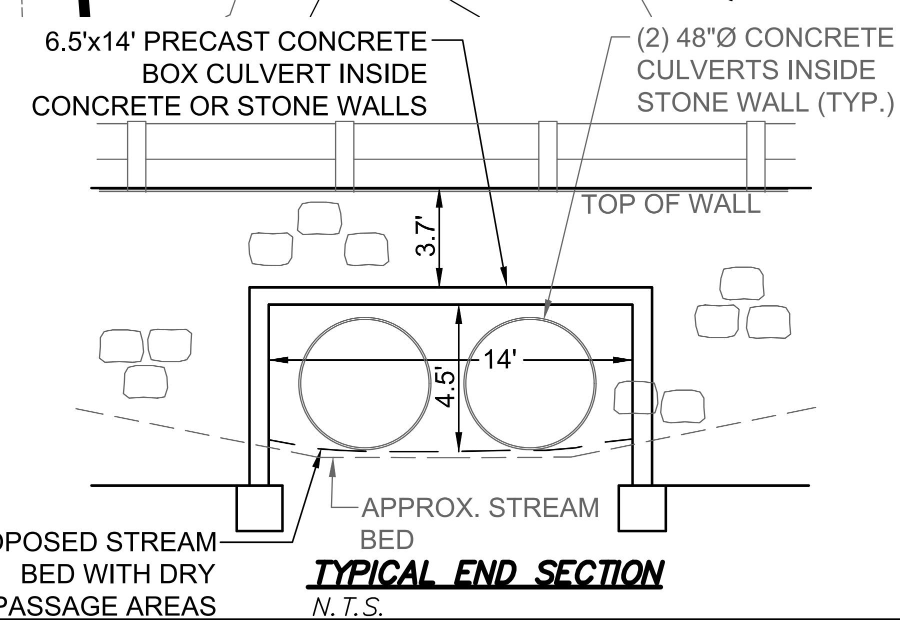
11. NAACC SURVEY ID: 5072



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 374
SKETCH PLAN

LOCATED IN
ANDOVER, MASSACHUSETTS
(ESSEX COUNTY)

PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 9, 2017
20 0 20 40 80

MERIDIAN
ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
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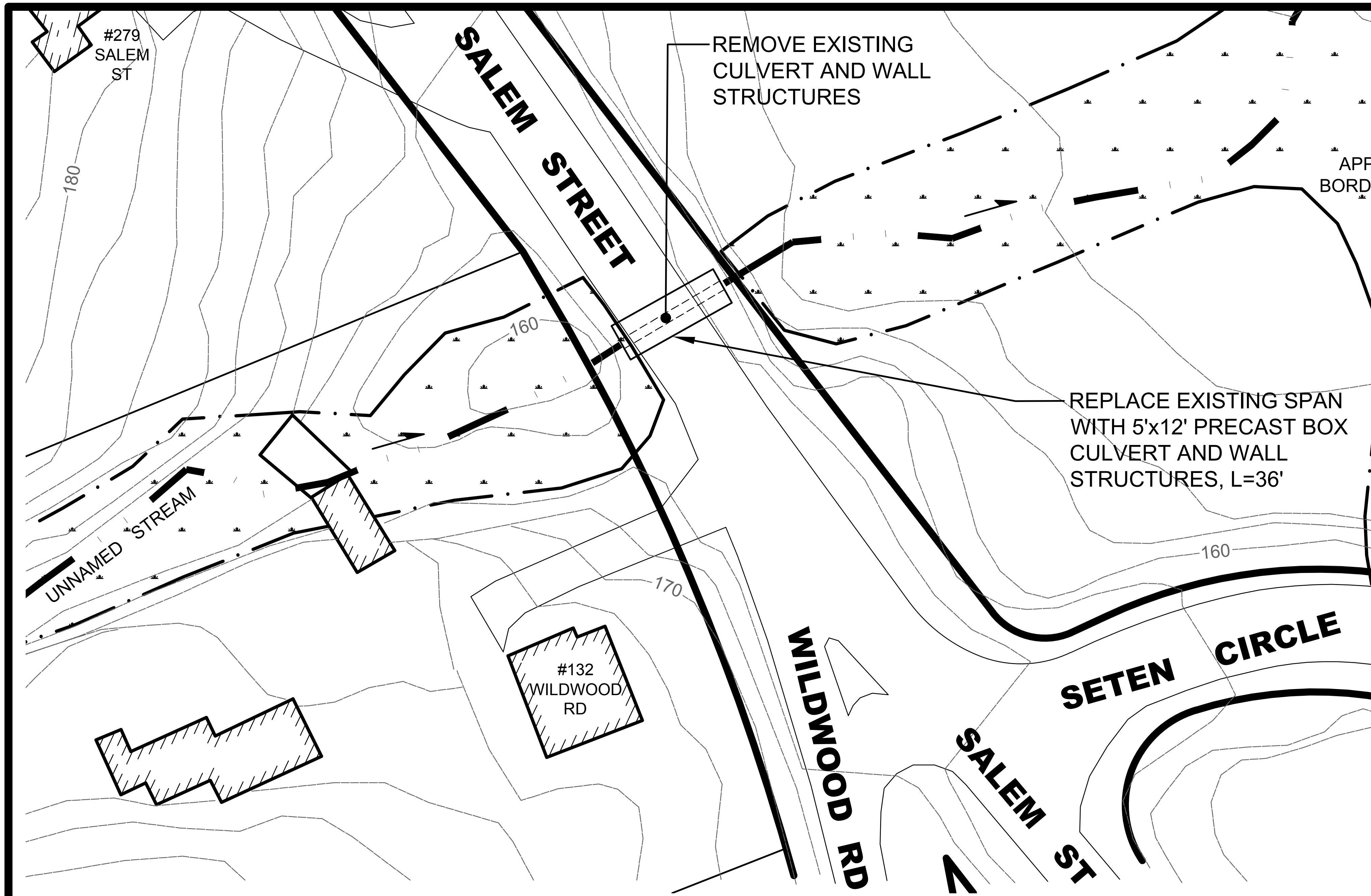
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 374.dwg
MAI Project: 5900



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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.00
10. NAACC CROSSING CODE: xy4262904671106245
11. NAACC SURVEY ID: 5069

CROSSING ID# 408
SKETCH PLAN

LOCATED IN

ANDOVER, MASSACHUSETTS

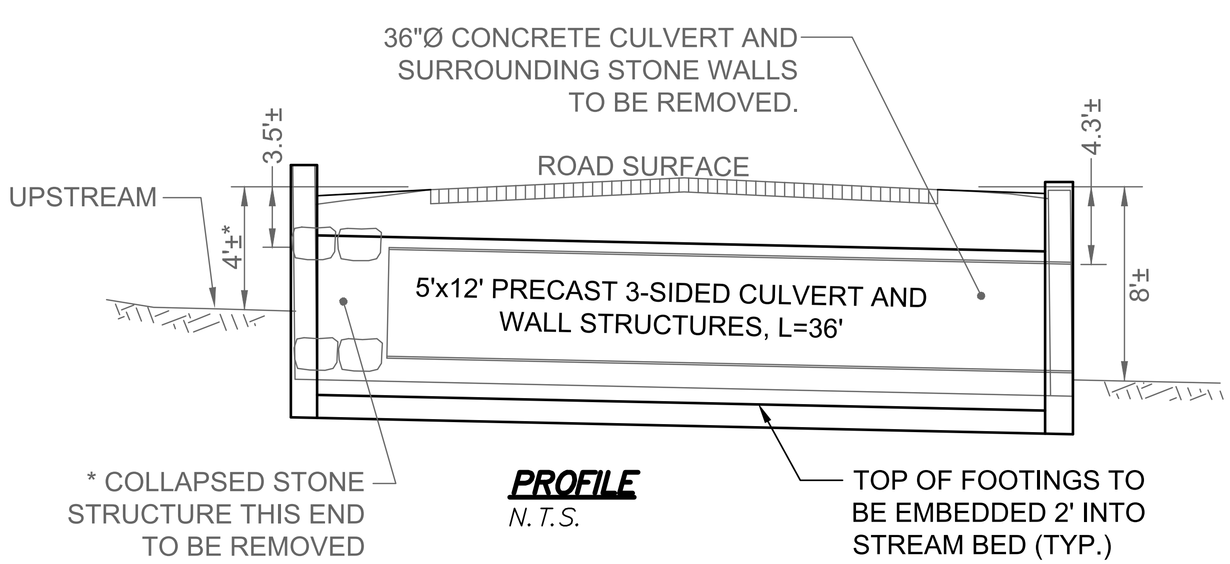
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 9, 2017

20 0 20 40 80



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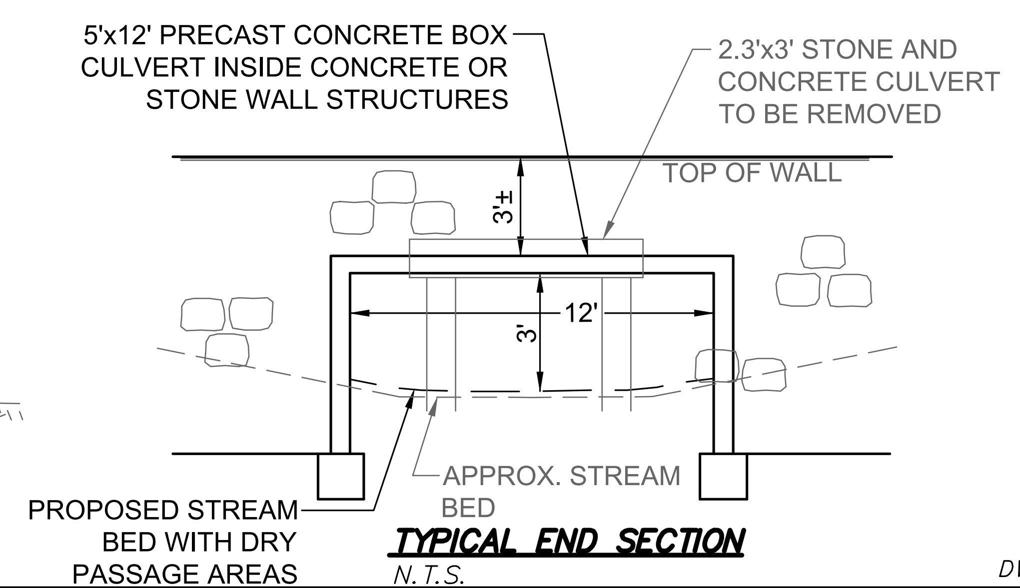

TYPICAL END SECTION
N.T.S.

MERIDIAN ASSOCIATES

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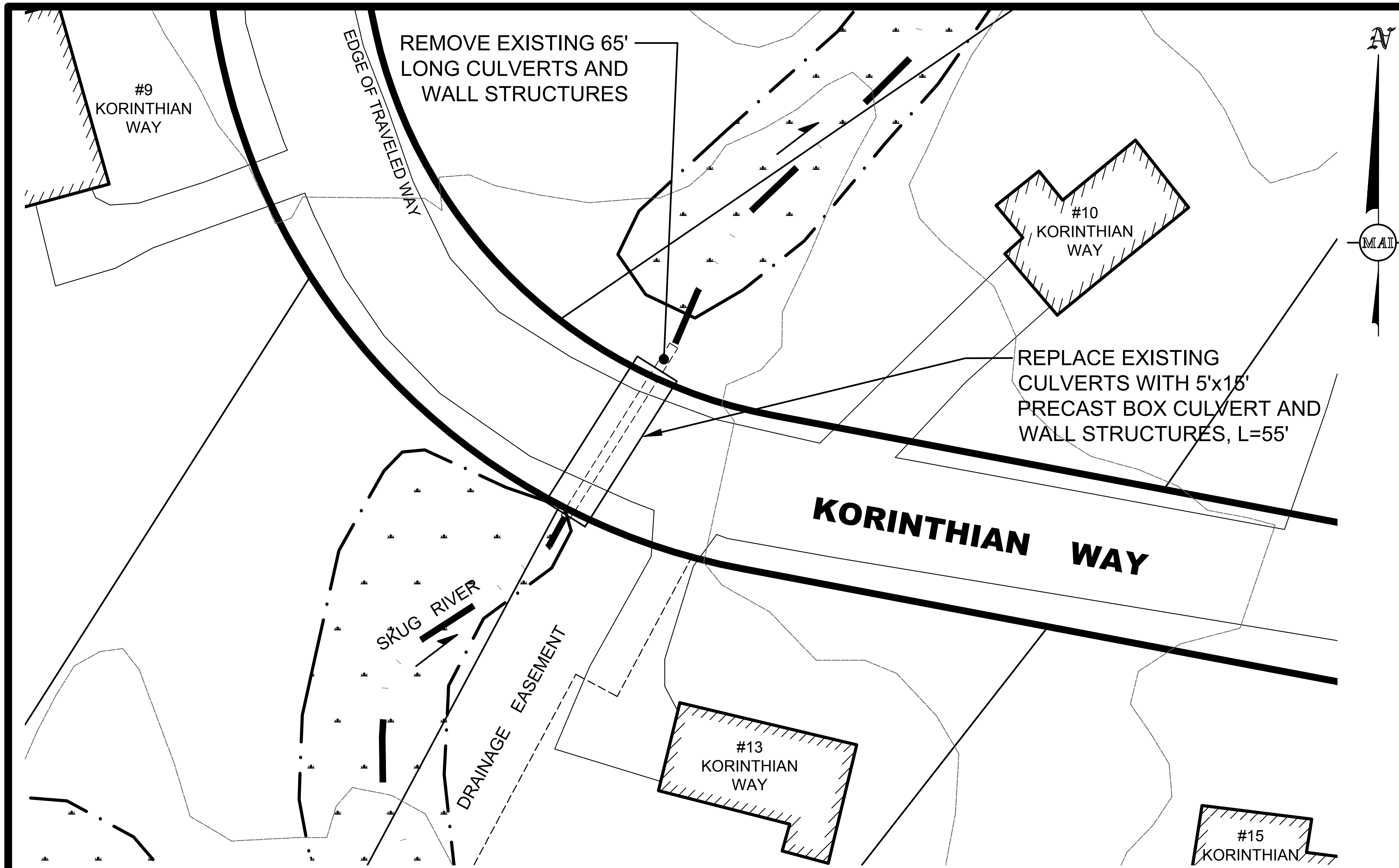
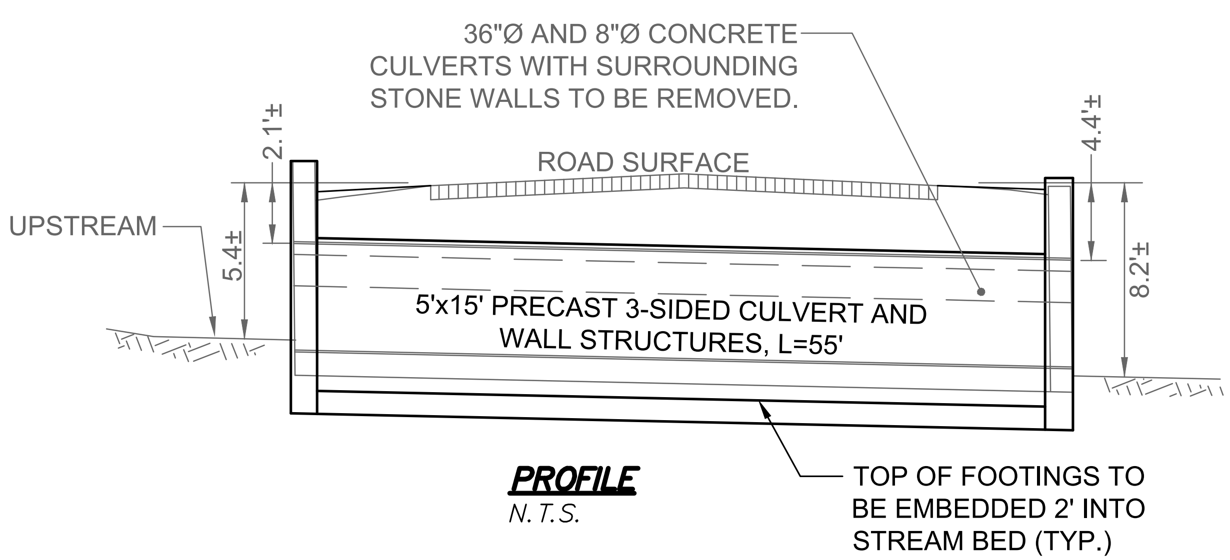
DWG. No. Site 408.dwg MAI Project: 5900





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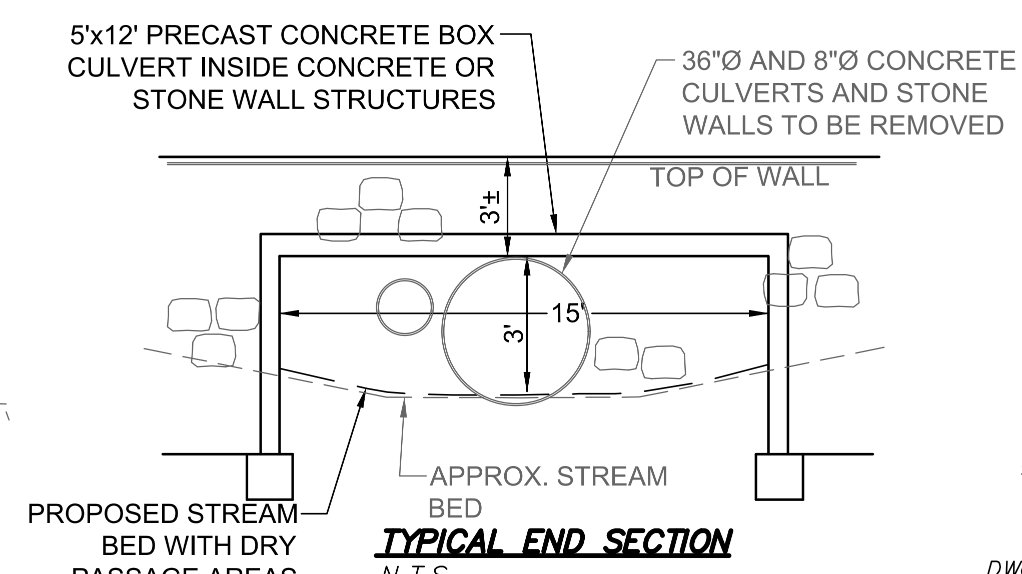

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8. APPROXIMATE BANKFULL WIDTH=12 FEET. PROPOSED CULVERT WIDTH=15 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4262976271100454
11. NAACC SURVEY ID: 5071

CROSSING ID# 415 SKETCH PLAN

LOCATED IN

ANDOVER, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 9, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES
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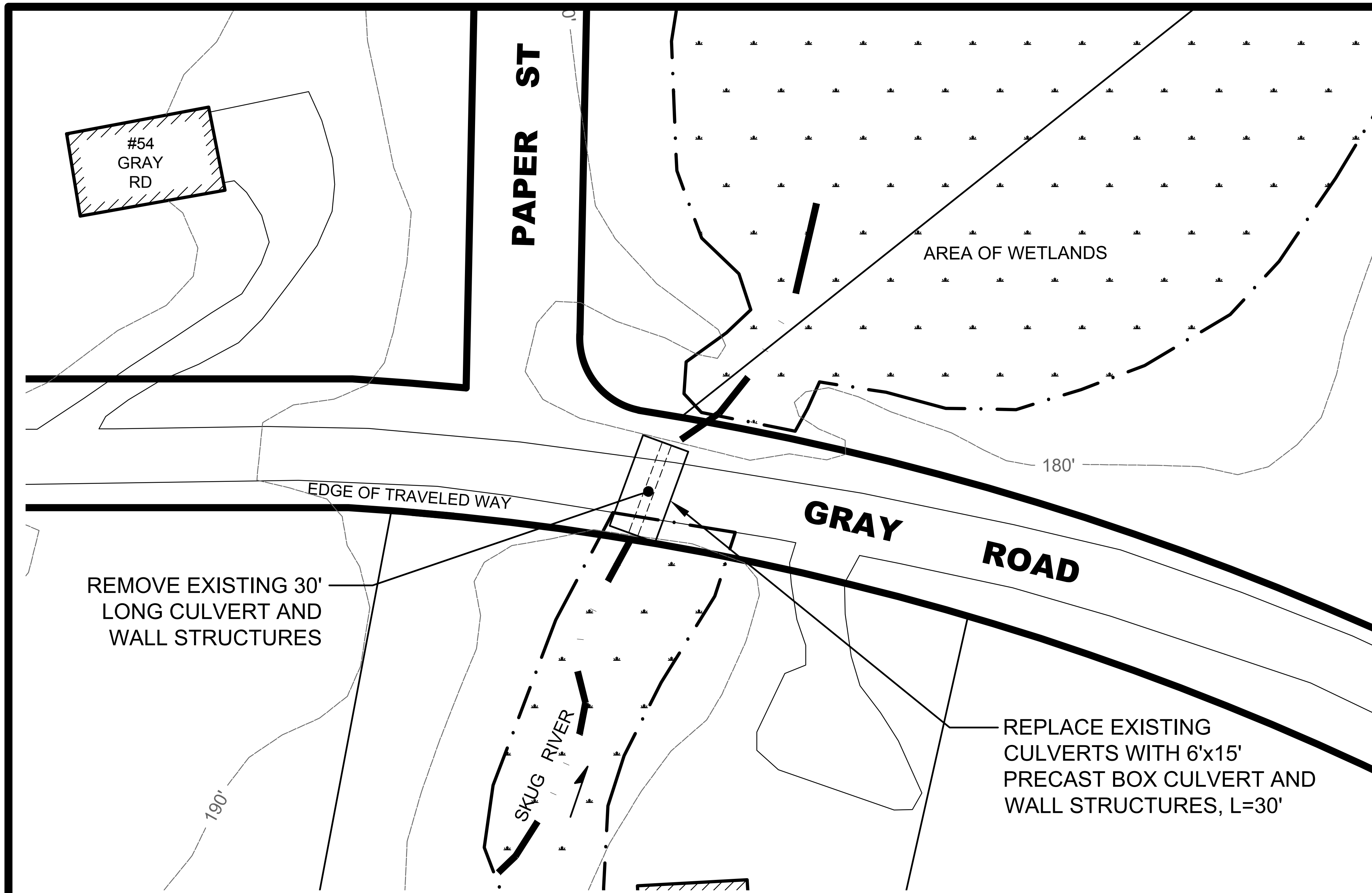
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 415.dwg

MAI Project: 5900



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8. APPROXIMATE BANKFULL WIDTH=12 FEET. PROPOSED CULVERT WIDTH=15 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.5
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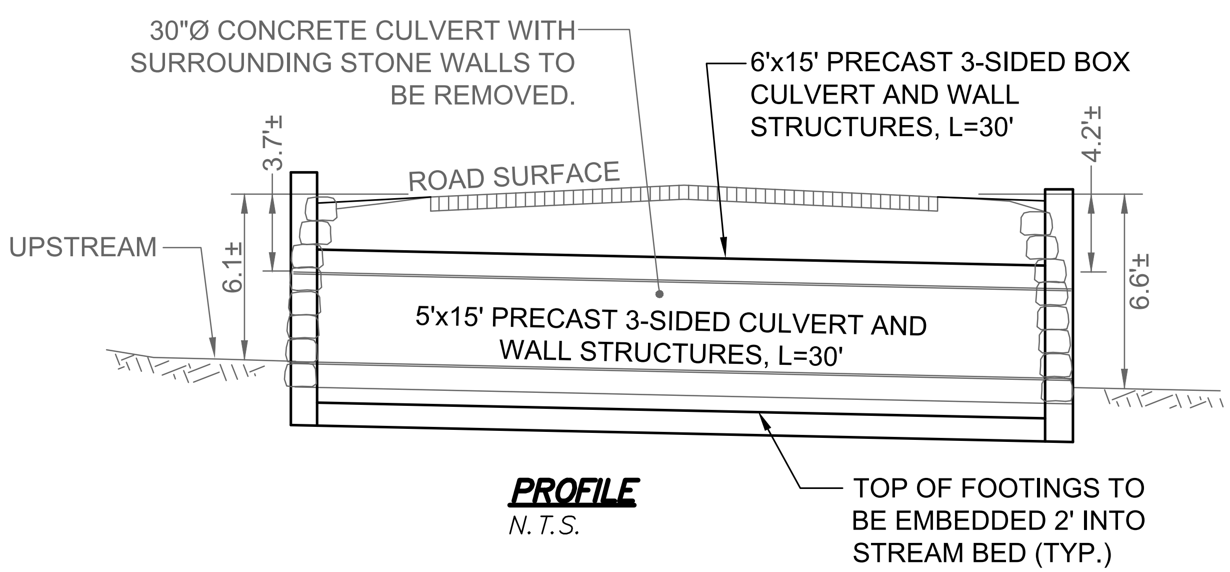
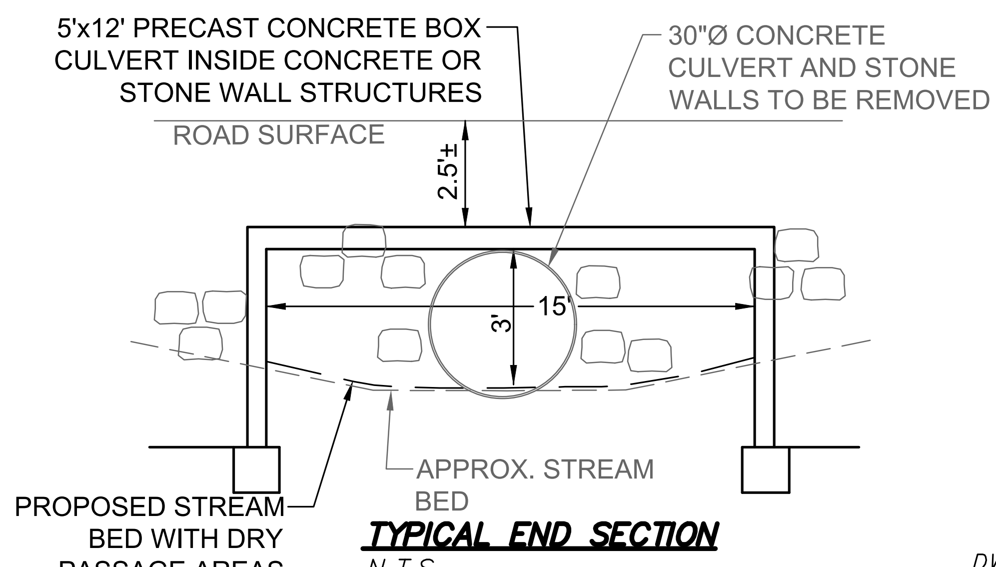
11. NAACC SURVEY ID: 5070



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 421
SKETCH PLAN
LOCATED IN
ANDOVER, MASSACHUSETTS
(ESSEX COUNTY)
PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 9, 2017
20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

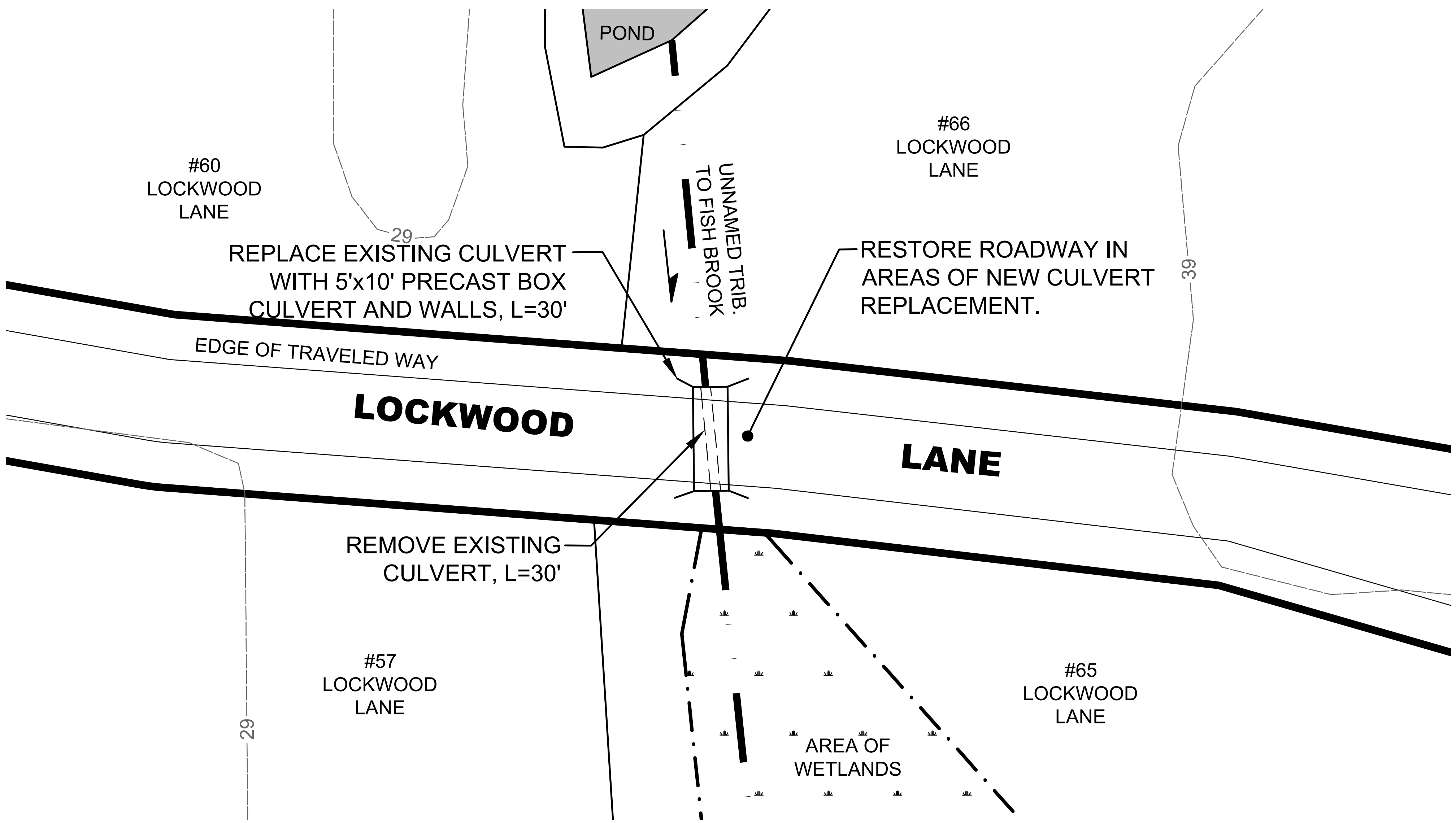
WWW.MERIDIANASSOC.COM

DWG. No. Site 421.dwg
MAI Project: 5900

Boxford Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Boxford, MA

15 pages



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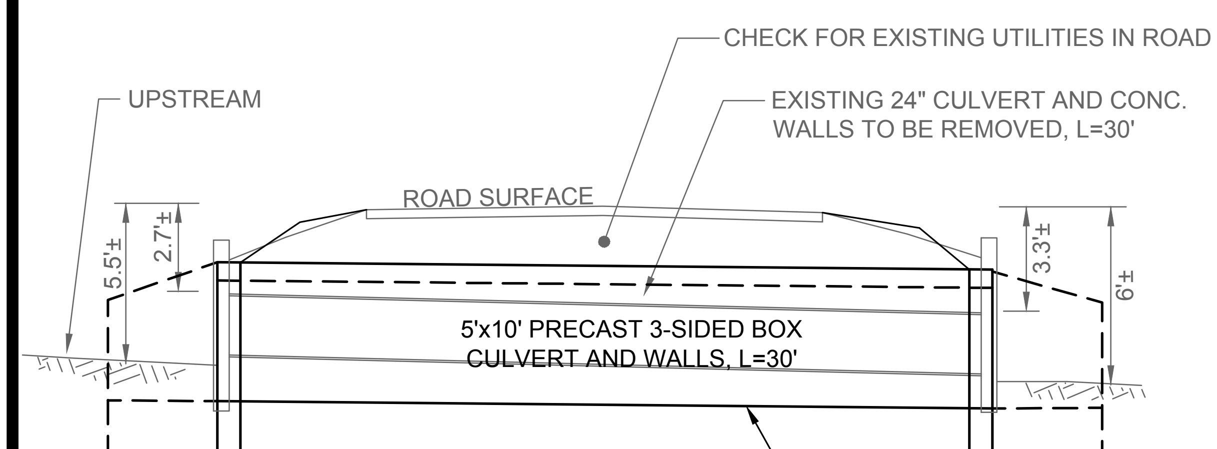
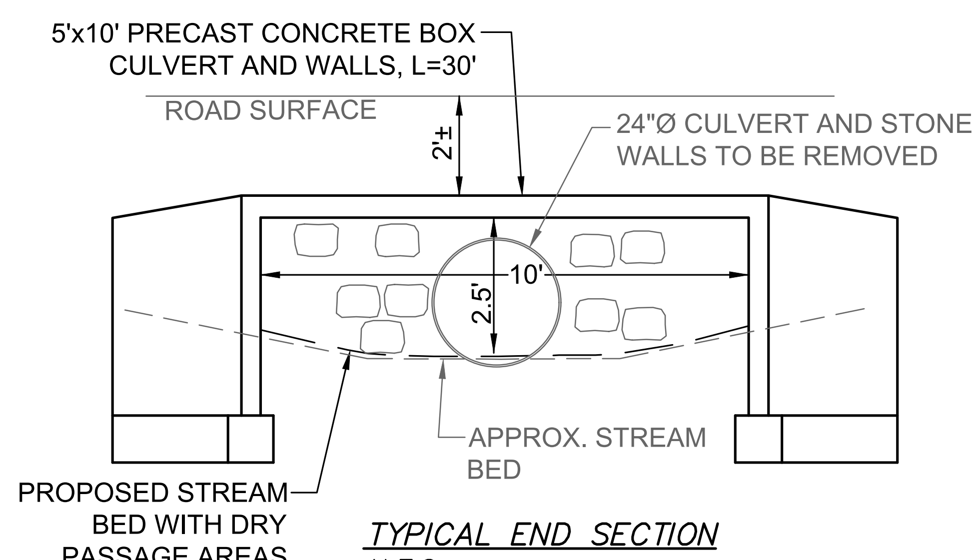
8. APPROXIMATE BANKFULL WIDTH=7.6 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.0
10. NAACC CROSSING CODE: xy4264370470981704
11. NAACC SURVEY ID: 6914



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#494
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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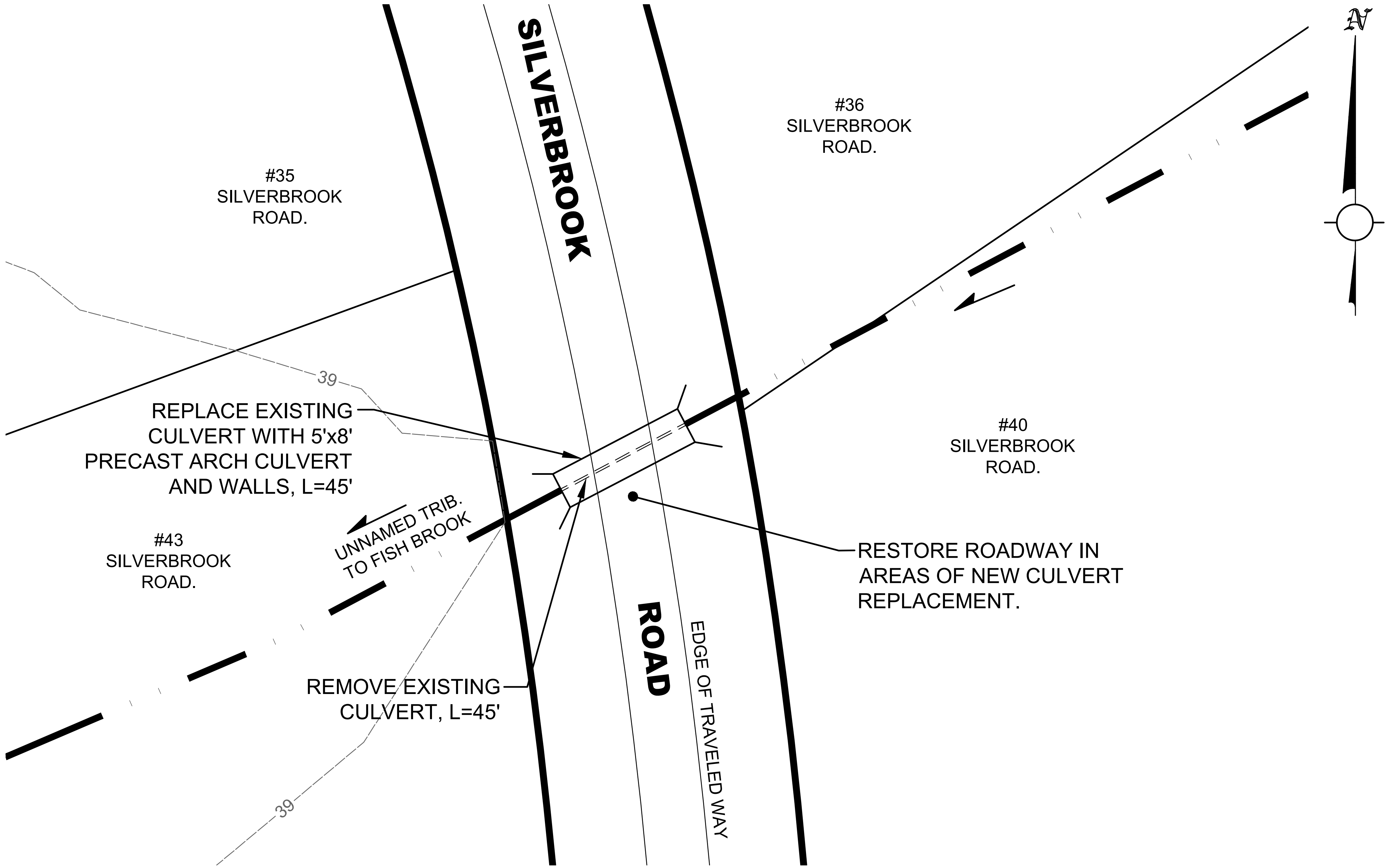
TELEPHONE: (978) 299-0447

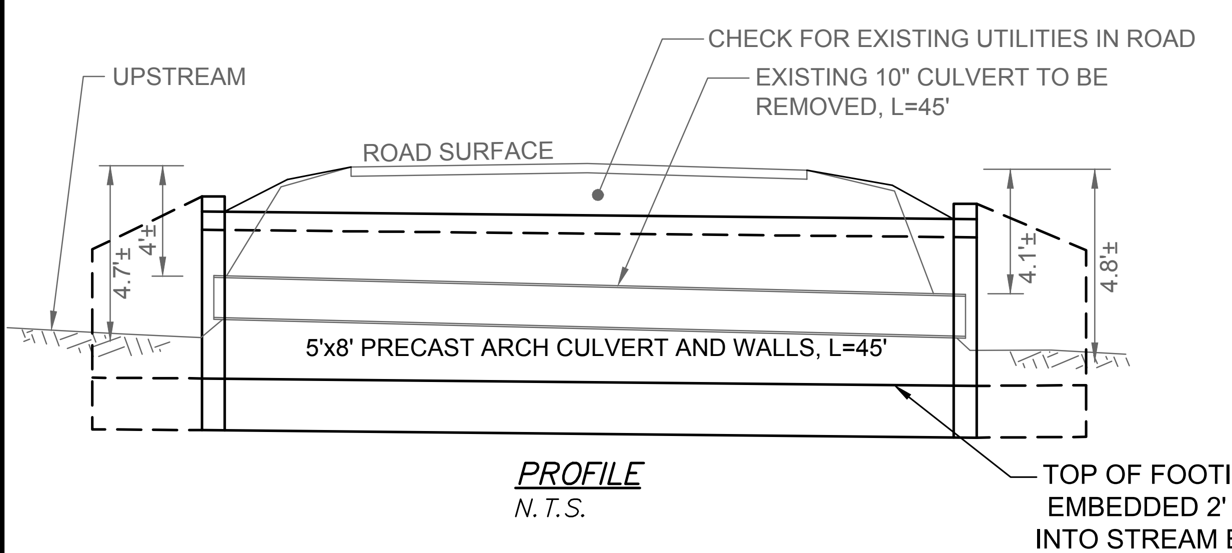
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

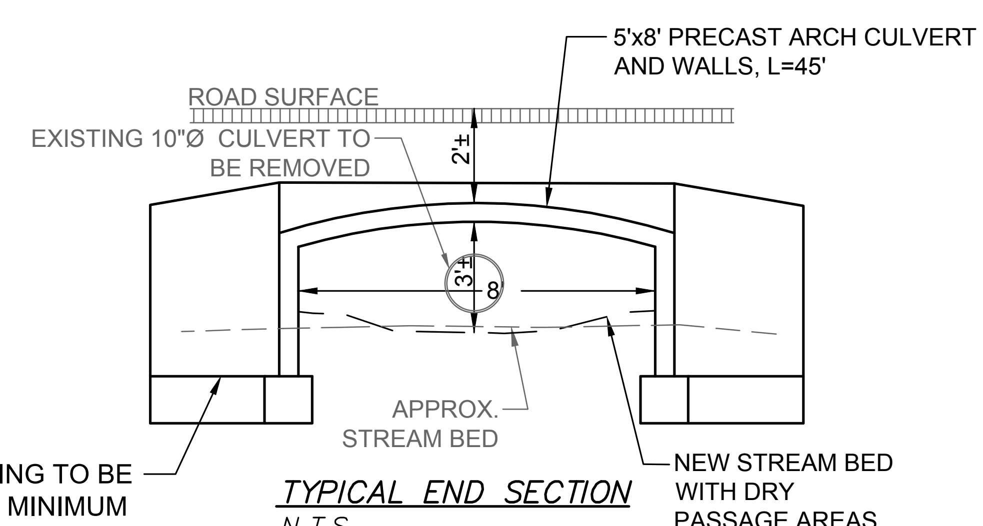
DWG. No. Site 494.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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7. *ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.*
8. *APPROXIMATE BANKFULL WIDTH=4 FEET. PROPOSED CULVERT WIDTH=8 FEET.*
9. *MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.53*
10. *NAACC CROSSING CODE: xy4264445370972227*
11. *NAACC SURVEY ID: 6750*

CROSSING ID#498
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

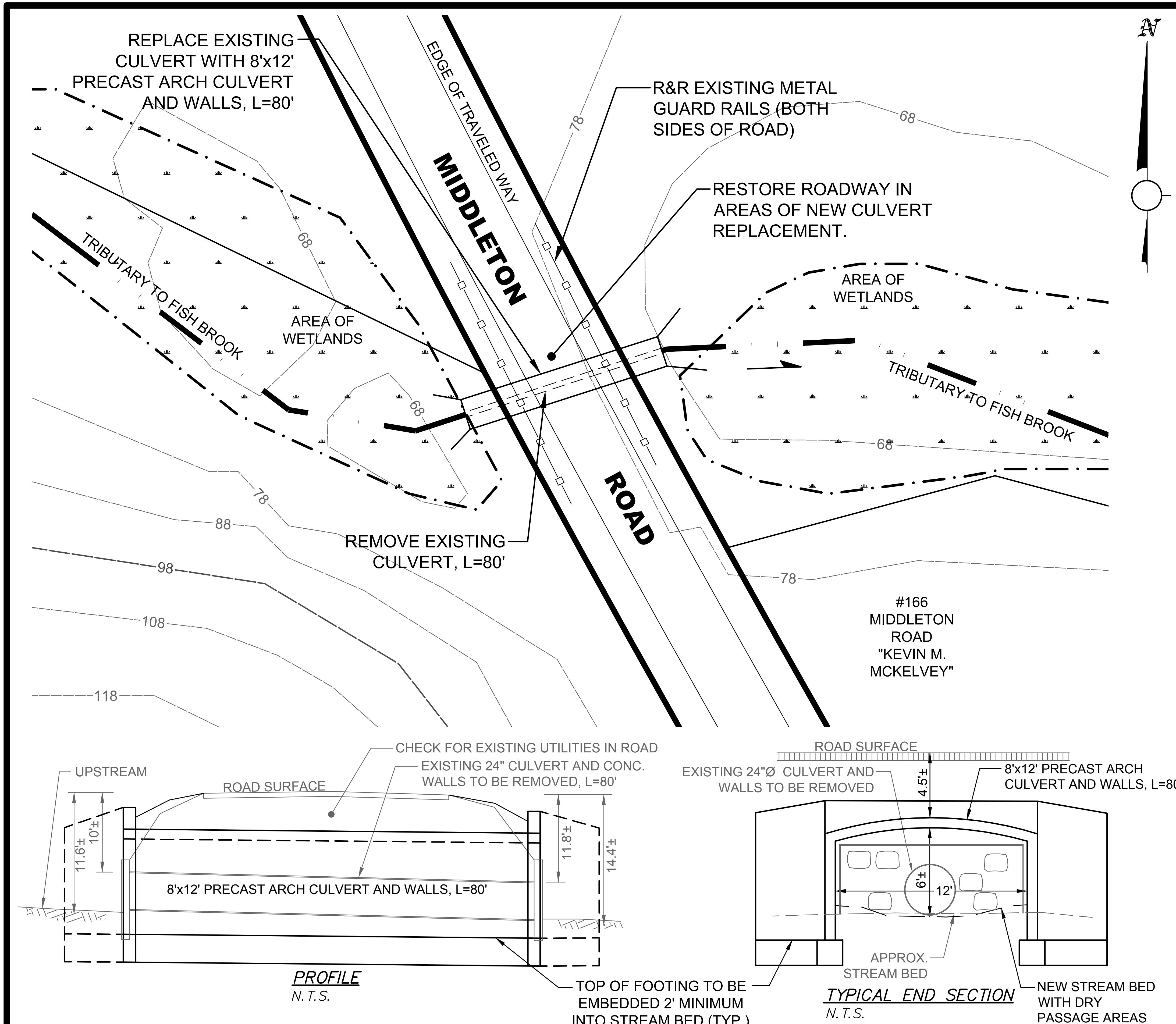
MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 498.dwg *MAI Project: 5900*



N

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.90
10. NAACC CROSSING CODE: xy4264621270995978
11. NAACC SURVEY ID: 11211

CROSSING ID#511
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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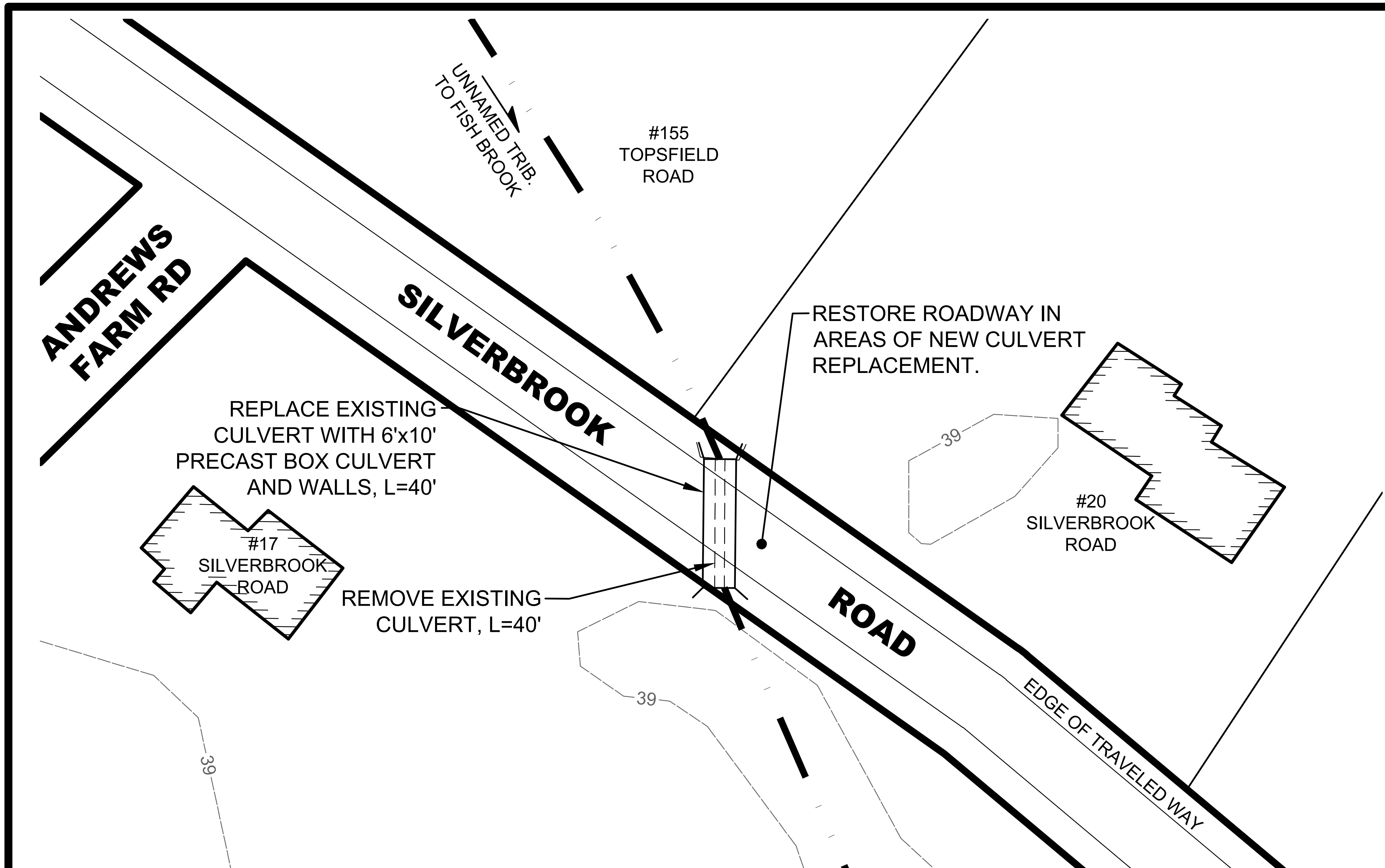
WWW.MERIDIANASSOC.COM

DWG. No. Site 511.dwg

MAI Project: 5900



NOTES:

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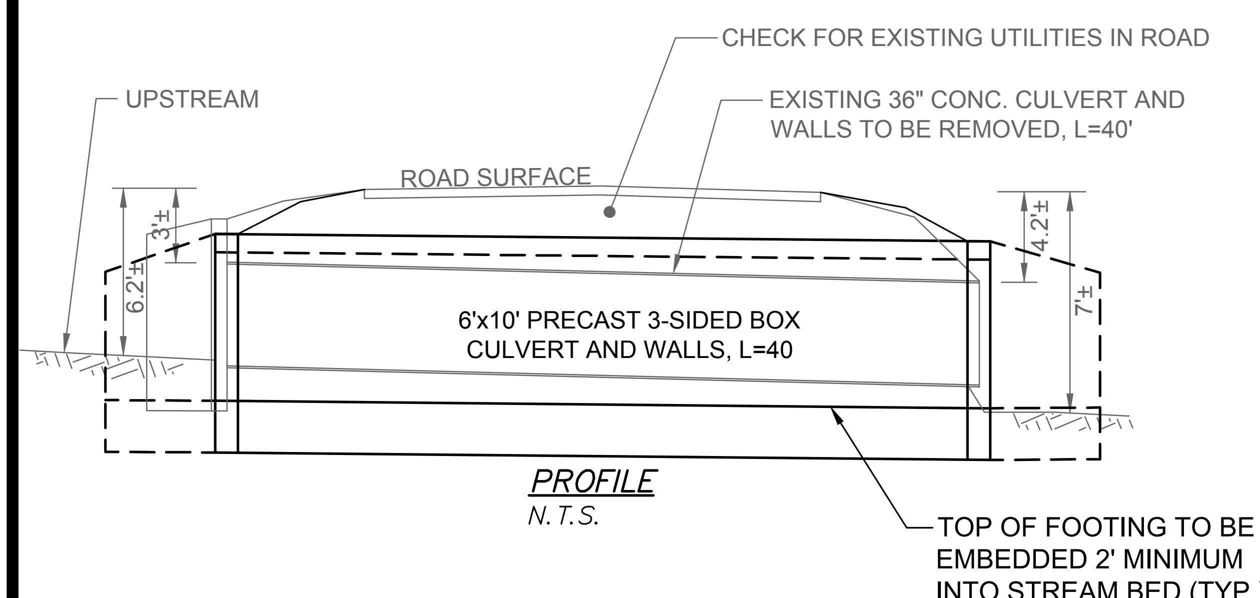
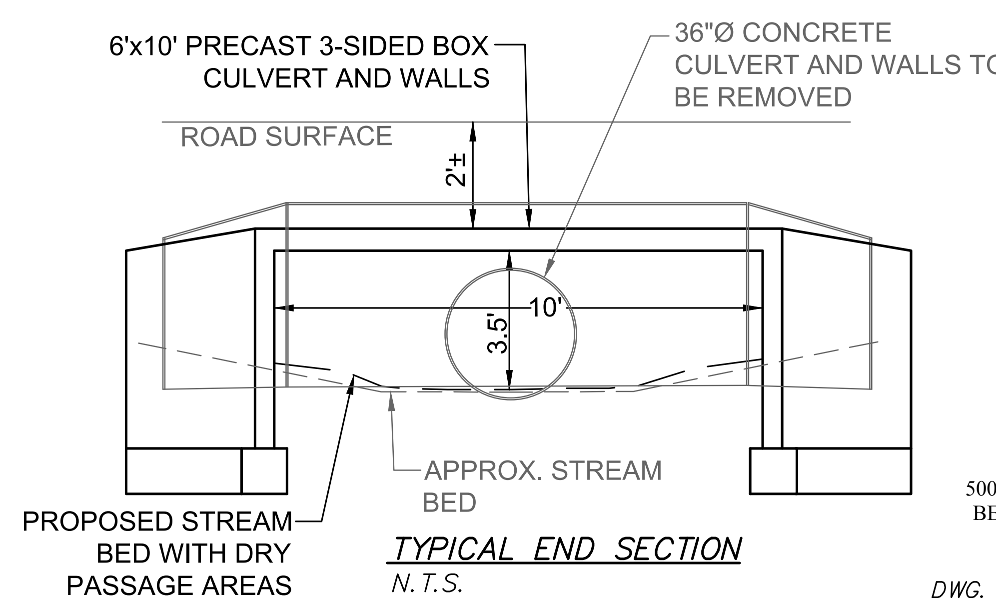
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.87
10. NAACC CROSSING CODE: xy4264681670974505
11. NAACC SURVEY ID: 6751



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#516
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
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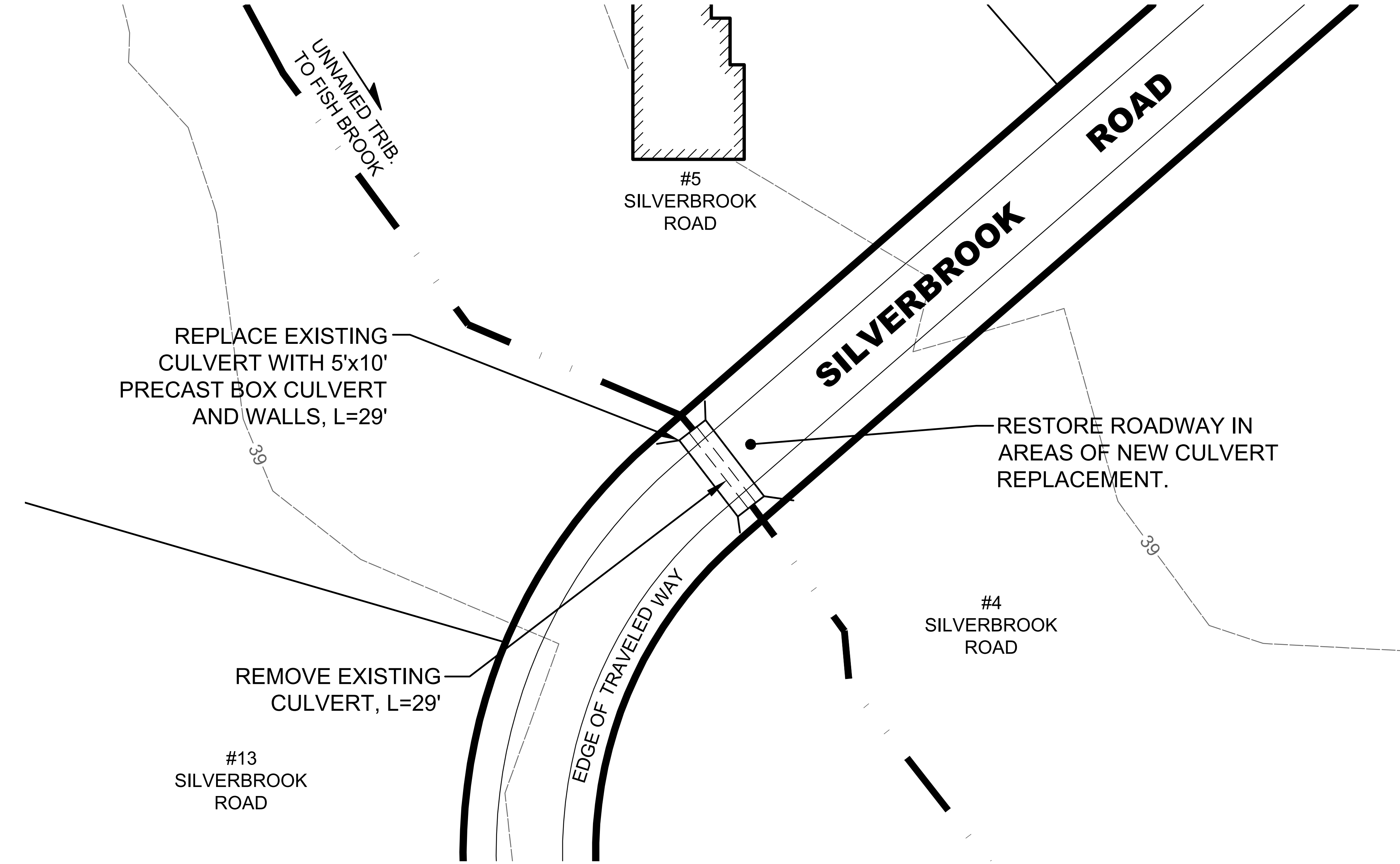
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

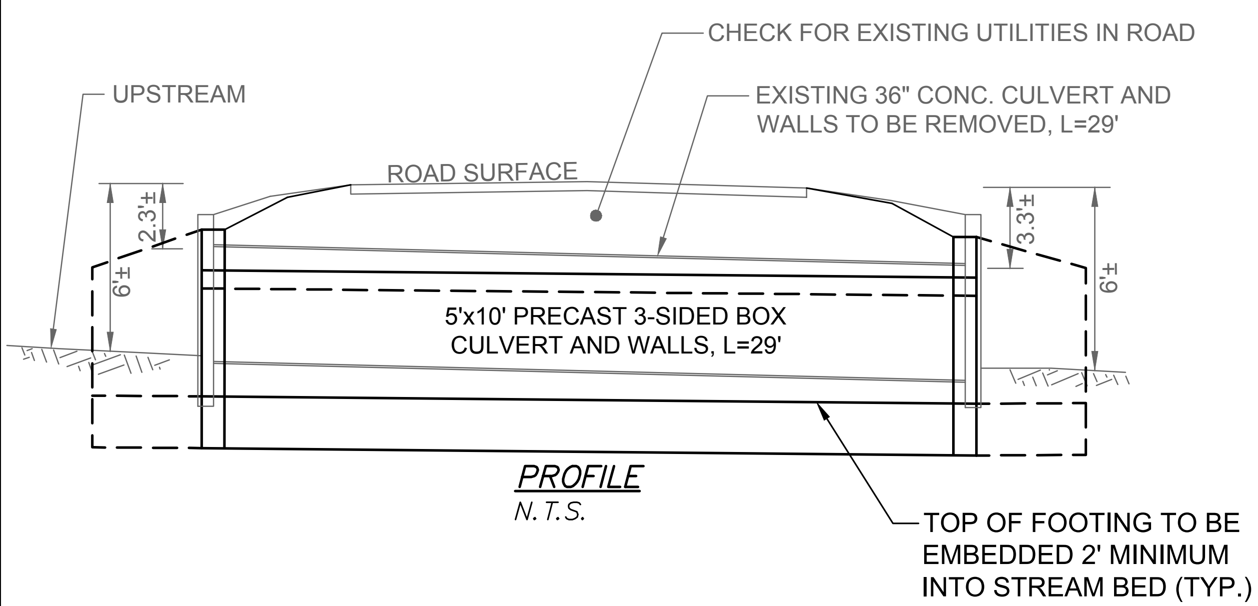
DWG. No. Site 516.dwg

MAI Project: 5900

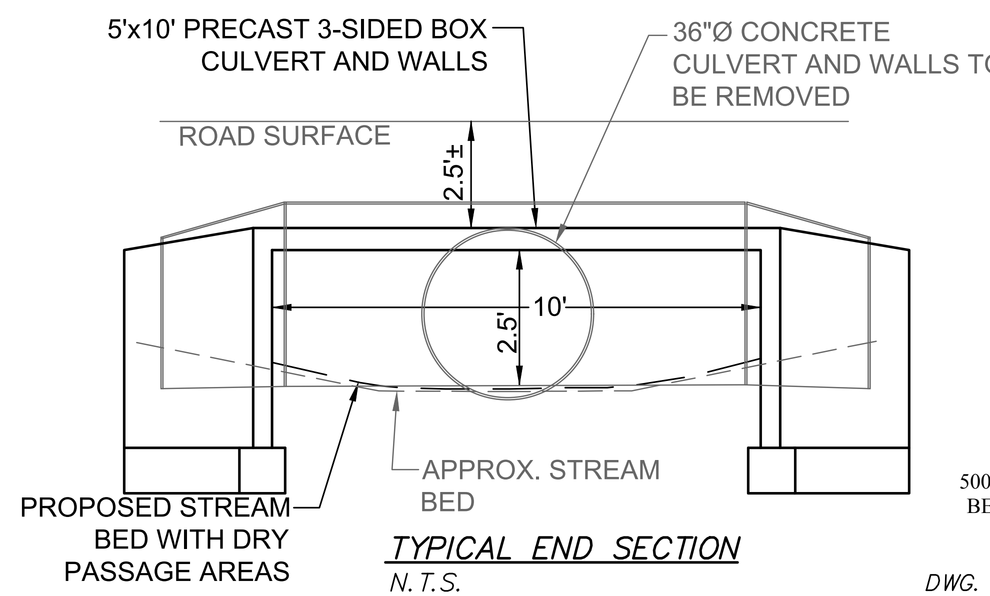


NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=7.2 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.86
10. NAACC CROSSING CODE: xy4264794270975412
11. NAACC SURVEY ID: 11254



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#523
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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TELEPHONE: (508) 871-7030

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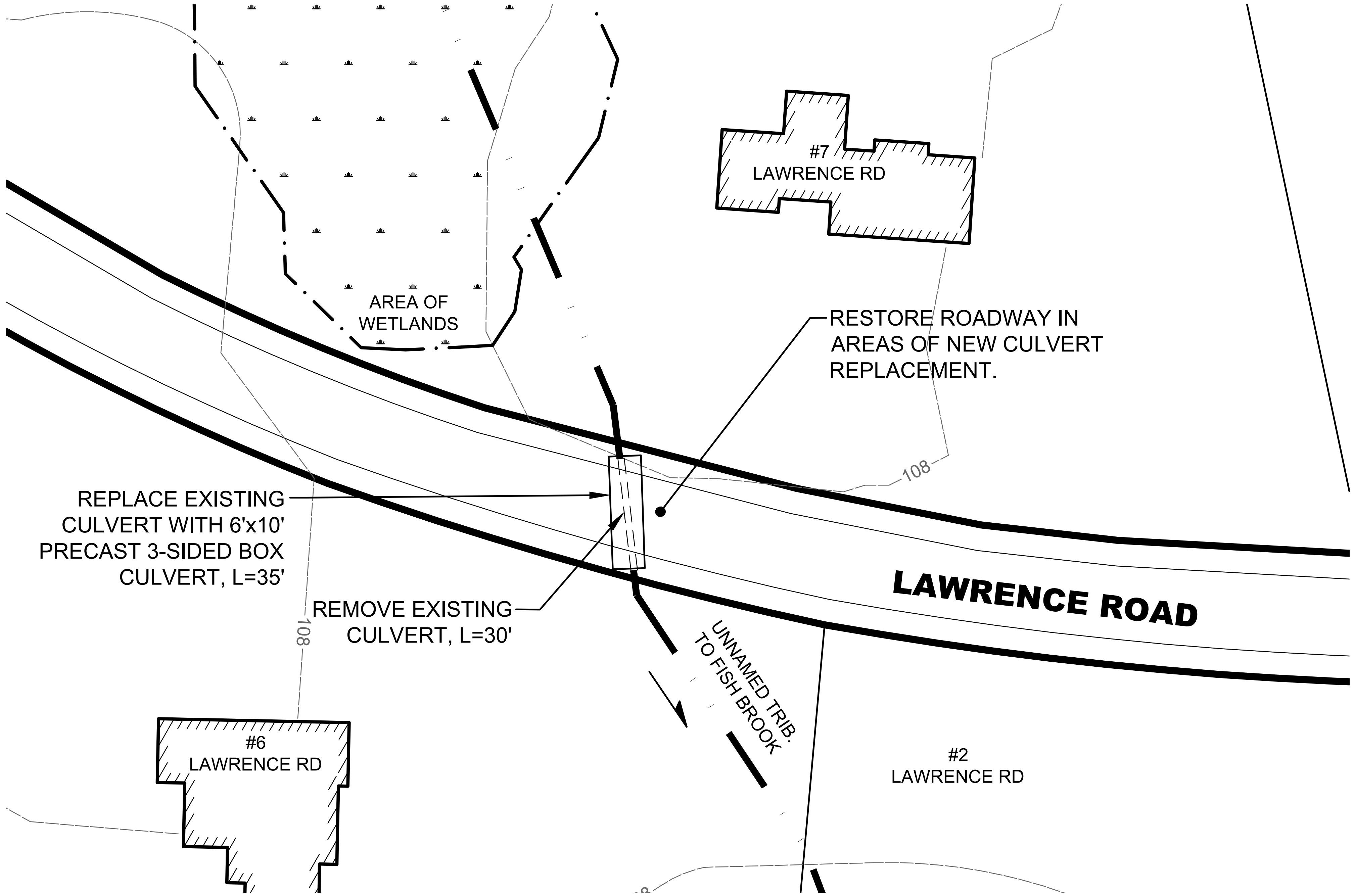
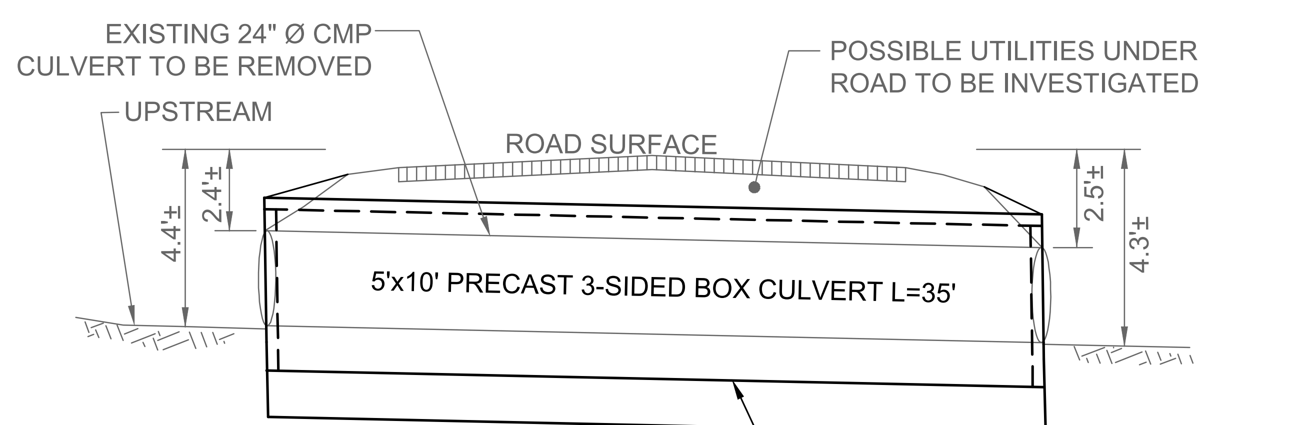
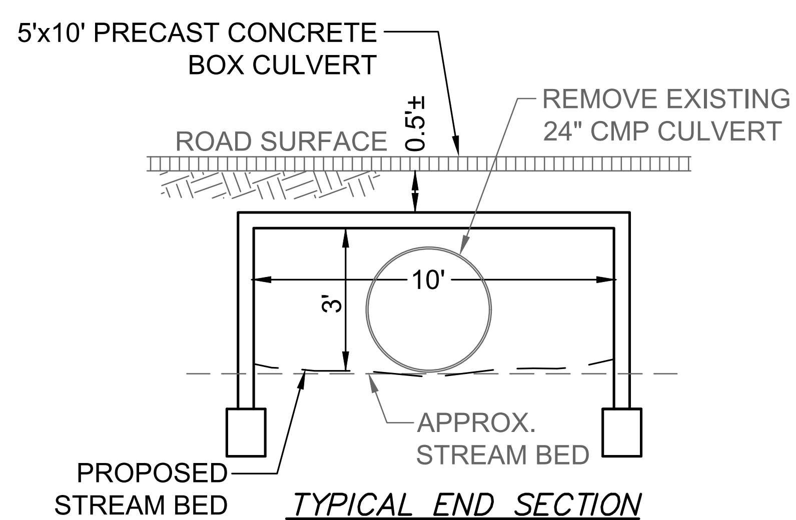
DWG. No. Site 523.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=7 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.85
10. NAACC CROSSING CODE: xy4266462671020687
11. NAACC SURVEY ID: 7272

CROSSING ID#638
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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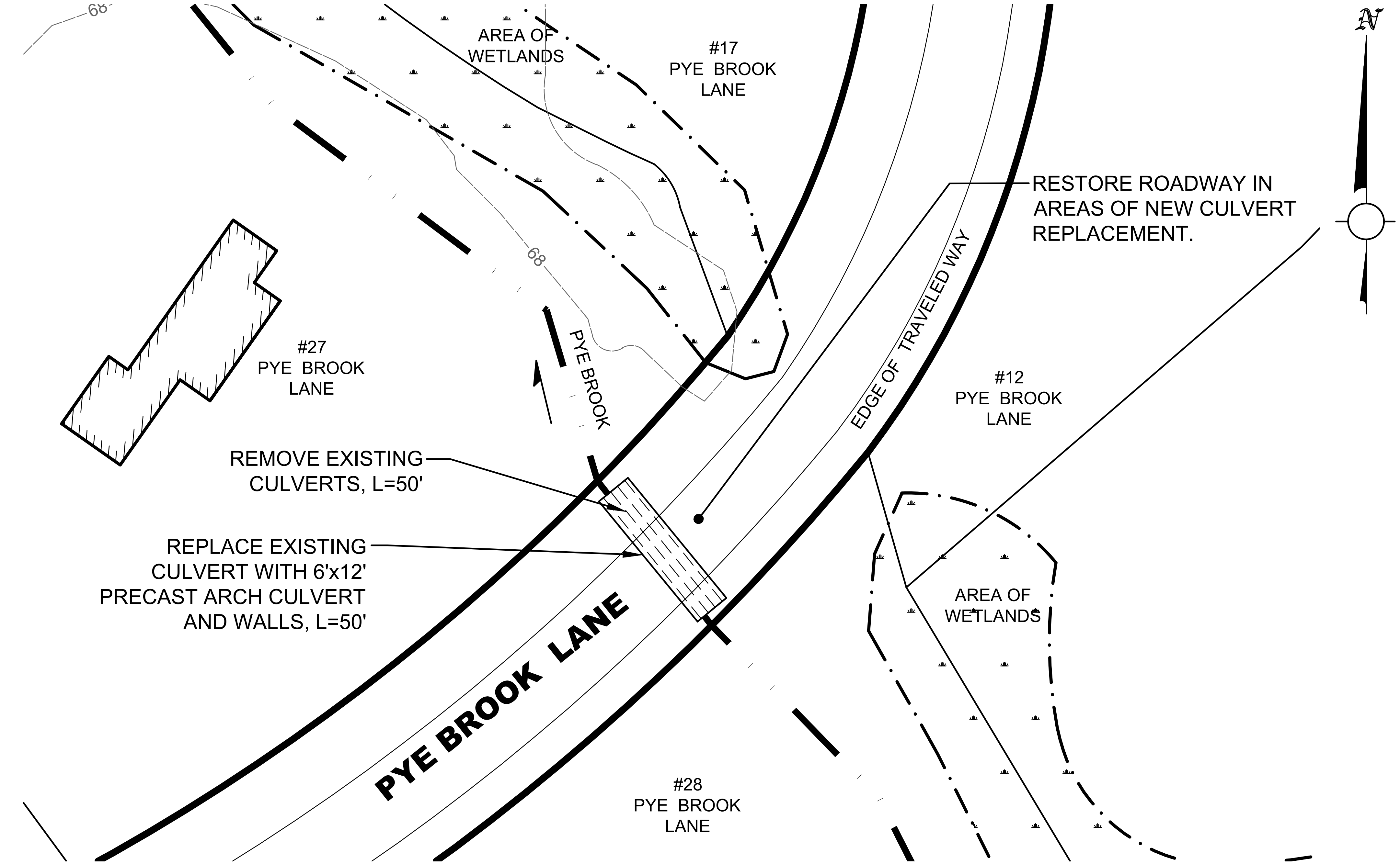
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 638.dwg

MAI Project: 5900



NOTES:

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.95
10. NAACC CROSSING CODE: xy4267077070969409
11. NAACC SURVEY ID: 23524

CROSSING ID#679 SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

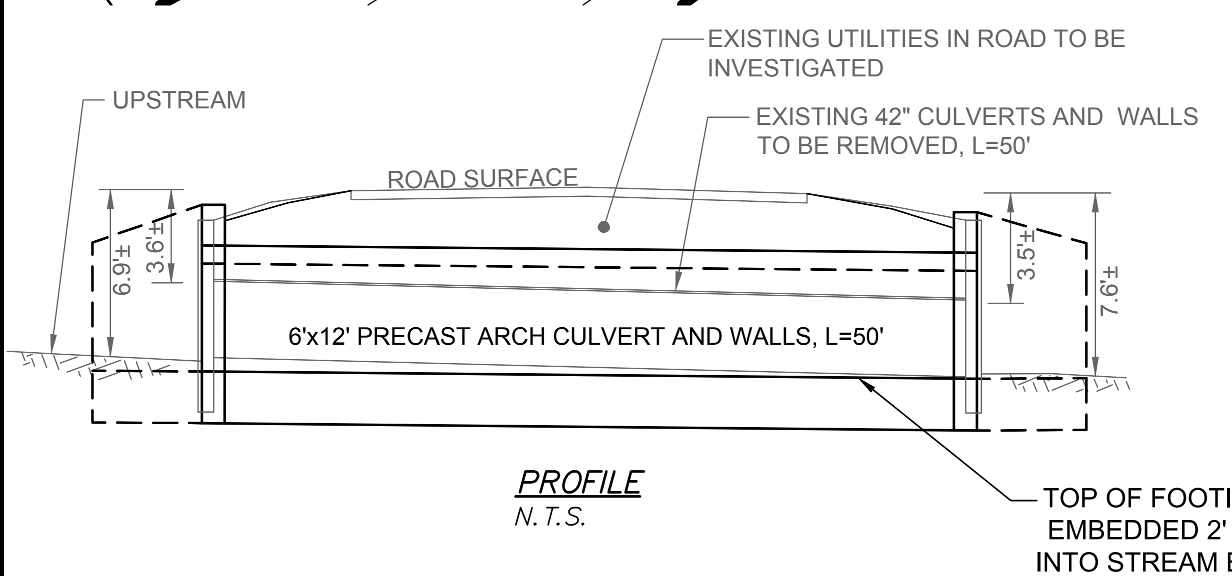
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

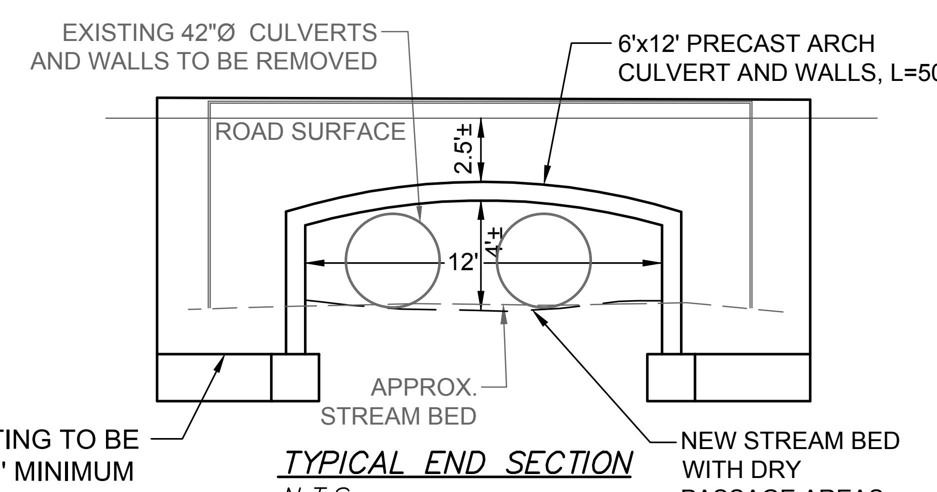
SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80



PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)

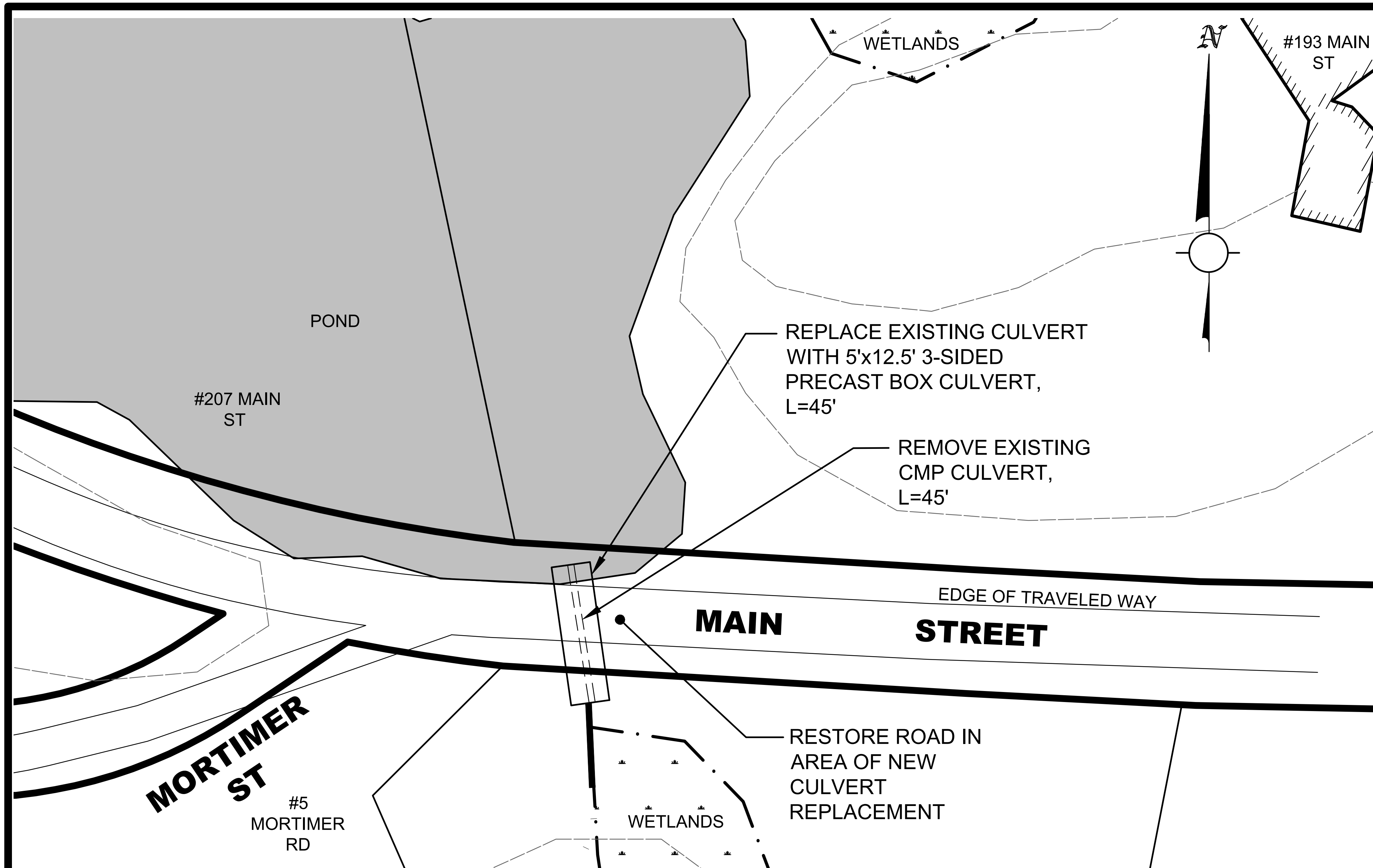


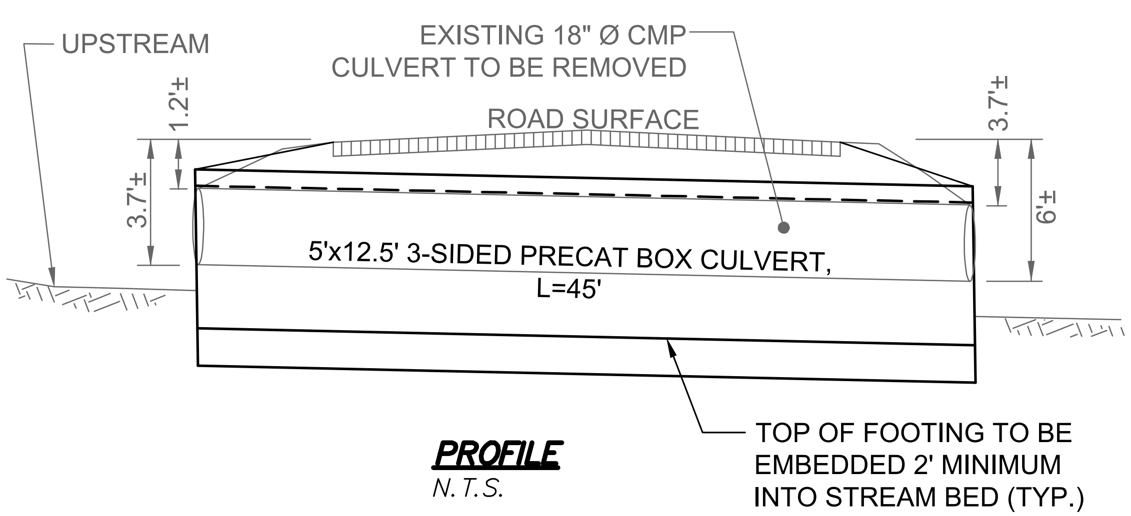
TYPICAL END SECTION
N.T.S.

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

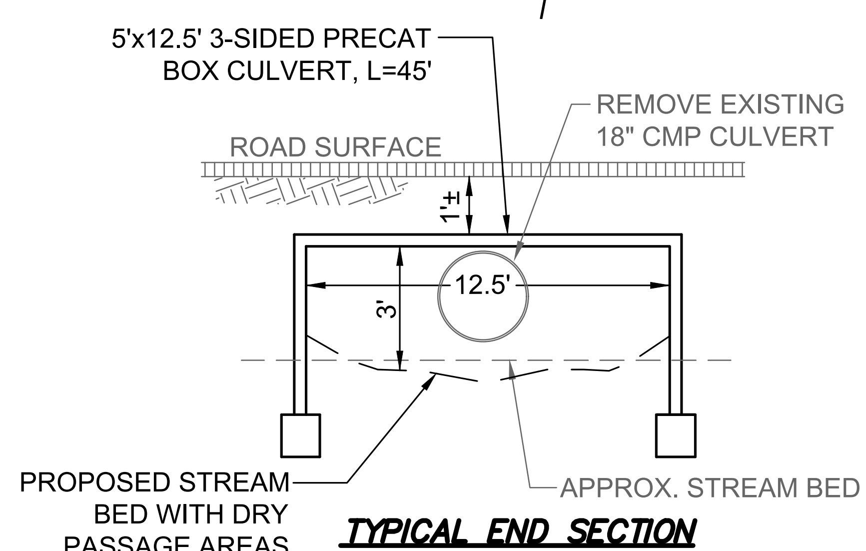
DWG. No. Site 494.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=4 FEET. PROPOSED CULVERT WIDTH=12.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.83
10. NAACC CROSSING CODE: xy4267204171023936
11. NAACC SURVEY ID: 7511

CROSSING ID# 681
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 18, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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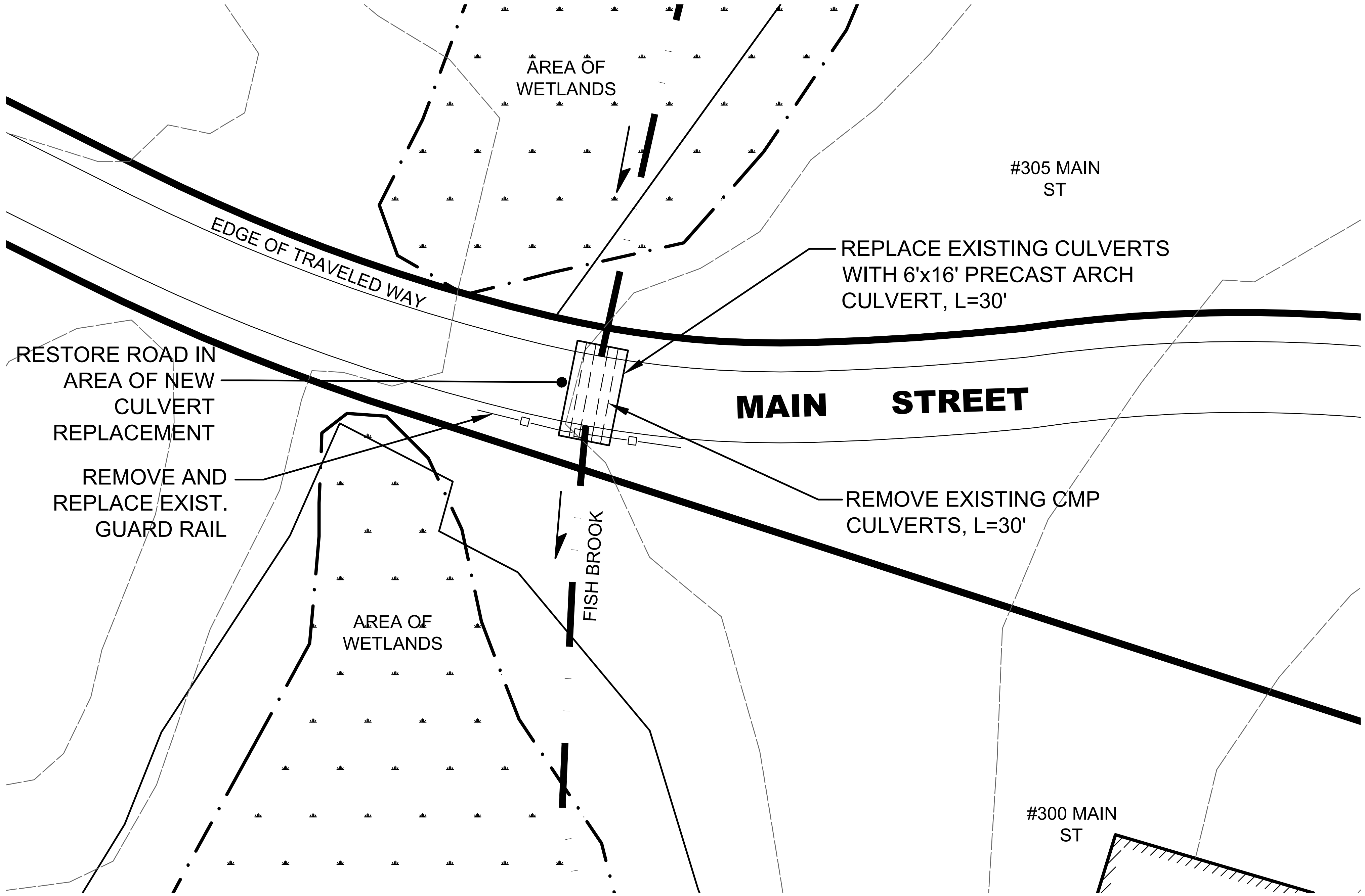
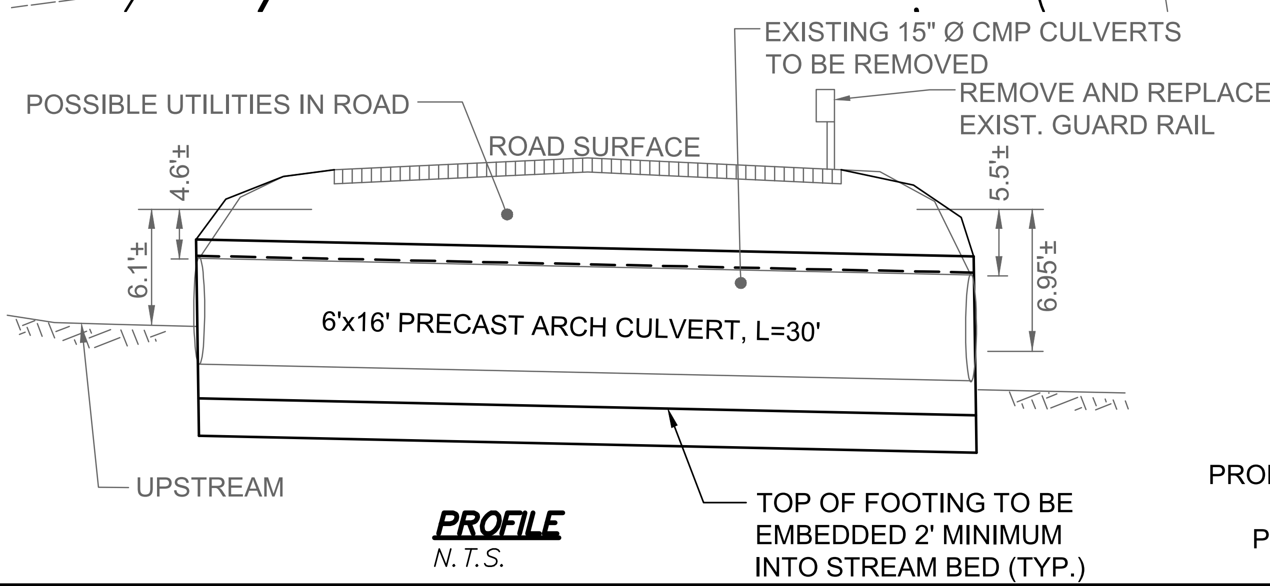
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

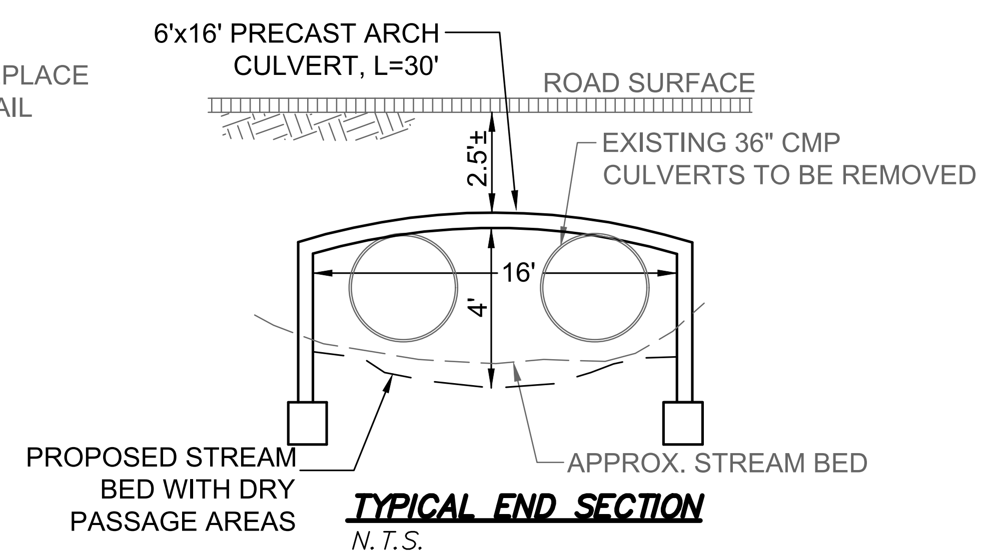
DWG. No. Site 681.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=13.4 FEET. PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.86
10. NAACC CROSSING CODE: xy4267883571043106
11. NAACC SURVEY ID: 7512

CROSSING ID#720
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 18, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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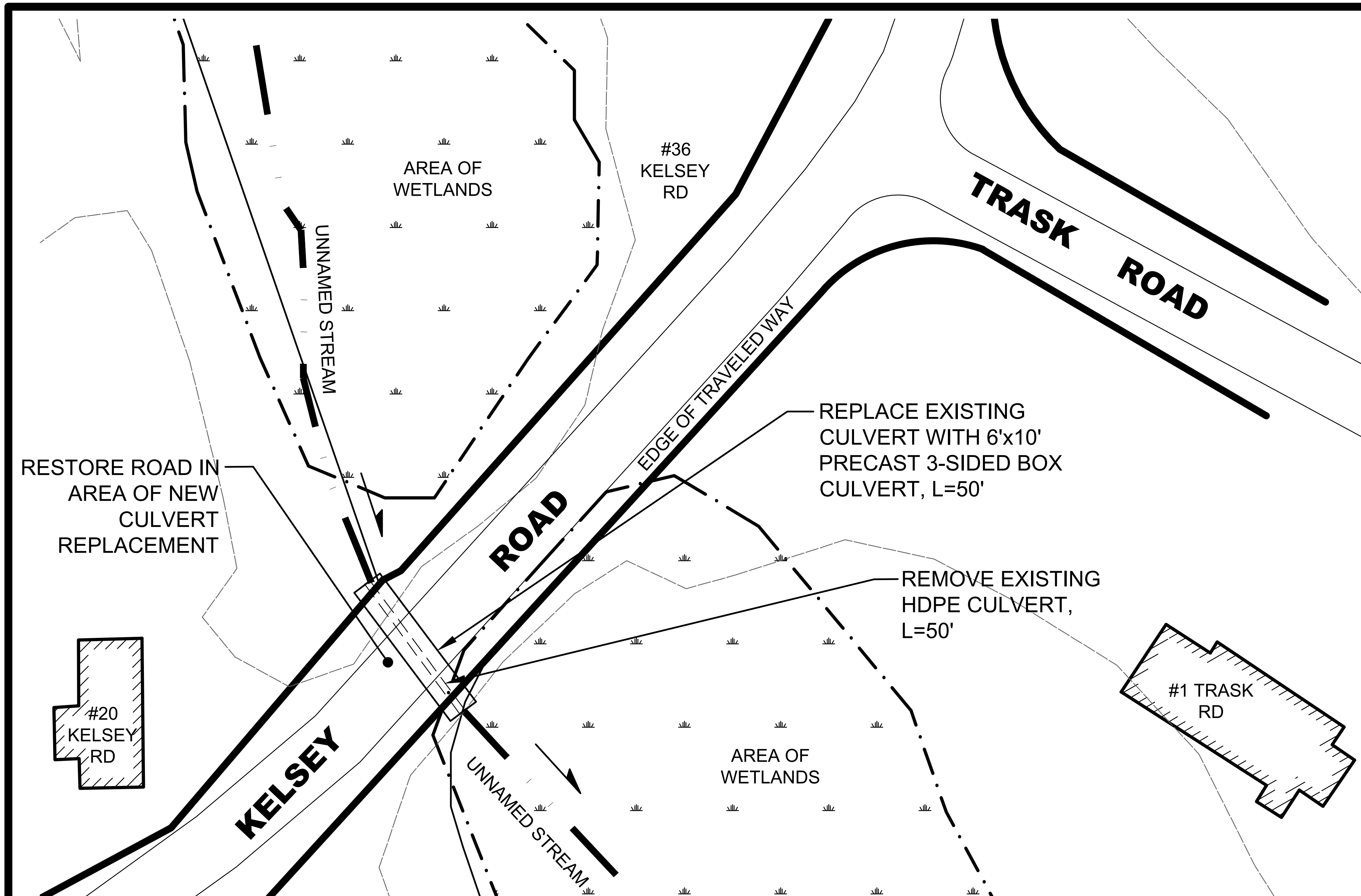
DWG. No. Site 720.dwg

MAI Project: 5900



NOTES:

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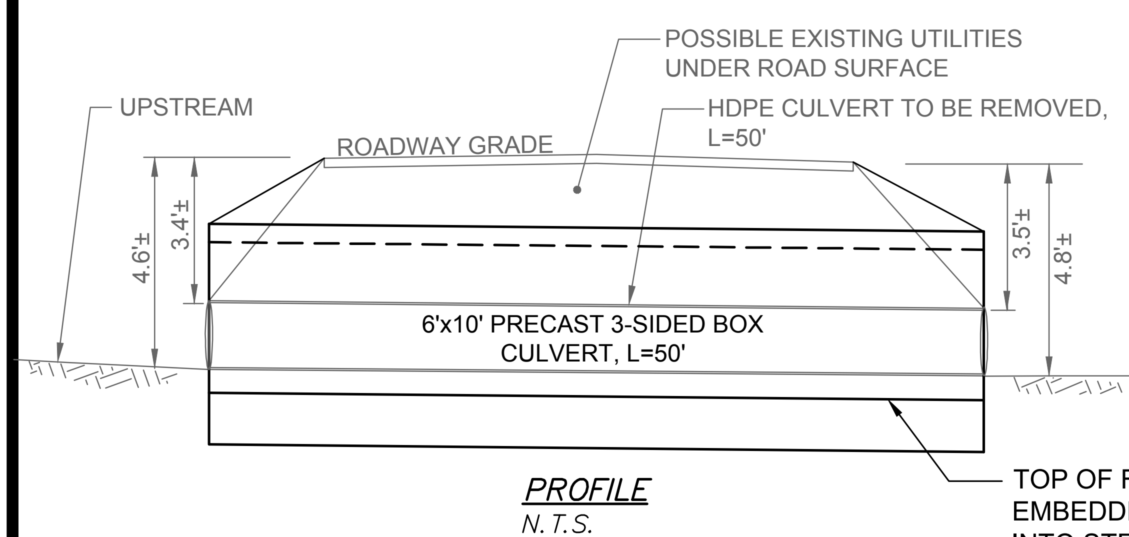
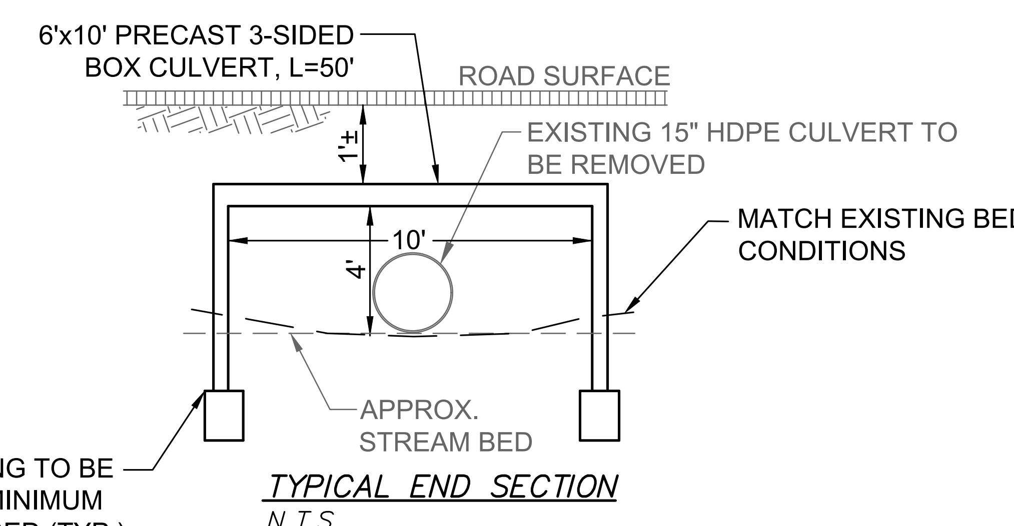
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.80
10. NAACC CROSSING CODE: xy4268382970984047
11. NAACC SURVEY ID: 11338



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#755 SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 24, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
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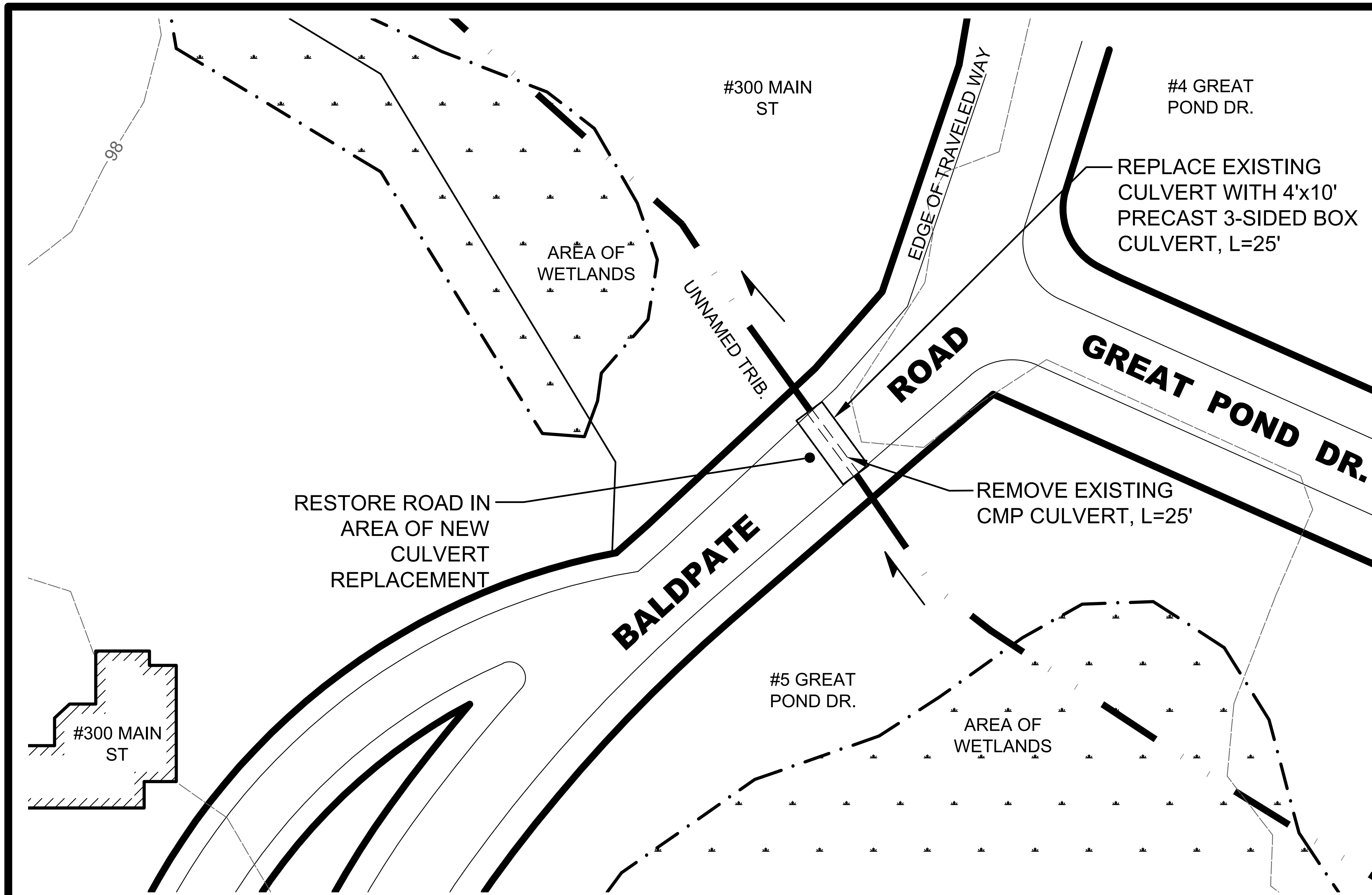
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 755.dwg

MAI Project: 5900



NOTES:

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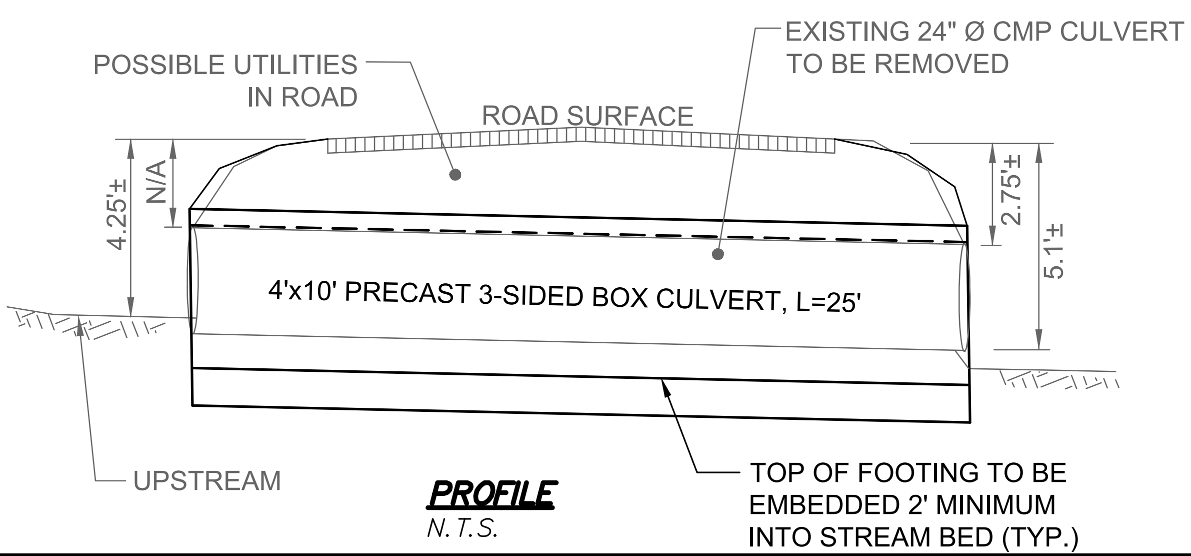
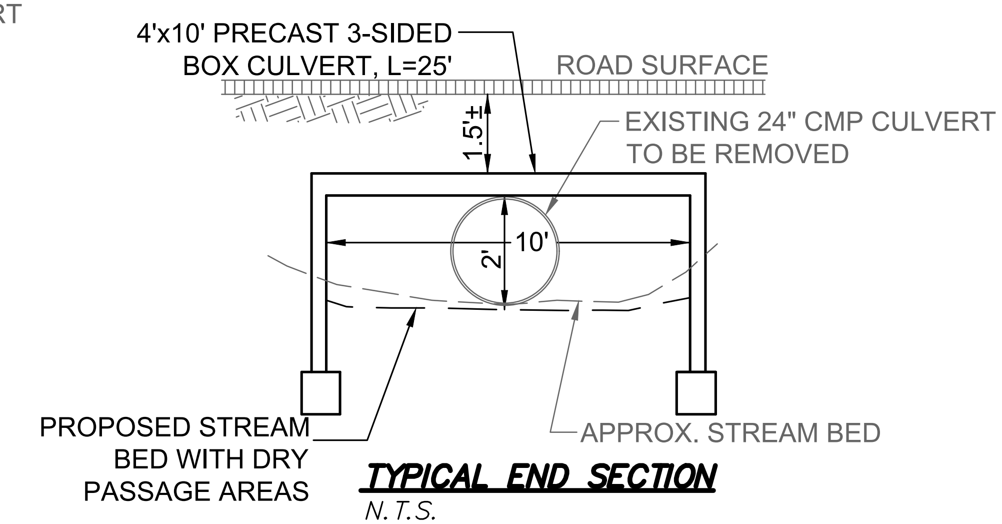
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.80
10. NAACC CROSSING CODE: xy4269521671007173
11. NAACC SURVEY ID: 6789



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#814 SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 18, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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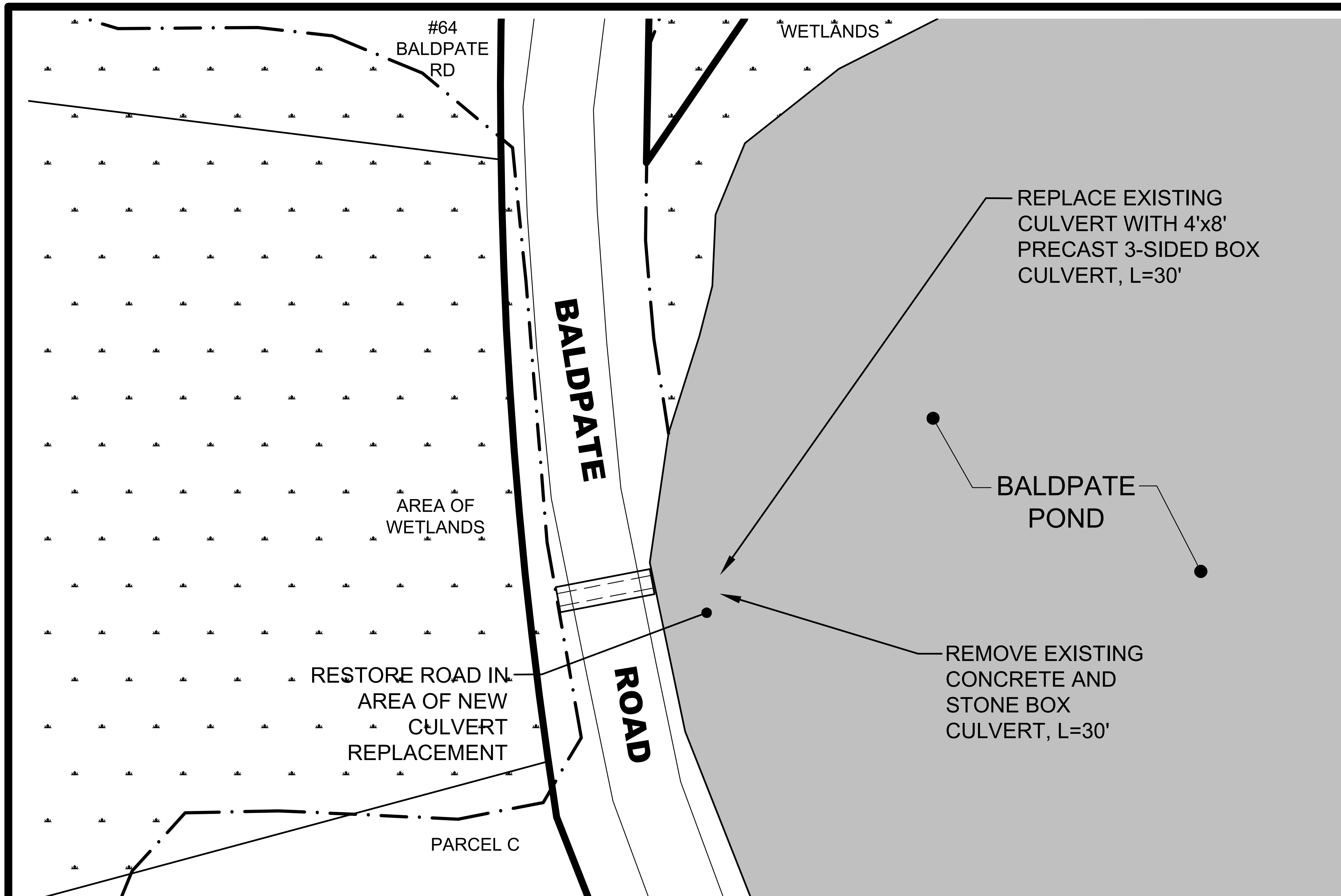
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 814.dwg

MAI Project: 5900



NOTES:

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5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.40
10. NAACC CROSSING CODE: xy4269786371007716
11. NAACC SURVEY ID: 11340

CROSSING ID#829 SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

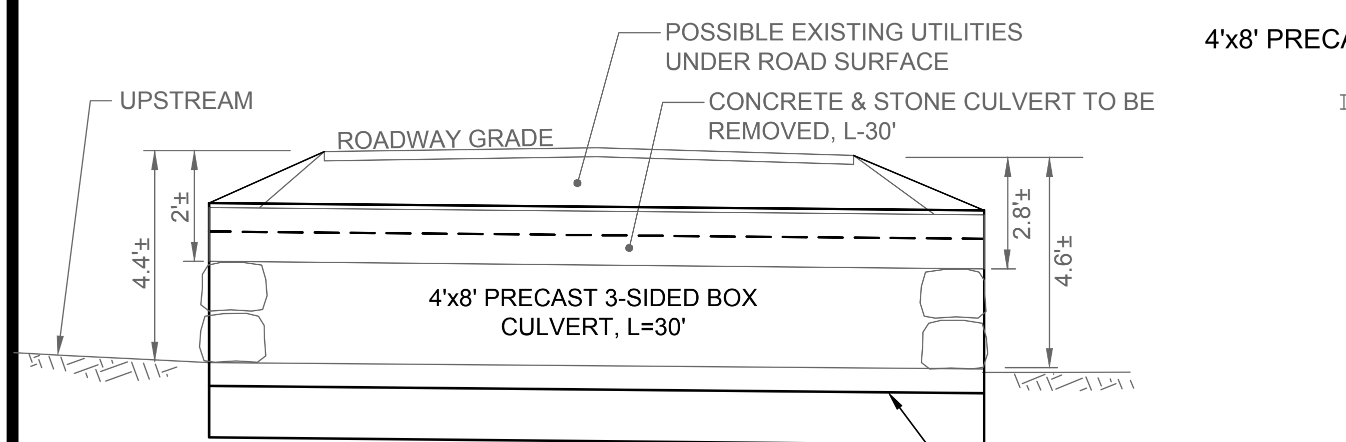
(ESSEX COUNTY)

PREPARED FOR

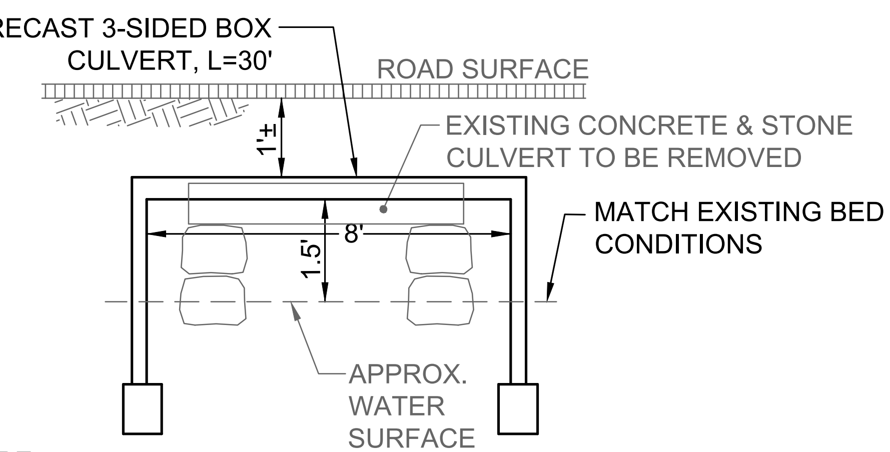
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 24, 2017

15 0 15 30 60



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

MERIDIAN ASSOCIATES

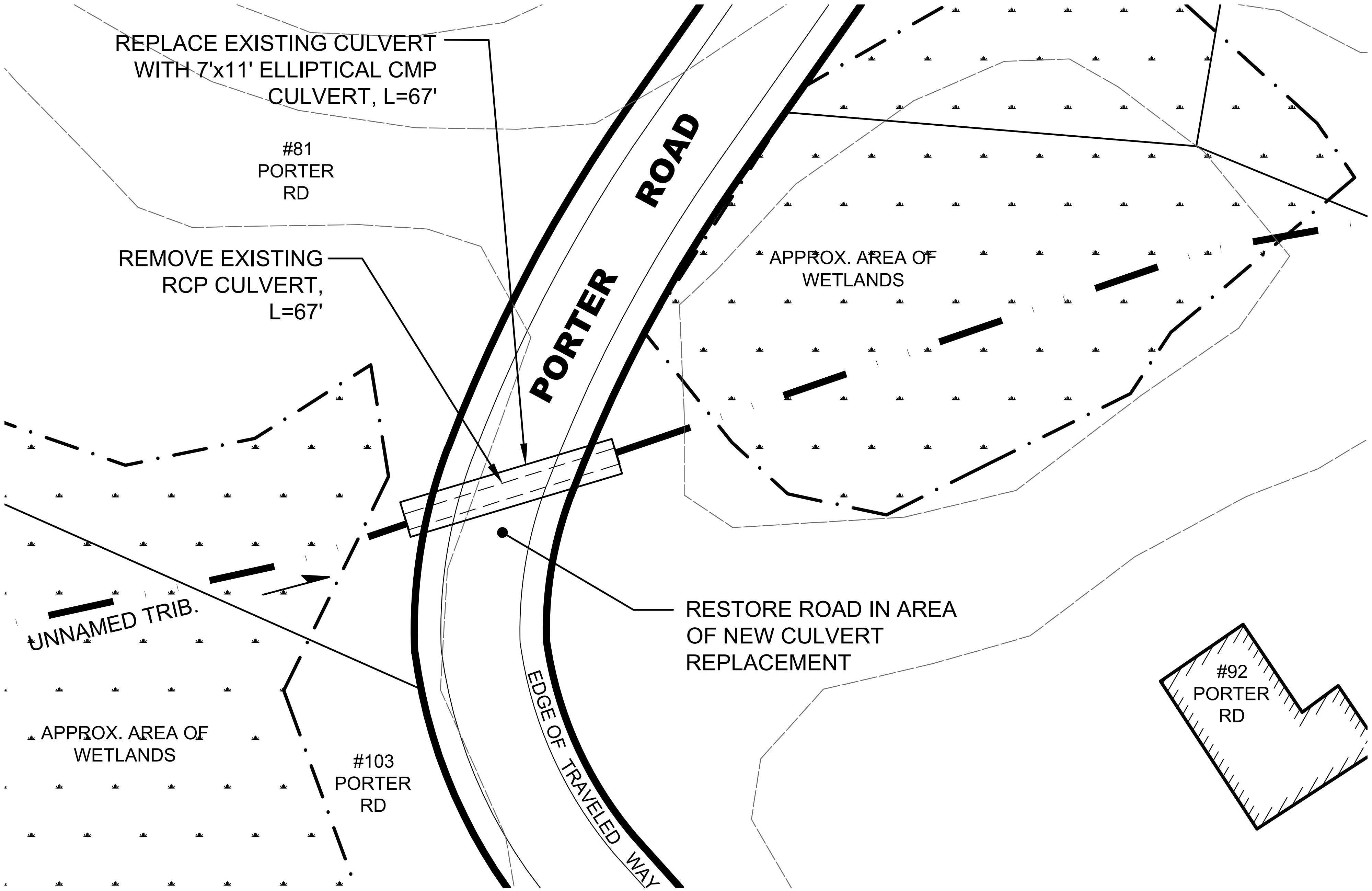
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

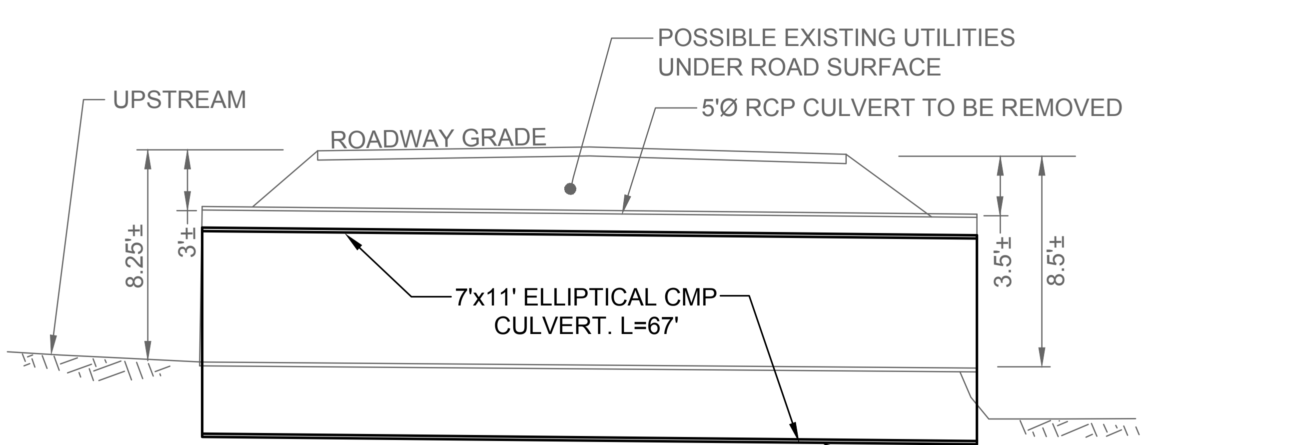
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

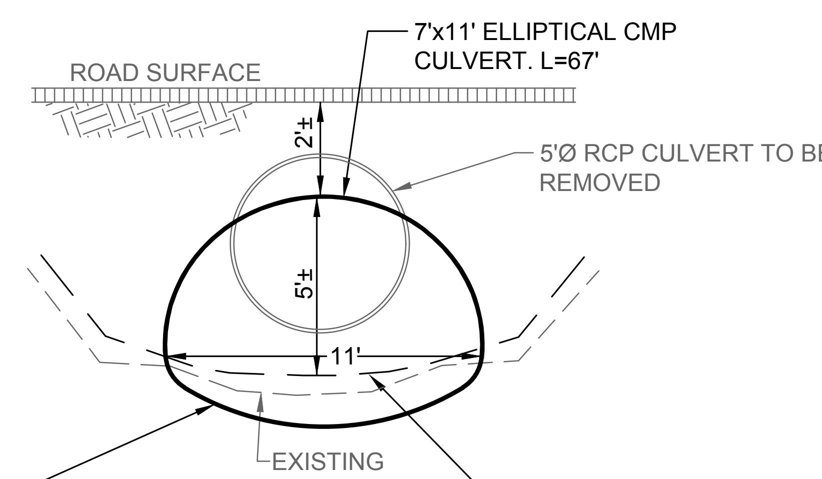
DWG. No. Site 829.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL OUTLET SECTION
N.T.S.

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=9.1 FEET. PROPOSED CULVERT WIDTH=11 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4269985371046063
11. NAACC SURVEY ID: 9479

CROSSING ID# 843
SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 18, 2017

15 0 15 30 60

MERIDIAN
ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

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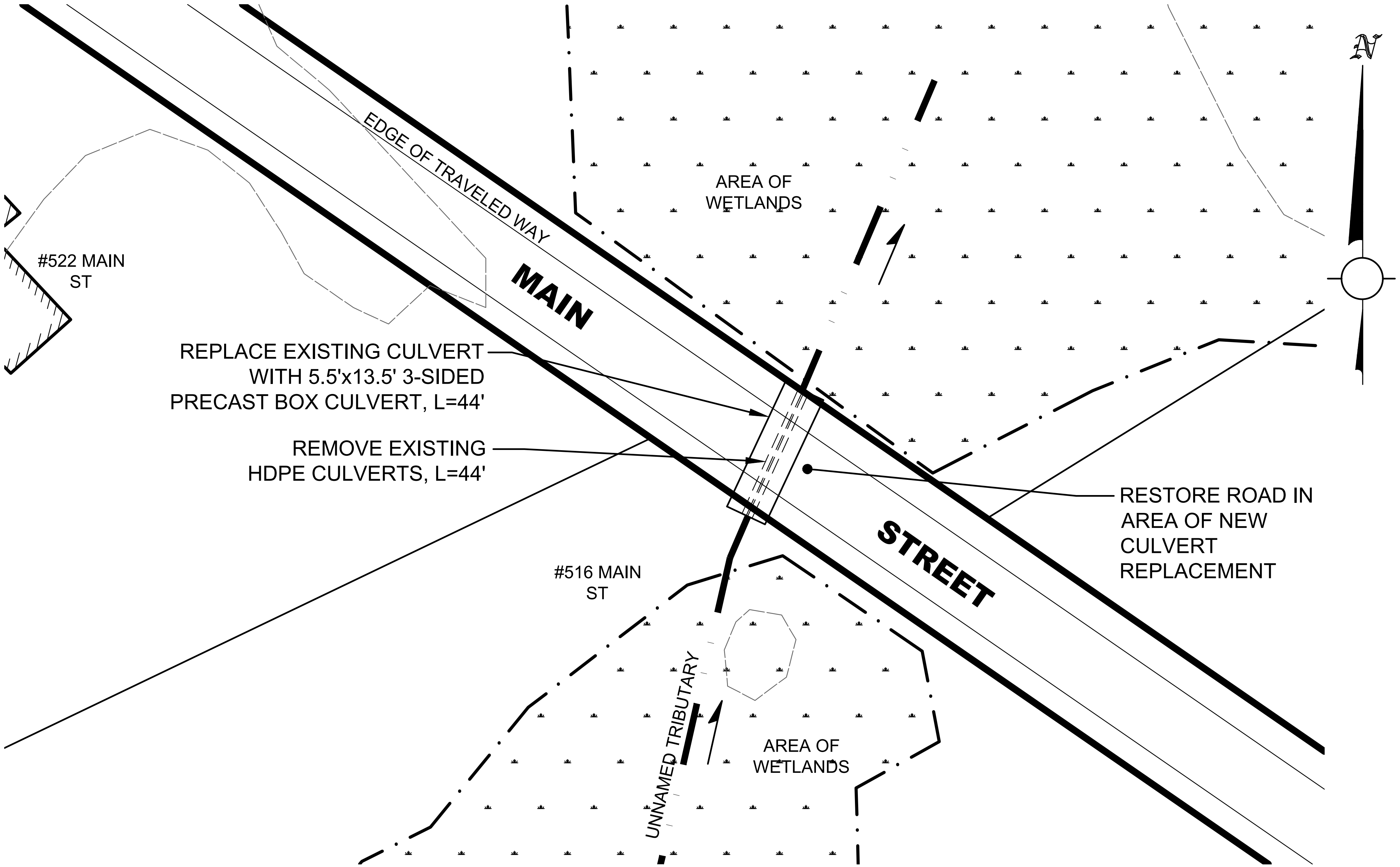
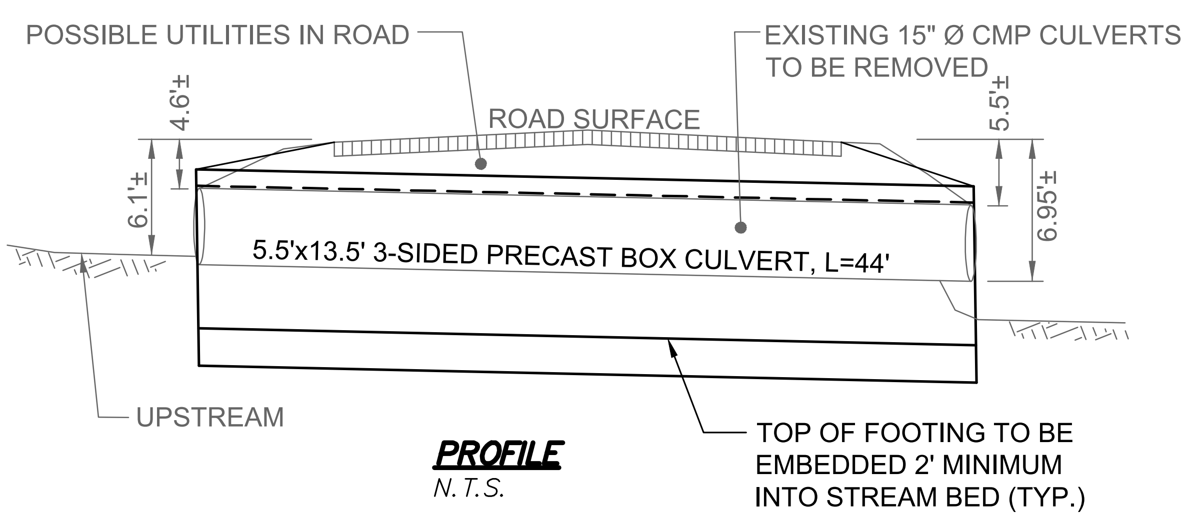
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

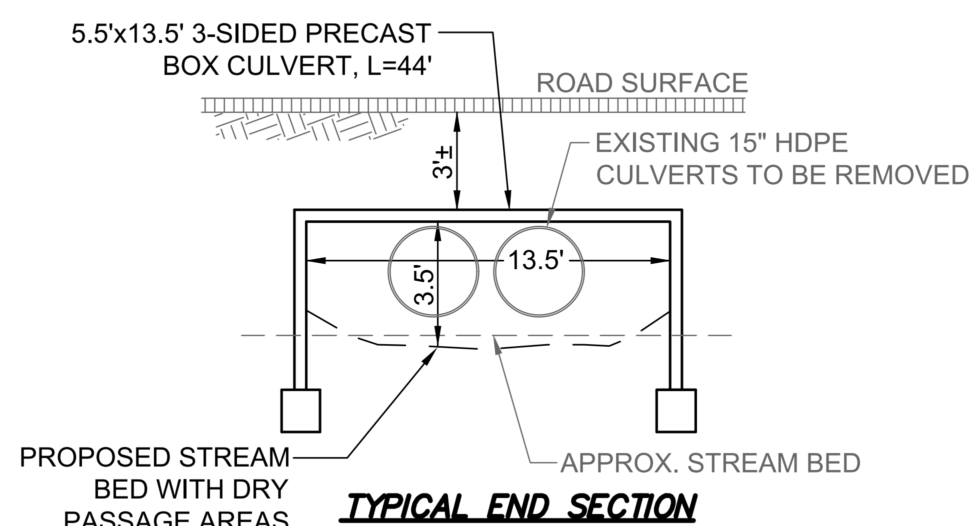
DWG. No. Site 843.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10.9 FEET. PROPOSED CULVERT WIDTH=13.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.92
10. NAACC CROSSING CODE: xy4270269871058659
11. NAACC SURVEY ID: 9489

CROSSING ID# 859 SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

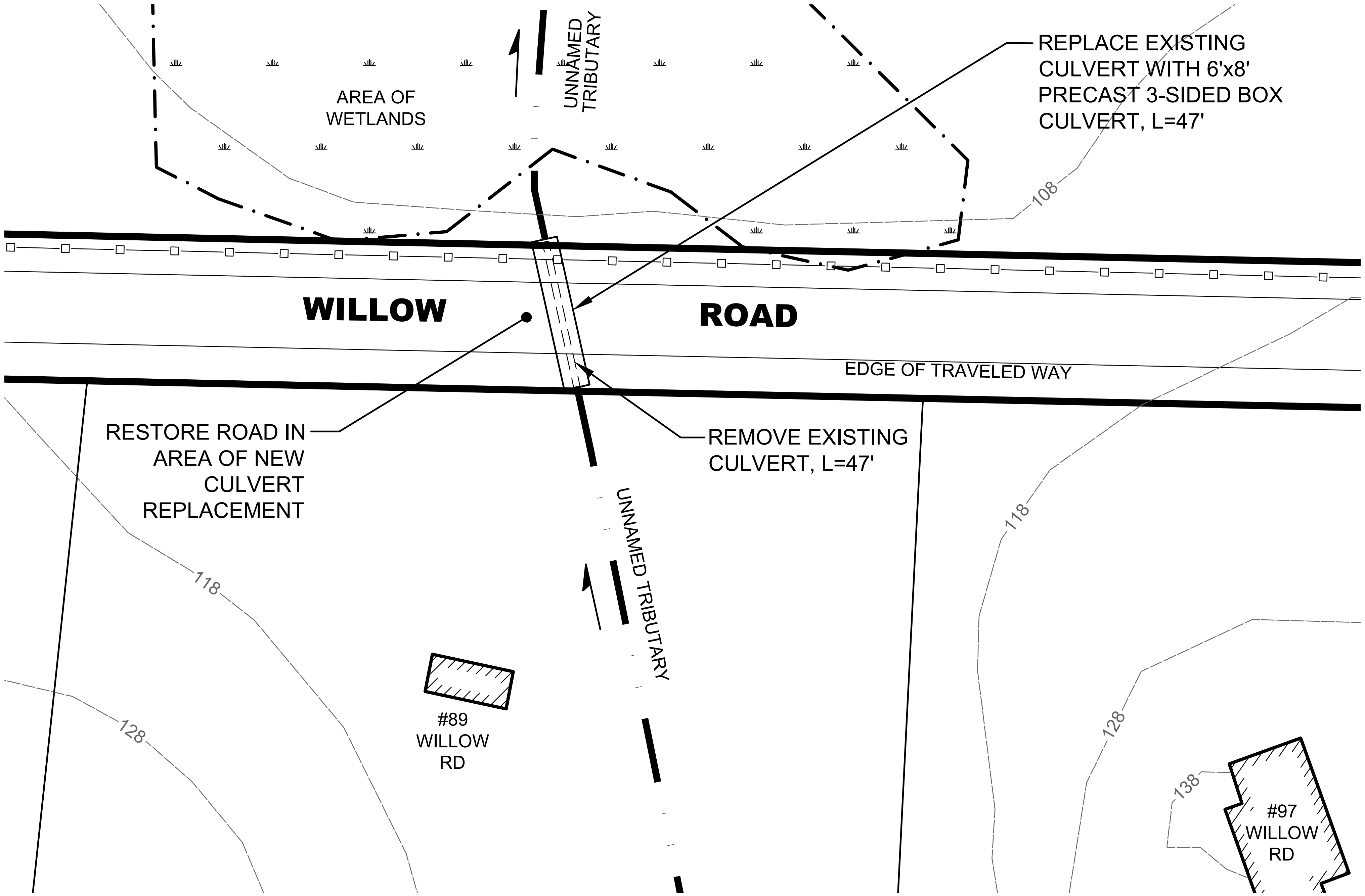
SCALE: 1"= 40' DATE: JAN. 18, 2017

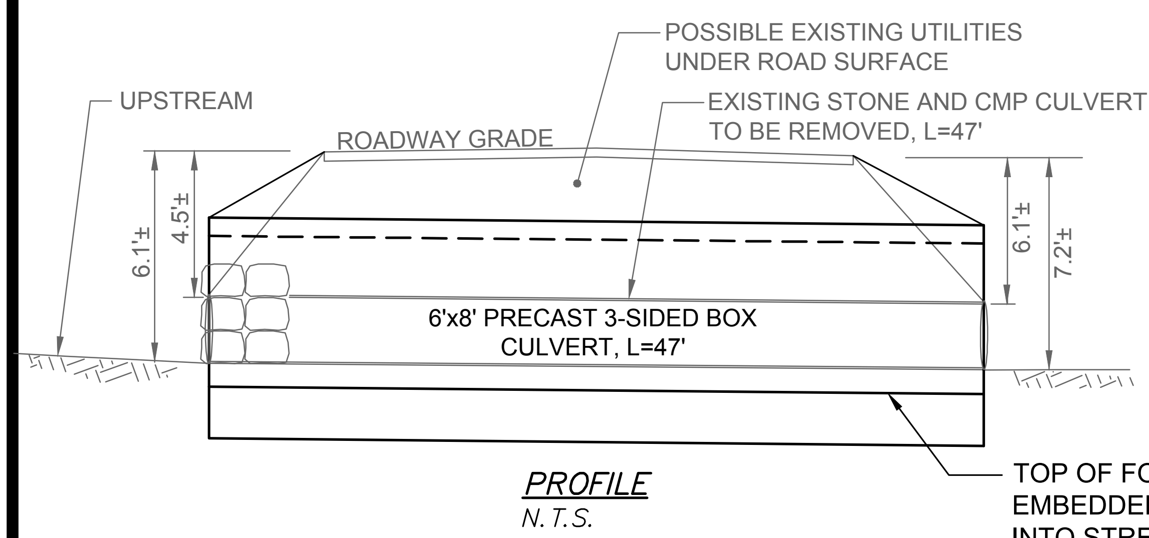
15 0 15 30 60

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

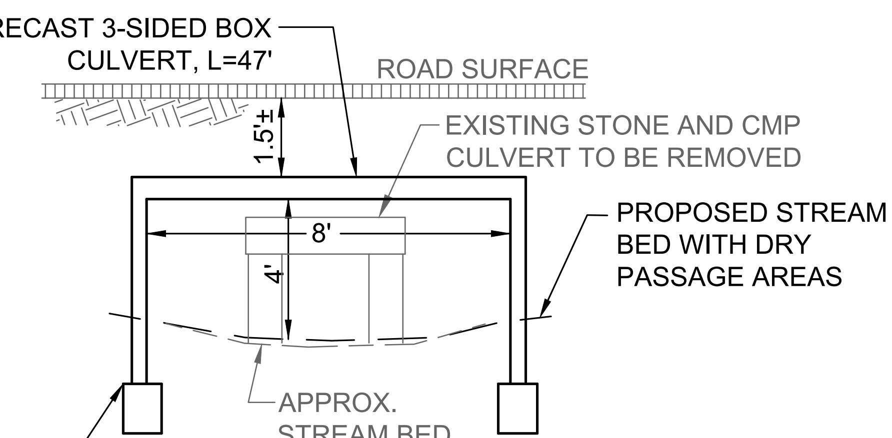
DWG. No. Site 859.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

NOTES:

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5. *IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.*
6. *STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.*
7. *ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.*
8. *APPROXIMATE BANKFULL WIDTH=6.1 FEET. PROPOSED CULVERT WIDTH=8 FEET.*
9. *MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.70*
10. *NAACC CROSSING CODE: xy4271185271036662*
11. *NAACC SURVEY ID: 9531*

CROSSING ID#910 SKETCH PLAN

LOCATED IN

BOXFORD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 24, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

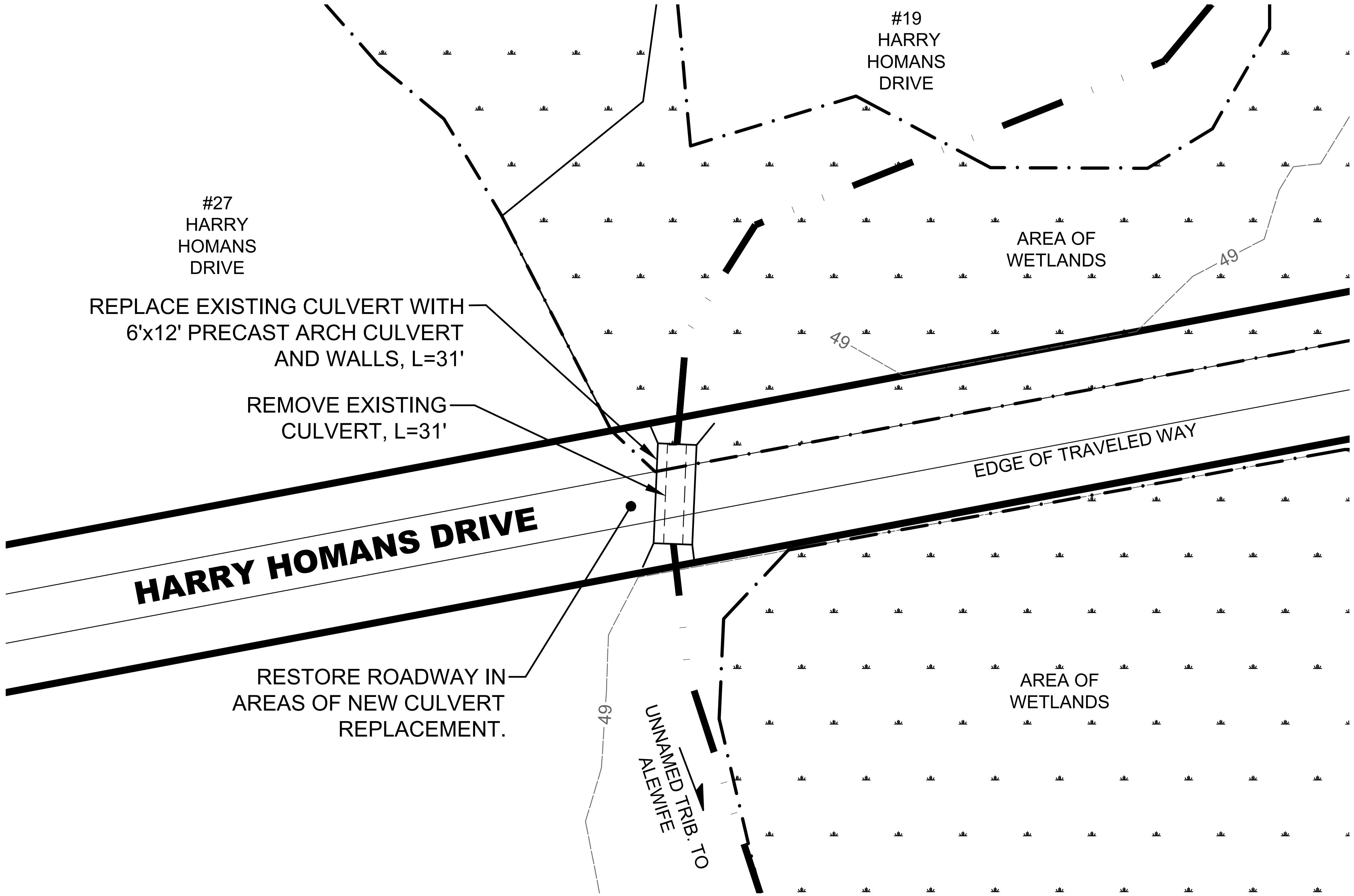
DWG. No. Site 910.dwg

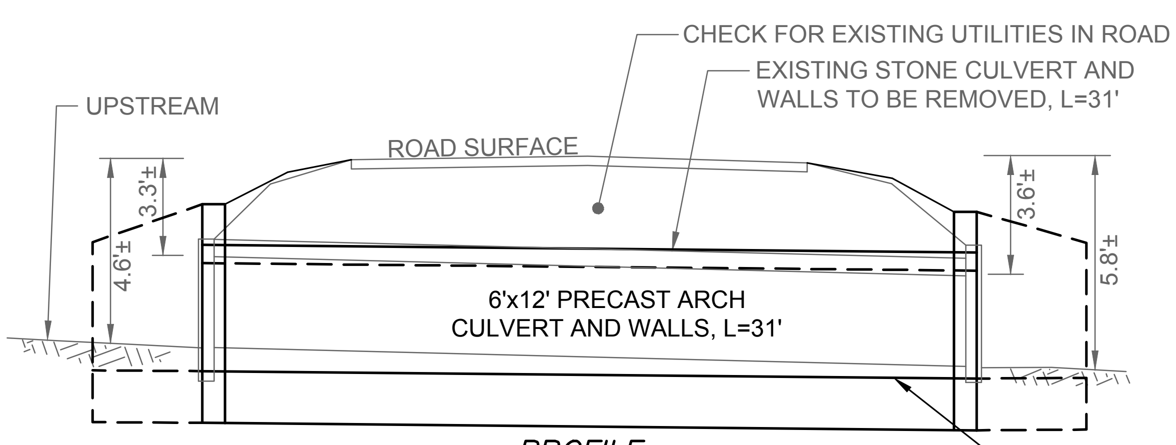
MAI Project: 5900

Essex Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Essex, MA

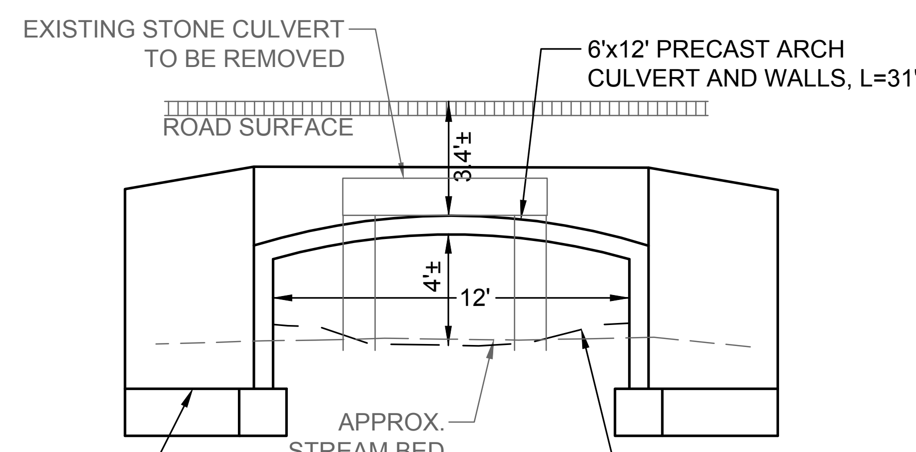
3 pages





PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.5
10. NAACC CROSSING CODE: xy4262146970803215
11. NAACC SURVEY ID: 8392

CROSSING ID#361
SKETCH PLAN

LOCATED IN

ESSEX, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

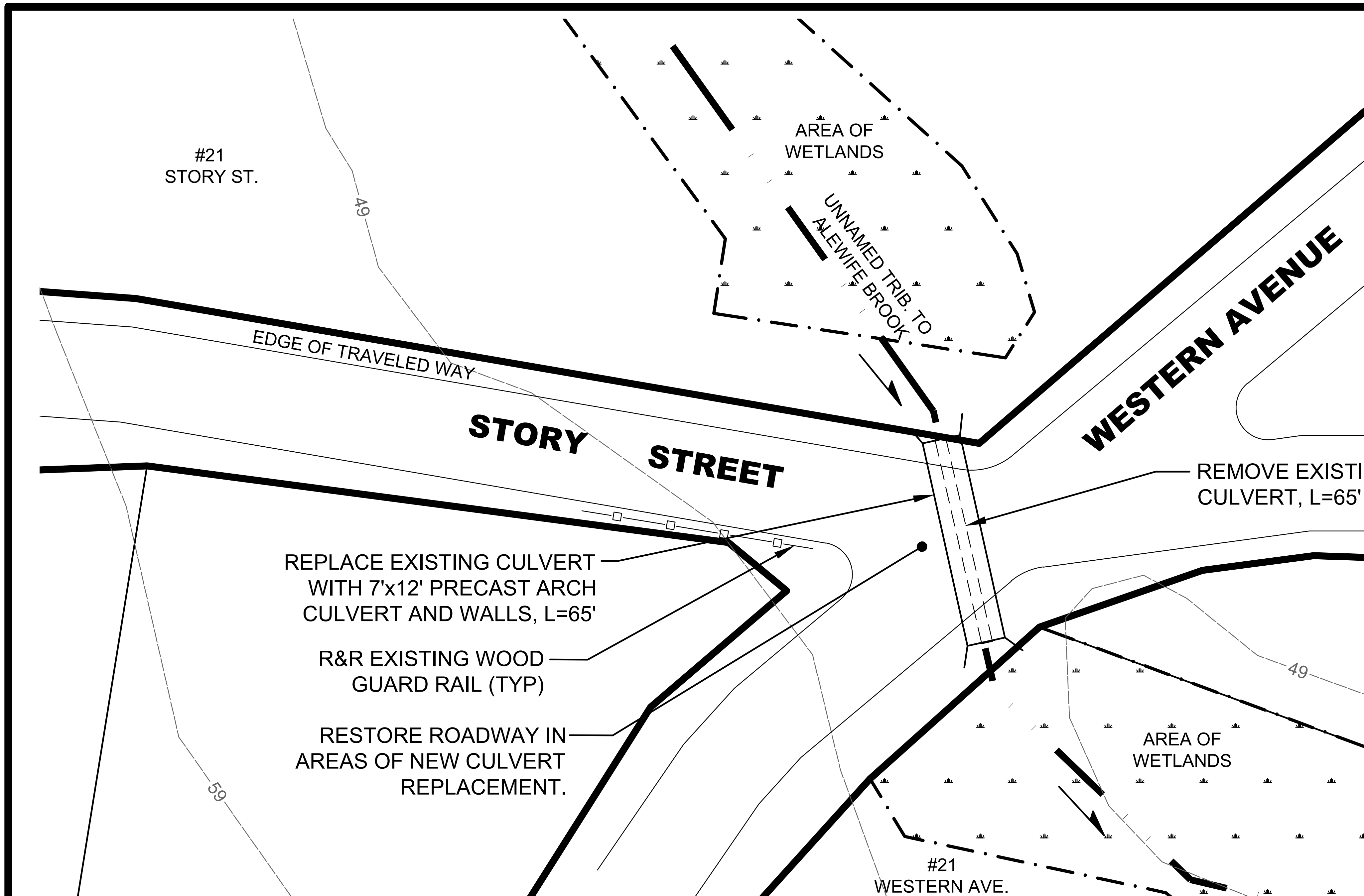
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

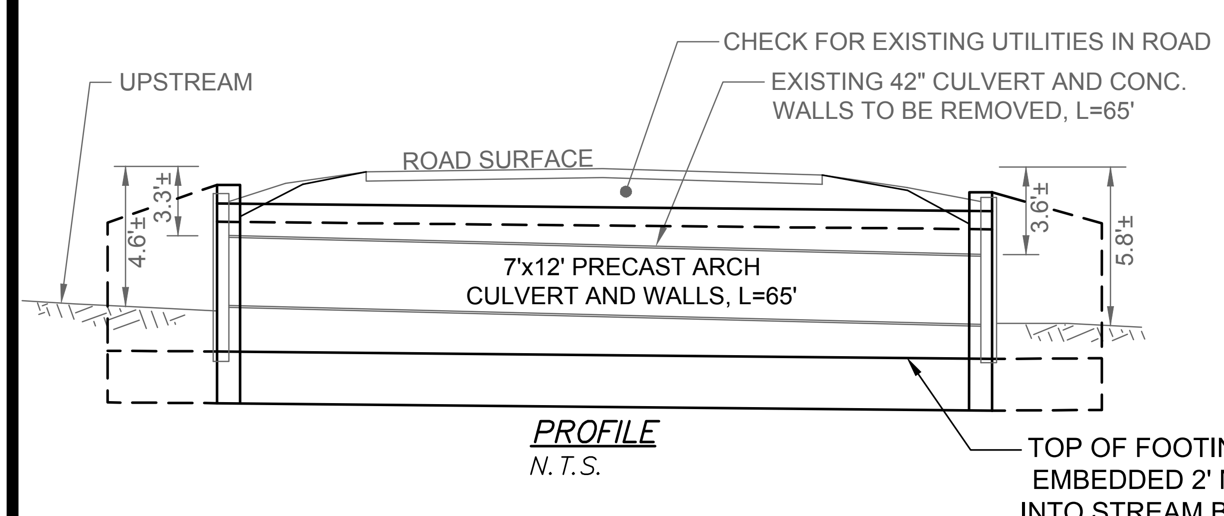
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

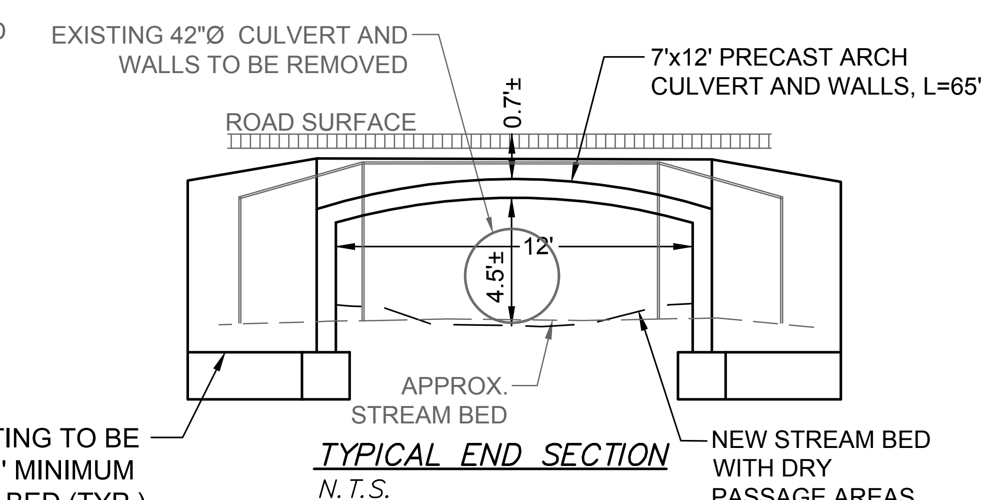
DWG. No. Site 361.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=6.4 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.83
10. NAACC CROSSING CODE: xy4263312370787879
11. NAACC SURVEY ID: 10304

CROSSING ID#439
SKETCH PLAN

LOCATED IN

ESSEX, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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69 MILK STREET, SUITE 302
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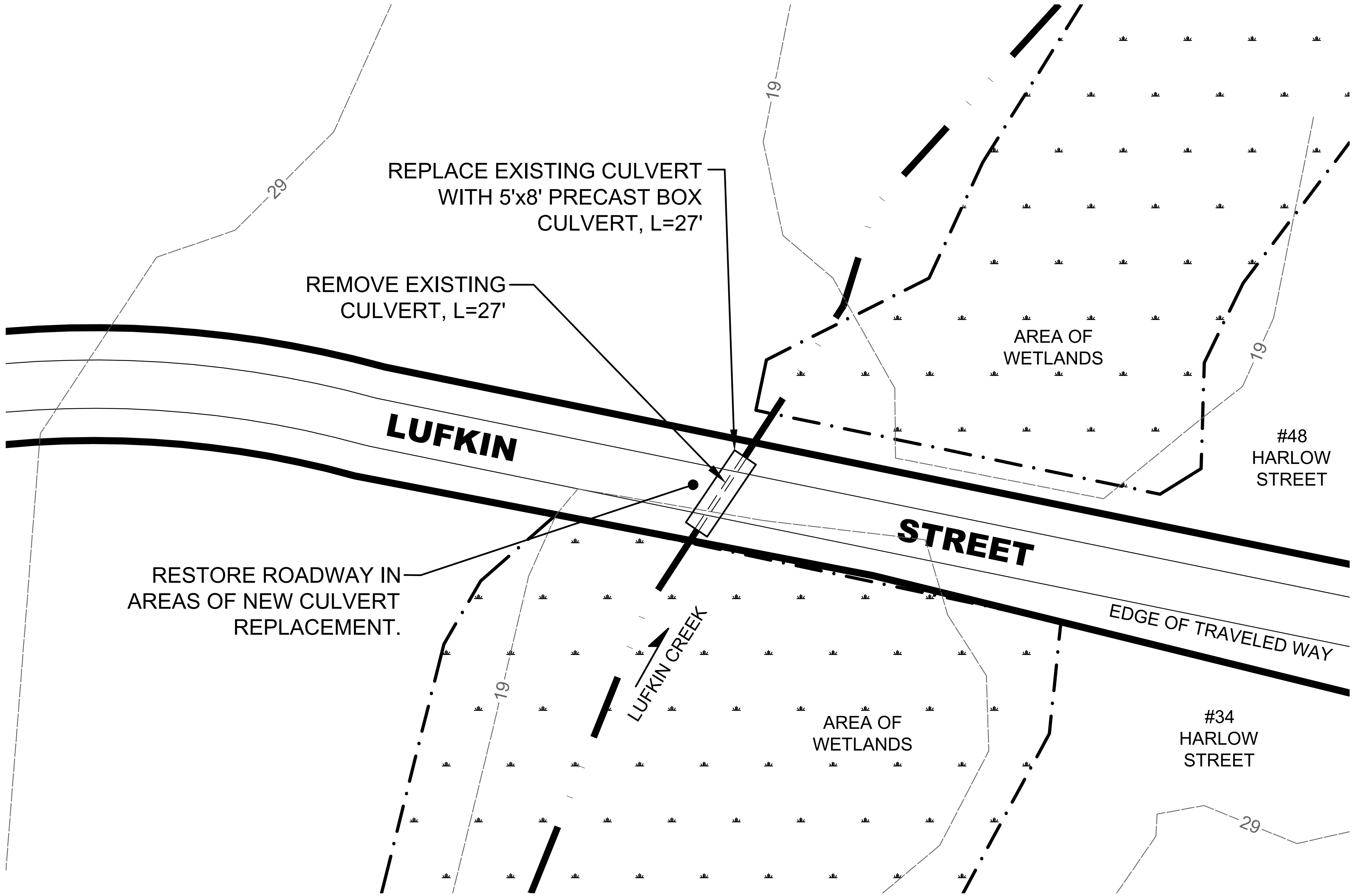
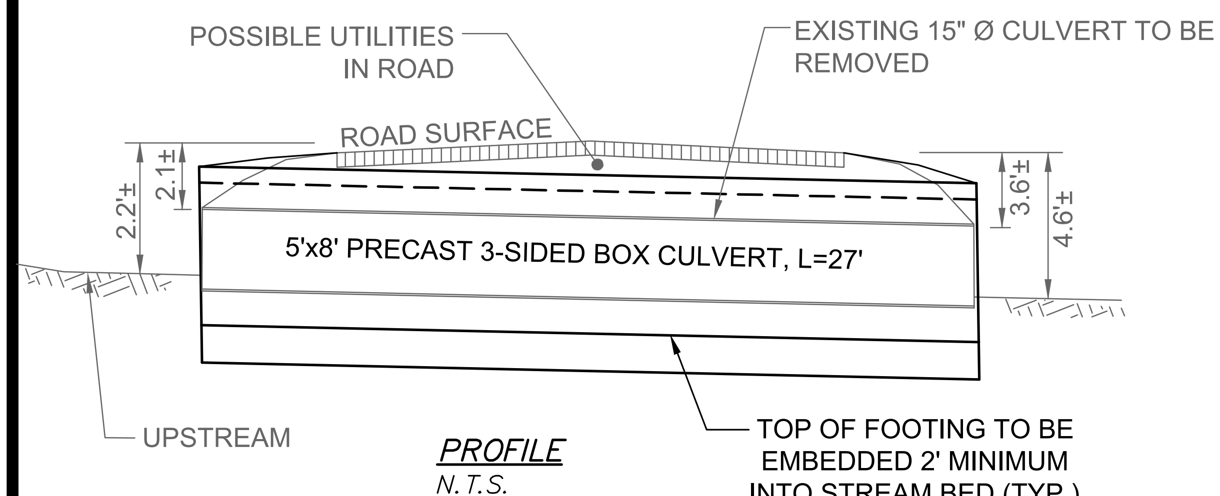
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

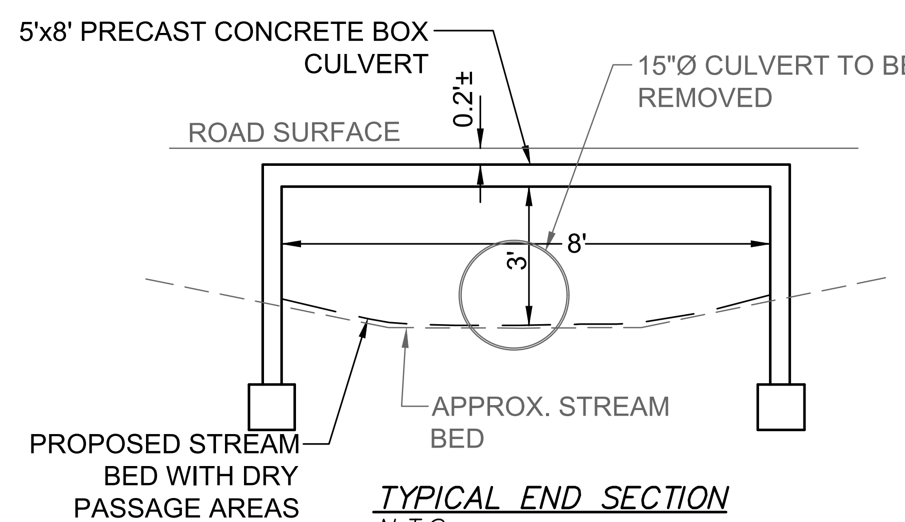
DWG. No. Site 439.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

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8. APPROXIMATE BANKFULL WIDTH=3 FEET. PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.88
10. NAACC CROSSING CODE: xy4263410470749019
11. NAACC SURVEY ID: 9874

CROSSING ID#449
SKETCH PLAN

LOCATED IN

ESSEX, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN
ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
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TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

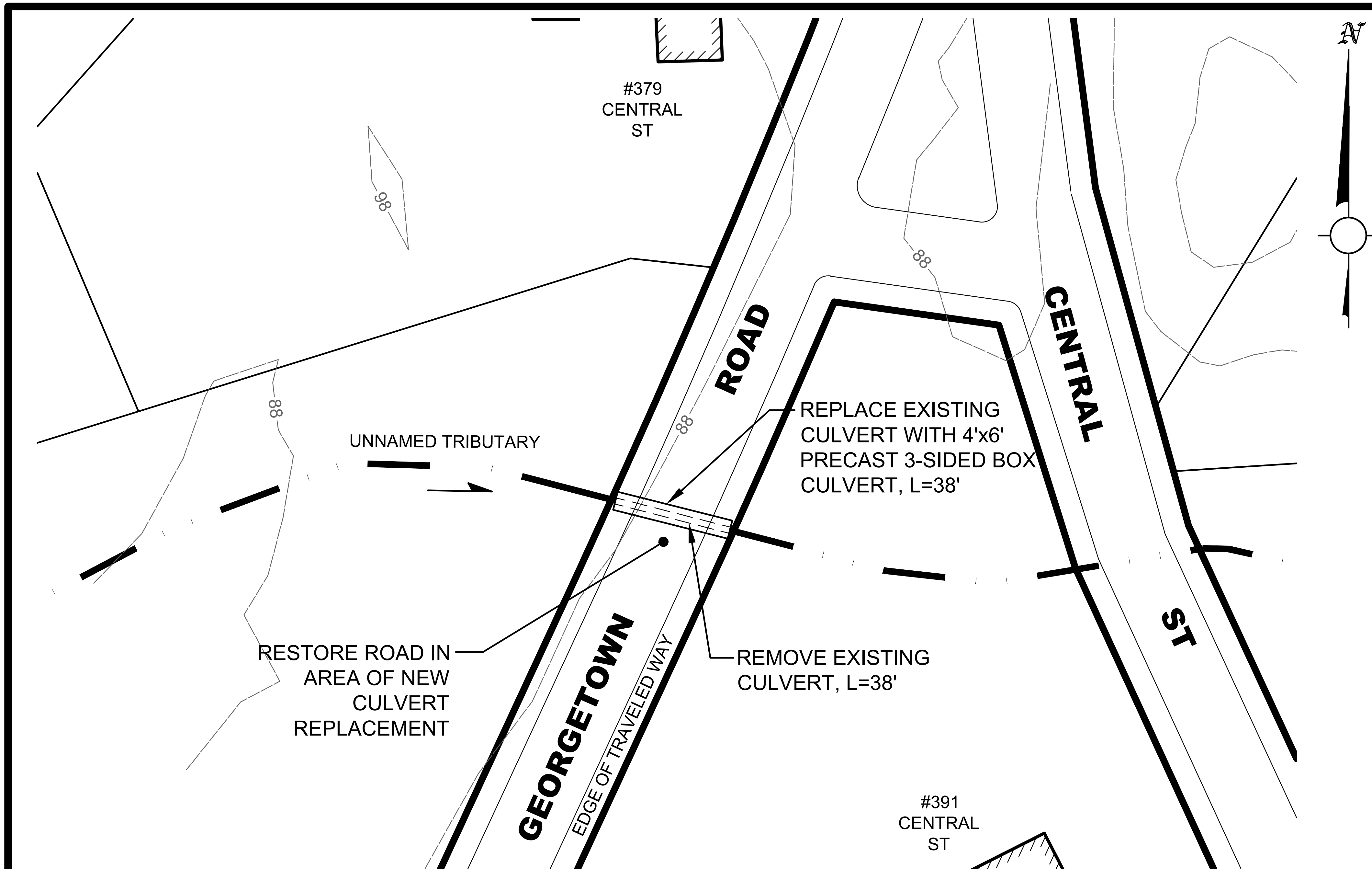
DWG. No. Site 449.dwg

MAI Project: 5900

Georgetown Designs

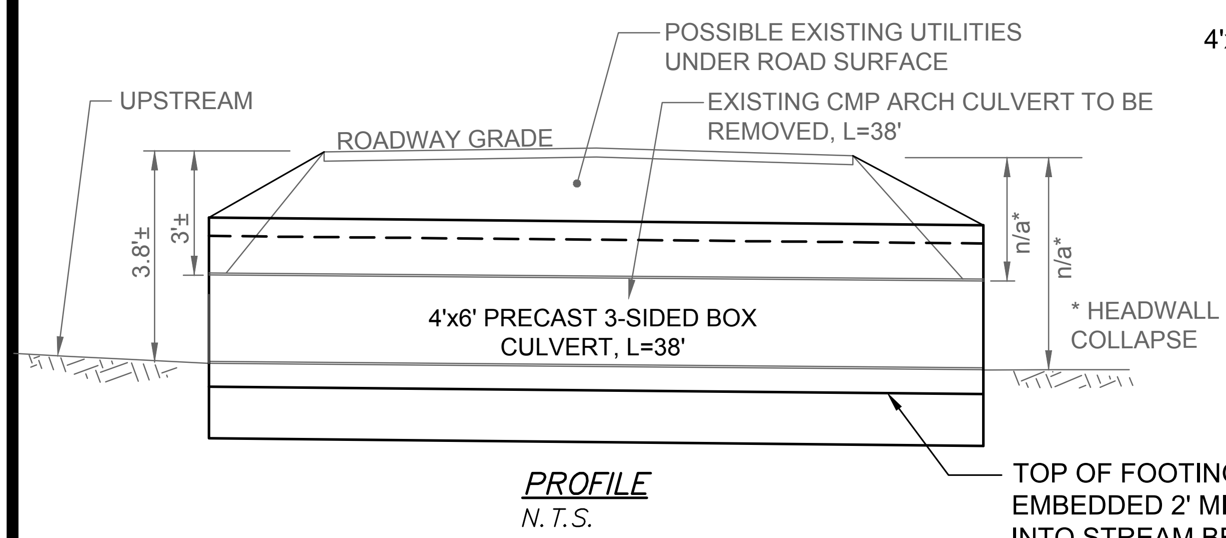
Conceptual designs for the replacement of select road-stream crossings in the Town of Georgetown, MA

4 pages

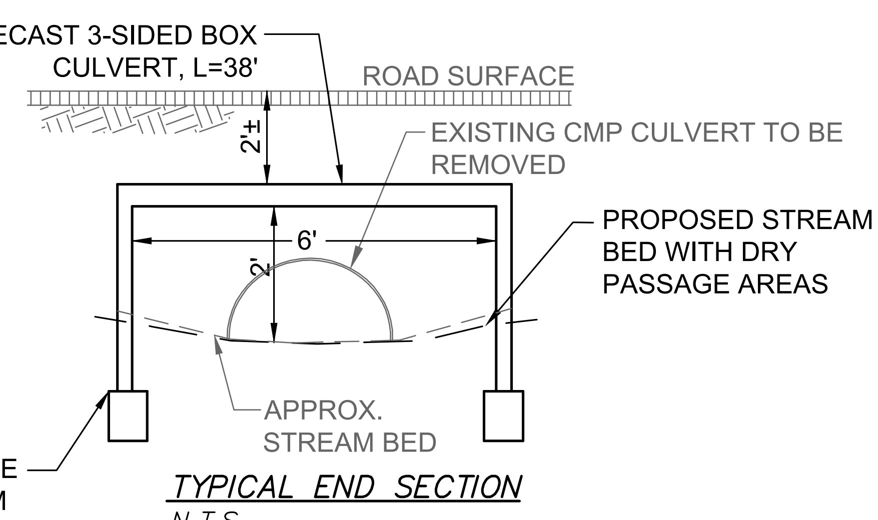


NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=4.9 FEET. PROPOSED CULVERT WIDTH=6 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.32
10. NAACC CROSSING CODE: xy4269889570987030
11. NAACC SURVEY ID: 6927



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#838
SKETCH PLAN

LOCATED IN

GEORGETOWN, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

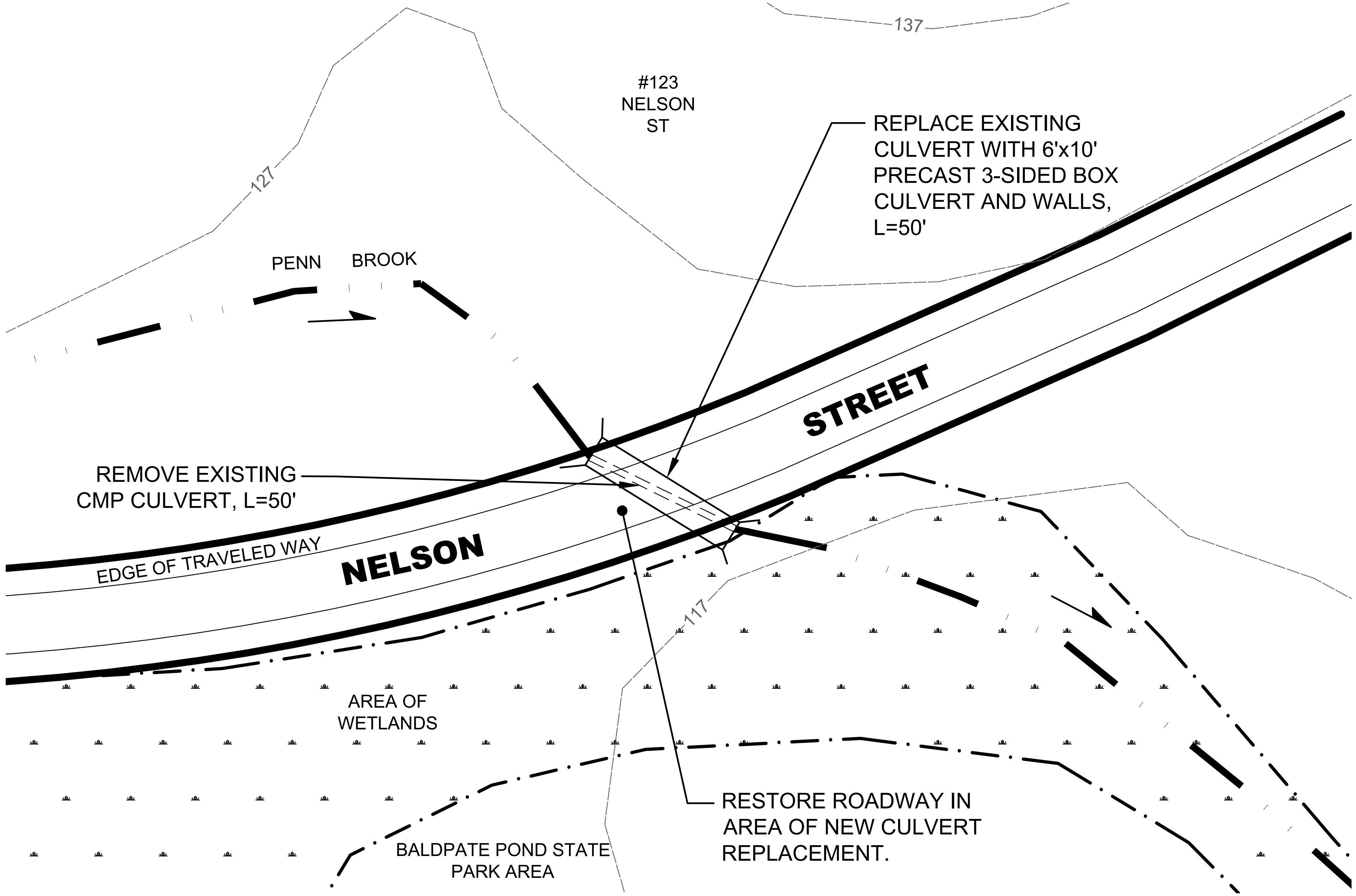
SCALE: 1"= 40' DATE: JAN. 24, 2017

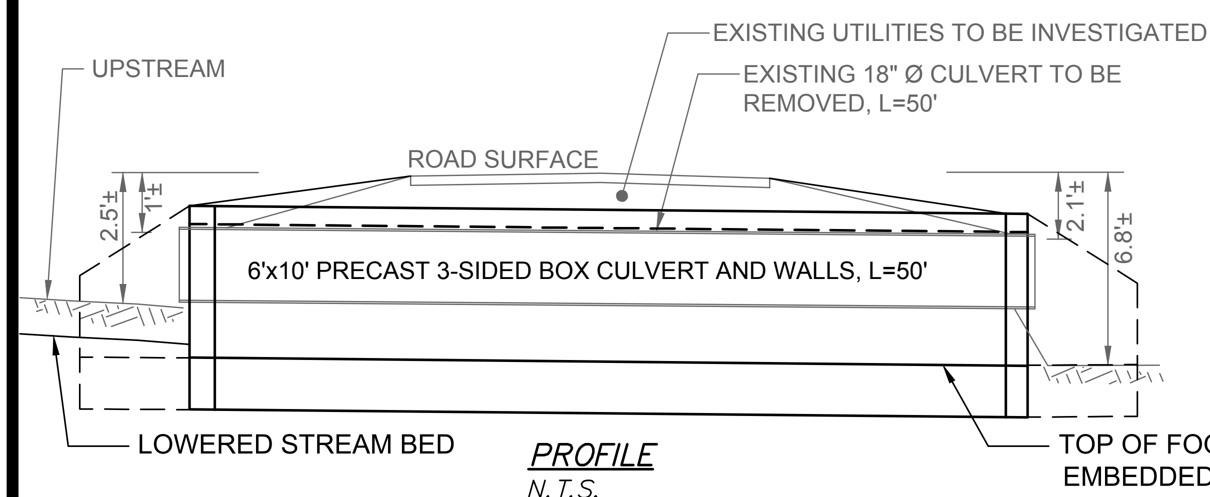
15 0 15 30 60

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

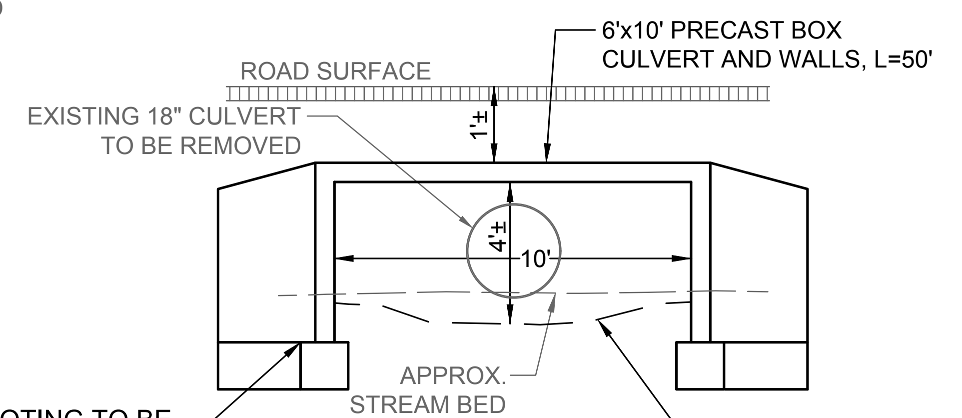
DWG. No. Site 838.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

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5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=6.8 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4270339071001322
11. NAACC SURVEY ID: 9492

CROSSING ID#862 SKETCH PLAN

LOCATED IN

GEORGETOWN, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 25, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
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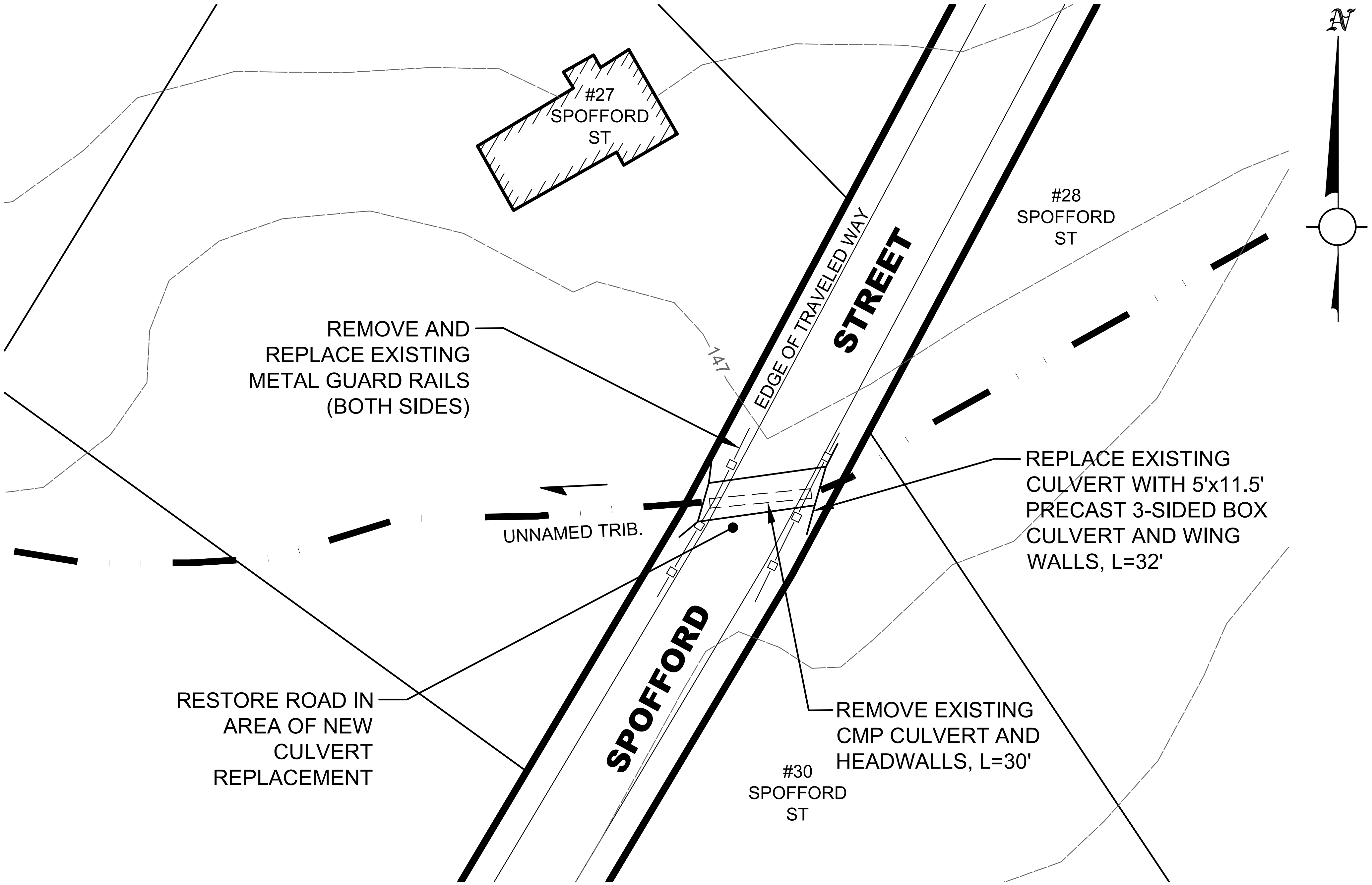
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 862.dwg

MAI Project: 5900



NOTES:

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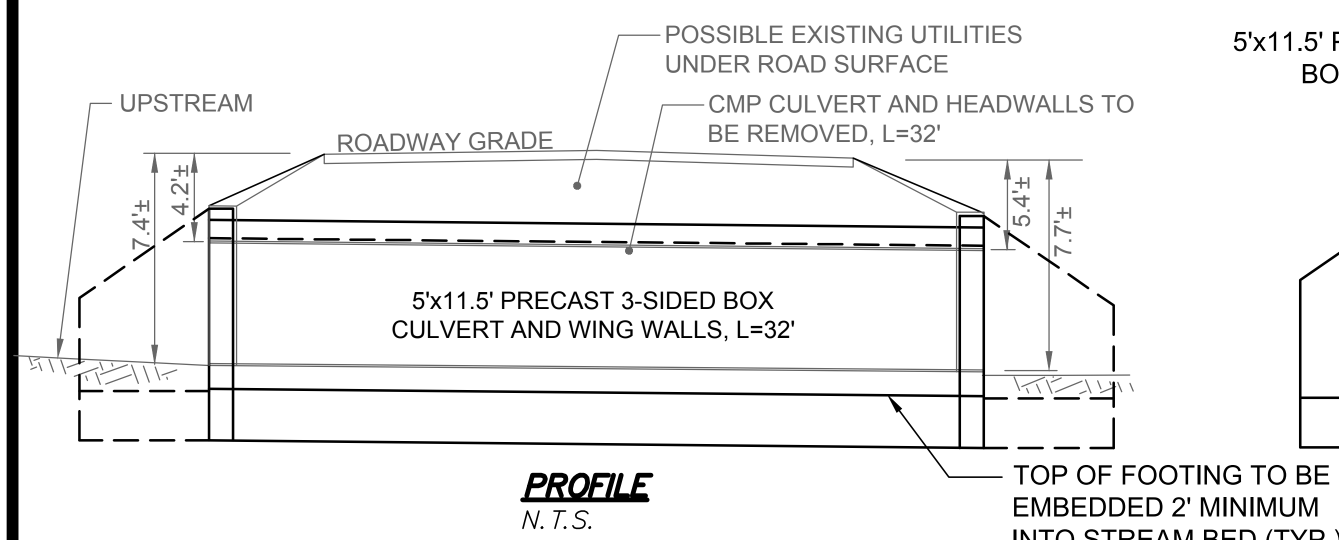
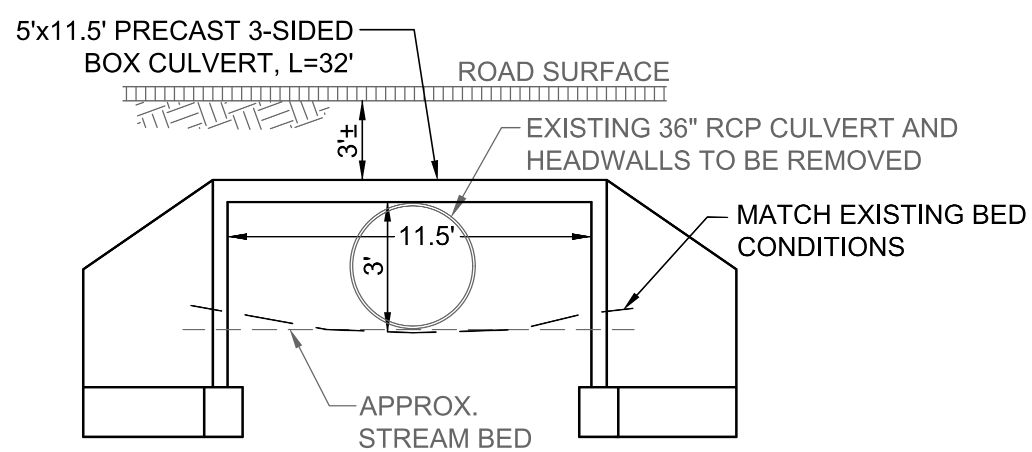
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=9.4 FEET. PROPOSED CULVERT WIDTH=11.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.07
10. NAACC CROSSING CODE: xy4271017371020275
11. NAACC SURVEY ID: 9513



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

IRWA CROSSING ID#902
SKETCH PLAN

LOCATED IN

GEORGETOWN, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 24, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
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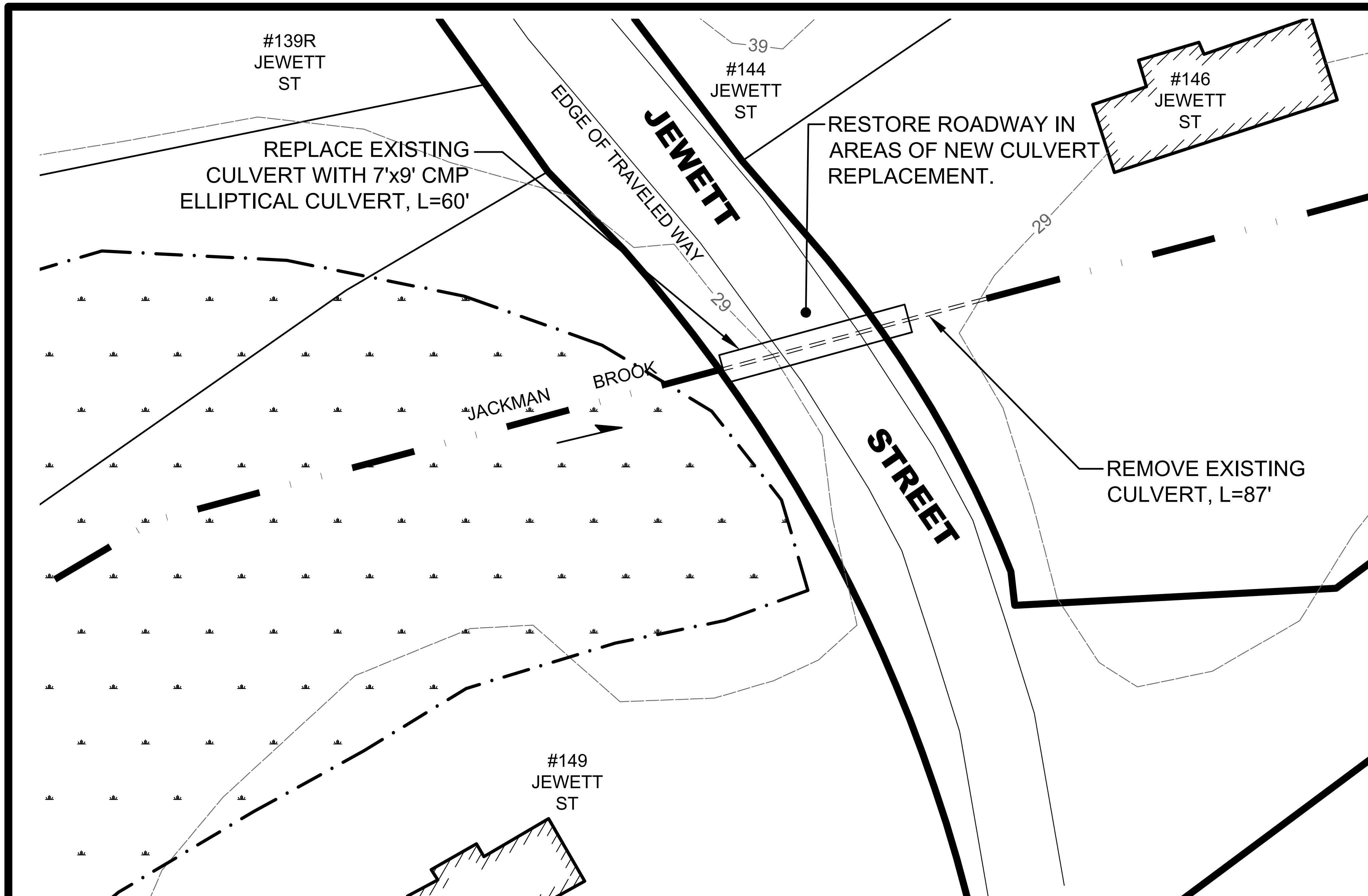
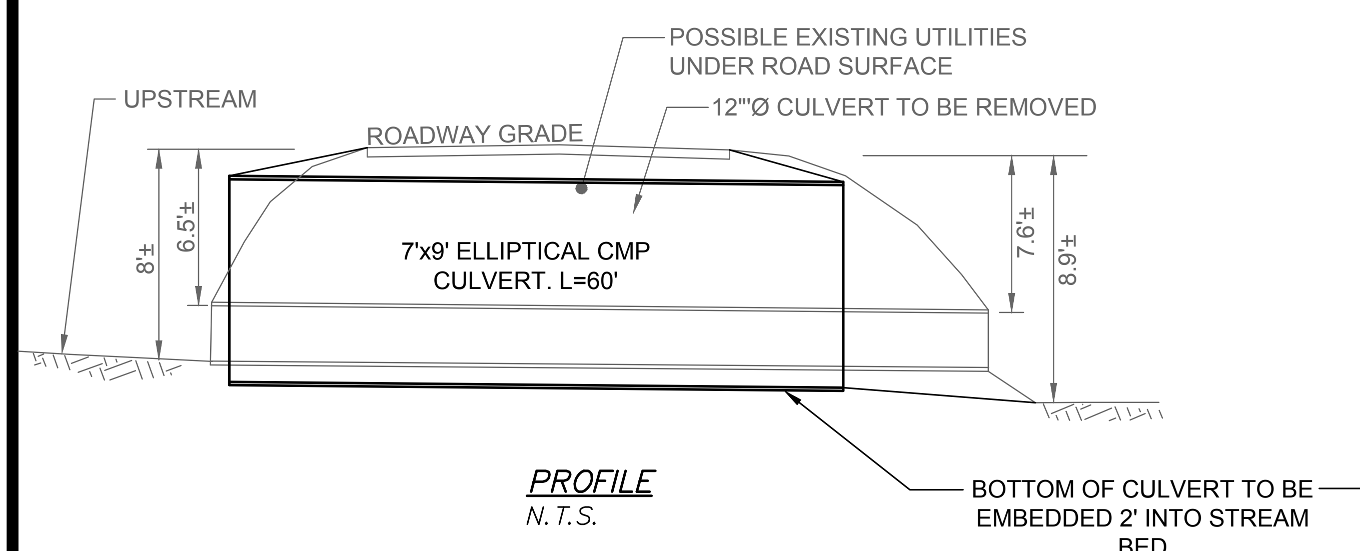
DWG. No. Site 902.dwg

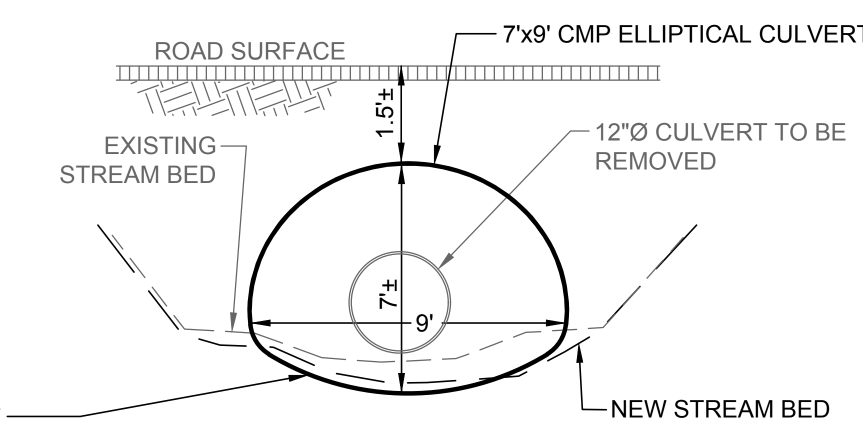
MAI Project: 5900





PROFILE

N.T.S.



TYPICAL OUTLET SECTION

N.T.S.

NOTES:

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=5.3 FEET. PROPOSED CULVERT WIDTH=7 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.97
10. NAACC CROSSING CODE: xy4273140270947446
11. NAACC SURVEY ID: 9572

CROSSING ID#1003 SKETCH PLAN

LOCATED IN

GEORGETOWN, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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WWW.MERIDIANASSOC.COM

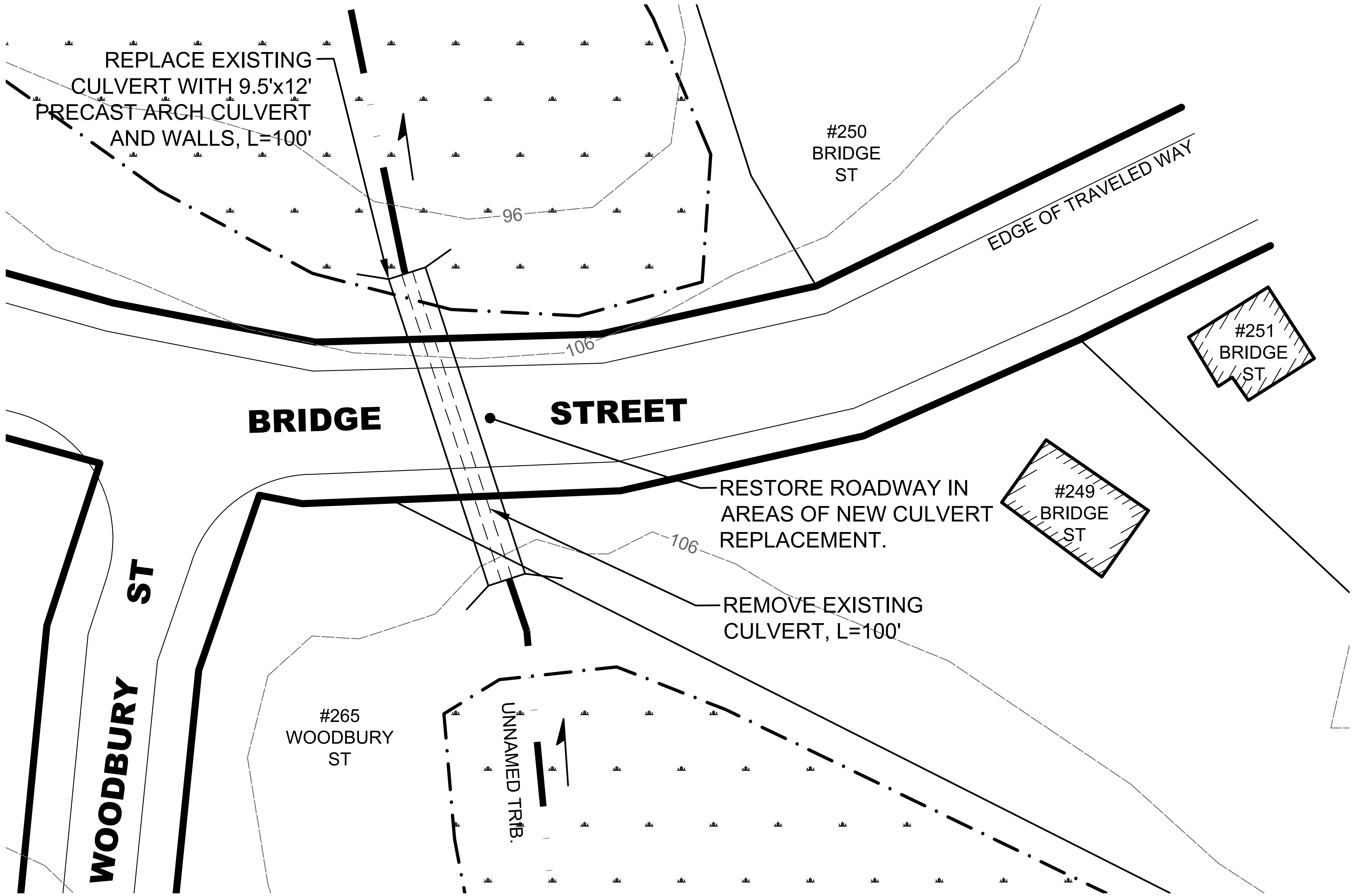
DWG. No. Site 1003.dwg

MAI Project: 5900

Hamilton Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Hamilton, MA

3 pages



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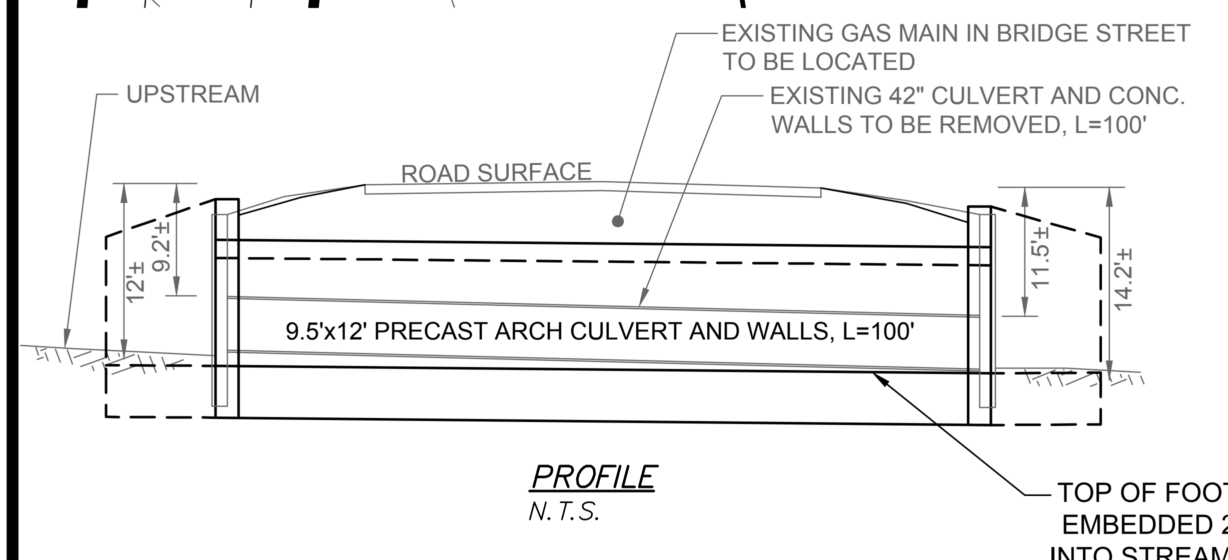
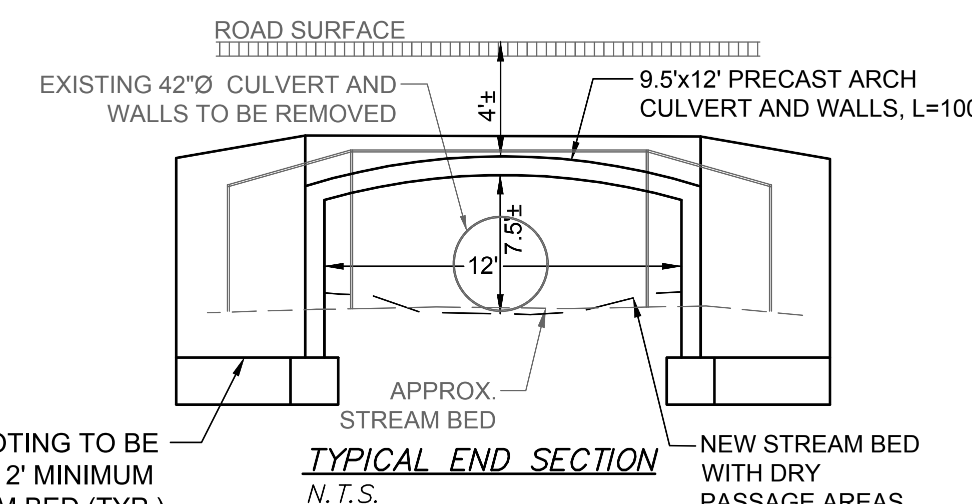
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=9.3 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.84
10. NAACC CROSSING CODE: xy4261390870840322
11. NAACC SURVEY ID: 11247



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#319 SKETCH PLAN

LOCATED IN

HAMILTON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

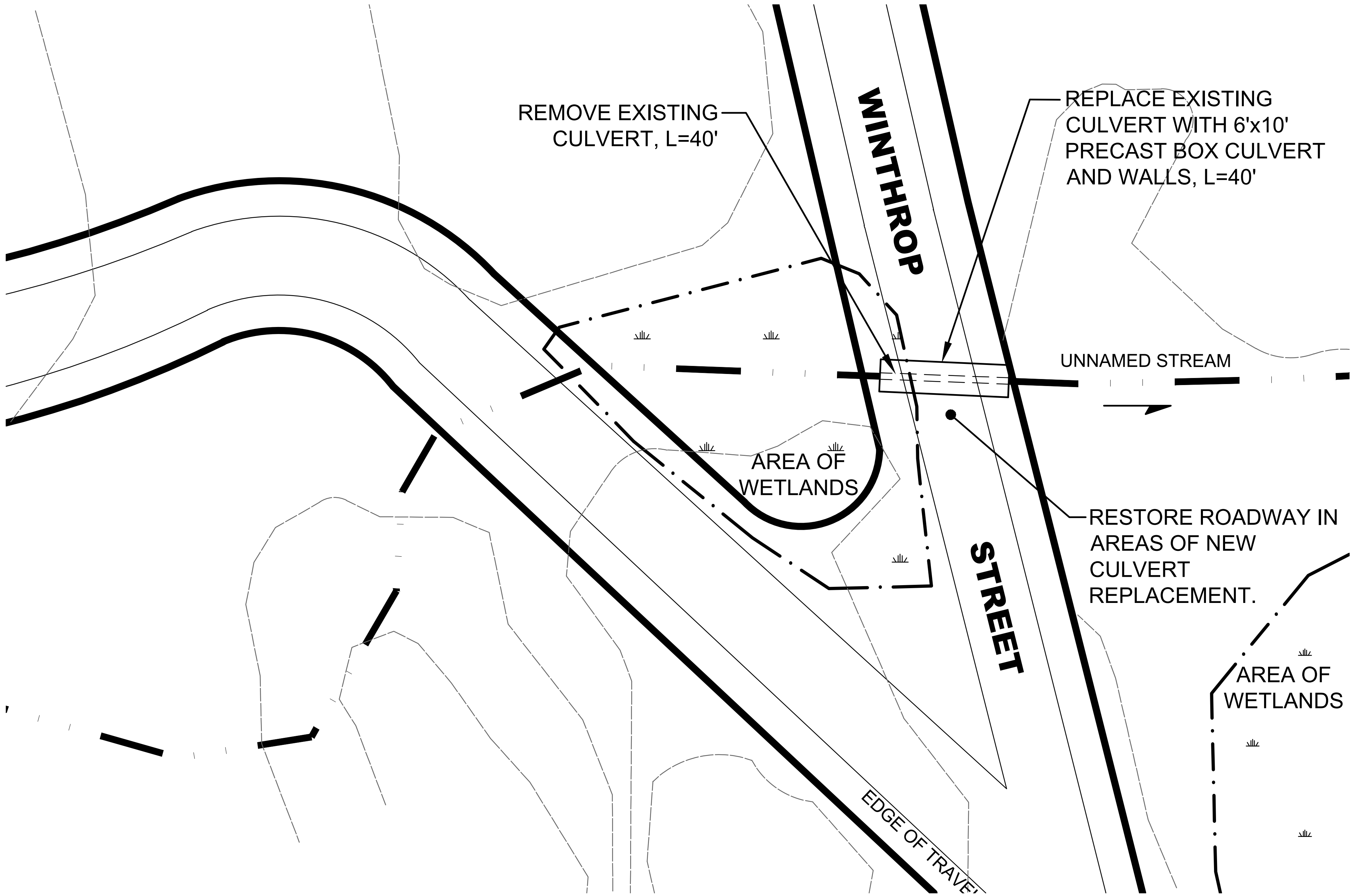
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

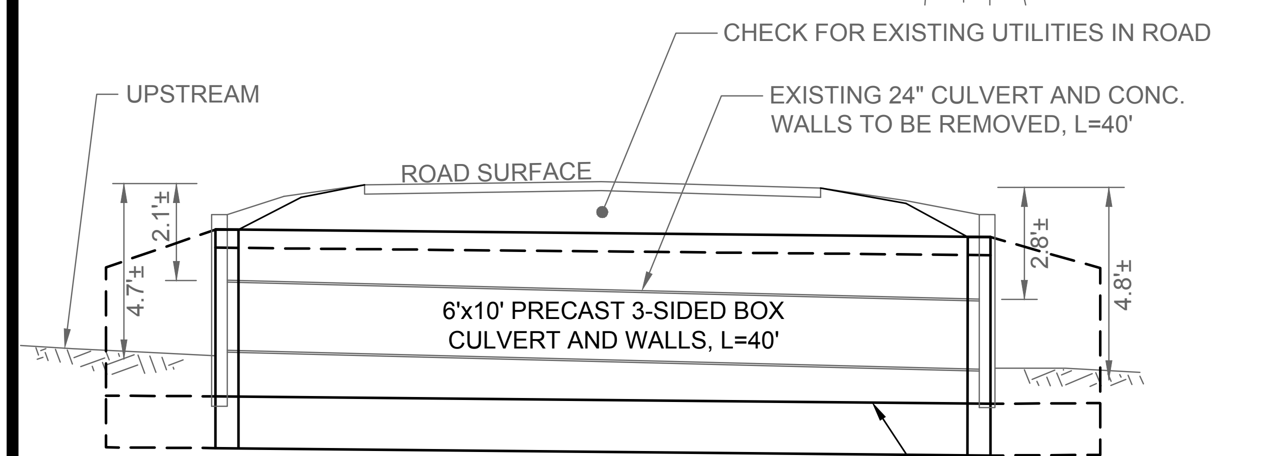
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

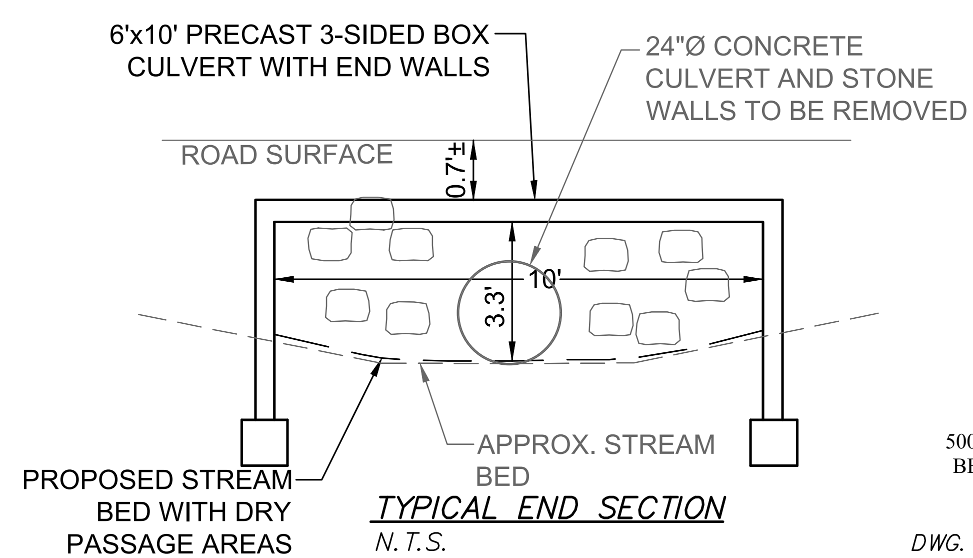
DWG. No. Site 319.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8.2 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4264675670882209
11. NAACC SURVEY ID: 7181

CROSSING ID#517 SKETCH PLAN

LOCATED IN

HAMILTON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

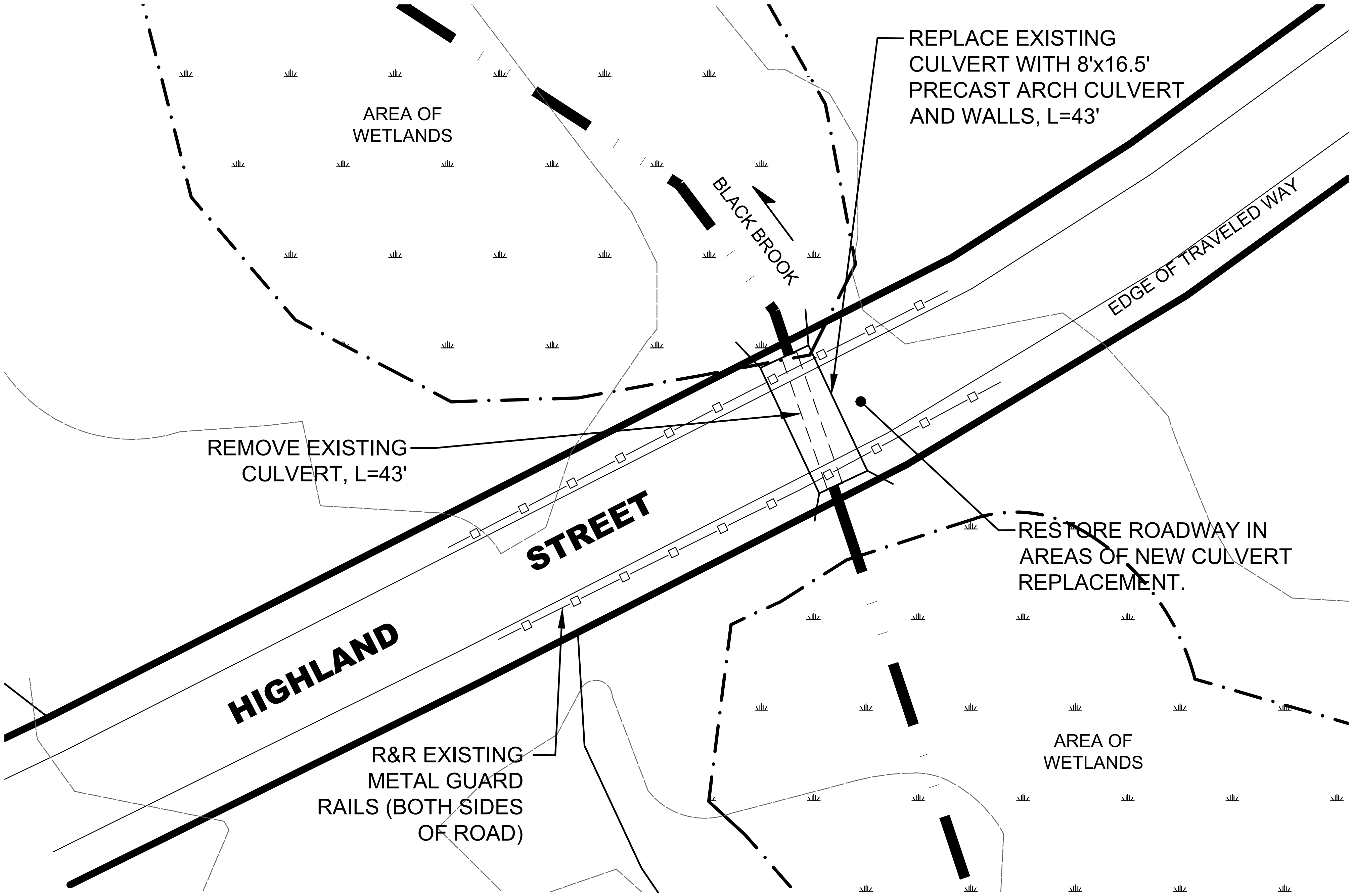
SCALE: 1"= 40' DATE: FEB. 16, 2017

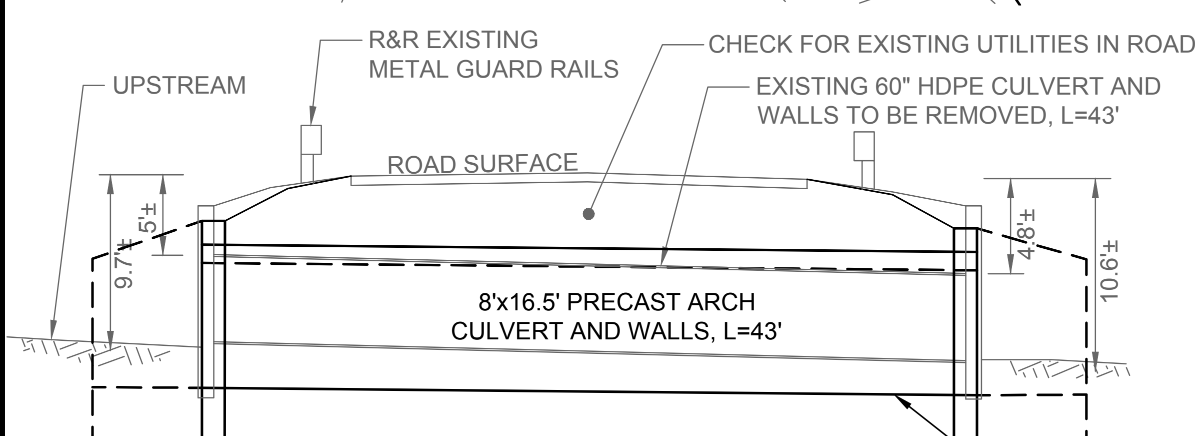
20 0 20 40 80

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

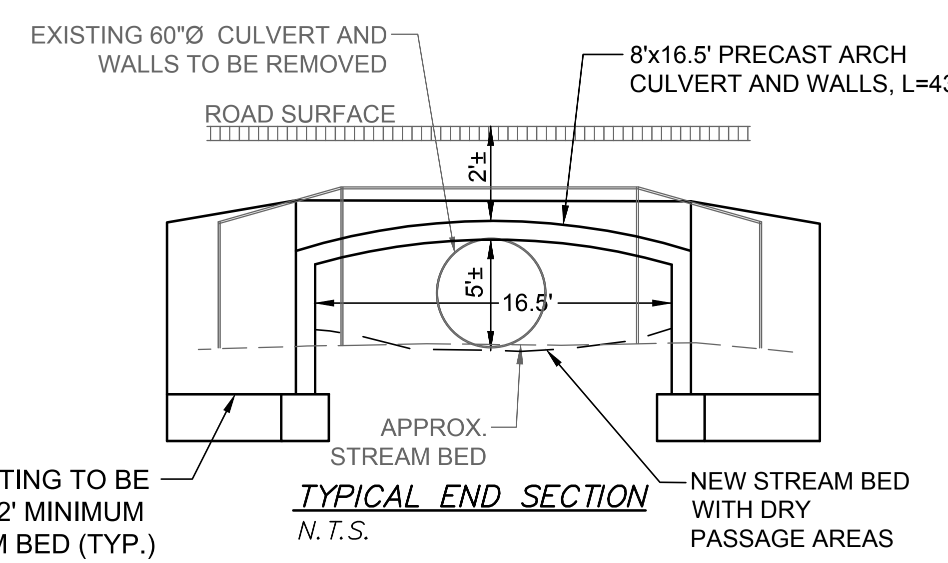
DWG. No. Site 517.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=13.8 FEET. PROPOSED CULVERT WIDTH=16.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.7
10. NAACC CROSSING CODE: xy42646771070873417
11. NAACC SURVEY ID: 6727

CROSSING ID#527 SKETCH PLAN

LOCATED IN

HAMILTON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

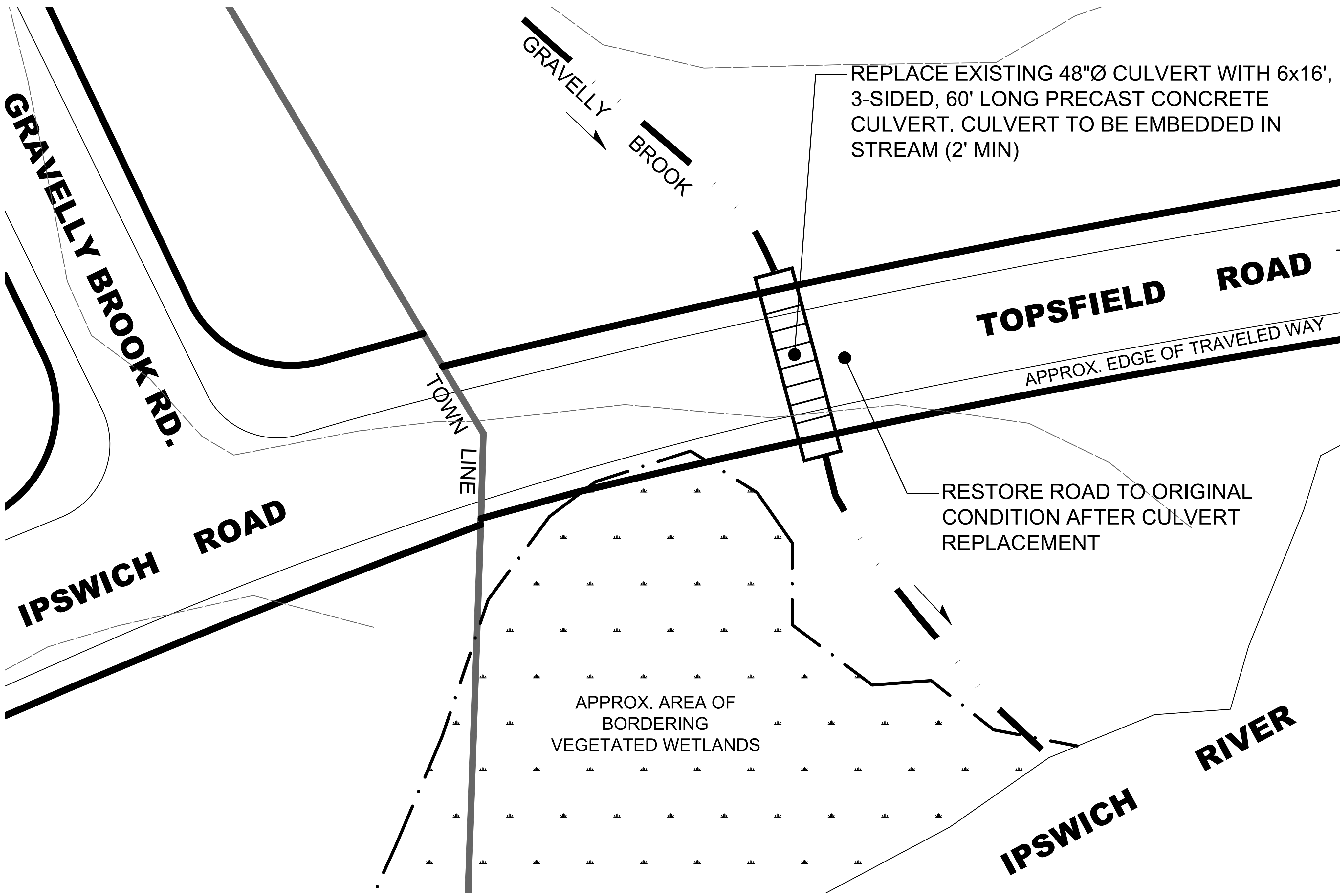
DWG. No. Site 527.dwg

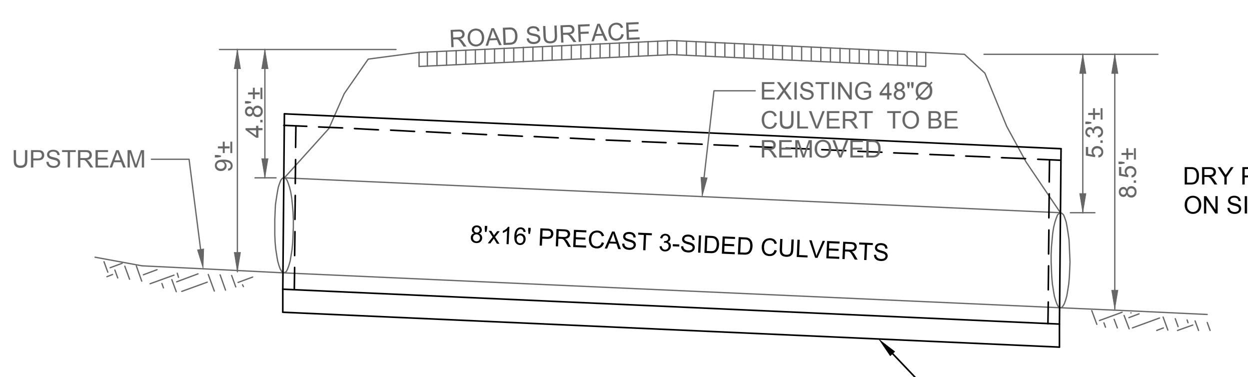
MAI Project: 5900

Ipswich Designs

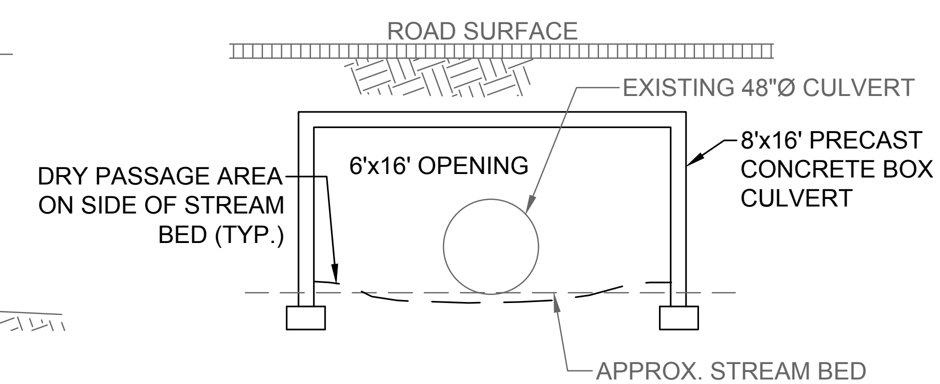
Conceptual designs for the replacement of select road-stream crossings in the Town of Ipswich, MA

4 pages





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=13 FEET. PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.6
10. NAACC CROSSING CODE: xy4266035770903202
11. NAACC SURVEY ID: 9461

CROSSING ID#616
SKETCH PLAN

LOCATED IN

IPSWICH, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 20' DATE: OCT. 27, 2016

10 0 10 20 40

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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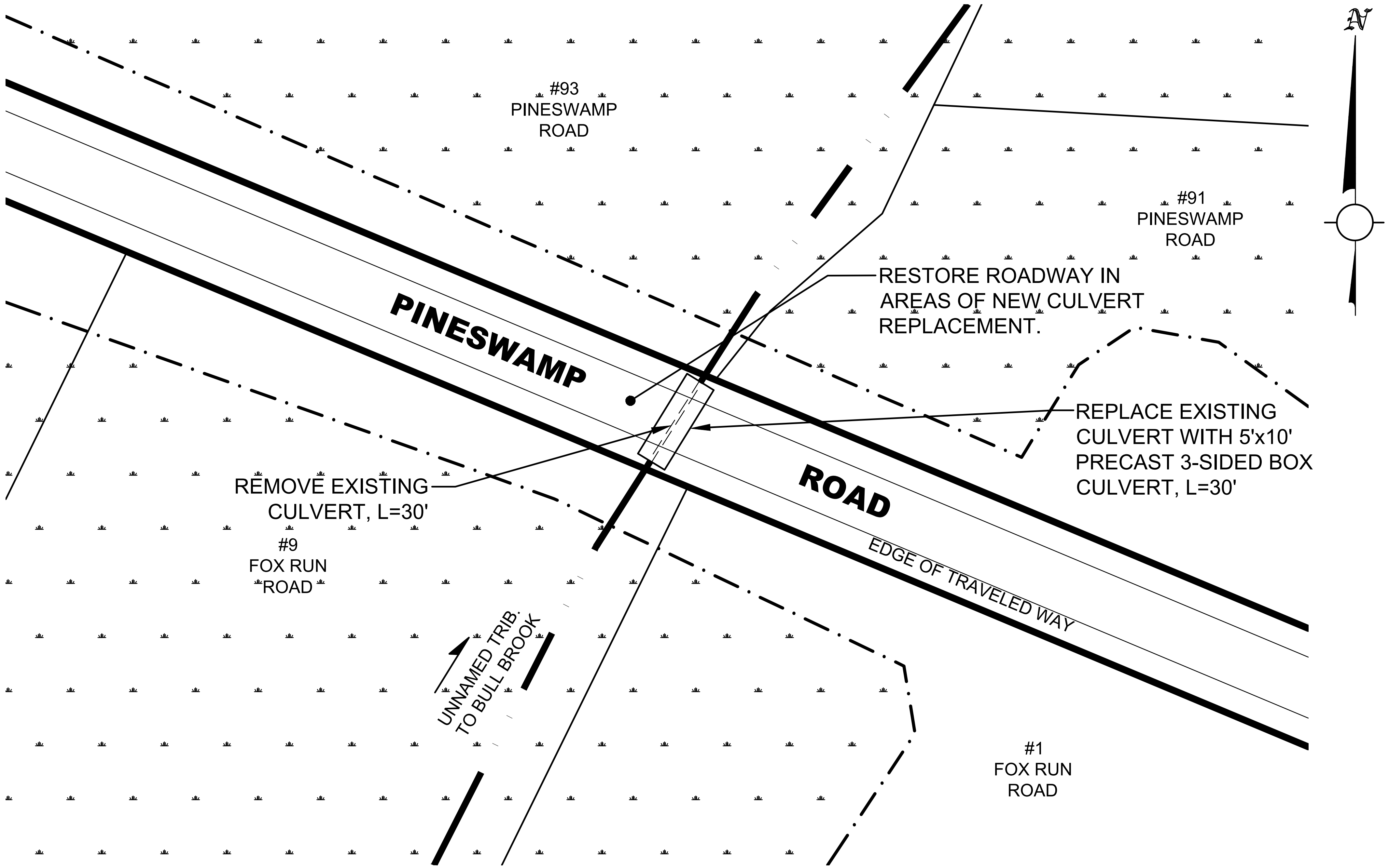
WWW.MERIDIANASSOC.COM

DWG. No. Site 616.dwg

MAI Project: 5900



NOTES:

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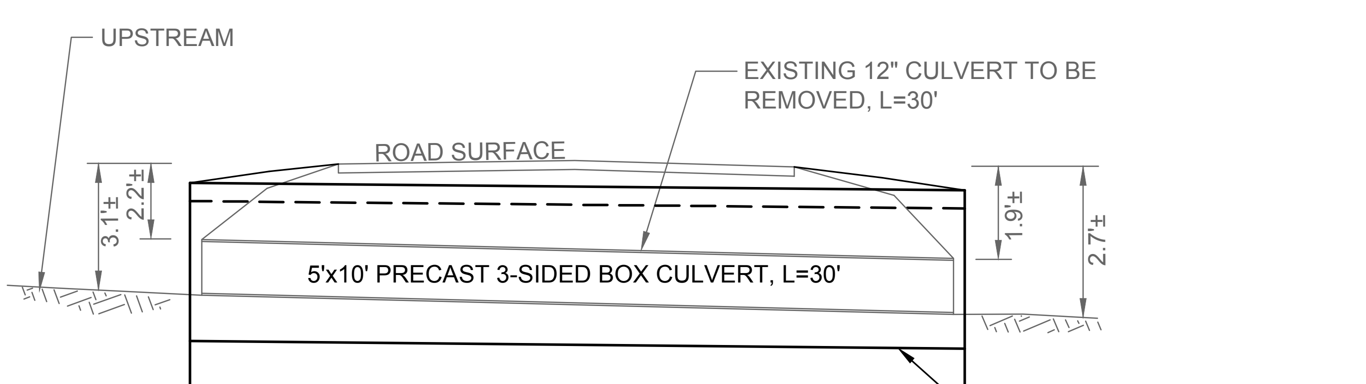
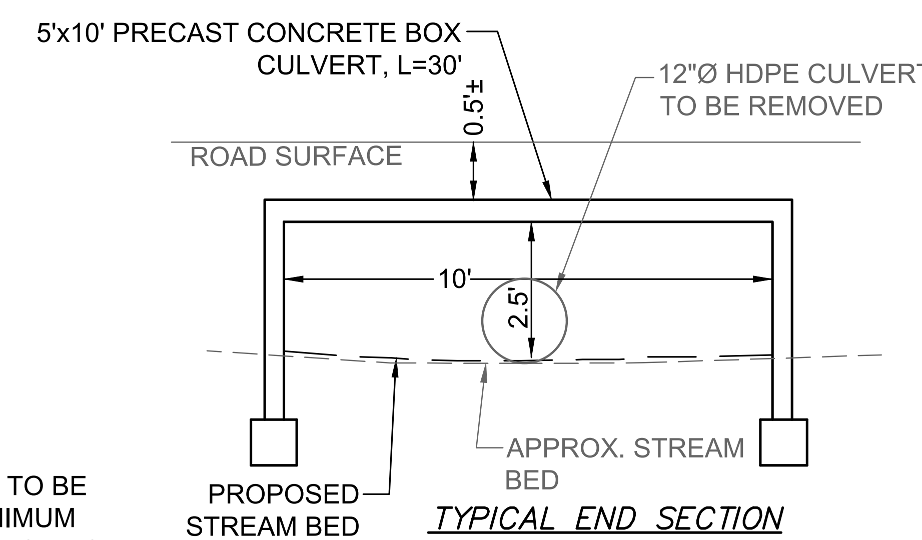
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.83
10. NAACC CROSSING CODE: xy4267422770875074
11. NAACC SURVEY ID: 7584



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#697
SKETCH PLAN

LOCATED IN

IPSWICH, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

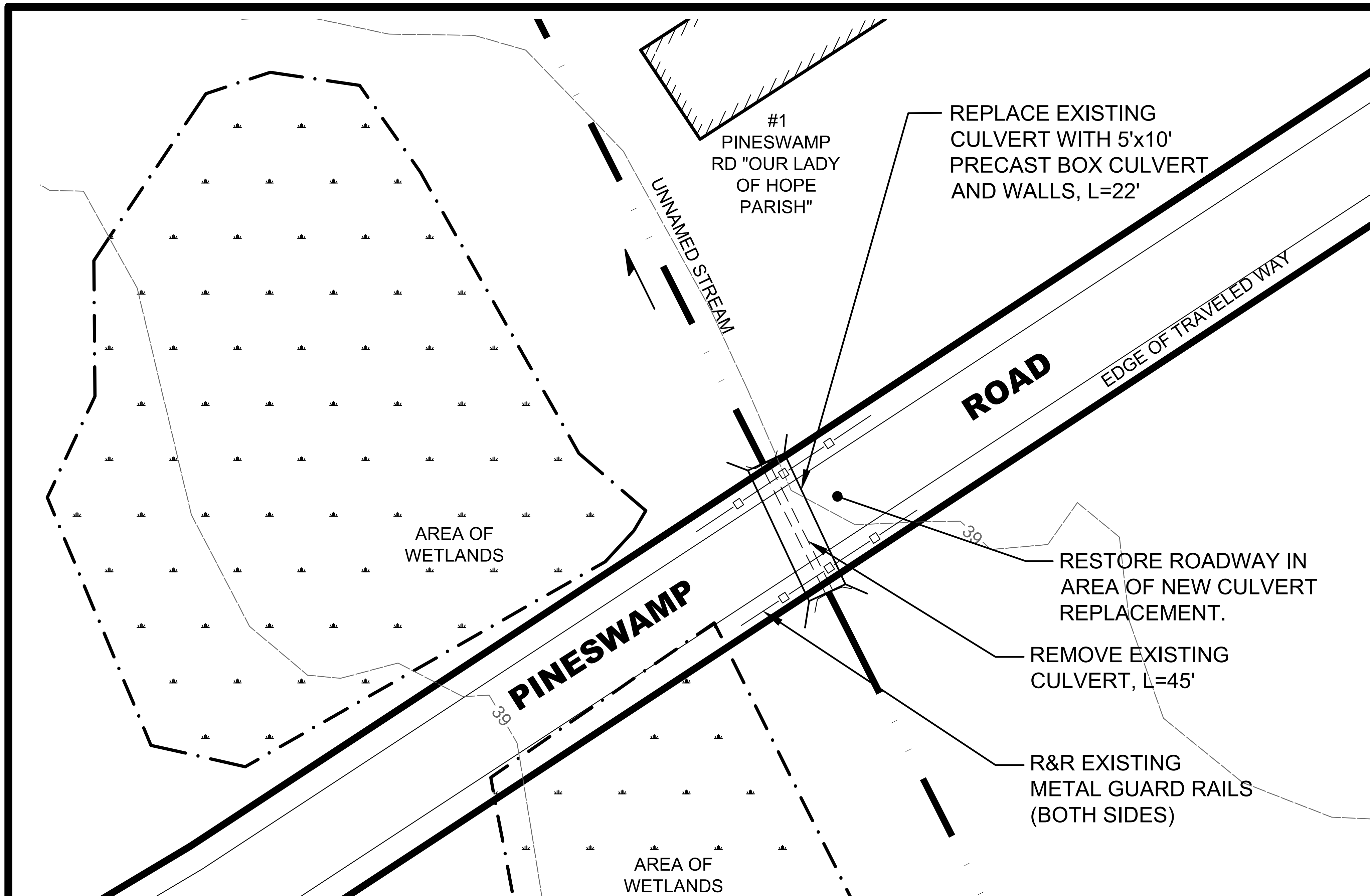
SCALE: 1"= 40' DATE: FEB. 16, 2017

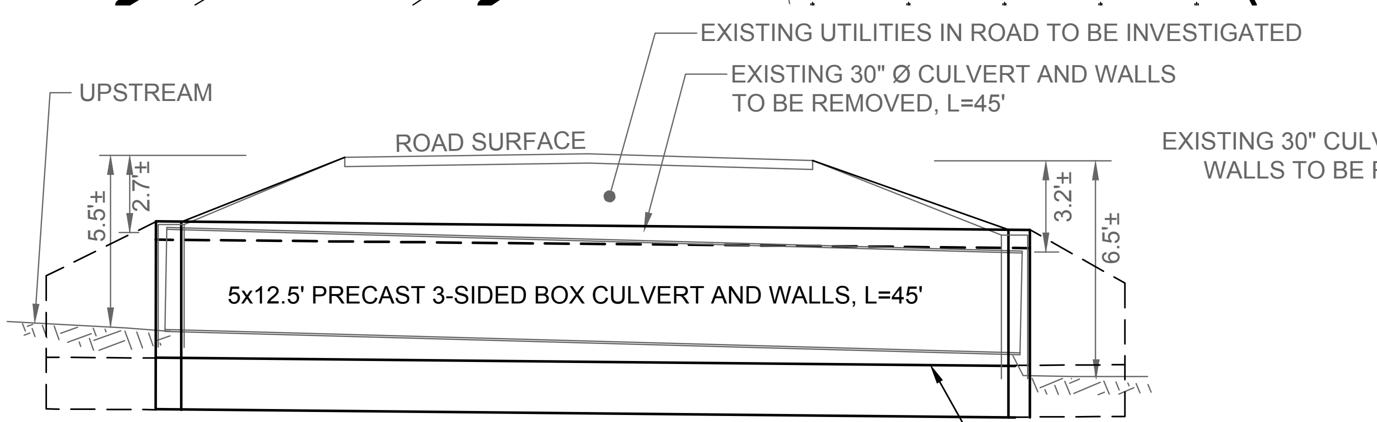
20 0 20 40 80

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

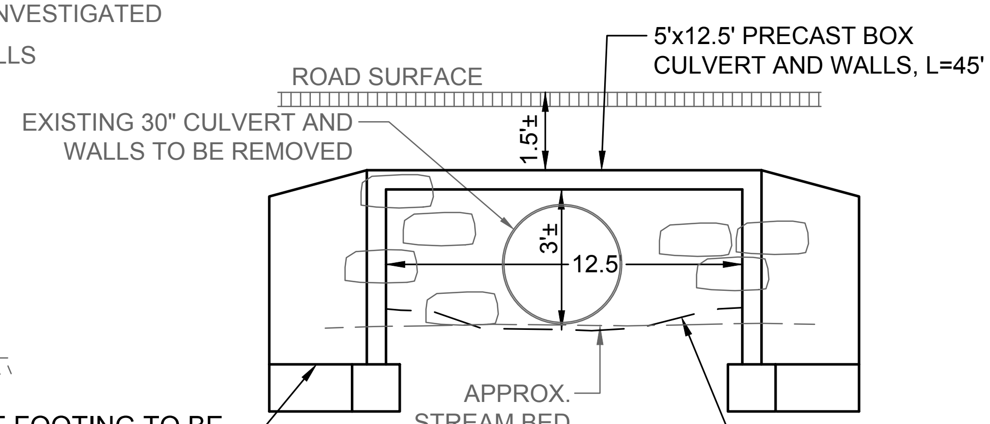
DWG. No. Site 697.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10.3 FEET. PROPOSED CULVERT WIDTH=12.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.83
10. NAACC CROSSING CODE: xy4268309470851892
11. NAACC SURVEY ID: 4742

CROSSING ID#753
SKETCH PLAN

LOCATED IN

IPSWICH, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 25, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

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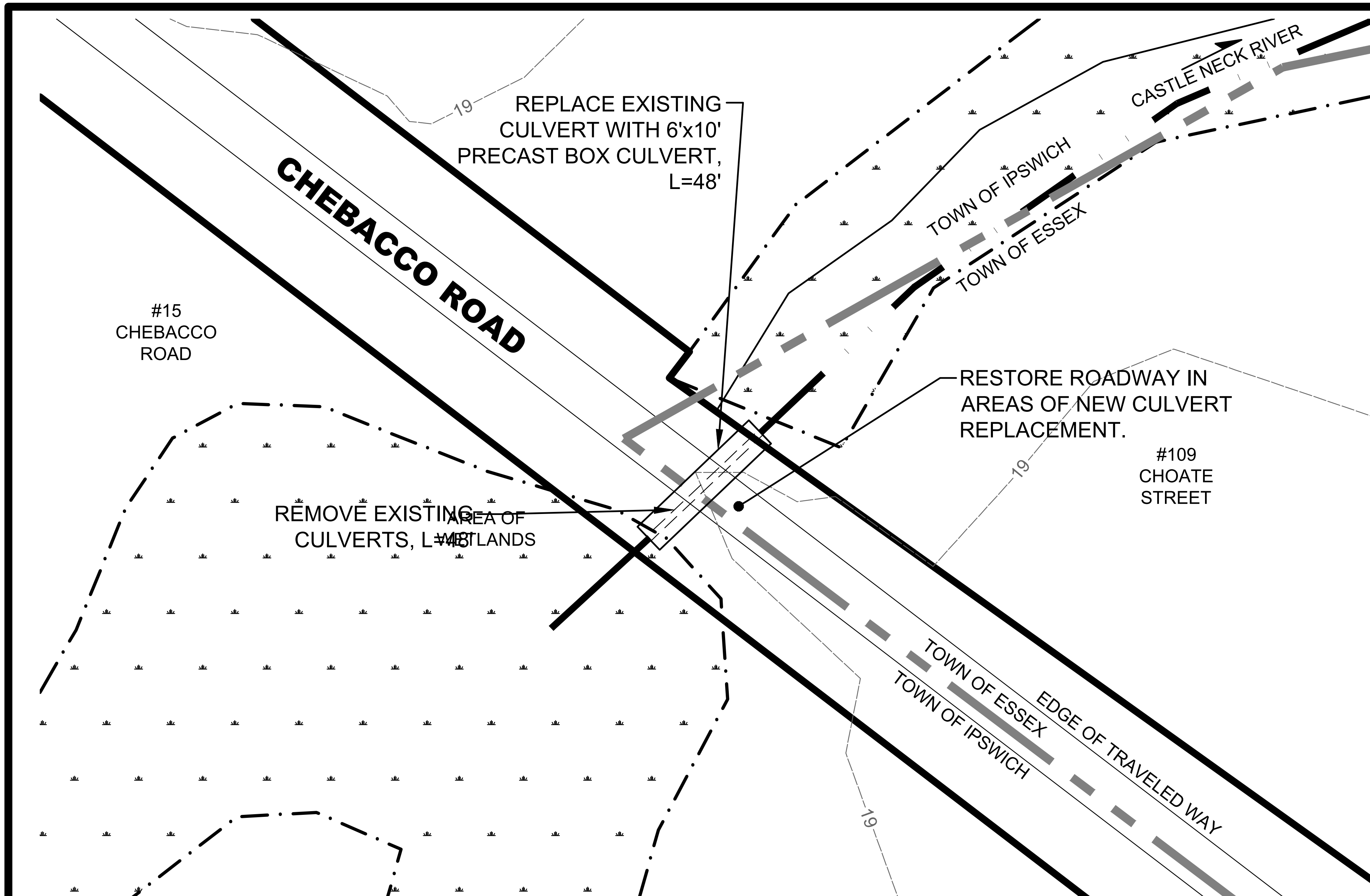
DWG. No. Site 753.dwg

MAI Project: 5900



NOTES:

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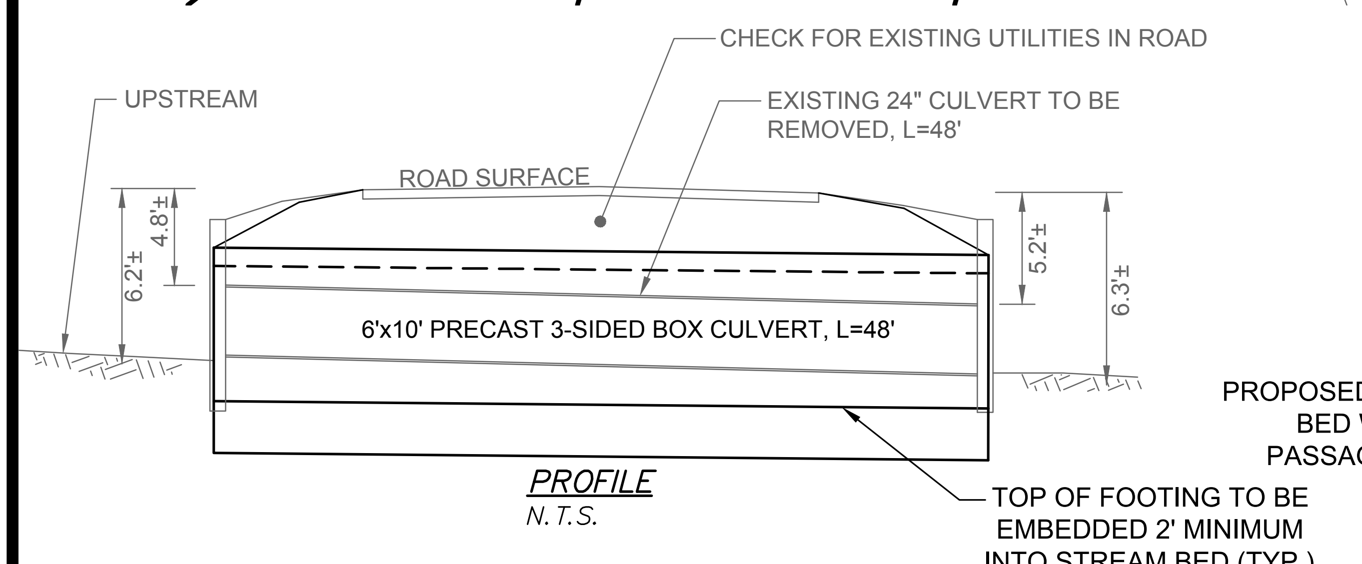
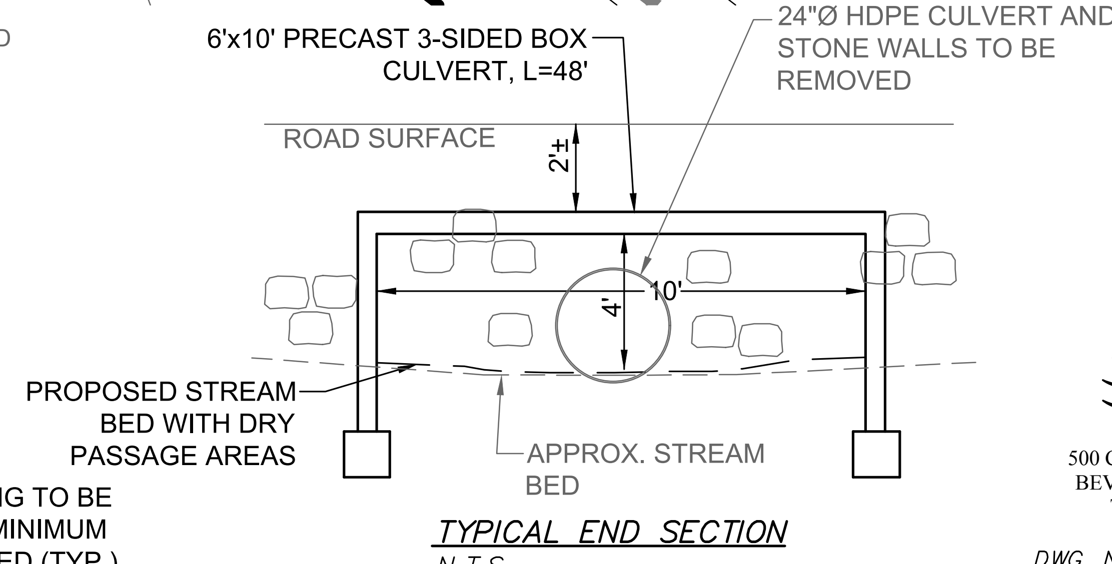
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=6.5 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.83
10. NAACC CROSSING CODE: xy4264713770816032
11. NAACC SURVEY ID: 42688



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#6610
SKETCH PLAN
LOCATED IN
IPSWICH, MASSACHUSETTS
(ESSEX COUNTY)
PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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TELEPHONE: (508) 871-7030

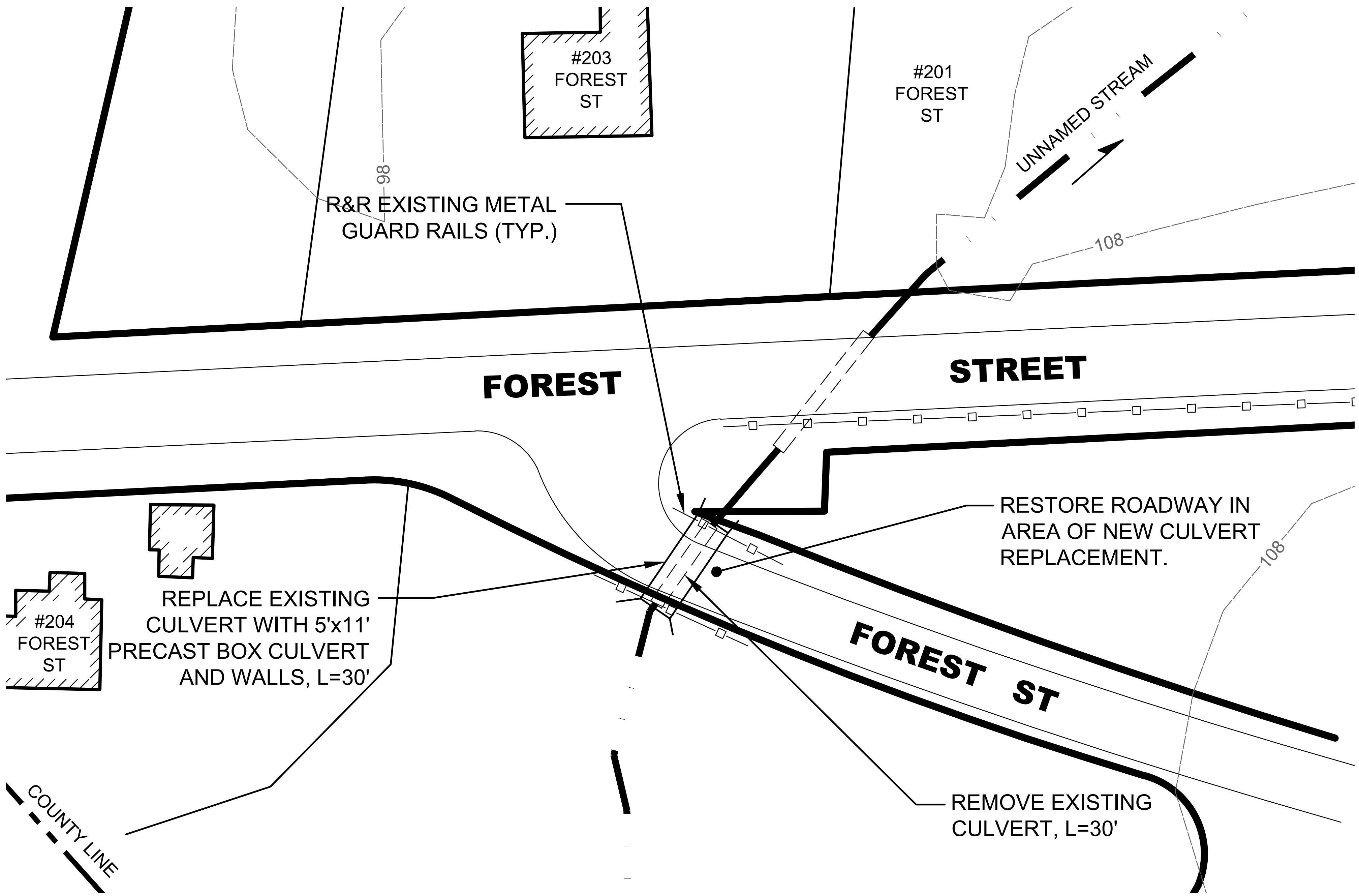
WWW.MERIDIANASSOC.COM

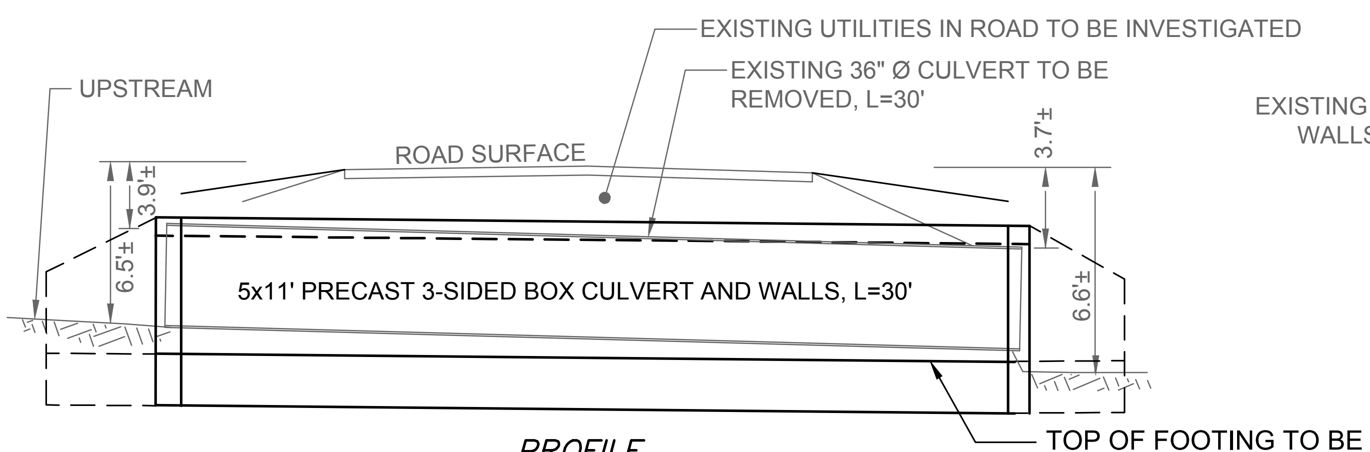
DWG. No. Site 6610.dwg MAI Project: 5900

Middleton Designs

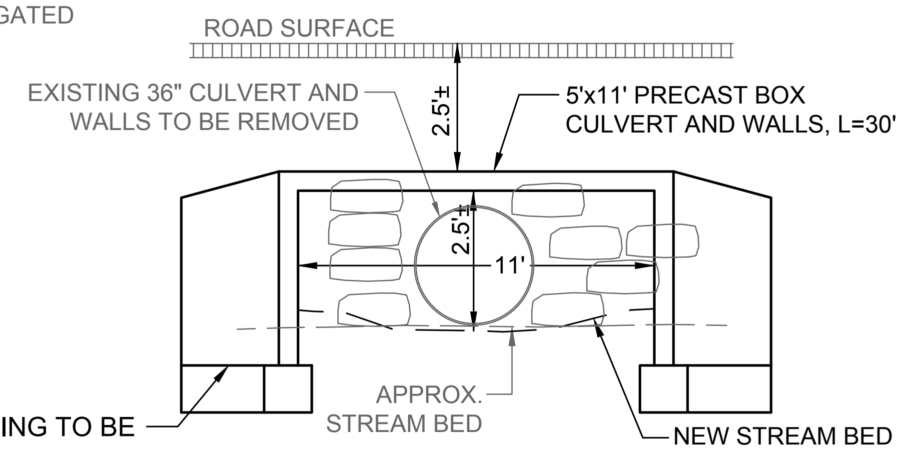
Conceptual designs for the replacement of select road-stream crossings in the Town of Middleton, MA

3 pages





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8.6 FEET. PROPOSED CULVERT WIDTH=11 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.91
10. NAACC CROSSING CODE: xy4260479071056091
11. NAACC SURVEY ID: 7699

CROSSING ID#273
SKETCH PLAN

LOCATED IN

MIDDLETON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MAR. 5, 2017

15 0 15 30 60

MERIDIAN
ASSOCIATES

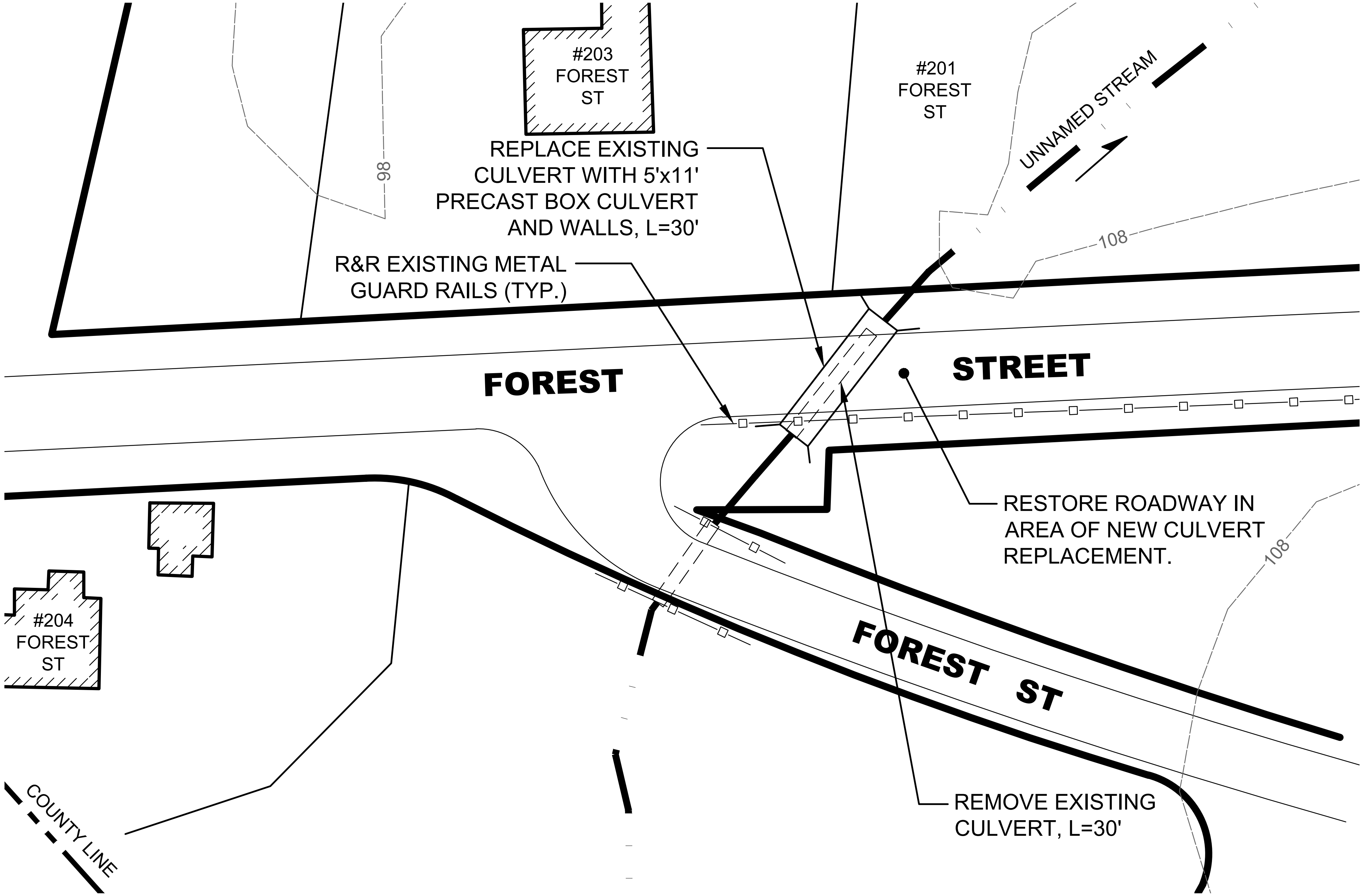
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

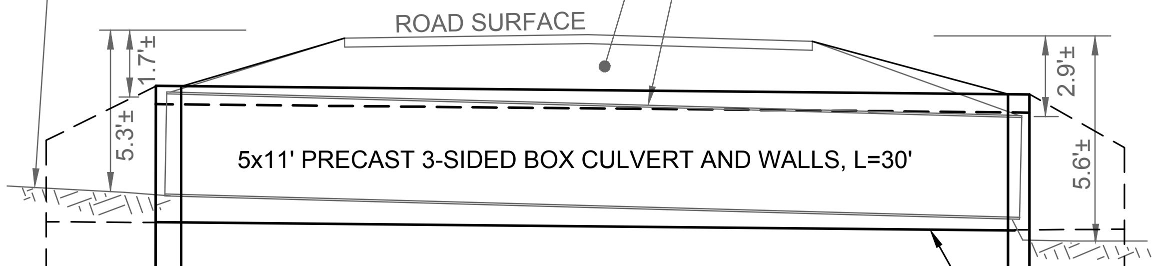
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

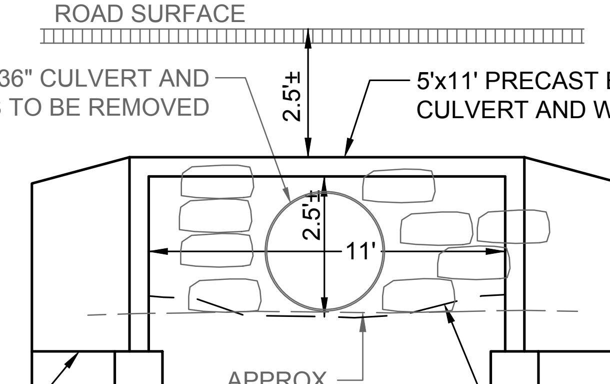
DWG. No. Site 273.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8.6 FEET. PROPOSED CULVERT WIDTH=11 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.90
10. NAACC CROSSING CODE: xy4260464071056253
11. NAACC SURVEY ID: 7700

CROSSING ID#274
SKETCH PLAN

LOCATED IN

MIDDLETON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MAR. 5, 2017

15 0 15 30 60

MERIDIAN
ASSOCIATES

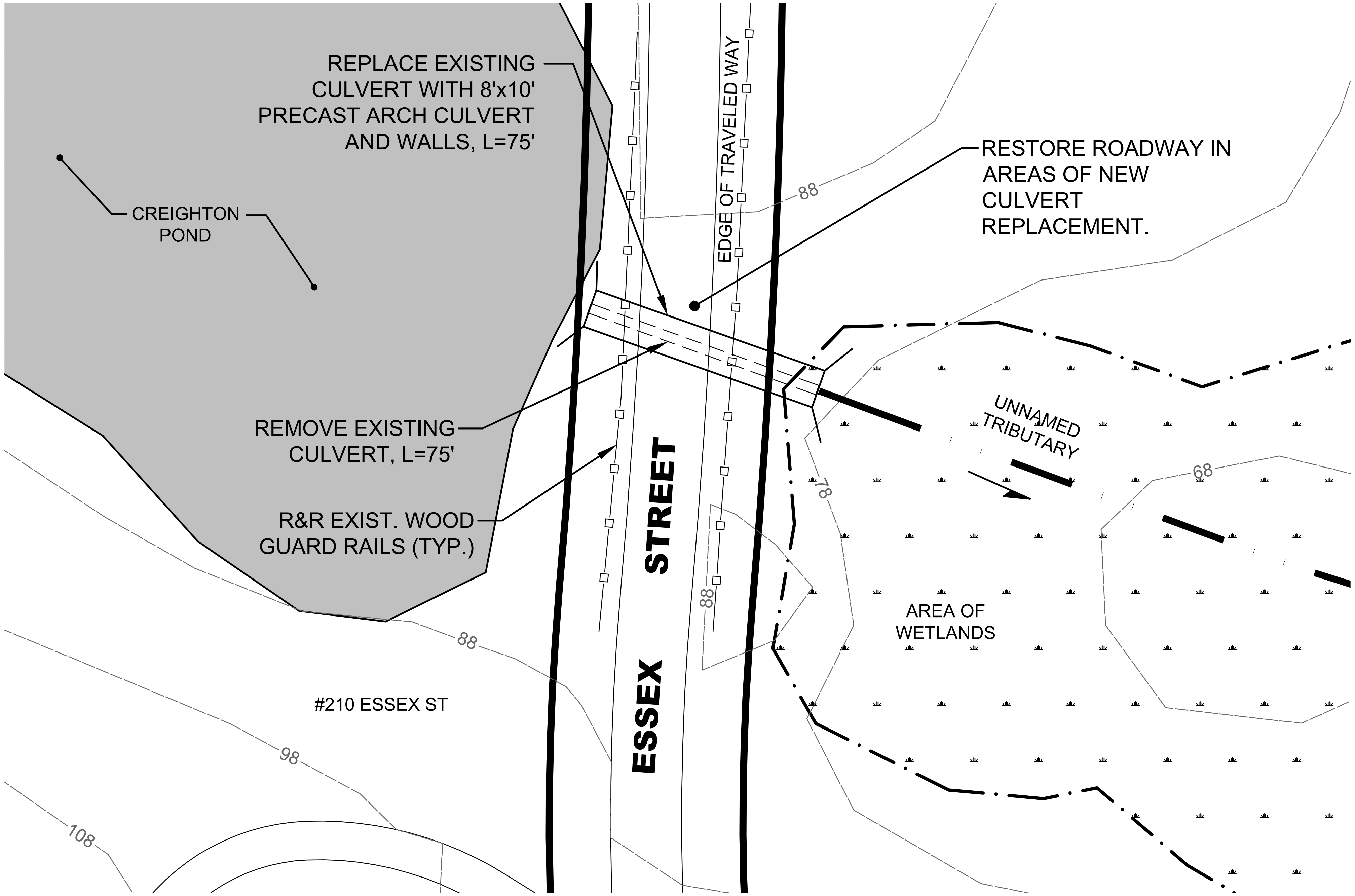
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

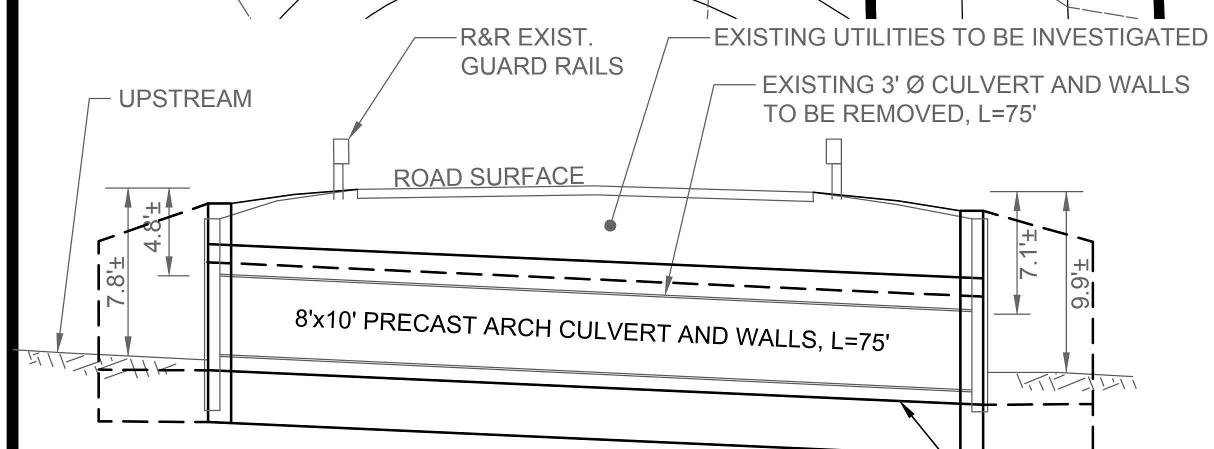
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 274.dwg

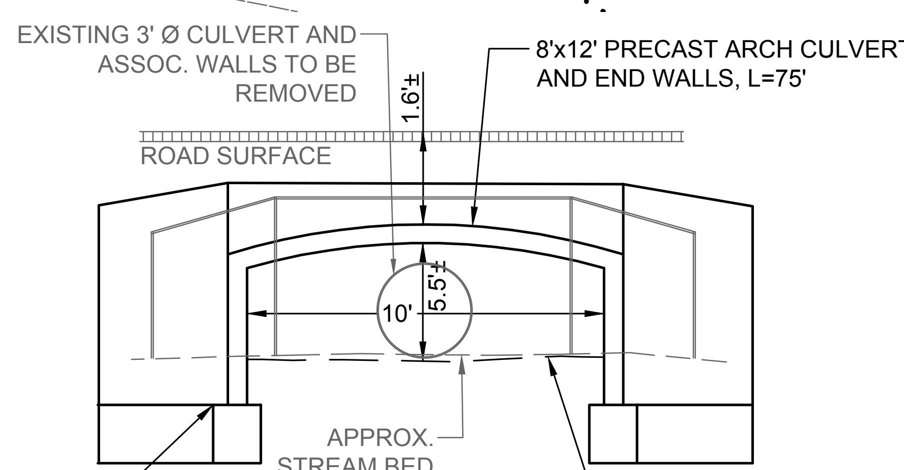
MAI Project: 5900





PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

NOTES:

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.73
10. NAACC CROSSING CODE: xy4262610471040686
11. NAACC SURVEY ID: 6547

CROSSING ID#380
SKETCH PLAN

LOCATED IN

MIDDLETON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 10, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

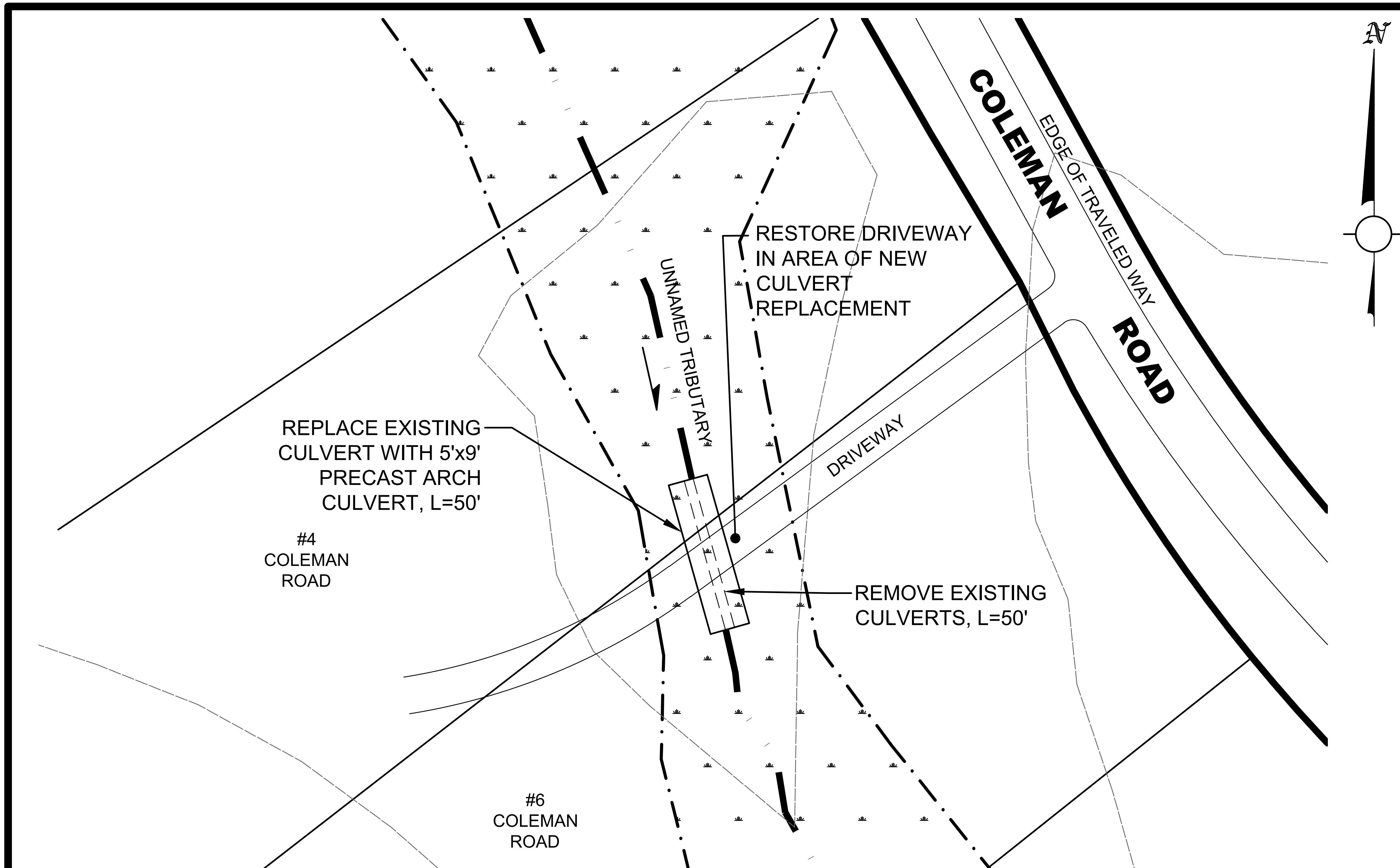
DWG. No. Site 380.dwg

MAI Project: 5900

Newbury Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Newbury, MA

12 pages



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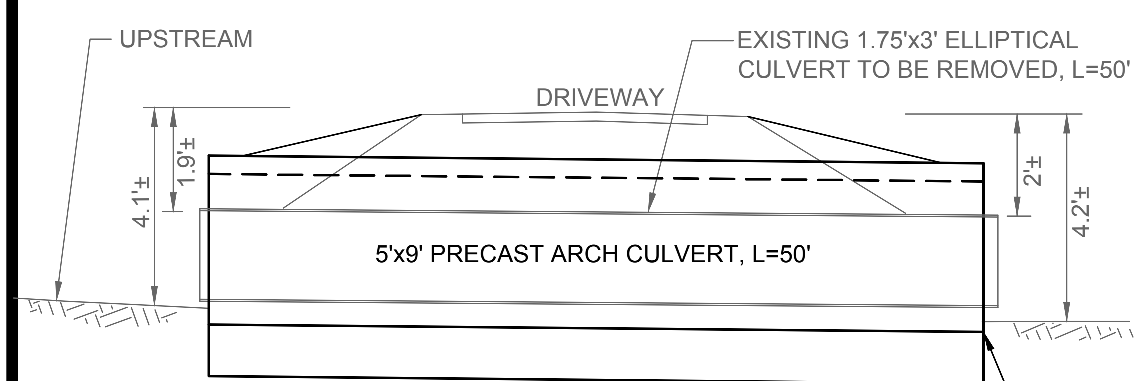
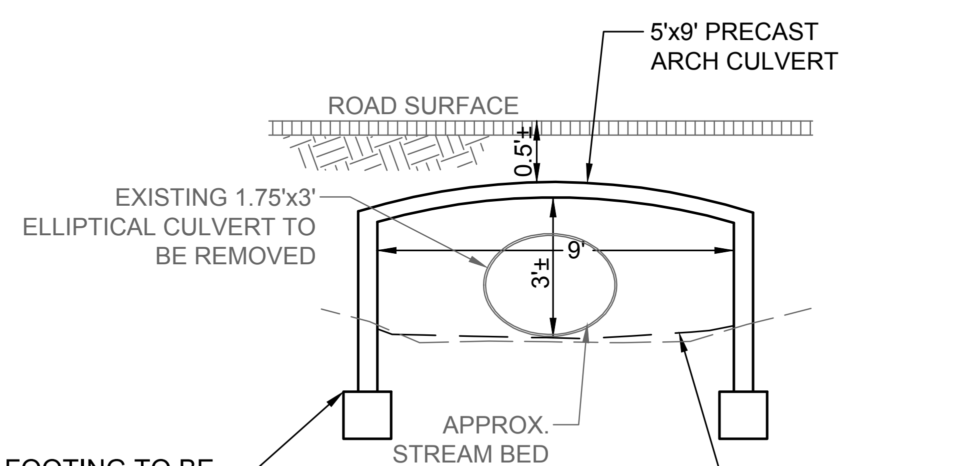
8. APPROXIMATE BANKFULL WIDTH=10.6 FEET. PROPOSED CULVERT WIDTH=9 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.54
10. NAACC CROSSING CODE: xy4274075270916901
11. NAACC SURVEY ID: 10059



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#1049
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

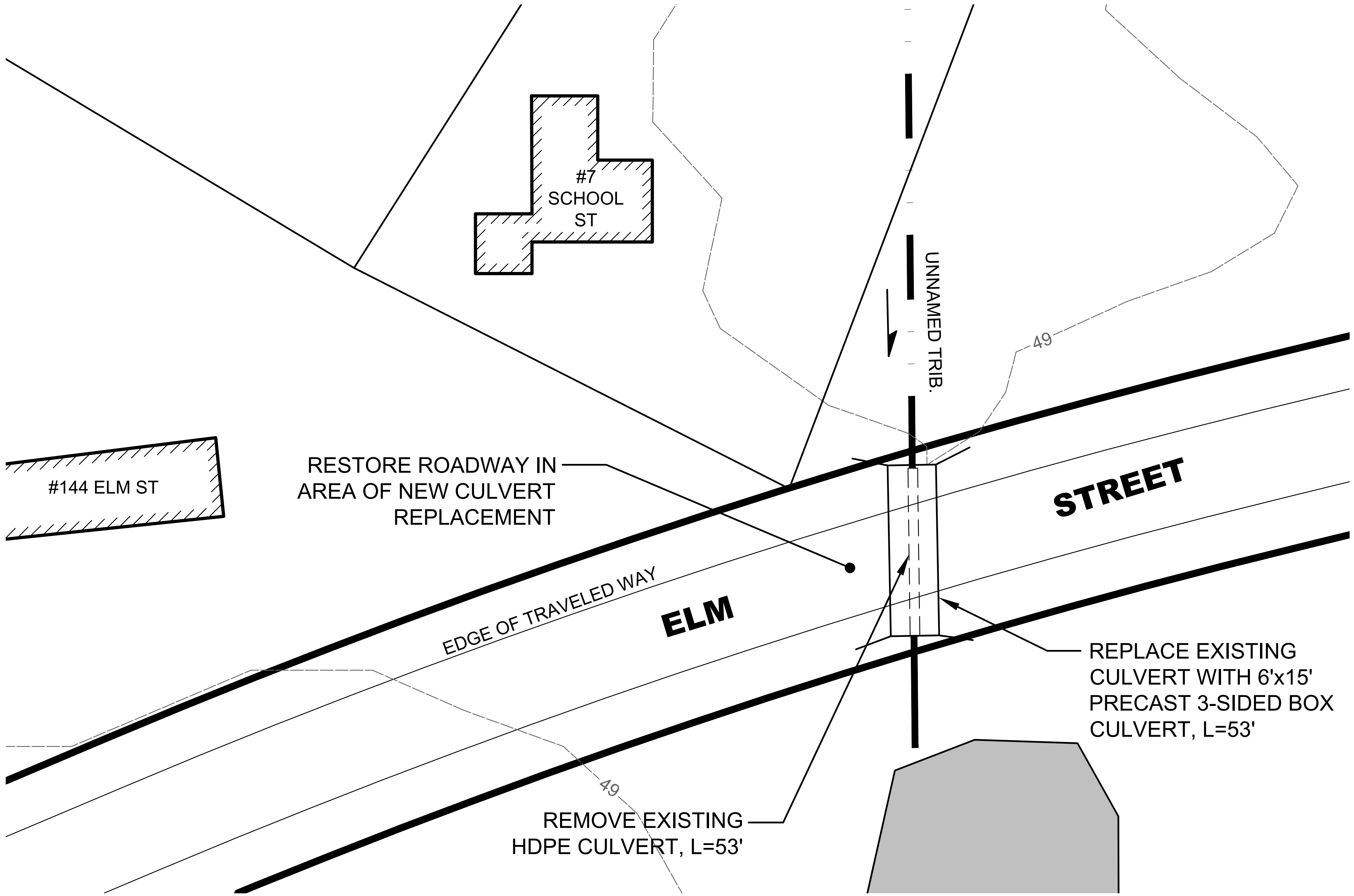
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 1049.dwg

MAI Project: 5900



NOTES:

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6. *STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.*
7. *ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.*
8. *APPROXIMATE BANKFULL WIDTH=13 FEET. PROPOSED CULVERT WIDTH=15 FEET.*
9. *MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.1*
10. *NAACC CROSSING CODE: xy4274206070921196*
11. *NAACC SURVEY ID: 10060*

CROSSING ID#1053 SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

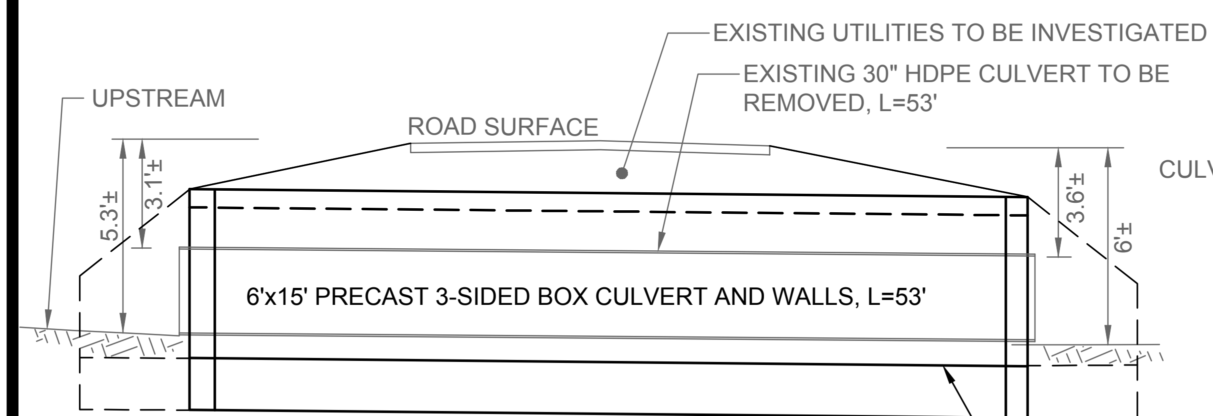
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 1, 2017

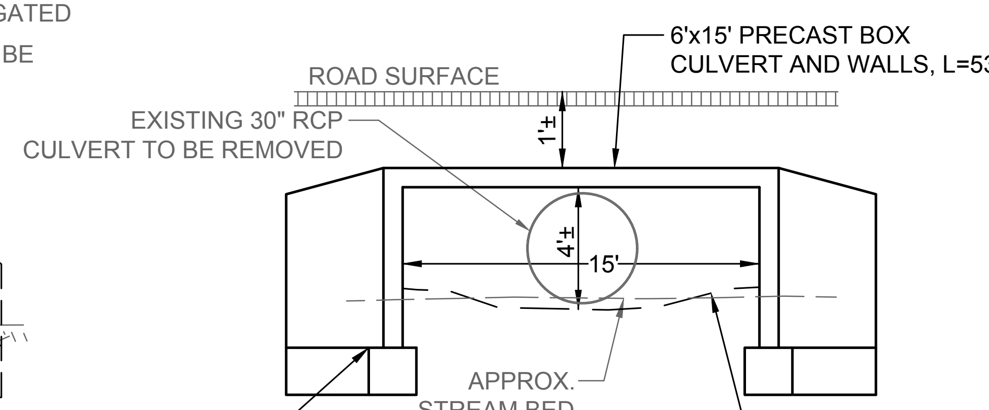
15 0 15 30 60



PROFILE

N.T.S.

TOP OF FOOTING TO BE
EMBEDDED 2' MINIMUM
INTO STREAM BED (TYP.)

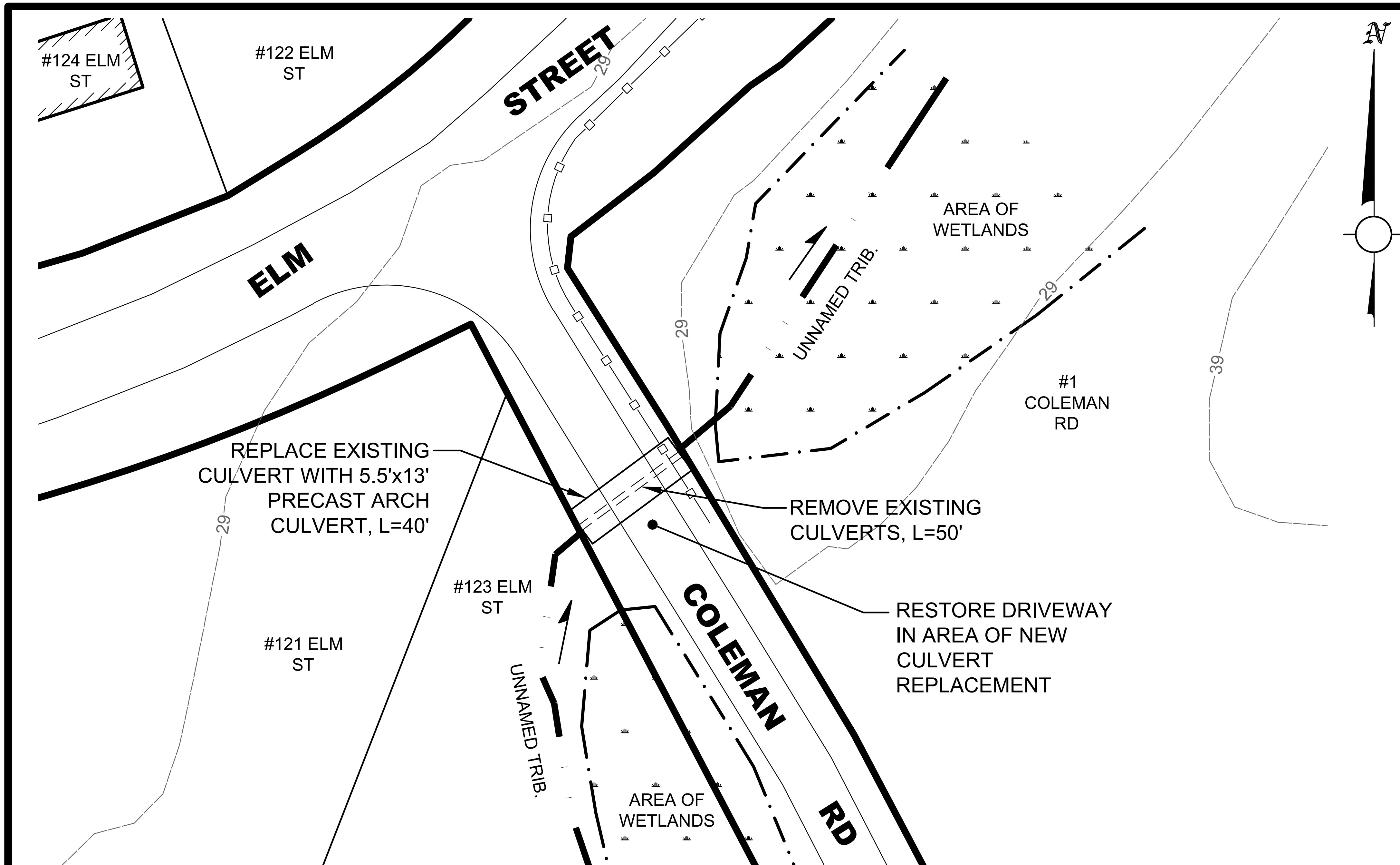


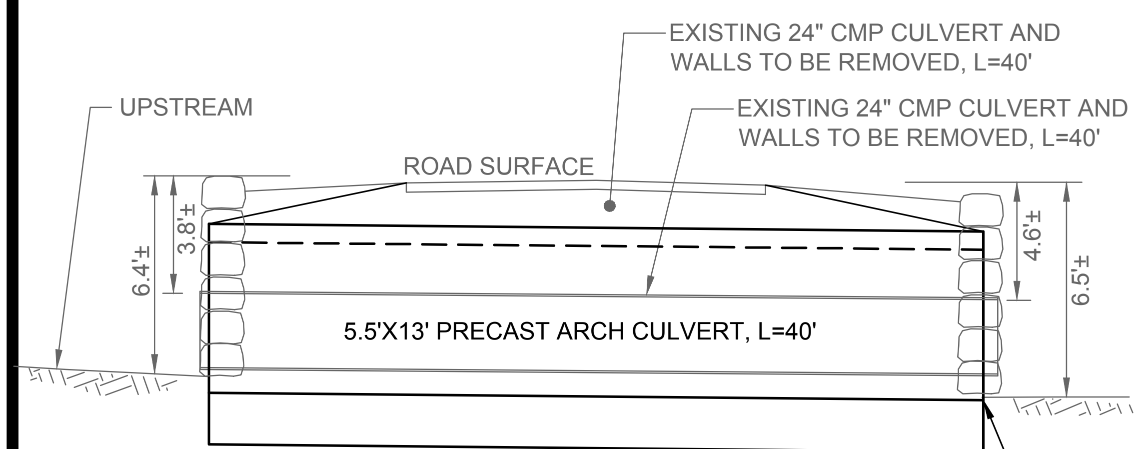
TYPICAL END SECTION

N.T.S.

MERIDIAN
ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

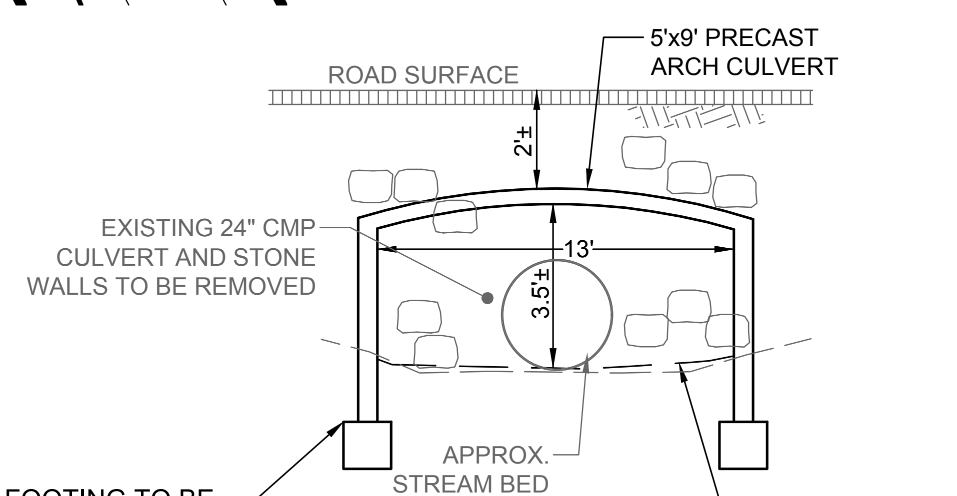
DWG. No. Site 1053.dwg *MAI Project: 5900*





PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10.6 FEET. PROPOSED CULVERT WIDTH=13 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.9
10. NAACC CROSSING CODE: xy4274235670917458
11. NAACC SURVEY ID: 9168

CROSSING ID#1054
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

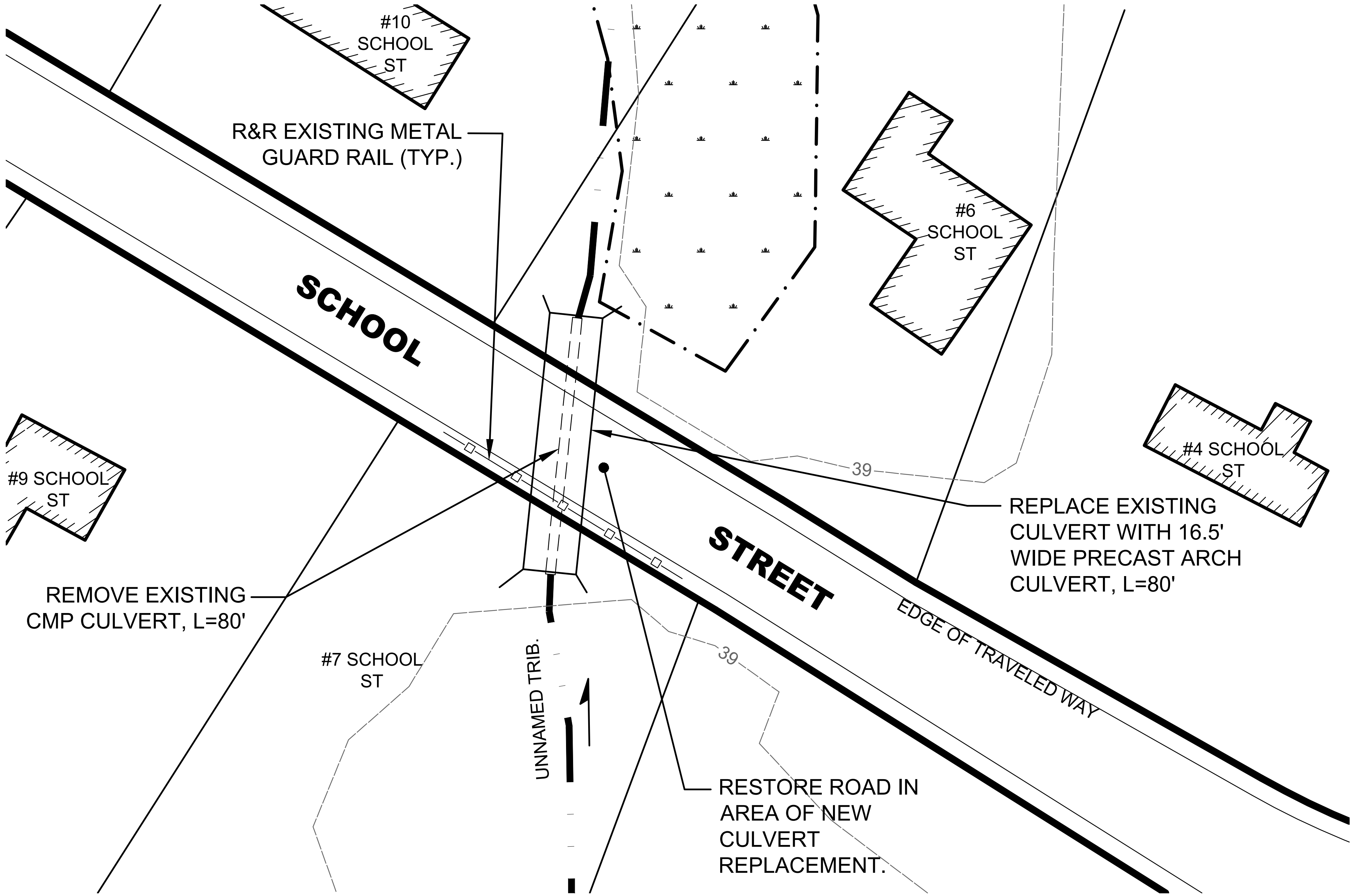
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

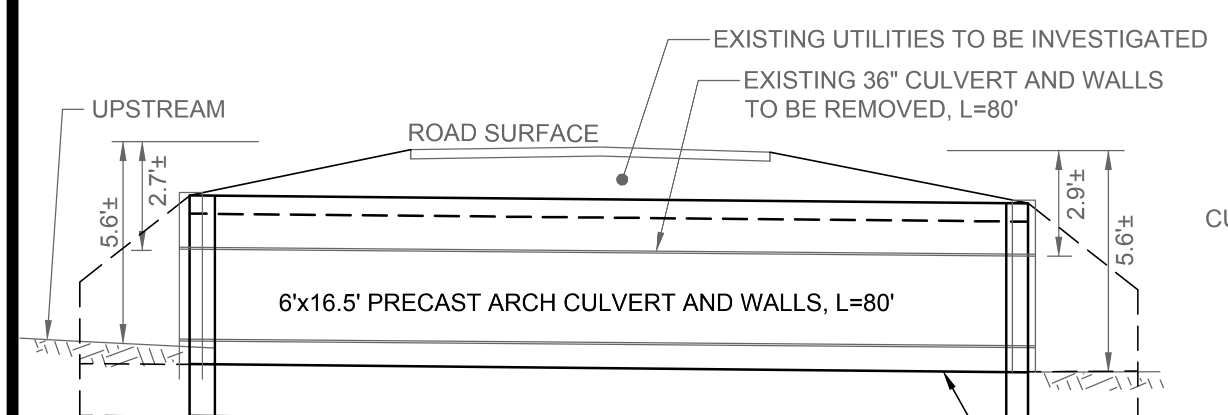
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 1054dwg

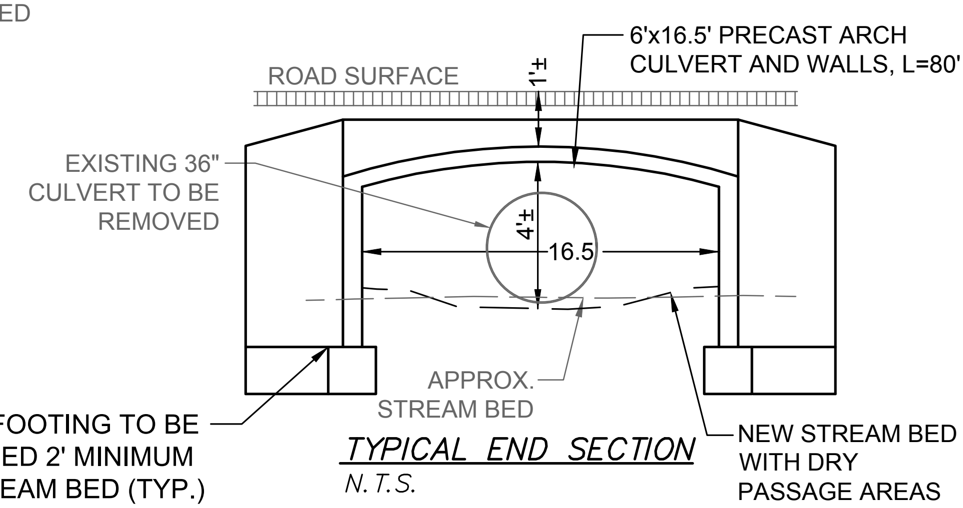
MAI Project: 5900





PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

N

NOTES:

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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10.1 FEET. PROPOSED CULVERT WIDTH=16.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4274282770921225
11. NAACC SURVEY ID: 10799

CROSSING ID#1056
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

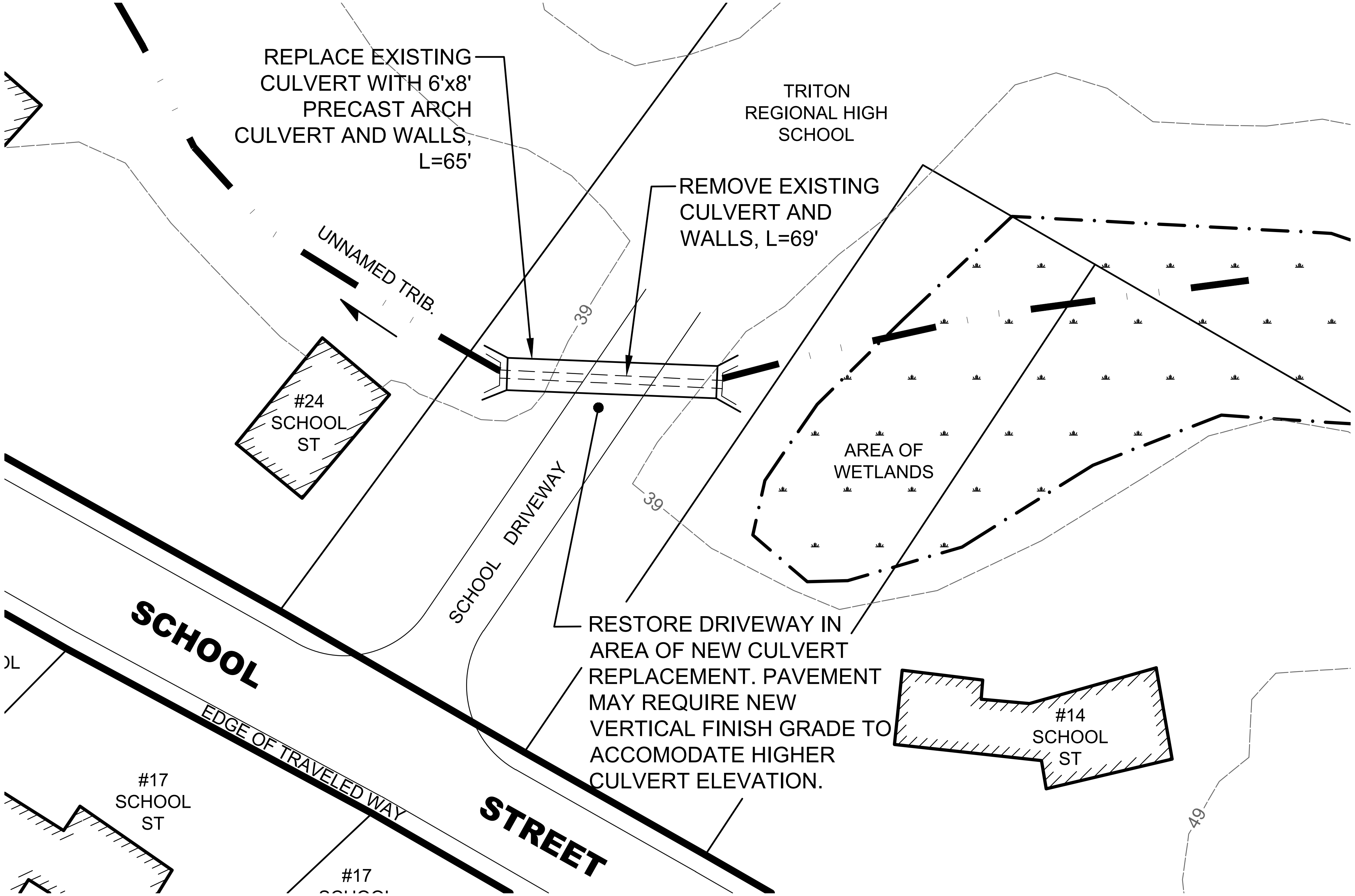
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

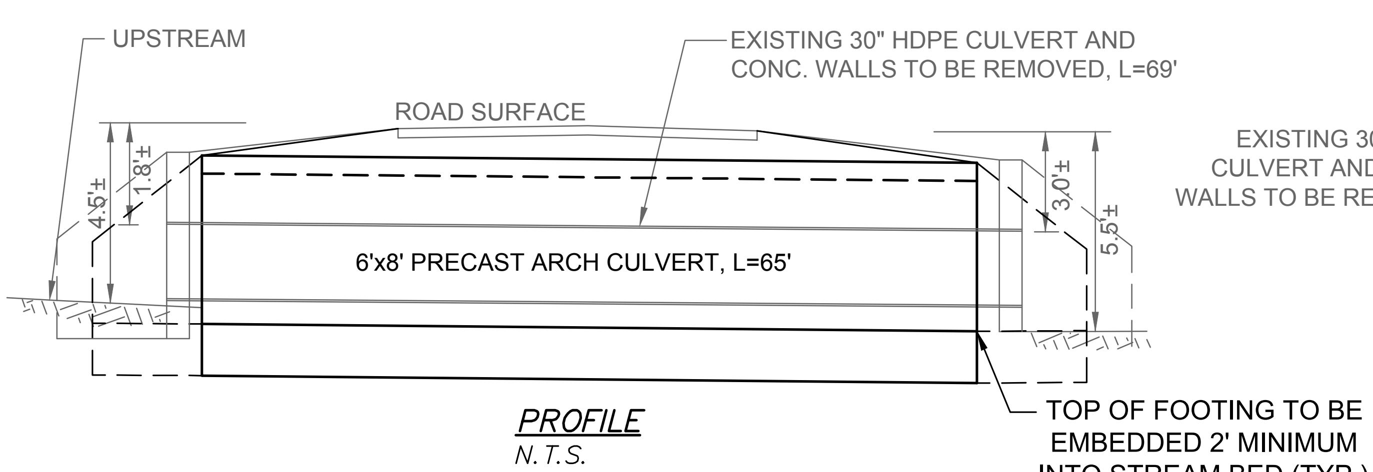
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

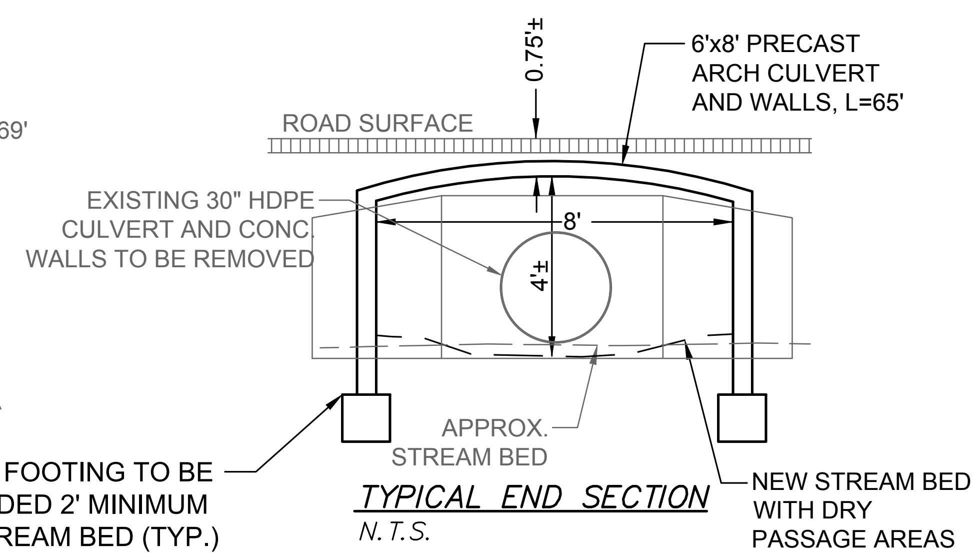
DWG. No. Site 1056.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=7.3 FEET. PROPOSED CULVERT WIDTH=14 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.70
10. NAACC CROSSING CODE: xy4274384770922610
11. NAACC SURVEY ID: 10062

CROSSING ID#1058 SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

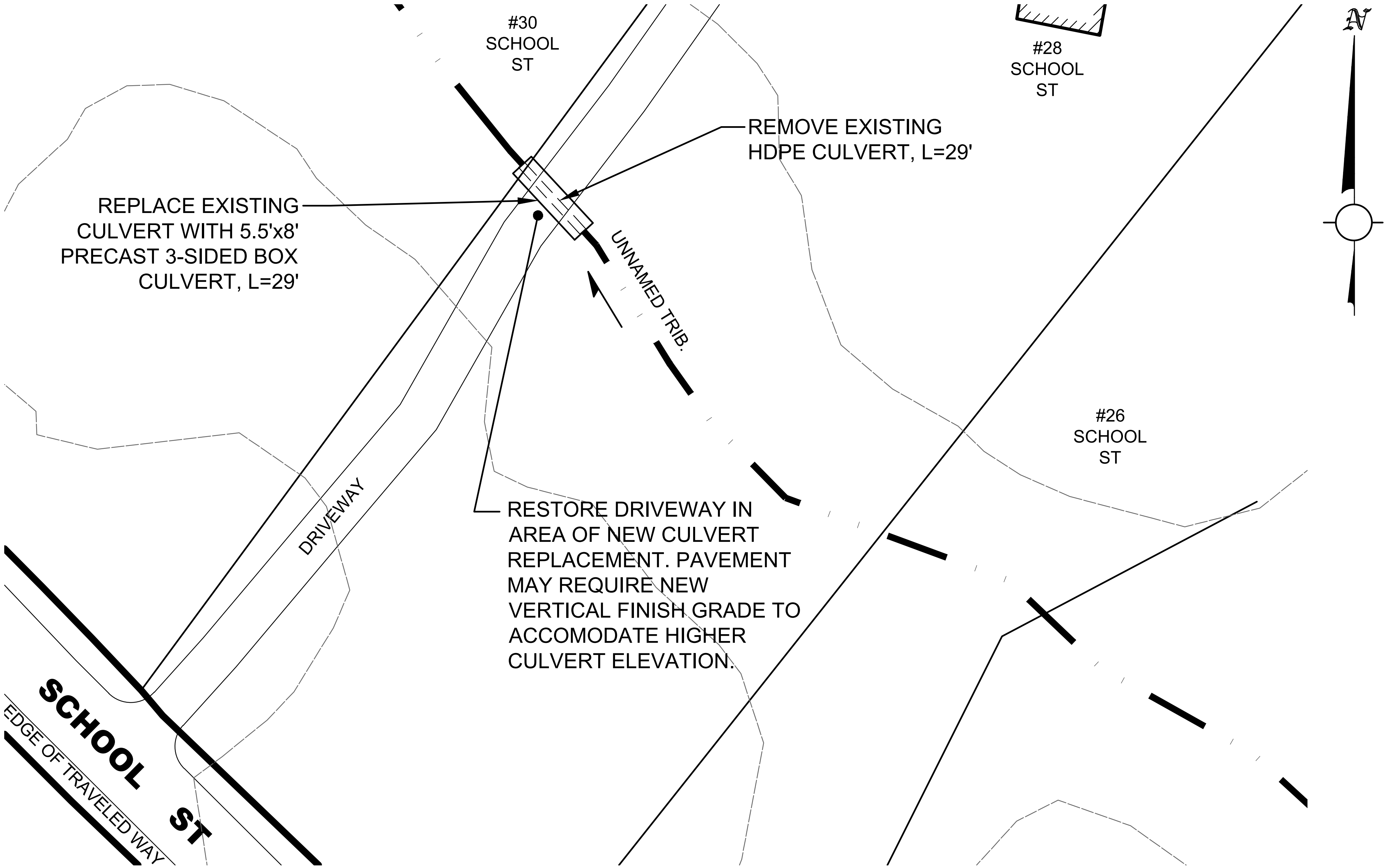
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 1058.dwg

MAI Project: 5900



NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
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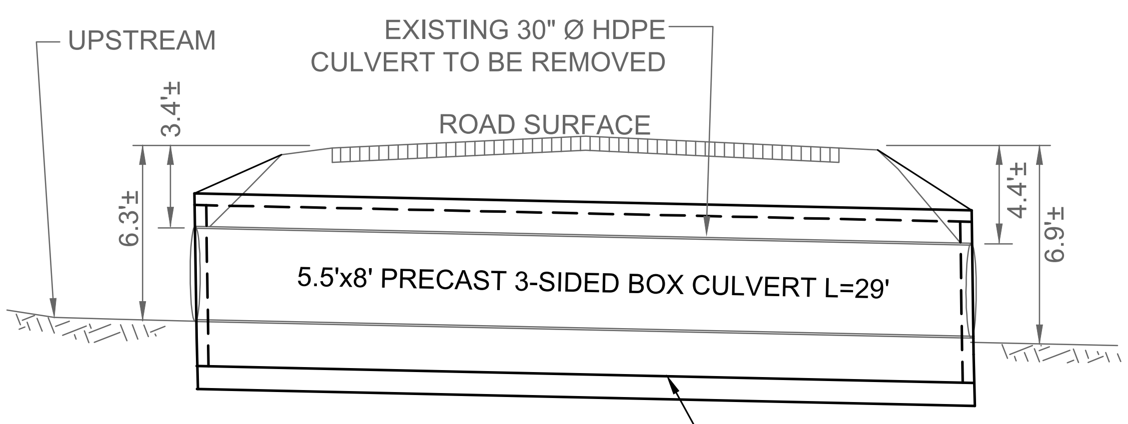
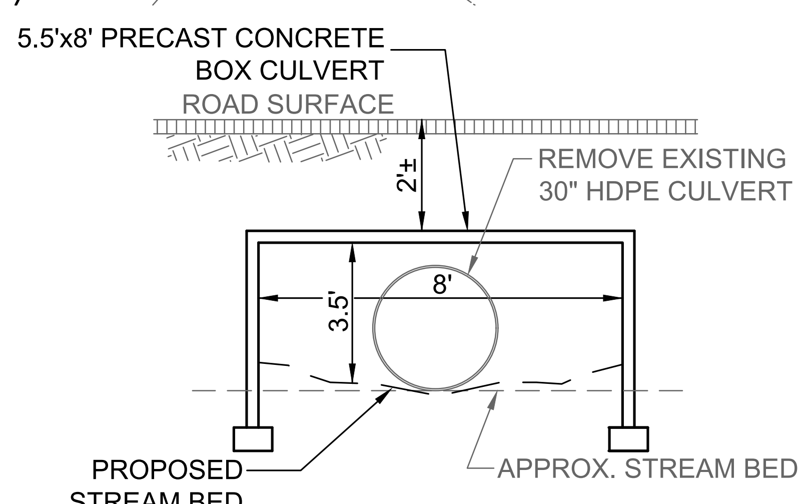
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=6.7 FEET. PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.96
10. NAACC CROSSING CODE: xy42745132709224552
11. NAACC SURVEY ID: 10063



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#1069
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

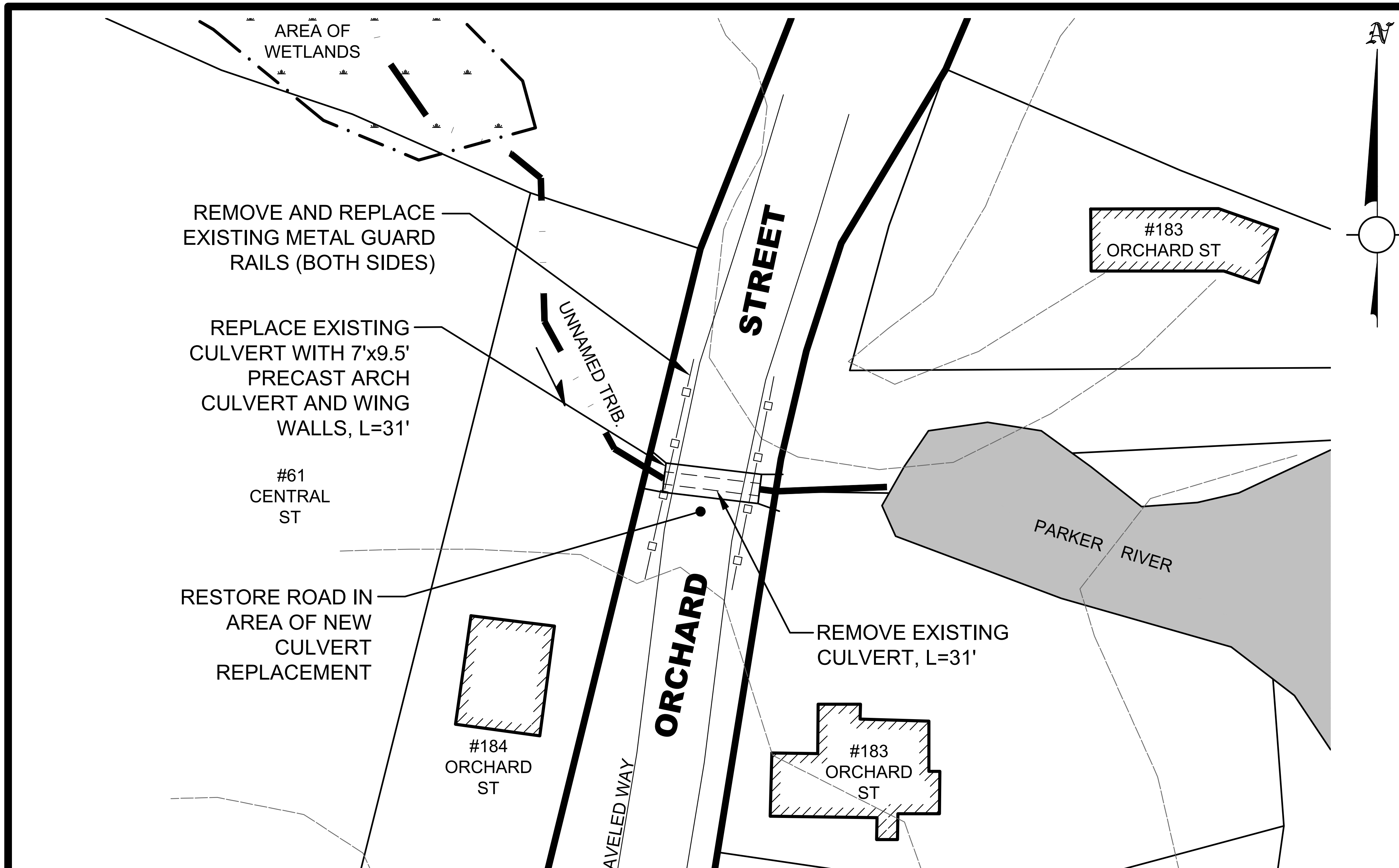
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 1069.dwg

MAI Project: 5900



NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
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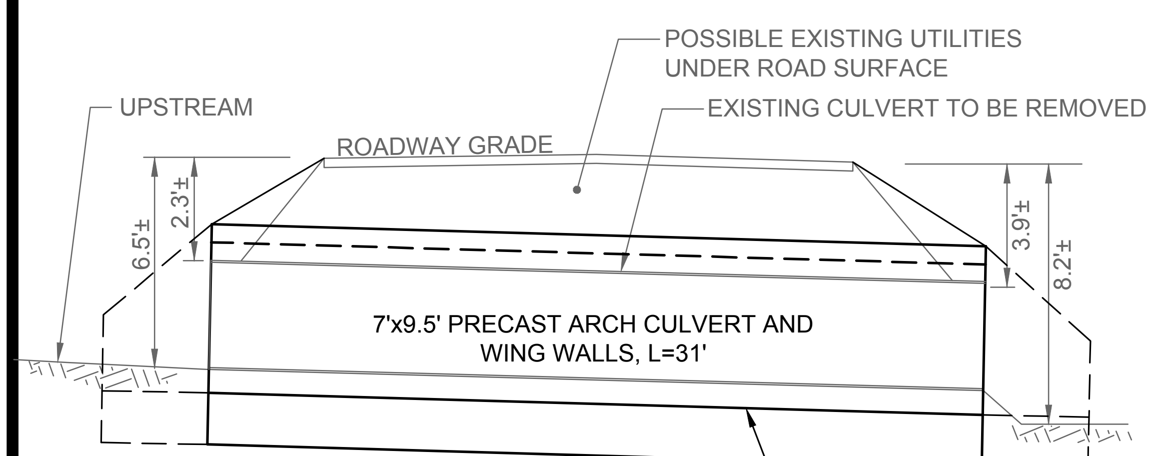
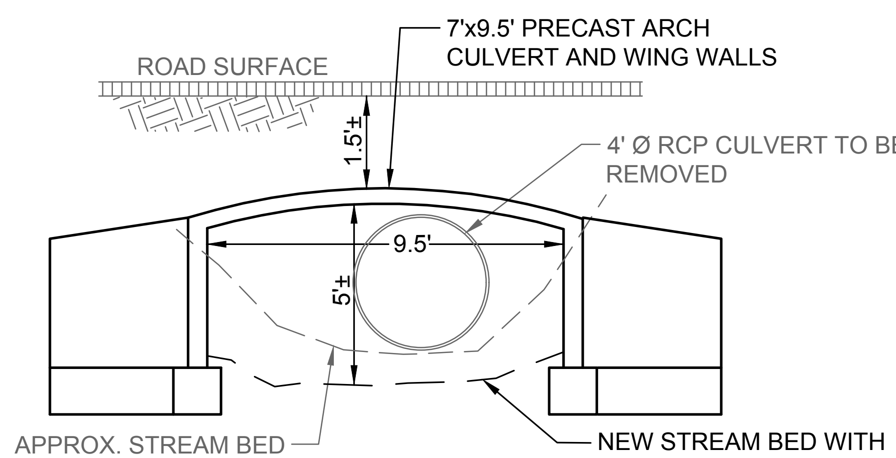
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=4.6 FEET. PROPOSED CULVERT WIDTH=9.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.5
10. NAACC CROSSING CODE: xy4275128670929289
11. NAACC SURVEY ID: 10169



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#1094 SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

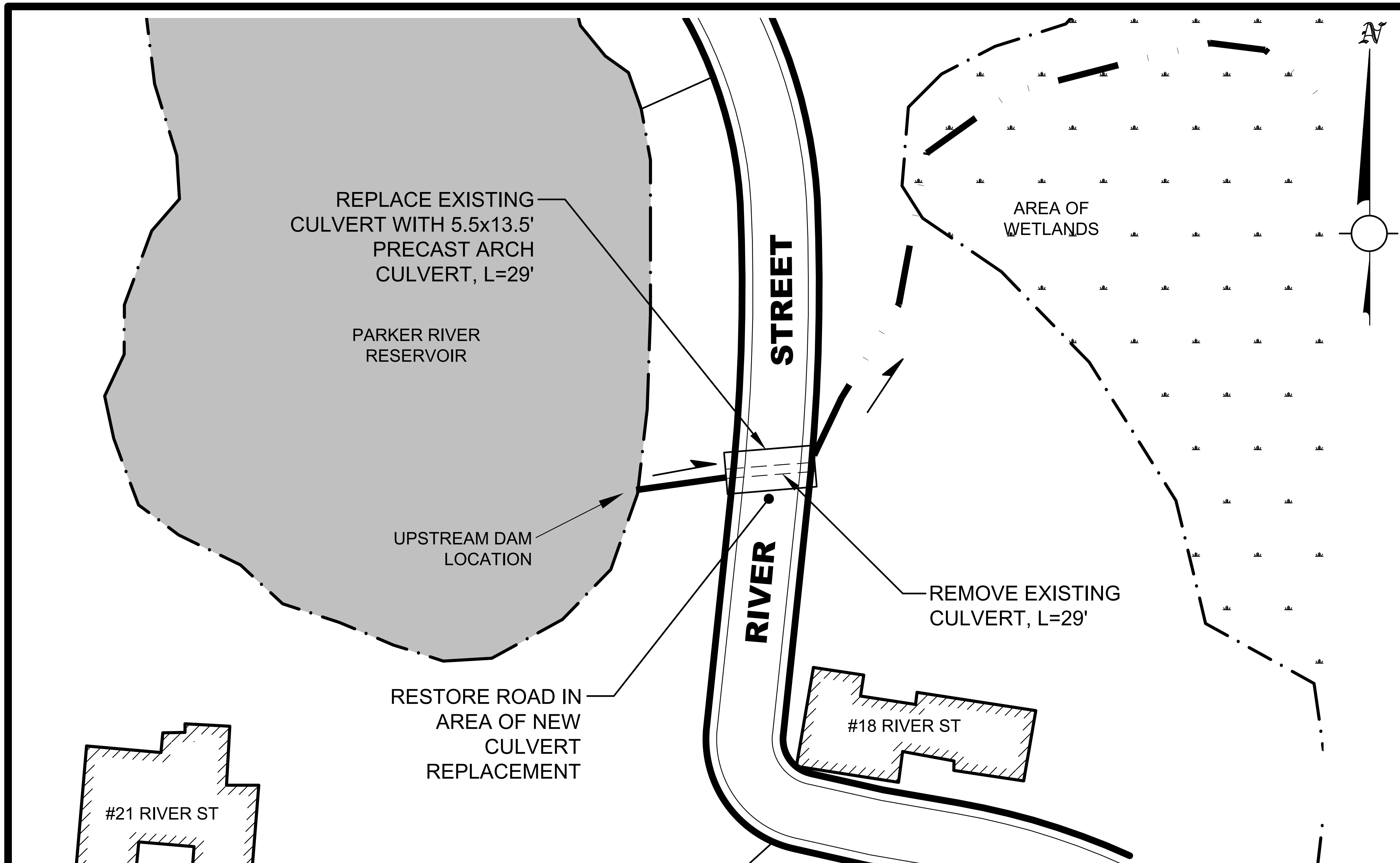
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 1094.dwg

MAI Project: 5900



NOTES:

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2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=11 FEET. PROPOSED CULVERT WIDTH=13.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.1
10. NAACC CROSSING CODE: xy4275479770953151
11. NAACC SURVEY ID: 10171

CROSSING ID#1099
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

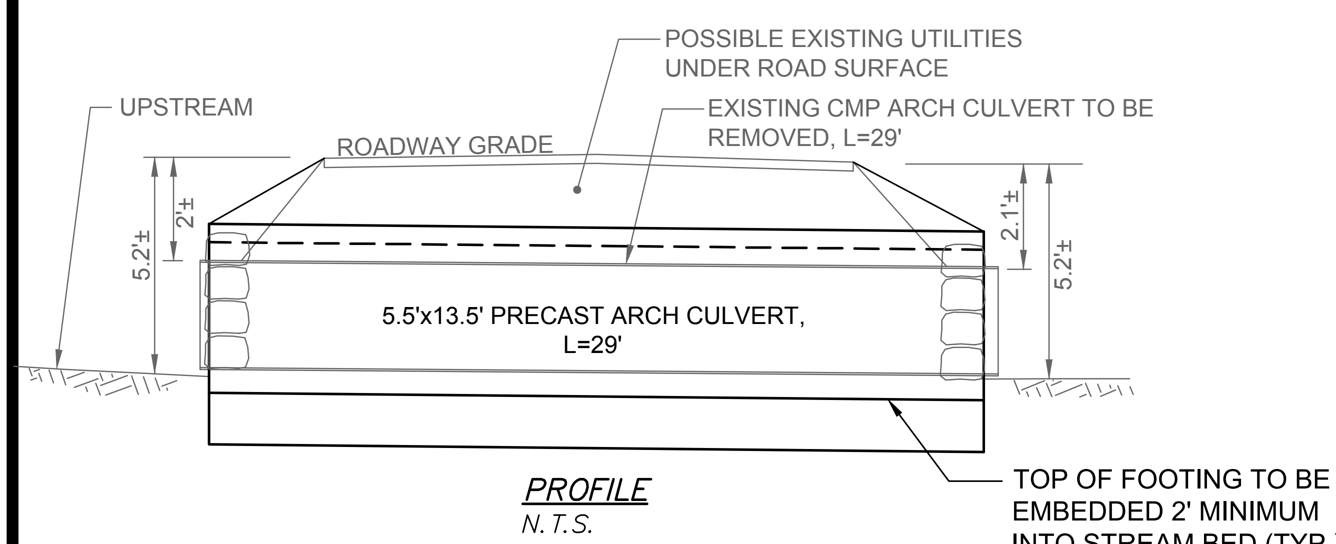
(ESSEX COUNTY)

PREPARED FOR

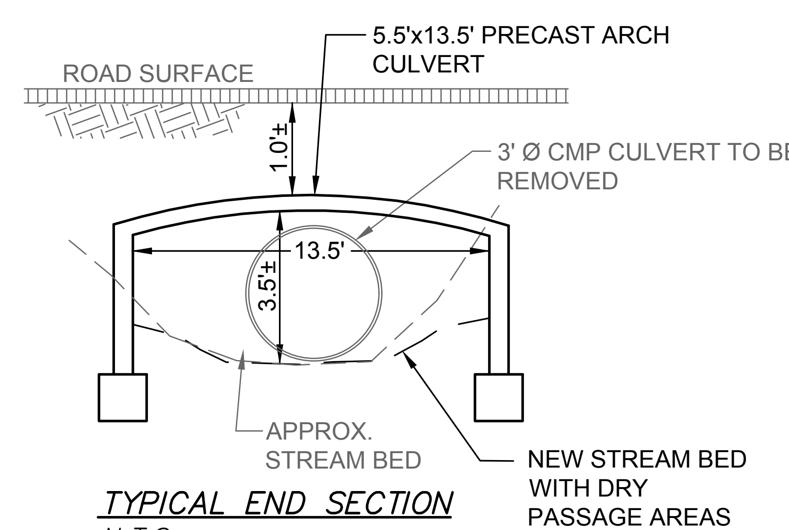
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60



PROFILE
N.T.S.

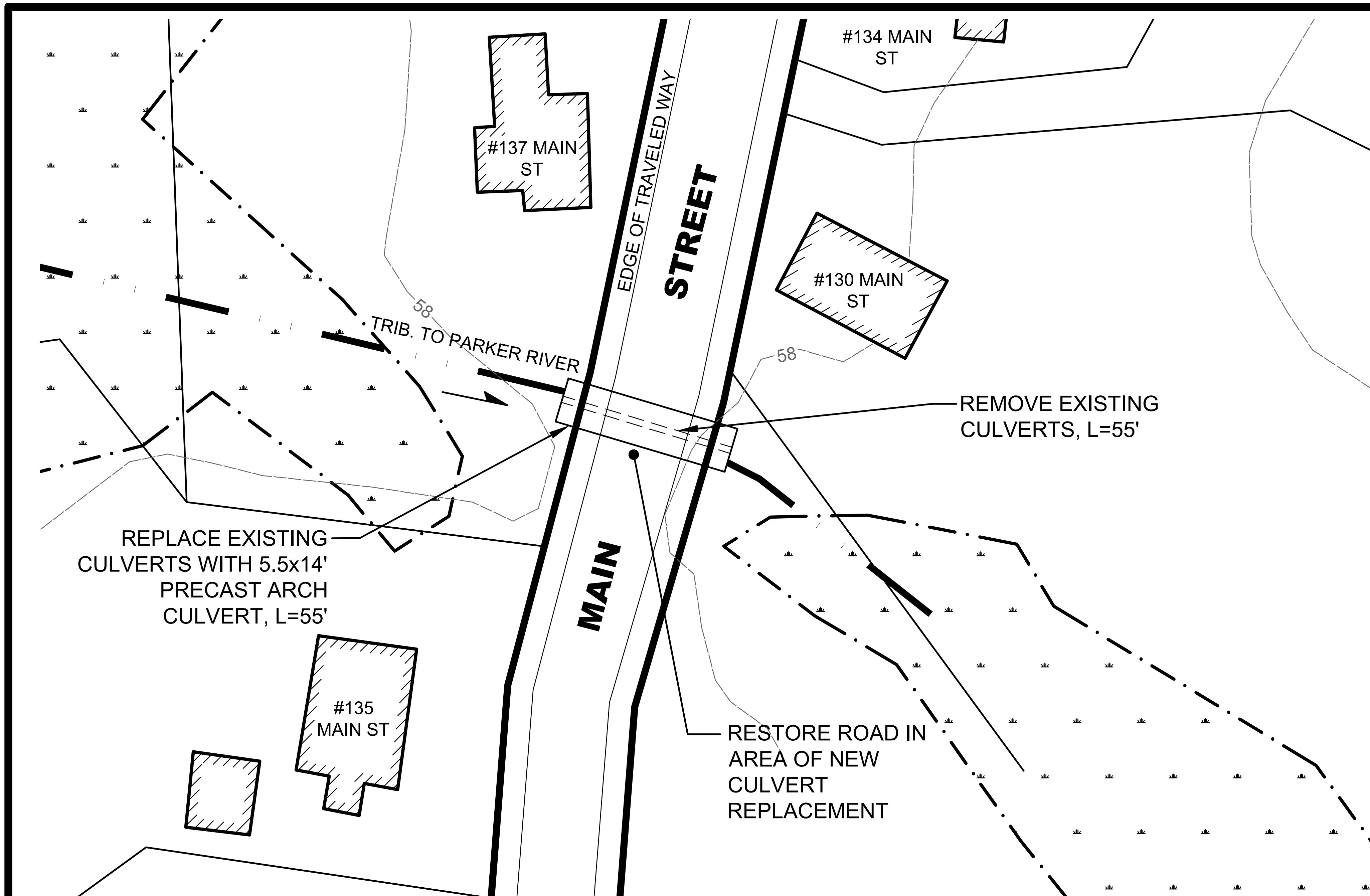


TYPICAL END SECTION
N.T.S.

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 1099.dwg

MAI Project: 5900



NOTES:

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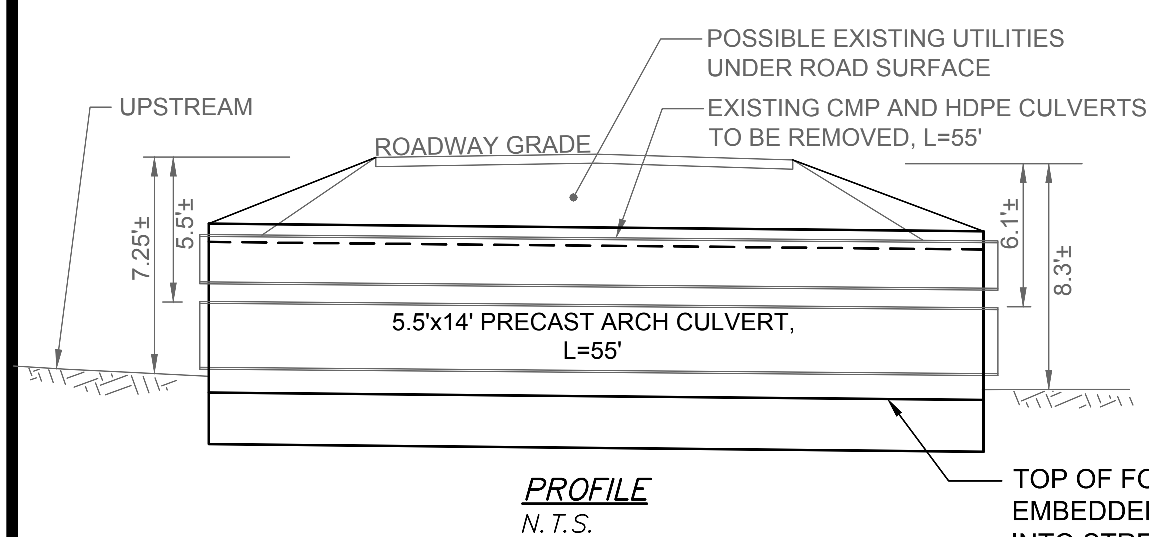
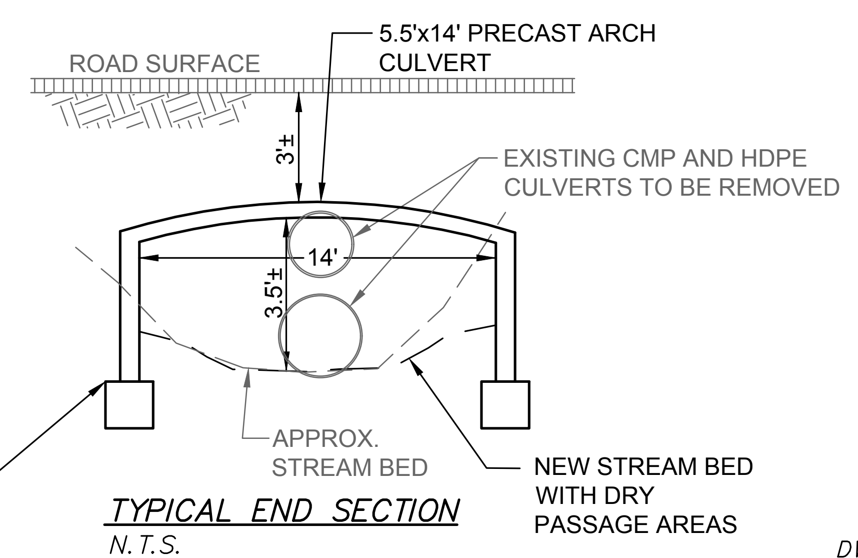
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=12 FEET. PROPOSED CULVERT WIDTH=14 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.96
10. NAACC CROSSING CODE: xy4276884970943232
11. NAACC SURVEY ID: 9593



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#1125
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

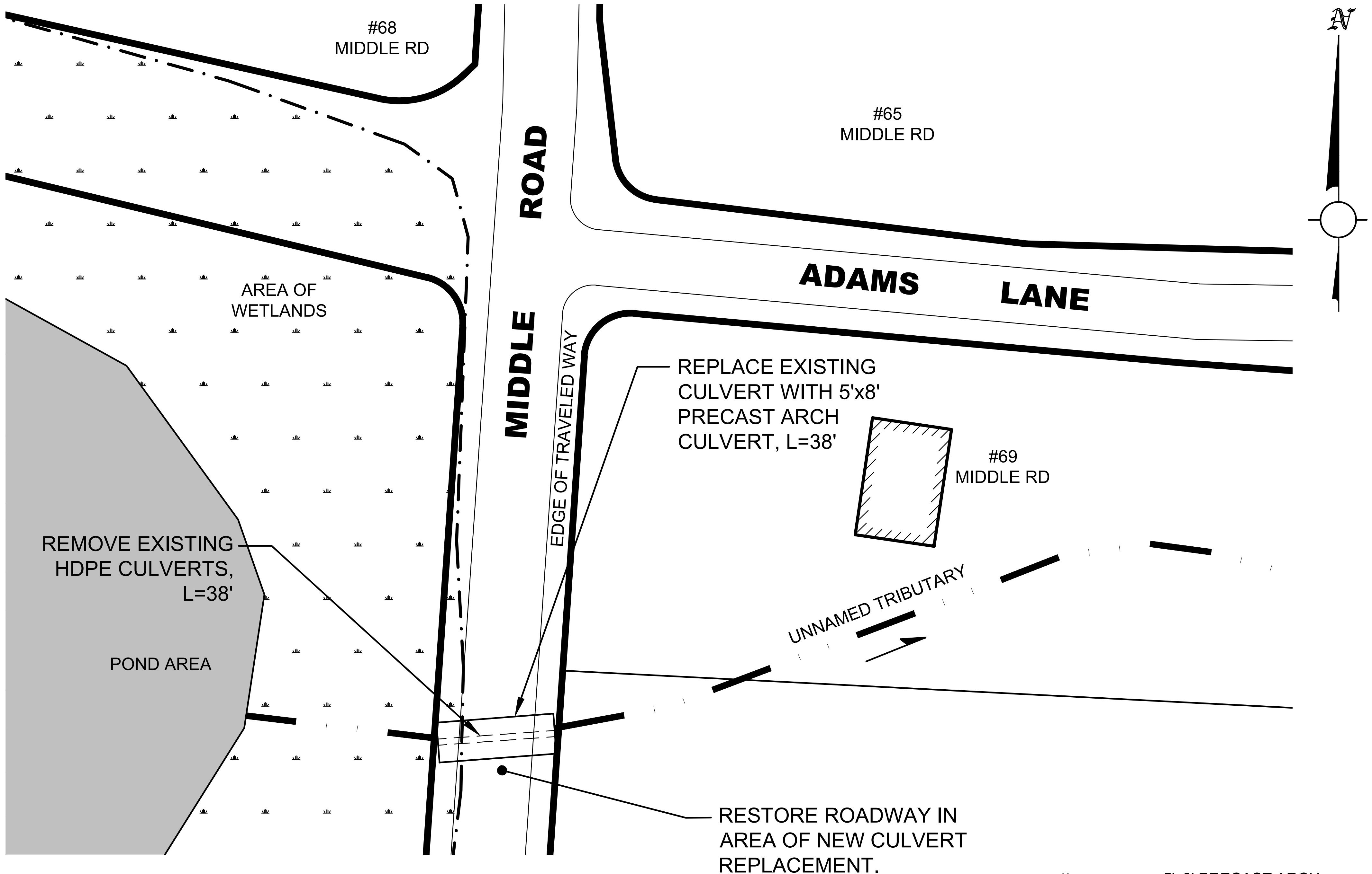
SCALE: 1"= 40' DATE: FEB. 1, 2017

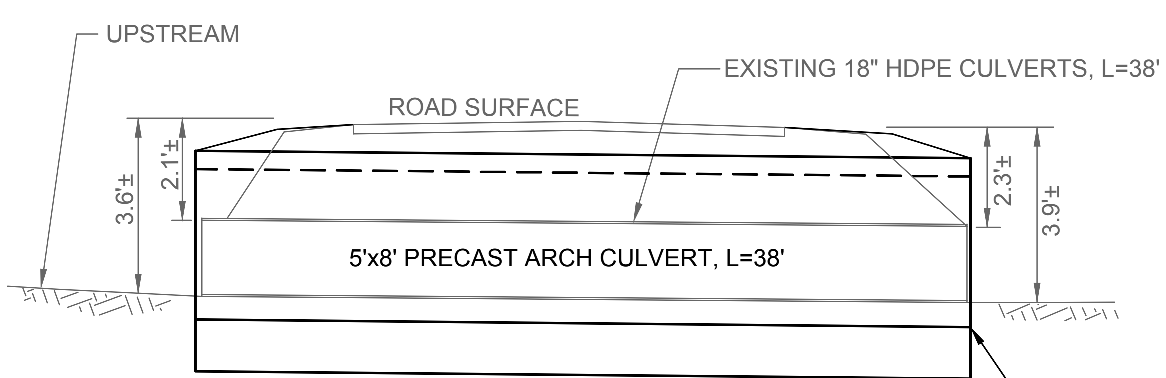
15 0 15 30 60

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 1125.dwg

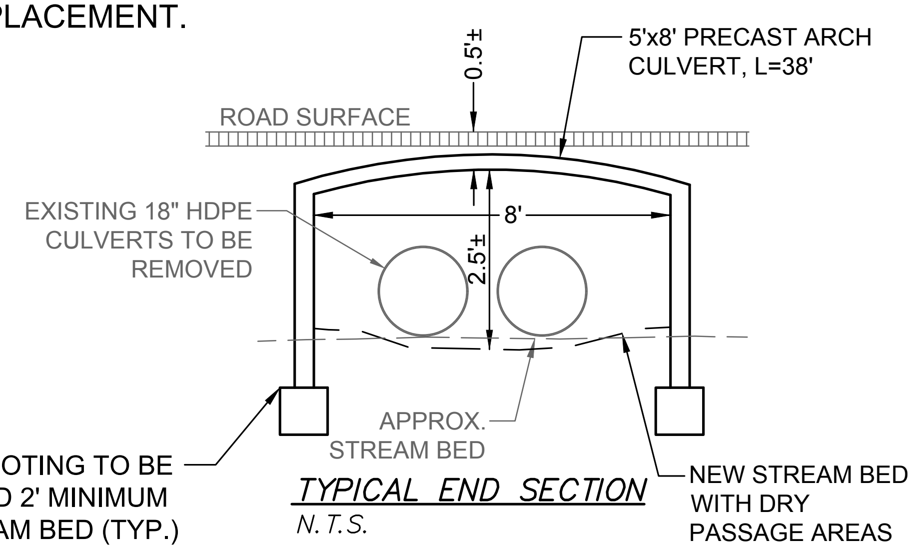
MAI Project: 5900





TOP OF FOOTING TO BE
EMBEDDED 2' MINIMUM
INTO STREAM BED (TYP.)

PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=5.8 FEET. PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.53
10. NAACC CROSSING CODE: xy4278076870886919
11. NAACC SURVEY ID: 10802

CROSSING ID#1164
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

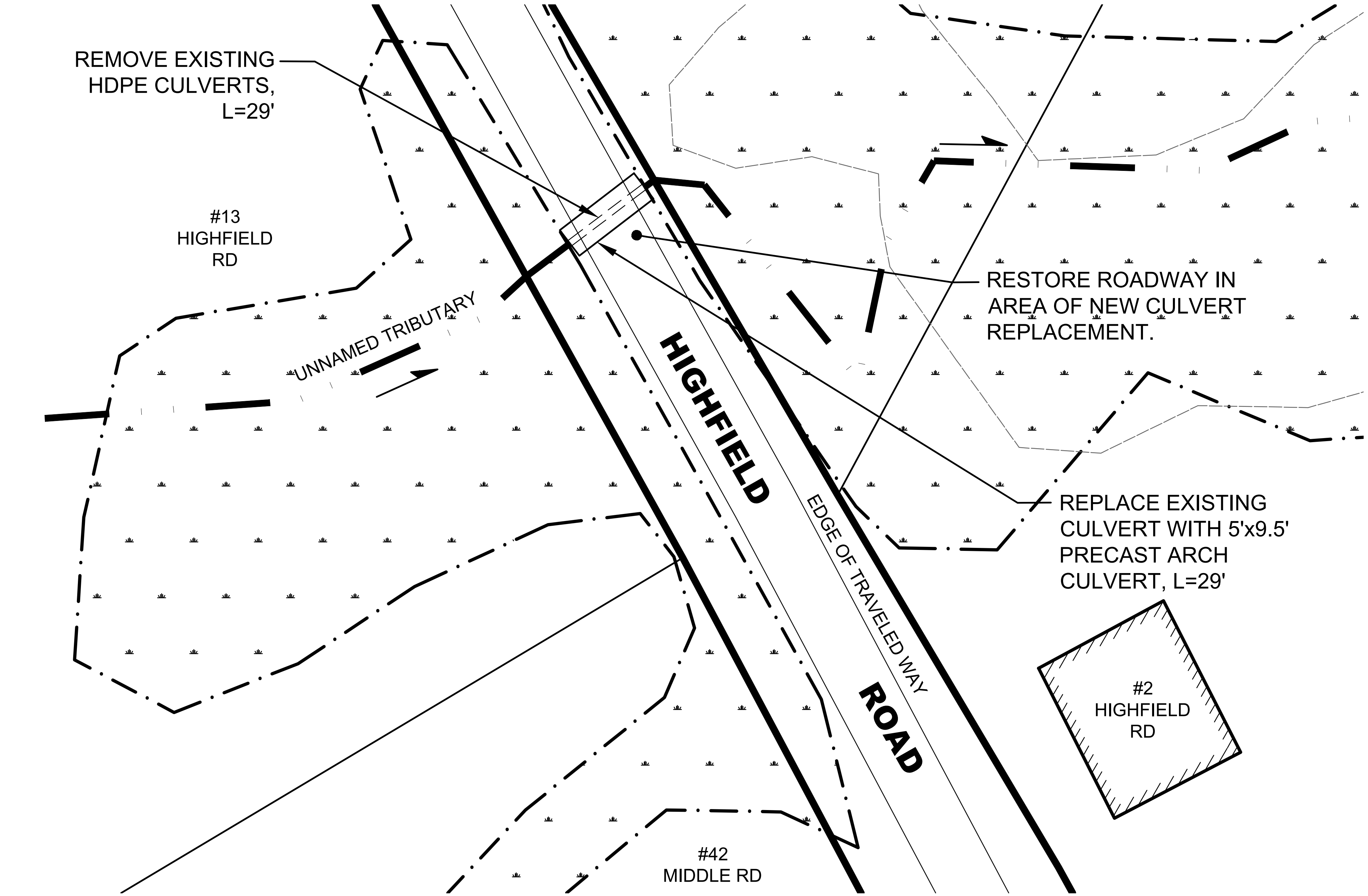
IPSWICH RIVER WATERSHED ASSOC.

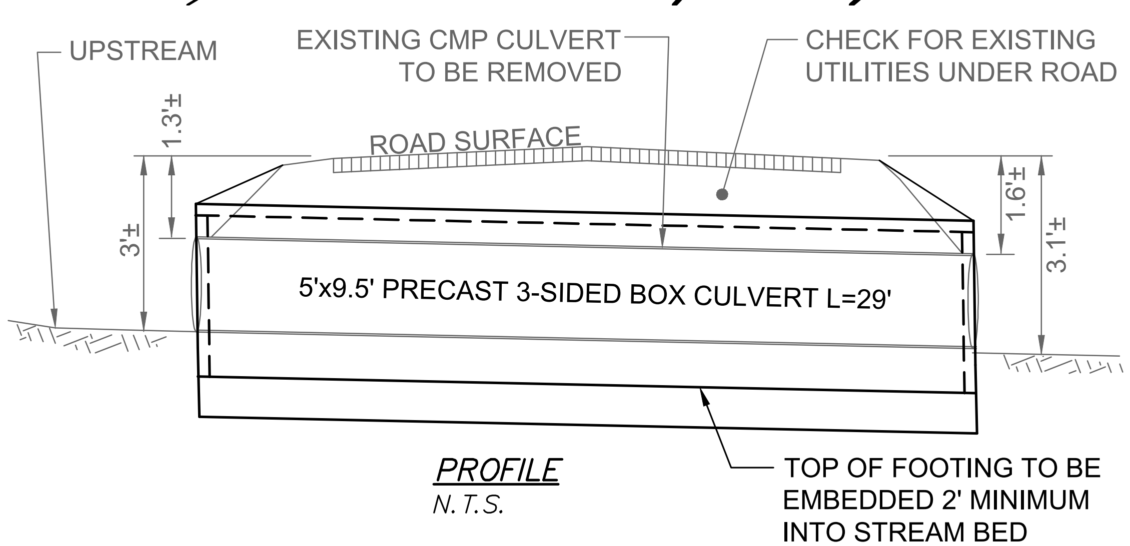
SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

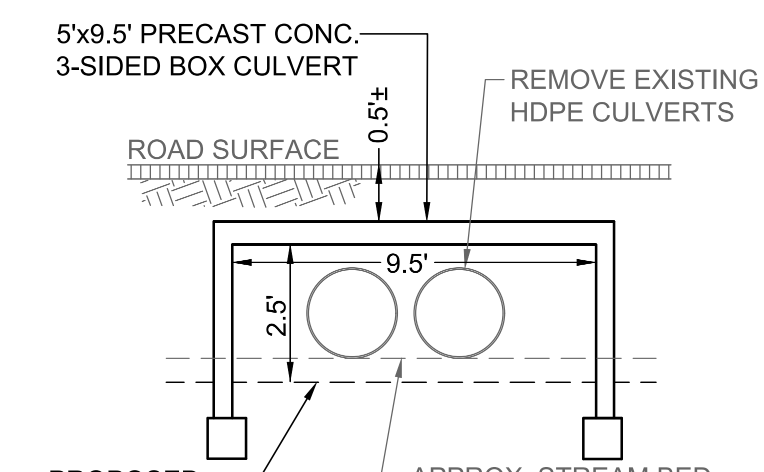
MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 1164.dwg MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=7.8 FEET. PROPOSED CULVERT WIDTH=9.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4278696970884964
11. NAACC SURVEY ID: 9605

CROSSING ID#1187 SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

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69 MILK STREET, SUITE 302
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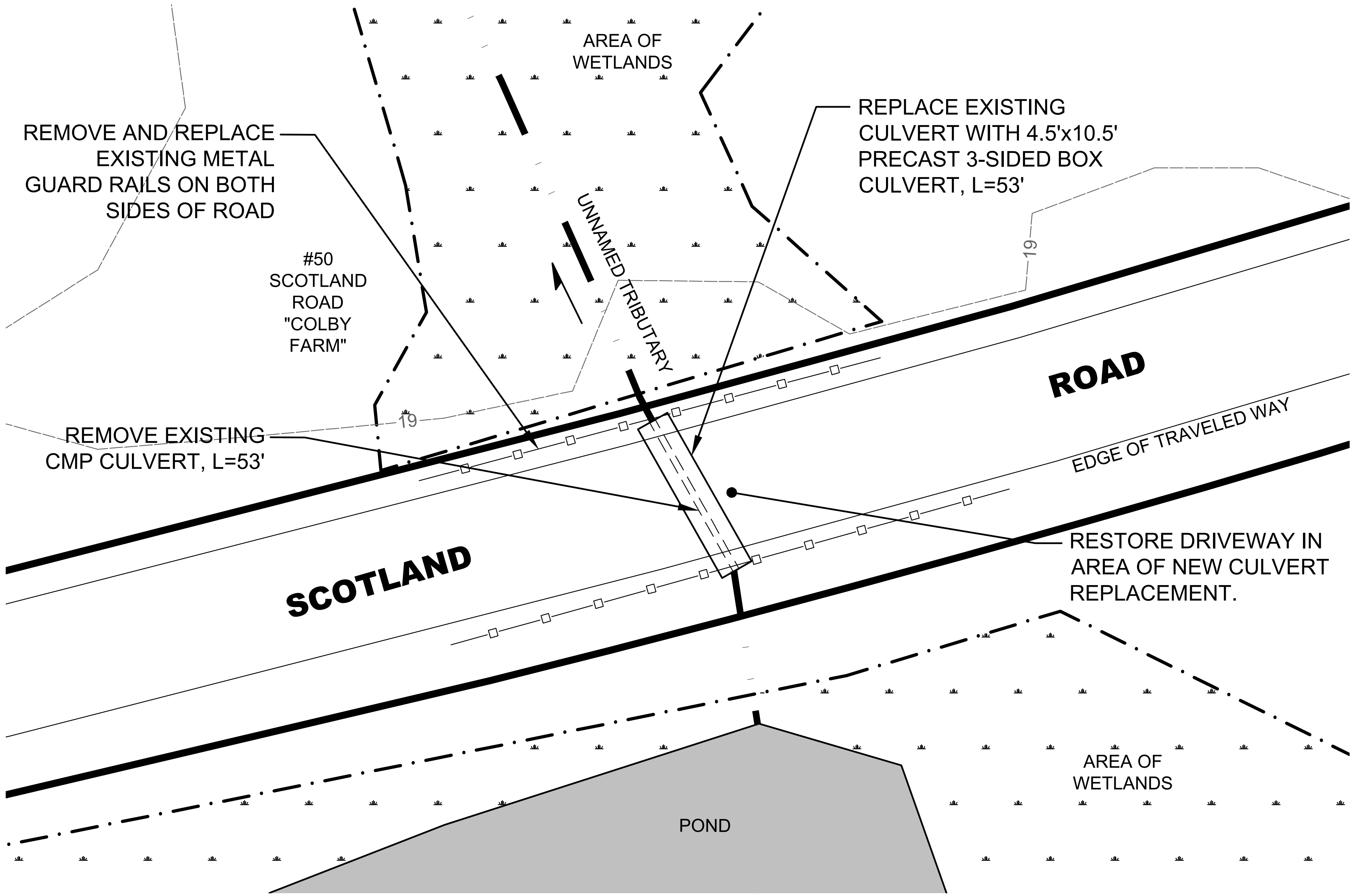
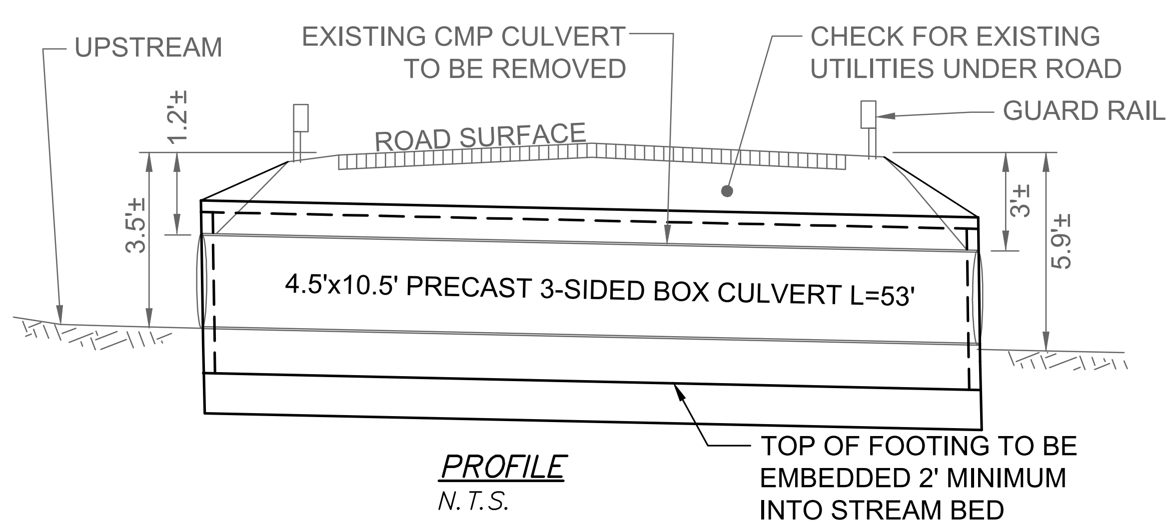
DWG. No. Site 1187.dwg

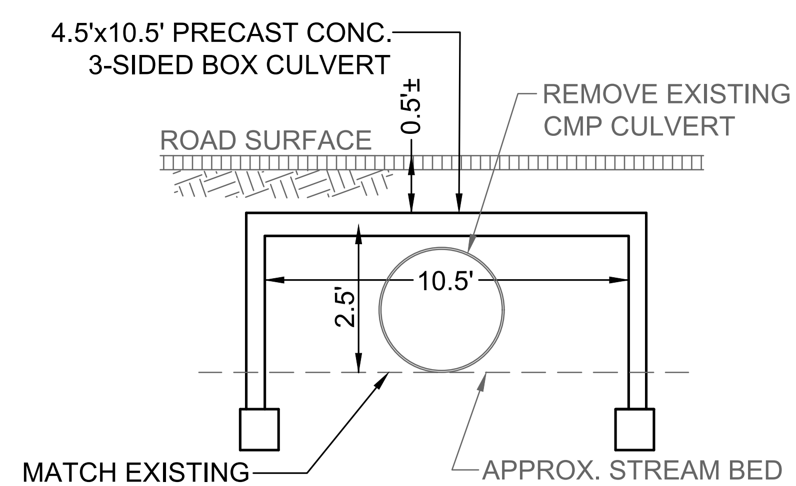
MAI Project: 5900





PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

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5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8.7 FEET. PROPOSED CULVERT WIDTH=10.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.50
10. NAACC CROSSING CODE: xy4279152370896249
11. NAACC SURVEY ID: 10180

CROSSING ID#1194
SKETCH PLAN

LOCATED IN

NEWBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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WWW.MERIDIANASSOC.COM

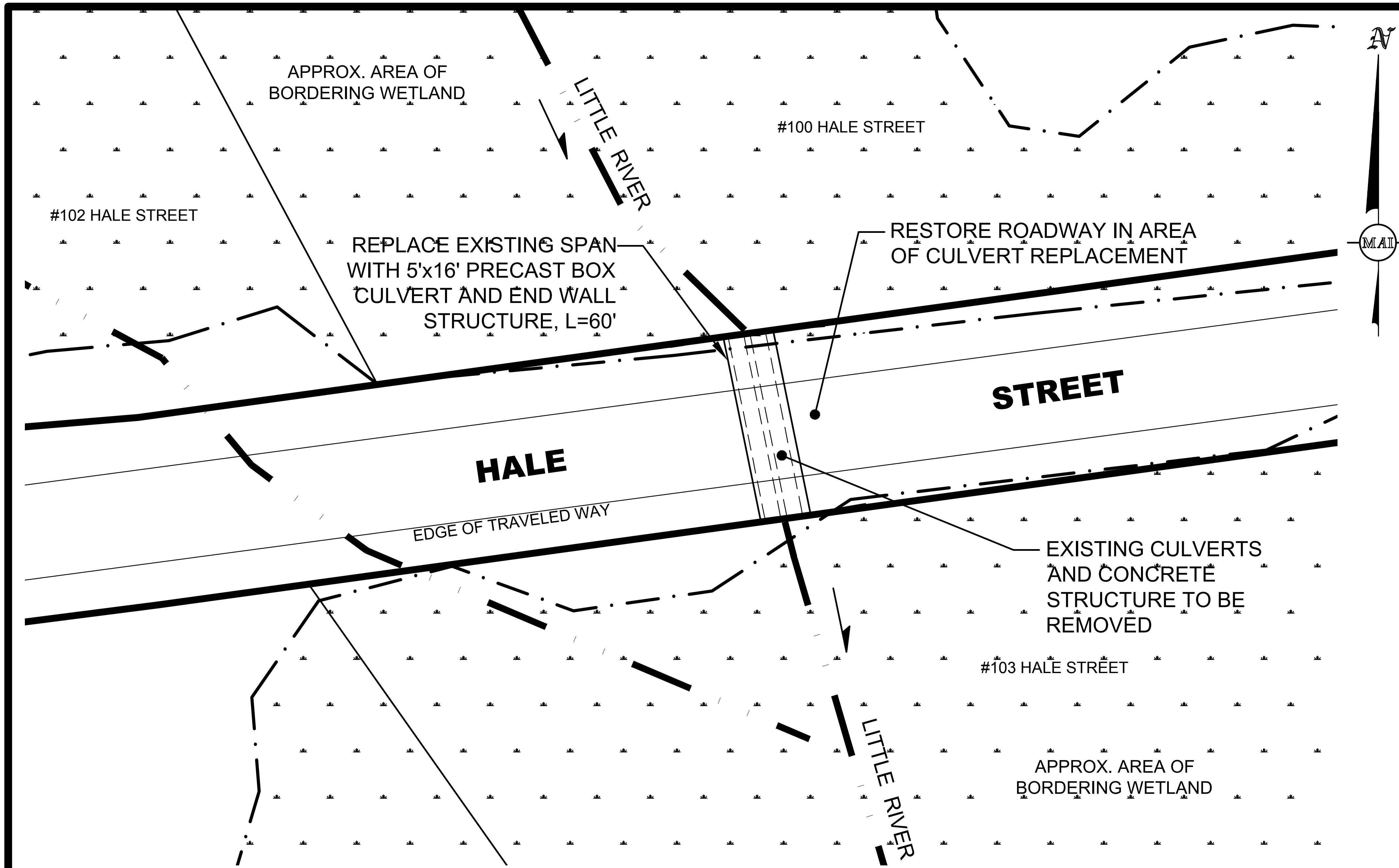
DWG. No. Site 1194.dwg

MAI Project: 5900

Newburyport Designs

Conceptual designs for the replacement of select road-stream crossings in the City of Newburyport, MA

2 pages



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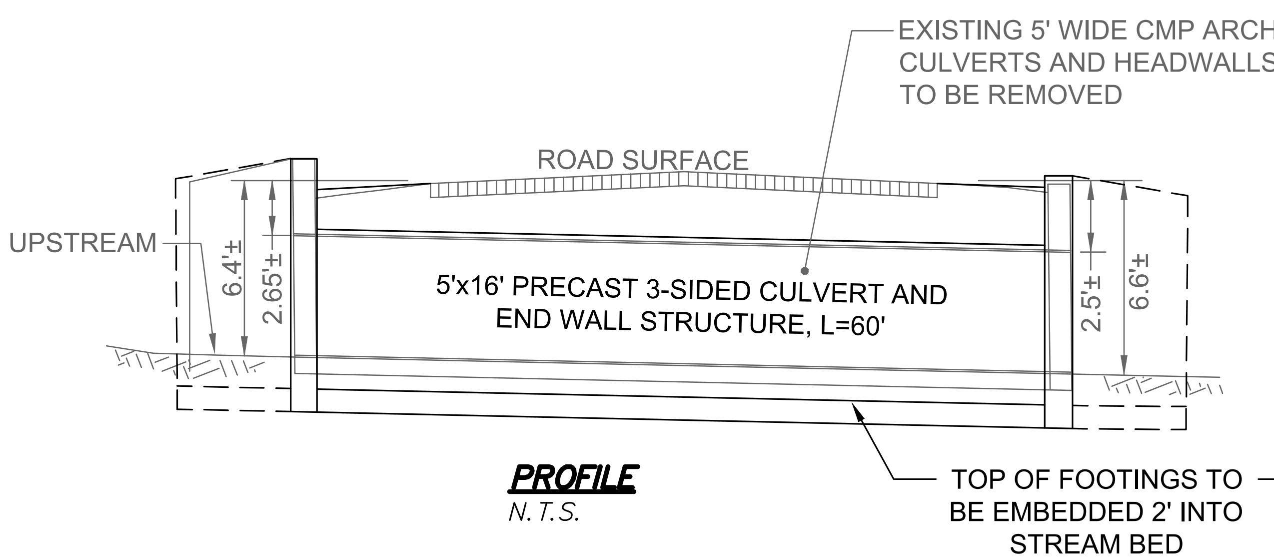
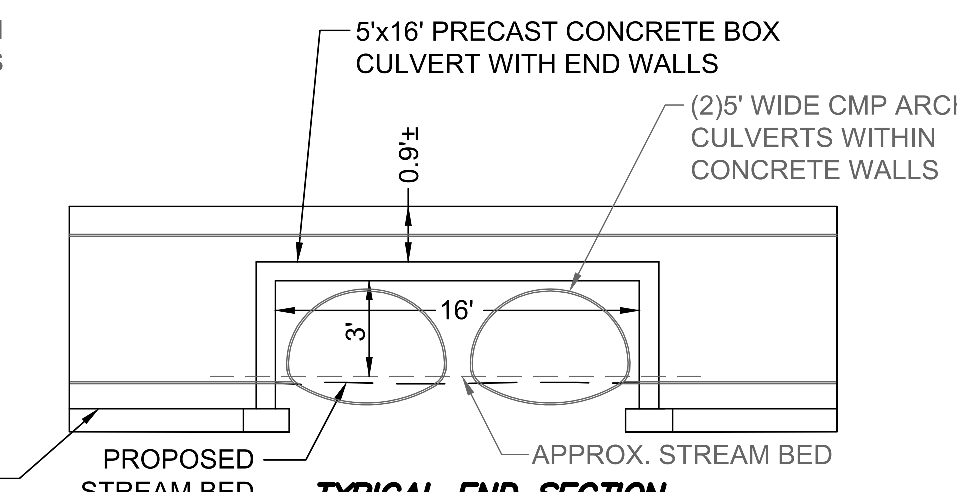
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.80
10. NAACC CROSSING CODE: xy4280304570911045
11. NAACC SURVEY ID: 10805



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 1218
SKETCH PLAN

LOCATED IN
NEWBURYPORT, MA
(ESSEX COUNTY)
PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JULY 17, 2017
20 0 20 40 80

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
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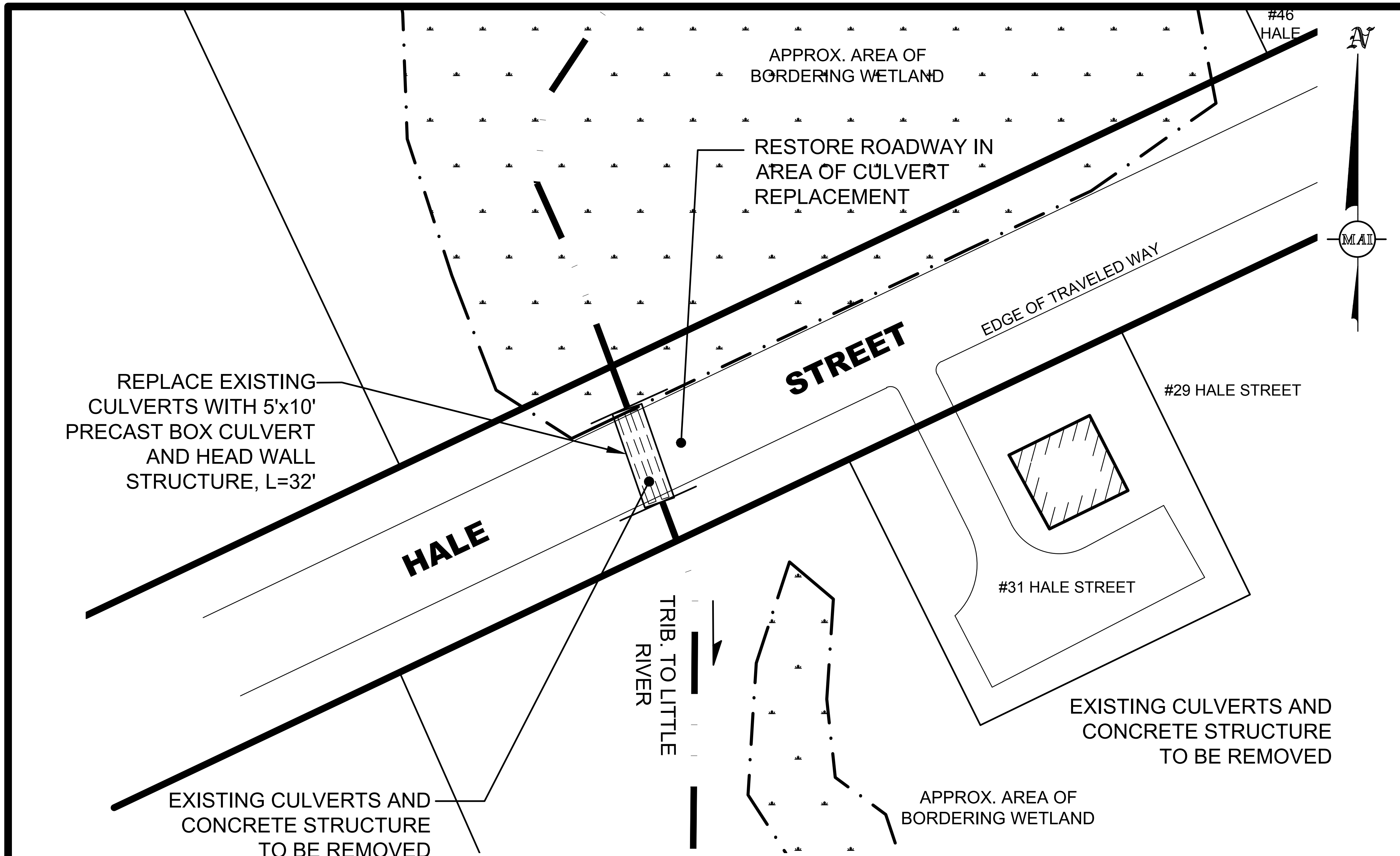
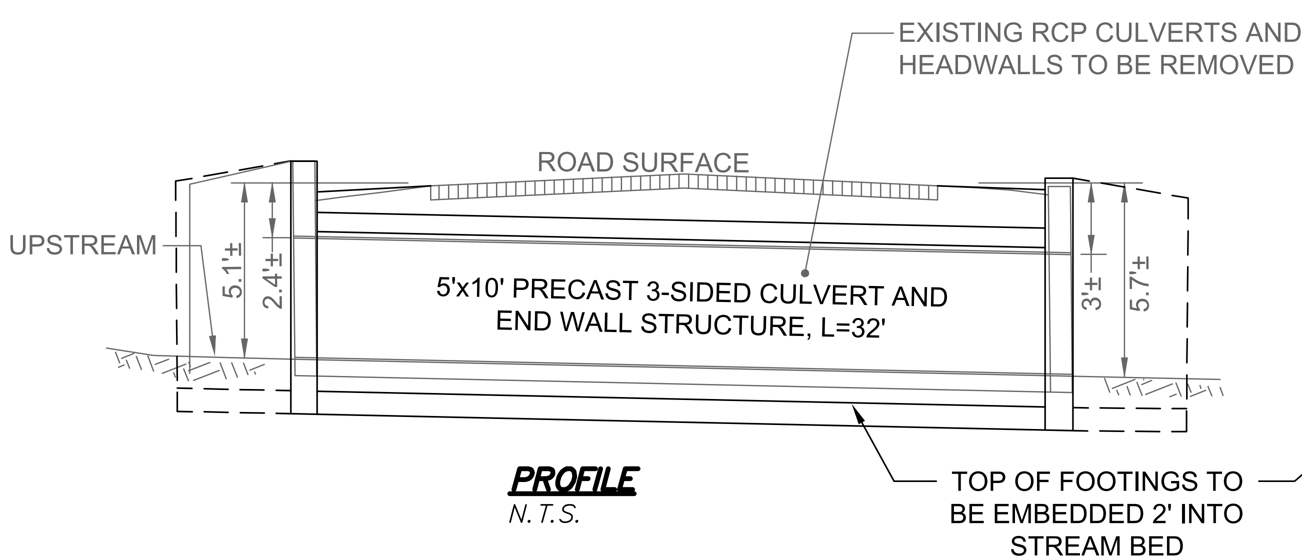
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 1218.dwg
MAI Project: 5900





PROFILE
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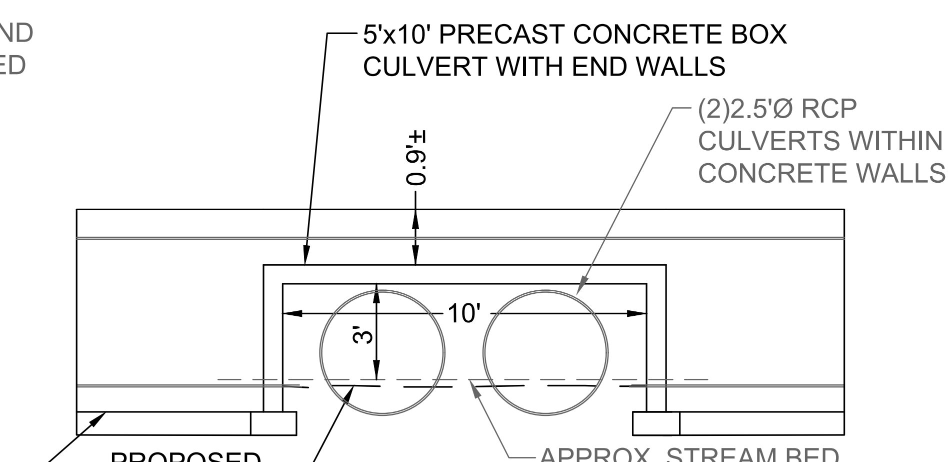

TYPICAL END SECTION
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8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.1
10. NAACC CROSSING CODE: xy4280560070901023
11. NAACC SURVEY ID: 10222

CROSSING ID# 1225
SKETCH PLAN

LOCATED IN
NEWBURYPORT, MA
(ESSEX COUNTY)

PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JULY 17, 2017
20 0 20 40 80

MERIDIAN
ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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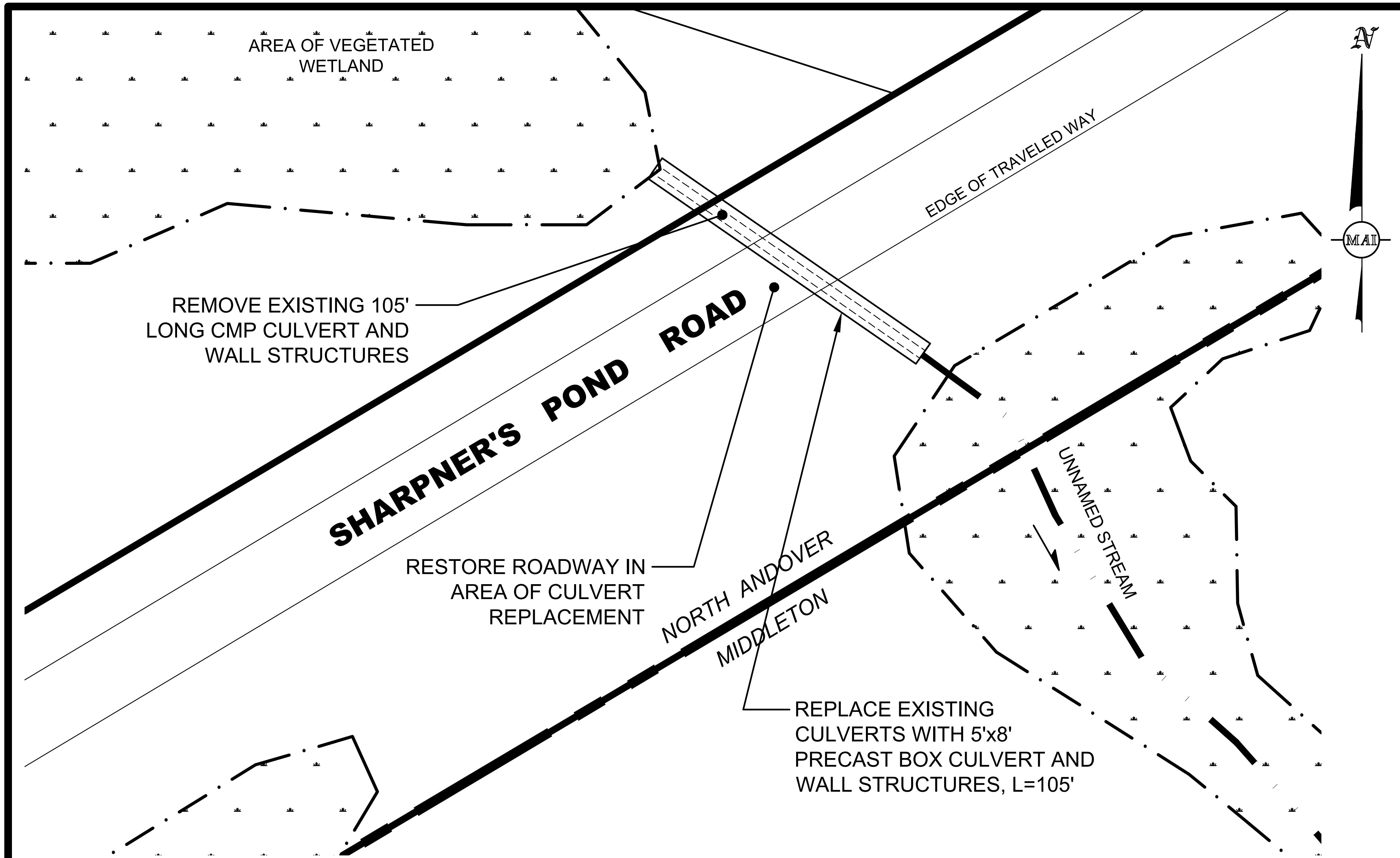
DWG. No. Site 1225.dwg

MAI Project: 5900

North Andover Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of North Andover, MA

10 pages



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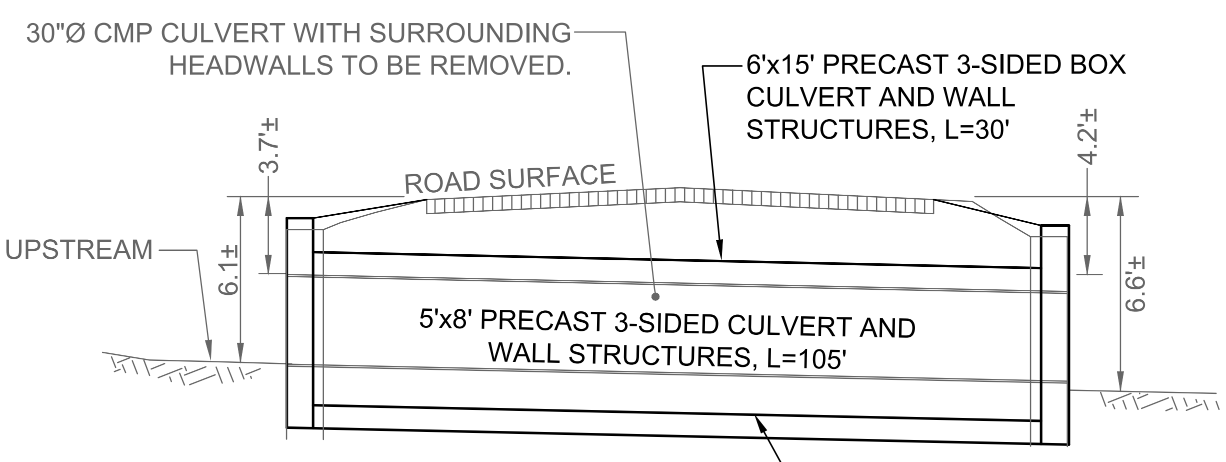
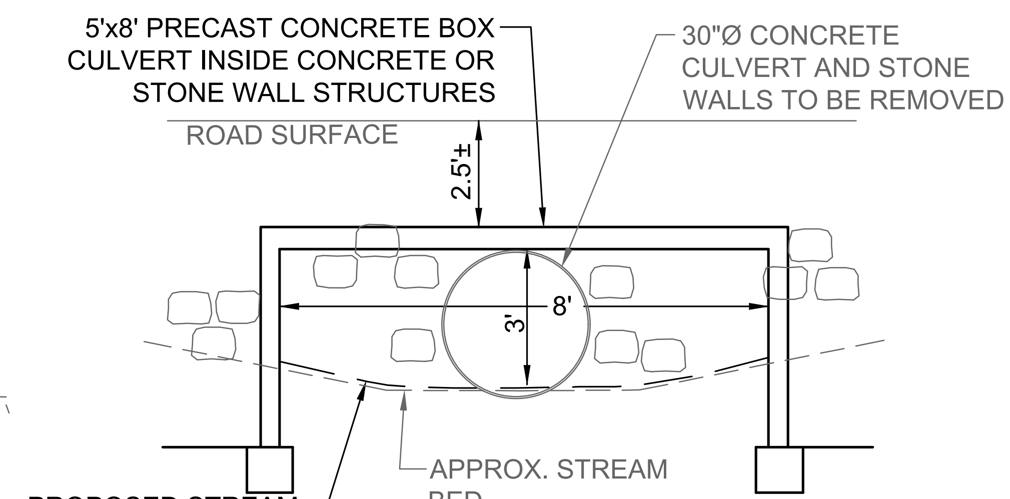
8. APPROXIMATE BANKFULL WIDTH=6 FEET. PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.23
10. NAACC CROSSING CODE: xy4262900471052030
11. NAACC SURVEY ID: 11163



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 411
SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 11, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

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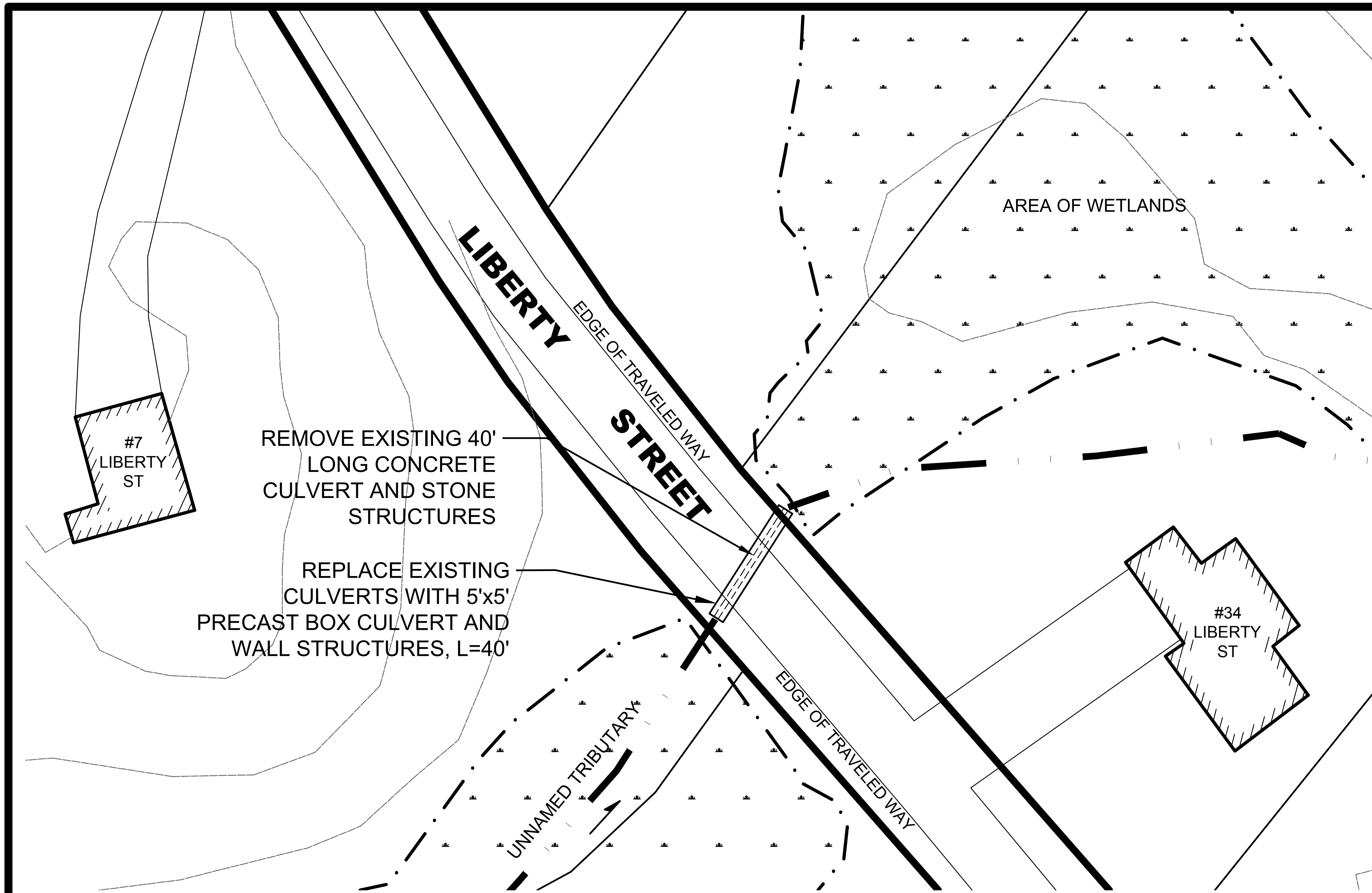
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 411.dwg

MAI Project: 5900



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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.31
10. NAACC CROSSING CODE: xy4264102571035456
11. NAACC SURVEY ID: 7357

CROSSING ID# 472 SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

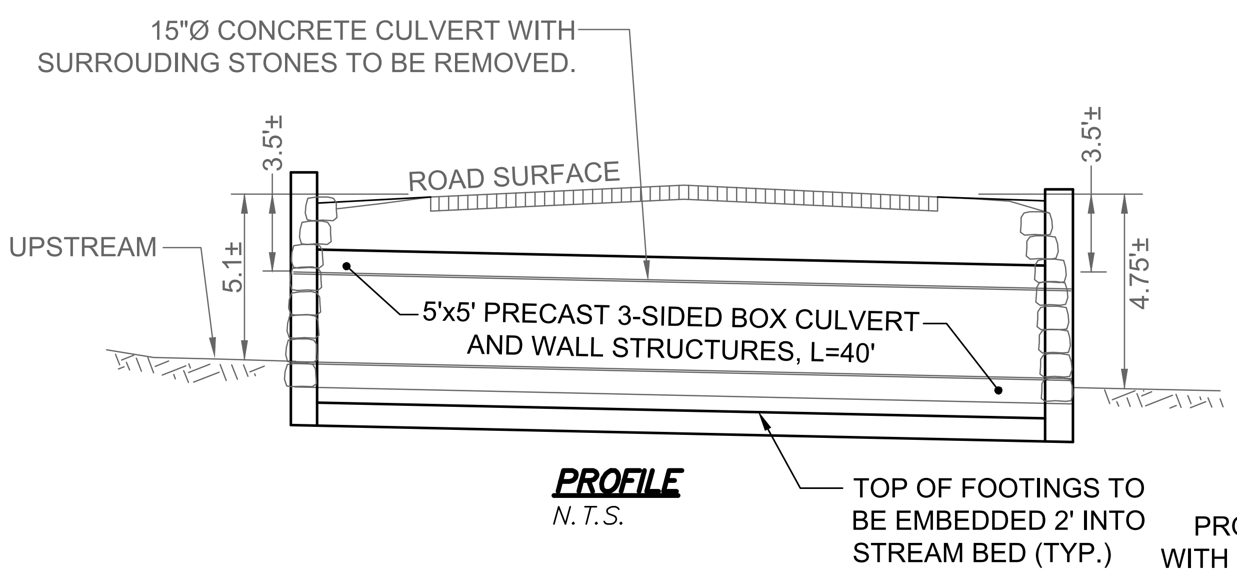
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

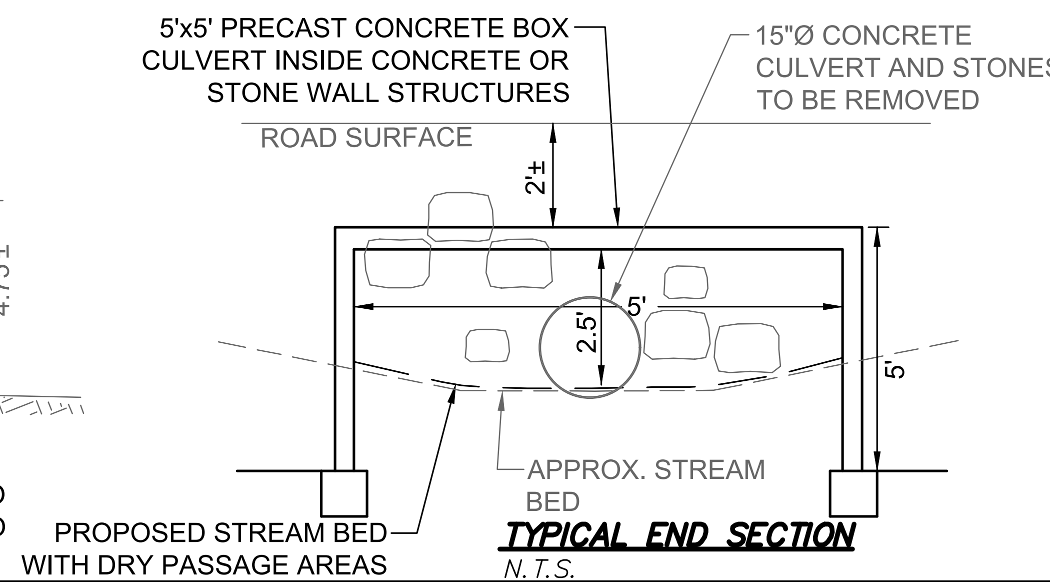
SCALE: 1"= 40' DATE: JAN. 11, 2017

20 0 20 40 80



PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

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TELEPHONE: (508) 871-7030

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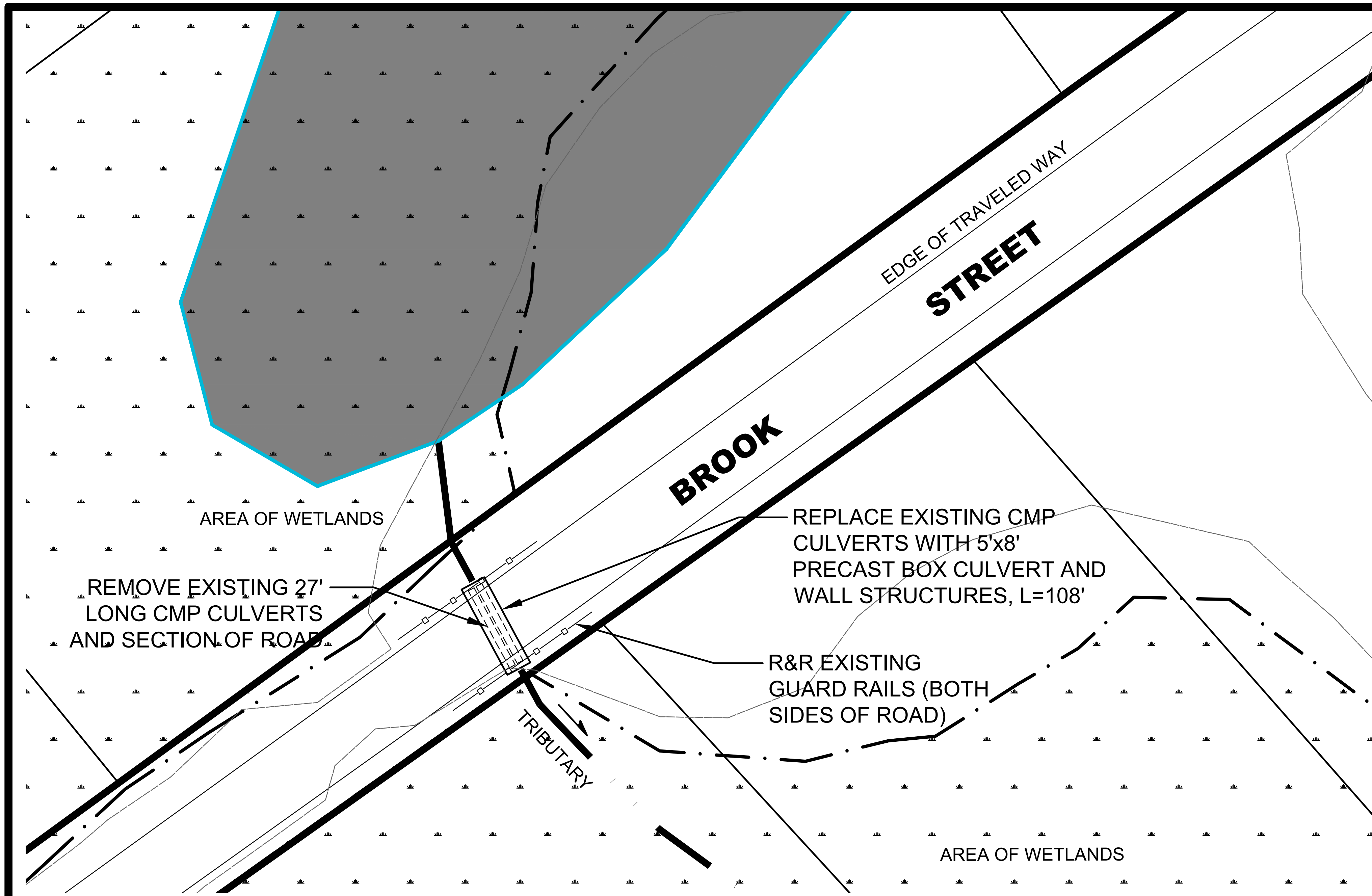
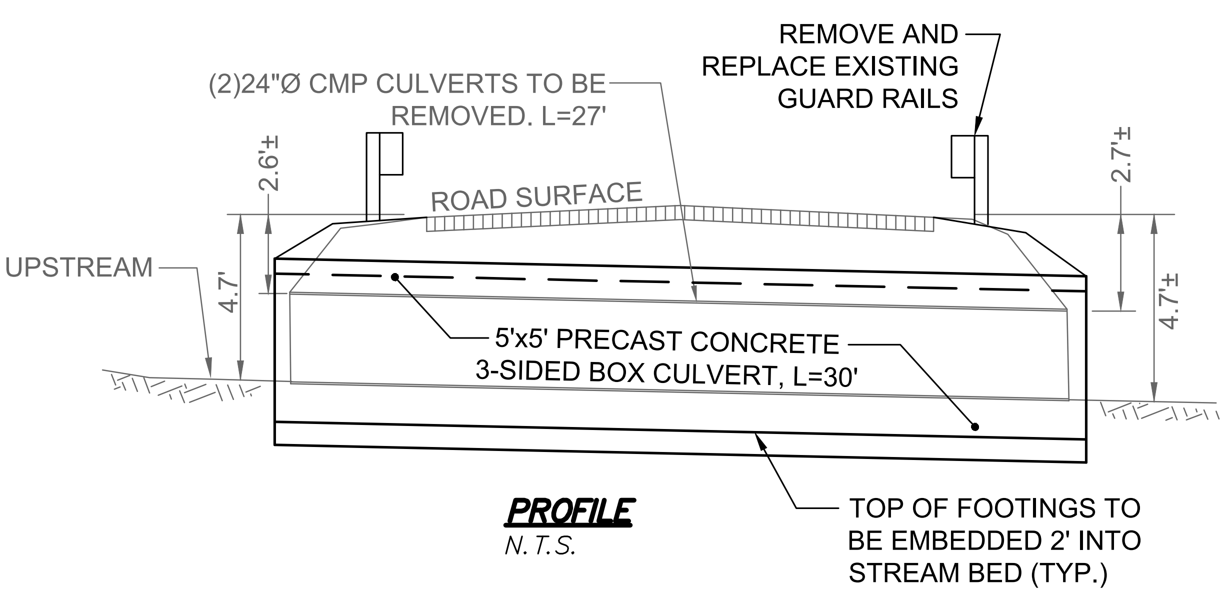
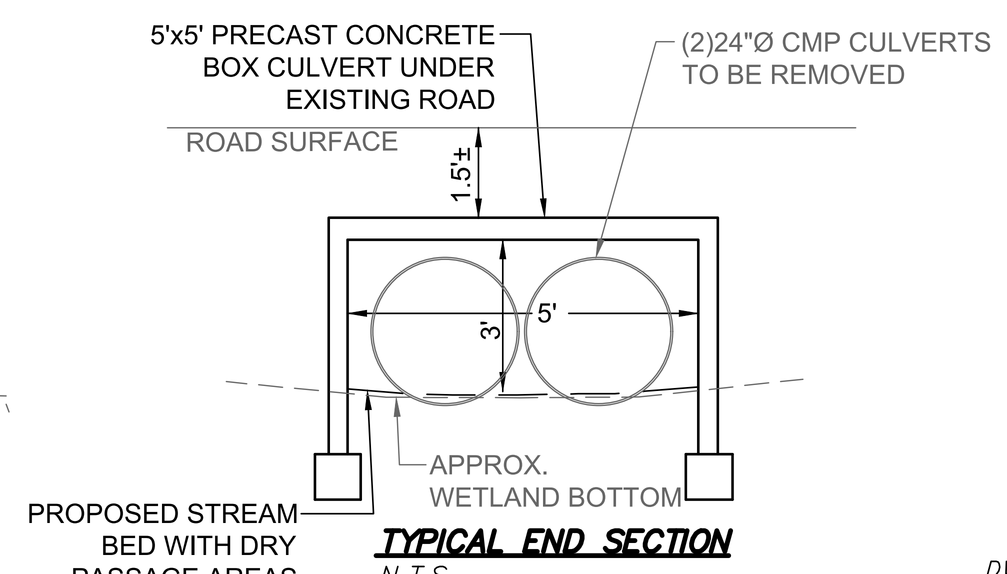
DWG. No. Site 472.dwg

MAI Project: 5900





PROFILE
N.T.S.



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9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.50
10. NAACC CROSSING CODE: xy4264798771088006
11. NAACC SURVEY ID: 5095

CROSSING ID# 519
SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 11, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

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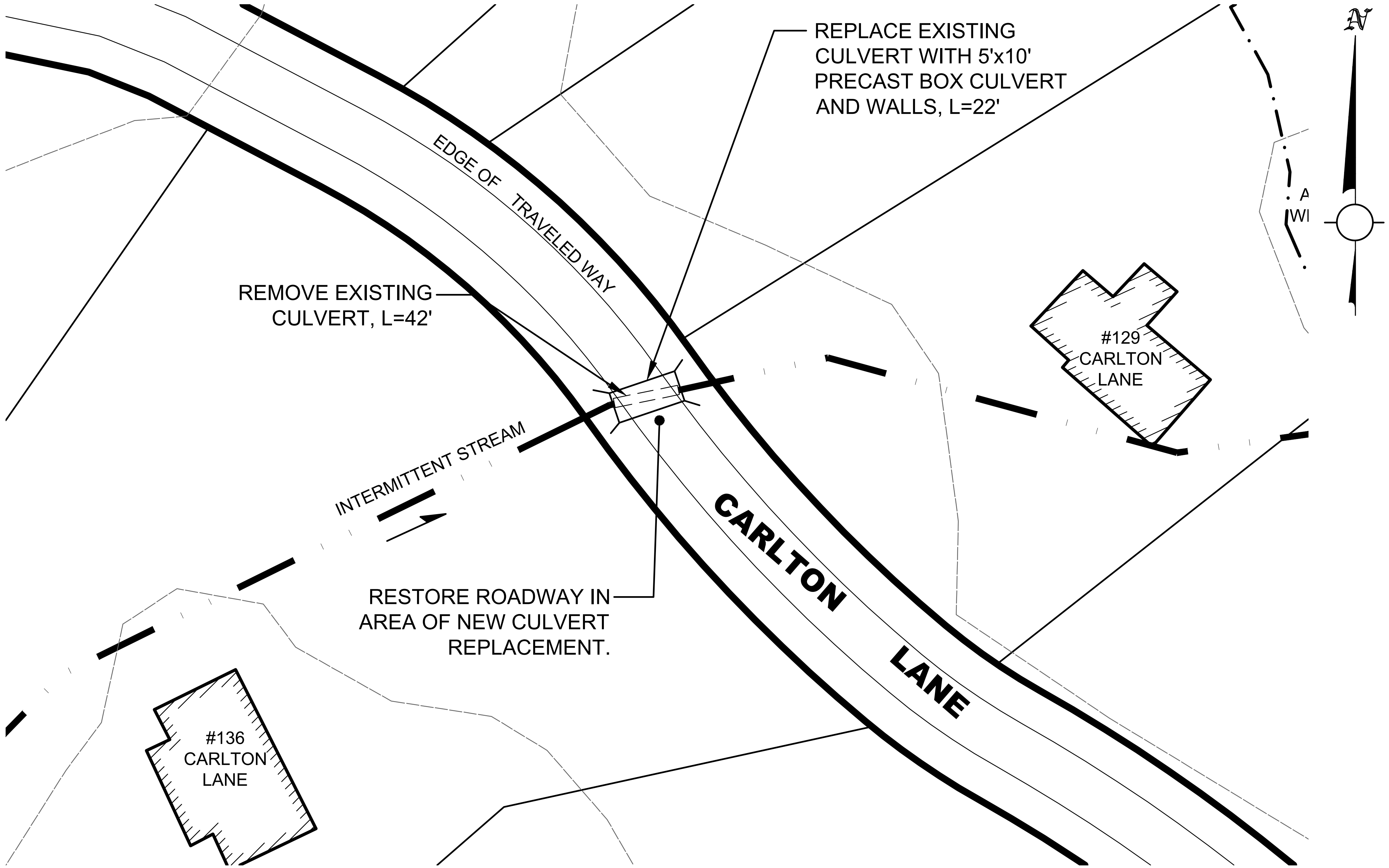
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 519.dwg

MAI Project: 5900



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8. APPROXIMATE BANKFULL WIDTH=7.9 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.15
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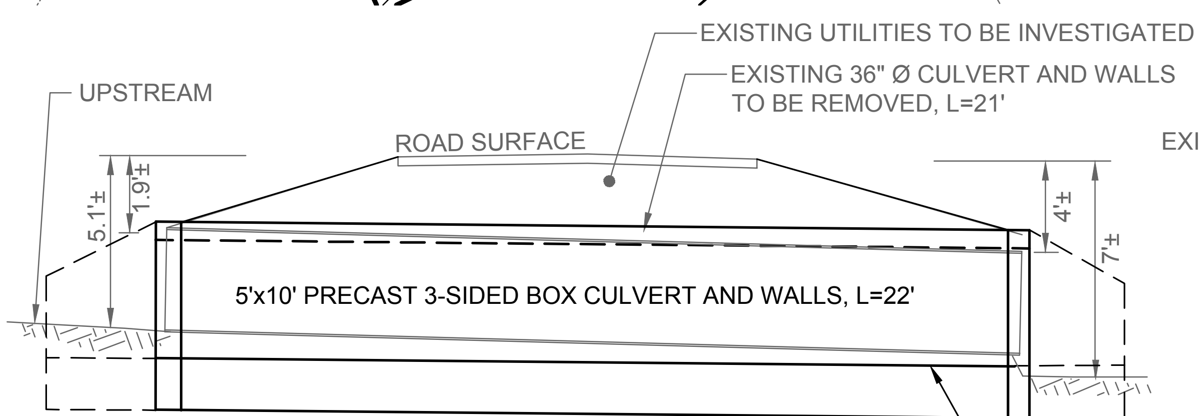
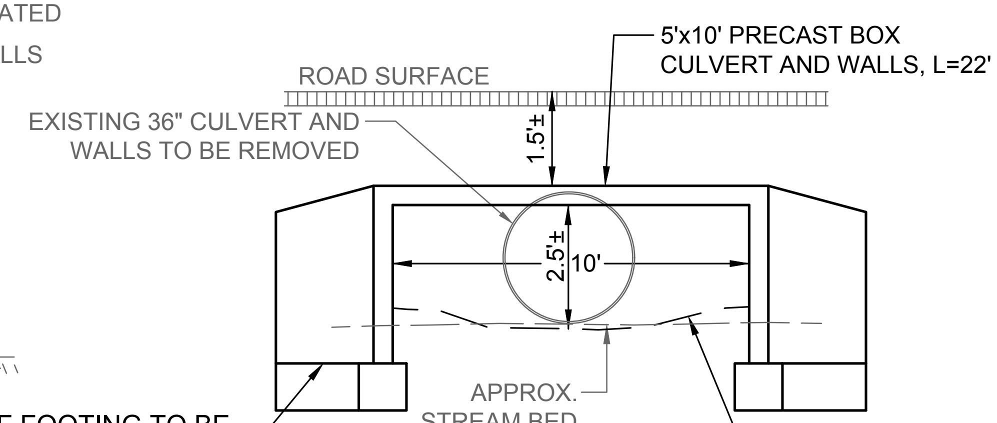
11. NAACC SURVEY ID: 5136



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#587 SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 25, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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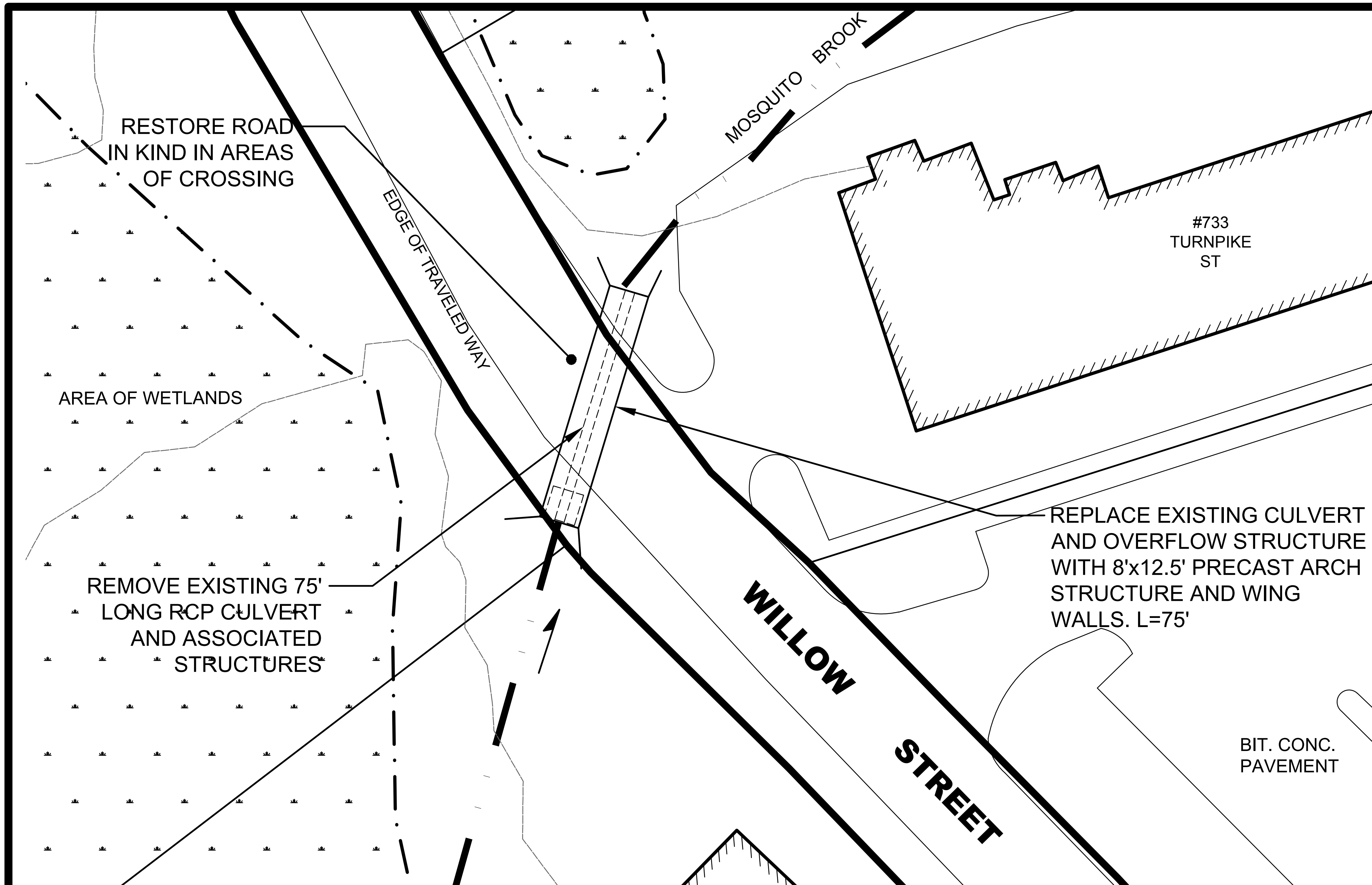
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 587.dwg

MAI Project: 5900



NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10.4 FEET. PROPOSED CULVERT WIDTH=12.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.83
10. NAACC CROSSING CODE: xy4266083471111593
11. NAACC SURVEY ID: 5088

CROSSING ID# 613 SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

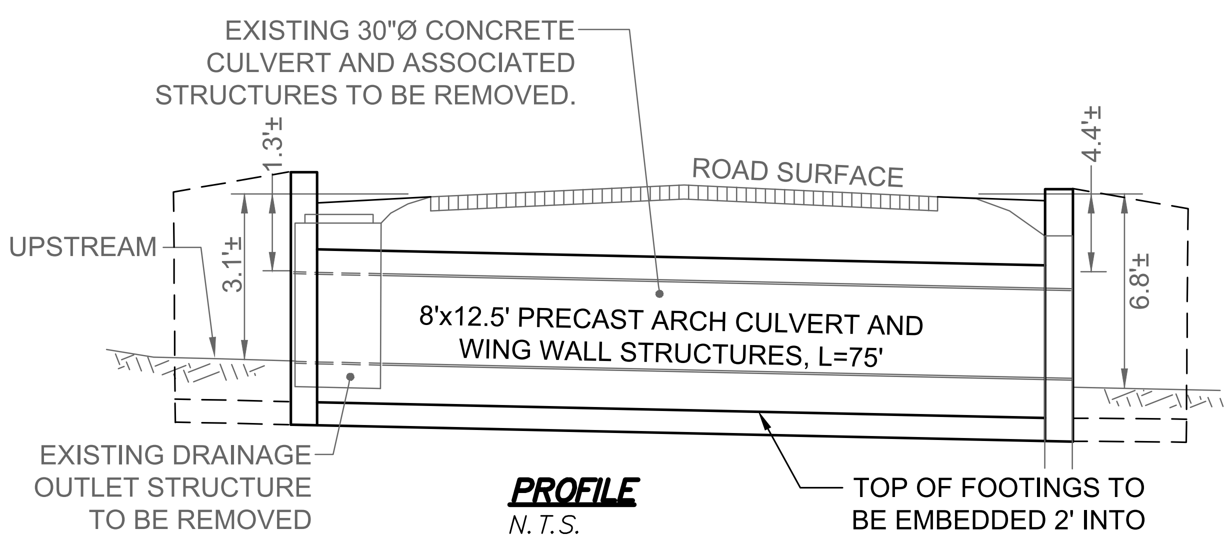
(ESSEX COUNTY)

PREPARED FOR

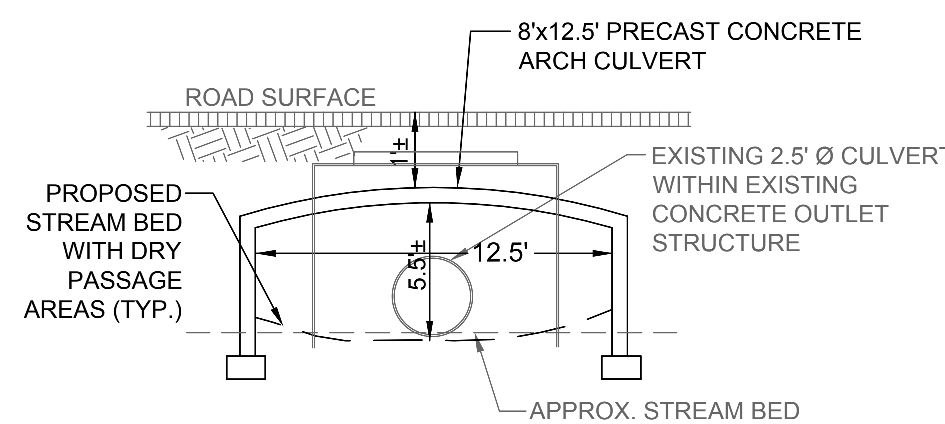
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 11, 2017

20 0 20 40 80



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
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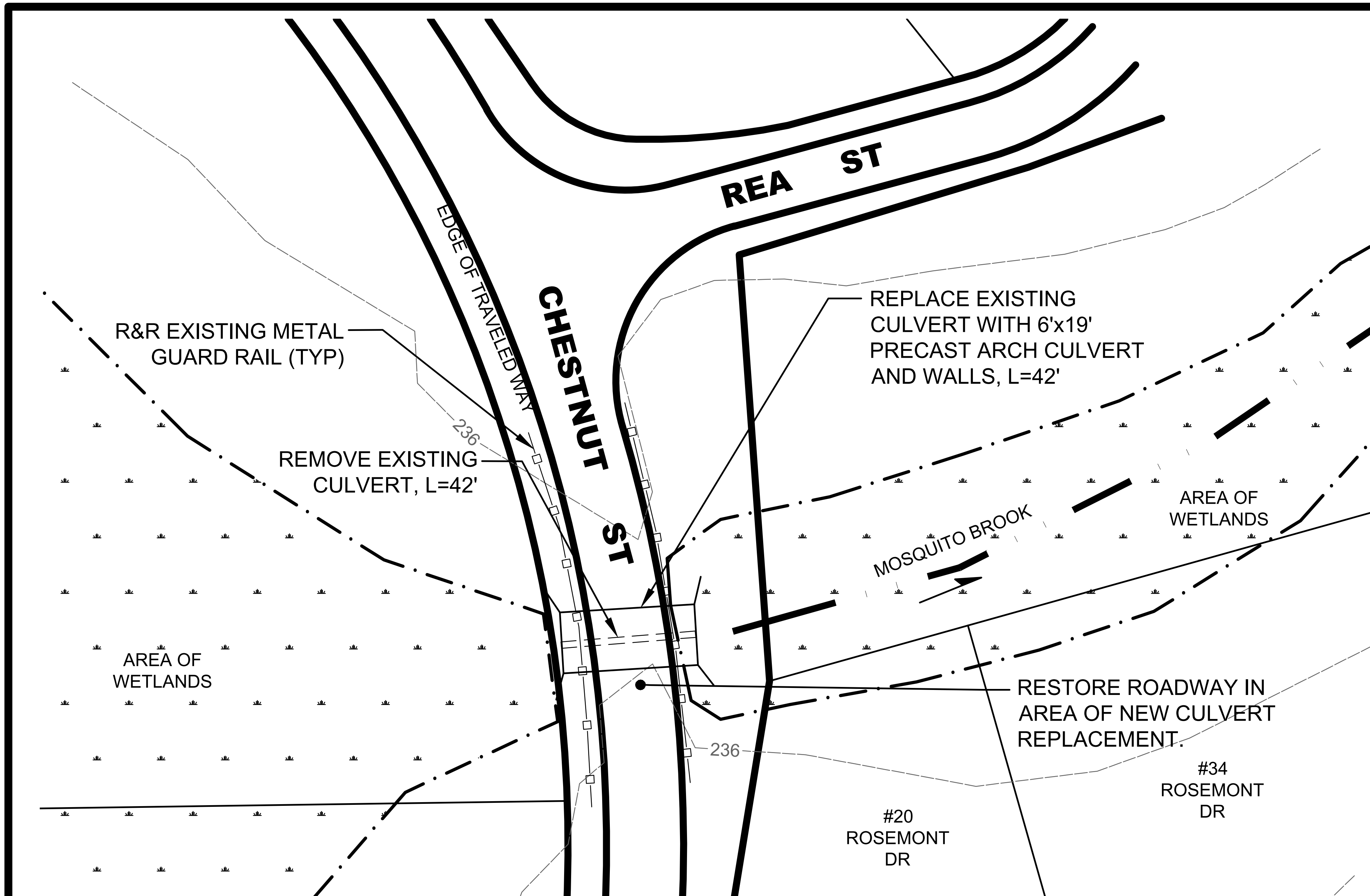
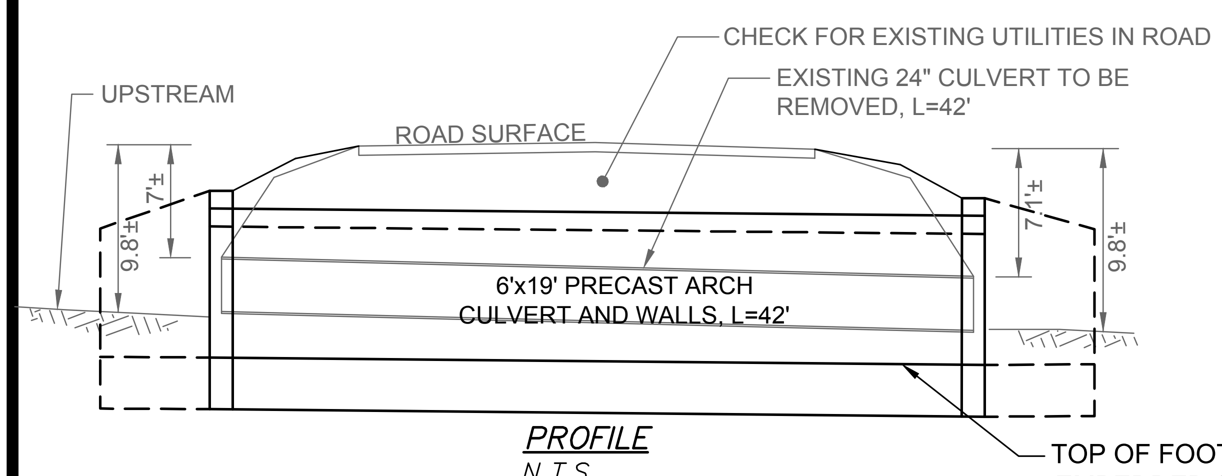
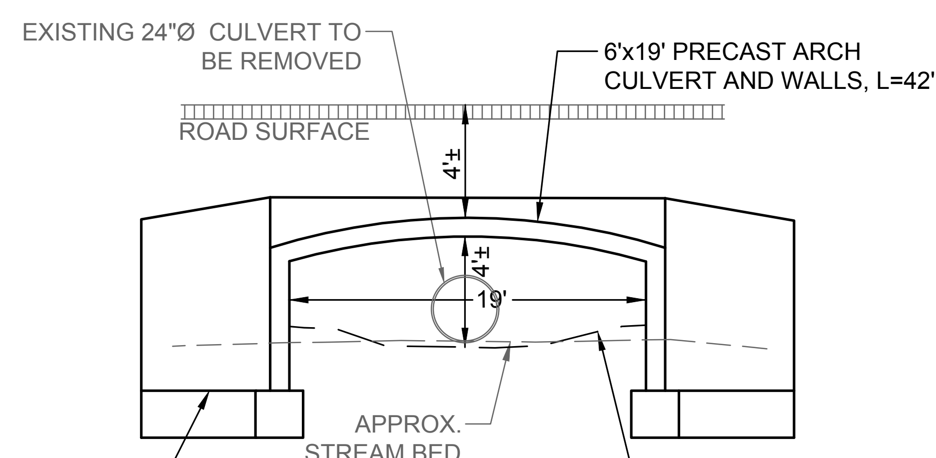
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 613.dwg MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=15.5 FEET. PROPOSED CULVERT WIDTH=19 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.3
10. NAACC CROSSING CODE: xy4266389371106962
11. NAACC SURVEY ID: 5130

CROSSING ID#632 SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 25, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
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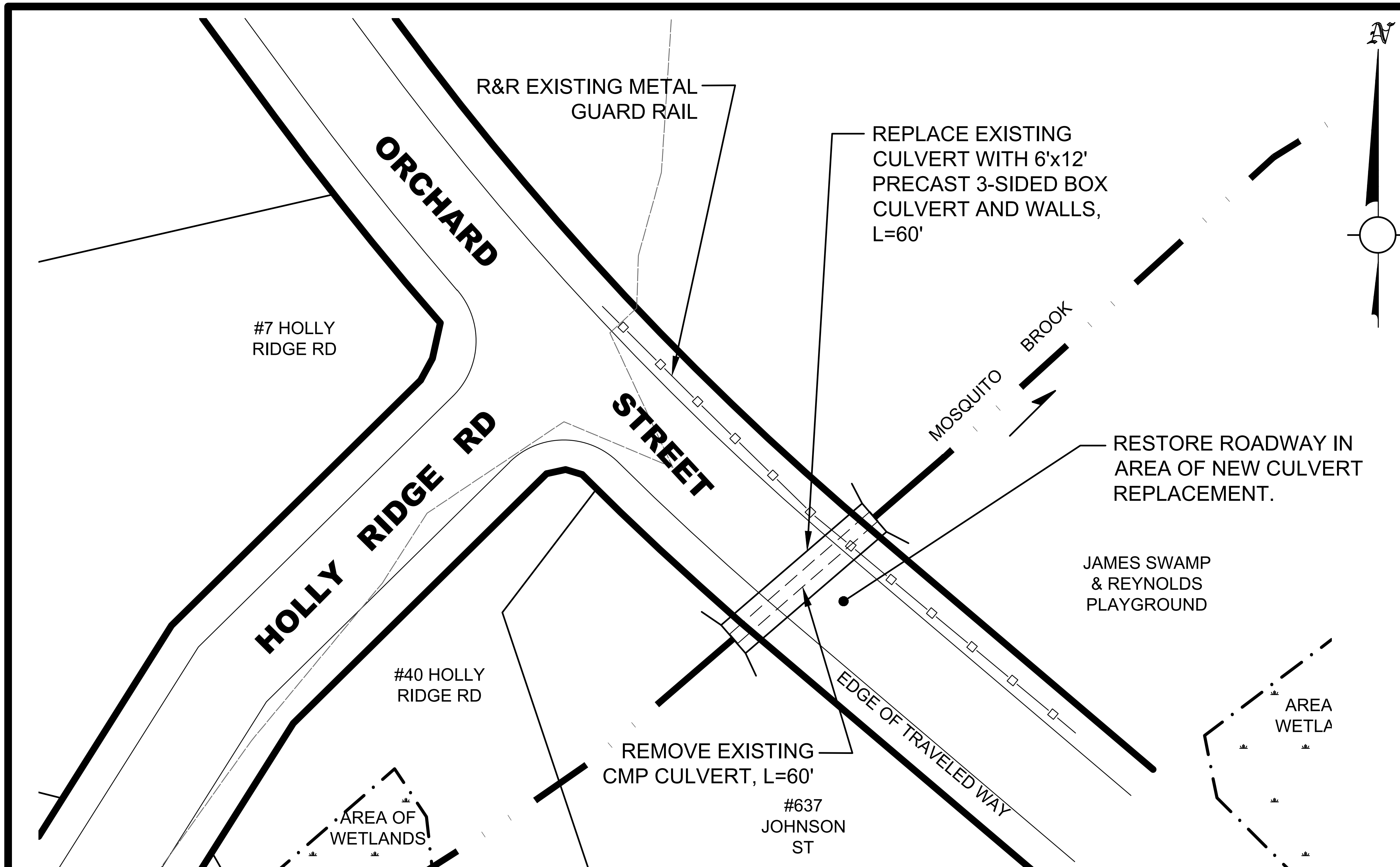
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 632.dwg

MAI Project: 5900



NOTES:

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=9.1 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.92
10. NAACC CROSSING CODE: xy4266616871098001
11. NAACC SURVEY ID: 5132

CROSSING ID#648
SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

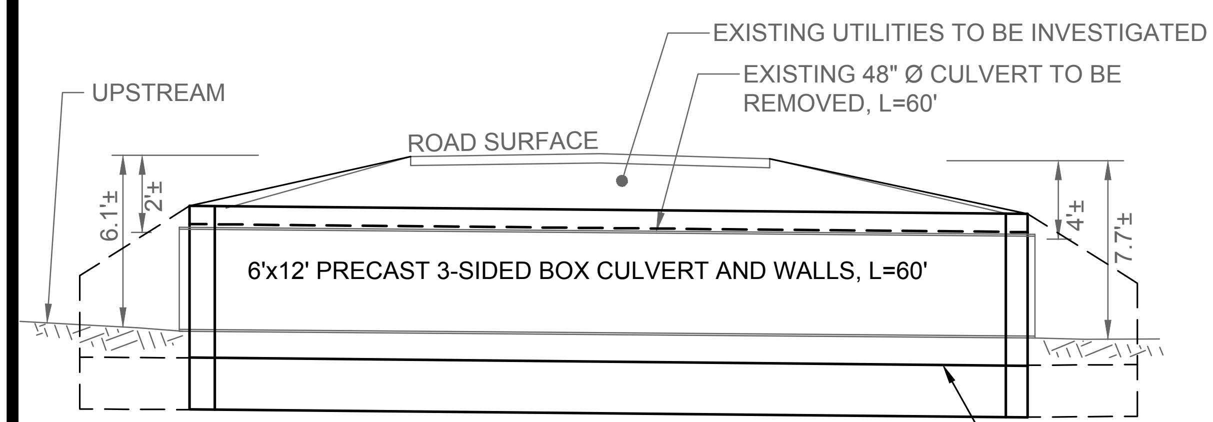
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

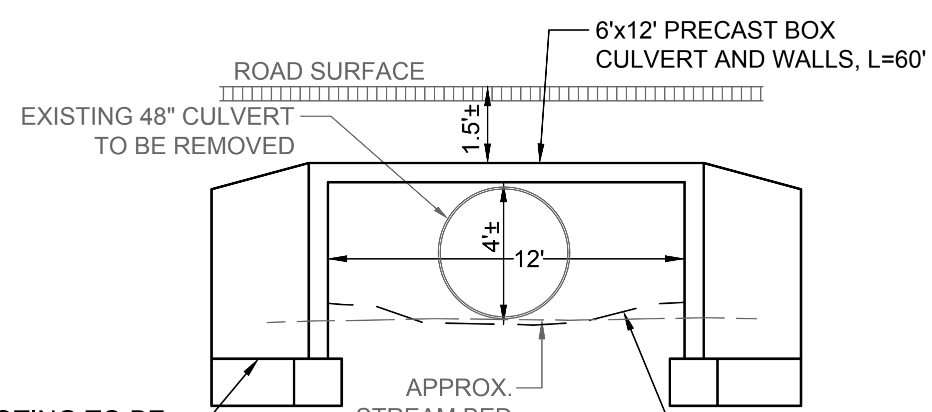
SCALE: 1"= 40' DATE: FEB. 25, 2017

15 0 15 30 60



PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
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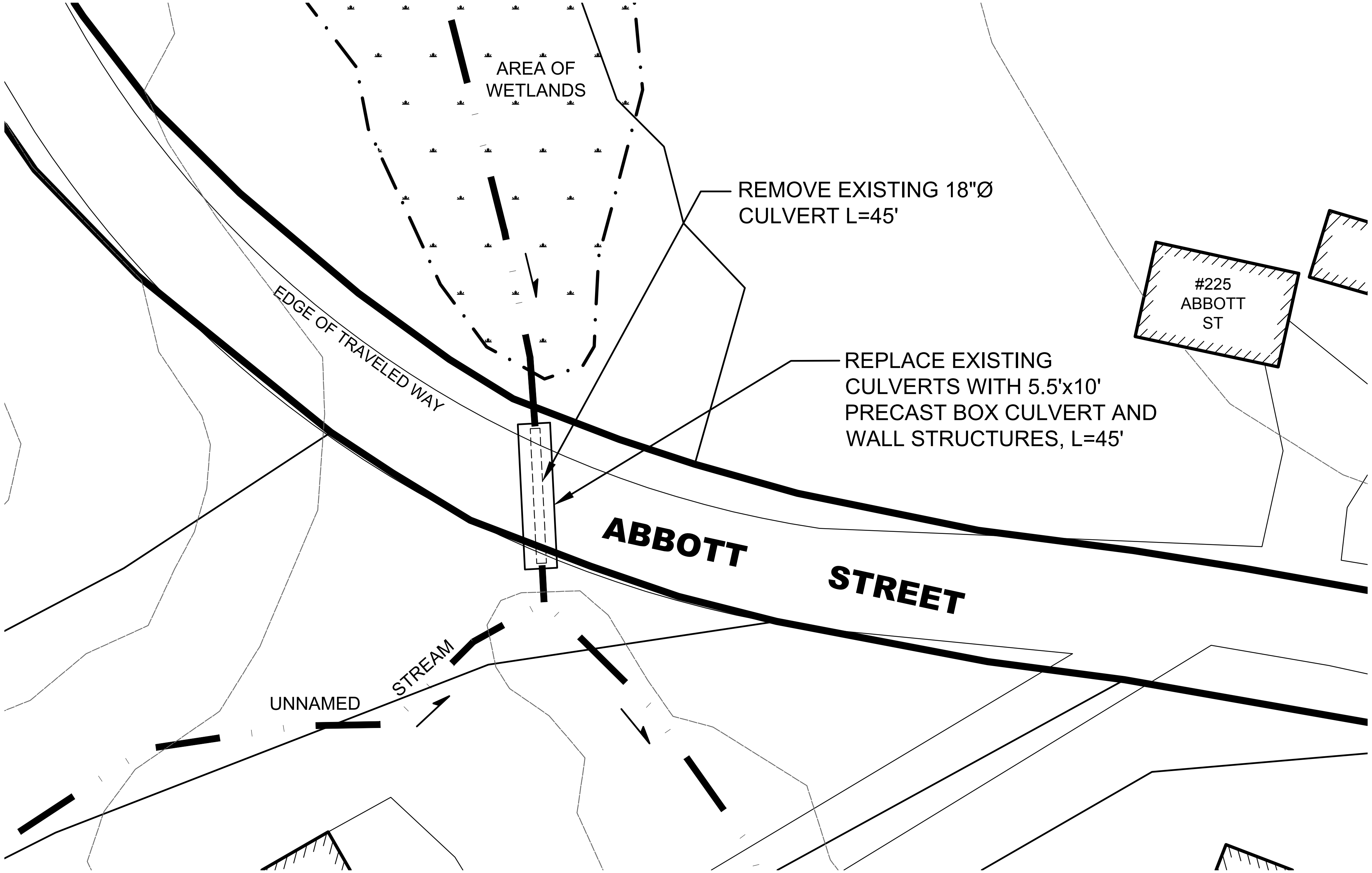
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 648.dwg

MAI Project: 5900



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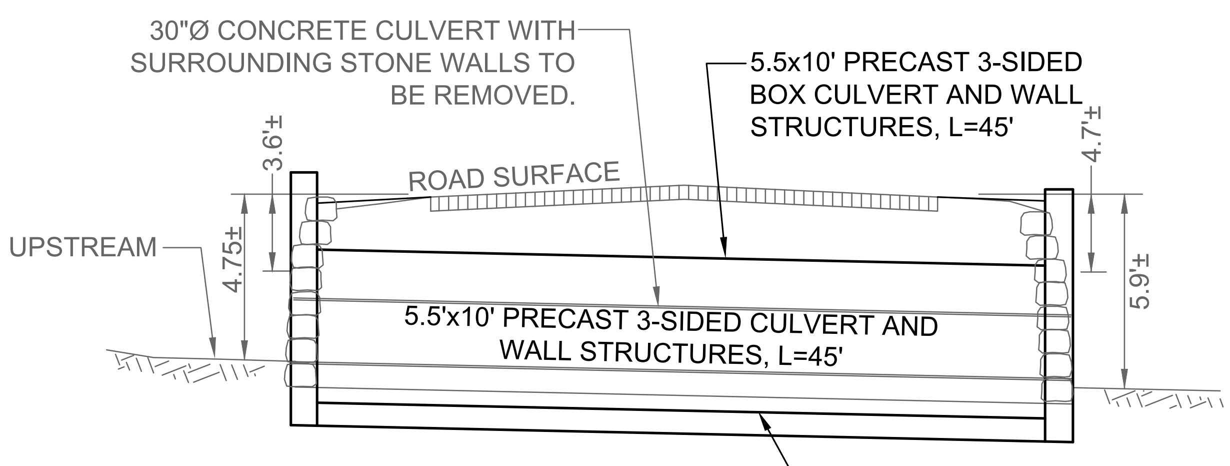
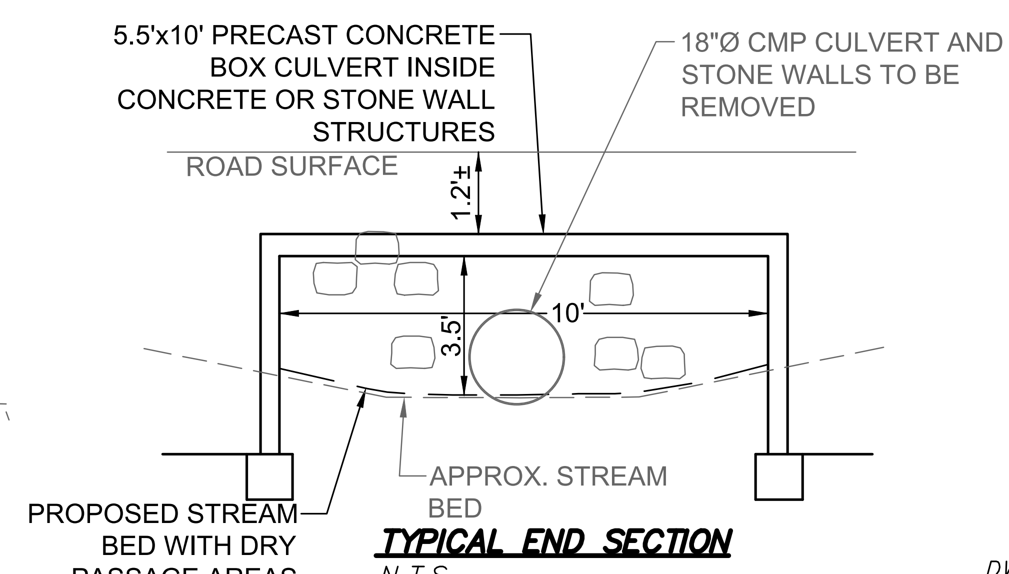
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8.2 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.78
10. NAACC CROSSING CODE: xy4266991271095666
11. NAACC SURVEY ID: 7127



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 668
SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 11, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
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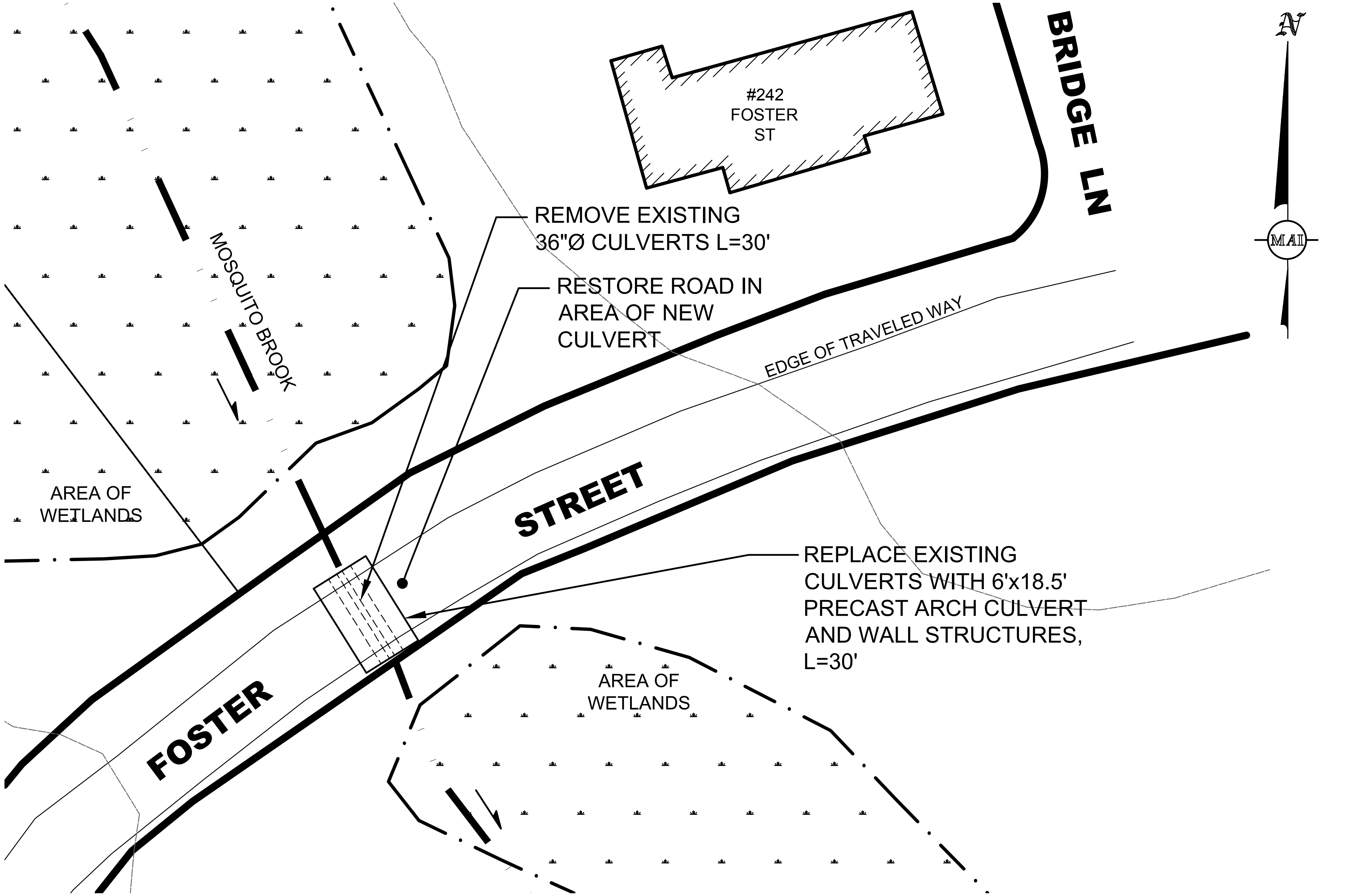
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 668.dwg

MAI Project: 5900



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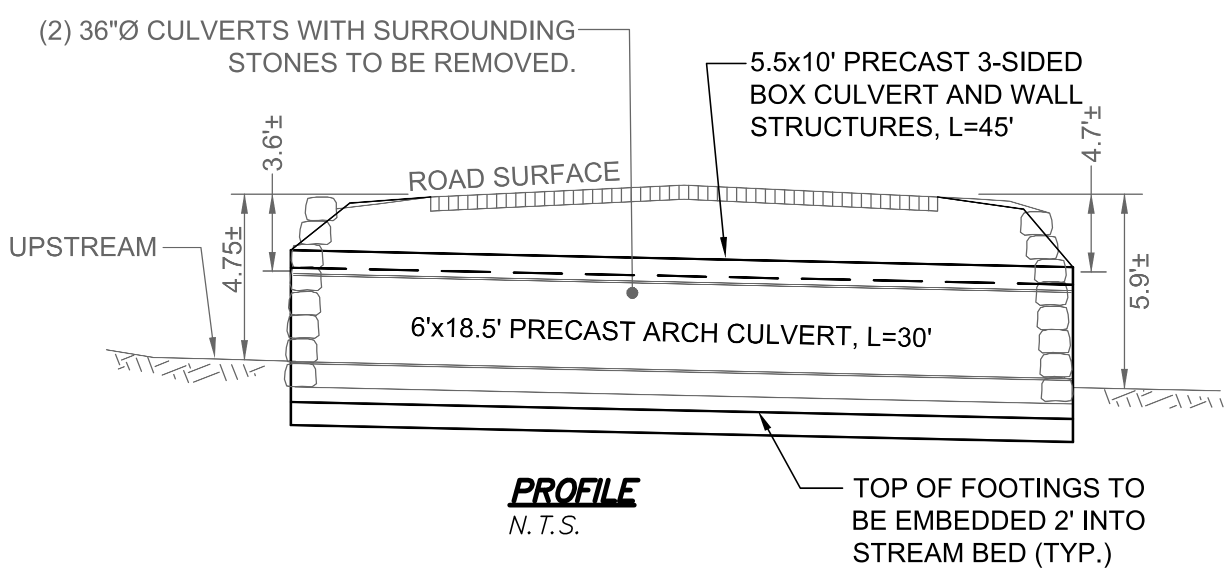
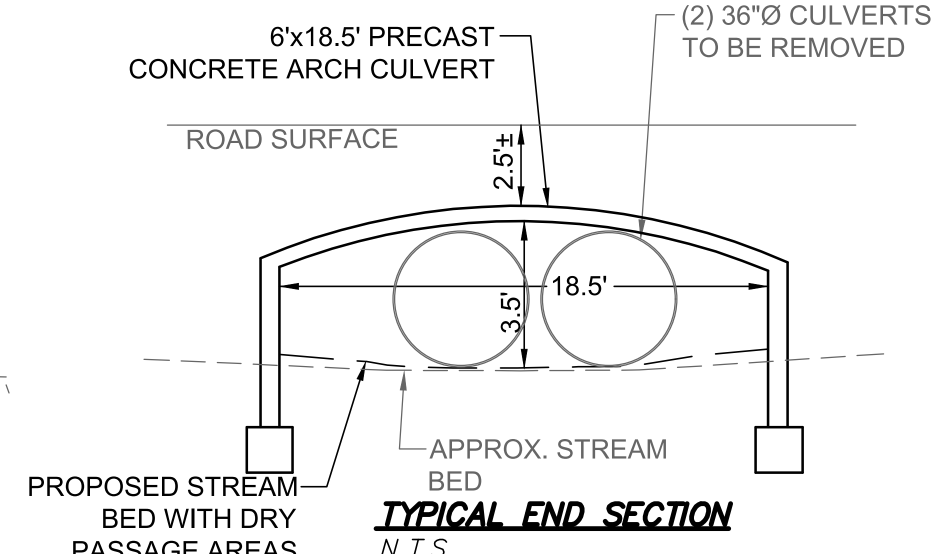
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=15.5 FEET. PROPOSED CULVERT WIDTH=18.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.85
10. NAACC CROSSING CODE: xy4267048471064193
11. NAACC SURVEY ID: 7626



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 674
SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

(ESSEX COUNTY)

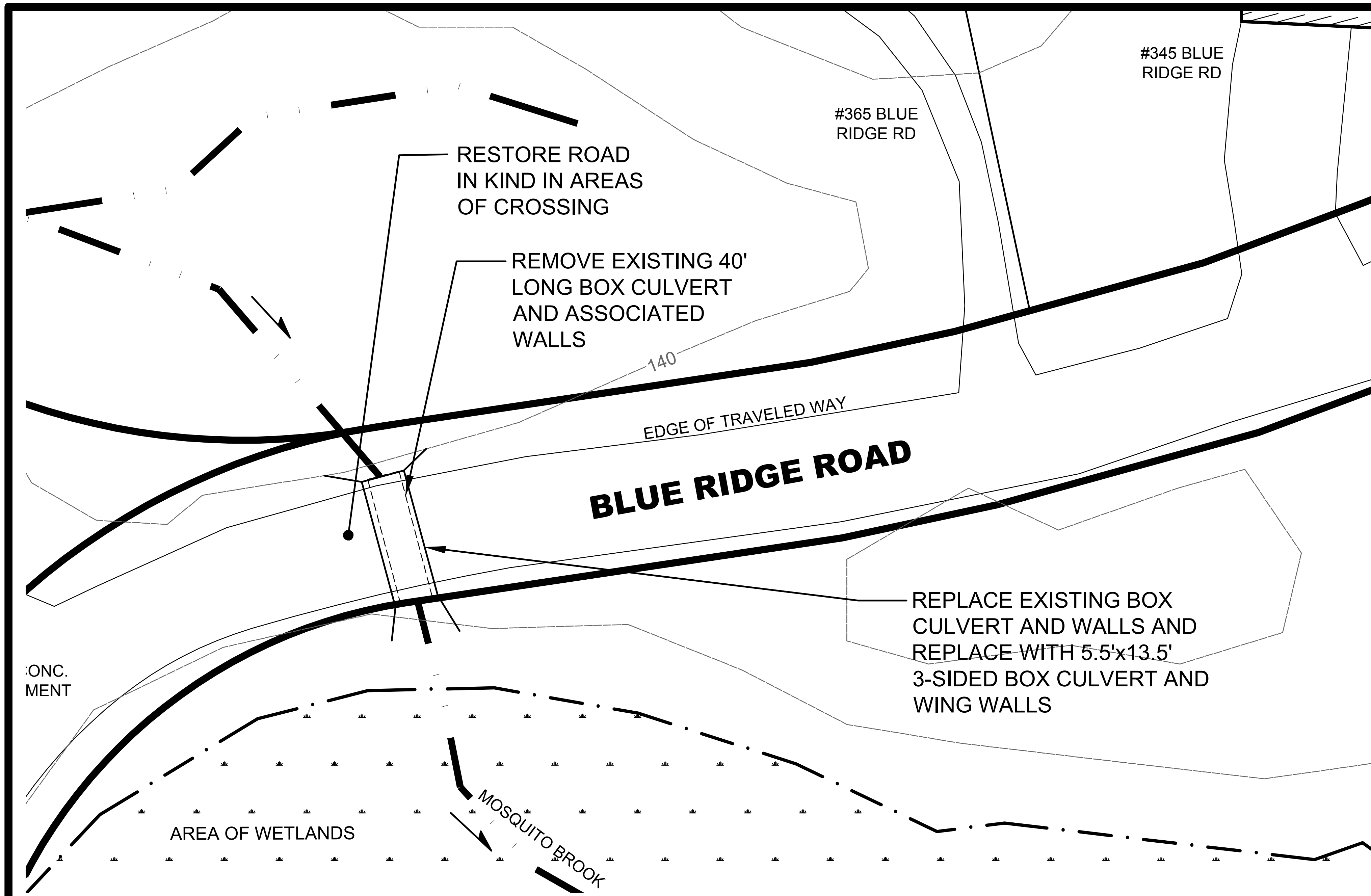
PREPARED FOR

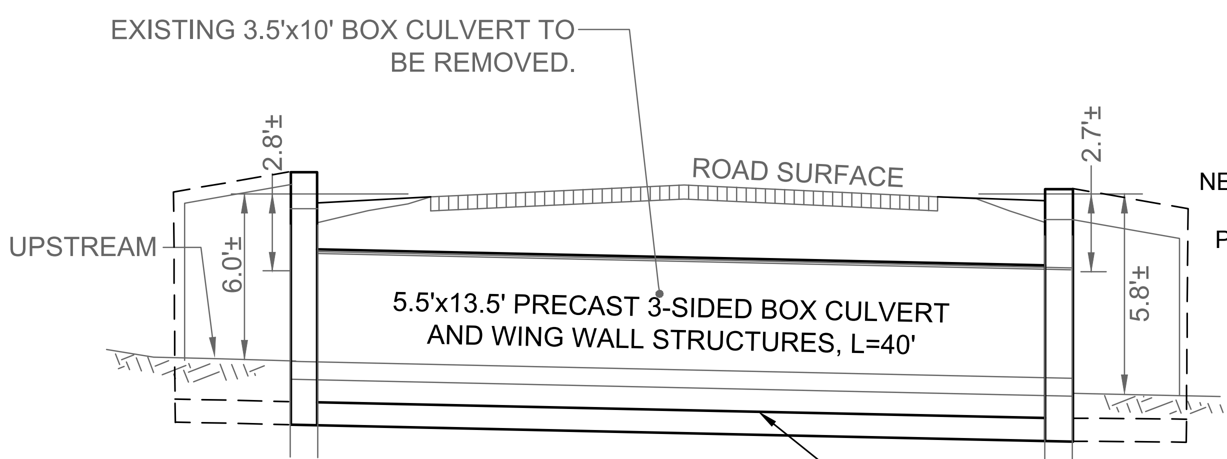
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 17, 2017
20 0 20 40 80

MERIDIAN
ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

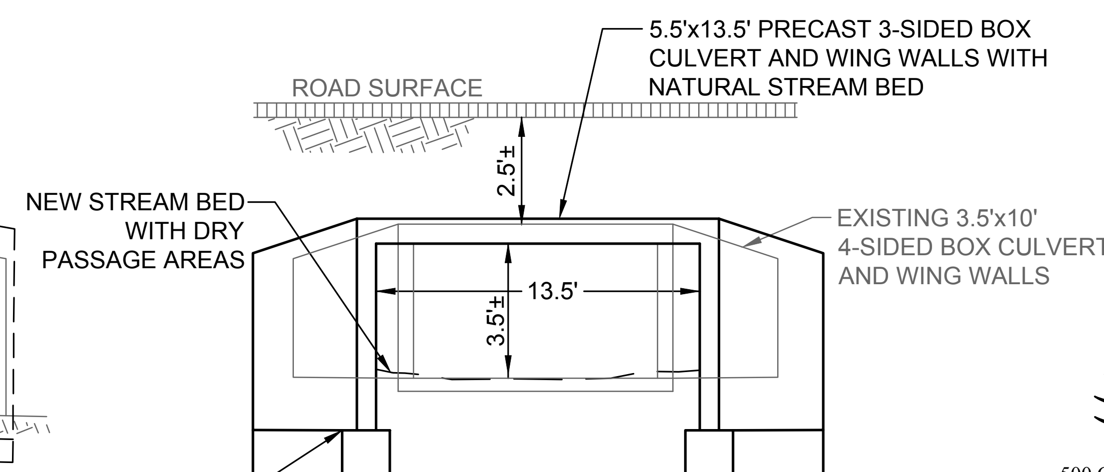
DWG. No. Site 674.dwg
MAI Project: 5900





PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=11.3 FEET. PROPOSED CULVERT WIDTH=13.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.18
10. NAACC CROSSING CODE: xy4267056671080163
11. NAACC SURVEY ID: 7625

CROSSING ID# 675 SKETCH PLAN

LOCATED IN

NORTH ANDOVER, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 17, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

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TELEPHONE: (508) 871-7030

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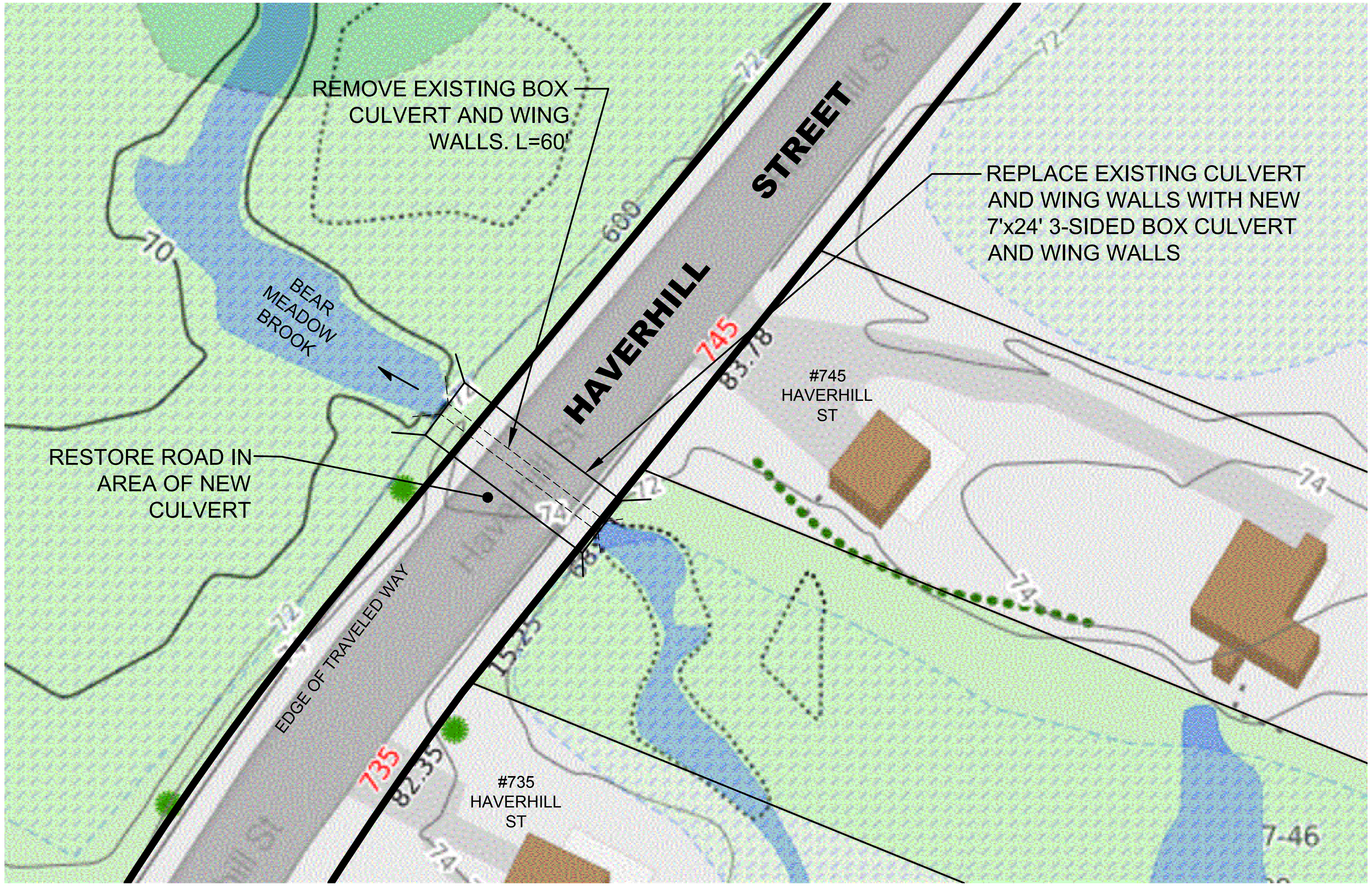
DWG. No. Site 675.dwg

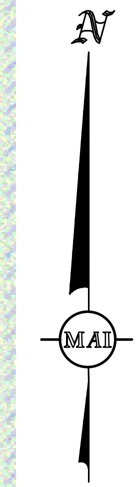
MAI Project: 5900

Reading Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Reading, MA

1 page





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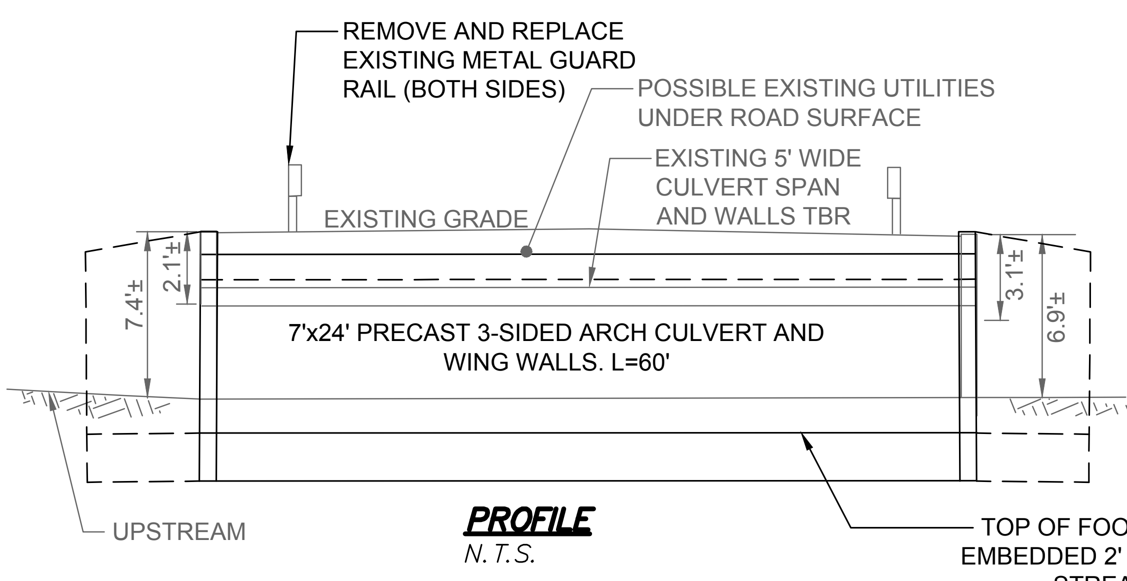
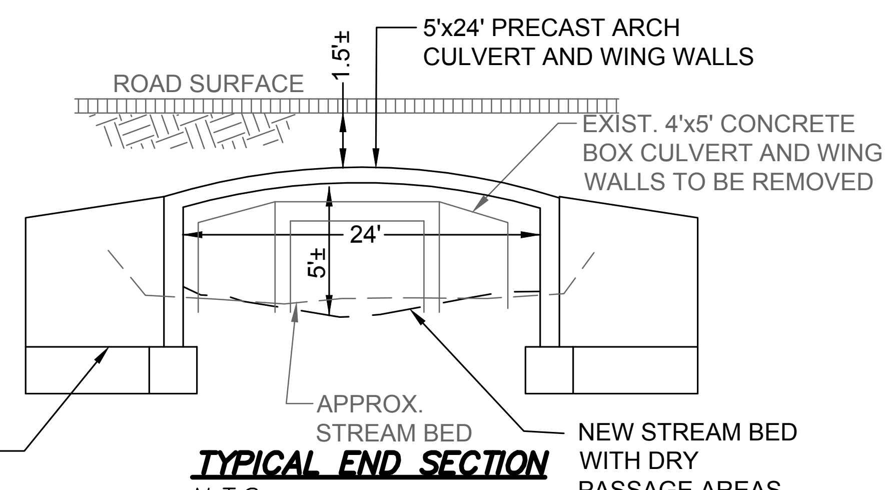
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=20 FEET. PROPOSED CULVERT WIDTH=24 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.67
10. NAACC CROSSING CODE: xy4255840571093779
11. NAACC SURVEY ID: 4787



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 76 SKETCH PLAN

LOCATED IN

READING, MASSACHUSETTS

(MIDDLESEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: JAN. 17, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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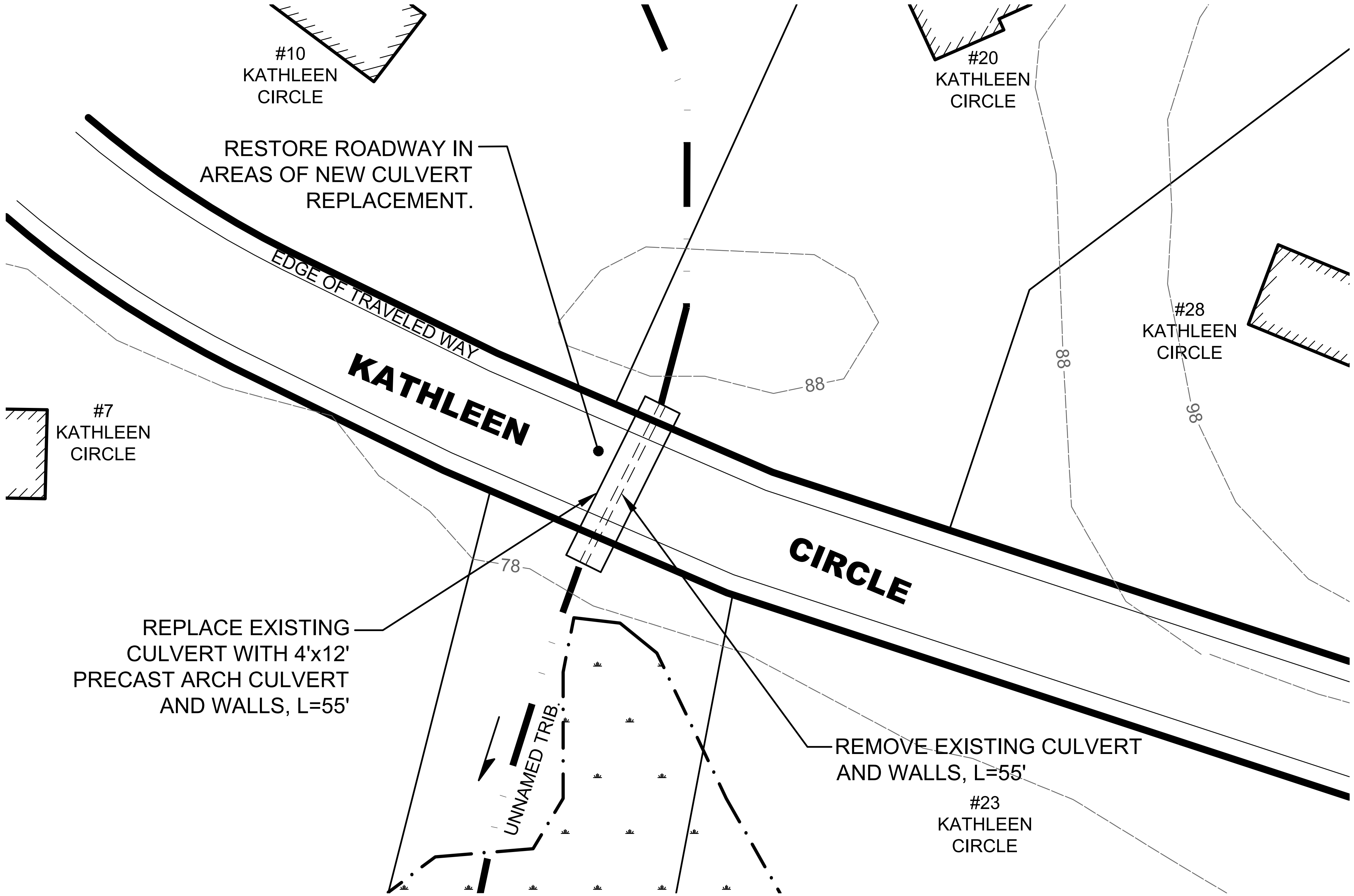
WWW.MERIDIANASSOC.COM

DWG. No. Site 76.dwg MAI Project: 5900

Rowley Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Rowley, MA

6 pages



N

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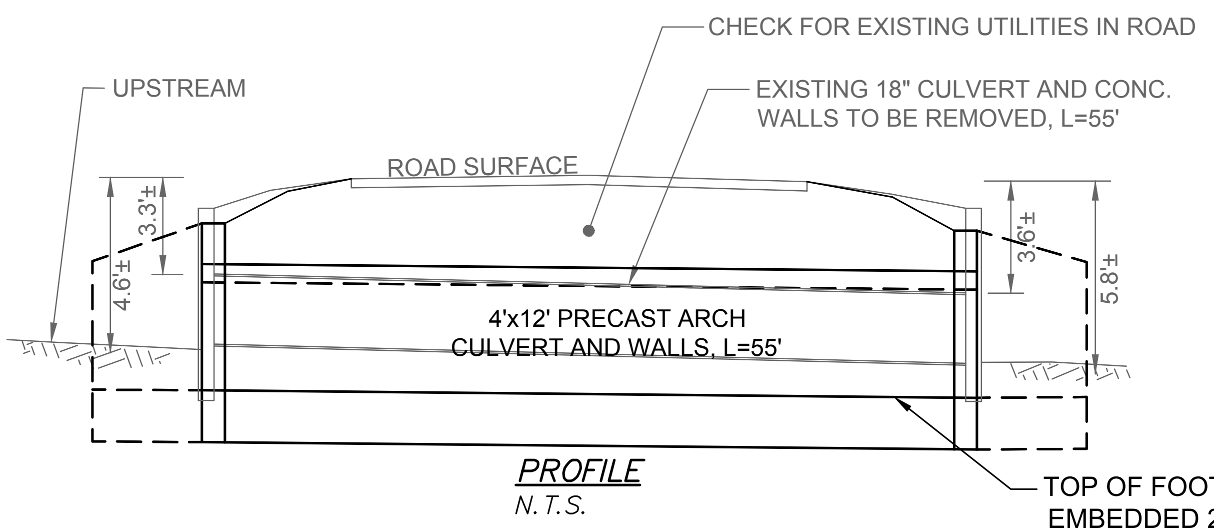
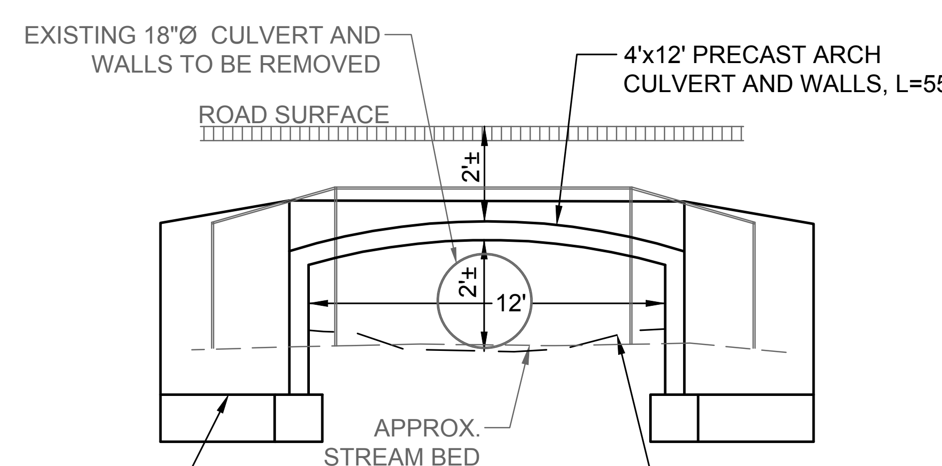
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=5.7 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.55
10. NAACC CROSSING CODE: xy4270035470927162
11. NAACC SURVEY ID: 6983



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#850 SKETCH PLAN

LOCATED IN

ROWLEY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

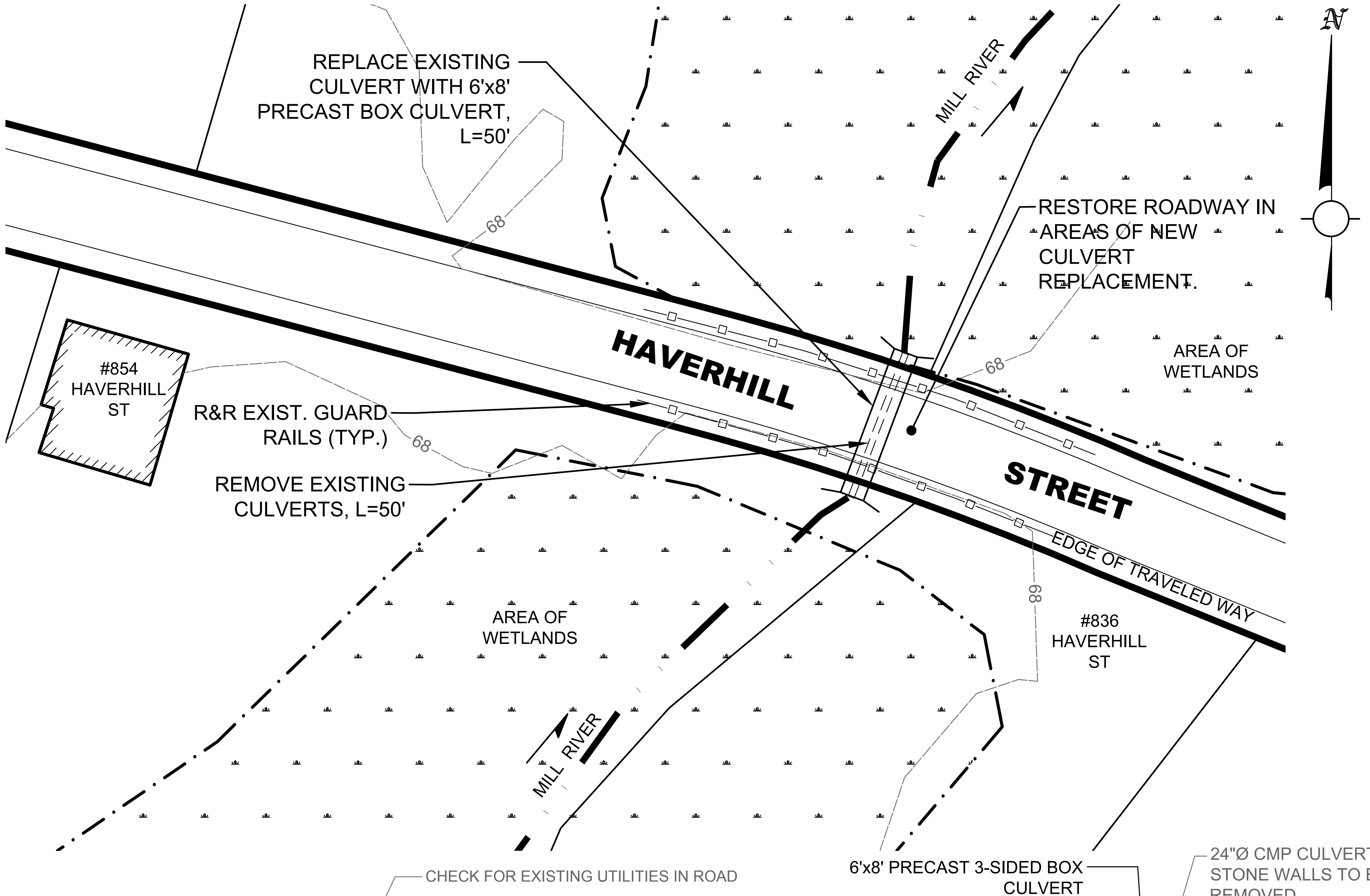
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

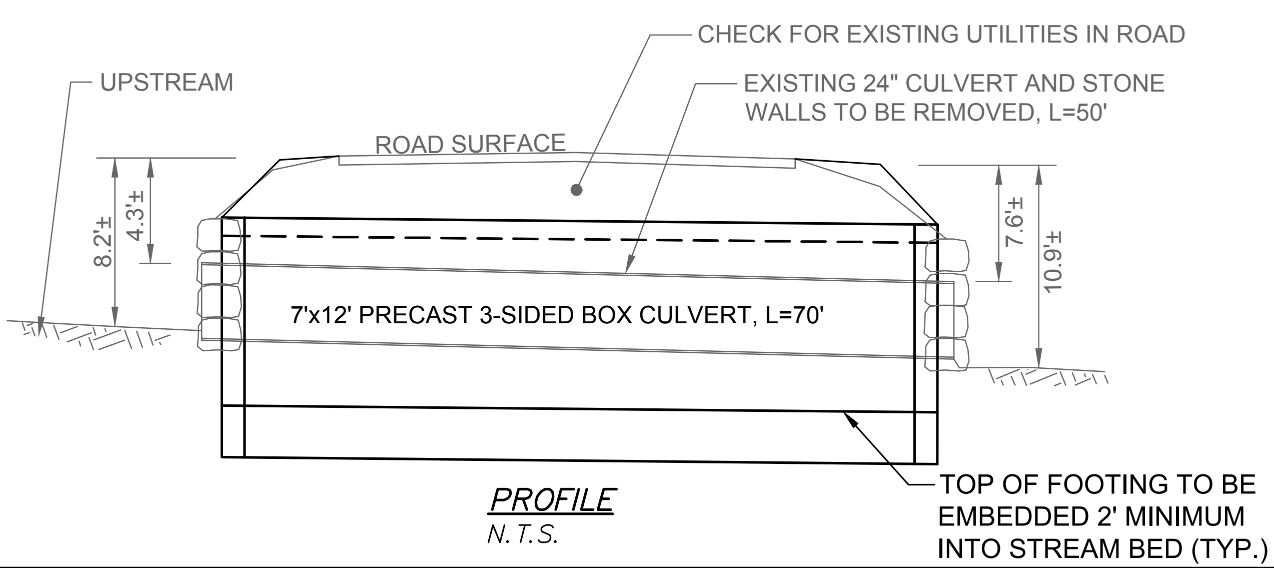
DWG. No. Site 850.dwg

MAI Project: 5900

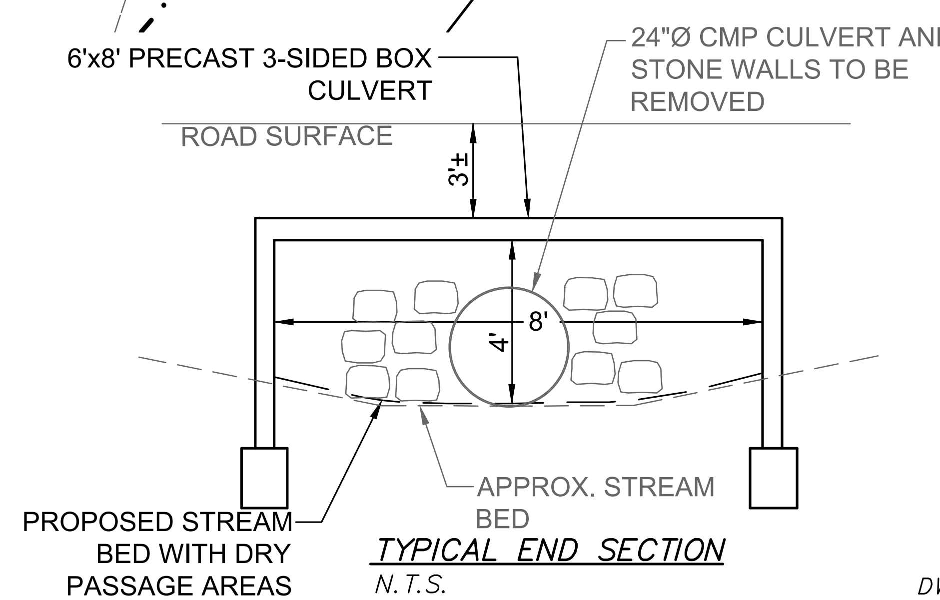


NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.64
10. NAACC CROSSING CODE: xy4270349270945353
11. NAACC SURVEY ID: 7915



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#866
SKETCH PLAN

LOCATED IN

ROWLEY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 10, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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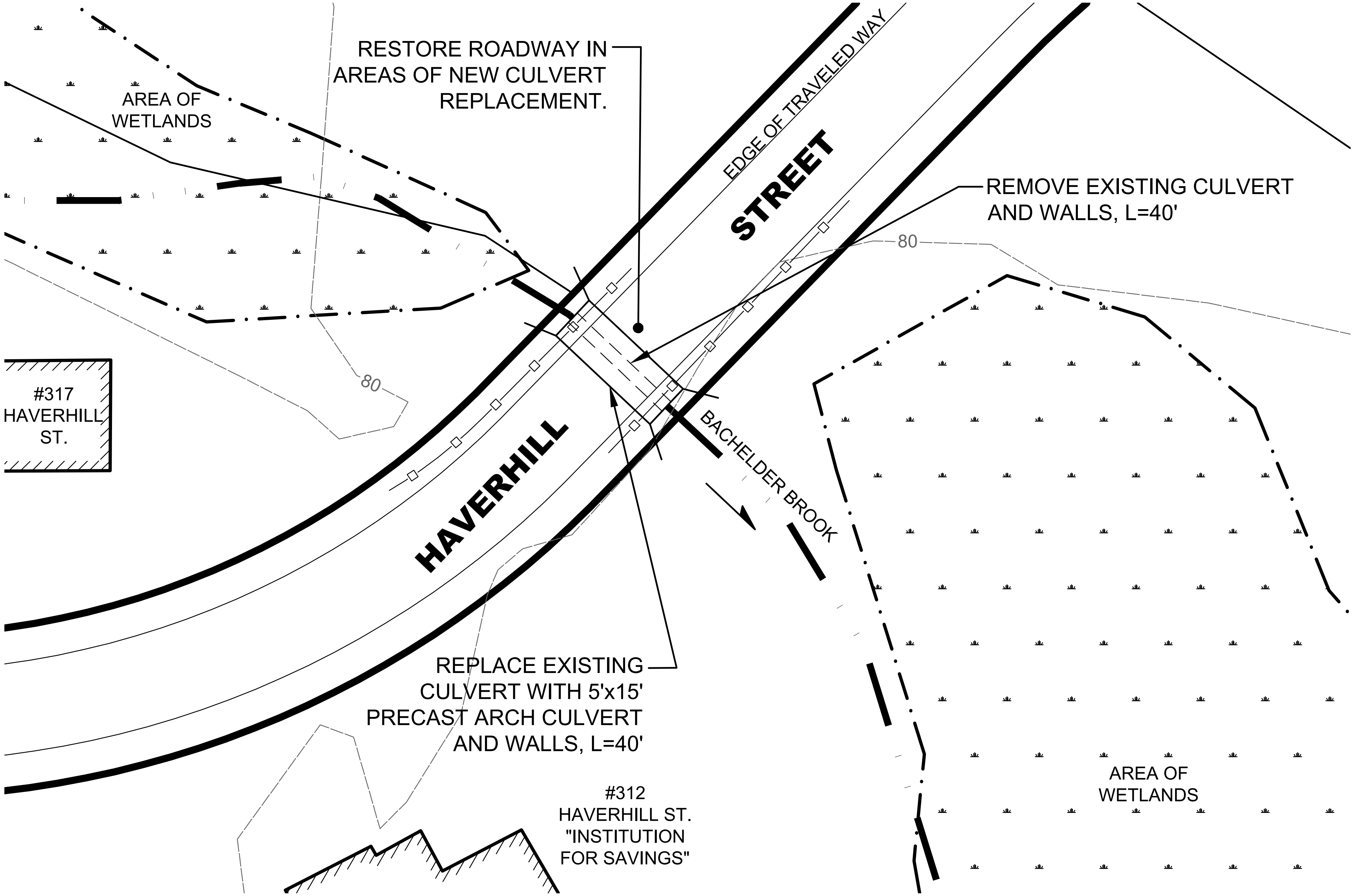
TELEPHONE: (978) 299-0447

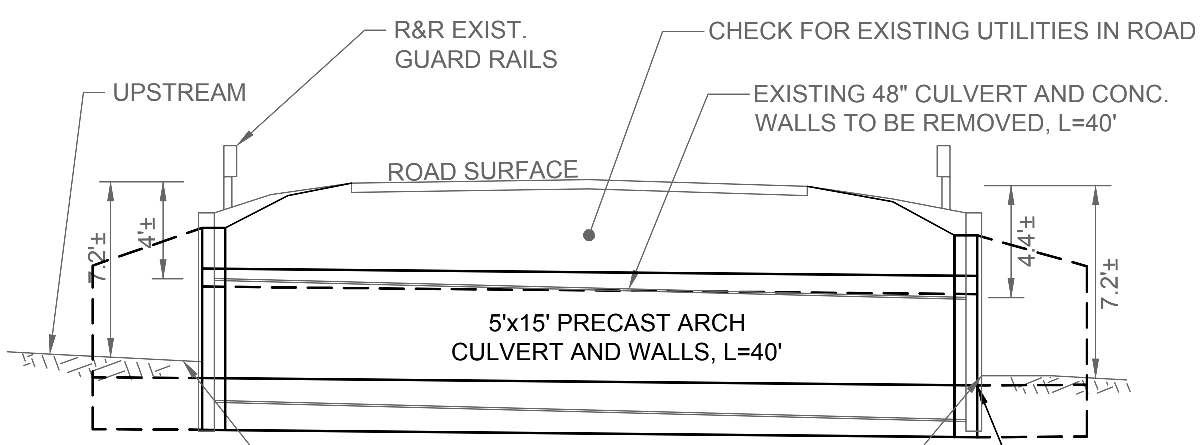
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

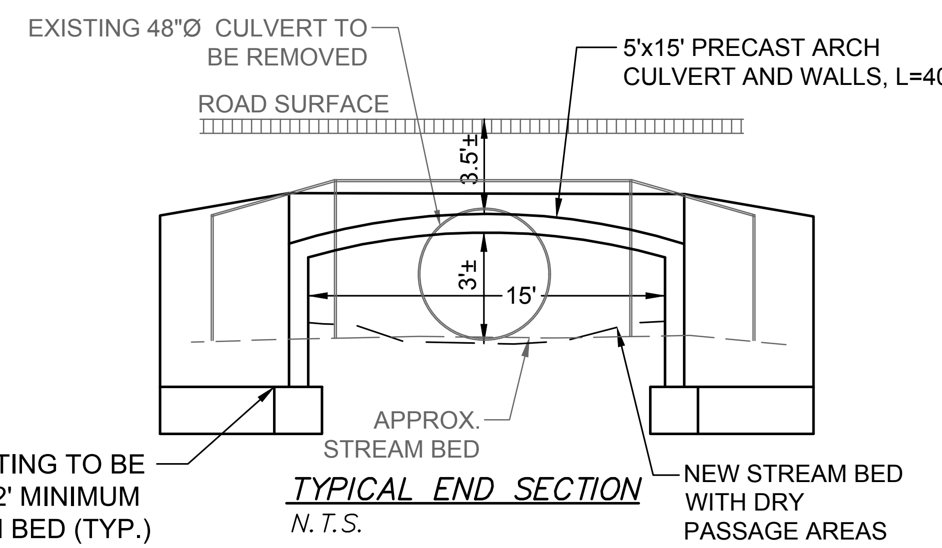
DWG. No. Site 500.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=12.2 FEET. PROPOSED CULVERT WIDTH=15 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.93
10. NAACC CROSSING CODE: xy4270526770907483
11. NAACC SURVEY ID: 9089

CROSSING ID#878 SKETCH PLAN

LOCATED IN

ROWLEY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

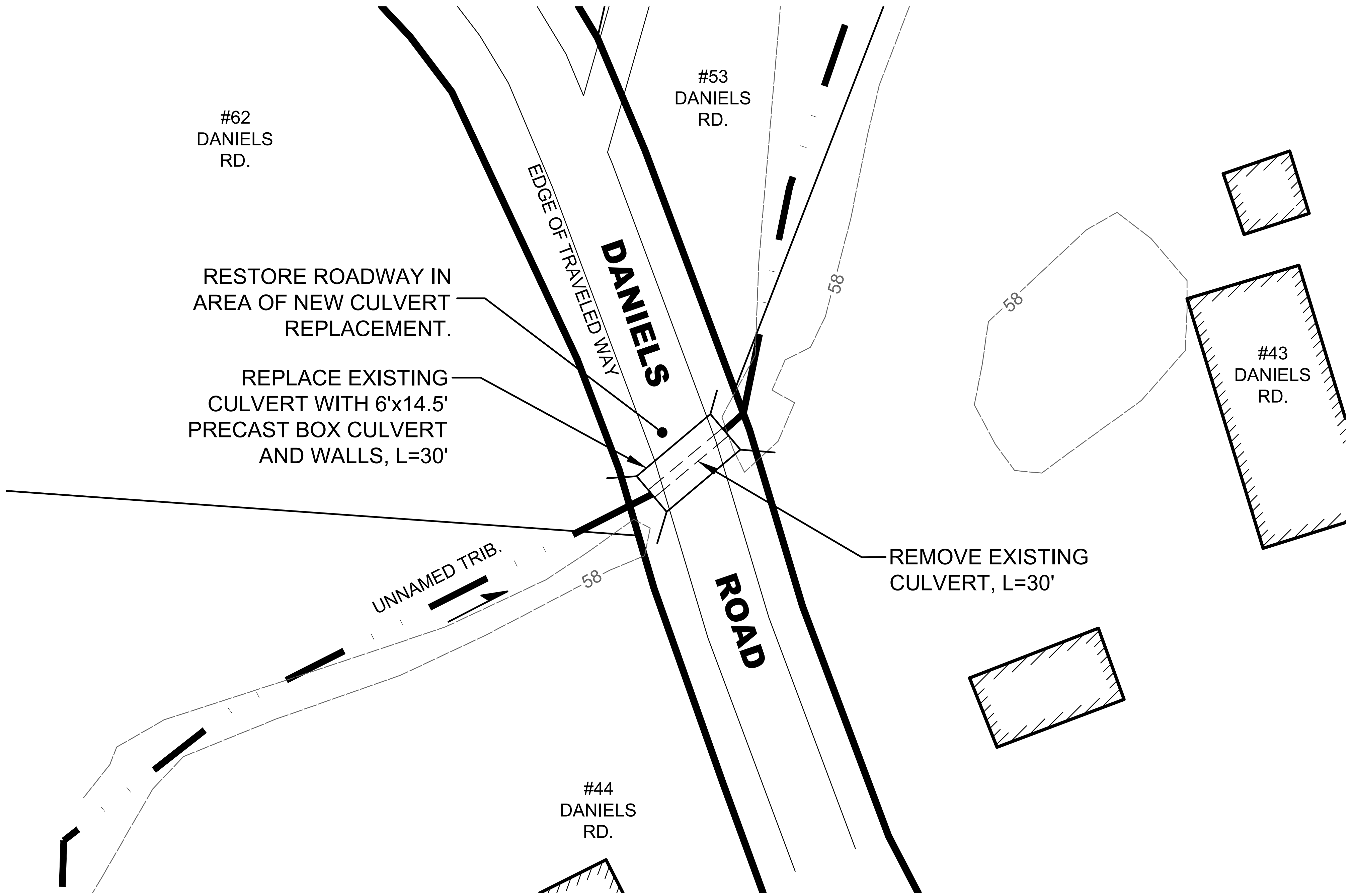
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 878.dwg

MAI Project: 5900



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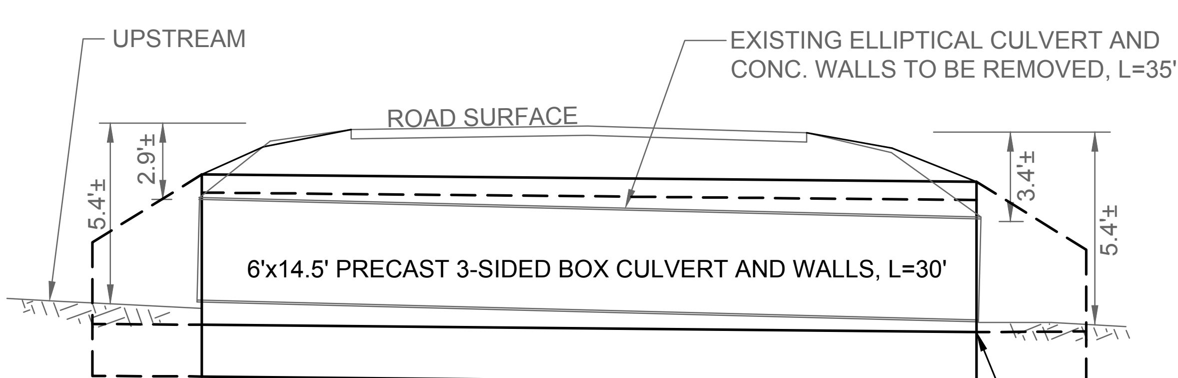
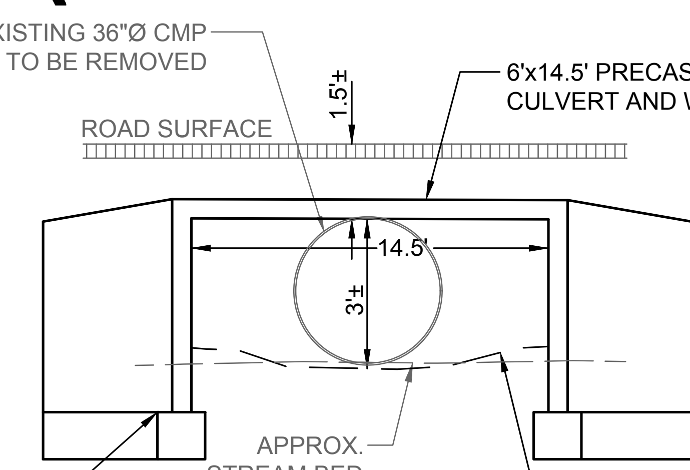
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=11.9 FEET. PROPOSED CULVERT WIDTH=14.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.45
10. NAACC CROSSING CODE: xy4270856970927269
11. NAACC SURVEY ID: 7951



TOP OF FOOTING TO BE
EMBEDDED 2' MINIMUM
INTO STREAM BED (TYP.)

PROFILE
N.T.S.



NEW STREAM BED
WITH DRY
PASSAGE AREAS

TYPICAL END SECTION
N.T.S.

CROSSING ID#898
SKETCH PLAN

LOCATED IN

ROWLEY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

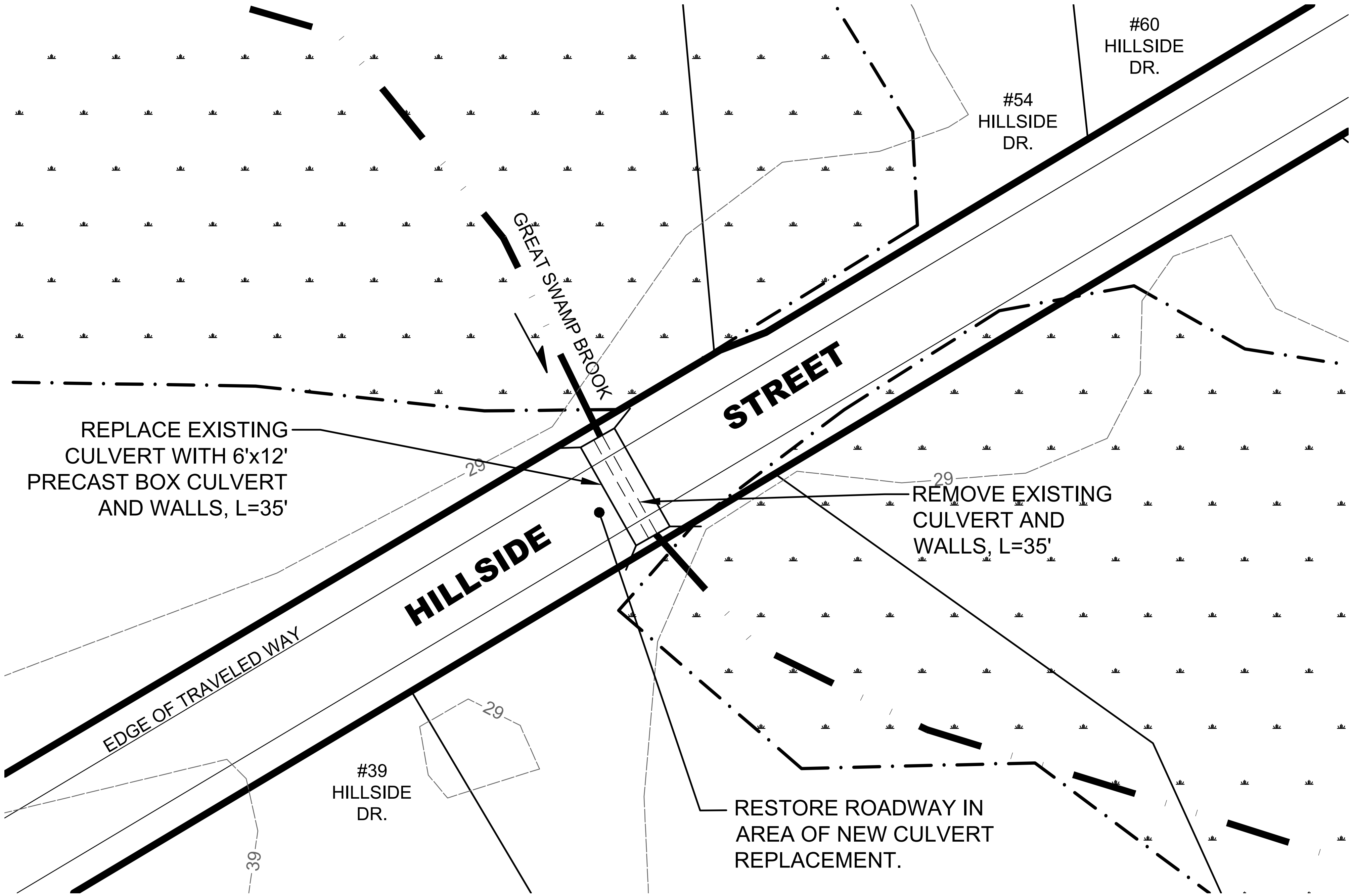
SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN
ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 898.dwg

MAI Project: 5900



NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.03
10. NAACC CROSSING CODE: xy4272859270915327
11. NAACC SURVEY ID: 9568

CROSSING ID#989 SKETCH PLAN

LOCATED IN

ROWLEY, MASSACHUSETTS

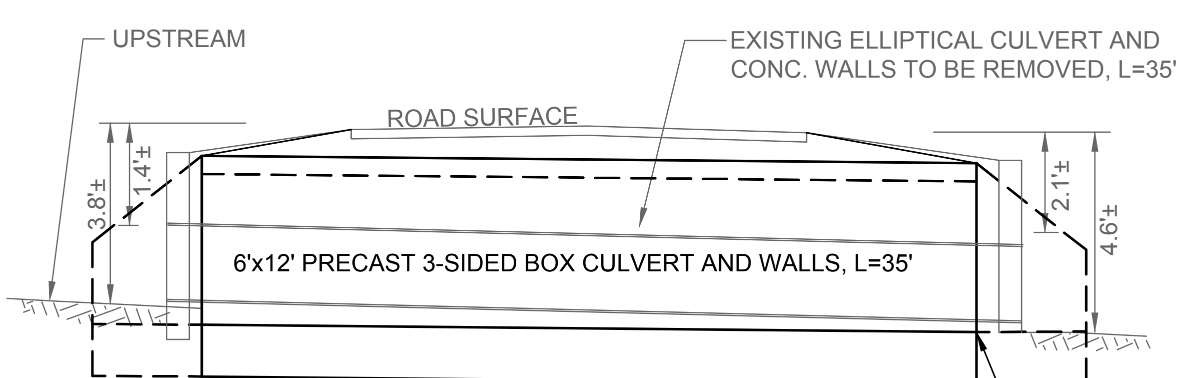
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

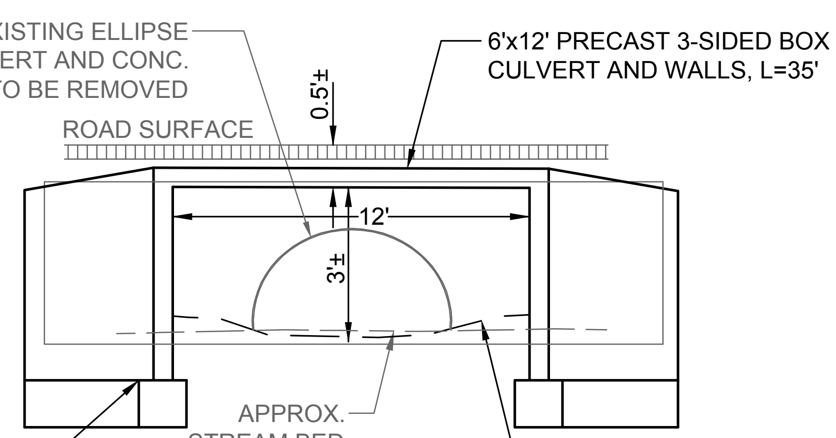
15 0 15 30 60



PROFILE

N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



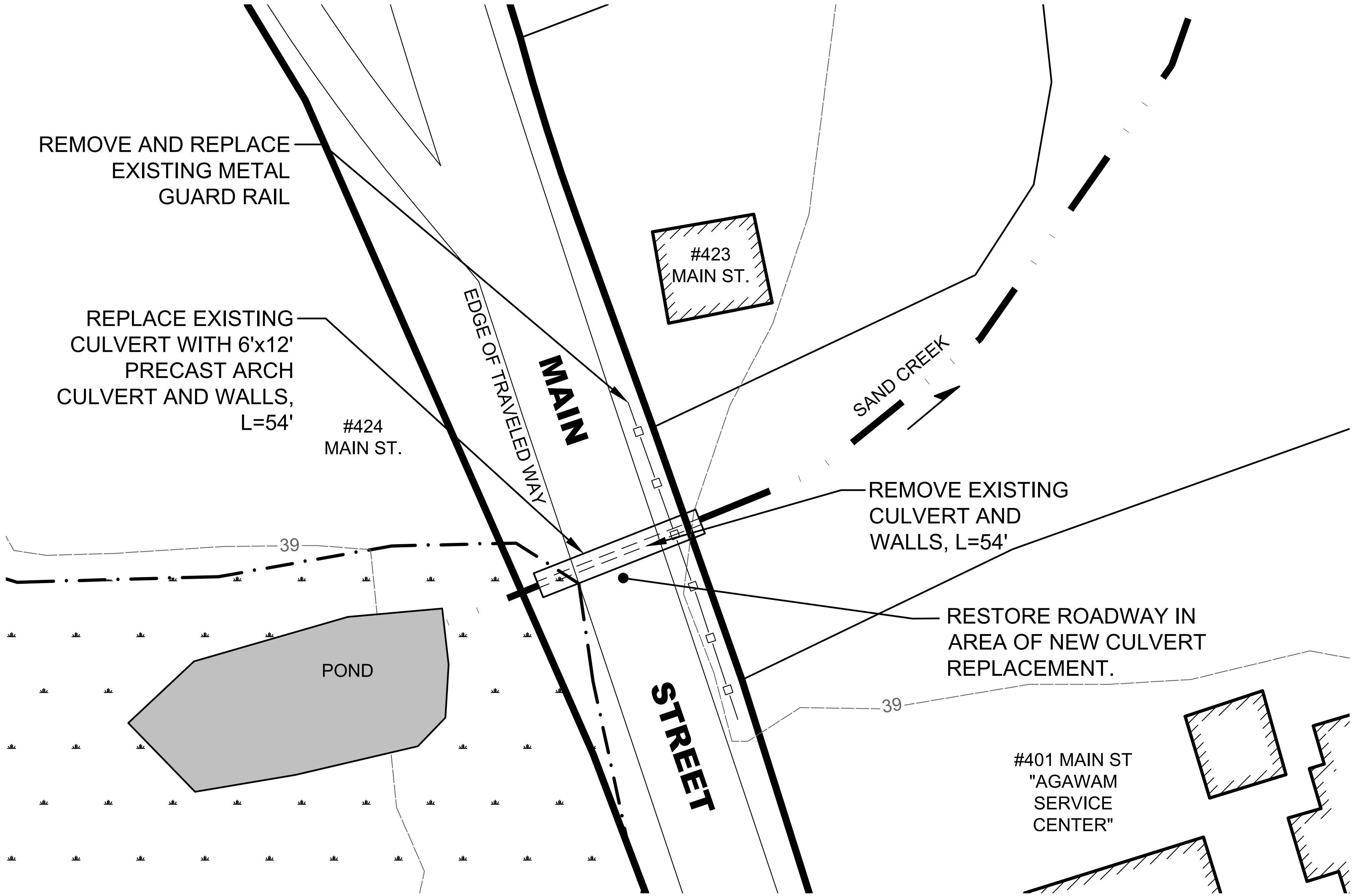
TYPICAL END SECTION

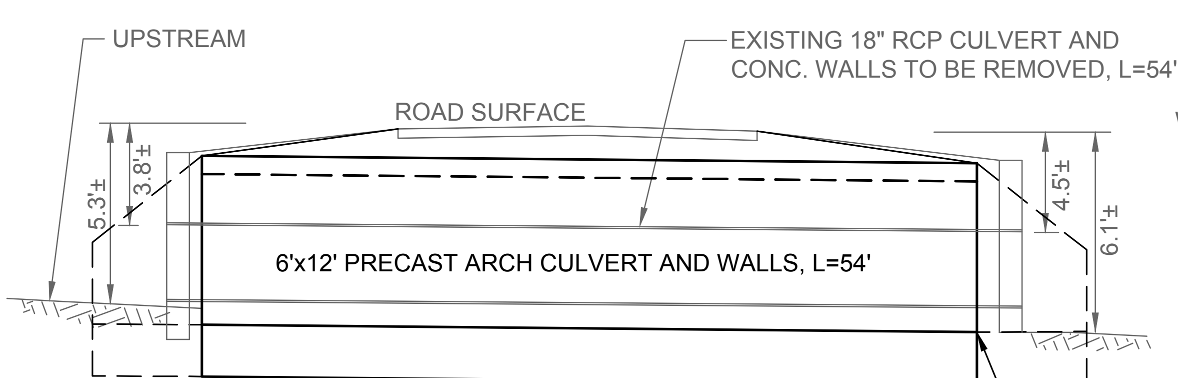
N.T.S.

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 989.dwg

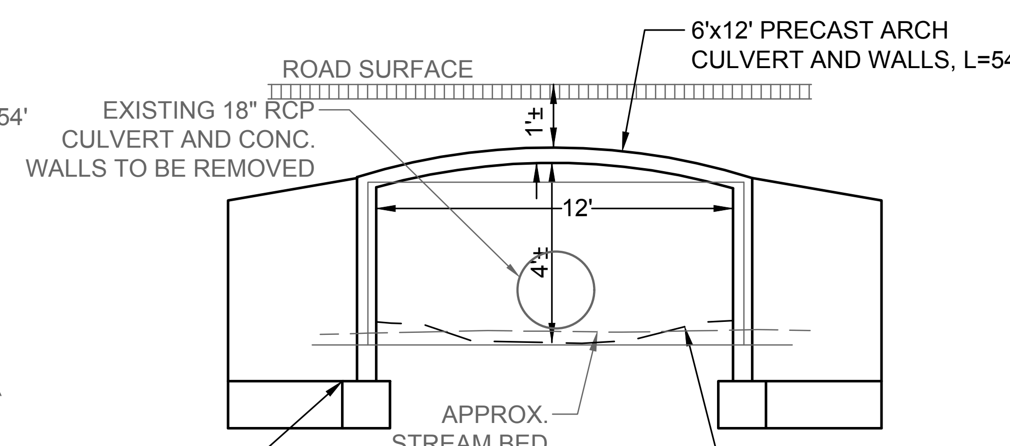
MAI Project: 5900





PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

NEW STREAM BED WITH DRY PASSAGE AREAS

N

NOTES:

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4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=6.3 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.89
10. NAACC CROSSING CODE: xy4272840470865353
11. NAACC SURVEY ID: 10221

CROSSING ID#990 SKETCH PLAN

LOCATED IN

ROWLEY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

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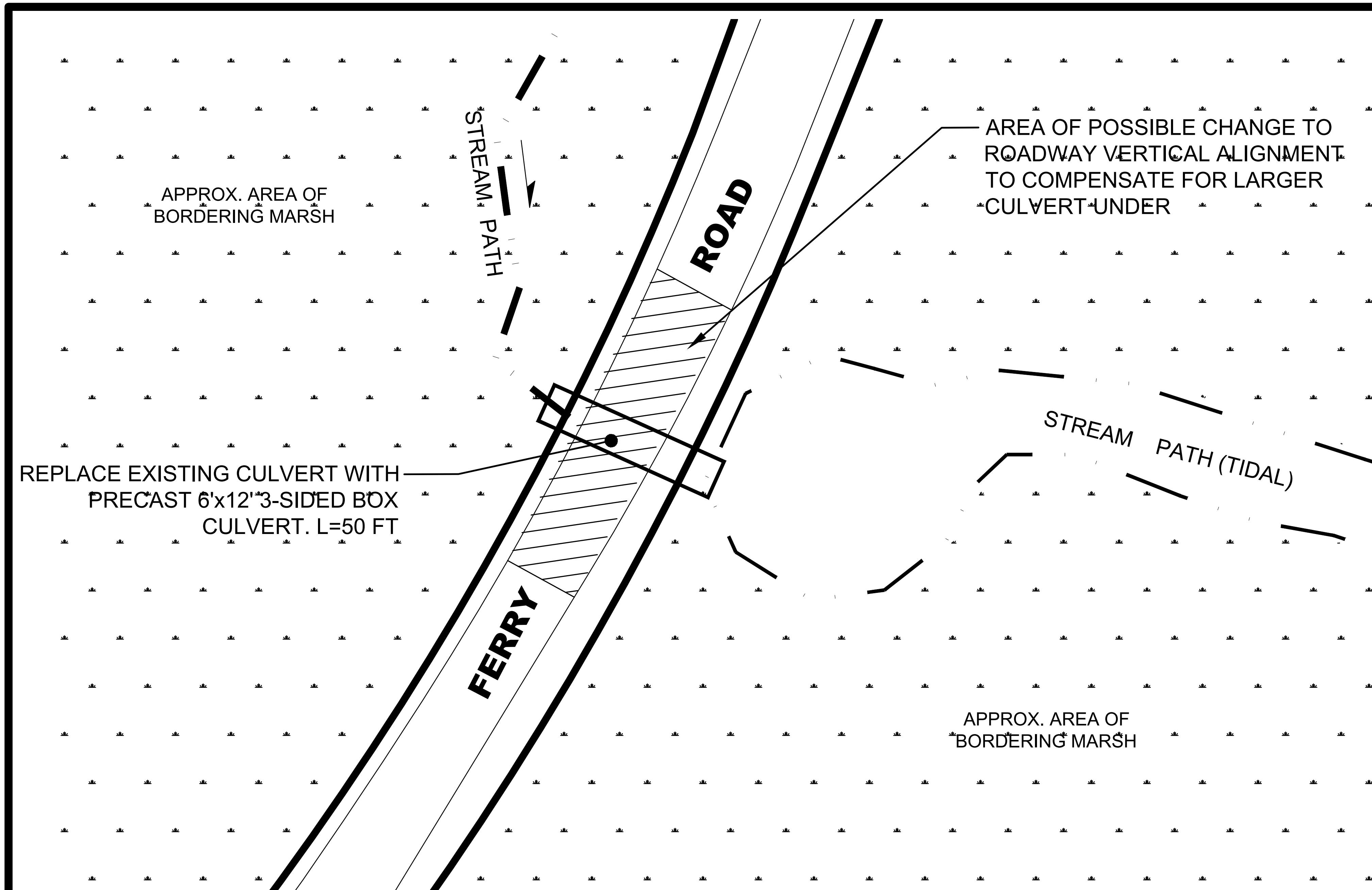
DWG. No. Site 990.dwg

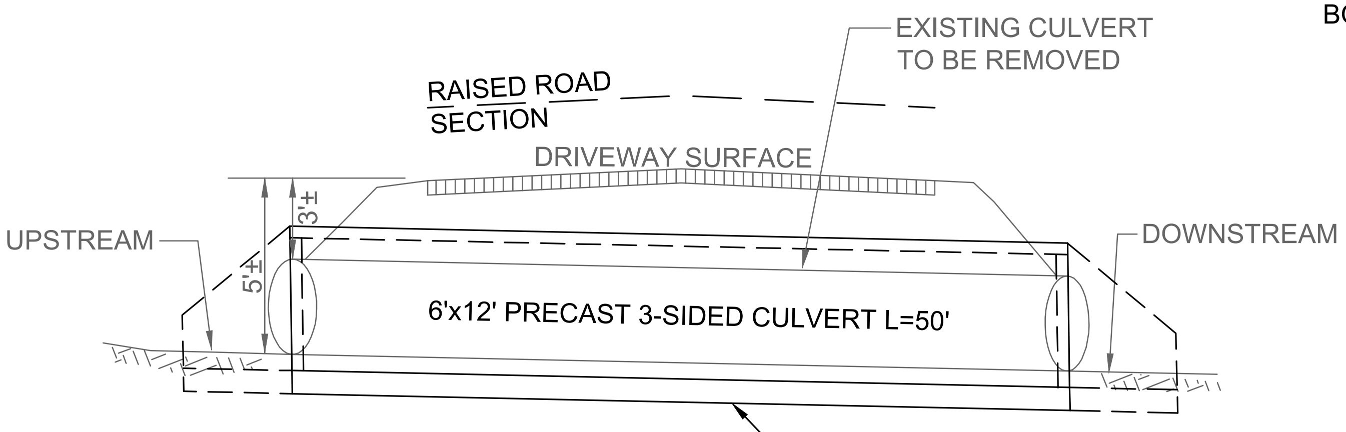
MAI Project: 5900

Salisbury Designs

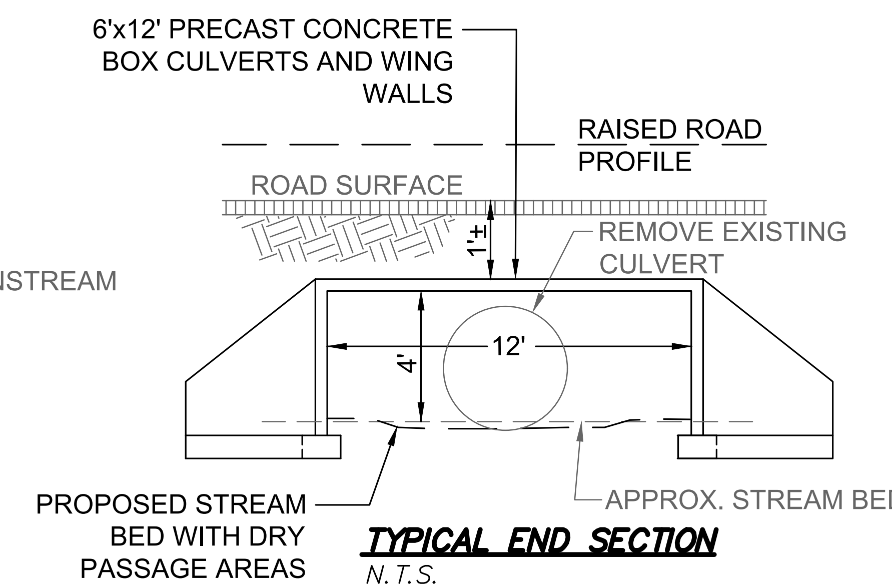
Conceptual designs for the replacement of select road-stream crossings in the Town of Salisbury, MA

5 pages





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (TIDAL). PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.96
10. NAACC CROSSING CODE: xy4281866470863472
11. NAACC SURVEY ID: 23419

CROSSING ID# 10104
SKETCH PLAN

LOCATED IN

SALISBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 9, 2016

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

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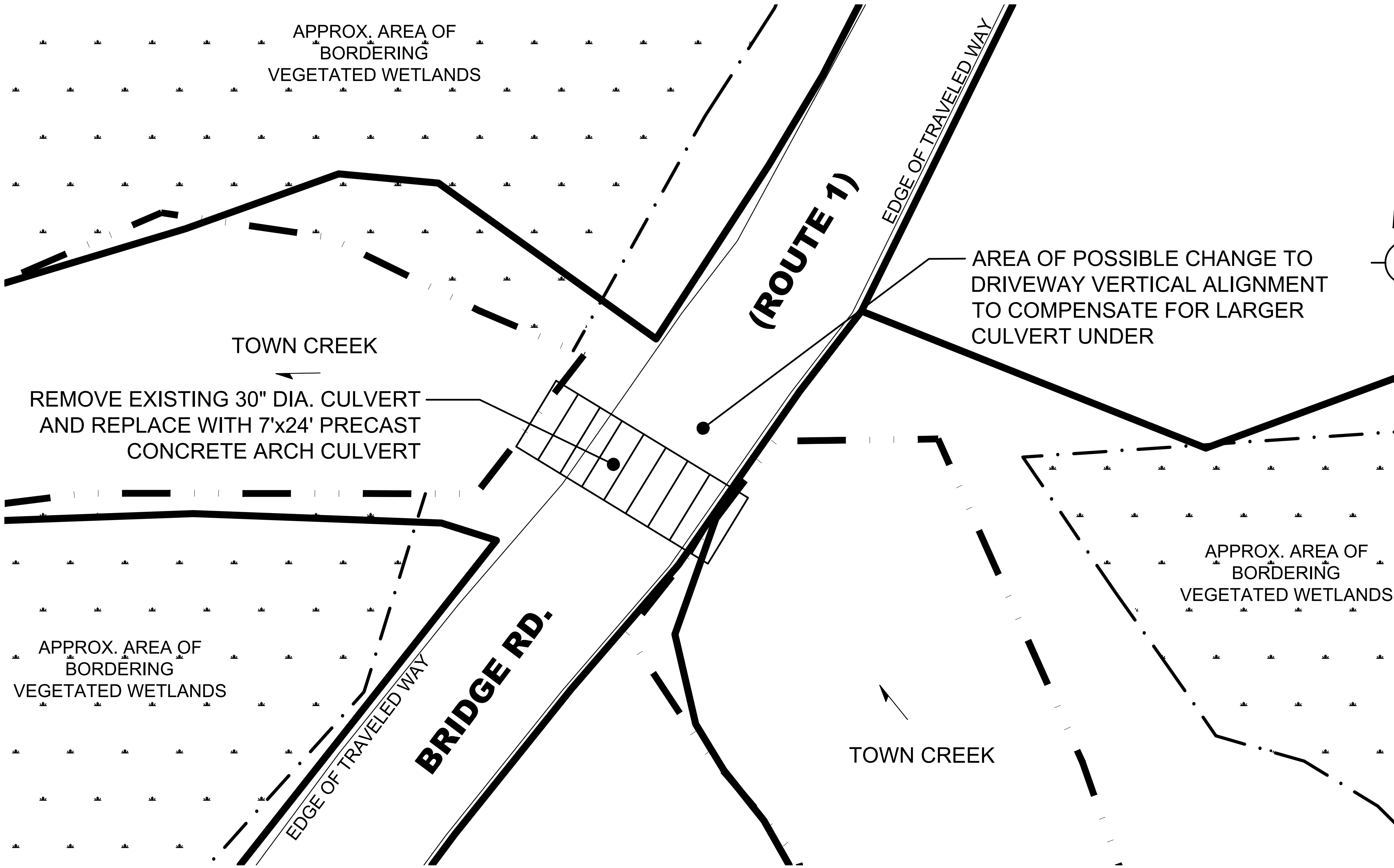
DWG. No. Site 10104.dwg

MAI Project: 5900



NOTES:

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (TIDAL). PROPOSED CULVERT WIDTH=24 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.4
10. NAACC CROSSING CODE: xy4283158770863070
11. NAACC SURVEY ID: 23404

CROSSING ID# 10107
SKETCH PLAN

LOCATED IN

SALISBURY, MASSACHUSETTS

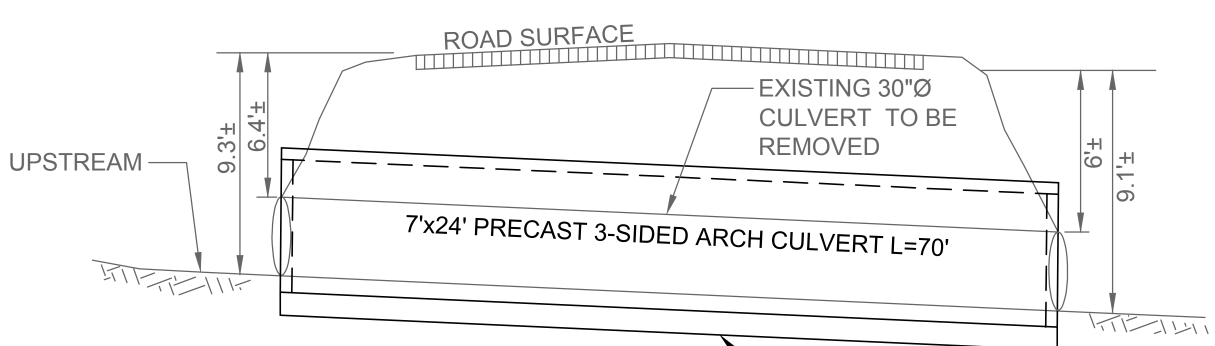
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

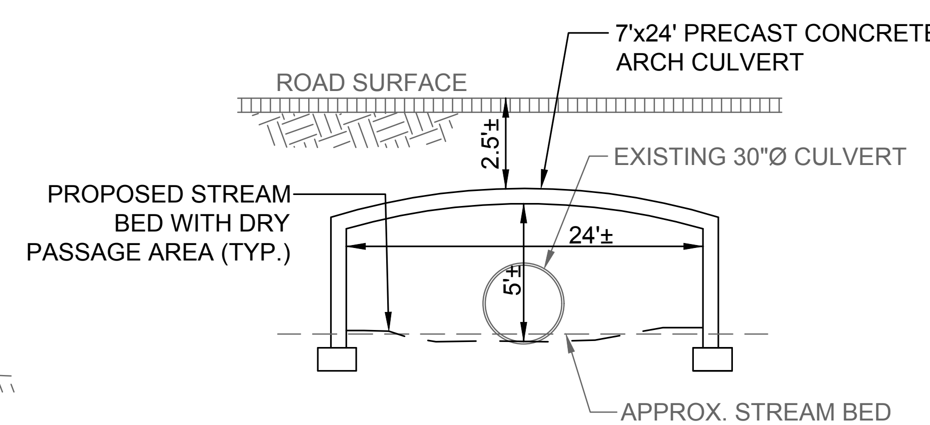
SCALE: 1"= 40' DATE: NOV. 1, 2016

20 0 20 40 80



PROFILE

N.T.S.



DOWNSTREAM END SECTION

N.T.S.

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

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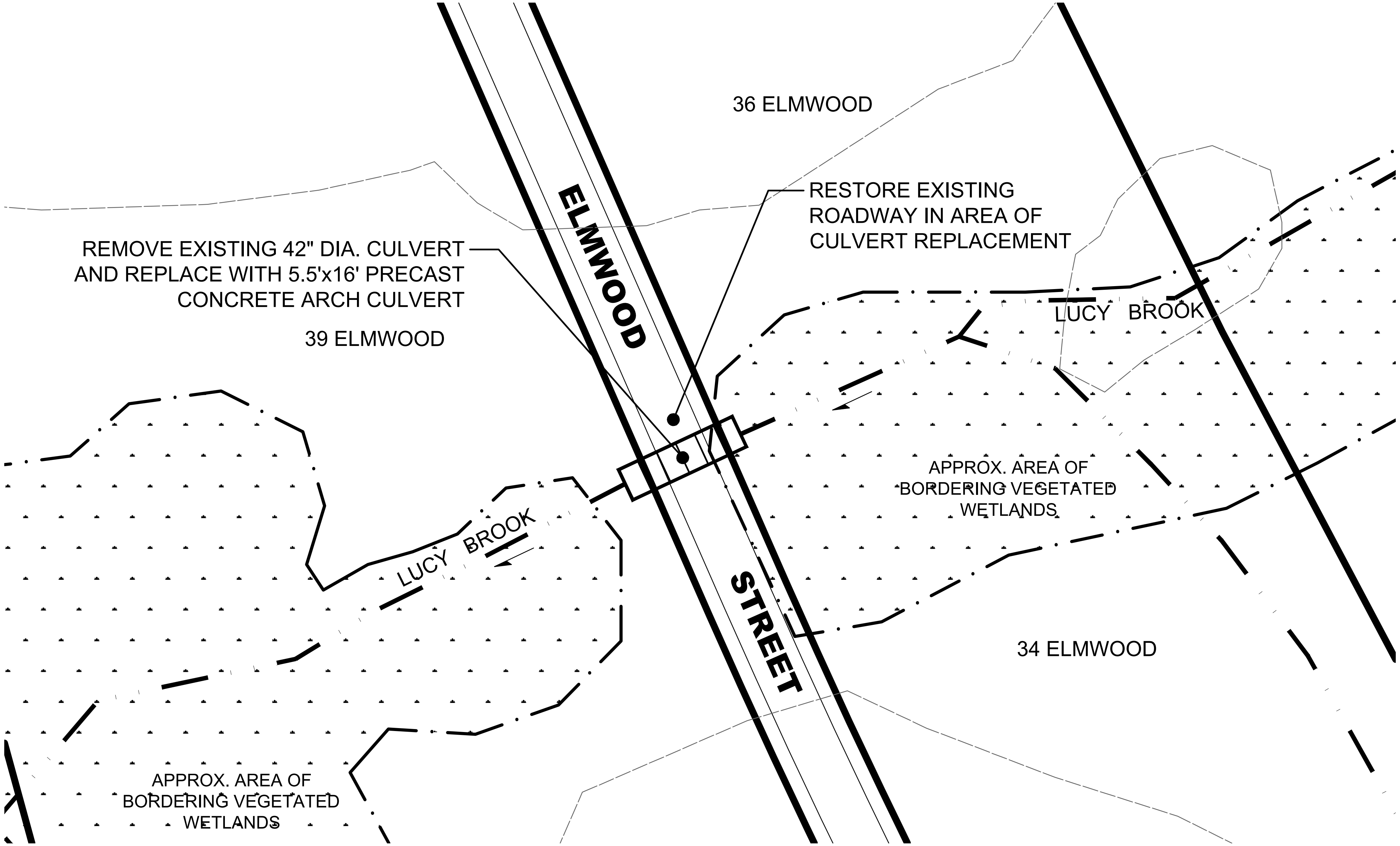
DWG. No. Site 10107.dwg

MAI Project: 5900



NOTES:

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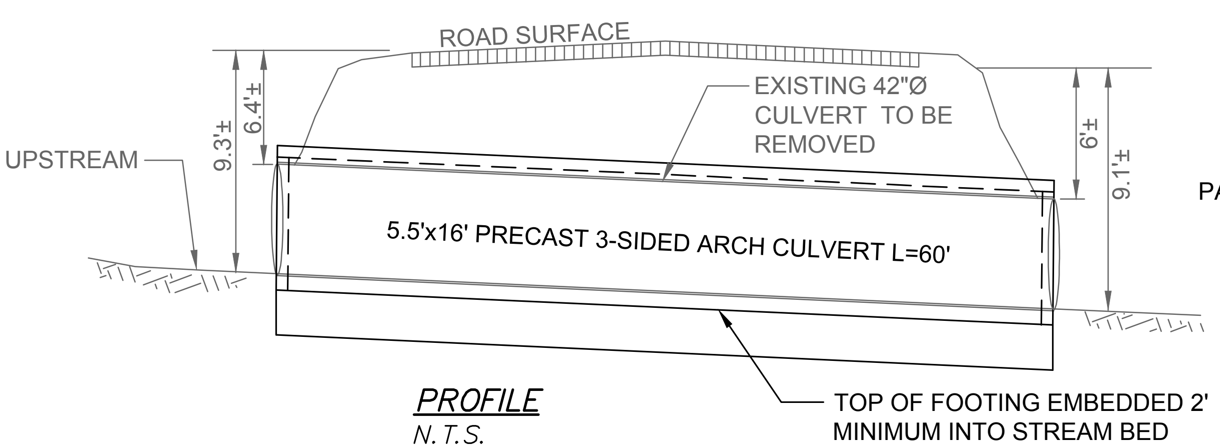
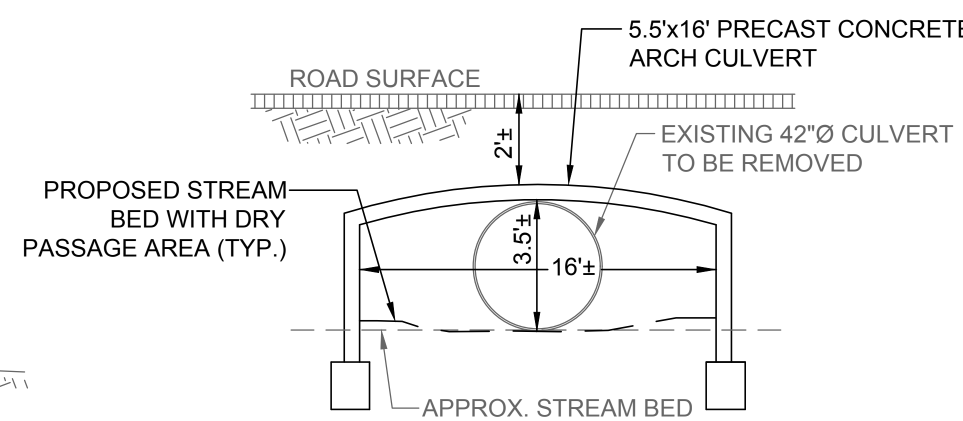
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=13± FEET. PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.93
10. NAACC CROSSING CODE: xy4288052970910918
11. NAACC SURVEY ID: 23436



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 10109
SKETCH PLAN

LOCATED IN

SALISBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 60' DATE: NOV. 9, 2016

30 0 30 60 120

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
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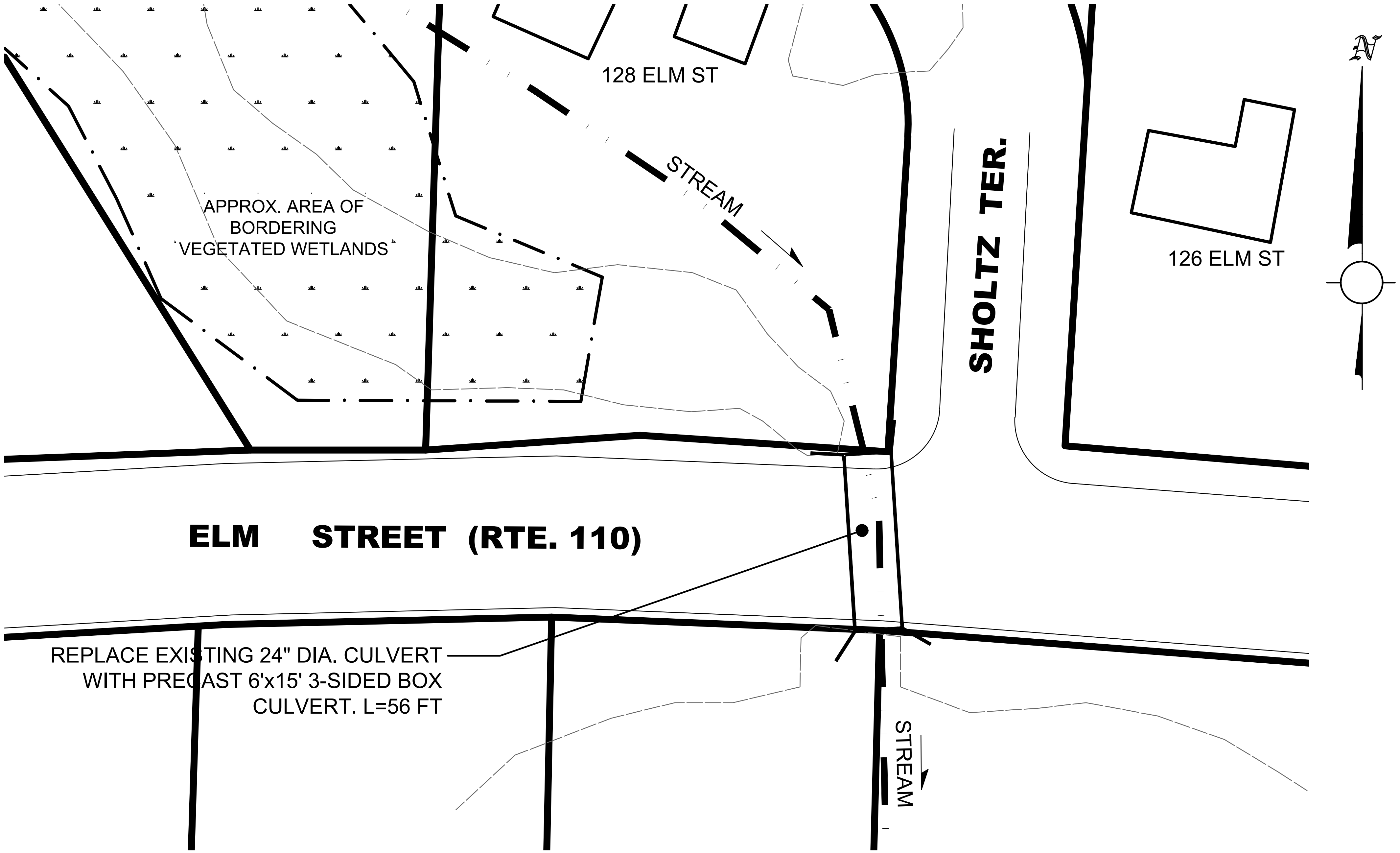
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 10109.dwg

MAI Project: 5900



NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=12 FEET. PROPOSED CULVERT WIDTH=15 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.93
10. NAACC CROSSING CODE: xy4284442970882533
11. NAACC SURVEY ID: 23441

CROSSING ID# 10111 SKETCH PLAN

LOCATED IN

SALISBURY, MASSACHUSETTS

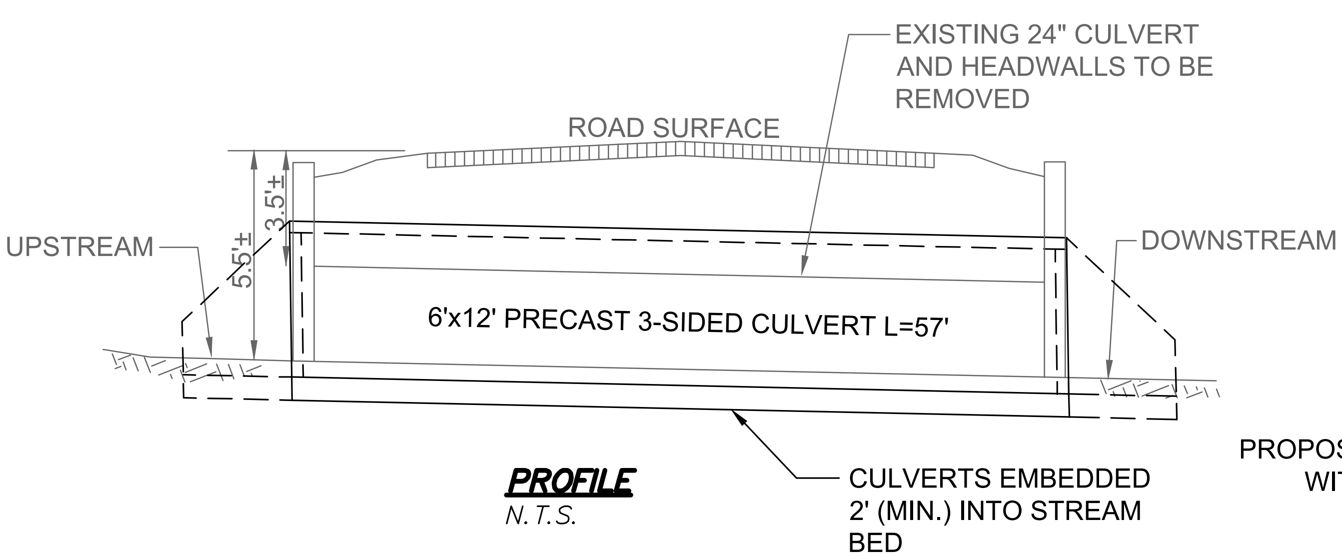
(ESSEX COUNTY)

PREPARED FOR

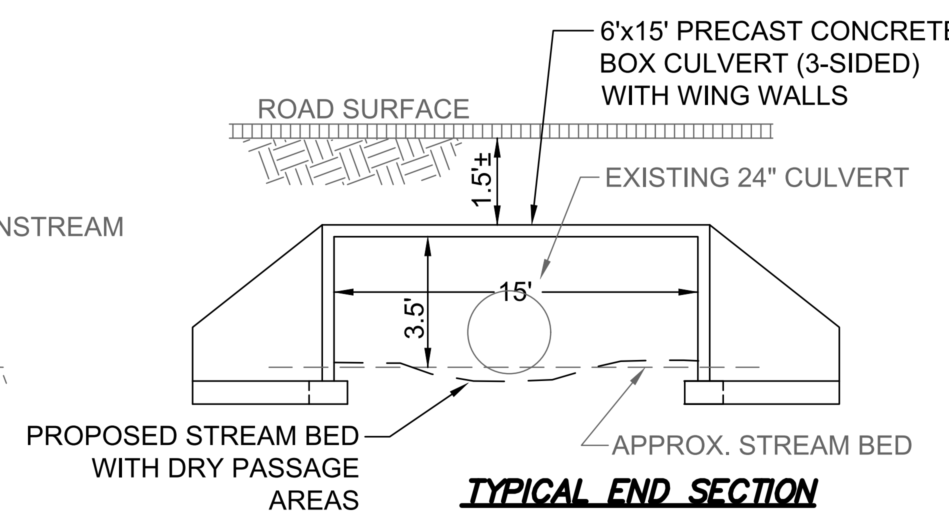
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: NOV. 1, 2016

20 0 20 40 80



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
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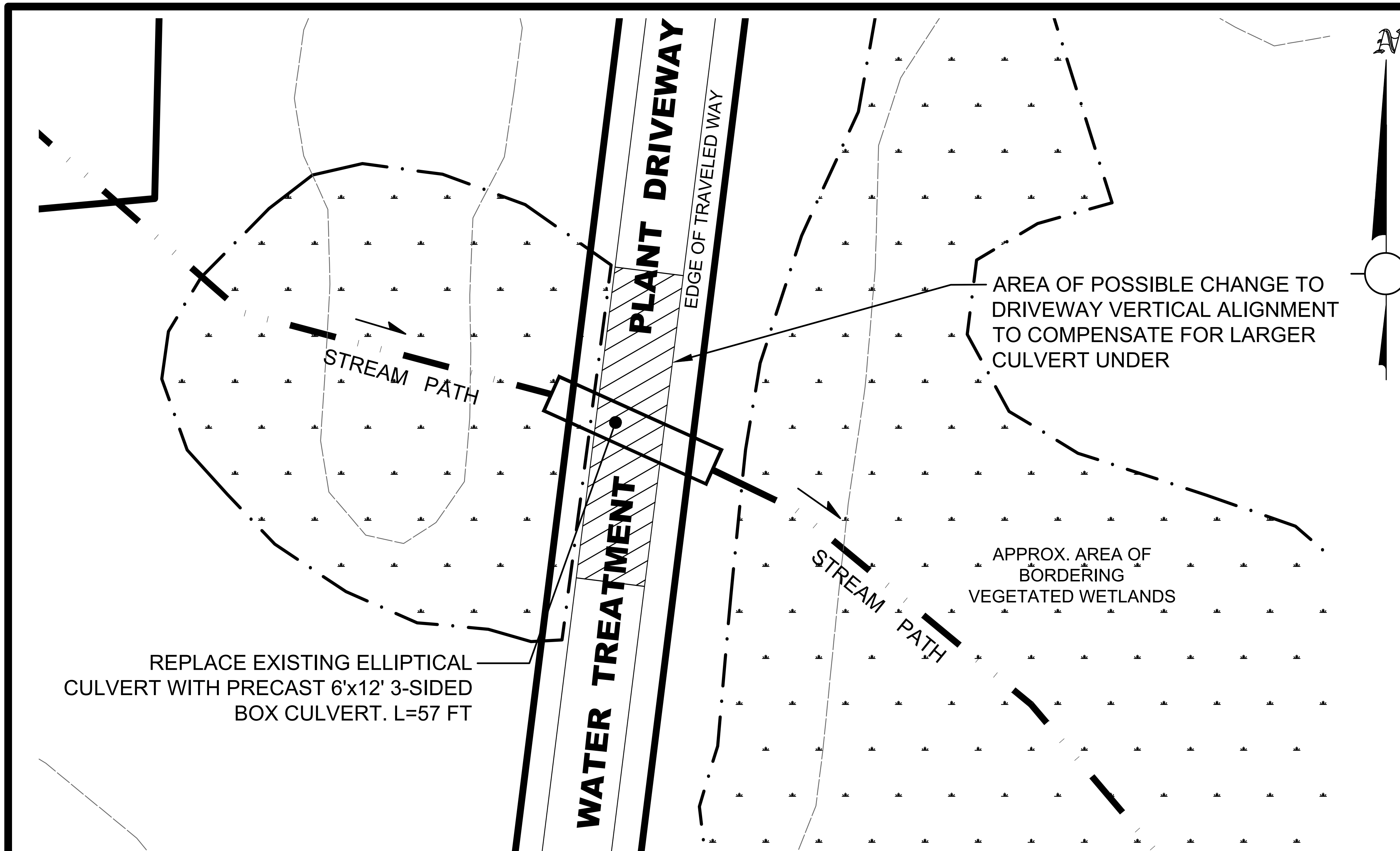
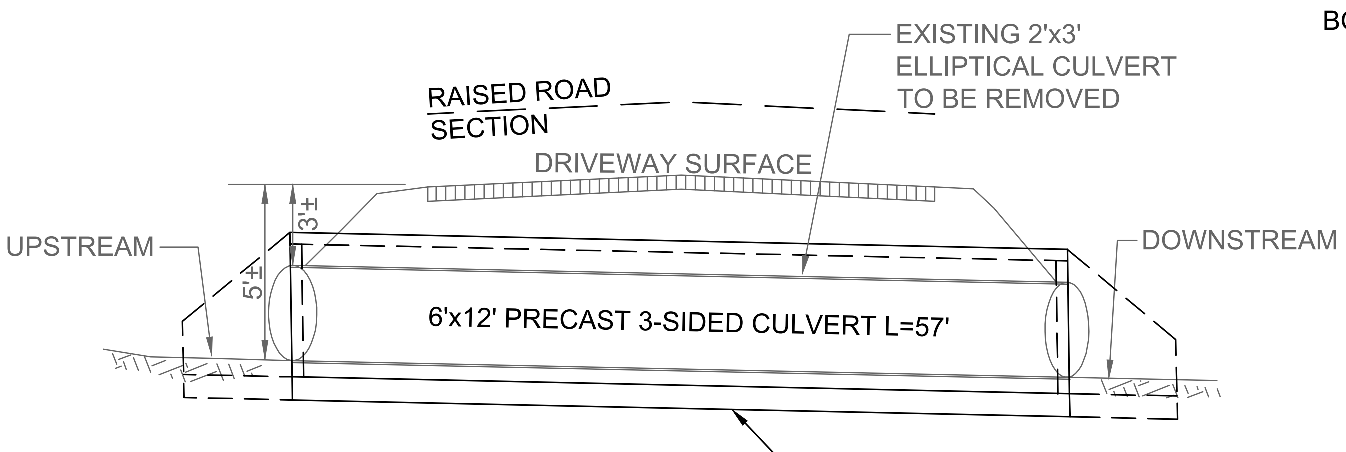
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

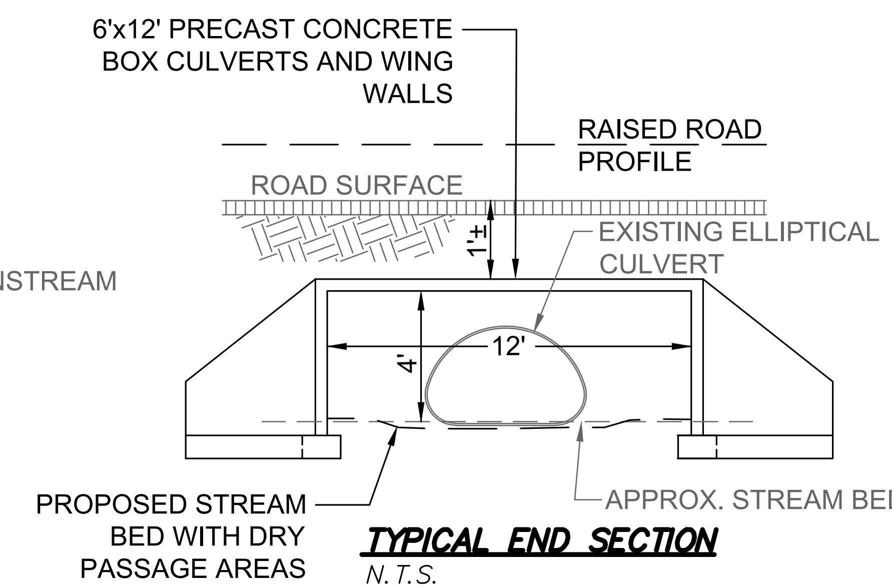
DWG. No. Site 10111.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

1. *THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.*
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3. *THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.*
4. *EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.*
5. *IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.*
6. *STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.*
7. *ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.*
8. *APPROXIMATE BANKFULL WIDTH=5.5 FEET. PROPOSED CULVERT WIDTH=12 FEET.*
9. *MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.84*
10. *NAACC CROSSING CODE: xy4284269170882041*
11. *NAACC SURVEY ID: 23444*

CROSSING ID# 10112
SKETCH PLAN

LOCATED IN

SALISBURY, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: NOV. 1, 2016

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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WWW.MERIDIANASSOC.COM

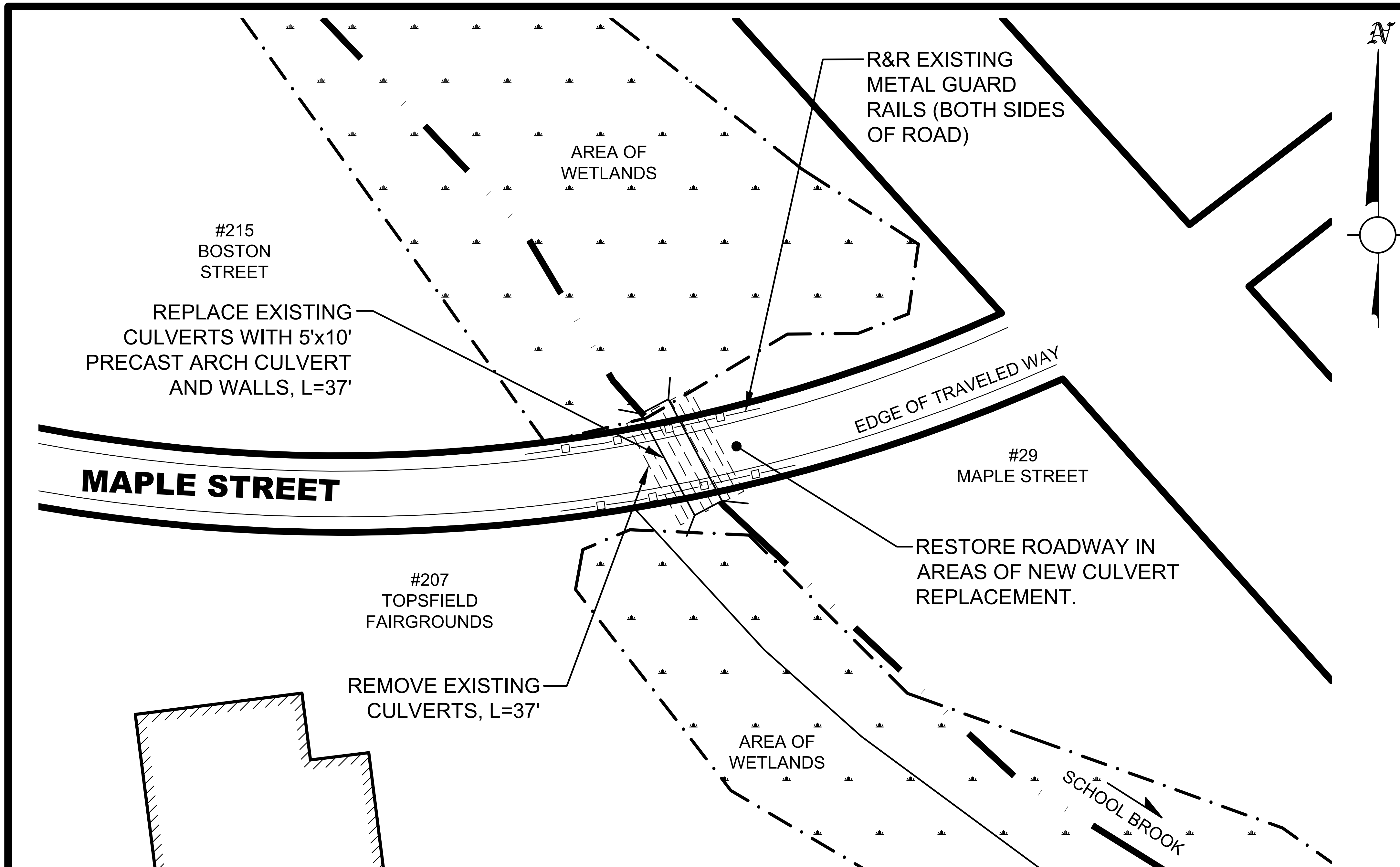
DWG. No. Site 10112.dwg

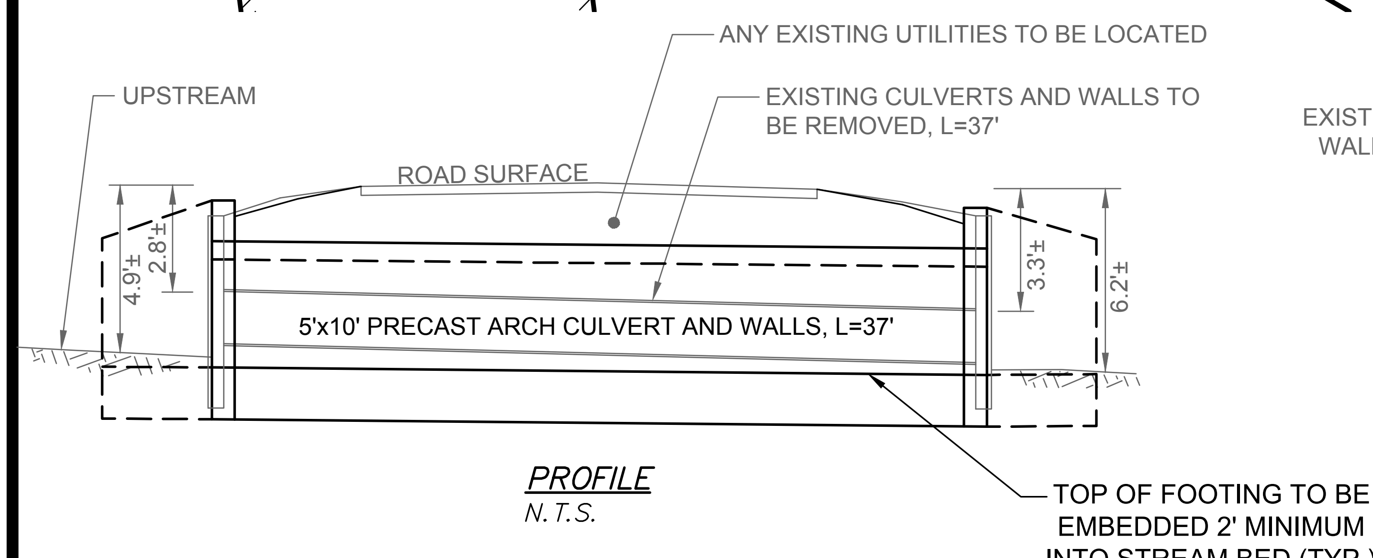
MAI Project: 5900

Topsfield Designs

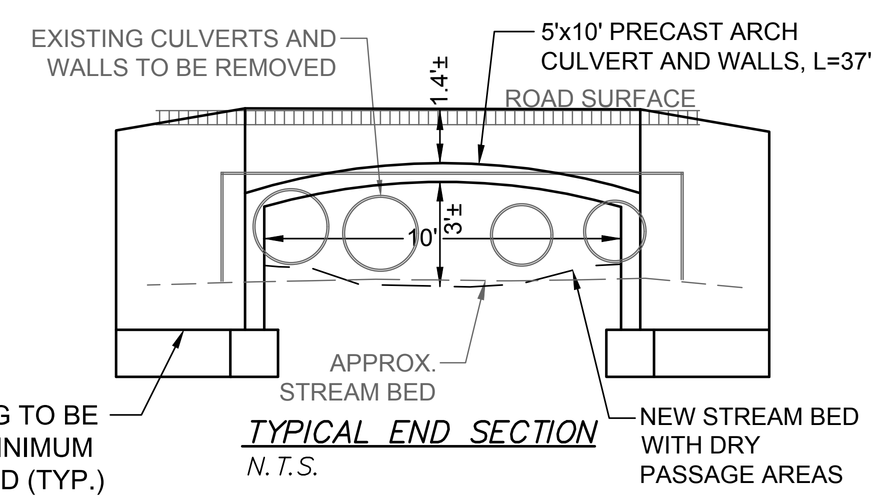
Conceptual designs for the replacement of select road-stream crossings in the Town of Topsfield, MA

14 pages





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4263072070943198
11. NAACC SURVEY ID: 9449

CROSSING ID#420
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN
ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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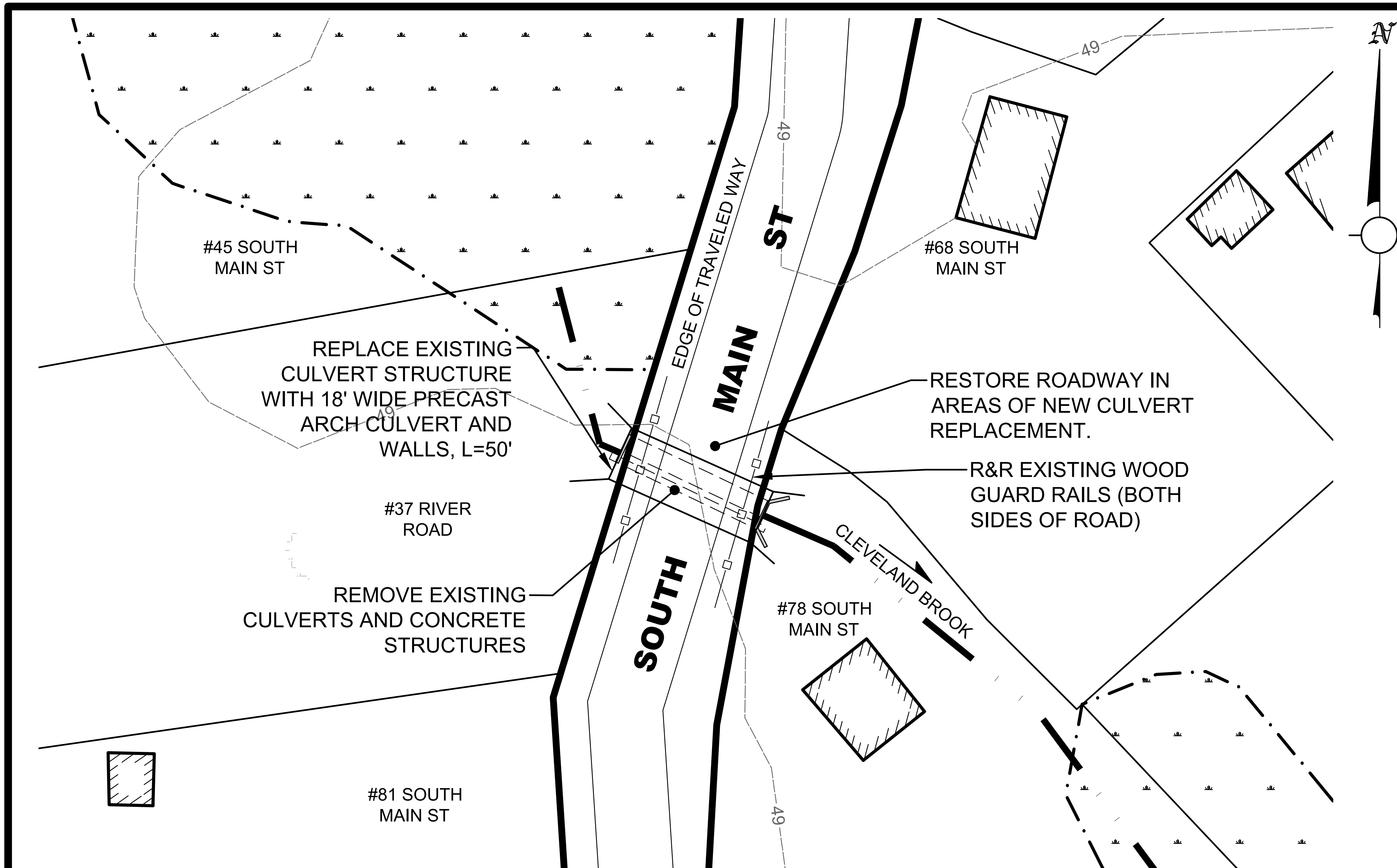
WWW.MERIDIANASSOC.COM

DWG. No. Site 420.dwg

MAI Project: 5900



NOTES:

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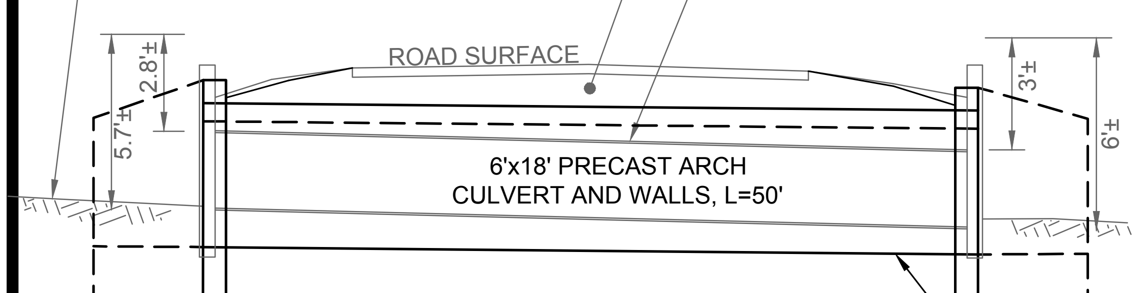
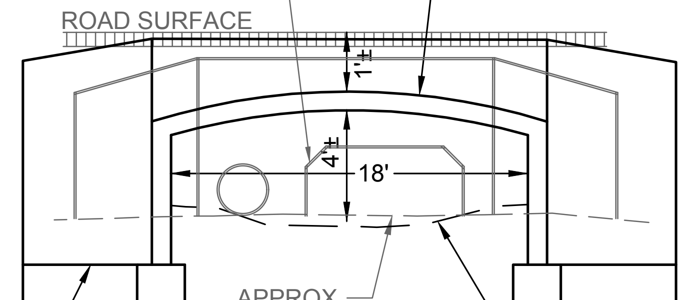
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=14.9 FEET. PROPOSED CULVERT WIDTH=18 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.4
10. NAACC CROSSING CODE: xy4263375970949088
11. NAACC SURVEY ID: 7221



PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

CROSSING ID#433 SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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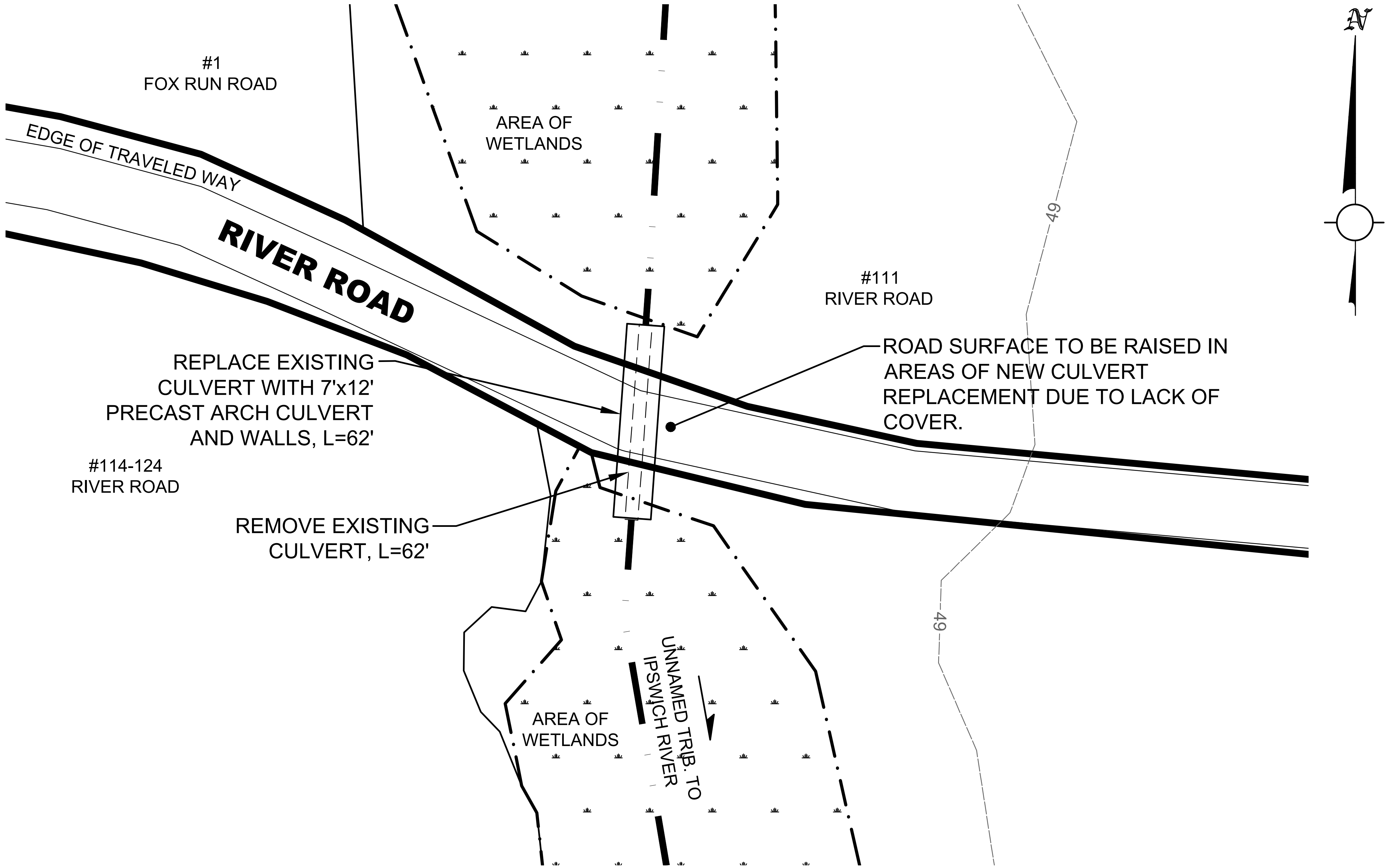
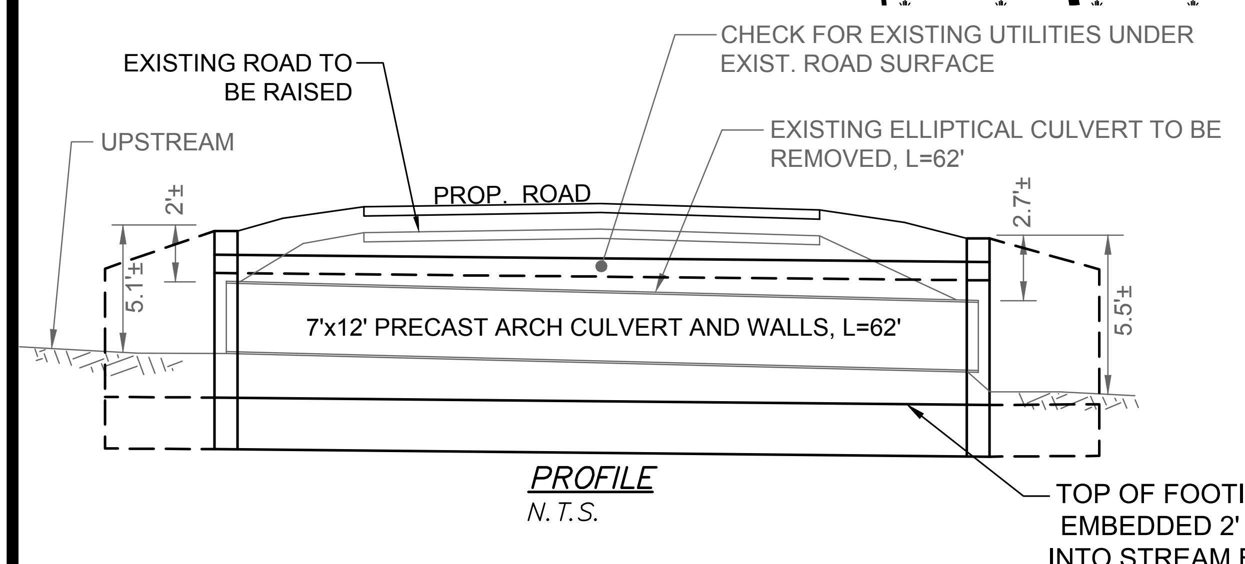
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

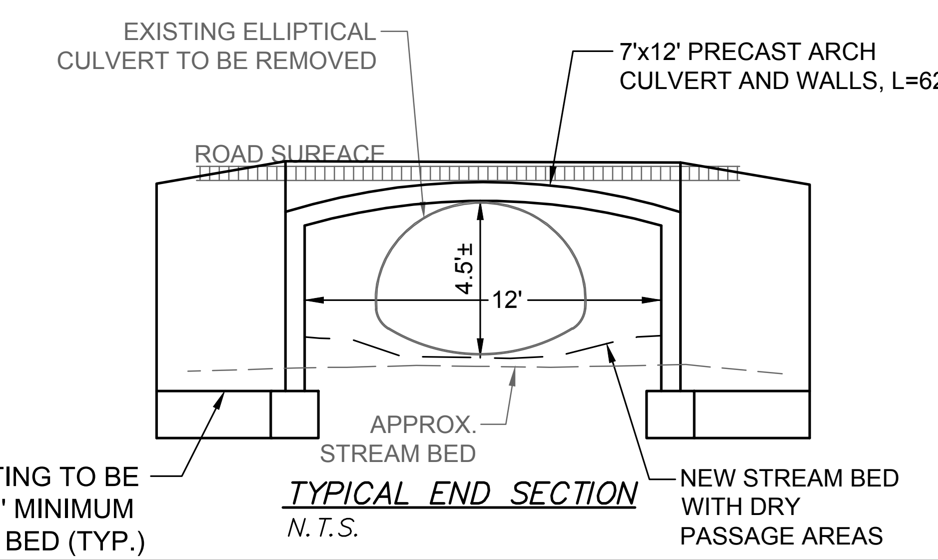
DWG. No. Site 433.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.87
10. NAACC CROSSING CODE: xy4263392770964943
11. NAACC SURVEY ID: 7170

CROSSING ID#435
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
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69 MILK STREET, SUITE 302
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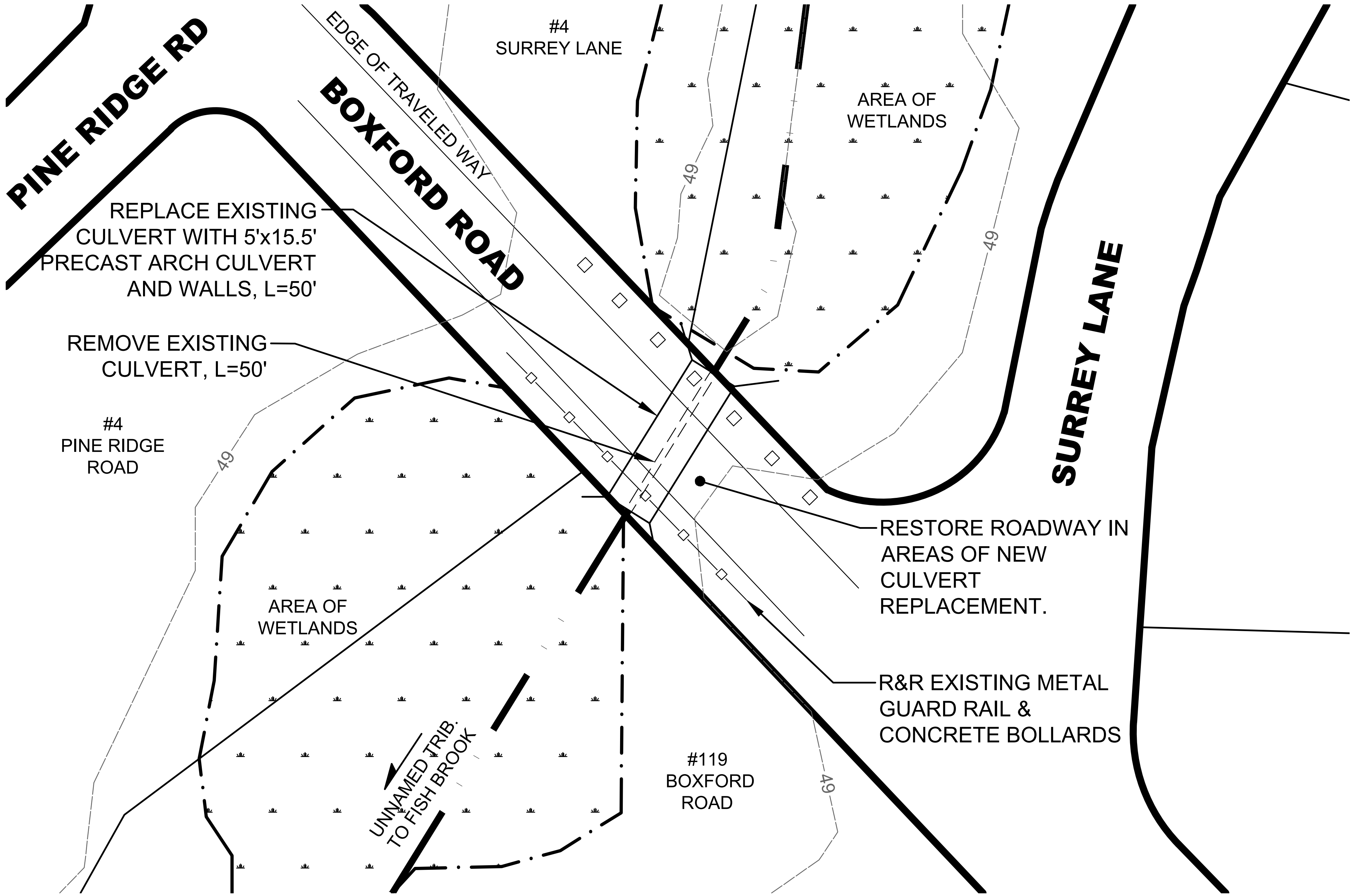
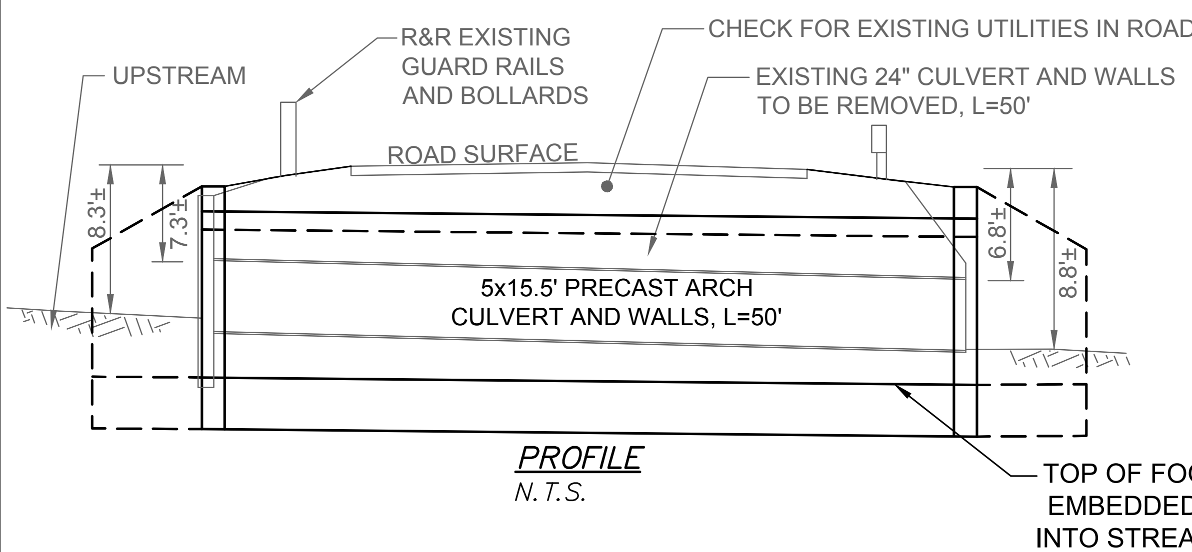
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

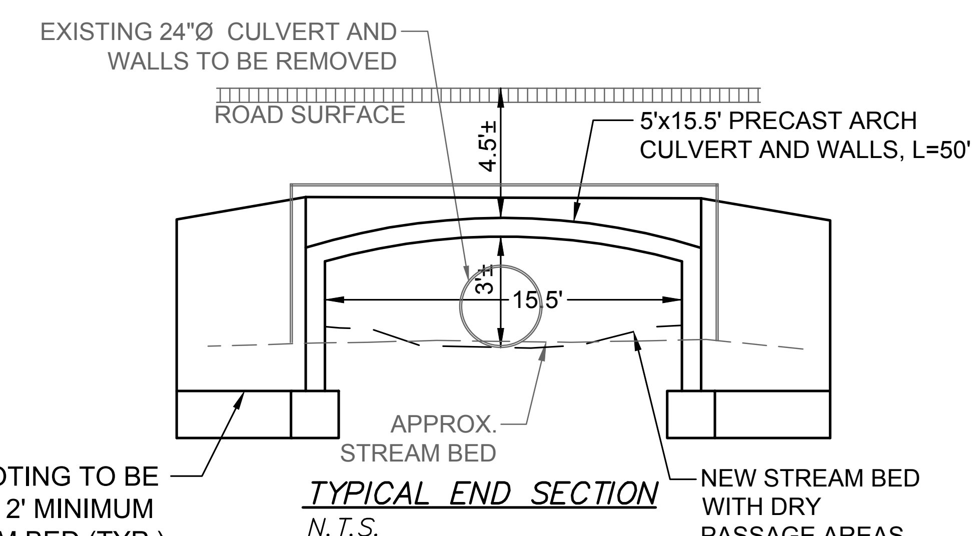
DWG. No. Site 435.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=12.7 FEET. PROPOSED CULVERT WIDTH=15.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.93
10. NAACC CROSSING CODE: xy4264261170966992
11. NAACC SURVEY ID: 6970

CROSSING ID#487
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
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69 MILK STREET, SUITE 302
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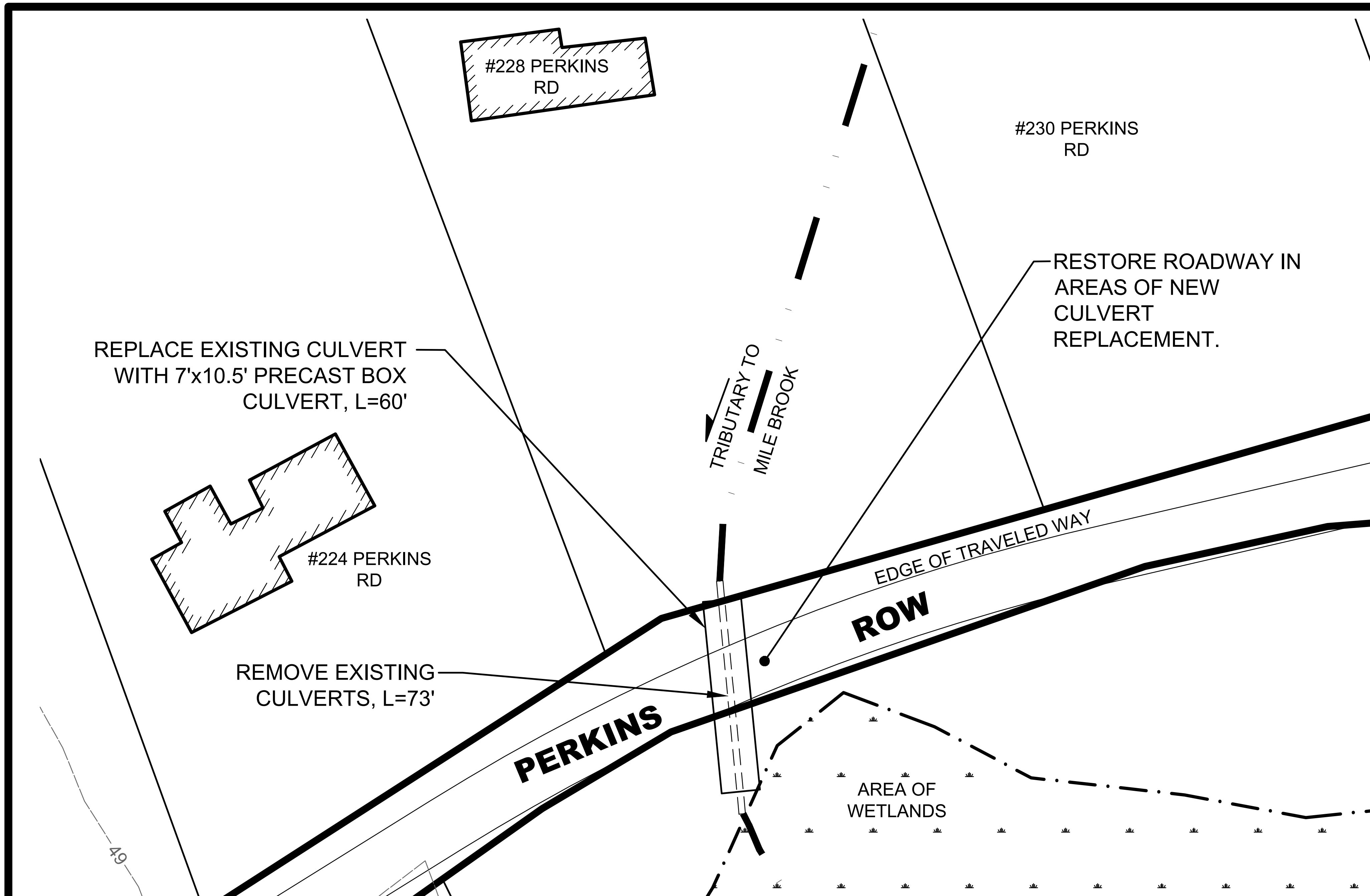
WWW.MERIDIANASSOC.COM

DWG. No. Site 487.dwg

MAI Project: 5900



NOTES:

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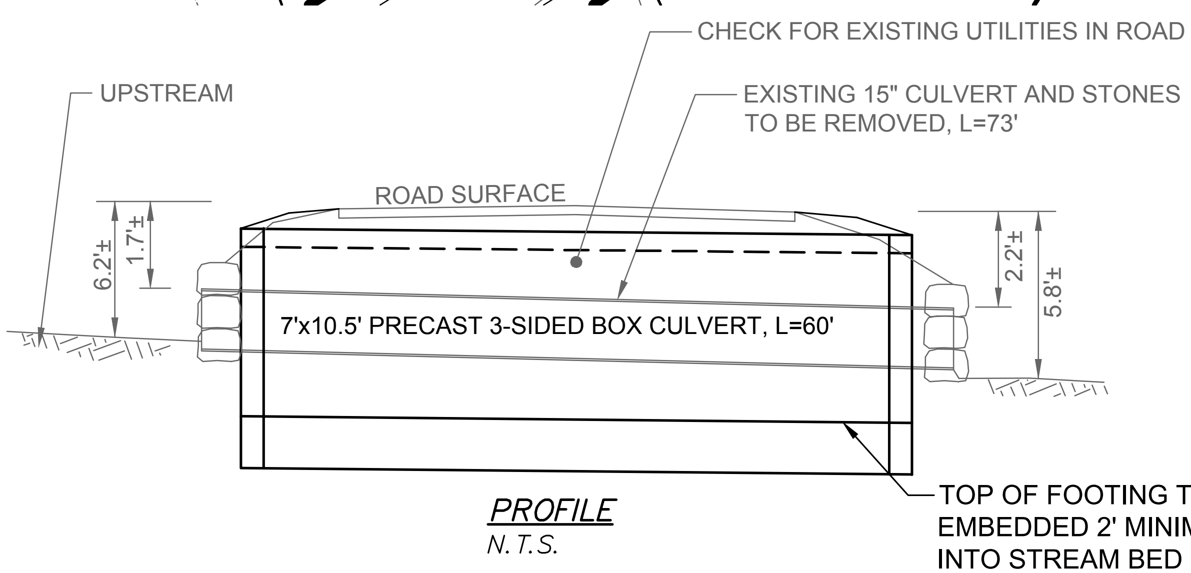
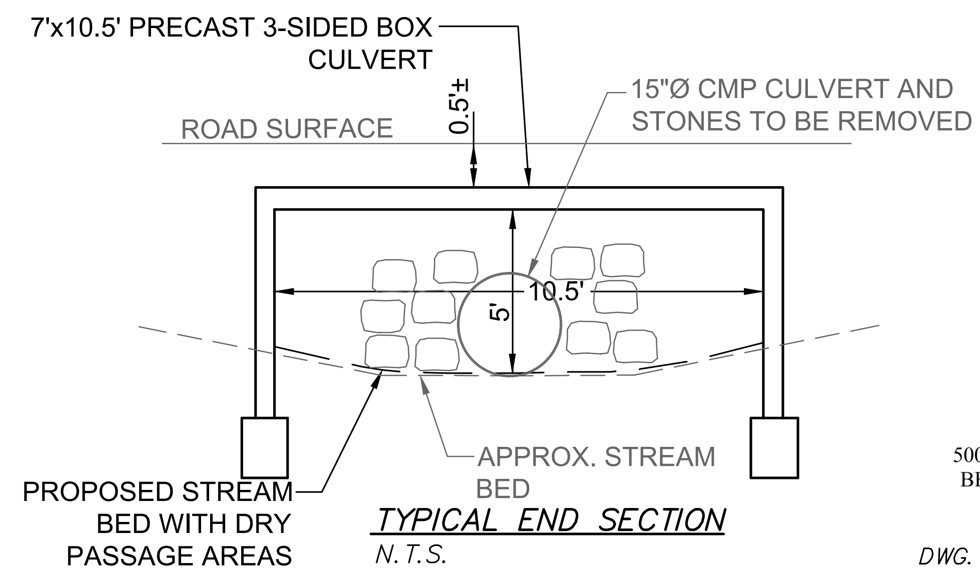
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8.6 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.85
10. NAACC CROSSING CODE: xy4264453870929212
11. NAACC SURVEY ID: 11139



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#500 SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 10, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
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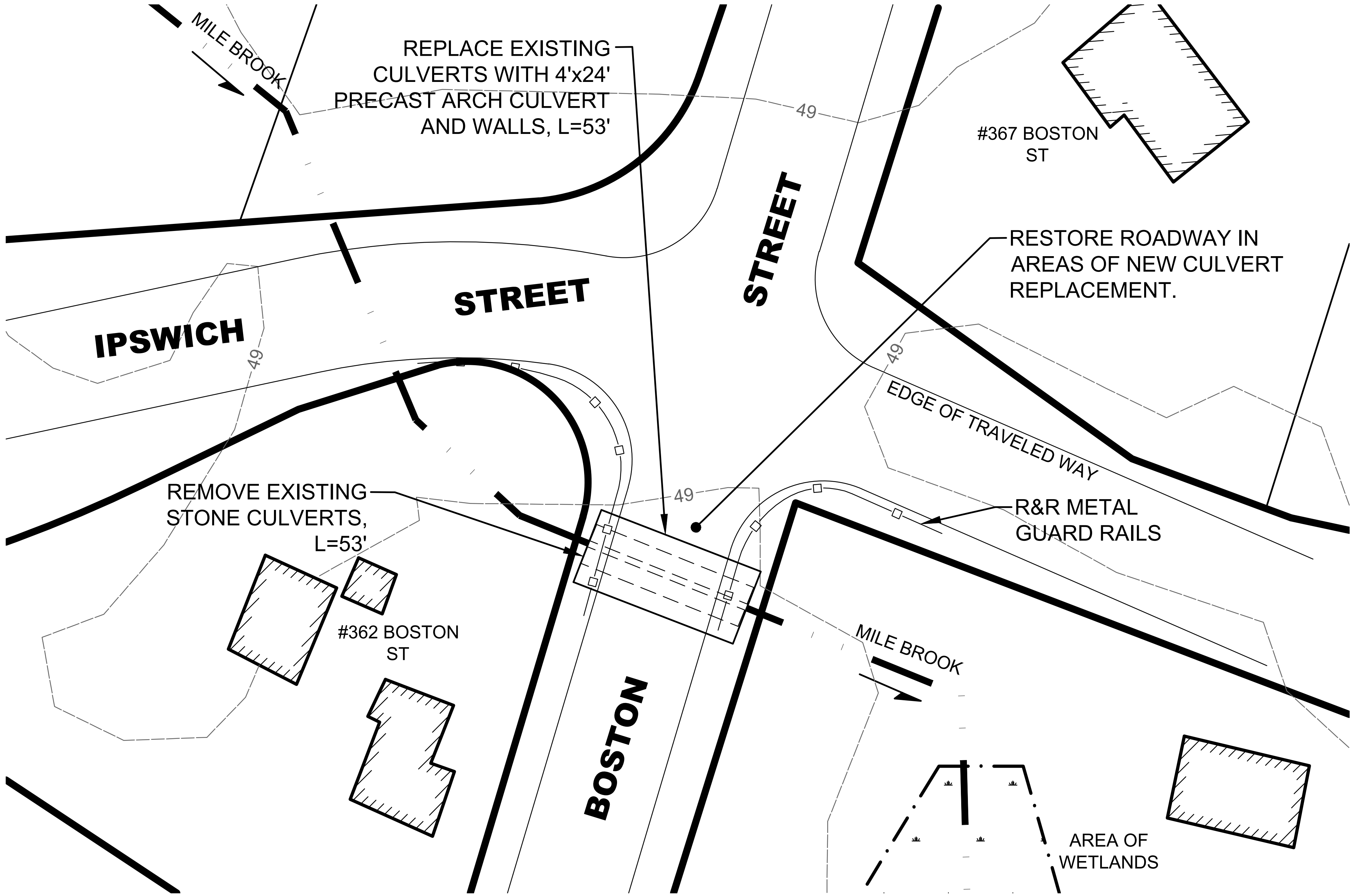
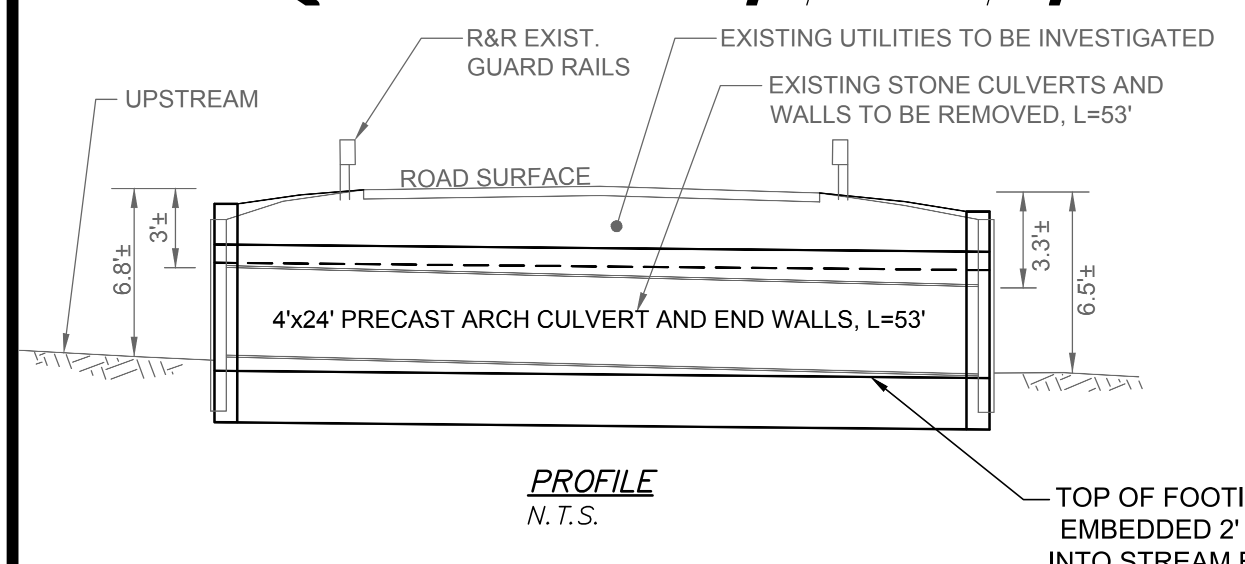
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

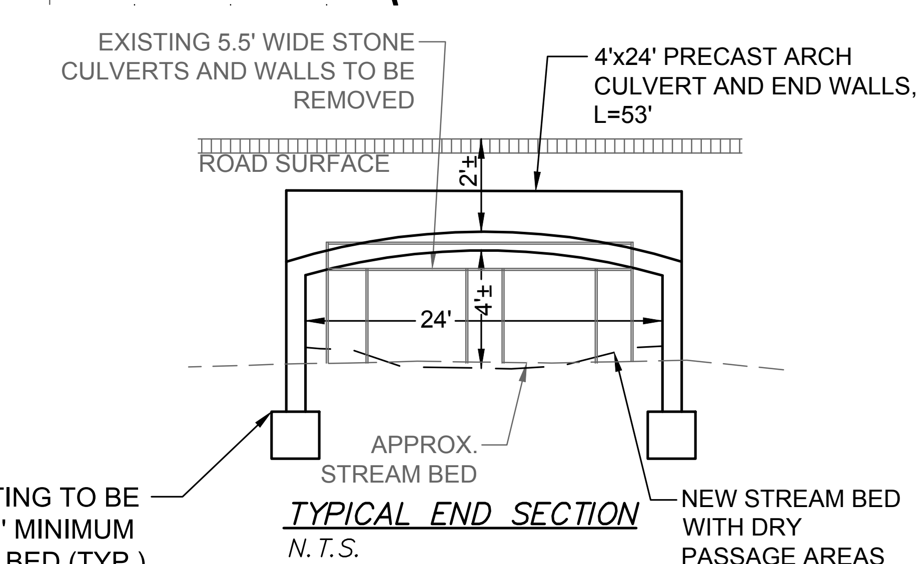
DWG. No. Site 500.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=20.1 FEET. PROPOSED CULVERT WIDTH=24 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.3
10. NAACC CROSSING CODE: xy4265019770935604
11. NAACC SURVEY ID: 7104

CROSSING ID#536
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 10, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

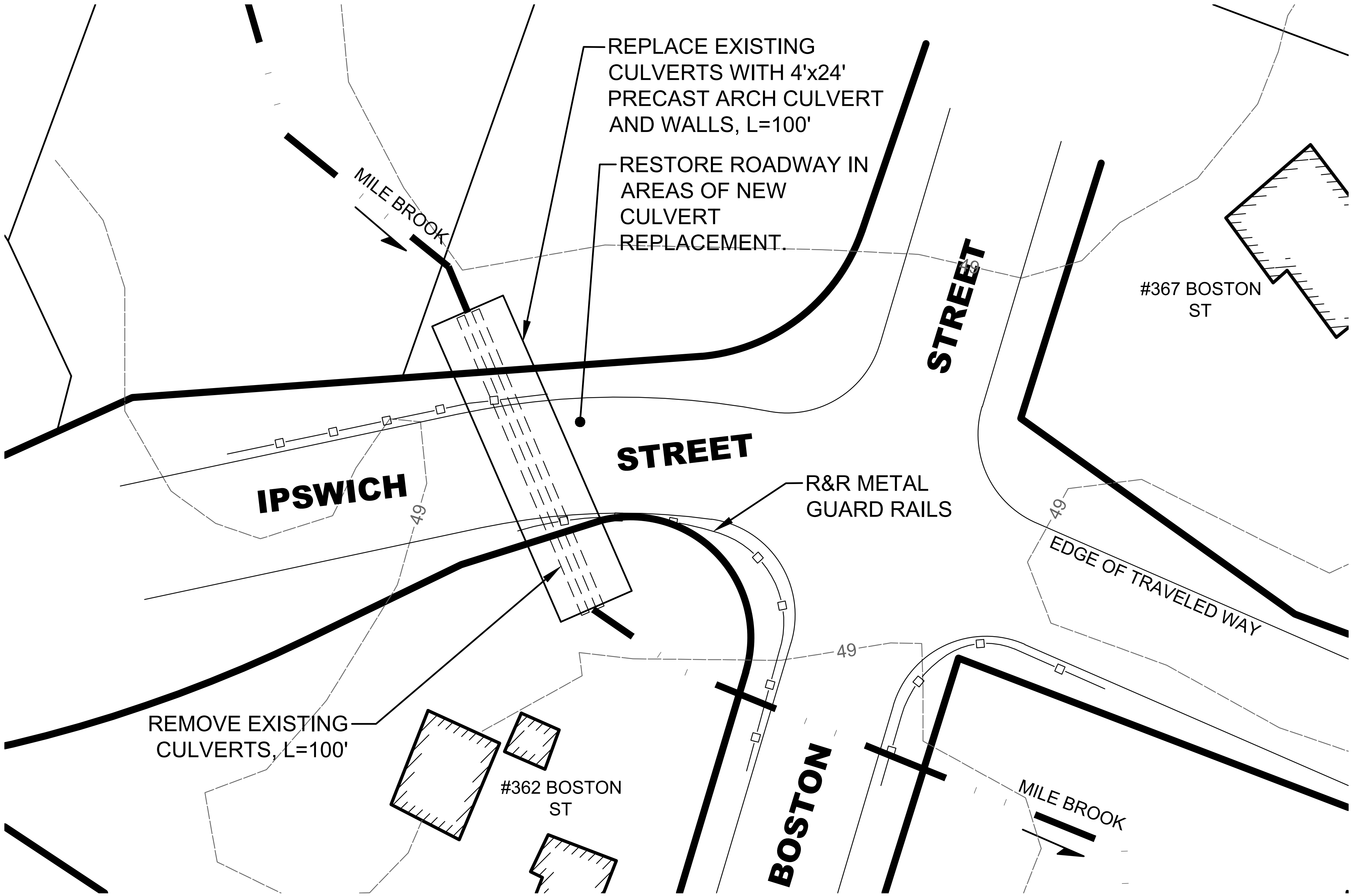
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

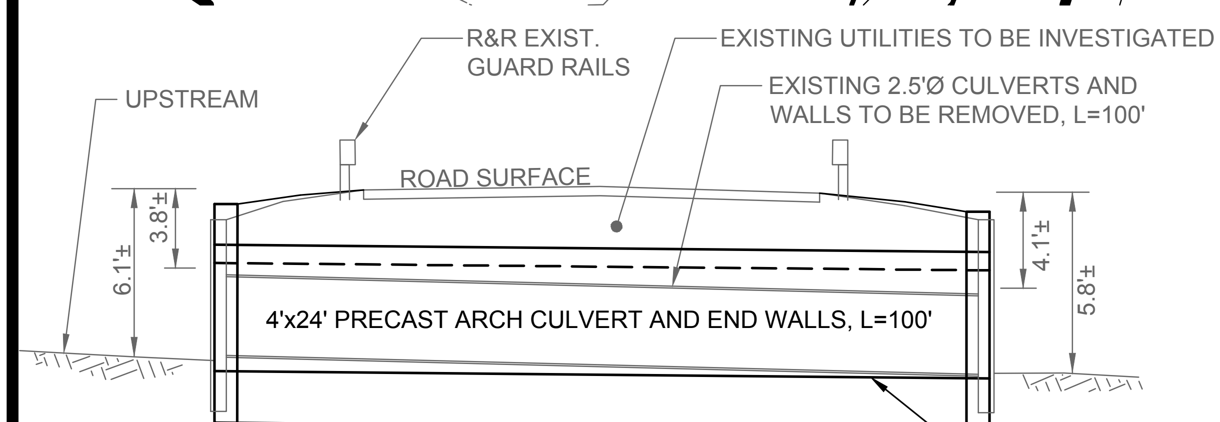
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 536.dwg

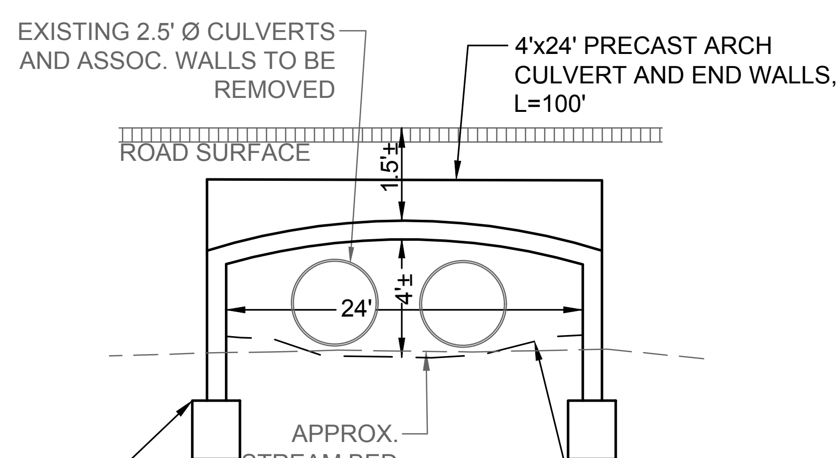
MAI Project: 5900





PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=20.1 FEET. PROPOSED CULVERT WIDTH=24 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.84
10. NAACC CROSSING CODE: xy4265040570935946
11. NAACC SURVEY ID: 7100

CROSSING ID#537 SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 10, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

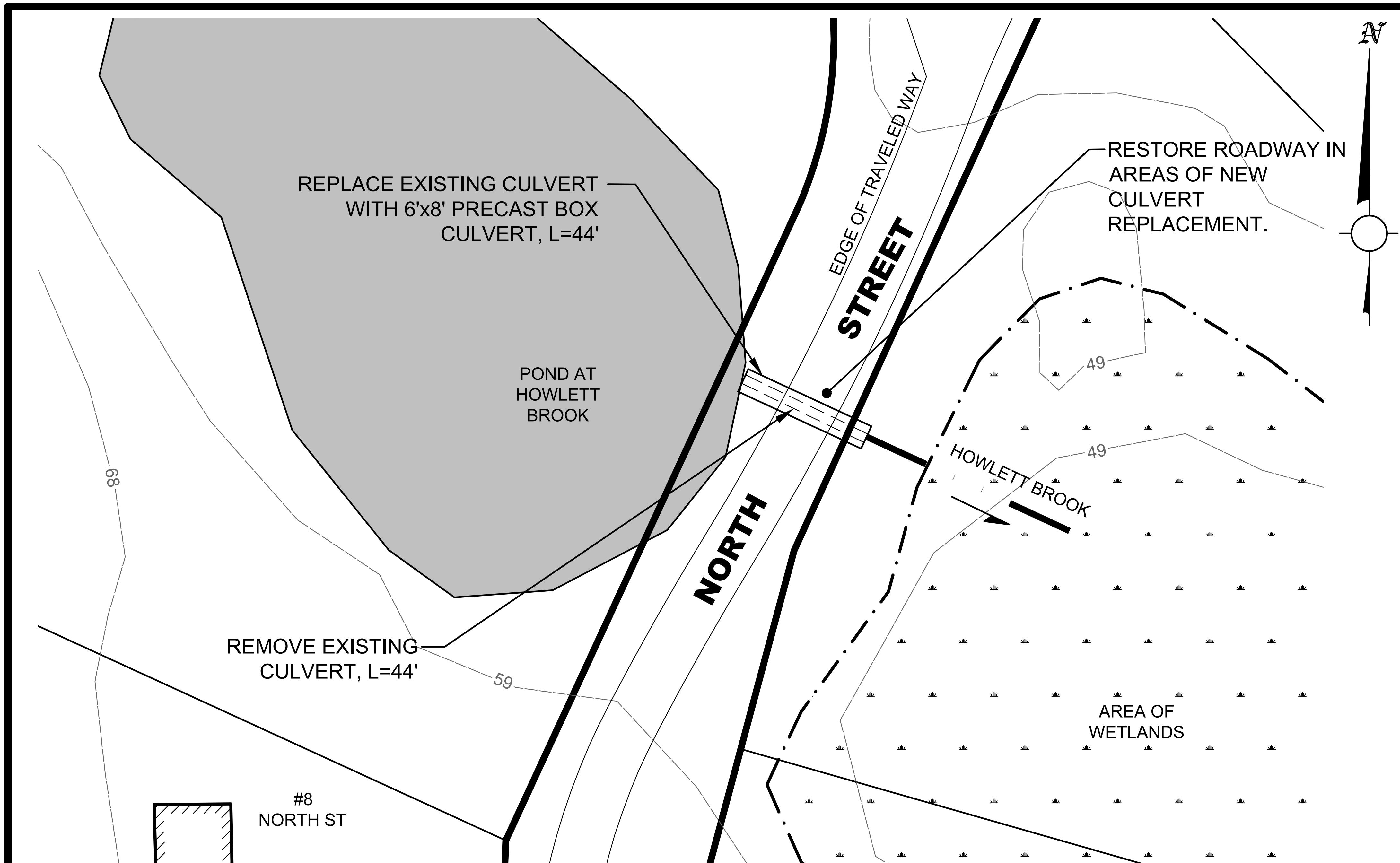
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

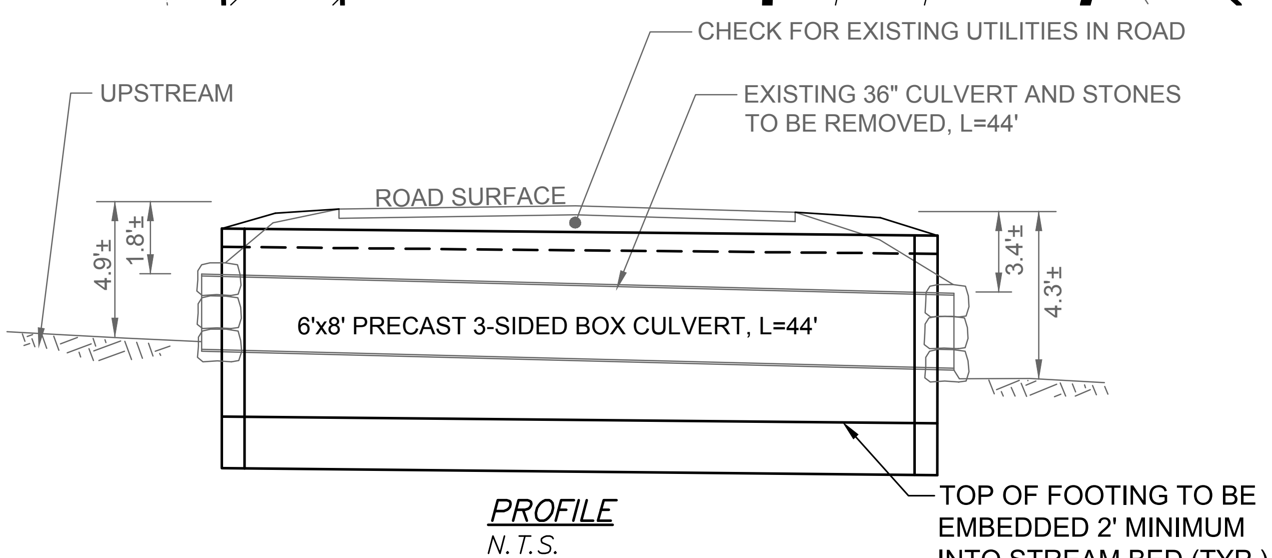
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 537.dwg

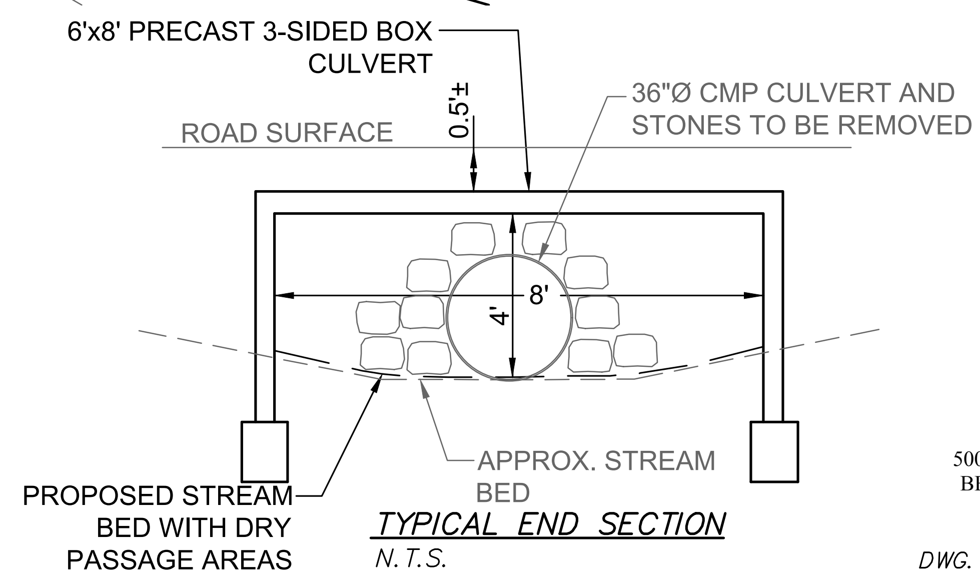
MAI Project: 5900





PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=8 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.73
10. NAACC CROSSING CODE: xy4265238670940431
11. NAACC SURVEY ID: 7102

CROSSING ID#550
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 10, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

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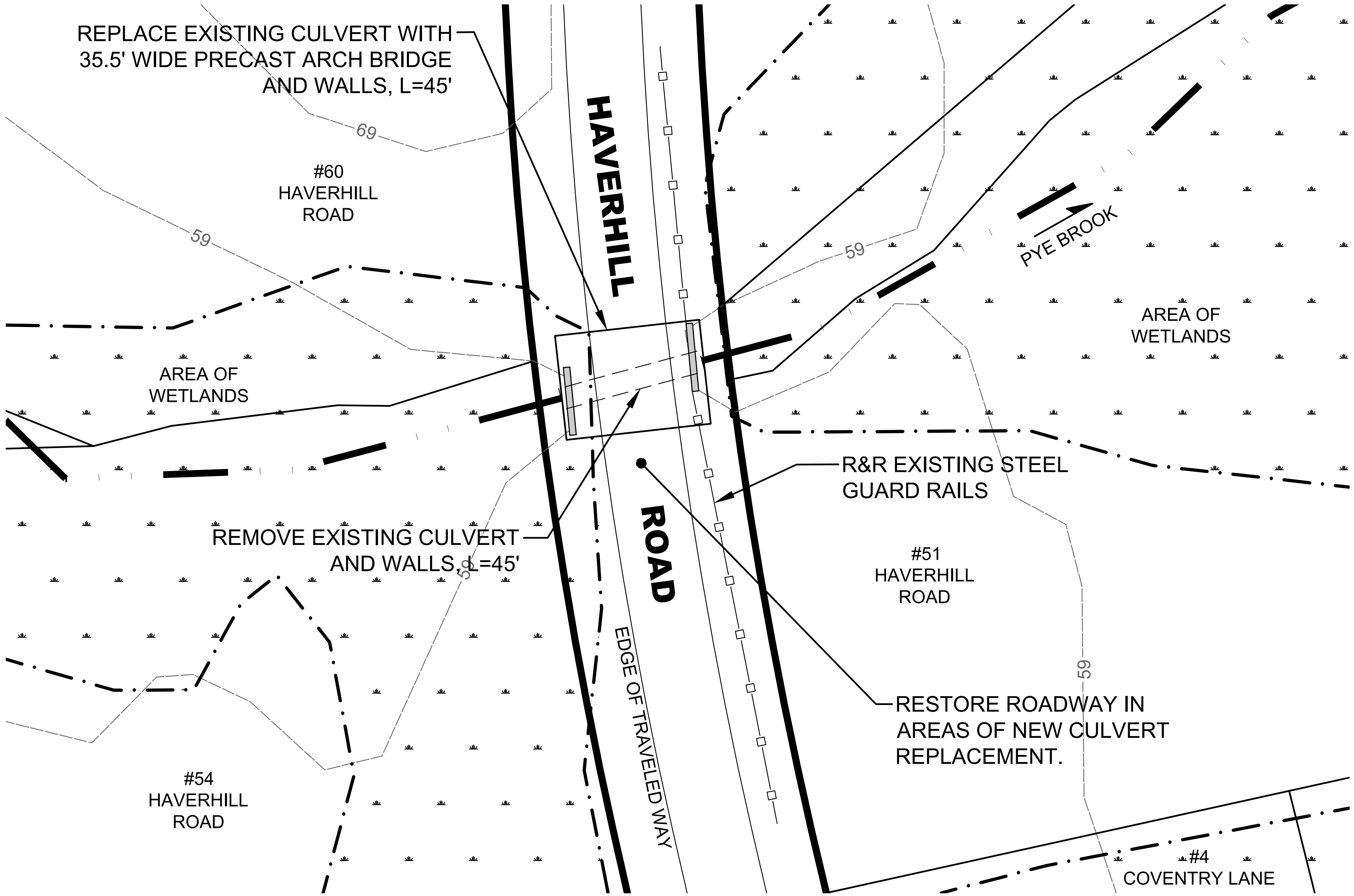
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 550.dwg

MAI Project: 5900



NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
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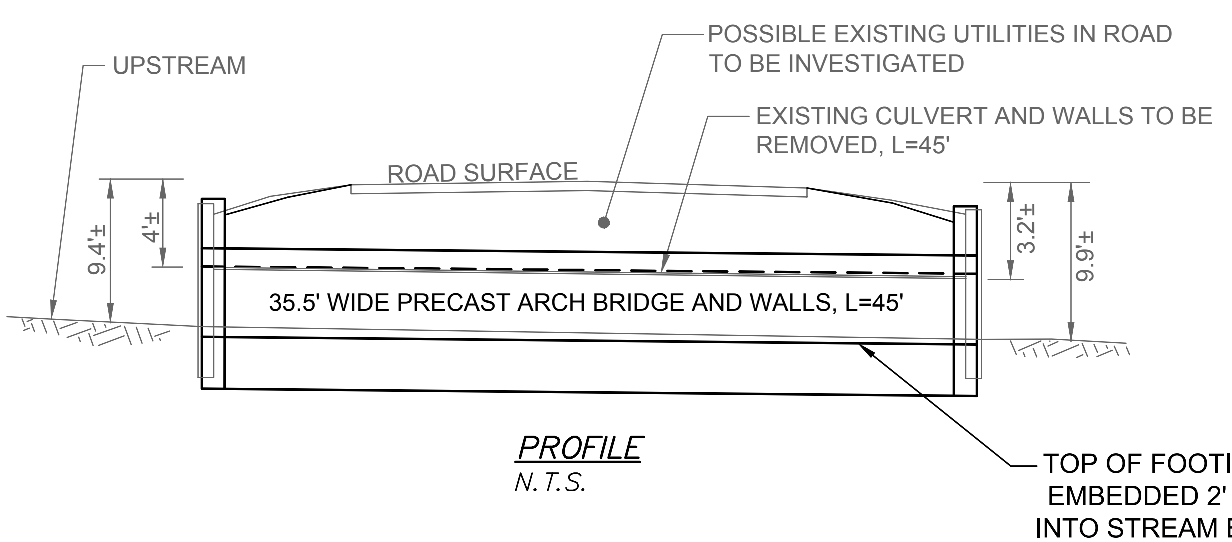
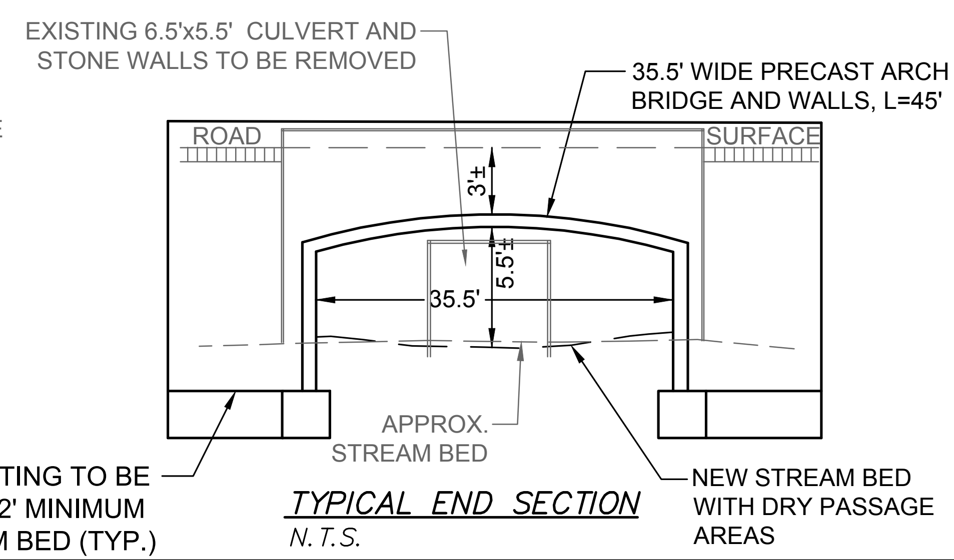
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=27.4 FEET. PROPOSED CULVERT WIDTH=32.5 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=4.0
10. NAACC CROSSING CODE: xy4265457370952953
11. NAACC SURVEY ID: 23427



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#570
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

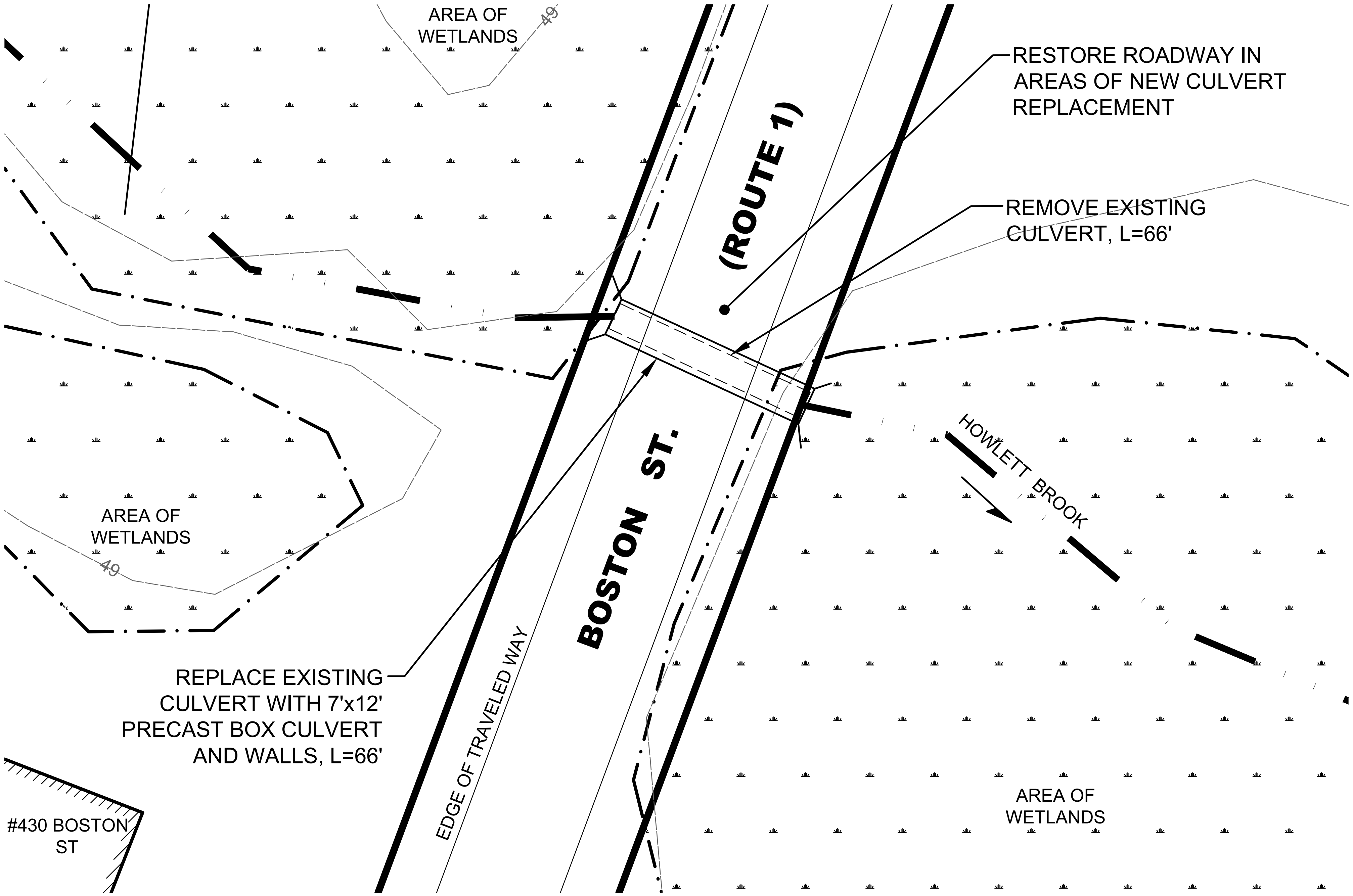
SCALE: 1"= 40' DATE: FEB. 16, 2017

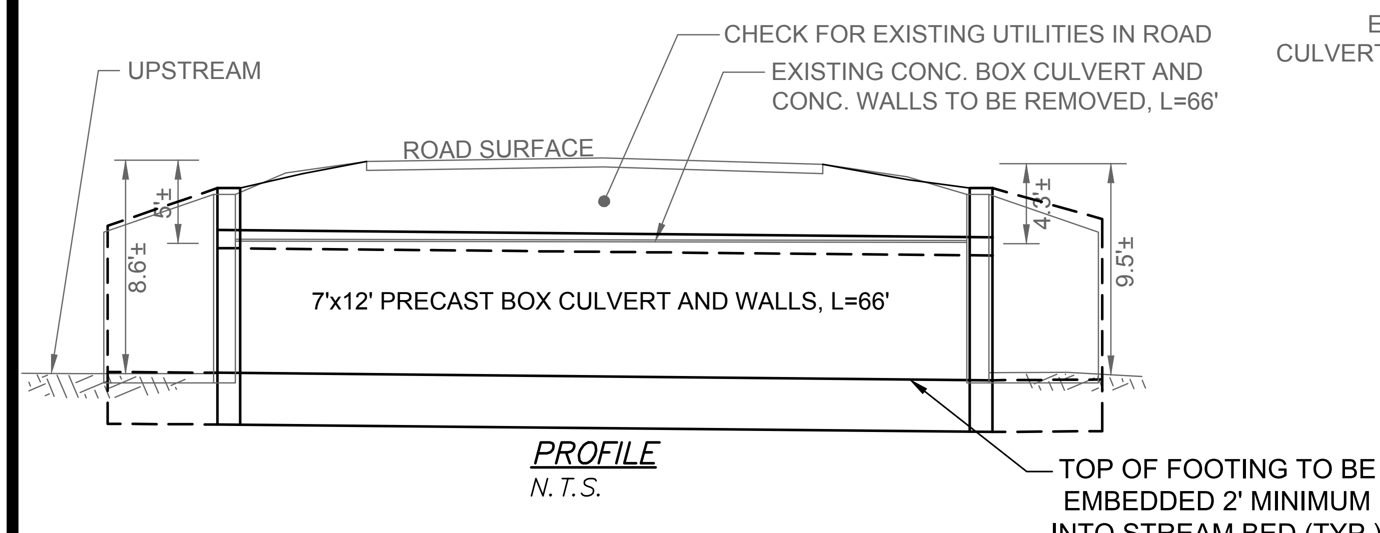
20 0 20 40 80

MERIDIAN
ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

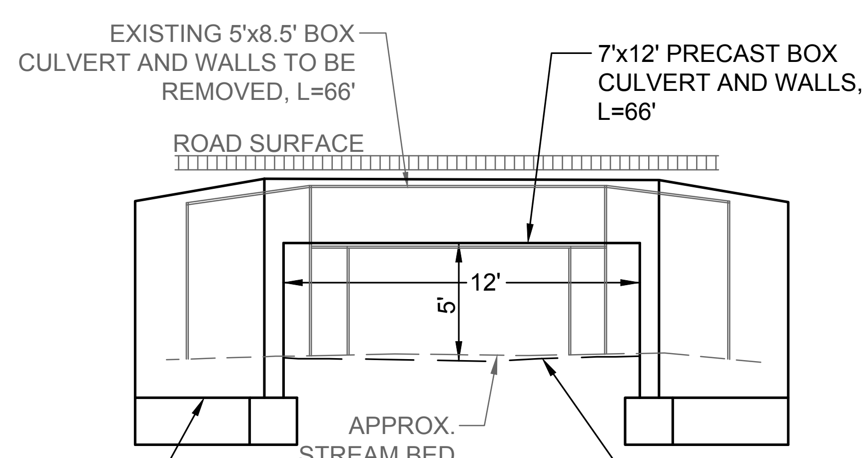
DWG. No. Site 570.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

NOTES:

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4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=N/A (WETLAND)
10. NAACC CROSSING CODE: xy4266010070931122
11. NAACC SURVEY ID: 23533

CROSSING ID#614
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 27, 2017

20 0 20 40 80

MERIDIAN
ASSOCIATES

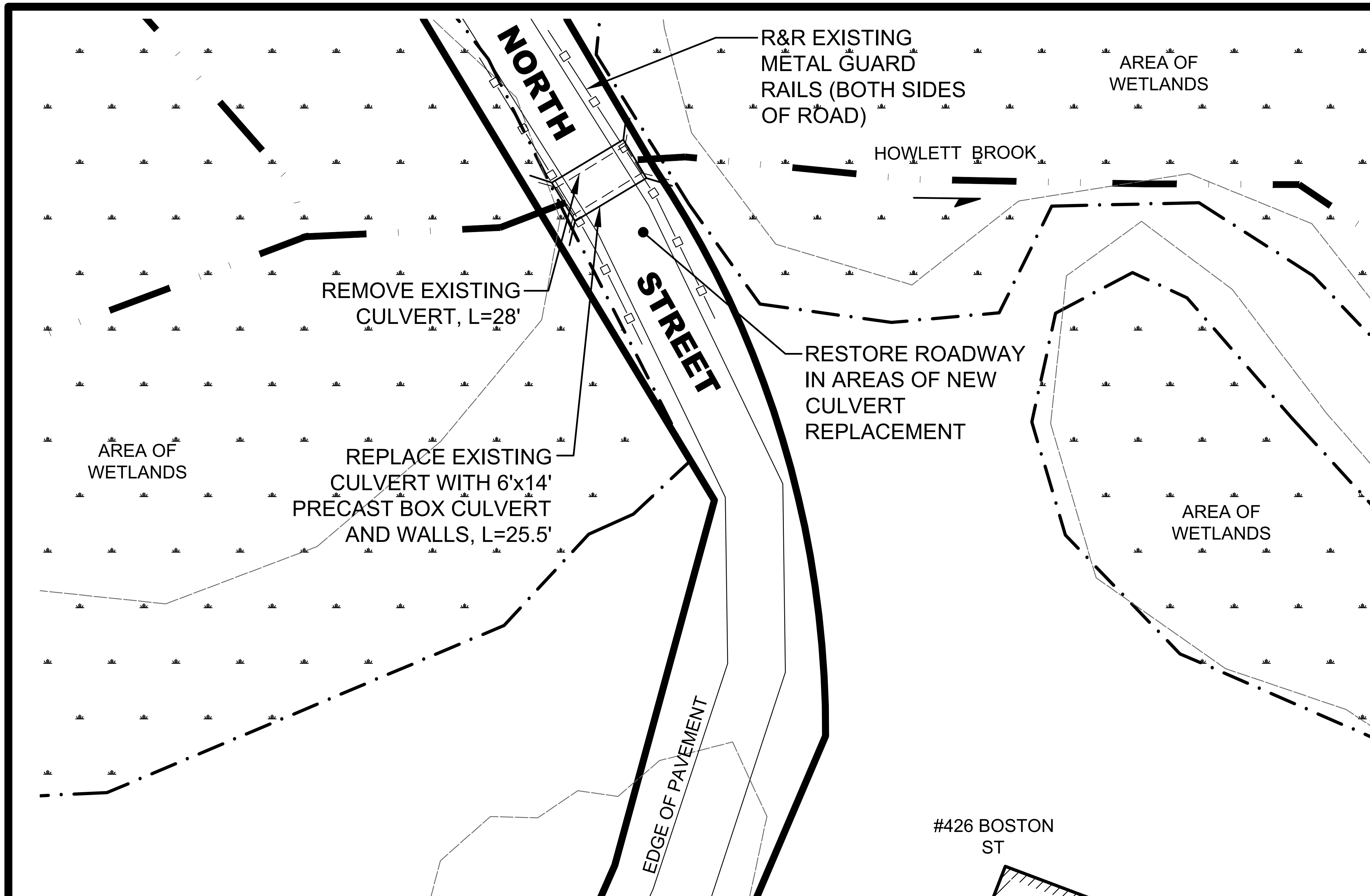
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

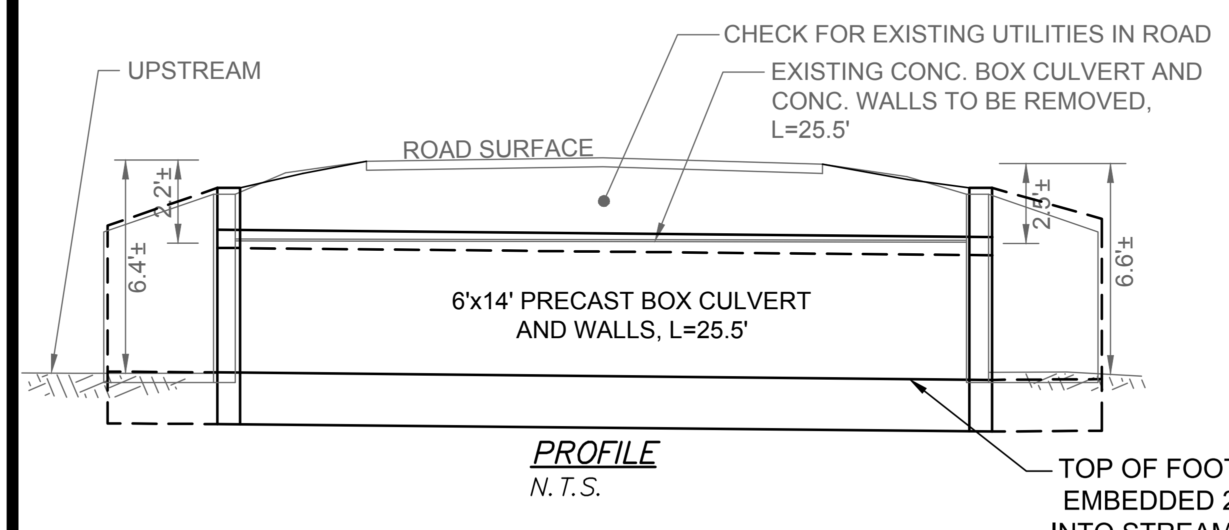
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

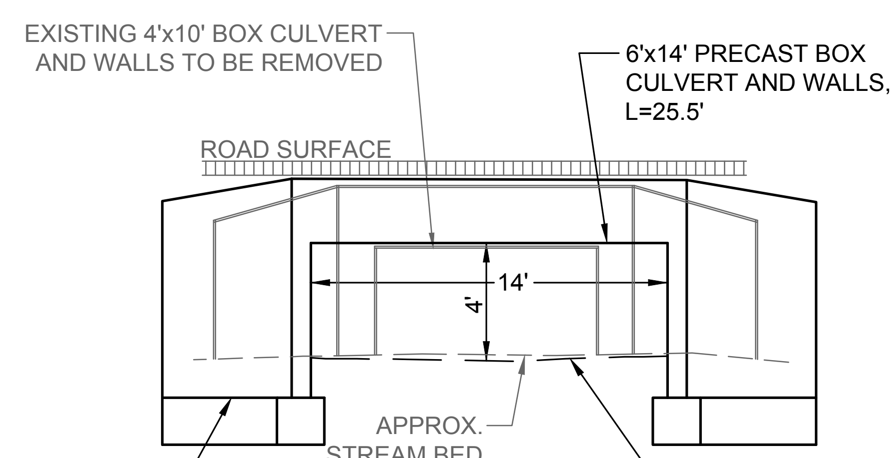
DWG. No. Site 614.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

N

NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A (WETLAND). PROPOSED CULVERT WIDTH=14 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=N/A (WETLAND)
10. NAACC CROSSING CODE: xy4266048470932936
11. NAACC SURVEY ID: 23431

CROSSING ID#615 SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: MARCH 27, 2017

20 0 20 40 80

MERIDIAN ASSOCIATES

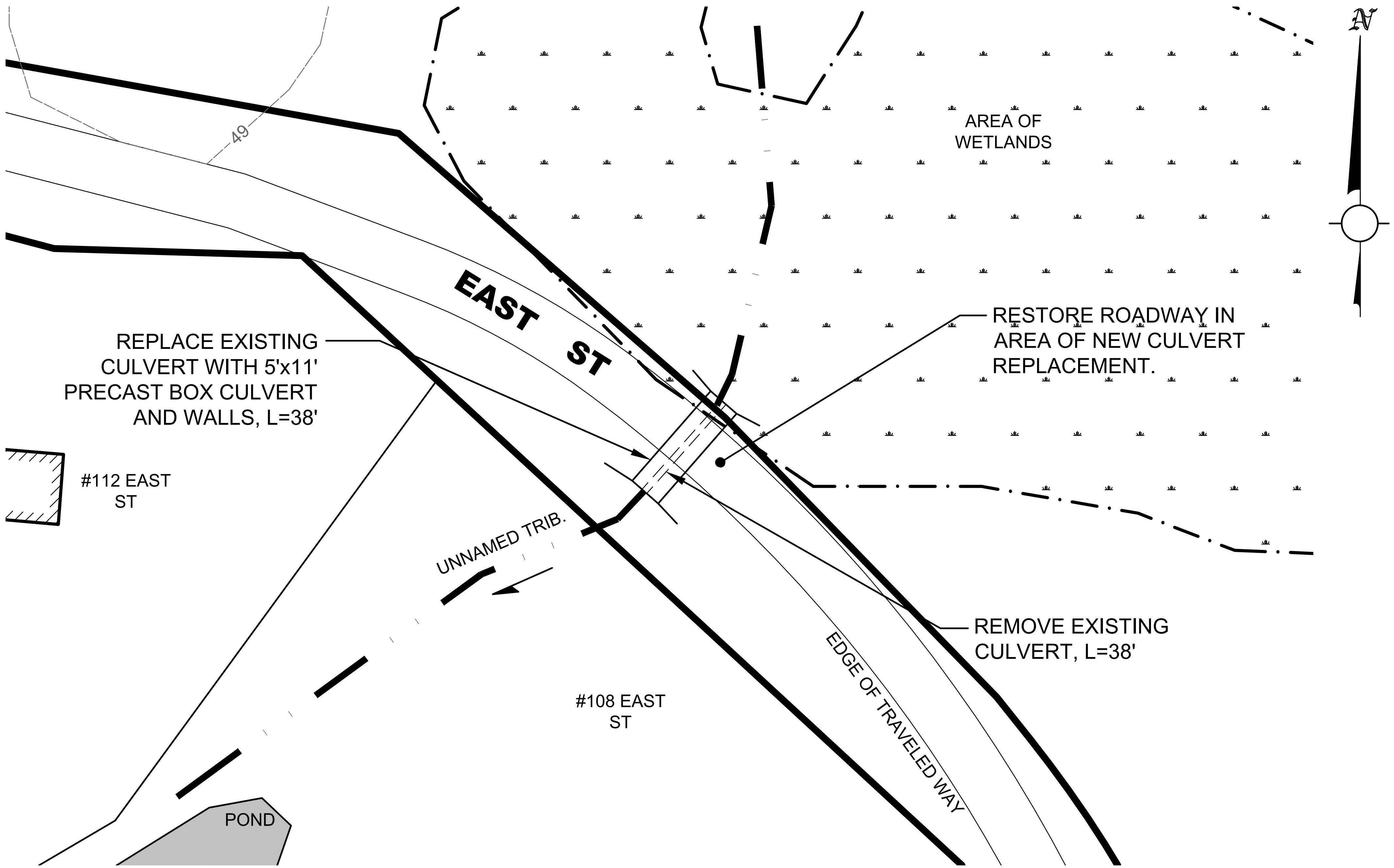
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

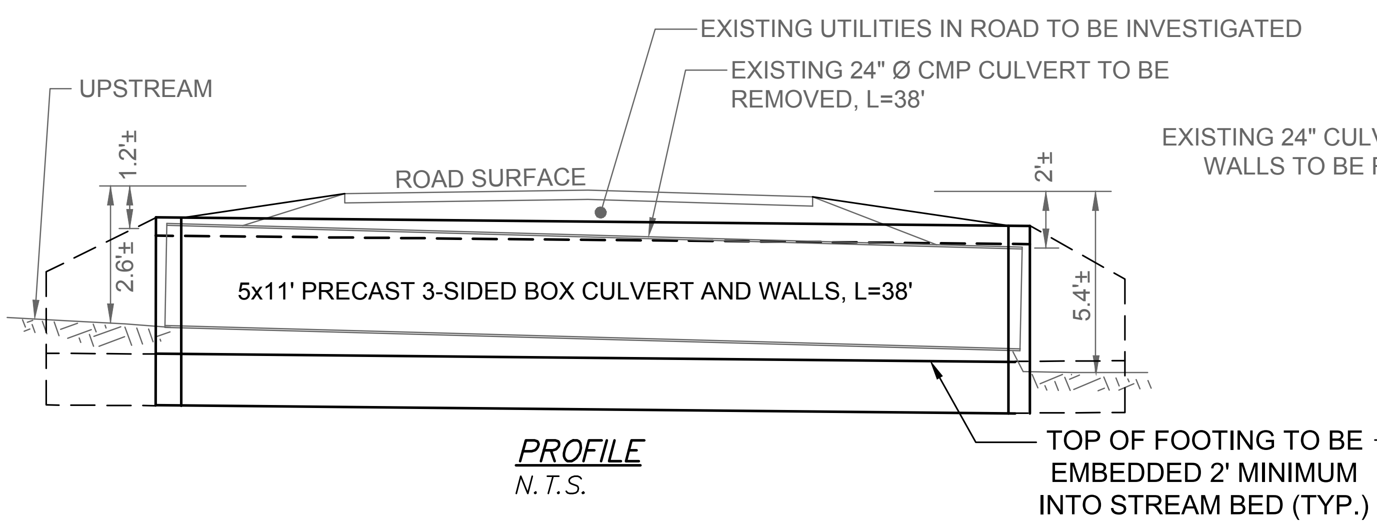
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

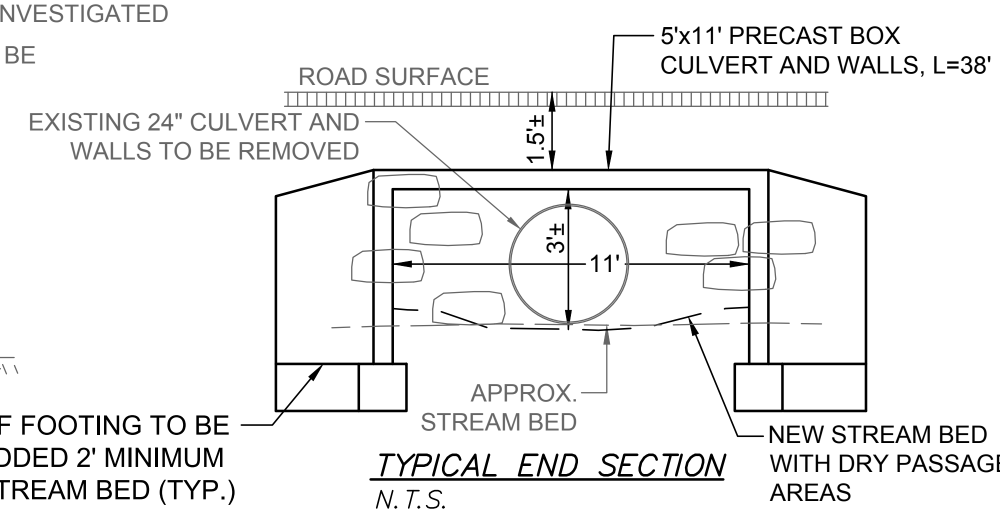
DWG. No. Site 615.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=7 FEET. PROPOSED CULVERT WIDTH=11 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.87
10. NAACC CROSSING CODE: xy4266825770920664
11. NAACC SURVEY ID: 6138

CROSSING ID#658 SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 25, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

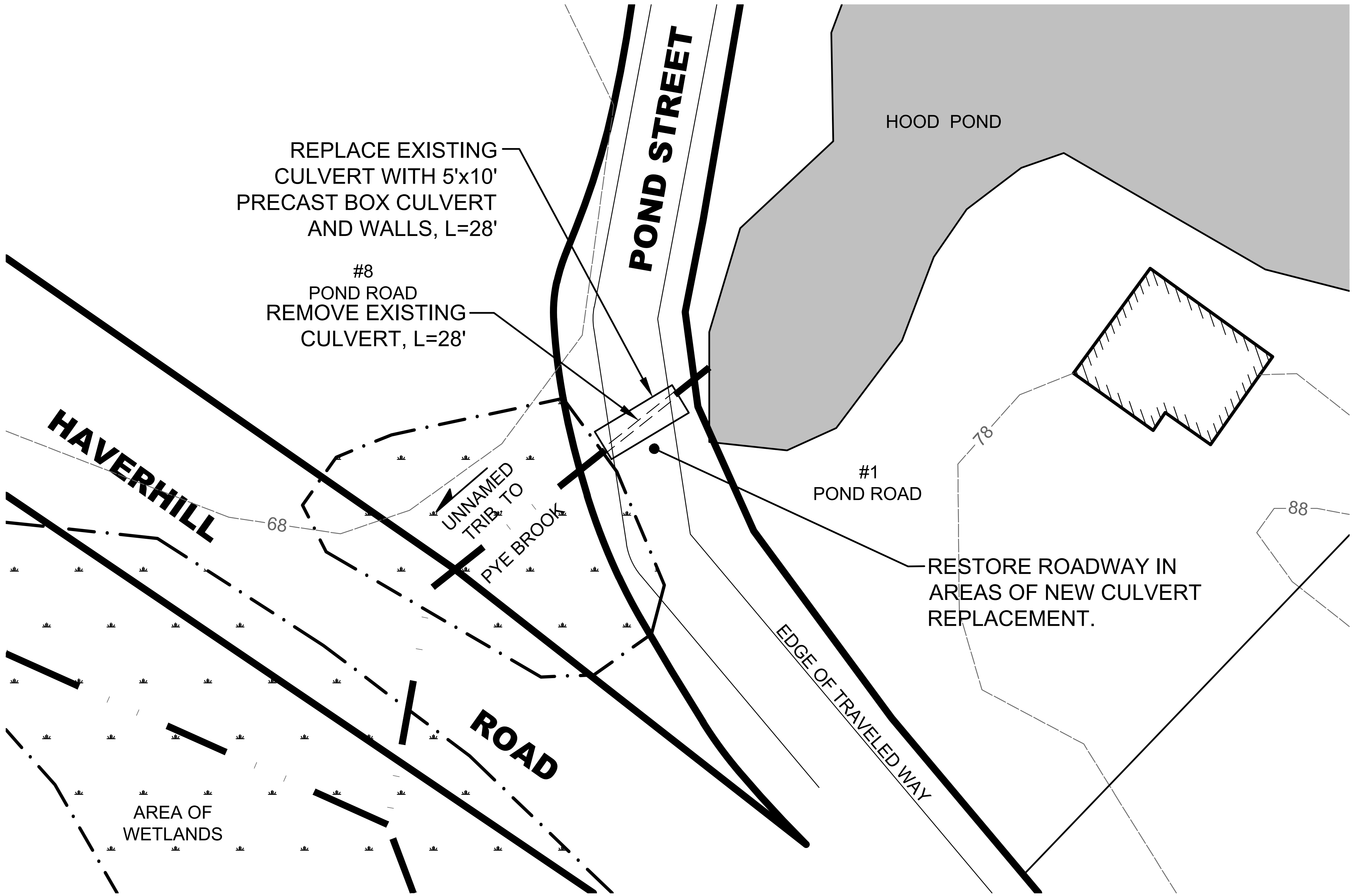
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

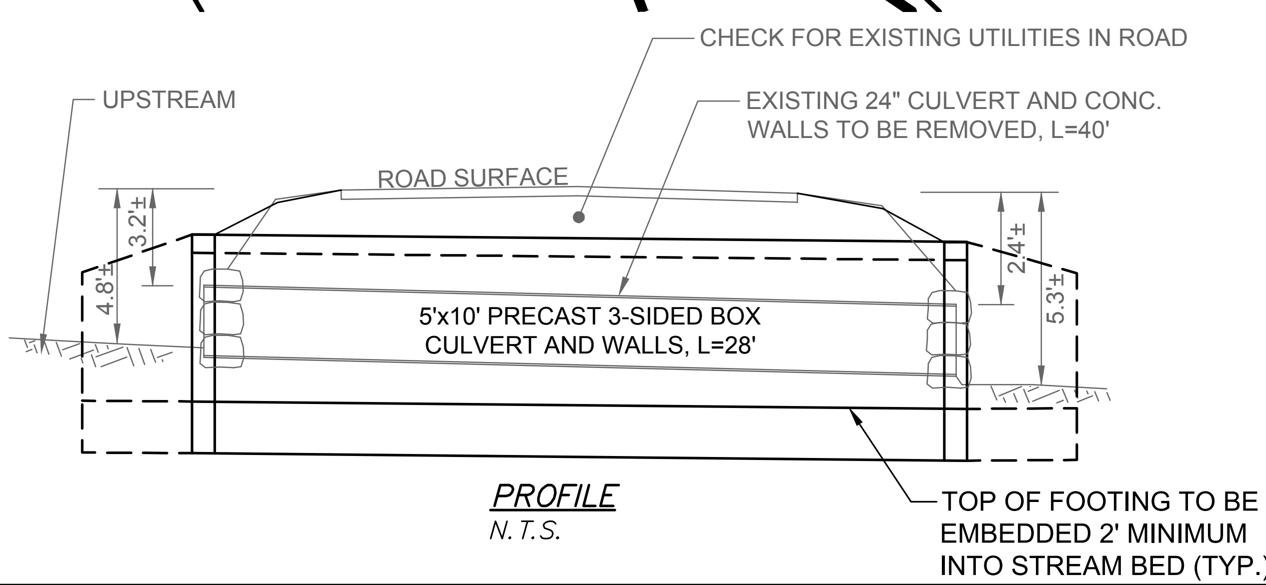
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

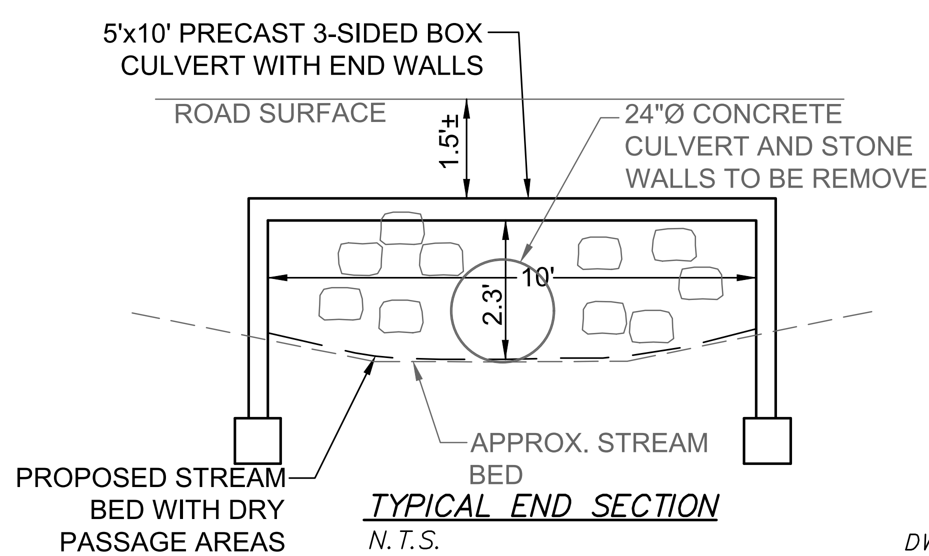
DWG. No. Site 658.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=8 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4266944270961264
11. NAACC SURVEY ID: 6987

CROSSING ID#670 SKETCH PLAN

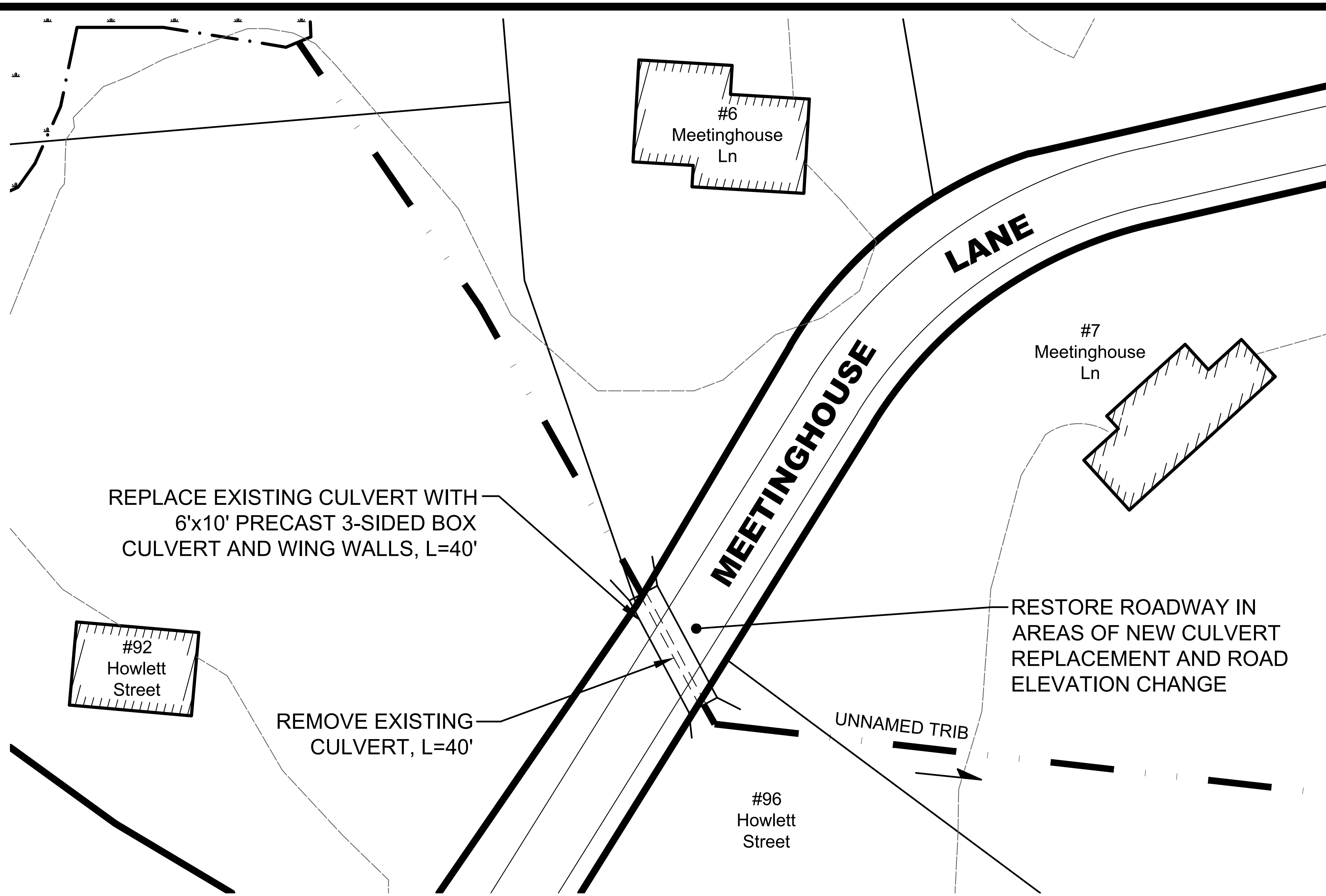
LOCATED IN
TOPSFIELD, MASSACHUSETTS
(ESSEX COUNTY)
PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

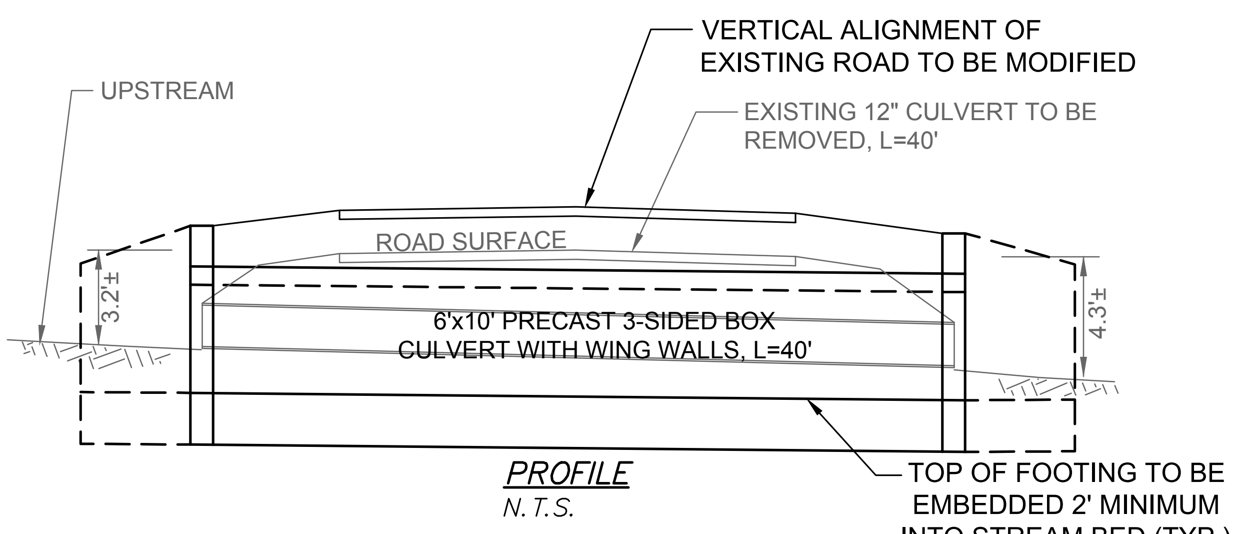
SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

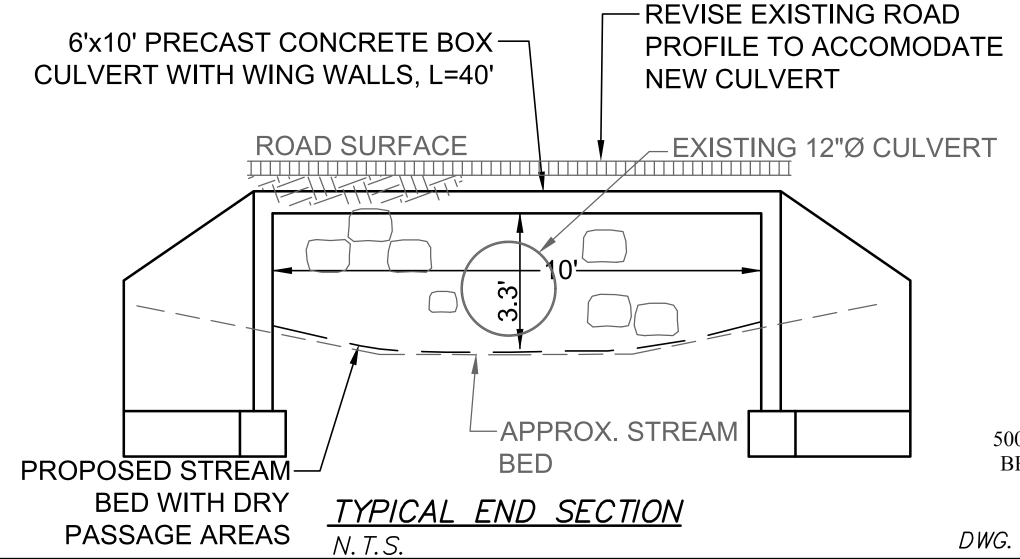
MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 670.dwg
MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=6.5 FEET. PROPOSED CULVERT WIDTH=10 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.82
10. NAACC CROSSING CODE: xy4264239370935955
11. NAACC SURVEY ID: 7106

CROSSING ID#9011
SKETCH PLAN

LOCATED IN

TOPSFIELD, MASSACHUSETTS
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 16, 2017

20 0 20 40 80

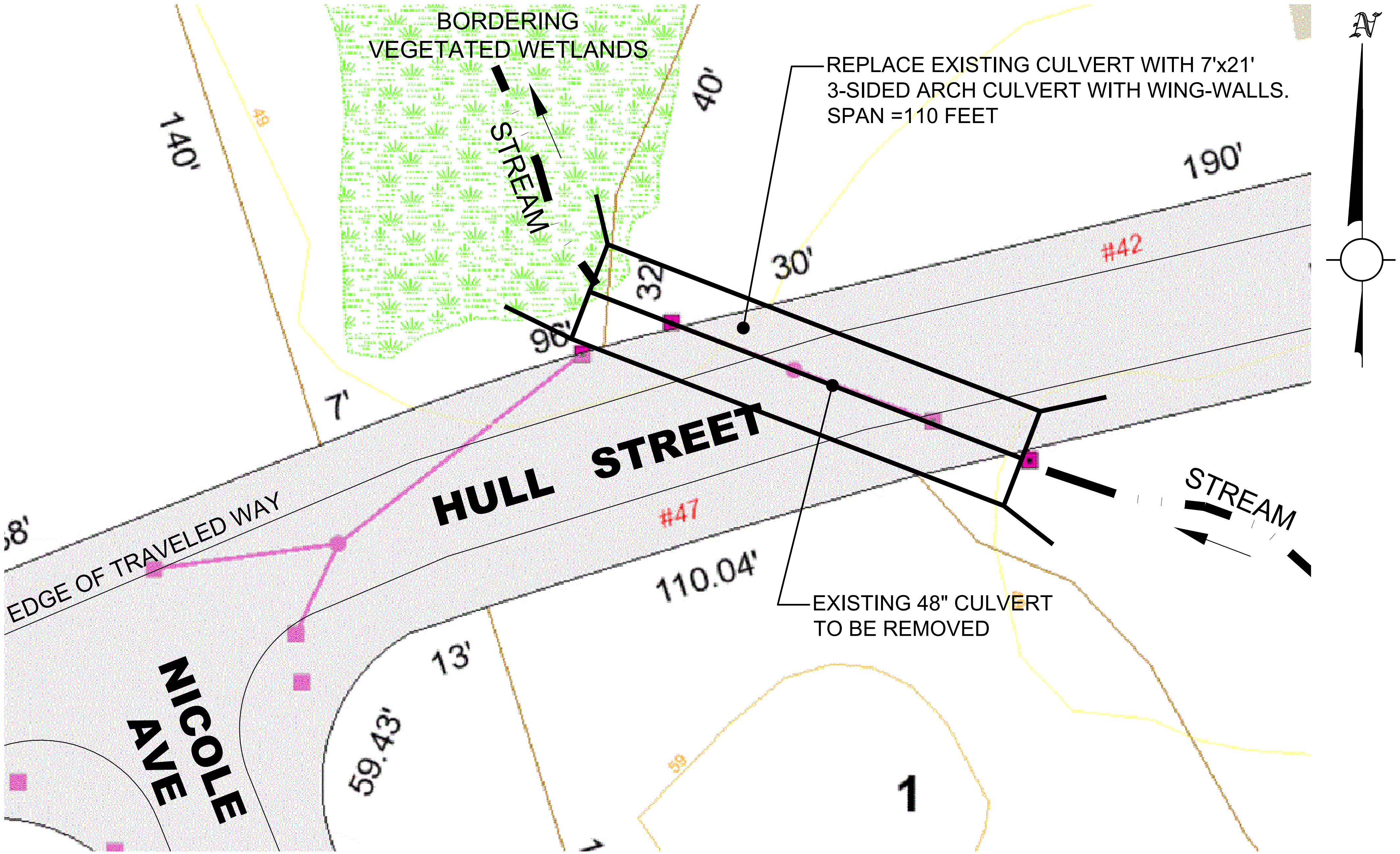
MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 9011.dwg
MAI Project: 5900

Wenham Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Wenham, MA

3 pages



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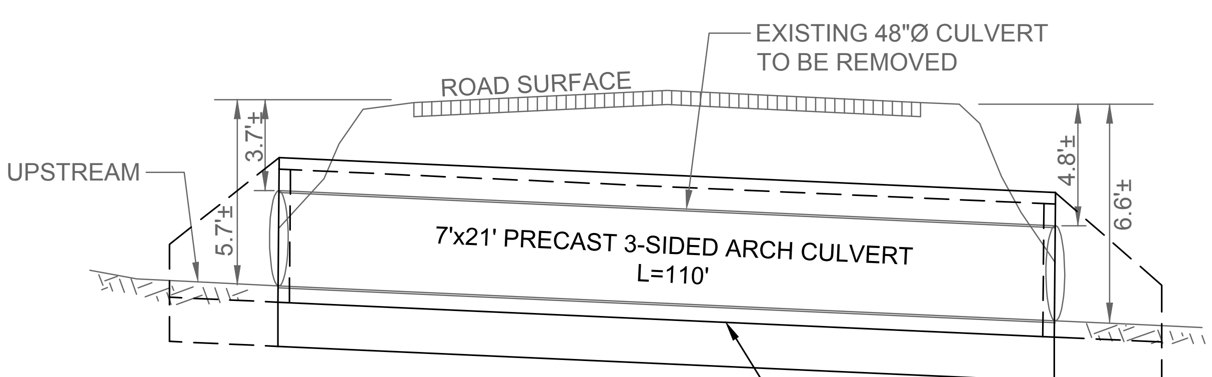
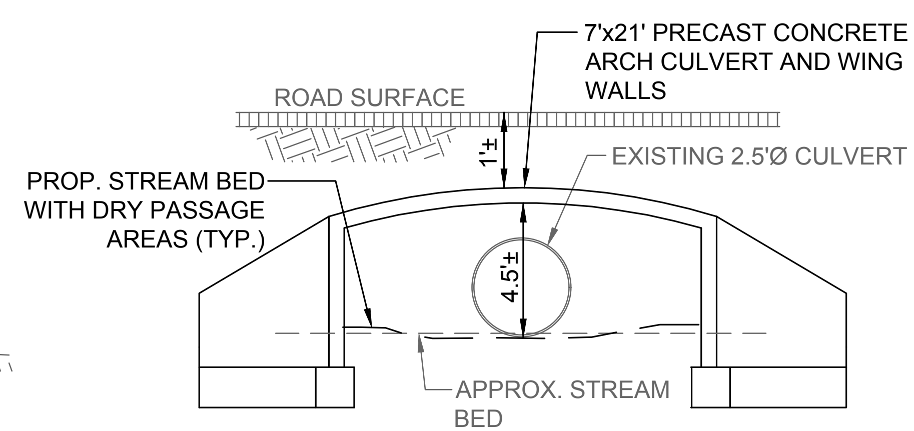
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=17.5 FEET. PROPOSED CULVERT WIDTH=24 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.85
10. NAACC CROSSING CODE: xy4258551470828958
11. NAACC SURVEY ID: 23510



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 161
SKETCH PLAN

LOCATED IN

WENHAM, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 30' DATE: OCT. 30, 2016
15 0 15 30 60

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
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TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
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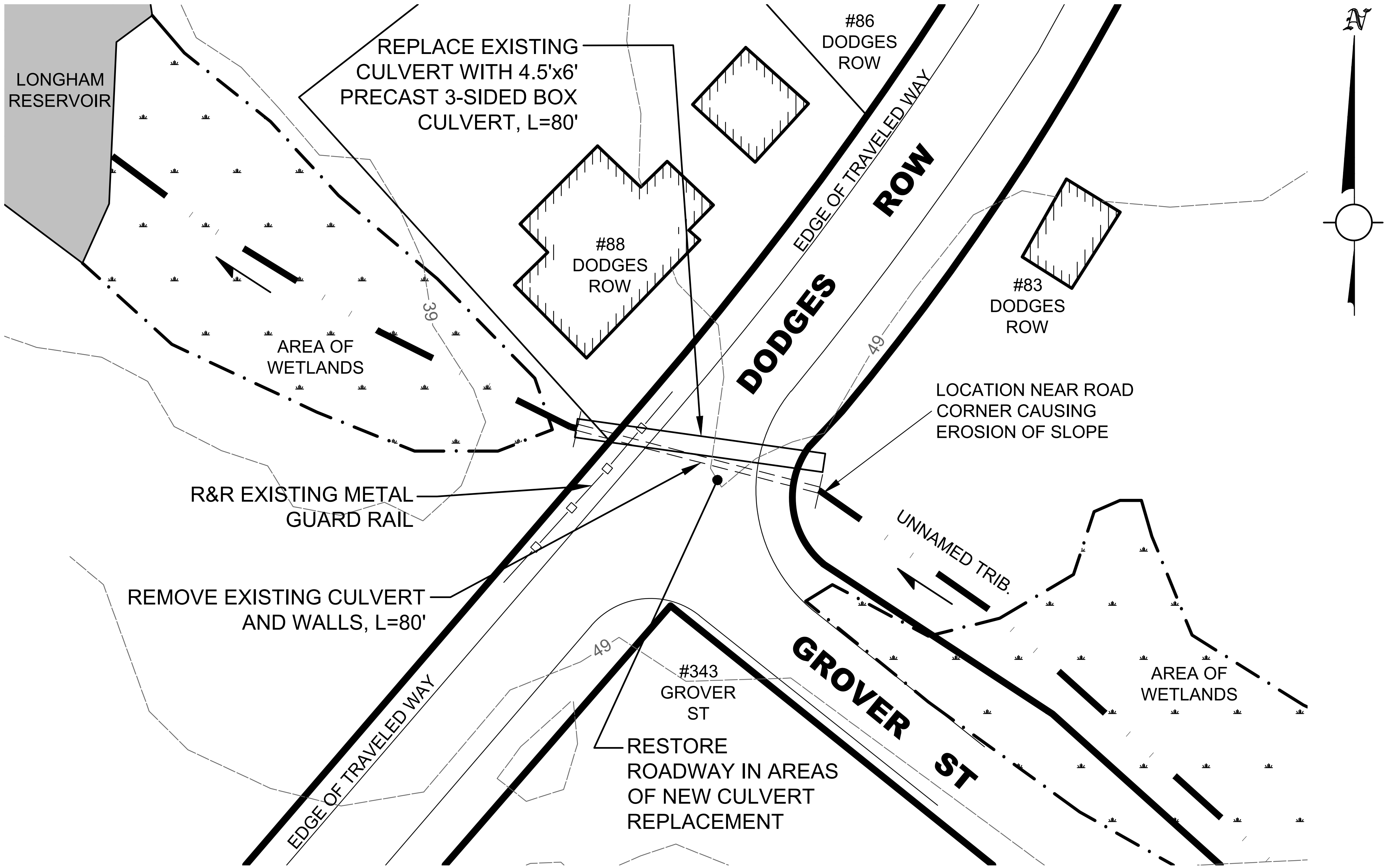
WWW.MERIDIANASSOC.COM

DWG. No. Site 161.dwg
MAI Project: 5900



NOTES:

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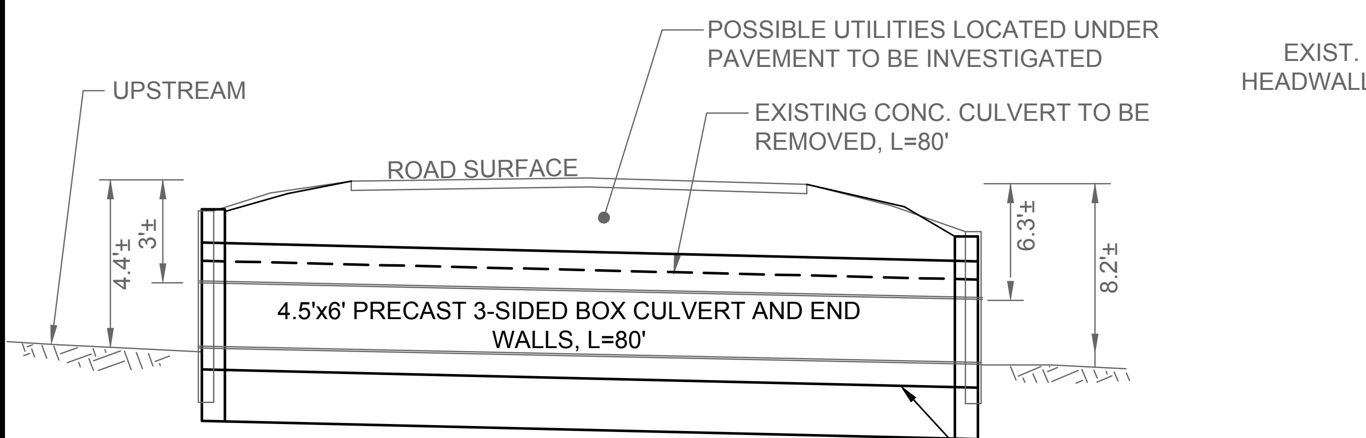
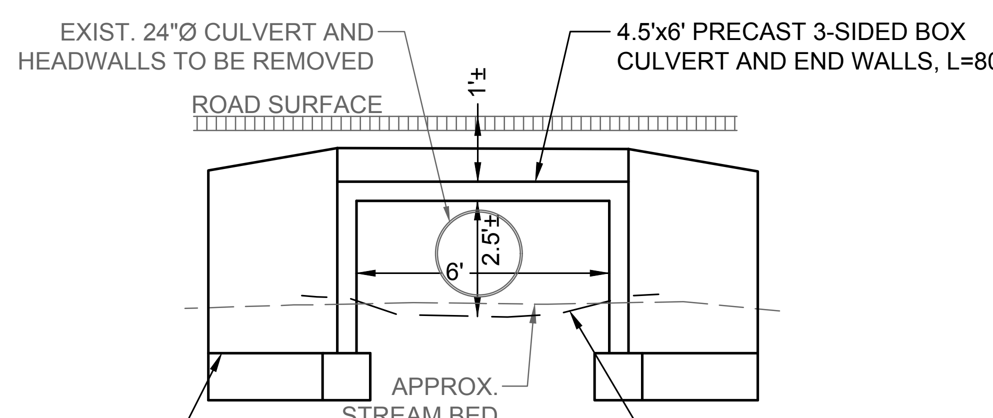
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=4.7 FEET. PROPOSED CULVERT WIDTH=6 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.19 (LACK OF UPSTREAM COVER)
10. NAACC CROSSING CODE: xy4259130570861496
11. NAACC SURVEY ID: 7330



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID#188 SKETCH PLAN

LOCATED IN

WENHAM, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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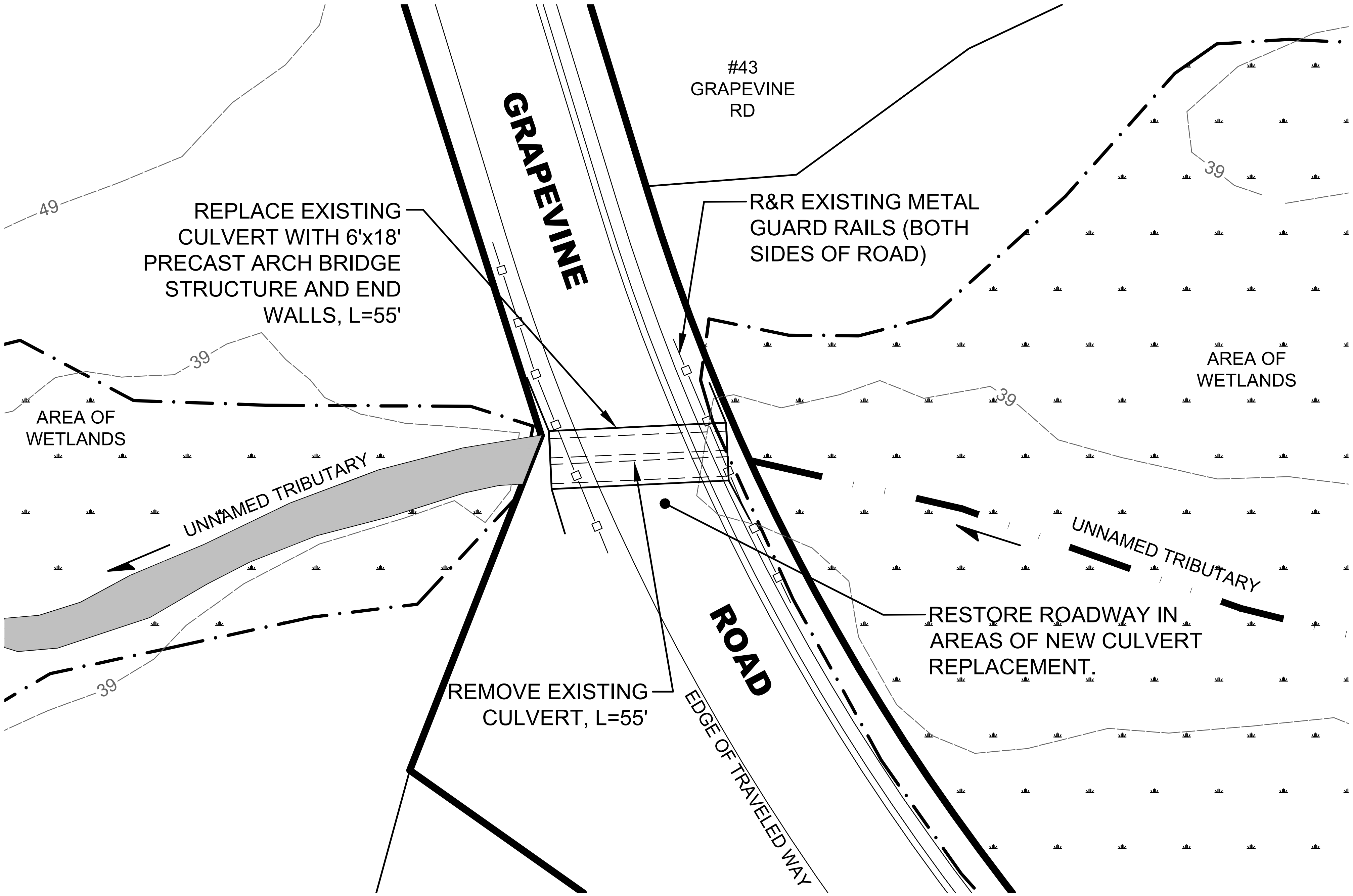
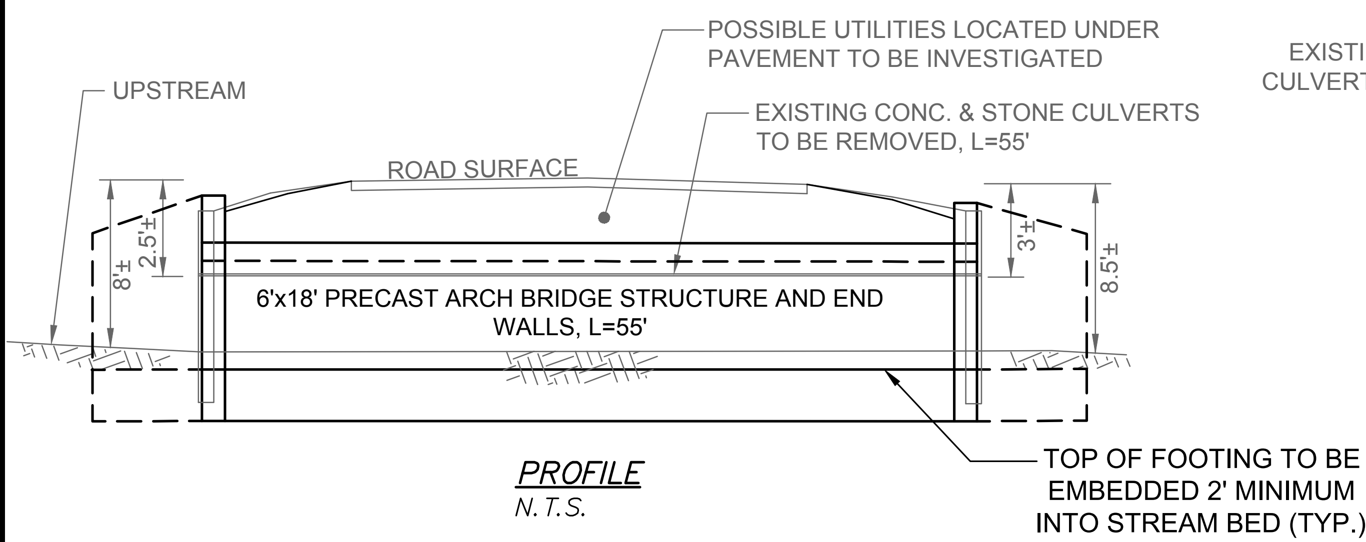
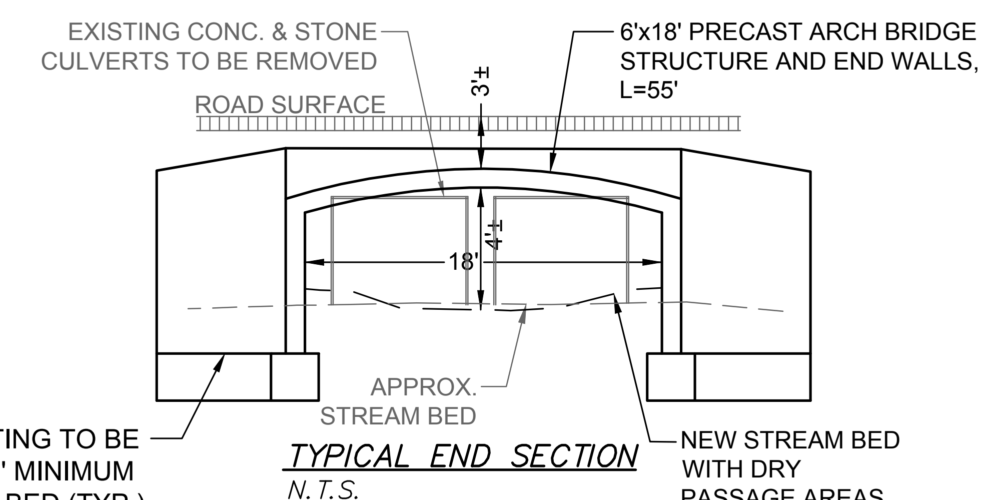
DWG. No. Site 188.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=15 FEET. PROPOSED CULVERT WIDTH=18 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.3
10. NAACC CROSSING CODE: xy4259733970850727
11. NAACC SURVEY ID: 10855

CROSSING ID#233
SKETCH PLAN

LOCATED IN

WENHAM, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 10, 2017

15 0 15 30 60

MERIDIAN
ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
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WWW.MERIDIANASSOC.COM

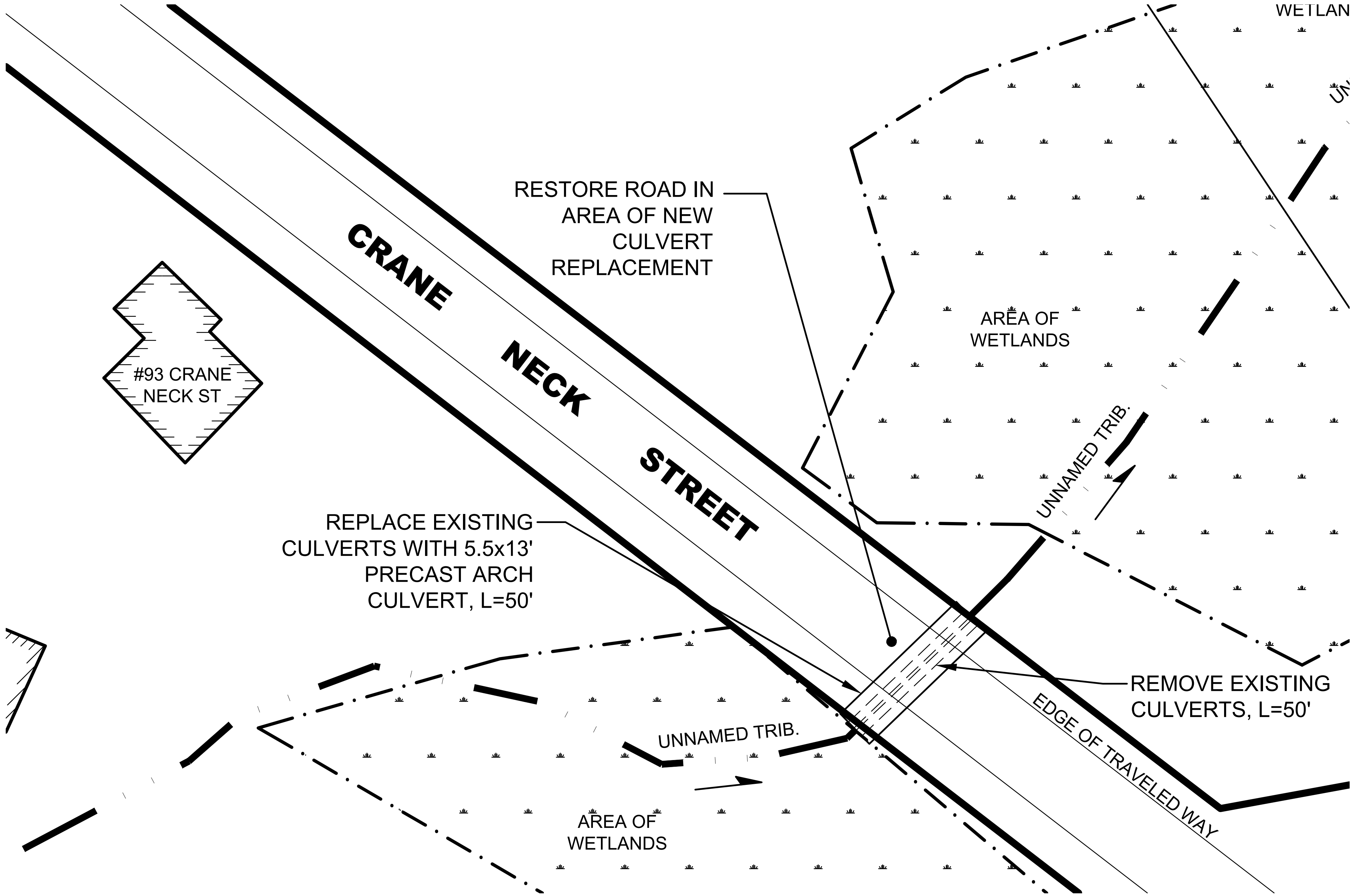
DWG. No. Site 233.dwg

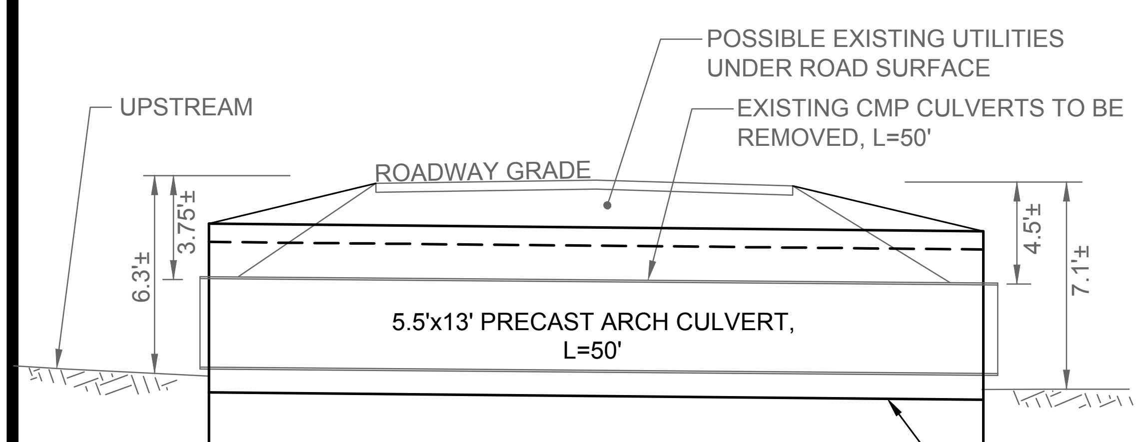
MAI Project: 5900

West Newbury Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of West Newbury, MA

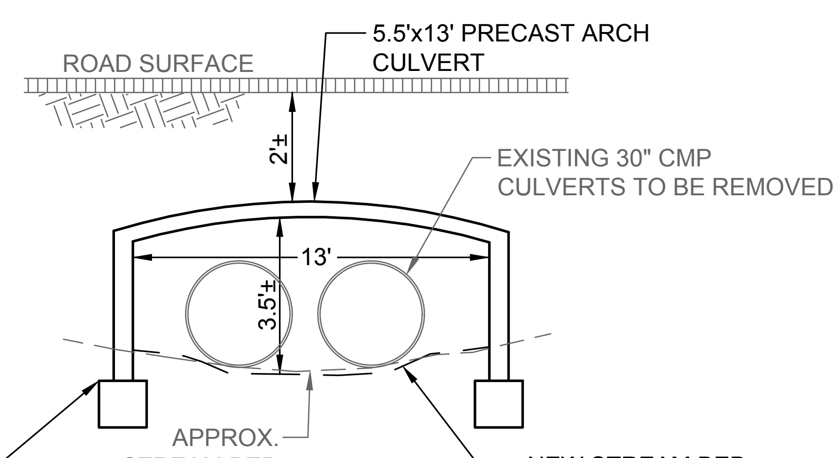
2 pages





PROFILE
N.T.S.

TOP OF FOOTING TO BE EMBEDDED 2' MINIMUM INTO STREAM BED (TYP.)



TYPICAL END SECTION
N.T.S.

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8. APPROXIMATE BANKFULL WIDTH=11 FEET. PROPOSED CULVERT WIDTH=13 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.84
10. NAACC CROSSING CODE: xy4277828270988182
11. NAACC SURVEY ID: 9595

CROSSING ID#1153 SKETCH PLAN

LOCATED IN

WEST NEWBURY, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN ASSOCIATES

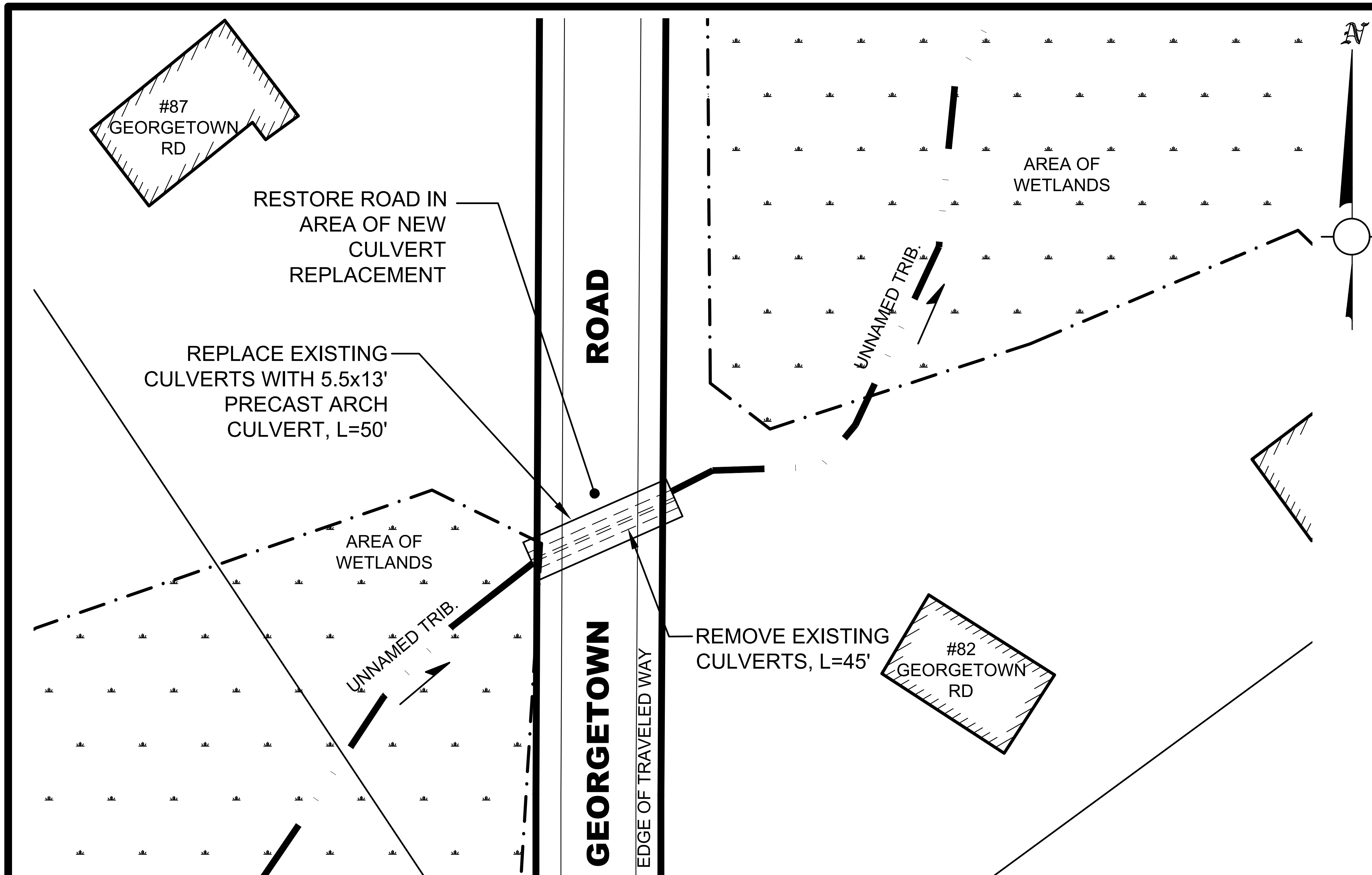
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

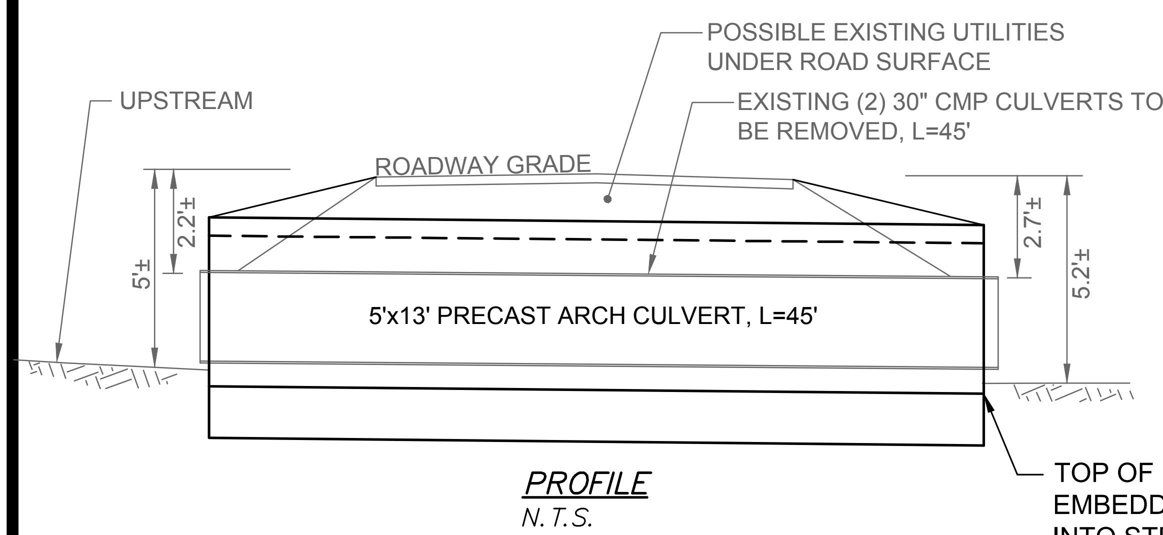
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 1153.dwg

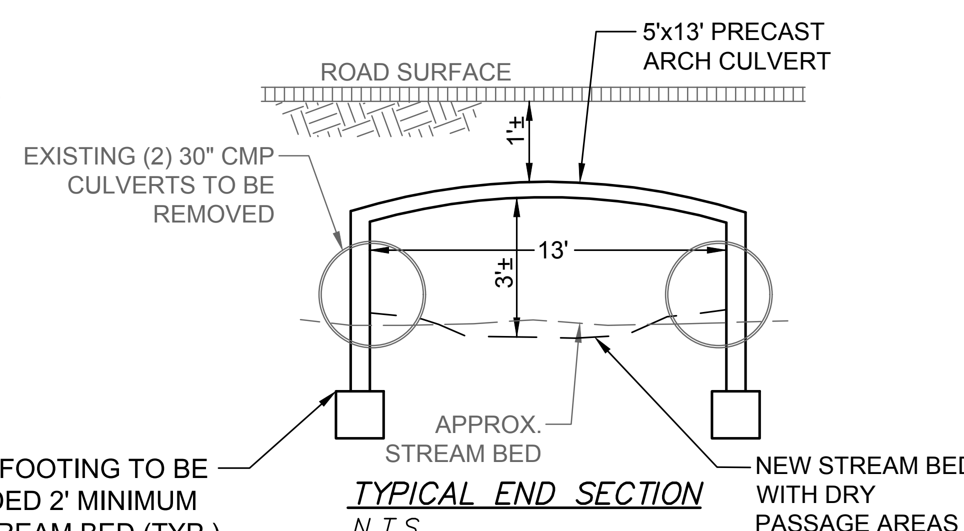
MAI Project: 5900





PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

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7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=11 FEET. PROPOSED CULVERT WIDTH=13 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.86
10. NAACC CROSSING CODE: xy4277886270987463
11. NAACC SURVEY ID: 9596

CROSSING ID#1155 SKETCH PLAN

LOCATED IN

WEST NEWBURY, MA

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: FEB. 1, 2017

15 0 15 30 60

MERIDIAN
ASSOCIATES

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69 MILK STREET, SUITE 302
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WWW.MERIDIANASSOC.COM

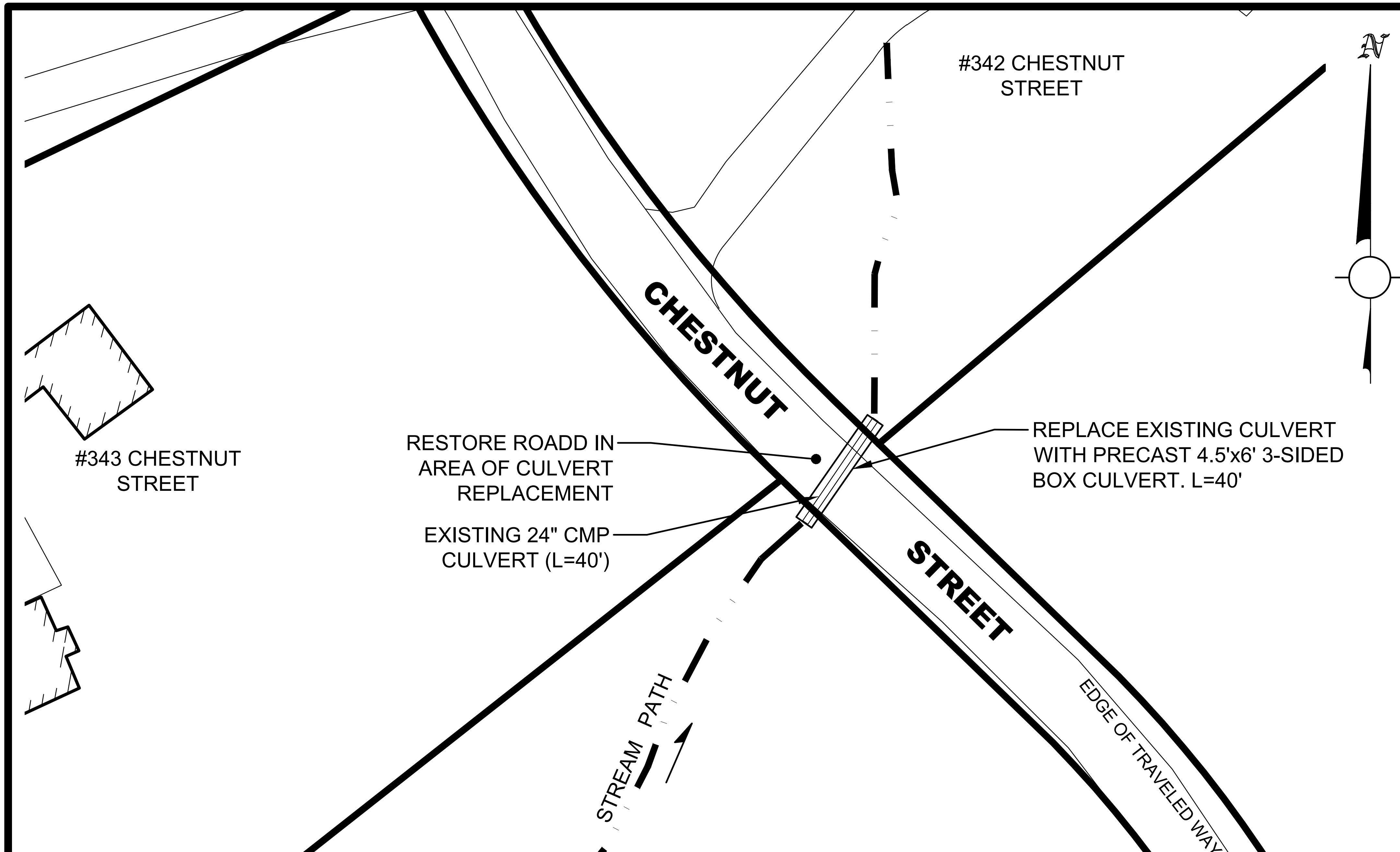
DWG. No. Site 1155.dwg

MAI Project: 5900

Wilmington Designs

Conceptual designs for the replacement of select road-stream crossings in the Town of Wilmington, MA

11 pages



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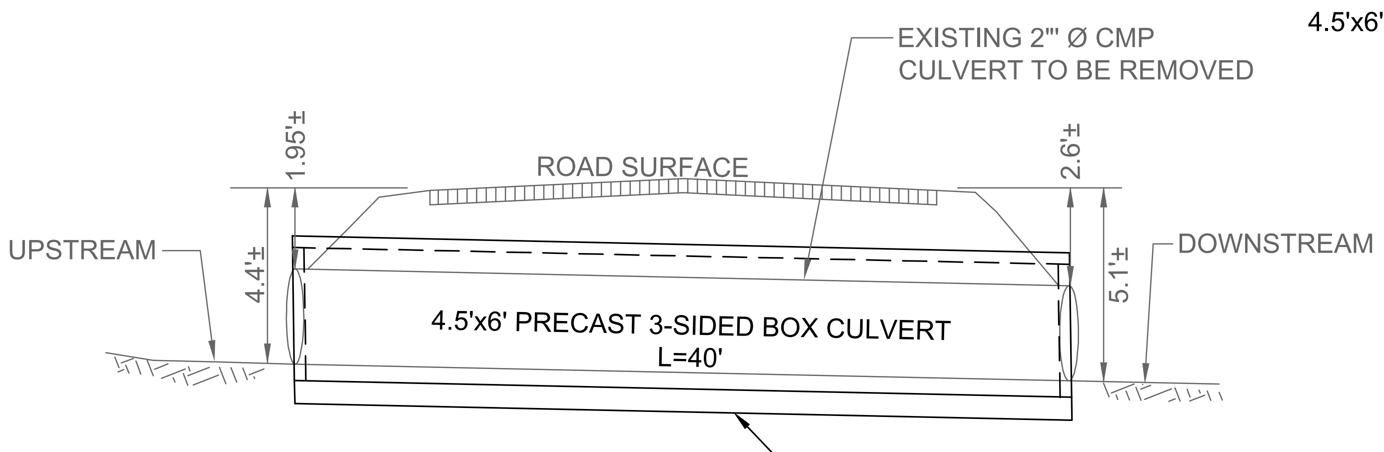
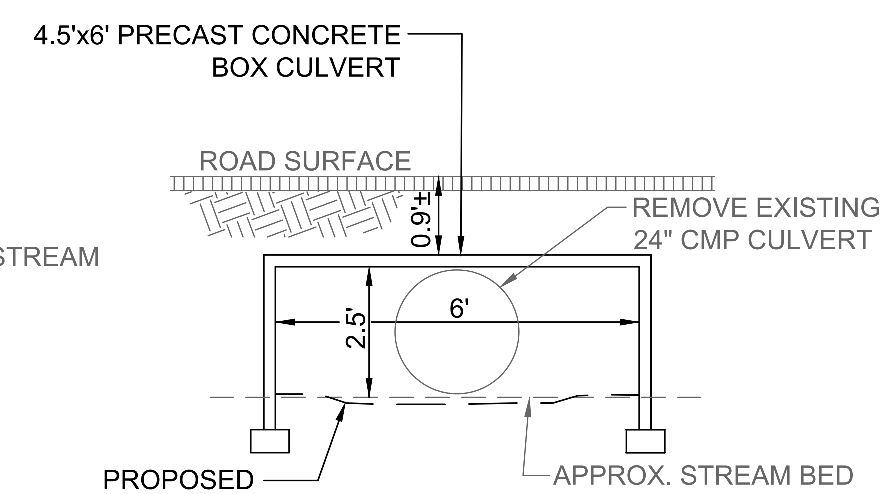
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=5 FEET. PROPOSED CULVERT WIDTH=6 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.37 (INTERMITTENT STREAM)
10. NAACC CROSSING CODE: xy4252206871169537
11. NAACC SURVEY ID: 4749



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 7
SKETCH PLAN

LOCATED IN
WILMINGTON, MASSACHUSETTS
(ESSEX COUNTY)

PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 17, 2016
20 0 20 40 80

MERIDIAN
ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
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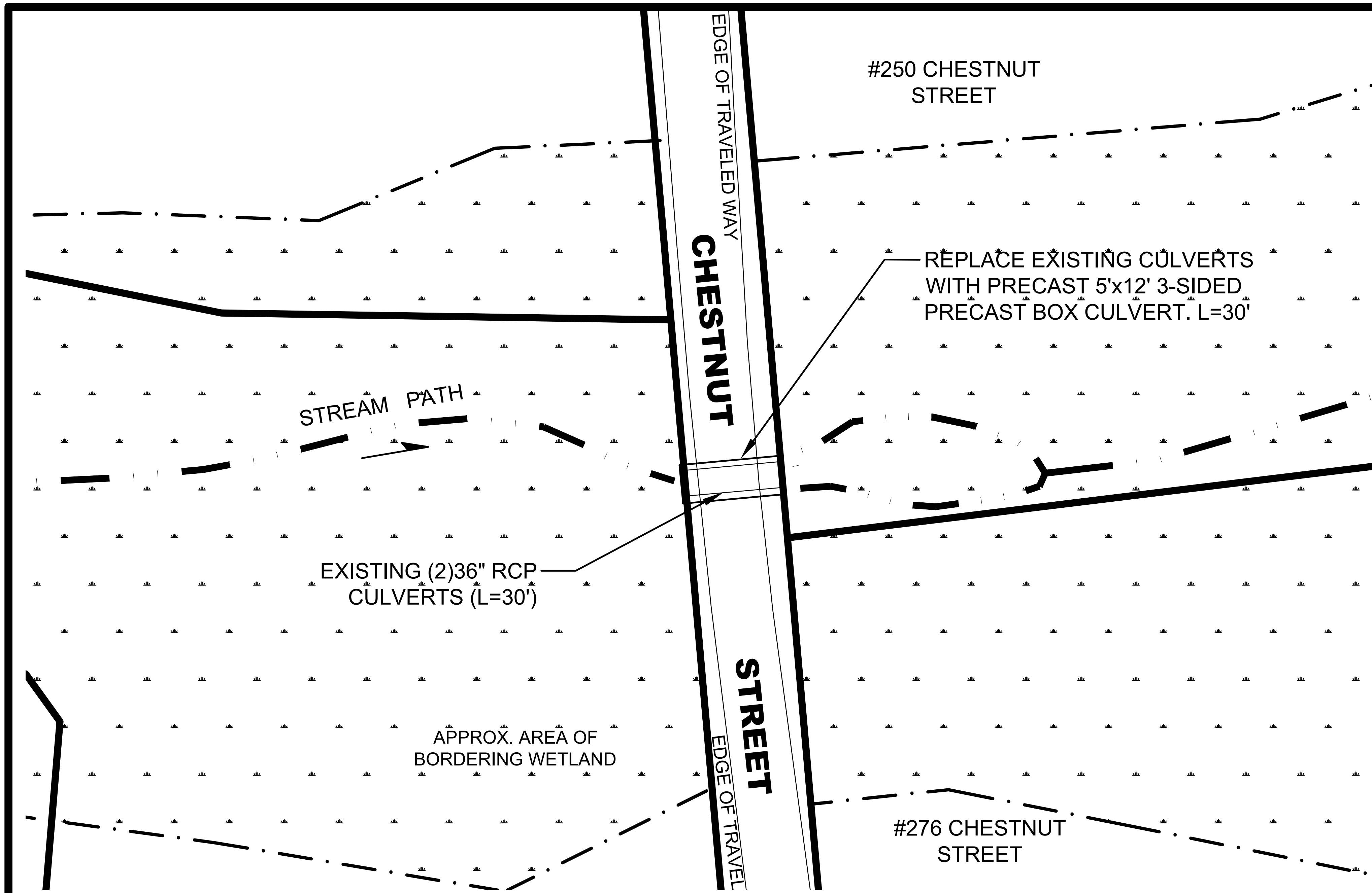
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 7.dwg
MAI Project: 5900



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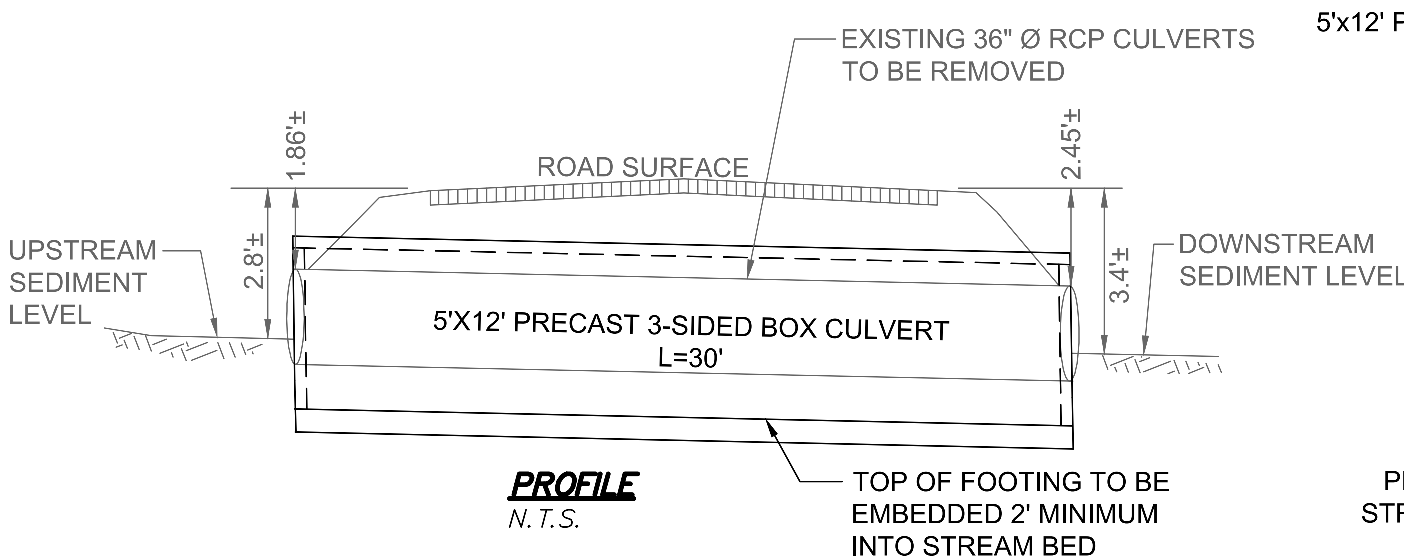
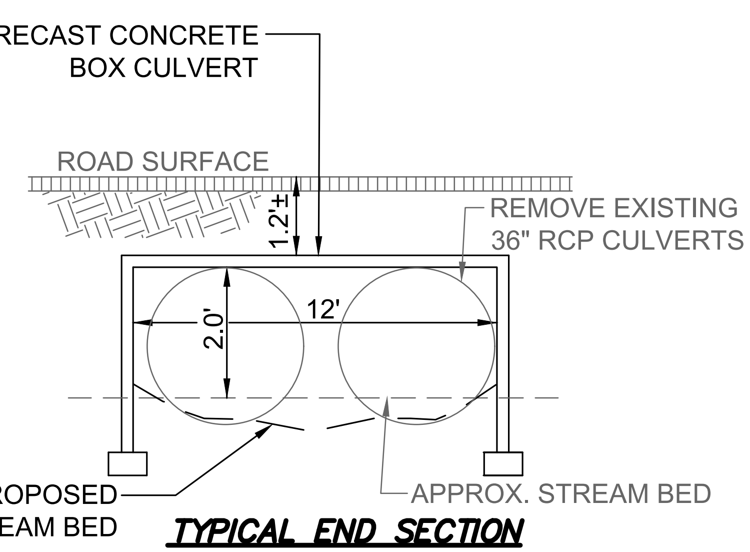
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=10 FEET. PROPOSED CULVERT WIDTH=12 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.8
10. NAACC CROSSING CODE: xy4252720871172387
11. NAACC SURVEY ID: 7286



PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

CROSSING ID# 9
SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 17, 2016

20 0 20 40 80

MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
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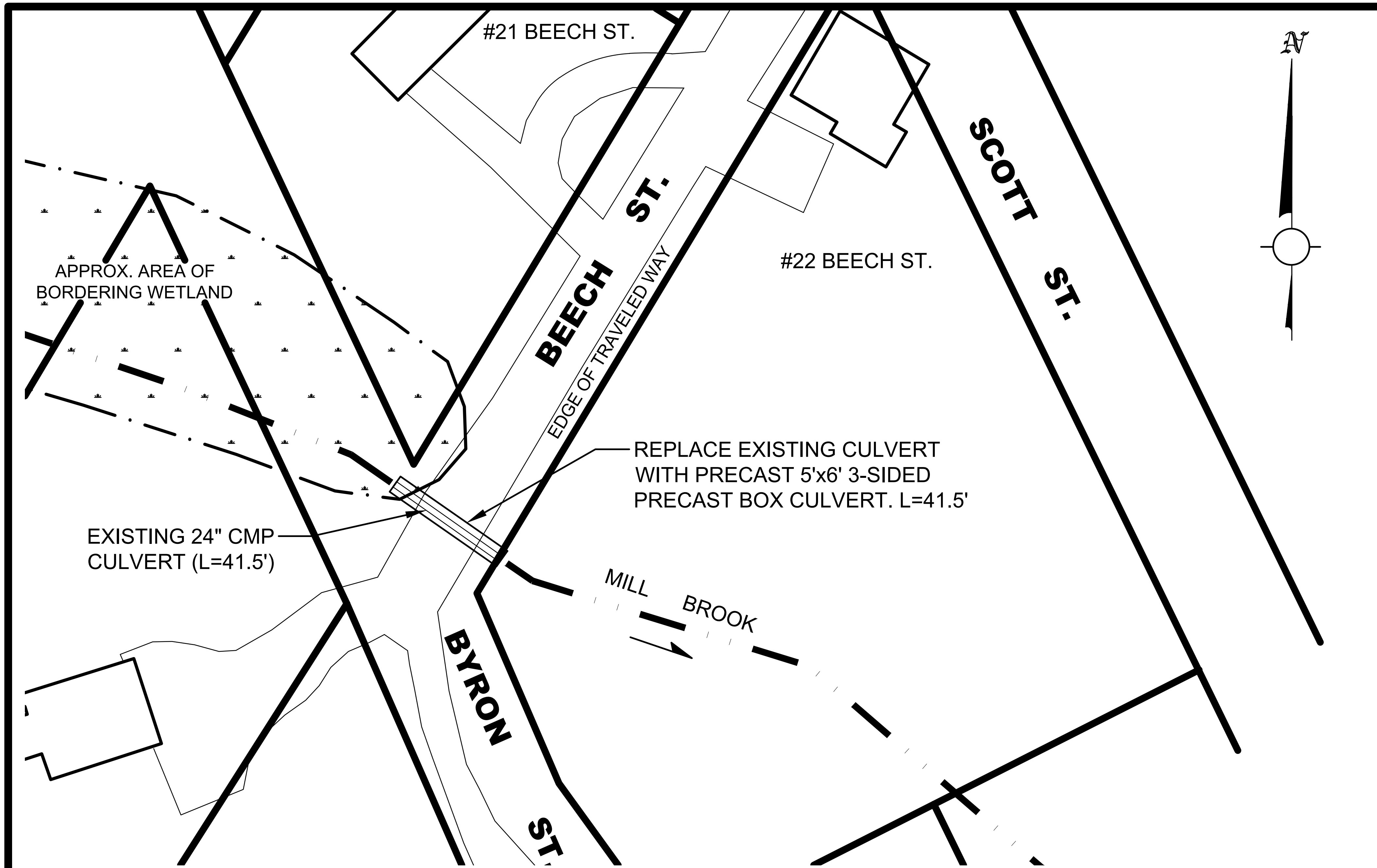
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 9.dwg

MAI Project: 5900



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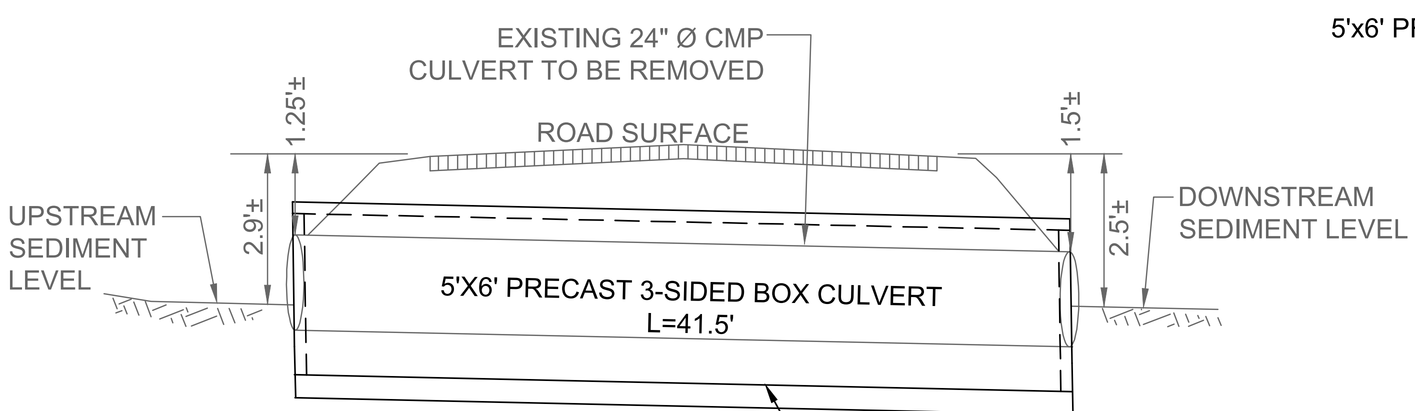
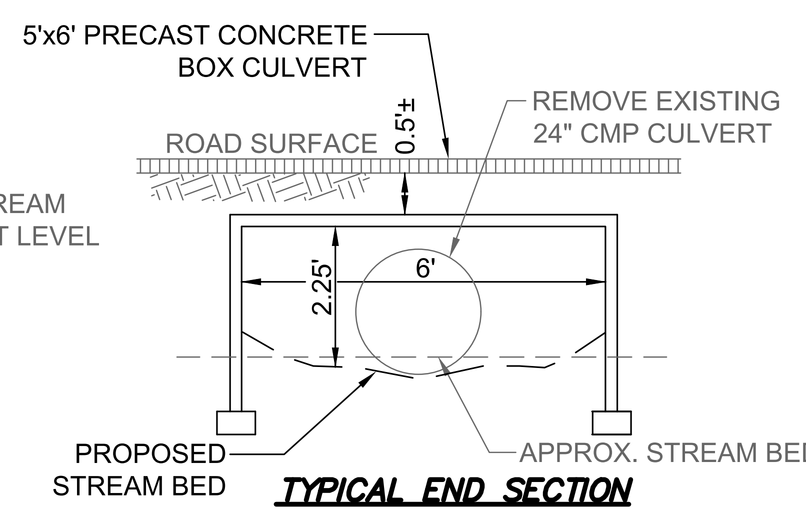
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=5 FEET. PROPOSED CULVERT WIDTH=6 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.33
10. NAACC CROSSING CODE: xy4253688171195394
11. NAACC SURVEY ID: 9832



TOP OF FOOTING TO BE
EMBEDDED 2' MINIMUM
INTO STREAM BED

PROFILE
N.T.S.



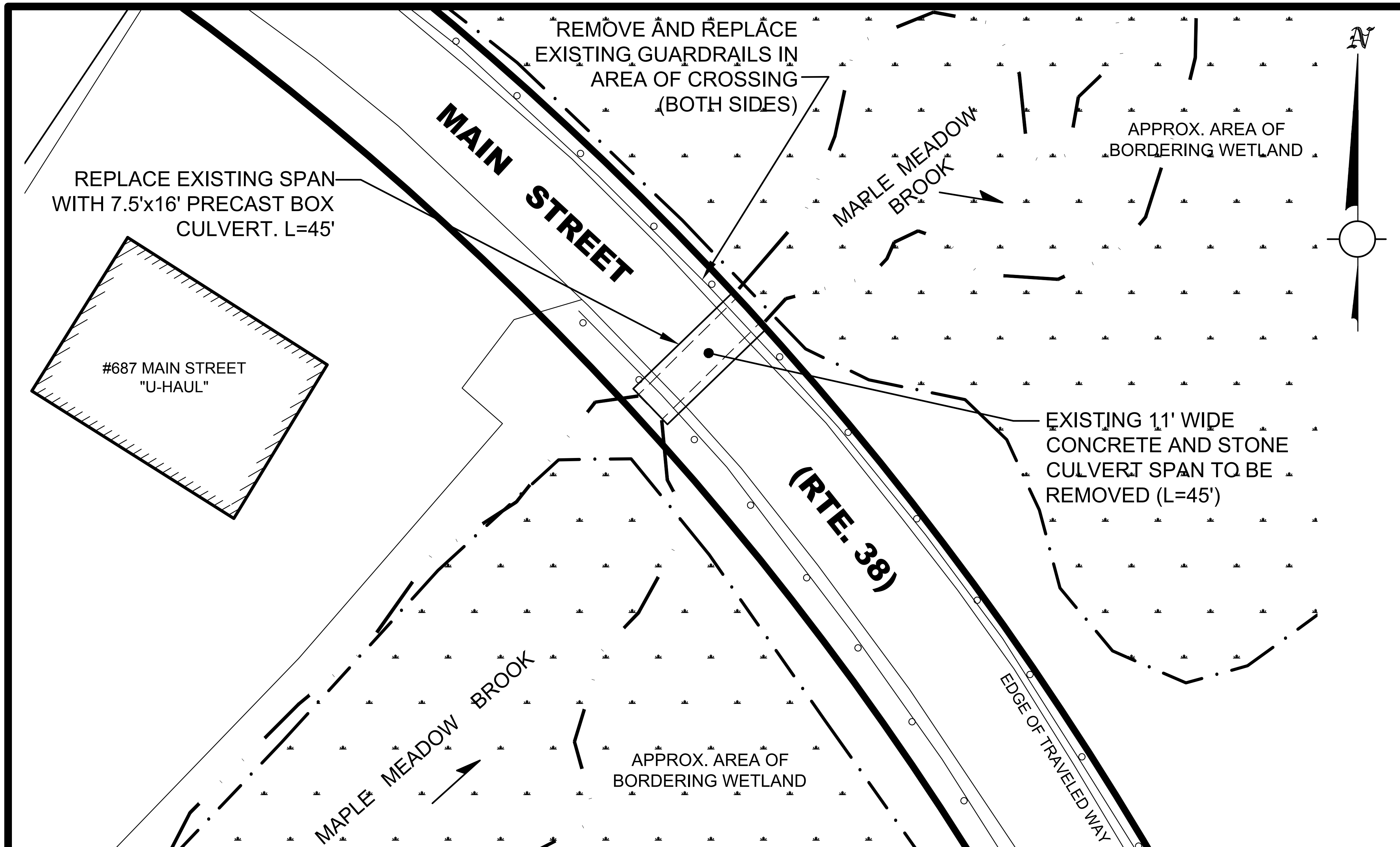
TYPICAL END SECTION
N.T.S.

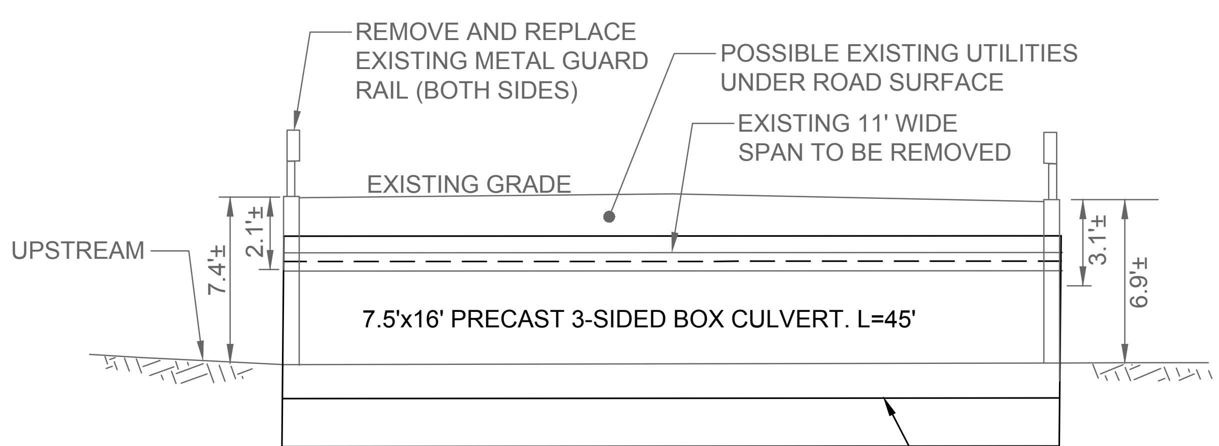
CROSSING ID# 16
SKETCH PLAN
LOCATED IN
WILMINGTON, MASSACHUSETTS
(ESSEX COUNTY)
PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 17, 2016
20 0 20 40 80

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

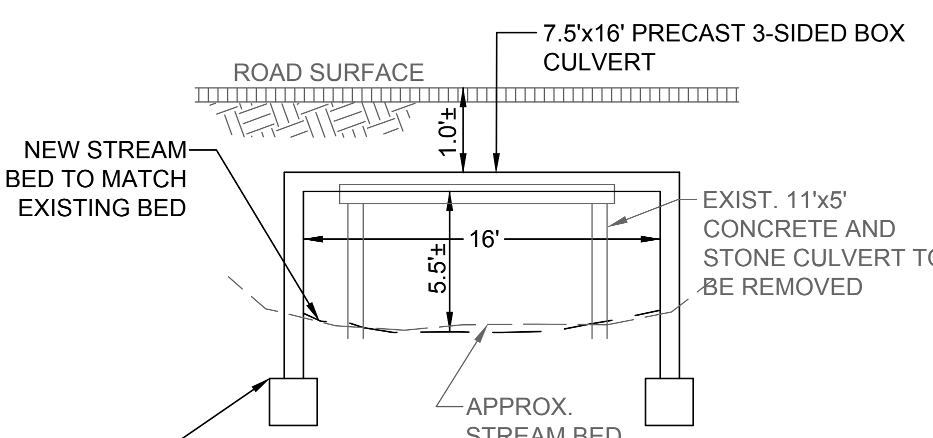
DWG. No. Site 16.dwg
MAI Project: 5900





PROFILE
N.T.S.

TOP OF FOOTINGS TO BE EMBEDDED 2' MINIMUM INTO STREAM BED



TYPICAL END SECTION
N.T.S.

NOTES:

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4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=N/A(WETLAND CROSSING). PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.77
10. NAACC CROSSING CODE: xy4253748671160605
11. NAACC SURVEY ID: 5642

CROSSING ID# 18
SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 22, 2016

20 0 20 40 80

MERIDIAN ASSOCIATES

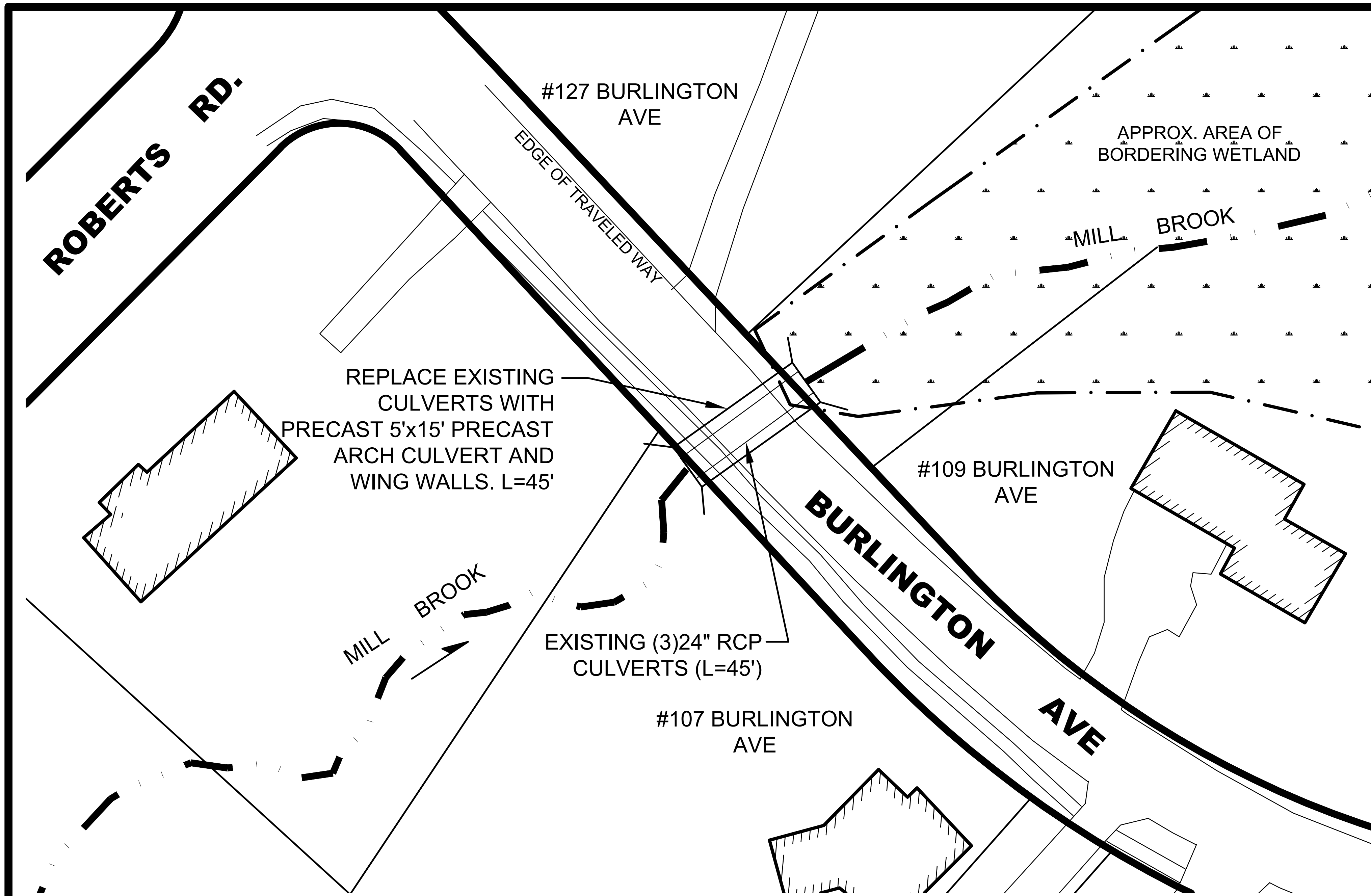
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

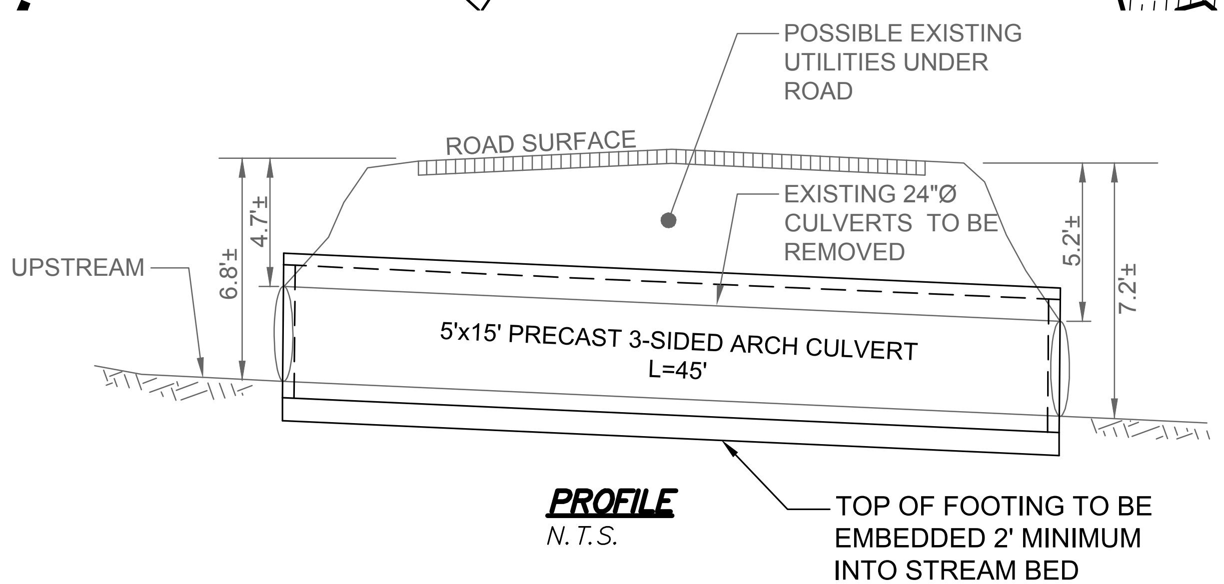
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

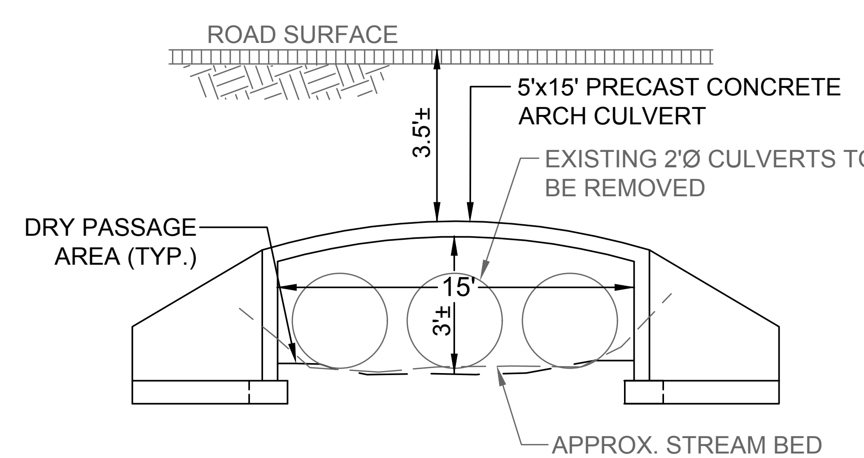
DWG. No. Site 18.dwg

MAI Project: 5900





PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

NOTES:

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2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=12.1 FEET. PROPOSED CULVERT WIDTH=15 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.83
10. NAACC CROSSING CODE: xy4254191471181512
11. NAACC SURVEY ID: 4751

CROSSING ID# 28 SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 17, 2016

20 0 20 40 80

MERIDIAN ASSOCIATES

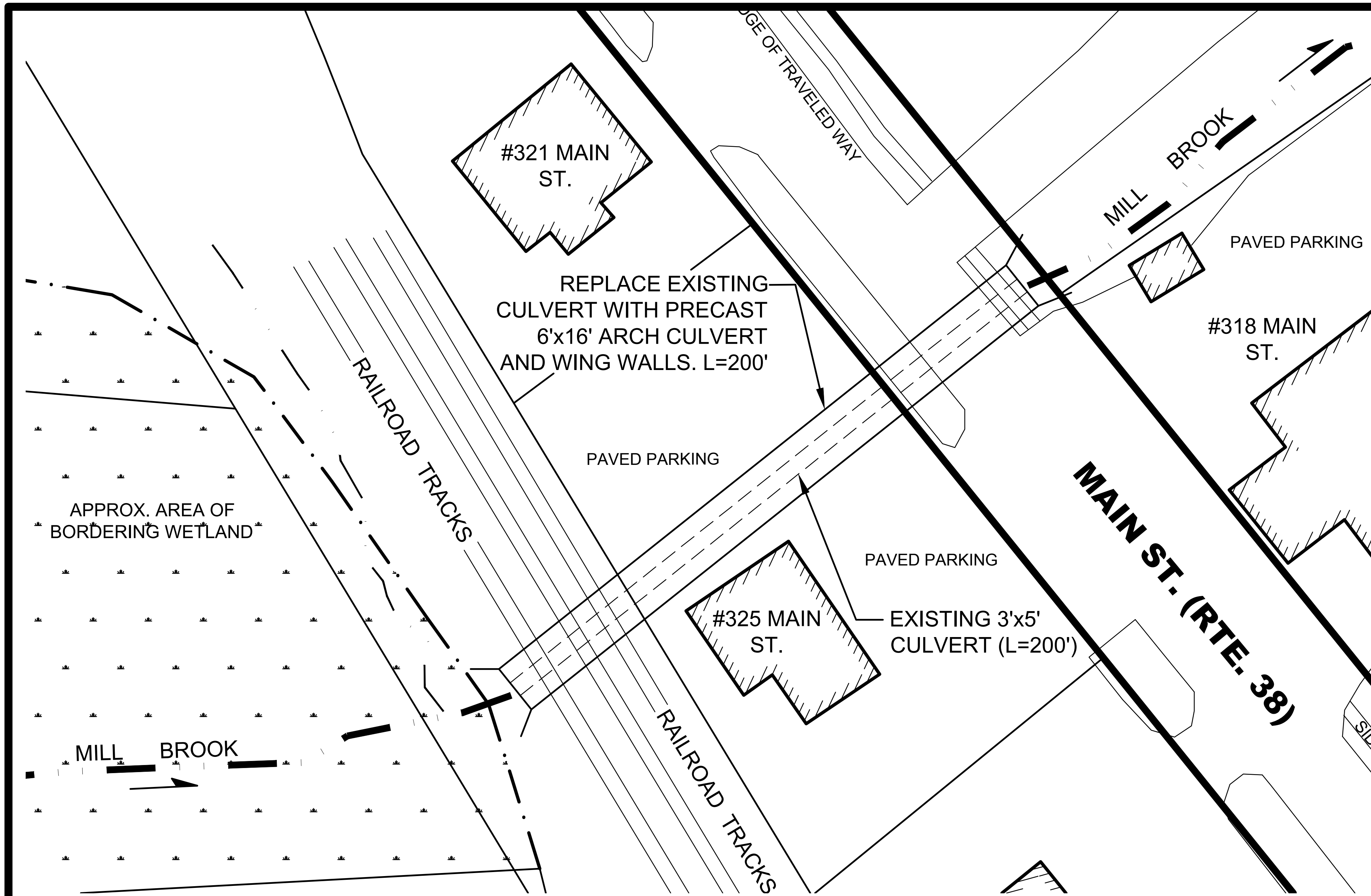
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 16.dwg

MAI Project: 5900



NOTES:

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=13.2 FEET. PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.25
10. NAACC CROSSING CODE: xy4255084971177167
11. NAACC SURVEY ID: 6395

CROSSING ID# 55 SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

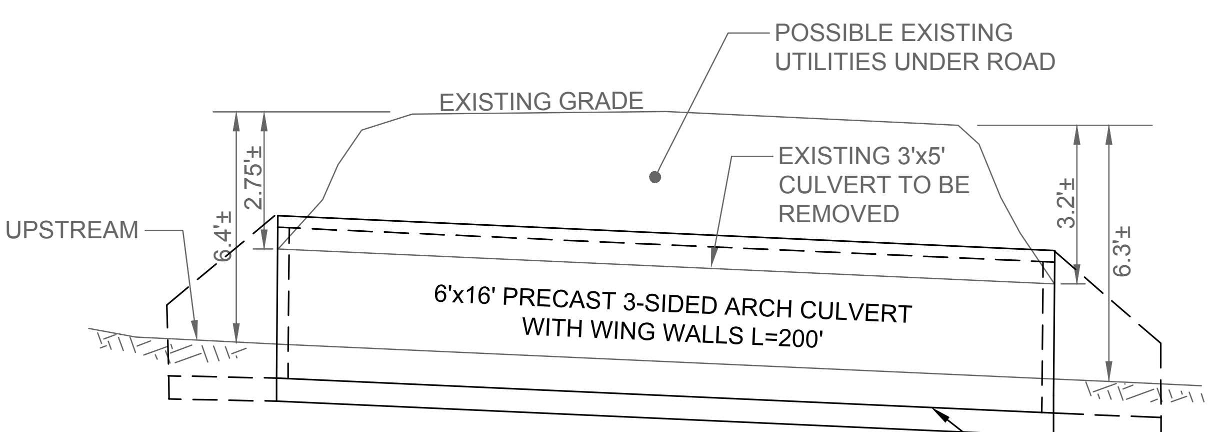
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

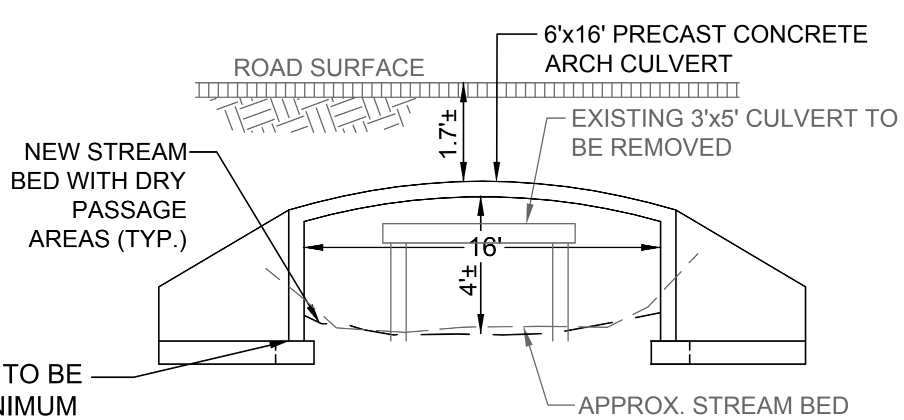
SCALE: 1"= 40' DATE: DEC. 22, 2016

20 0 20 40 80



PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

MERIDIAN ASSOCIATES

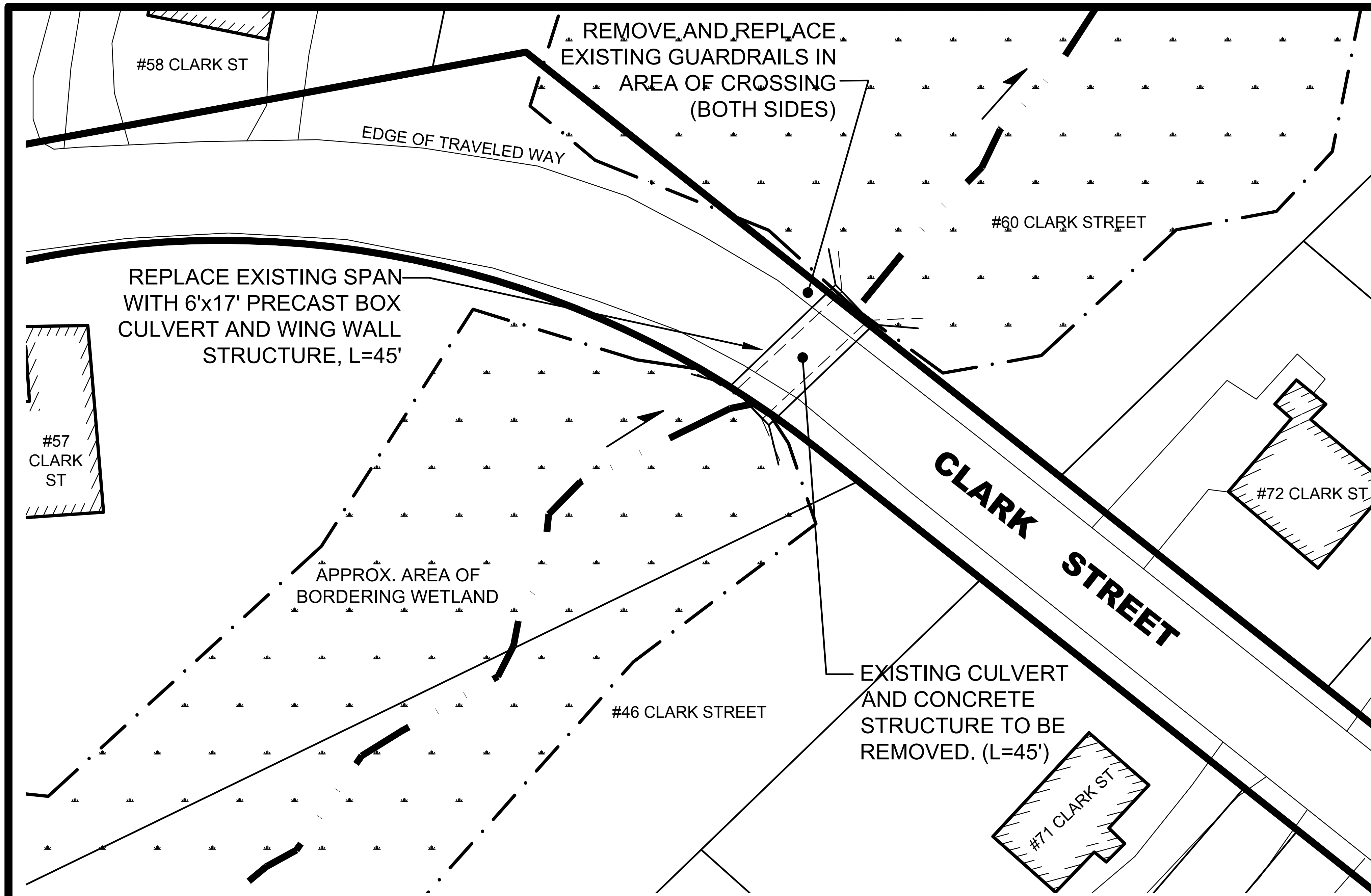
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 55.dwg

MAI Project: 5900



NOTES:

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3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=14 FEET. PROPOSED CULVERT WIDTH=17 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.4
10. NAACC CROSSING CODE: xy4255275671172977
11. NAACC SURVEY ID: 5662

CROSSING ID# 63
SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

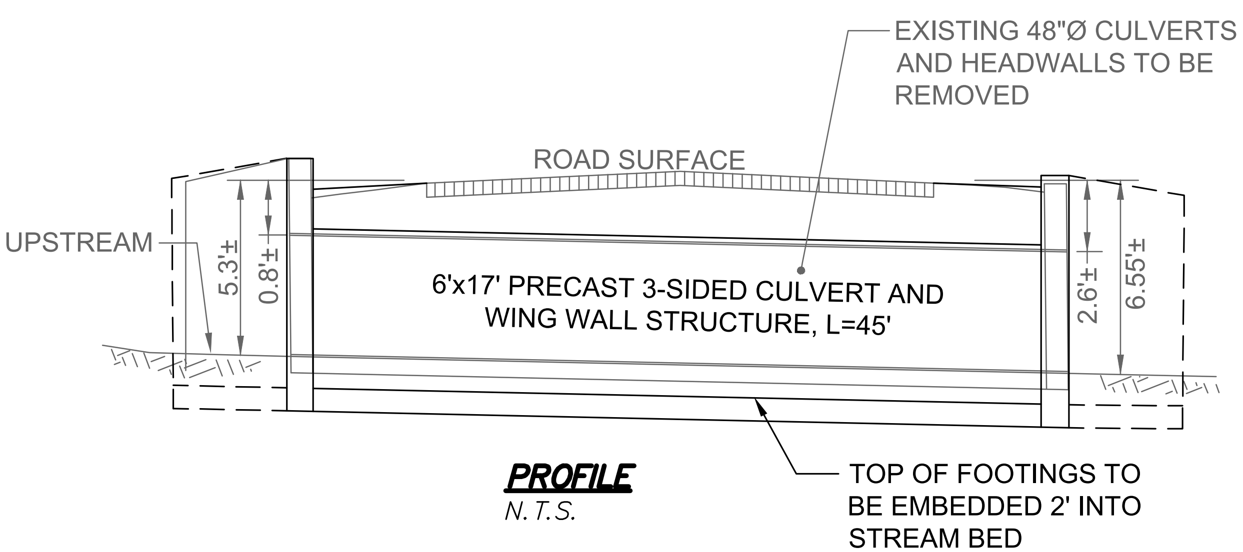
(ESSEX COUNTY)

PREPARED FOR

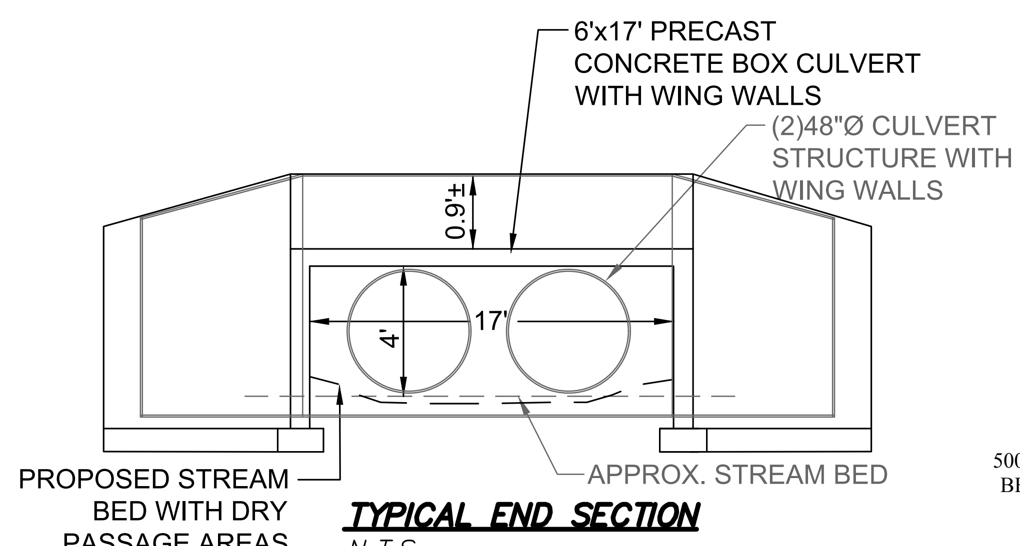
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 29, 2016

20 0 20 40 80



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

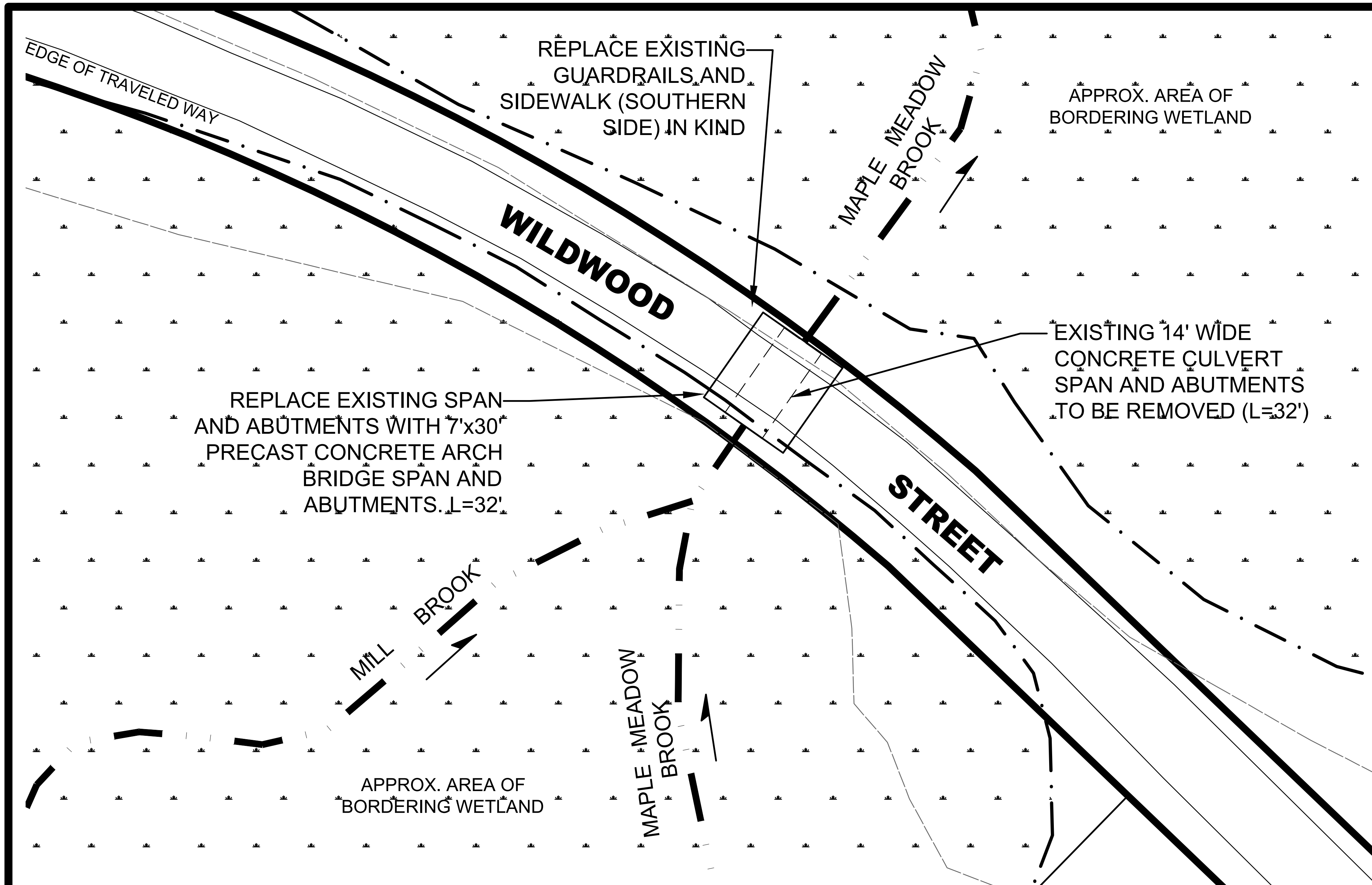
MERIDIAN ASSOCIATES

500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 63.dwg MAI Project: 5900



NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
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4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=25 FEET. PROPOSED CULVERT WIDTH=30 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=4.6
10. NAACC CROSSING CODE: xy4255279171156522
11. NAACC SURVEY ID: 5655

CROSSING ID# 65 SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

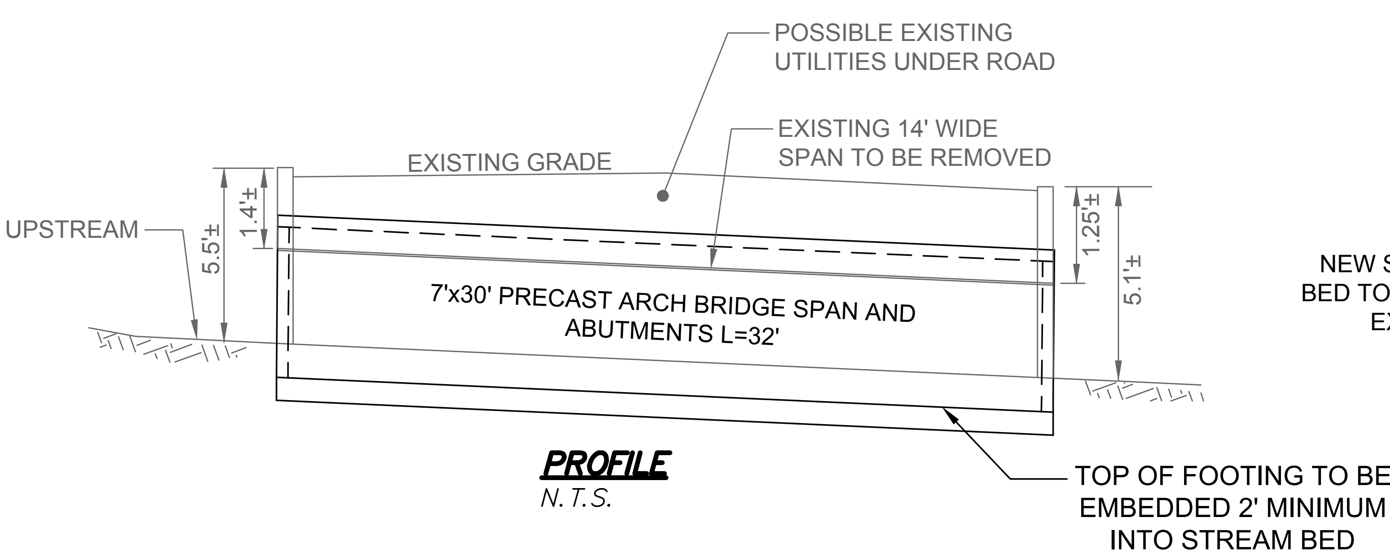
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

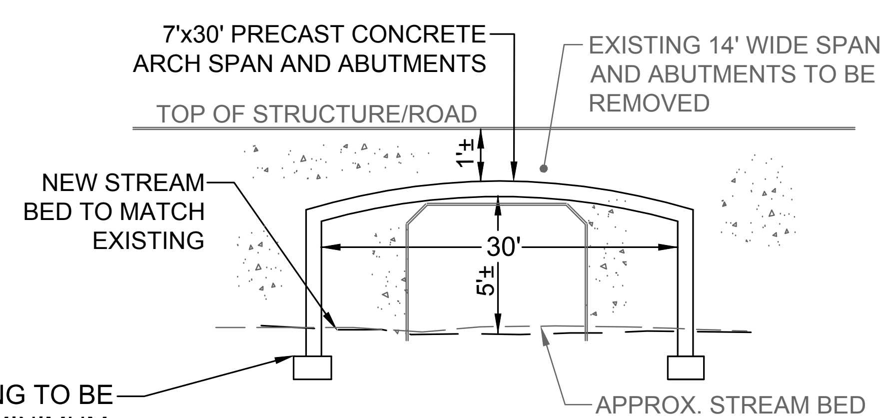
SCALE: 1"= 40' DATE: DEC. 22, 2016

20 0 20 40 80



PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

MERIDIAN ASSOCIATES

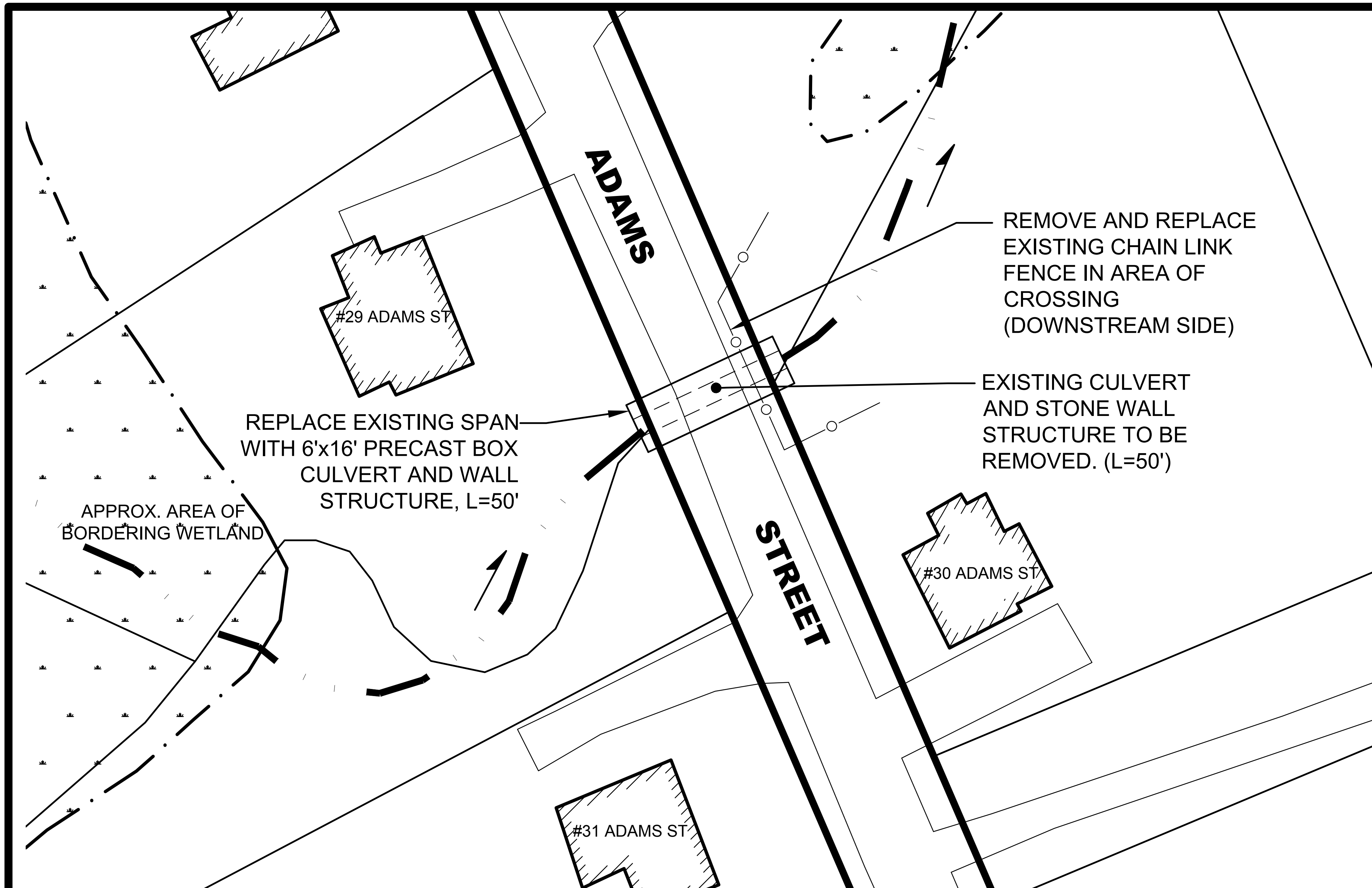
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 65.dwg

MAI Project: 5900



NOTES:

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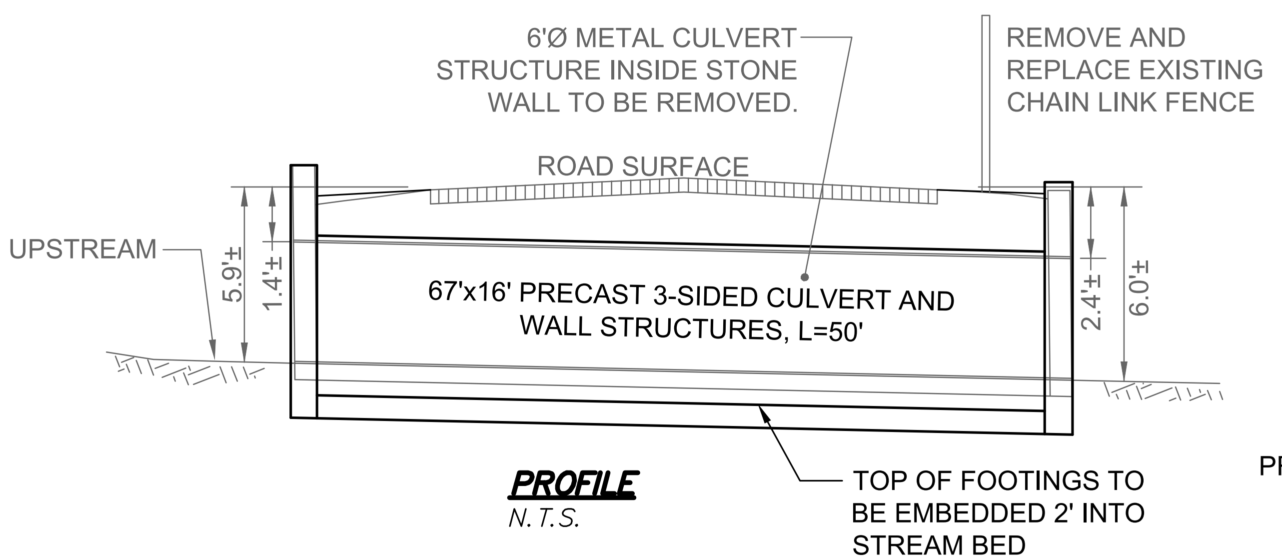
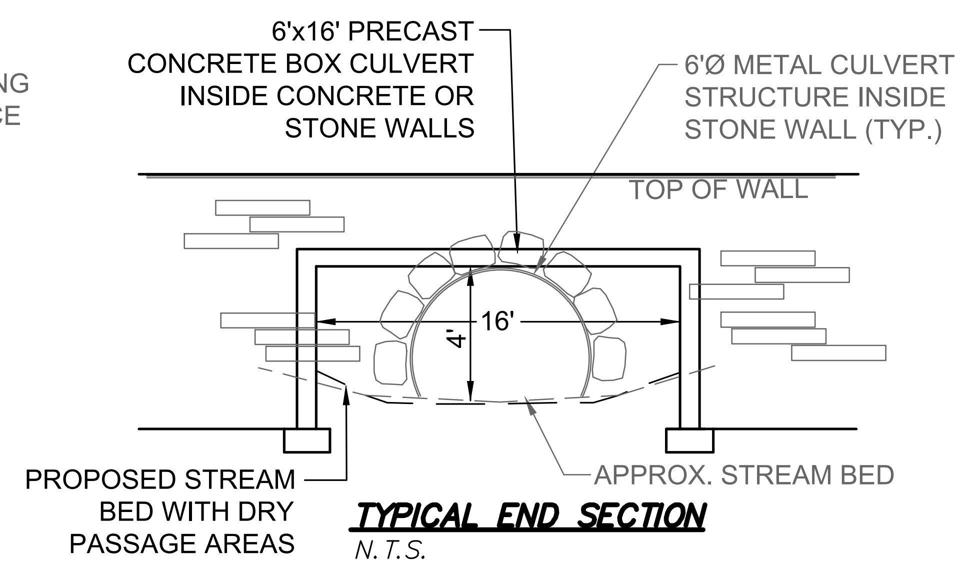
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=13 FEET. PROPOSED CULVERT WIDTH=16 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.28
10. NAACC CROSSING CODE: xy4255330371164730
11. NAACC SURVEY ID: 5659



PROFILE
N.T.S.



TYPICAL END SECTION
N.T.S.

CROSSING ID# 68
SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 29, 2016

20 0 20 40 80

MERIDIAN ASSOCIATES

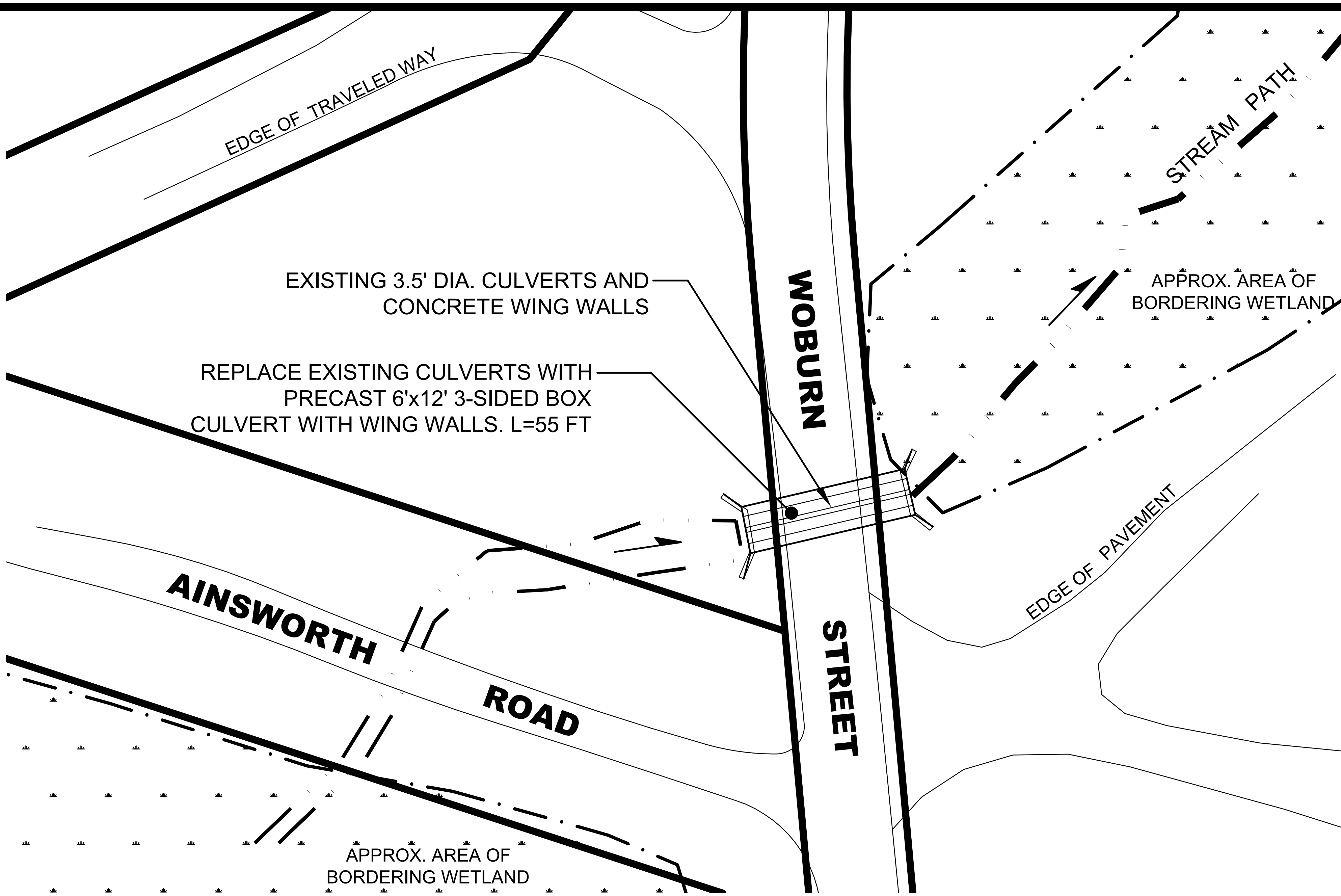
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

DWG. No. Site 68.dwg

MAI Project: 5900



NOTES:

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6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=11.5 FEET. PROPOSED CULVERT WIDTH=14 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=0.87
10. NAACC CROSSING CODE: xy4258244271148212
11. NAACC SURVEY ID: 5653

CROSSING ID# 148
SKETCH PLAN

LOCATED IN

WILMINGTON, MASSACHUSETTS

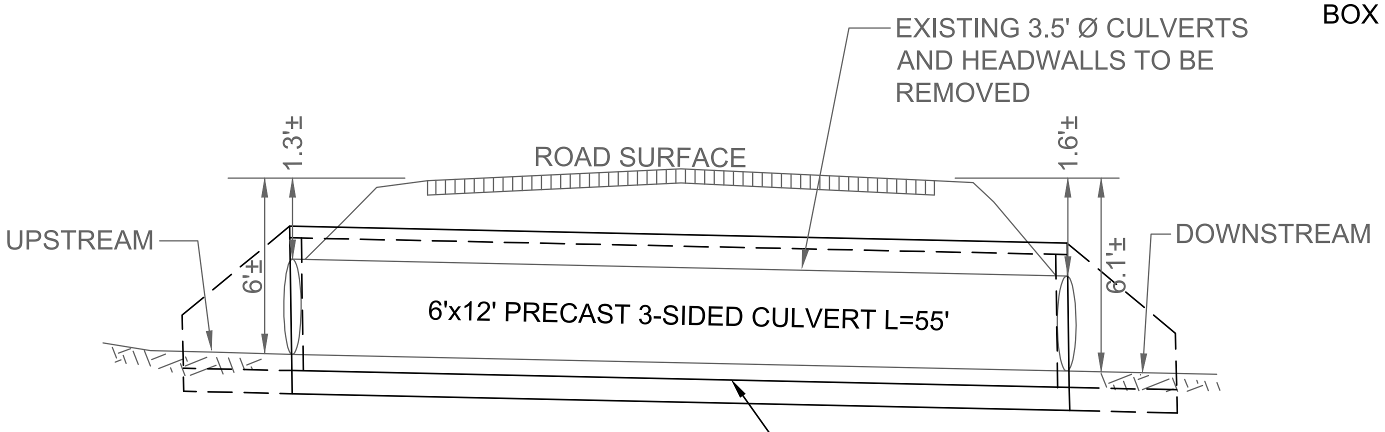
(ESSEX COUNTY)

PREPARED FOR

IPSWICH RIVER WATERSHED ASSOC.

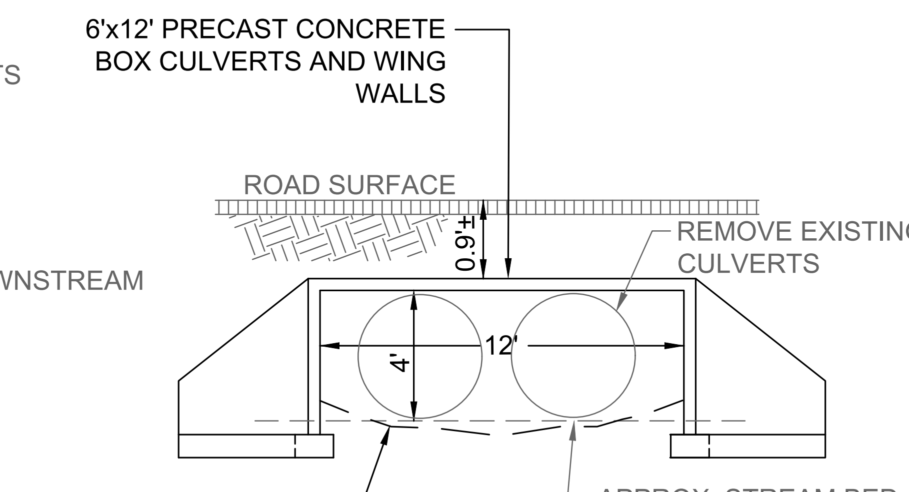
SCALE: 1"= 40' DATE: DEC. 9, 2016

20 0 20 40 80



PROFILE

N.T.S.



TYPICAL END SECTION

N.T.S.

MERIDIAN ASSOCIATES

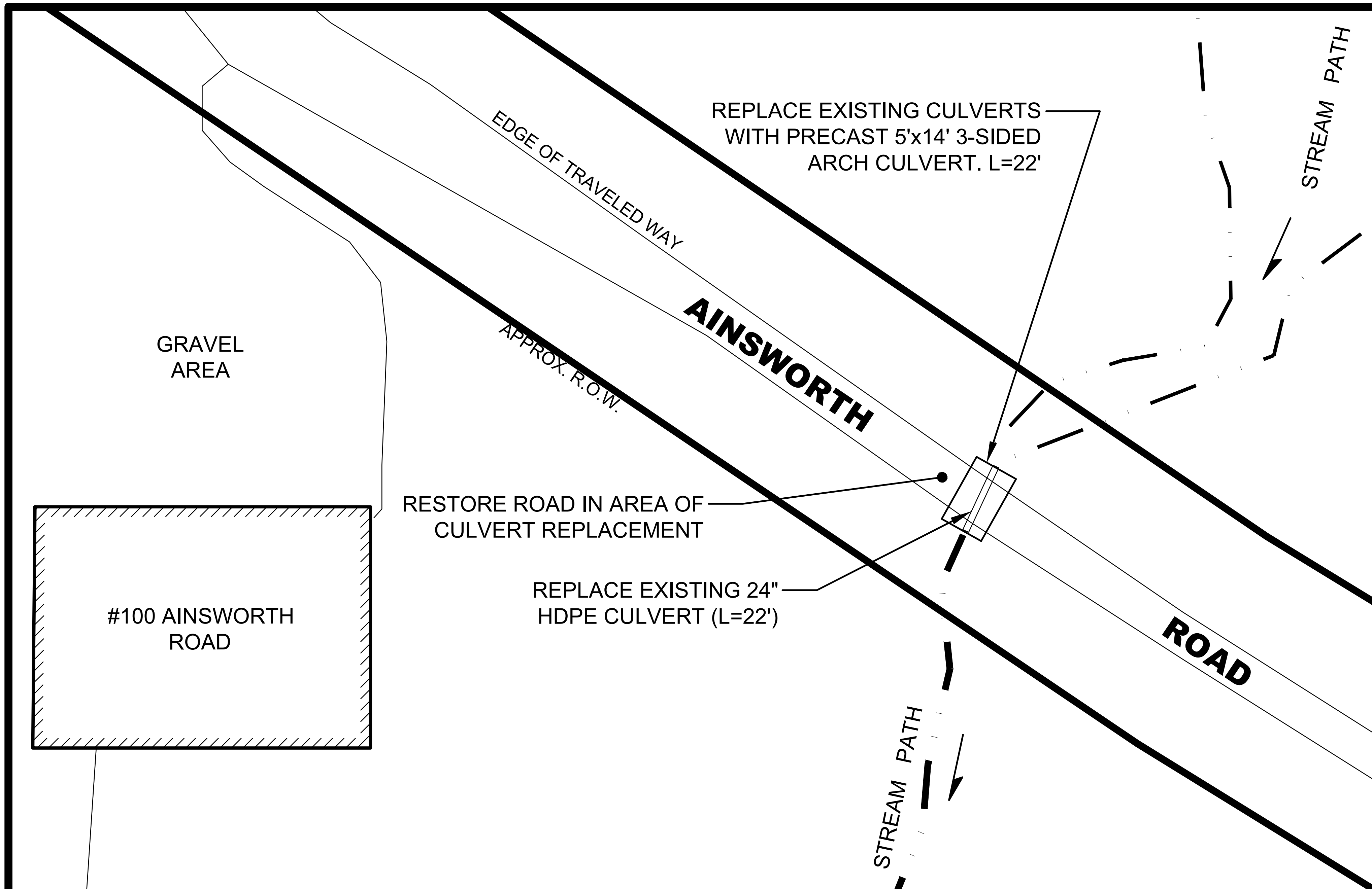
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447

69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030

WWW.MERIDIANASSOC.COM

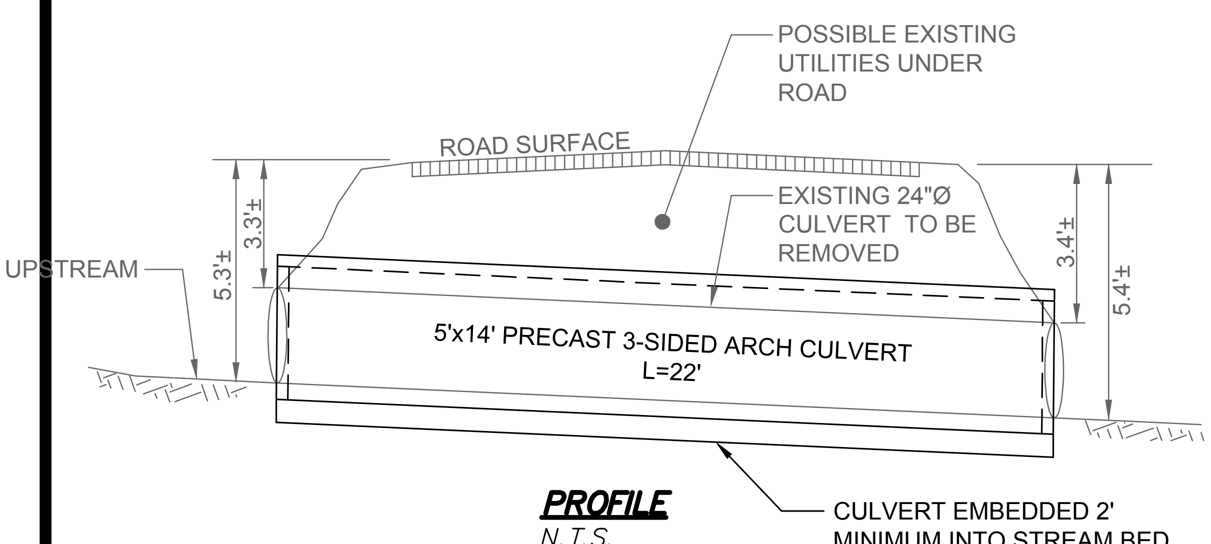
DWG. No. Site 148.dwg

MAI Project: 5900

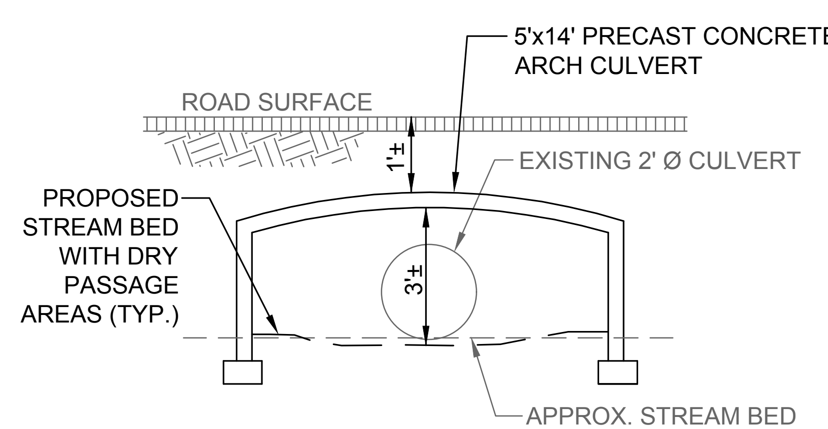


NOTES:

1. THIS SKETCH PLAN IS FOR PRELIMINARY PLANNING PURPOSES ONLY, AND NOT TO BE USED FOR CONSTRUCTION. NO TOPOGRAPHIC SURVEY OR FORMAL HYDRAULIC DESIGN HAS BEEN PERFORMED.
2. THIS SITE HAS BEEN SELECTED BY IRWA BASED ON A HYDRAULIC AND ECOLOGICAL SCREENING ASSESSMENT AS PART OF THE 'GREAT MARSH RESILIENCY PROJECT'. SEE ATTACHED REPORT FOR A DESCRIPTION OF THE SELECTION CRITERIA.
3. THIS CULVERT CONCEPT IS INTENDED TO MEET THE MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS. NO ANALYSIS OF POTENTIAL CHANGES IN HYDROLOGY AND HYDRAULICS HAS BEEN CONDUCTED.
4. EXISTING UTILITIES THAT MAY EXIST IN ROAD NEED TO BE RESEARCHED AS PART OF ANY FORMAL DESIGN PROCESS.
5. IF MINIMAL COVER EXISTS OVER PROPOSED CULVERT, VERTICAL ALIGNMENT OF ROAD IN THIS AREA MAY HAVE TO BE REVISED TO ACCOMMODATE ANY UTILITY CROSSINGS.
6. STREAM BED SUBSTRATE SHALL BE SIMILAR IN SIZE, SHAPE AND MATERIAL TO THE STREAM BED UPSTREAM AND DOWNSTREAM.
7. ANY DOWNSTREAM DEBRIS AND OBSTACLES TO BE REMOVED TO ALLOW FREE FLOW THROUGH CROSSING.
8. APPROXIMATE BANKFULL WIDTH=11.6 FEET. PROPOSED CULVERT WIDTH=14 FEET.
9. MINIMUM REQUIRED OPENNESS RATIO=0.82 PROPOSED OPENNESS RATIO=1.25
10. NAACC CROSSING CODE: xy4258365071152705
11. NAACC SURVEY ID: 10111



PROFILE
N.T.S.



DOWNSTREAM END SECTION
N.T.S.

CROSSING ID# 151
SKETCH PLAN
LOCATED IN
WILMINGTON, MASSACHUSETTS
(ESSEX COUNTY)
PREPARED FOR
IPSWICH RIVER WATERSHED ASSOC.

SCALE: 1"= 40' DATE: DEC. 9, 2016
20 0 20 40 80

MERIDIAN ASSOCIATES
500 CUMMINGS CENTER, SUITE 5950
BEVERLY, MASSACHUSETTS 01915
TELEPHONE: (978) 299-0447
69 MILK STREET, SUITE 302
WESTBOROUGH, MASSACHUSETTS 01581
TELEPHONE: (508) 871-7030
WWW.MERIDIANASSOC.COM

DWG. No. Site 151.dwg
MAI Project: 5900

Appendix 4 – Full Result Tables

Printout of excel table for entire region (4 types) are printed in the pages below. Electronic copies of GIS and excel data sets are available by contacting the Ipswich River Watershed Association (bkelder@ipswichriver.org).

Table of Contents (Appendix 4)

Dams

Dam ID	Priority Ranking: Final Adjusted*	Priority Ranking: Overall	Priority Ranking: Town	Dam Name	Town	Hazard Code	Priority Scoring: Infrastructure Risk (RI)	Priority Scoring: Ecological Impact (EI)	Priority Scoring: Priority Score (DP)	Active Project or Local Priority	Exclude	Exclude Reason
MA00745	-1	1	-1	Putnamville Reservoir Dam	Danvers	High Hazard	2	1	3	No	Yes	Water Supply
MA00726	-1	2	-1	Winona Pond Dam	Peabody	High Hazard	2	0.5	2.5	No	Yes	Water Supply
MA00744	-1	2	-1	Putnamville Reservoir West Dike	Danvers	High Hazard	2	0.5	2.5	No	Yes	Water Supply
MA01297	-1	2	-1	Putnamville Reservoir East Dike	Danvers	High Hazard	2	0.5	2.5	No	Yes	Water Supply
MA01121	-1	6	-1	Mill Pond Dam	Burlington	High Hazard	2	0	2	No	Yes	Water Supply
MA01123	-1	6	-1	Mill Pond South Dike	Burlington	High Hazard	2	0	2	No	Yes	Water Supply
MA00165	-1	8	-1	Dow Brook Reservoir Dam	Ipswich	Significant Hazard	1	1	2	No	Yes	Water Supply
MA00182	-1	8	-1	Longham Reservoir Dam	Wenham	Significant Hazard	1	1	2	No	Yes	Water Supply
MA00273	0	17	-1	Emerson Brook Dam At Lake Street	Middleton	Significant Hazard	1	0.5	1.5	No	Yes	Water Supply
MA01139	0	17	-1	Suntaug Lake Dam	Peabody	Significant Hazard	1	0.5	1.5	No	Yes	Water Supply
MA00230	0	23	-1	Bull Brook Reservoir Dam	Ipswich	Low Hazard	0.5	1	1.5	No	Yes	Water Supply
MA00264	0	23	-1	Lower Artichoke Reservoir Dam	Newburyport	Low Hazard	0.5	1	1.5	No	Yes	Water Supply
MA00295	0	23	-1	Middleton Pond Outlet Dam	Middleton	Low Hazard	0.5	1	1.5	No	Yes	Water Supply
MA01600	0	23	-1	Artichoke River Dam	Newburyport	Low Hazard	0.5	1	1.5	No	Yes	Water Supply
MA01122	0	35	-1	Mill Pond Reservoir North Dike	Burlington	Significant Hazard	1	0	1	No	Yes	Water Supply
MA02277	0	42	-1	Middleton Pond Southeast Dike	Middleton	Low Hazard	0.5	0.5	1	No	Yes	Water Supply
MA00189	0	47	-1	Upper Artichoke Reservoir Dam	Newburyport	Low Hazard	0.5	0.5	1	No	Yes	Water Supply
MA01137	1	5	1	Ipswich River Dam (South Middleton)	Middleton	Significant Hazard	1	1.5	2.5	Active	No	
MA00159	2	8	1	Howe Pond Dam	Boxford	Significant Hazard	1	1	2		No	

Dam ID	Priority Ranking: Final Adjusted*	Priority Ranking: Overall	Priority Ranking: Town	Dam Name	Town	Hazard Code	Priority Scoring: Infrastructure Risk (RI)	Priority Scoring: Ecological Impact (EI)	Priority Scoring: Priority Score (DP)	Active Project or Local Priority	Exclude	Exclude Reason
MA00261	2	8	1	Pentucket Pond Outlet Dam	Georgetown	Significant Hazard	1	1	2		No	
MA01604	2	8	1	Jewel Mill Dam	Rowley	Significant Hazard	1	1	2	Priority	No	
MA00231	5	13	1	Ipswich Mills Dam	Ipswich	Low Hazard	0.5	1.5	2	Active	No	
MA00241	5	13	1	Parker River Dam #1 (Central Street)	Newbury	Low Hazard	0.5	1.5	2		No	
MA01198	5	13	2	Baldpate Pond Dam	Boxford	Low Hazard	0.5	1.5	2		No	
MA01610	8	16	1	Howletts Brook Dam	Topsfield	N/A	0	2	2	Priority	No	
MA00158	9	17	3	Stiles Pond Outlet Dam	Boxford	Significant Hazard	1	0.5	1.5		No	
MA01613	9	17	2	Bethune Pond Dam	Topsfield	Significant Hazard	1	0.5	1.5		No	
MA03006	9	17	1	Mill Pond Dam	Middleton	Significant Hazard	1	0.5	1.5		No	
MA00160	12	22	4	Lowe Pond Outlet Dam	Boxford	Low Hazard	0.5	1	1.5		No	
MA00277	12	22	3	Mile Brook Dam	Topsfield	Low Hazard	0.5	1	1.5		No	
MA01143	12	22	1	Stearns Pond Dam	North Andover	Low Hazard	0.5	1	1.5		No	
MA01202	12	22	4	Towne Pond Dam	Boxford	Low Hazard	0.5	1	1.5		No	
MA01207	12	22	2	Rantoul Pond Dam	Ipswich	Low Hazard	0.5	1	1.5		No	
MA01211	12	22	2	Mill Pond Dam	Newbury	Low Hazard	0.5	1	1.5		No	
MA01599	12	22	1	Fred Maudslay Dam	Newburyport	Low Hazard	0.5	1	1.5		No	
MA03008	12	22	2	Blackwell Dam	Newbury	Low Hazard	0.5	1	1.5		No	
MA00276	20	34	3	Willowdale Dam	Ipswich	N/A	0	1.5	1.5	Active	No	
MA01133	21	35	1	Brackett Pond Dam	Andover	Significant Hazard	1	0	1		No	
MA01134	21	35	1	Field Pond Dam	Andover	Significant Hazard	1	0	1		No	
MA01141	21	35	1	Elginwood Pond Dam	Peabody	Significant Hazard	1	0	1		No	
MA03181	21	35	1	Collins Pond Dam	Andover	Significant Hazard	1	0	1		No	

Dam ID	Priority Ranking			Dam Name	Town	Hazard Code	Priority Scoring			Active Project or Local Priority	Exclude	Exclude Reason
	Final Adjusted*	Overall	Town				Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)			
MA03217	21	35	1	Field Pond Dike	Andover	Significant Hazard	1	0	1		No	
MA00243	26	41	2	Lower Millpond Dam	Rowley	Low Hazard	0.5	0.5	1		No	
MA01205	26	41	2	Creighton Pond Dam	Middleton	Low Hazard	0.5	0.5	1		No	
MA01206	26	41	2	Farnums Mill Pond Dam	North Andover	Low Hazard	0.5	0.5	1		No	
MA01605	26	41	2	Central Street Dam	Rowley	Low Hazard	0.5	0.5	1		No	
MA00242	30	47	4	Parker River Dam #4 (Blacksmith Shop)	Newbury	N/A	0	1	1		No	
MA01525	30	47	6	Lockwood Dam 1	Boxford	N/A	0	1	1		No	
MA01590	30	47	3	Prichard Pond Dam	Middleton	N/A	0	1	1		No	
MA01596	30	47	4	Parker River Dam #3 (Snuff Mill)	Newbury	N/A	0	1	1		No	
MA01598	30	47	4	Parker River Dam #5 (River Street)	Newbury	N/A	0	1	1		No	
MA01603	30	47	4	Ox Pasture Brook Dam	Rowley	N/A	0	1	1		No	
MA01611	30	47	4	Pleasure Pond Dam	Topsfield	N/A	0	1	1		No	
MA01612	30	47	4	Peirce Pond Dam	Topsfield	N/A	0	1	1		No	
MA02989	30	47	4	Argilla Farm Pond Dam	Ipswich	N/A	0	1	1		No	
MA03009	30	47	4	Highfield Road Dam	Newbury	N/A	0	1	1		No	
MA01201	40	57	7	Fourmile Pond Dam	Boxford	Low Hazard	0.5	0	0.5		No	
MA02504	40	57	1	Bradford Pond Dam	North Reading	Low Hazard	0.5	0	0.5		No	
MA02512	40	57	5	Deleano Pond Dam	Andover	Low Hazard	0.5	0	0.5		No	
MA02514	40	57	3	Salem Pond Dam	North Andover	Low Hazard	0.5	0	0.5		No	
MA02517	40	57	5	Frye Pond Dam	Andover	Low Hazard	0.5	0	0.5		No	
MA00240	45	62	4	Parker River Dam #2 (Larkin Road)	Newbury	N/A	0	0.5	0.5	Priority	No	
MA01199	45	62	8	Lockwood Dam 3	Boxford	N/A	0	0.5	0.5		No	
MA01592	45	62	4	Boston Brook Dam	North Andover	N/A	0	0.5	0.5		No	
MA01597	45	62	9	Parker River Dam South At River St.	Newbury	N/A	0	0.5	0.5		No	
MA01602	45	62	5	Country Club Pond Dam	Rowley	N/A	0	0.5	0.5		No	

Dam ID	Priority Ranking			Dam Name	Town	Hazard Code	Priority Scoring			Active Project or Local Priority	Exclude	Exclude Reason
	Final Adjusted*	Overall	Town				Infrastructure Risk (RI)	Ecological Impact (EI)	Priority Score (DP)			
MA02509	45	62	6	Ipswich Pond Dam	Topsfield	N/A	0	0.5	0.5		No	
MA03227	45	62	8	Spofford Pond Outlet Dam	Boxford	N/A	0	0.5	0.5		No	
MA00181	45	62	1	Norwood Pond Dam	Beverly	N/A	0	0.5	0.5		No	
MA03229	45	62	8	Fish Brook Dam	Boxford	N/A	0	0.5	0.5		No	
MA00244	54	71	6	Upper Millpond Dam	Rowley	N/A	0	0	0		No	
MA01138	54	71	2	Devils Dishfull Pond Dam	Peabody	N/A	0	0	0		No	
MA01594	54	71	5	Farm Pond - On Skug River D #10	North Andover	N/A	0	0	0		No	
MA02497	54	71	7	Skug River Dam	Andover	N/A	0	0	0		No	
MA02510	54	71	7	Farm Trail Pond	Topsfield	N/A	0	0	0		No	
MA02511	54	71	7	Otter Pond Dam	Topsfield	N/A	0	0	0		No	
MA02515	54	71	5	Sudden Pond Dam	North Andover	N/A	0	0	0		No	
MA03007	54	71	5	Farr Pond Dam	North Andover	N/A	0	0	0		No	
MA03203	54	71	4	Coppermine Road Dam	Middleton	N/A	0	0	0		No	
MA03204	54	71	4	Paradise Park Dam	Middleton	N/A	0	0	0		No	
MA03218	54	71	2	Elginwood Pond Dam #2	Peabody	N/A	0	0	0		No	
MA03221	54	71	2	Puritan Lawn Pond Dam	Peabody	N/A	0	0	0		No	
MA03248	54	71	1	Pocahontas- Greenbelt Dam	Lynnfield	N/A	0	0	0		No	
MA03338	54	71	7	Bradley Palmer Entrance Dam	Topsfield	N/A	0	0	0		No	

Non-Tidal Crossings

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
188	1	1	Wenham	Single Culvert	Dodge Row	5.0	4.9	9.9	Yes
9011	2	1	Topsfield	Single Culvert	Meetinghouse Lane	5.0	4.3	9.3	Yes
472	3	1	North Andover	Single Culvert	Liberty Street	4.6	4.4	9.0	Yes
670	4	2	Topsfield	Single Culvert	Pond Street	5.0	3.9	8.9	Yes
1054	5	1	Newbury	Single Culvert	Coleman Road	5.0	3.9	8.9	Yes
151	6	1	Wilmington	Single Culvert	Ainsworth Road	5.0	3.7	8.7	Yes
879	7	1	Boxford	Single Culvert	Washington Street	5.0	3.7	8.7	
421	8	1	Andover	Single Culvert	Gray Road	4.0	4.6	8.6	Yes
408	9	2	Andover	Single Culvert	Salem Street	4.0	4.6	8.6	Yes
862	10	1	Georgetown	Single Culvert	Nelson Street	5.0	3.5	8.5	Yes
435	11	3	Topsfield	Single Culvert	River Rd	4.6	3.7	8.3	Yes
84	12	1	North Reading	Single Culvert	Off of Concord Street	5.0	3.3	8.3	
859	13	2	Boxford	Multiple Culvert	Main Street	5.0	3.3	8.3	Yes
990	14	1	Rowley	Single Culvert	Main Street	3.6	4.7	8.3	Yes
517	15	1	Hamilton	Single Culvert	Winthrop Sreet	3.6	4.4	8.0	Yes
753	16	1	Ipswich	Single Culvert	Pine Swamp Road	5.0	2.9	7.9	Yes
681	17	3	Boxford	Single Culvert	Main Street	3.0	4.8	7.8	Yes
755	18	4	Boxford	Single Culvert	Kelsey Road	5.0	2.7	7.7	Yes
439	19	1	Essex	Single Culvert	Story Street	4.0	3.7	7.7	Yes
413	20	2	Hamilton	Single Culvert	Moulton Street	5.0	2.7	7.7	
1162	21	2	Newbury	Single Culvert	Off Middle Road	4.6	3.0	7.6	
1094	22	3	Newbury	Single Culvert	Orchard Street	2.6	5.0	7.6	Yes
765	23	5	Boxford	Single Culvert	Off Styles pond road	2.6	5.0	7.6	
898	24	2	Rowley	Single Culvert	Daniels Rd	5.0	2.5	7.5	Yes
860	25	2	Georgetown	Single Culvert	Central Street	5.0	2.5	7.5	
639	26	2	Ipswich	Single Culvert	Essex Road	5.0	2.4	7.4	
587	27	2	North Andover	Single Culvert	Carlton Lane	3.6	3.6	7.2	Yes
462	28	4	Topsfield	Single Culvert	Summer Street	5.0	2.1	7.1	
878	29	3	Rowley	Single Culvert	Haverhill Street	5.0	2.1	7.1	Yes
1231	30	1	Newburyport	Multiple Culvert	Pheasant Run Drive	5.0	2.1	7.1	
788	31	4	Rowley	Single Culvert	Boxford Road	5.0	2.1	7.1	
9017	32	4	Newbury	Single Culvert	Off_Middle Road	5.0	2.0	7.0	
1155	33	1	West Newbury	Multiple Culvert	Georgetown Road	5.0	2.0	7.0	Yes
292	34	3	Hamilton	Single Culvert	Alan Road	5.0	2.0	7.0	
484	35	6	Boxford	Single Culvert	Middleton Road	4.0	3.0	7.0	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
9006	36	7	Boxford	Single Culvert	Georgetown Road	5.0	2.0	7.0	
874	37	3	Georgetown	Single Culvert	East Street	5.0	2.0	7.0	
633	38	5	Topsfield	Single Culvert	North Street	5.0	2.0	7.0	
341	39	3	North Andover	Single Culvert	Harold Parker Road	5.0	1.9	6.9	
1049	40	5	Newbury	Single Culvert	Off Coleman Road	4.0	2.9	6.9	Yes
758	41	5	Rowley	Single Culvert	Newbury Road	5.0	1.9	6.9	
86	42	2	North Reading	Single Culvert	Concord Street	5.0	1.9	6.9	
697	43	3	Ipswich	Single Culvert	Pine Swamp road	5.0	1.8	6.8	Yes
748	44	4	Ipswich	Single Culvert	Pineswamp Road	4.0	2.8	6.8	
744	45	5	Ipswich	Single Culvert	Newbury Road	5.0	1.8	6.8	
1187	46	6	Newbury	Multiple Culvert	Highfield Road	5.0	1.8	6.8	Yes
1101	47	1	Groveland	Single Culvert	Seven Star Road	5.0	1.8	6.8	
308	48	2	Essex	Single Culvert	Andrews Street	5.0	1.8	6.8	
682	49	6	Ipswich	Single Culvert	Boxford Road	5.0	1.8	6.8	
153	50	1	Beverly	Multiple Culvert	Landers Drive	5.0	1.8	6.8	
1158	51	2	West Newbury	Single Culvert	Hilltop Circle	5.0	1.7	6.7	
906	52	8	Boxford	Single Culvert	Main Street	4.6	2.1	6.7	
629	53	6	Topsfield	Single Culvert	Wildes Road	5.0	1.7	6.7	
1091	54	2	Groveland	Single Culvert	Bear hill road	4.0	2.7	6.7	No
60	55	1	Reading	Single Culvert	Haverhill	4.6	2.1	6.7	
415	56	3	Andover	Single Culvert	Korinthian Way	5.0	1.7	6.7	Yes
916	57	9	Boxford	Single Culvert	Willow Road	5.0	1.7	6.7	
100	58	1	Middleton	Single Culvert	River Street	5.0	1.7	6.7	
754	59	4	North Andover	Single Culvert	Saw Mill Road	5.0	1.7	6.7	
494	60	10	Boxford	Single Culvert	Lockwood Lane	5.0	1.7	6.7	Yes
638	61	11	Boxford	Single Culvert	Lawrence Road	5.0	1.7	6.7	Yes
319	62	4	Hamilton	Single Culvert	bridge street	4.0	2.7	6.7	Yes
868	63	6	Rowley	Single Culvert	Dodge Road	5.0	1.7	6.7	
902	64	4	Georgetown	Single Culvert	Spofford Street	4.6	2.0	6.6	Yes
272	65	4	Andover	Single Culvert	Jenkins Road	5.0	1.6	6.6	
396	66	5	Hamilton	Multiple Culvert	Morris Avenue	5.0	1.6	6.6	
636	67	5	North Andover	Single Culvert	Candlestick Rd	4.6	2.0	6.6	
896	68	7	Rowley	Single Culvert	Haverhill Street	5.0	1.6	6.6	
910	69	12	Boxford	Single Culvert	Willow Road	3.6	3.0	6.6	Yes
626	70	7	Topsfield	Single Culvert	Wildes Road	5.0	1.6	6.6	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
449	71	3	Essex	Single Culvert	Lufkin Road	5.0	1.6	6.6	Yes
240	72	2	Wenham	Single Culvert	Larch Row	5.0	1.6	6.6	
6107	73	2	Wilmington	Single Culvert	Glen Road	5.0	1.6	6.6	
1125	74	7	Newbury	Multiple Culvert	Main Street	4.0	2.6	6.6	Yes
355	75	4	Essex	Single Culvert	icehouse Ln	5.0	1.6	6.6	
784	76	13	Boxford	Culvert	Herrick Road	5.0	1.6	6.6	
7052	77	5	Georgetown	Multiple Culvert	Church Street	5.0	1.5	6.5	
176	78	2	Beverly	Culvert	Grover Road	5.0	1.5	6.5	
214	79	3	Wenham	Culvert	Dodges Row	5.0	1.5	6.5	
850	80	8	Rowley	Single Culvert	Kathleen Circle	4.0	2.5	6.5	Yes
115	81	2	Middleton	Single Culvert	Boston Street	5.0	1.5	6.5	
335	82	6	Hamilton	Single Culvert	Bay Road	4.0	2.5	6.5	
163	83	4	Wenham	Single Culvert	Hull Street	5.0	1.5	6.5	
648	84	6	North Andover	Single Culvert	Johnson Street	4.6	1.9	6.5	Yes
485	85	5	Andover	Single Culvert	Prospect Road	5.0	1.5	6.5	
622	86	14	Boxford	Single Culvert	Main Street	5.0	1.4	6.4	
866	87	9	Rowley	Single Culvert	Haverhill St	5.0	1.4	6.4	Yes
1030	88	6	Georgetown	Multiple Culvert	Brookmeadow Lane	4.6	1.8	6.4	No
867	89	10	Rowley	Multiple Culvert	Haverhill	5.0	1.4	6.4	
591	90	7	Ipswich	Single Culvert	Heatherside Lane	5.0	1.4	6.4	
9008	91	11	Rowley	Single Culvert	Haverhill Street	5.0	1.4	6.4	
470	92	8	Topsfield	Single Culvert	Lockwood Lane	5.0	1.4	6.4	
9005	93	8	Ipswich	Single Culvert	Linebrook Road	5.0	1.4	6.4	
926	94	12	Rowley	Open Bottom Arch	Independence St	4.6	1.8	6.4	
46	95	1	Billerica	Single Culvert	Cook Street	5.0	1.4	6.4	
838	96	7	Georgetown	Open Bottom Arch	Georgetown Road	5.0	1.4	6.4	Yes
526	97	15	Boxford	Single Culvert	Surrey Lane	5.0	1.3	6.3	
618	98	7	North Andover	Single Culvert	Route 114/ Turnpike Street	4.6	1.7	6.3	
1189	99	8	Newbury	Single Culvert	Green Street	5.0	1.3	6.3	
982	100	13	Rowley	Single Culvert	Cross St	5.0	1.3	6.3	
466	101	7	Hamilton	Single Culvert	Highland Street	5.0	1.3	6.3	
6961	102	16	Boxford	Single Culvert	Great Pond Drive	5.0	1.3	6.3	
1203	103	9	Newbury	Multiple Culvert	Parker Street	5.0	1.3	6.3	
338	104	6	Andover	Single Culvert	Jenkins Road	4.6	1.7	6.3	
1124	105	3	West Newbury	Single Culvert	Crane Neck Street	5.0	1.3	6.3	

IRWA Crossing ID	Priority Rank Region	Priority Rank Town	Town	Structure Type	Road	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Priority Score (CP)	Design
1056	106	10	Newbury	Single Culvert	School Street	5.0	1.3	6.3	Yes
912	107	8	Georgetown	Multiple Culvert	Brook Street	5.0	1.3	6.3	
857	108	14	Rowley	Single Culvert	Haverhill St	5.0	1.3	6.3	
498	109	17	Boxford	Single Culvert	Silverbrook Road	4.0	2.2	6.2	Yes
85	110	3	North Reading	Single Culvert	Off of Concord Street	4.6	1.6	6.2	
903	111	9	Georgetown	Single Culvert	Hardy Terrace	4.6	1.6	6.2	
218	112	4	North Reading	Single Culvert	Central Street	5.0	1.2	6.2	
829	113	18	Boxford	Single Culvert	Baldpate Road	5.0	1.2	6.2	Yes
827	114	9	Ipswich	Multiple Culvert	Mitchell Road	5.0	1.2	6.2	
1153	115	4	West Newbury	Multiple Culvert	Crane Neck Street	4.0	2.2	6.2	Yes
56	116	1	Peabody	Single Culvert	Lowell Street	5.0	1.2	6.2	
405	117	7	Andover	Single Culvert	Ivy Lane	4.0	2.2	6.2	
109	118	3	Middleton	Single Culvert	River Street	4.6	1.6	6.2	
552	119	9	Topsfield	Bridge	Thompson Lane	4.6	1.5	6.1	
278	120	4	Middleton	Culvert	Coppermine Road	5.0	1.1	6.1	
474	121	10	Topsfield	Single Culvert	High Street	5.0	1.1	6.1	
99	122	5	North Reading	Single Culvert	Park Street	5.0	1.1	6.1	
691	123	10	Ipswich	Bridge	County Rd	5.0	1.1	6.1	
1075	124	10	Georgetown	Multiple Culvert	Charles Street	5.0	1.1	6.1	
229	125	5	Wenham	Single Culvert	Lake Avenue	5.0	1.1	6.1	
557	126	11	Ipswich	Single Culvert	off of Waldingfield Road	5.0	1.1	6.1	
807	127	15	Rowley	Bridge	Turnpike Road	5.0	1.1	6.1	
925	128	16	Rowley	Single Culvert	Bradford Street	5.0	1.1	6.1	
161	129	6	Wenham	Culvert	Hull Street	4.0	2.1	6.1	Yes
243	130	7	Wenham	Single Culvert	Danes Way	4.6	1.5	6.1	
791	131	8	North Andover	Single Culvert	Winter Street	5.0	1.0	6.0	
333	132	8	Hamilton	Single Culvert	Highland Street	5.0	1.0	6.0	
1164	133	11	Newbury	Multiple Culvert	Middle Road	5.0	1.0	6.0	Yes
453	134	9	North Andover	Single Culvert	Turnpike Street	5.0	1.0	6.0	
759	135	12	Ipswich	Open Bottom Arch	Linebrook Road	5.0	1.0	6.0	
9009	136	19	Boxford	Single Culvert	Off_Pinehurst Drive	5.0	1.0	6.0	
1171	137	5	West Newbury	Multiple Culvert	Georgetown Road	5.0	0.9	5.9	
885	138	11	Georgetown	Single Culvert	East Main Street	5.0	0.9	5.9	
881	139	17	Rowley	Single Culvert	Newburyport Turnpike	4.0	1.9	5.9	
820	140	20	Boxford	Single Culvert	Off Ipswich Road	5.0	0.9	5.9	

IRWA Crossing ID	Priority Rank Region	Priority Rank Town	Town	Structure Type	Road	Priority Scoring Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	Design
564	141	11	Topsfield	Single Culvert	Bare Hill Road	4.0	1.9	5.9	
181	142	3	Beverly	Single Culvert	DODGE STREET	4.6	1.3	5.9	
1026	143	12	Georgetown	Multiple Culvert	Jewett Street	5.0	0.8	5.8	
534	144	10	North Andover	Multiple Culvert	Rt 114/Turnpike Street	2.2	3.6	5.8	
1020	145	18	Rowley	Single Culvert	Newburyport Turnpike	5.0	0.8	5.8	
705	146	13	Ipswich	Single Culvert	Hodgkins	4.6	1.2	5.8	
273	147	5	Middleton	Single Culvert	Forest Street	4.6	1.2	5.8	Yes
706	148	14	Ipswich	Bridge	Hayward Street	4.6	1.2	5.8	
786	149	21	Boxford	Single Culvert	King George Drive	3.6	2.2	5.8	
795	150	22	Boxford	Single Culvert	Ipswich Road	5.0	0.8	5.8	
1234	151	2	Newburyport	Single Culvert	Storeybrook Drive	2.6	3.1	5.7	
35	152	3	Wilmington	Single Culvert	Forest Street	4.6	1.1	5.7	
274	153	6	Middleton	Single Culvert	Forest Street	3.6	2.1	5.7	Yes
1218	154	3	Newburyport	Multiple Culvert	Hale Street	4.0	1.7	5.7	Yes
876	155	13	Georgetown	Multiple Culvert	Nelson Street	3.6	2.1	5.7	
1228	156	4	Newburyport	Bridge	Doe Run Drive	5.0	0.7	5.7	
1080	157	14	Georgetown	Bridge	Off_Dereck Circle	5.0	0.7	5.7	
232	158	6	North Reading	Single Culvert	Hillview Road	5.0	0.7	5.7	
16	159	4	Wilmington	Single Culvert	Beech Street	5.0	0.7	5.7	Yes
9043	160	8	Wenham	Bridge	Topsfield Nature Trail	4.6	1.1	5.7	
279	161	9	Wenham	Bridge	Danvers Rail Trail	5.0	0.6	5.6	
632	162	11	North Andover	Single Culvert	Chestnut Street	4.0	1.6	5.6	Yes
769	163	15	Ipswich	Single Culvert	Linebrook Road	4.0	1.6	5.6	
9040	164	23	Boxford	Bridge	Off Willow Road	4.6	1.0	5.6	
907	165	15	Georgetown	Single Culvert	Andover Street	4.0	1.6	5.6	
246	166	10	Wenham	Single Culvert	Rubbly Road	4.0	1.6	5.6	
1186	167	12	Newbury	Single Culvert	Newburyport turnpike	5.0	0.6	5.6	
843	168	24	Boxford	Single Culvert	Porter Road	0.6	5.0	5.6	Yes
483	169	9	Hamilton	Open Bottom Arch	Bay Road	5.0	0.6	5.6	
722	170	12	North Andover	Multiple Culvert	South Bradford Street	3.6	2.0	5.6	
613	171	13	North Andover	Single Culvert	Willow Road	3.0	2.6	5.6	Yes
800	172	16	Ipswich	Single Culvert	High Street	4.6	0.9	5.5	
923	173	19	Rowley	Single Culvert	Summer Street	4.0	1.5	5.5	
468	174	12	Topsfield	Single Culvert	School Street	5.0	0.5	5.5	
821	175	25	Boxford	Single Culvert	Ipswich Road	4.6	0.9	5.5	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
935	176	20	Rowley	Single Culvert	Newburyport Turnpike	4.0	1.5	5.5	
148	177	5	Wilmington	Multiple Culvert	Woburn Street	2.2	3.2	5.4	Yes
628	178	13	Topsfield	Single Culvert	East St	4.0	1.4	5.4	
1225	179	5	Newburyport	Multiple Culvert	Hale Street	4.0	1.4	5.4	Yes
282	180	1	Danvers	Single Culvert	Valley Road	4.0	1.4	5.4	
481	181	14	Topsfield	Single Culvert	Washington Street	4.0	1.4	5.4	
9033	182	26	Boxford	Single Culvert	High Ridge Road	4.0	1.4	5.4	
661	183	15	Topsfield	Single Culvert	Off_Haverhill Street	3.6	1.8	5.4	No
519	184	14	North Andover	Multiple Culvert	Brook Strete	4.0	1.3	5.3	Yes
761	185	17	Ipswich	Single Culvert	Linebrook Rd	4.0	1.3	5.3	
680	186	18	Ipswich	Single Culvert	NEWBURYPORT TURNPIKE	4.0	1.3	5.3	
9016	187	13	Newbury	Bridge	Off Middle Road	4.0	1.3	5.3	
147	188	6	Wilmington	Open Bottom Arch	Ainsworth Road	4.0	1.3	5.3	
239	189	7	North Reading	Single Culvert	Central Street	4.6	0.6	5.2	
523	190	27	Boxford	Single Culvert	Silver Brook Road	2.0	3.2	5.2	Yes
329	191	7	Middleton	Bridge	Peabody Street	5.0	0.2	5.2	
198	192	8	North Reading	Single Culvert	Wagon Drive	4.0	1.2	5.2	
149	193	4	Beverly	Open Bottom Arch	Essex Street	4.0	1.2	5.2	
1238	194	6	Newburyport	Single Culvert	Virginia Lane	2.6	2.6	5.2	
614	195	16	Topsfield	Culvert	Route 1	4.0	1.2	5.2	Yes
561	196	17	Topsfield	Single Culvert	Parsonage Lane	4.0	1.1	5.1	
394	197	18	Topsfield	Single Culvert	river road	3.6	1.5	5.1	
766	198	19	Ipswich	Single Culvert	Linebrook Road	4.0	1.1	5.1	
701	199	20	Ipswich	Bridge	Topsfield Road	4.6	0.4	5.0	
543	200	19	Topsfield	Multiple Culvert	North Street	0.0	5.0	5.0	
166	201	8	Middleton	Single Culvert	Middleton Street	3.6	1.3	4.9	
678	202	15	North Andover	Single Culvert	Keyes Way	3.6	1.3	4.9	
516	203	28	Boxford	Single Culvert	Silverbrook Road		4.9	4.9	Yes
579	204	29	Boxford	Single Culvert	Topsfield Road	4.0	0.9	4.9	
1076	205	14	Newbury	Multiple Culvert	Fatherland Drive	4.0	0.9	4.9	
275	206	2	Danvers	Multiple Culvert	Locust Street	2.6	2.2	4.8	
9003	207	9	Middleton	Bridge	Off_N Liberty Street	4.6	0.2	4.8	
482	208	30	Boxford	Single Culvert	Lockwood Lane	3.0	1.8	4.8	
136	209	5	Beverly	Single Culvert	Beaver Pond Road	4.0	0.8	4.8	
420	210	20	Topsfield	Multiple Culvert	Maple Street	3.6	1.2	4.8	Yes

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
655	211	21	Ipswich	Single Culvert	Linebrook Road	3.0	1.8	4.8	
235	212	11	Wenham	Multiple Culvert	Maple Street	3.6	1.2	4.8	
644	213	16	North Andover	Single Culvert	Woodlea Road	3.6	1.1	4.7	
382	214	5	Essex	Bridge	Grove Street	4.0	0.7	4.7	
7	215	7	Wilmington	Single Culvert	Chestnut Street	0.0	4.6	4.6	Yes
289	216	10	Middleton	Multiple Culvert	Liberty Street	3.2	1.4	4.6	
9050	217	11	Middleton	Single Culvert	Driveway off Boston Street	3.6	1.0	4.6	
257	218	12	Wenham	Single Culvert	Larch Row	2.6	2.0	4.6	
230	219	13	Wenham	Multiple Culvert	Burley	2.6	1.8	4.4	
530	220	17	North Andover	Single Culvert	Johnson Street	3.6	0.8	4.4	
1108	221	15	Newbury	Open Bottom Arch	River Road	3.6	0.8	4.4	
6896	222	18	North Andover	Multiple Culvert	Cortland Drive	0.0	4.4	4.4	
968	223	21	Rowley	Bridge	Cross St	4.0	0.3	4.3	
403	224	31	Boxford	Single Culvert	Middleton Road	3.0	1.3	4.3	
890	225	22	Rowley	Single Culvert	HaverhillSt	2.6	1.7	4.3	
669	226	19	North Andover	Multiple Culvert	Blueberry Hill Lane	3.2	1.1	4.3	
656	227	20	North Andover	Single Culvert	Rea Street	3.0	1.3	4.3	
570	228	21	Topsfield	Bridge	Haverill Road	3.6	0.7	4.3	Yes
339	229	6	Essex	Single Culvert	Apple Street	2.6	1.7	4.3	
261	230	8	Andover	Single Culvert	Route 125/Andover Bypass	2.6	1.6	4.2	
326	231	21	North Andover	Single Culvert	stearns pond rd		4.2	4.2	
68	232	8	Wilmington	Single Culvert	Adams Street	4.0	0.2	4.2	Yes
487	233	22	Topsfield	Single Culvert	Boxford Road	2.6	1.6	4.2	Yes
870	234	16	Georgetown	Ford	Pingree Farm Road	3.6	0.5	4.1	
11	235	2	Peabody	Multiple Culvert	Lake Street	0.0	4.1	4.1	
6995	236	32	Boxford	Culvert	Brook Road	0.0	4.1	4.1	
10111	237	1	Salisbury	Culvert	Route 110	-1.0	4.1	4.1	Yes
550	238	23	Topsfield	Single Culvert	North St	0.6	3.4	4.0	Yes
505	239	7	Essex	Bridge	John Wise Avenue	2.6	1.3	3.9	
344	240	8	Essex	Single Culvert	Southern Avenue		3.9	3.9	
10109	241	2	Salisbury	Culvert	Elmwood Street	0.0	3.9	3.9	Yes
1173	242	6	West Newbury	Bridge	Tewksbury Lane	3.0	0.8	3.8	
675	243	22	North Andover	Single Culvert	Blue Ridge Road	0.0	3.7	3.7	Yes
938	244	23	Rowley	Single Culvert	Church St	1.6	1.9	3.5	
209	245	3	Danvers	Single Culvert	Ferncroft Road	2.2	1.3	3.5	

IRWA Crossing ID	Priority Rank Region	Priority Rank Town	Town	Structure Type	Road	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Priority Score (CP)	Design
1240	246	7	Newburyport	Single Culvert	Lt Leary Drive	1.6	1.9	3.5	
1003	247	17	Georgetown	Single Culvert	Jewett Street	0.0	3.5	3.5	Yes
616	248	22	Ipswich	Single Culvert	Topsfield Road	0.0	3.4	3.4	Yes
426	249	9	Essex	Single Culvert	Martin Street	2.6	0.8	3.4	
10112	250	3	Salisbury	Culvert	unnamed	-1.0	3.4	3.4	Yes
10116	251	4	Salisbury	Multiple Culvert	Forest Road	2.2	1.1	3.3	
402	252	10	Hamilton	Single Culvert	Moulton Street	1.0	2.3	3.3	
48	253	3	Peabody	Bridge	Crystal Drive	1.6	1.6	3.2	
814	254	33	Boxford	Single Culvert	Baldpate Road	0.0	3.2	3.2	Yes
1053	255	16	Newbury	Single Culvert	Elm Street	0.0	3.1	3.1	Yes
776	256	23	Ipswich	Single Culvert	School Street	1.6	1.5	3.1	
548	257	23	North Andover	Single Culvert	Rt 114/Turnpike Street		3.0	3.0	
414	258	9	Andover	Multiple Culvert	Holt Road	0.6	2.4	3.0	
63	259	9	Wilmington	Multiple Culvert	Clark Street	0.0	2.9	2.9	Yes
1017	260	18	Georgetown	Single Culvert	North Street	0.0	2.9	2.9	No
139	261	9	North Reading	Single Culvert	Lowell Rd (Rt 62) & Main St (Rt 28)	1.6	1.2	2.8	
9048	262	4	Danvers	Bridge	Off_Ferncroft Road	2.6	0.2	2.8	
668	263	24	North Andover	Single Culvert	Abbott St		2.8	2.8	Yes
917	264	19	Georgetown	Single Culvert	Rail Bed off BROOK STREET		2.7	2.7	
349	265	12	Middleton	Bridge	East Street	1.8	0.9	2.7	
285	266	11	Hamilton	Multiple Culvert	Woodbury Rd	0.6	2.1	2.7	
527	267	12	Hamilton	Single Culvert	Highland Street	0.0	2.7	2.7	Yes
236	268	5	Danvers	Single Culvert	Old North Street	1.2	1.4	2.6	
51	269	4	Peabody	Multiple Culvert	Cobb Ave	0.0	2.6	2.6	
577	270	34	Boxford	Single Culvert	Cahoon Road	1.6	1.0	2.6	
676	271	25	North Andover	Open Bottom Arch	Nutmeg Lane	2.6	0.0	2.6	
380	272	13	Middleton	Single Culvert	Essex Street		2.6	2.6	Yes
411	273	26	North Andover	Single Culvert	Sharpners Pond Road	0.0	2.6	2.6	Yes
1069	274	17	Newbury	Single Culvert	Off_School Street	0.0	2.5	2.5	Yes
663	275	27	North Andover	Single Culvert	Abbott Street	1.6	0.9	2.5	
313	276	13	Hamilton	Single Culvert	Myopia Hunt Club access Road	1.2	1.3	2.5	
469	277	28	North Andover	Single Culvert	sharpners Pond Rd		2.5	2.5	
565	278	35	Boxford	Single Culvert	Off_Winding Oaks Way		2.5	2.5	
300	279	10	Andover	Single Culvert	Harold Parker Road		2.4	2.4	
1119	280	3	Groveland	Multiple Culvert	Center Street	1.6	0.8	2.4	

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6930	281	24	Rowley	Multiple Culvert	Off_Boxford Road	0.0	2.4	2.4	
607	282	36	Boxford	Single Culvert	Topsfield Road	0.0	2.4	2.4	
307	283	24	Topsfield	Multiple Culvert	Salem Road	0.0	2.4	2.4	
78	284	1	Lynnfield	Single Culvert	Main Street	0.6	1.8	2.4	
203	285	14	Middleton	Single Culvert	South Main Street Rt 114		2.4	2.4	
1233	286	8	Newburyport	Single Culvert	Little River Bike Trail		2.4	2.4	
647	287	24	Ipswich	Single Culvert	Heartbreak Road		2.4	2.4	
1230	288	9	Newburyport	Multiple Culvert	Fox Run Drive	0.6	1.7	2.3	
1226	289	10	Newburyport	Single Culvert	Little River Bike Trail		2.3	2.3	
683	290	25	Ipswich	Single Culvert	Old Right Road		2.3	2.3	
1130	291	18	Newbury	Single Culvert	Burns WMA West Road		2.2	2.2	
531	292	25	Topsfield	Multiple Culvert	Brookside Road	1.2	1.0	2.2	
1058	293	19	Newbury	Single Culvert	Off SCHOOL STREET	0.0	2.2	2.2	Yes
200	294	14	Wenham	Bridge	Essex street	1.6	0.6	2.2	
1219	295	11	Newburyport	Single Culvert	Off I 95		2.2	2.2	
608	296	26	Ipswich	Single Culvert	County Rd		2.2	2.2	
652	297	29	North Andover	Multiple Culvert	South Cross Road	0.0	2.2	2.2	
979	298	25	Rowley	Single Culvert	Wethersfield Street	0.0	2.2	2.2	
1232	299	12	Newburyport	Single Culvert	Newburyport bike path		2.1	2.1	
1185	300	20	Newbury	Single Culvert	Middle Road	0.0	2.1	2.1	
1227	301	13	Newburyport	Single Culvert	Hale Street	0.0	2.1	2.1	
747	302	30	North Andover	Single Culvert	Hay Meadow Road	0.0	2.0	2.0	
32	303	5	Peabody	Single Culvert	Pine Street	0.0	2.0	2.0	
989	304	26	Rowley	Single Culvert	Hillside Street	0.0	2.0	2.0	Yes
6316	305	15	Middleton	Single Culvert	Ferncroft Golf Cart Path		2.0	2.0	
694	306	37	Boxford	Single Culvert	Depot Road	0.6	1.4	2.0	
432	307	38	Boxford	Single Culvert	Wildmeadow Road		2.0	2.0	
23	308	6	Peabody	Single Culvert	Lake Street		2.0	2.0	
589	309	27	Ipswich	Multiple Culvert	Fellows Road		2.0	2.0	
324	310	14	Hamilton	Single Culvert	Linden Street		2.0	2.0	
603	311	28	Ipswich	Single Culvert	County Rd		1.9	1.9	
568	312	39	Boxford	Single Culvert	I-95 SB		1.9	1.9	
659	313	31	North Andover	Multiple Culvert	Salem Street	0.0	1.9	1.9	
448	314	40	Boxford	Single Culvert	Holmes Rd	0.0	1.9	1.9	
897	315	27	Rowley	Single Culvert	Mill Rd		1.9	1.9	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
502	316	26	Topsfield	Multiple Culvert	Howlett St	0.6	1.3	1.9	
391	317	15	Hamilton	Single Culvert	Sagamore Street	0.6	1.3	1.9	
9012	318	29	Ipswich	Single Culvert	Off Road		1.9	1.9	
451	319	41	Boxford	Single Culvert	Middleton Road		1.9	1.9	
433	320	27	Topsfield	Bridge	South Main St	0.0	1.9	1.9	Yes
252	321	15	Wenham	Single Culvert	Larch Row	0.0	1.9	1.9	
9004	322	42	Boxford	Multiple Culvert	Off_Lockwood Lane		1.9	1.9	
49	323	10	Wilmington	Multiple Culvert	Canal Street	0.0	1.8	1.8	
135	324	11	Wilmington	Bridge	Salem Street/Rt 62	0.0	1.8	1.8	
199	325	16	Middleton	Single Culvert	Mount Vernon	0.0	1.8	1.8	
74	326	12	Wilmington	Multiple Culvert	Shawsheen Avenue	0.0	1.8	1.8	
17000	327	17	Middleton	Single Culvert	Essex Street		1.8	1.8	
1194	328	21	Newbury	Single Culvert	Scotland Road	0.0	1.8	1.8	Yes
852	329	20	Georgetown	Single Culvert	Hiking Trail		1.8	1.8	
674	330	32	North Andover	Multiple Culvert	Foster Street	0.0	1.8	1.8	Yes
980	331	28	Rowley	Culvert	Weathersfield Road	-1.0	1.8	1.8	
140	332	13	Wilmington	Single Culvert	I-93		1.8	1.8	
372	333	16	Hamilton	Single Culvert	Bay Road		1.8	1.8	
9	334	14	Wilmington	Multiple Culvert	Chestnut Street	0.0	1.8	1.8	Yes
942	335	21	Georgetown	Single Culvert	West Street	0.0	1.8	1.8	
327	336	17	Hamilton	Multiple Culvert	Howard Street	0.0	1.8	1.8	
1099	337	22	Newbury	Single Culvert	River Street	0.0	1.8	1.8	Yes
658	338	28	Topsfield	Single Culvert	East Street	0.0	1.7	1.7	Yes
687	339	43	Boxford	Single Culvert	Main Street		1.7	1.7	
370	340	10	Essex	Single Culvert	western ave	0.0	1.7	1.7	
94	341	18	Middleton	Single Culvert	Boston Street		1.7	1.7	
715	342	33	North Andover	Multiple Culvert	Foster Road	0.0	1.7	1.7	
154	343	10	North Reading	Single Culvert	Lindor Road	0.0	1.7	1.7	
169	344	15	Wilmington	Multiple Culvert	Route 125	0.0	1.7	1.7	
83	345	16	Wilmington	Multiple Culvert	Wild Avenue	0.0	1.7	1.7	
969	346	29	Rowley	Single Culvert	Taylors Lane		1.7	1.7	
263	347	19	Middleton	Single Culvert	Lake Street		1.7	1.7	
893	348	44	Boxford	Single Culvert	Valley Road	0.0	1.7	1.7	
864	349	22	Georgetown	Single Culvert	Central Street	0.0	1.7	1.7	
6276	350	6	Danvers	Culvert	Route 1	0.0	1.7	1.7	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
828	351	30	Ipswich	Single Culvert	High Street	0.0	1.6	1.6	
28	352	17	Wilmington	Multiple Culvert	Burlington Avenue	0.0	1.6	1.6	Yes
657	353	31	Ipswich	Single Culvert	Off Heartbreak Road		1.6	1.6	
309	354	18	Hamilton	Open Bottom Arch	Myopia Hunt Club access Road		1.6	1.6	
260	355	11	Andover	Multiple Culvert	Mohawk Road	0.0	1.6	1.6	Yes
511	356	45	Boxford	Single Culvert	Middleton Road	0.0	1.6	1.6	Yes
924	357	30	Rowley	Single Culvert	Victory Lane	0.0	1.6	1.6	
33	358	7	Peabody	Single Culvert	Pine Street	0.0	1.6	1.6	
290	359	12	Andover	Single Culvert	Jenkins Road		1.6	1.6	
578	360	29	Topsfield	Bridge	Ipswich Road	1.2	0.4	1.6	
1089	361	23	Newbury	Open Bottom Arch	Central Street	0.0	1.6	1.6	
546	362	34	North Andover	Single Culvert	Rt 114/Turnpike Street		1.6	1.6	
168	363	20	Middleton	Single Culvert	Off_South Main Street		1.6	1.6	
571	364	46	Boxford	Multiple Culvert	Townsend Farm Road	0.0	1.6	1.6	
378	365	21	Middleton	Culvert	Essex Street	0.0	1.6	1.6	
10110	366	5	Salisbury	Culvert	Black Snake Road	-1.0	1.6	1.6	
478	367	35	North Andover	Multiple Culvert	Salem Street		1.5	1.5	
423	368	30	Topsfield	Single Culvert	Newburyport Turnpike	0.0	1.5	1.5	
662	369	36	North Andover	Single Culvert	Abbott Street		1.5	1.5	
500	370	31	Topsfield	Single Culvert	Perkins Row	0.0	1.5	1.5	Yes
592	371	47	Boxford	Single Culvert	Towne Road	0.0	1.5	1.5	
646	372	37	North Andover	Multiple Culvert	Holly Ridge Road	0.6	0.9	1.5	
31	373	8	Peabody	Single Culvert	Pine Brook Lane		1.5	1.5	
673	374	32	Ipswich	Single Culvert	Linebrook Road		1.5	1.5	
883	375	31	Rowley	Single Culvert	Haverhill St	0.0	1.5	1.5	
325	376	38	North Andover	Bridge	Stearns Pond Road	0.0	1.5	1.5	
975	377	32	Rowley	Single Culvert	Central St		1.5	1.5	
588	378	48	Boxford	Single Culvert	Townsend Farm Road	0.6	0.9	1.5	
797	379	33	Ipswich	Multiple Culvert	Mile Lane	0.6	0.9	1.5	
128	380	11	North Reading	Multiple Culvert	Elm Street	0.0	1.5	1.5	
789	381	33	Rowley	Multiple Culvert	Cindy Lane	0.0	1.4	1.4	
379	382	11	Essex	Single Culvert	County Rd	0.0	1.4	1.4	
677	383	49	Boxford	Single Culvert	I-95 NB		1.4	1.4	
763	384	50	Boxford	Multiple Culvert	Stiles Pond Road	0.0	1.4	1.4	
752	385	51	Boxford	Multiple Culvert	Batchelder Road	0.0	1.4	1.4	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
9002	386	52	Boxford	Open Bottom Arch	Andrew's Farm Road	0.6	0.8	1.4	
976	387	34	Rowley	Single Culvert	Newburyport Turnpike	0.0	1.4	1.4	
207	388	7	Danvers	Single Culvert	Us 1 I95 Interchange		1.4	1.4	
7133	389	23	Georgetown	Culvert	JAckman Road	0.0	1.4	1.4	
730	390	53	Boxford	Single Culvert	Service Road off Pond Street	0.0	1.4	1.4	
958	391	24	Georgetown	Bridge	East Main Street	0.0	1.4	1.4	
9007	392	54	Boxford	Single Culvert	Off_Georgetown Road		1.4	1.4	
428	393	32	Topsfield	Single Culvert	Topsfield Linear Common	0.0	1.4	1.4	
726	394	39	North Andover	Single Culvert	Haymeadow Road	0.0	1.3	1.3	
427	395	40	North Andover	Single Culvert	Berry Street	0.0	1.3	1.3	
251	396	33	Topsfield	Multiple Culvert	I-95 NB		1.3	1.3	
293	397	13	Andover	Single Culvert	Harold Parker Campground Road		1.3	1.3	
223	398	8	Danvers	Multiple Culvert	Old North Street	0.0	1.3	1.3	
956	399	25	Georgetown	Bridge	Penn Brook Avenue	0.0	1.3	1.3	
460	400	41	North Andover	Single Culvert	Stiles Street		1.3	1.3	
215	401	22	Middleton	Multiple Culvert	Lake Street	0.0	1.3	1.3	
617	402	34	Topsfield	Single Culvert	East Street		1.3	1.3	
720	403	55	Boxford	Multiple Culvert	Main Street	0.0	1.3	1.3	Yes
116	404	12	North Reading	Multiple Culvert	Winter Street/Rt 62	0.0	1.3	1.3	
7156	405	24	Newbury	Multiple Culvert	Elm Street		1.3	1.3	No
537	406	35	Topsfield	Multiple Culvert	Ipswich Rd	0.0	1.3	1.3	Yes
593	407	36	Topsfield	Multiple Culvert	Aaron Drive		1.3	1.3	
974	408	35	Rowley	Bridge	Wethersfield Street	0.0	1.3	1.3	
212	409	23	Middleton	Single Culvert	Pleasant Street	0.0	1.3	1.3	
698	410	34	Ipswich	Multiple Culvert	Peabody Street		1.3	1.3	
98	411	24	Middleton	Single Culvert	Boston Road		1.3	1.3	
10106	412	6	Salisbury	Culvert	Beach Road	-1.0	1.3	1.3	
374	413	14	Andover	Multiple Culvert	Salem Street	0.0	1.3	1.3	Yes
103	414	13	North Reading	Bridge	Southwick Road	0.0	1.3	1.3	
398	415	19	Hamilton	Single Culvert	Asbury Street	0.0	1.2	1.2	
445	416	42	North Andover	Single Culvert	Turnpike Street/ Route 114		1.2	1.2	
401	417	15	Andover	Single Culvert	Andover Bypass		1.2	1.2	
770	418	43	North Andover	Multiple Culvert	Winter Street	0.0	1.2	1.2	
384	419	20	Hamilton	Single Culvert	Blueberry Lane	0.0	1.2	1.2	
490	420	56	Boxford	Single Culvert	Middleton Road		1.2	1.2	

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	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
699	421	44	North Andover	Single Culvert	Lost Pond Lane	0.0	1.2	1.2	
76	422	2	Reading	Open Bottom Arch	Haverhill Street	0.0	1.2	1.2	Yes
192	423	9	Danvers	Multiple Culvert	I-95 NB		1.2	1.2	
373	424	12	Essex	Single Culvert	Essex Park Road	0.0	1.2	1.2	
454	425	37	Topsfield	Single Culvert	Fox Run Extension		1.2	1.2	
318	426	25	Middleton	Bridge	Essex Street	0.0	1.2	1.2	
259	427	38	Topsfield	Bridge	Rowley Bridge Road		1.2	1.2	
615	428	39	Topsfield	Culvert	North Street		1.2	1.2	Yes
718	429	57	Boxford	Single Culvert	Ipswich Road		1.2	1.2	
641	430	58	Boxford	Bridge	Brookview Road		1.1	1.1	
703	431	35	Ipswich	Single Culvert	Heard Drive		1.1	1.1	
248	432	14	North Reading	Single Culvert	Marblehead Street	0.0	1.1	1.1	
231	433	16	Wenham	Single Culvert	Grapevine Road	0.0	1.1	1.1	
514	434	21	Hamilton	Culvert	Gardner Street	0.0	1.1	1.1	
1104	435	4	Groveland	Ford	J B Little Road		1.1	1.1	
539	436	36	Ipswich	Multiple Culvert	unnamed	0.0	1.1	1.1	
524	437	37	Ipswich	Single Culvert	Route 1A	0.0	1.1	1.1	
1159	438	7	West Newbury	Open Bottom Arch	Middle Street	0.0	1.1	1.1	
377	439	22	Hamilton	Single Culvert	Juniper Road	0.0	1.1	1.1	
1178	440	25	Newbury	Single Culvert	Boston Road	0.0	1.1	1.1	
165	441	6	Beverly	Open Bottom Arch	Dodge St	0.0	1.1	1.1	
9034	442	59	Boxford	Bridge	Off_Topsfield Road		1.1	1.1	
721	443	60	Boxford	Bridge	Georgetown Road	0.0	1.1	1.1	
900	444	36	Rowley	Single Culvert	Haverhill Street	0.0	1.1	1.1	
1015	445	26	Georgetown	Bridge	Off_WEST MAIN STREET	0.0	1.1	1.1	
9015	446	5	Groveland	Bridge	JB Little Road	0.6	0.4	1.0	
480	447	23	Hamilton	Single Culvert	Bay Road		1.0	1.0	
4	448	1	Burlington	Multiple Culvert	Freeport Road	0.0	1.0	1.0	
947	449	27	Georgetown	Bridge	EAST MAIN STREET	0.6	0.4	1.0	
665	450	40	Topsfield	Single Culvert	Haverhill ROad	0.0	1.0	1.0	
107	451	26	Middleton	Single Culvert	Natsue Way	0.0	1.0	1.0	
542	452	45	North Andover	Single Culvert	Rt 114/ Turnpike Street		1.0	1.0	
695	453	38	Ipswich	Single Culvert	Plains Road		1.0	1.0	
113	454	15	North Reading	Bridge	Central Street	0.0	1.0	1.0	
34	455	9	Peabody	Single Culvert	Off_Pine Street	0.0	1.0	1.0	

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	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
419	456	41	Topsfield	Bridge	Washington Street		1.0	1.0	
146	457	18	Wilmington	Multiple Culvert	Andover Street	0.0	1.0	1.0	
6	458	2	Burlington	Single Culvert	Mill Street	0.0	1.0	1.0	
59	459	3	Reading	Multiple Culvert	Eastway	0.0	1.0	1.0	
845	460	61	Boxford	Single Culvert	Anna's Way	0.0	1.0	1.0	
1007	461	28	Georgetown	Bridge	Mill Street	0.0	0.9	0.9	
346	462	27	Middleton	Single Culvert	Mill Street	0.0	0.9	0.9	
679	463	62	Boxford	Multiple Culvert	Pye Brook Lane	0.0	0.9	0.9	Yes
9021	464	16	North Reading	Bridge	Salem and Lowell Railroad	0.0	0.9	0.9	
352	465	28	Middleton	Multiple Culvert	North Libery Street	0.0	0.9	0.9	
624	466	63	Boxford	Multiple Culvert	Towne Road	0.0	0.9	0.9	
348	467	24	Hamilton	Single Culvert	Bridge Street	0.0	0.9	0.9	
10102	468	7	Salisbury	Culvert	bike path	0.0	0.9	0.9	
6610	469	39	Ipswich	Culvert	Chebacco Road		0.9	0.9	Yes
576	470	46	North Andover	Multiple Culvert	Willow Street	0.0	0.9	0.9	
736	471	64	Boxford	Bridge	Service Road off Pond Street	0.0	0.9	0.9	
450	472	42	Topsfield	Multiple Culvert	Central Street		0.9	0.9	
732	473	65	Boxford	Single Culvert	I-95 NB		0.9	0.9	
597	474	66	Boxford	Bridge	Middleton Road		0.8	0.8	
233	475	17	Wenham	Multiple Culvert	Grapevine Road	0.0	0.8	0.8	Yes
447	476	43	Topsfield	Bridge	River Road		0.8	0.8	
171	477	17	North Reading	Bridge	Darrel Drive	0.6	0.2	0.8	
284	478	18	Wenham	Bridge	Walnut Street	0.0	0.8	0.8	
409	479	67	Boxford	Single Culvert	Interstate 95		0.8	0.8	
499	480	68	Boxford	Multiple Culvert	Lockwood Lane	0.0	0.8	0.8	
7160	481	26	Newbury	Bridge	Parish Road	0.0	0.8	0.8	
551	482	40	Ipswich	Single Culvert	Off Route 1A		0.8	0.8	
696	483	41	Ipswich	Single Culvert	Safford Street		0.8	0.8	
9041	484	19	Wenham	Multiple Culvert	Topsfield Nature Trail	0.0	0.8	0.8	
773	485	42	Ipswich	Single Culvert	Linebrook Road	0.0	0.8	0.8	
1067	486	29	Georgetown	Bridge	Thurlow Street	0.0	0.8	0.8	
9051	487	47	North Andover	Bridge	Off Blue Ridge Road		0.8	0.8	
36	488	19	Wilmington	Single Culvert	I-93 SB		0.8	0.8	
55	489	20	Wilmington	Bridge	Main Street/Route 38	0.0	0.8	0.8	Yes
206	490	20	Wenham	Bridge	Essex Street	0.0	0.7	0.7	

IRWA Crossing ID	Priority Rank Region	Priority Rank Town	Town	Structure Type	Road	Priority Scoring Infrastructure Risk (CRI)	Priority Scoring Ecological Impact (CEI)	Priority Scoring Priority Score (CP)	Design
488	491	48	North Andover	Bridge	Off_Salem Street		0.7	0.7	
152	492	18	North Reading	Multiple Culvert	Country Club Road	0.0	0.7	0.7	
320	493	21	Wenham	Single Culvert	Topsfield Linear common	0.0	0.7	0.7	
544	494	49	North Andover	Bridge	Hawkins Lane	0.0	0.7	0.7	
145	495	19	North Reading	Open Bottom Arch	Duane Drive	0.6	0.1	0.7	
717	496	43	Ipswich	Bridge	Pine Swamp Rd	0.6	0.1	0.7	
988	497	30	Georgetown	Single Culvert	Farnham Road	0.0	0.7	0.7	
301	498	25	Hamilton	Single Culvert	Miles River Road		0.7	0.7	
10105	499	8	Salisbury	Culvert	Beach Road	-1.0	0.7	0.7	
583	500	44	Topsfield	Bridge	Unnamed Path		0.7	0.7	
429	501	50	North Andover	Multiple Culvert	Sharpners Pond Rd	0.0	0.7	0.7	
606	502	45	Topsfield	Single Culvert	Off_Timber Lane		0.7	0.7	
180	503	20	North Reading	Multiple Culvert	Burrough Road	0.0	0.7	0.7	
590	504	44	Ipswich	Bridge	Off_Winthrop Street	0.0	0.7	0.7	
27	505	10	Peabody	Bridge	Winona Street	0.0	0.7	0.7	
334	506	26	Hamilton	Bridge	Bridge Street		0.7	0.7	
105	507	21	North Reading	Multiple Culvert	Chestnut Street	0.0	0.7	0.7	
609	508	45	Ipswich	Bridge	Willowdale Road		0.7	0.7	
224	509	22	Wenham	Open Bottom Arch	Main St		0.7	0.7	
562	510	46	Topsfield	Bridge	Asbury Street	0.0	0.6	0.6	
79	511	21	Wilmington	Multiple Culvert	Concord Street	0.0	0.6	0.6	
1105	512	27	Newbury	Bridge	Main Street	0.0	0.6	0.6	
10113	513	9	Salisbury	Bridge	Lafayette Road (Rt 1)	0.0	0.6	0.6	
361	514	13	Essex	Open Bottom Arch	Harry Homans Drive	0.0	0.6	0.6	Yes
839	515	46	Ipswich	Bridge	High Street	0.0	0.6	0.6	
688	516	69	Boxford	Single Culvert	I-95 NB		0.6	0.6	
702	517	47	Ipswich	Bridge	Kimball Street	0.0	0.6	0.6	
654	518	51	North Andover	Single Culvert	Boxford Street		0.6	0.6	
981	519	37	Rowley	Bridge	Wethersfield Street	0.0	0.6	0.6	
831	520	70	Boxford	Single Culvert	Georgetown Road	0.0	0.6	0.6	
237	521	23	Wenham	Open Bottom Arch	Dodges Rowe	0.0	0.6	0.6	
1012	522	31	Georgetown	Single Culvert	West Main Street	0.0	0.6	0.6	
442	523	27	Hamilton	Bridge	Moulton Street	0.0	0.6	0.6	
457	524	71	Boxford	Single Culvert	I-95 SB		0.6	0.6	
692	525	72	Boxford	Open Bottom Arch	I-95 NB	0.0	0.6	0.6	

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10115	526	10	Salisbury	Bridge	Gerrish Road	-1.0	0.6	0.6	
501	527	73	Boxford	Bridge	Lockwood Lane	0.0	0.6	0.6	
18	528	22	Wilmington	Bridge	Main Street/Route 38	0.0	0.6	0.6	Yes
22	529	23	Wilmington	Bridge	Lowell Street	0.0	0.5	0.5	
364	530	14	Essex	Open Bottom Arch	Western ave		0.5	0.5	
71	531	11	Peabody	Bridge	Russell Street	0.0	0.5	0.5	
253	532	24	Wenham	Bridge	Larch Row	0.0	0.5	0.5	
957	533	38	Rowley	Bridge	Dodge St	0.0	0.5	0.5	
937	534	39	Rowley	Multiple Culvert	Turcotte Drive	0.0	0.5	0.5	
1139	535	28	Newbury	Ford	WMA power line and trail		0.5	0.5	
53	536	12	Peabody	Bridge	Lowell Street	0.0	0.5	0.5	
120	537	22	North Reading	Bridge	Washington Street	0.0	0.5	0.5	
889	538	40	Rowley	Open Bottom Arch	Powerhouse Lane		0.5	0.5	
961	539	32	Georgetown	Bridge	West Street	0.0	0.5	0.5	
506	540	47	Topsfield	Open Bottom Arch	Perkins Row	0.0	0.5	0.5	
536	541	48	Topsfield	Bridge	Newburyport Turnpike	0.0	0.5	0.5	Yes
121	542	23	North Reading	Bridge	Route 28, Main Street	0.0	0.5	0.5	
623	543	48	Ipswich	Bridge	unnamed	0.0	0.5	0.5	
830	544	74	Boxford	Bridge	Great Pond Ave	0.0	0.5	0.5	
1016	545	33	Georgetown	Bridge	Off North Street	0.0	0.4	0.4	
601	546	49	Ipswich	Bridge	Route 1A	0.0	0.4	0.4	
62	547	24	Wilmington	Bridge	Church Street	0.0	0.4	0.4	
996	548	34	Georgetown	Bridge	Bailey Lane	0.0	0.4	0.4	
175	549	7	Beverly	Open Bottom Arch	Morgan's Island Rd	0.0	0.4	0.4	
245	550	24	North Reading	Bridge	Route 28/Main Street	0.0	0.4	0.4	
303	551	16	Andover	Bridge	Harold Parker Road	0.0	0.4	0.4	
155	552	8	Beverly	Multiple Culvert	Fern Street	0.0	0.4	0.4	
10101	553	11	Salisbury	Bridge	Steven	0.0	0.4	0.4	
1176	554	29	Newbury	Bridge	Off_Highfield Road		0.4	0.4	
336	555	29	Middleton	Bridge	Peabody Street		0.3	0.3	
529	556	52	North Andover	Single Culvert	Route 114/Turnpike Street	0.0	0.3	0.3	
6736	557	50	Ipswich	Bridge	Off-Road	0.0	0.3	0.3	
986	558	35	Georgetown	Bridge	Summer Street	0.0	0.3	0.3	
359	559	15	Essex	Bridge	Pond Street	0.0	0.3	0.3	
93	560	25	Wilmington	Multiple Culvert	Middlesex Avenue	0.0	0.3	0.3	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
104	561	25	North Reading	Bridge	Park Street	0.0	0.3	0.3	
992	562	36	Georgetown	Bridge	North Street	0.0	0.3	0.3	
966	563	37	Georgetown	Single Culvert	Winter Street	0.0	0.3	0.3	
9030	564	41	Rowley	Bridge	Off_Boxford Road	0.0	0.3	0.3	
65	565	26	Wilmington	Bridge	Wildwood Street	0.0	0.3	0.3	Yes
61	566	27	Wilmington	Open Bottom Arch	Federal Street	0.0	0.3	0.3	No
666	567	53	North Andover	Multiple Culvert	Blue Ridge Road		0.3	0.3	
70	568	28	Wilmington	Multiple Culvert	Woburn Street	0.0	0.3	0.3	
1014	569	42	Rowley	Bridge	Fenno Drive	0.0	0.3	0.3	
1006	570	38	Georgetown	Bridge	Mill Street	0.0	0.3	0.3	
9001	571	51	Ipswich	Bridge	Unnamed Road	0.0	0.3	0.3	
221	572	30	Middleton	Bridge	Maple Street	0.0	0.3	0.3	
337	573	54	North Andover	Bridge	Off_Harold Parker Road		0.3	0.3	
64	574	29	Wilmington	Single Culvert	I-93		0.3	0.3	
67	575	30	Wilmington	Bridge	Middlesex Avenue	0.0	0.2	0.2	
367	576	49	Topsfield	Bridge	Railroad		0.2	0.2	
685	577	75	Boxford	Bridge	Power Lines East of I-95 NB		0.2	0.2	
88	578	31	Wilmington	Bridge	Main Street/Route 38	0.0	0.2	0.2	
10114	579	12	Salisbury	Bridge	unnamed	0.0	0.2	0.2	
297	580	25	Wenham	Open Bottom Arch	Topsfield Road	0.0	0.2	0.2	
118	581	10	Danvers	Bridge	Andover Street Route 114	0.0	0.2	0.2	
475	582	76	Boxford	Ford	Off_Middleton Road		0.2	0.2	
390	583	16	Essex	Open Bottom Arch	Apple Street	0.0	0.2	0.2	
452	584	55	North Andover	Open Bottom Arch	Colonial Avenue	0.0	0.2	0.2	
1086	585	30	Newbury	Bridge	Larkin Street	0.0	0.2	0.2	
582	586	50	Topsfield	Bridge	Bradley Palmer Trail		0.2	0.2	
1025	587	39	Georgetown	Bridge	Hazan Court	0.0	0.2	0.2	
9049	588	28	Hamilton	Bridge	Off_Highland Street		0.1	0.1	
865	589	77	Boxford	Single Culvert	Main Street	0.0	0.1	0.1	
182	590	26	North Reading	Bridge	Barbie Lane	0.0	0.1	0.1	
97	591	13	Peabody	Bridge	Boston Street	0.0	0.1	0.1	
899	592	43	Rowley	Bridge	Mill Rd	0.0	0.1	0.1	
689	593	56	North Andover	Bridge	Ogunquit Road		0.1	0.1	
365	594	51	Topsfield	Bridge	Route 97	0.0	0.1	0.1	
515	595	57	North Andover	Open Bottom Arch	Pheasant Brook Road	0.0	0.1	0.1	

IRWA Crossing ID	Priority Rank		Town	Structure Type	Road	Priority Scoring			Design
	Region	Town				Infrastructure Risk (CRI)	Ecological Impact (CEI)	Priority Score (CP)	
383	596	17	Essex	Bridge	Off_Park Road	0.0	0.1	0.1	
9013	597	52	Ipswich	Bridge	Off Topsfield Road		0.1	0.1	
381	598	52	Topsfield	Bridge	Salem Road	0.0	0.1	0.1	
127	599	27	North Reading	Bridge	Washington Street	0.0	0.1	0.1	
471	600	78	Boxford	Bridge	I-95 NB		0.1	0.1	
473	601	79	Boxford	Bridge	I-95 SB		0.0	0.0	
395	602	53	Topsfield	Bridge	Rowley Bridge RD	0.0	0.0	0.0	
114	603	28	North Reading	Bridge	Haverhill Street	0.0	0.0	0.0	
357	604	80	Boxford	Bridge	Interstate 95		0.0	0.0	
356	605	81	Boxford	Bridge	Interstate 95		0.0	0.0	
375	606	54	Topsfield	Open Bottom Arch	Newburyport Turnpike (Rt. 1)		0.0	0.0	
600	607	53	Ipswich	Open Bottom Arch	Mill Road		0.0	0.0	
82	608	4	Reading	Bridge	Mill Street	0.0	0.0	0.0	
269	609	31	Middleton	Bridge	North Main Street	0.0	0.0	0.0	
89	610	29	North Reading	Bridge	Main Street/Rt. 28	0.0	0.0	0.0	
575	611	82	Boxford	Bridge	Mill Road	0.0	0.0	0.0	

Tidal Crossings

IRWA Crossing ID	Crossing Priority	Town	Road/Site	Public Way	Great Marsh Plan Priority Marsh	Great Marsh Plan Rapid Technical Assessment	Design or Local Priority
17107	High	Essex	Route 133	Yes	Medium		
17108	High	Essex	Old Essex Road	Yes	Medium		
17109	High	Essex	Behind Town Hall	No	High		
6864	High	Ipswich	Labor in Vain Road	Yes	Medium	Yes	
660	High	Ipswich	Argilla Road	Yes	Medium	Yes	
17240	High	Ipswich	MBTA	Yes	Medium		
17241	High	Ipswich	MBTA	Yes	Medium		
17242	High	Ipswich	Town Farm Road	Yes	Medium		
17243	High	Ipswich	Town Farm Road	Yes	Medium		
17246	High	Ipswich	Trustees East side of Castle Hill	No	High		
17329	High	Newbury	Route 1A	Yes	High	Yes	
17330	High	Newbury	Route 1A	Yes	High	Yes	
17331	High	Newbury	River Front	Yes	Medium		
17343	High	Newbury	Newman Road	Yes	High	Yes	
17462	High	Rowley	Red Gate Road	Yes	Medium	Yes	
17471	High	Salisbury	Rail Trail	No	High		
17472	High	Salisbury	Rail Trail	No	High		
17473	High	Salisbury	Route 1	Yes	High		
10108	High	Salisbury	State Reservation Road	Yes	Medium	Yes	
10117	High	Salisbury	State Reservation Road	Yes	Medium		
10118	High	Salisbury	State Reservation Road	Yes	Medium	Yes	
10107	High	Salisbury	Route 1 (Town Creek)	Yes	High		Design
10104	High	Salisbury	Ferry Road	Yes	High	Yes	Design
17474	High	Salisbury	Old County Road	Yes	Medium	Yes	
17475	High	Salisbury	Old County Road	Yes	Medium	Yes	
17477	High	Salisbury	March Road	Yes	High	Yes	
17478	High	Salisbury	1st Street	Yes	High	Yes	
436	High	Essex	Eastern Ave	Yes	Low	Yes	Priority
1192	High	Newbury	Hanover Street	Yes	Low		Priority
17337	High	Newbury	West of Plum Island Drive	No	Medium		Priority
17344	High	Newbury	Kents Island Road	No	Medium	Yes	Priority
406	High	Essex	Landing Road	Yes	NIP		Priority
1196	High	Newbury	Newburyport Turnpike	Yes	NIP		Priority
17336	High	Newbury	MBTA - Little River S of Boston Road	Yes	NIP		Priority
17112	Medium	Essex	Island Road	Yes	Low	Yes	
17114	Medium	Essex	North of Eastern Ave	Yes	Low	Yes	
17238	Medium	Ipswich	Labor in Vain Road	Yes	Low		
17328	Medium	Newbury	Newburyport Turnpike	Yes	Low		
17333	Medium	Newbury	MBTA	Yes	Low		
17334	Medium	Newbury	Boston Road	Yes	Low		
17347	Medium	Newbury	West of Middle Road	No	Medium		
17460	Medium	Rowley	MBTA	Yes	Low		
17476	Medium	Salisbury	East of Hayes Street	No	Medium	Yes	
430	Low	Essex	Main Street	Yes	NIP		

IRWA Crossing ID	Crossing Priority	Town	Road/Site	Public Way	Great Marsh Plan Priority Marsh	Great Marsh Plan Rapid Technical Assessment	Design or Local Priority
17111	Low	Essex	Island Road	Yes	NIP		
17113	Low	Essex	Conomo Point Road	Yes	NIP		
17115	Low	Essex	East side of Choate Island	No	Low		
17116	Low	Essex	East side of Choate Island	No	Low		
489	Low	Gloucester	Concord Street	Yes	NIP		
17167	Low	Gloucester	Concord Street	Yes	NIP		
17168	Low	Gloucester	Concord Street	Yes	NIP		
861	Low	Ipswich	Muddy Run East of Paradise Road	No	NIP		
17235	Low	Ipswich	MBTA over Rowley River	Yes	NIP		
17236	Low	Ipswich	Choate Bridge (Ipswich River)	Yes	NIP		
17237	Low	Ipswich	County Street Bridge (Ipswich River)	Yes	NIP		
17239	Low	Ipswich	Argilla Road	Yes	NIP		
17244	Low	Ipswich	West of Jeffrey's Neck Road	No	NIP		
17245	Low	Ipswich	West of Jeffrey's Neck Road	No	NIP		
17247	Low	Ipswich	Argilla Road	Yes	NIP		
17248	Low	Ipswich	Little Neck Road	Yes	NIP		
1113	Low	Newbury	Newburyport Turnpike	Yes	NIP		
1147	Low	Newbury	Hay Street	Yes	NIP		
1138	Low	Newbury	Newman Road	Yes	NIP		
1111	Low	Newbury	Middle Road	Yes	NIP		
1204	Low	Newbury	Off_Highfield Road	No	NIP		
17332	Low	Newbury	Orchard Street	Yes	NIP		
17338	Low	Newbury	Plum Island Turnpike	Yes	NIP		
17339	Low	Newbury	Plum Island Turnpike	Yes	NIP		
17340	Low	Newbury	Plum Island Turnpike	Yes	NIP		
17341	Low	Newbury	Plum Island Turnpike	Yes	NIP		
17342	Low	Newbury	Plum Island Turnpike	Yes	NIP		
17345	Low	Newbury	MBTA	Yes	NIP		
17346	Low	Newbury	MBTA	Yes	NIP		
17367	Low	Newburyport	Spofford Street over Merrimack	Yes	NIP		
17368	Low	Newburyport	Route 1 over Merrimack	Yes	NIP		
17369	Low	Newburyport	Interstate 95 over Merrimack	Yes	NIP		
17370	Low	Newburyport	Plum Island Turnpike near Rolfes Lane	Yes	NIP		
1040	Low	Rowley	Glen Street	Yes	NIP		
1041	Low	Rowley	Fullingmill Road	Yes	NIP		
1057	Low	Rowley	Newburyport Turnpike (Mill River)	Yes	NIP		
17456	Low	Rowley	Route 1A (West Creek)	Yes	NIP		
17458	Low	Rowley	MBTA (Sand Creek)	Yes	NIP		
17459	Low	Rowley	Patmos Road	Yes	NIP		
17461	Low	Rowley	North of Patmos Road	No	Low		
10103	Low	Salisbury	Rail Trail (Town Creek)	No	Other_AB		
17479	Low	Salisbury	Rail Trail	No	Low		

Coastal Stabilization Structures

Structure ID	Structure Category	Structure Priority	Town	Structure Type	Location Note	Length (Meters)
050-002U-000-044-100	Public	High	Newbury	Groin/ Jetty	Plum Island - Dartmouth Way	32
036-016-000-002-100	Public	Moderate	Ipswich	Groin/ Jetty	Plum Island	39
051-011-000-001B-100	Public	Moderate	Newburyport	Bulkhead/ Seawall	Railroad Avenue	163
051-030-000-009-100	Public	Moderate	Newburyport	Bulkhead/ Seawall	Water Street	27
051-030-000-013-200	Public	Moderate	Newburyport	Revetment	Simons Beach	60
051-030-000-013-100	Public	Moderate	Newburyport	Bulkhead/ Seawall	Simons Beach	41
051-011-000-002-100	Public	Moderate	Newburyport	Bulkhead/ Seawall	Gillis Bridge	54
051-030-000-013-300	Public	Moderate	Newburyport	Bulkhead/ Seawall	Simons Beach	28
051-054-000-003-400	Public	Moderate	Newburyport	Groin/ Jetty	Cashman Park	7
065-030-000-001-200	Public	Moderate	Salisbury	Groin/ Jetty	State Park	39
050-002U-000-029-100	Public	Low	Newbury	Groin/ Jetty	Plum Island Boulevard	59
051-054-000-003-200	Public	Low	Newburyport	Revetment	Cashman Park	134
051-054-000-003-100	Public	Low	Newburyport	Revetment	Cashman Park	178
051-011-000-001B-400	Public	Low	Newburyport	Bulkhead/ Seawall	Railroad Avenue	37
051-011-000-001B-300	Public	Low	Newburyport	Bulkhead/ Seawall	Railroad Avenue	72
051-011-000-001B-200	Public	Low	Newburyport	Bulkhead/ Seawall	Railroad Avenue	97
051-012-000-009-100	Public	Low	Newburyport	Bulkhead/ Seawall	Fish Coop	86
051-026-000-028-100	Public	Low	Newburyport	Bulkhead/ Seawall	Harrison Street Joppa Park	276
051-012-000-009-200	Public	Low	Newburyport	Bulkhead/ Seawall	Harbor Master Office Area	24
051-012-000-009-300	Public	Low	Newburyport	Revetment	Harbor Master Building	18
051-054-000-003-300	Public	Low	Newburyport	Revetment	Cashman Park	263
065-007-000-015-200	Public	Low	Salisbury	Groin/ Jetty	Gillis Bridge	38
065-007-000-010-100	Public	Low	Salisbury	Bulkhead/ Seawall	First Street	77
065-030-000-001-400	Public	Low	Salisbury	Groin/ Jetty	State Park	12
065-030-000-001-300	Public	Low	Salisbury	Bulkhead/ Seawall	State Park	628
065-030-000-001-100	Public	Low	Salisbury	Revetment	Merrimac River	159
065-007-000-015-100	Public	Low	Salisbury	Revetment	Gillis Bridge	64
107-259-000-004-001	Private	NA	Gloucester	Groin/Jetty		10
144-015A-013-000-001	Private	NA	Ipswich	Groin/Jetty		19
144-015D-014-000-001	Private	NA	Ipswich	Revetment		44
144-015D-029-000-001	Private	NA	Ipswich	Bulkhead/Seawall		49
144-024A-097-000-001	Private	NA	Ipswich	Bulkhead/Seawall		20
144-024A-097-000-002	Private	NA	Ipswich	Revetment		304
144-024A-102-000-001	Private	NA	Ipswich	Bulkhead/Seawall		20
144-024A-106-000-001	Private	NA	Ipswich	Revetment		146
144-024A-112-000-001	Private	NA	Ipswich	Bulkhead/Seawall		40
144-024A-111-000-001	Private	NA	Ipswich	Bulkhead/Seawall		21
144-024C-069-000-001	Private	NA	Ipswich	Revetment		601
144-024C-069-011-001	Private	NA	Ipswich	Bulkhead/Seawall		110
144-024C-069-000-002	Private	NA	Ipswich	Revetment		89
144-024C-069-000-003	Private	NA	Ipswich	Revetment		24
144-024C-069-000-004	Private	NA	Ipswich	Bulkhead/Seawall		28
144-023D-052C-000-001	Private	NA	Ipswich	Groin/Jetty		14
144-023D-086-000-001	Private	NA	Ipswich	Revetment		33
144-023D-052D-000-001	Private	NA	Ipswich	Revetment		18
144-023D-052K-000-001	Private	NA	Ipswich	Revetment		139

Structure ID	Structure Category	Structure Priority	Town	Structure Type	Location Note	Length (Meters)
144-000-000-000-001	Private	NA	Ipswich	Groin/Jetty		80
144-034-002-000-001	Private	NA	Ipswich	Revetment		52
144-024C-069-000-005	Private	NA	Ipswich	Revetment		18
144-024C-069-000-006	Private	NA	Ipswich	Bulkhead/Seawall		55
144-024C-069-000-007	Private	NA	Ipswich	Revetment		70
144-024C-195-000-001	Private	NA	Ipswich	Bulkhead/Seawall		30
205-U04-000-078-001	Private	NA	Newbury	Bulkhead/Seawall		29
205-U04-000-077-001	Private	NA	Newbury	Revetment		17
205-U04-000-074-001	Private	NA	Newbury	Bulkhead/Seawall		71
205-U04-000-072-001	Private	NA	Newbury	Bulkhead/Seawall		32
205-U04-000-070-001	Private	NA	Newbury	Bulkhead/Seawall		21
205-U04-000-069-001	Private	NA	Newbury	Bulkhead/Seawall		23
205-U04-000-067-001	Private	NA	Newbury	Revetment		34
205-U04-000-066-001	Private	NA	Newbury	Bulkhead/Seawall		10
205-U04-000-009-001	Private	NA	Newbury	Revetment		12
205-U04-000-003-001	Private	NA	Newbury	Revetment		113
205-U03-000-166-001	Private	NA	Newbury	Revetment		43
205-U03-000-133-001	Private	NA	Newbury	Revetment		42
205-U03-000-123-001	Private	NA	Newbury	Revetment		38
205-U03-000-187-001	Private	NA	Newbury	Groin/Jetty		19
205-U03-000-163-001	Private	NA	Newbury	Bulkhead/Seawall		26
205-U03-000-162-001	Private	NA	Newbury	Bulkhead/Seawall		15
205-U03-000-128-001	Private	NA	Newbury	Revetment		19
205-U03-000-129-001	Private	NA	Newbury	Bulkhead/Seawall		18
205-U01-000-010-001	Private	NA	Newbury	Groin/Jetty		45
206-077-000-018-001	Private	NA	Newburyport	Bulkhead/Seawall		60
206-077-000-015-001	Private	NA	Newburyport	Revetment		18
206-077-000-011-001	Private	NA	Newburyport	Bulkhead/Seawall		53
206-077-000-010-001	Private	NA	Newburyport	Revetment		25
206-077-000-006-001	Private	NA	Newburyport	Bulkhead/Seawall		39
206-077-000-021-001	Private	NA	Newburyport	Bulkhead/Seawall		55
206-076-000-085-001	Private	NA	Newburyport	Revetment		69
206-076-000-052-001	Private	NA	Newburyport	Bulkhead/Seawall		40
206-076-000-036-001	Private	NA	Newburyport	Bulkhead/Seawall		41
206-076-000-035-001	Private	NA	Newburyport	Revetment		25
206-076-000-019-001	Private	NA	Newburyport	Bulkhead/Seawall		27
206-076-000-018-001	Private	NA	Newburyport	Revetment		27
206-077-000-125-001	Private	NA	Newburyport	Groin/Jetty		24
206-077-000-076-001	Private	NA	Newburyport	Bulkhead/Seawall		54
259-035-000-224-001	Private	NA	Salisbury	Revetment		21
259-035-000-234-001	Private	NA	Salisbury	Bulkhead/Seawall		20

Appendix 5 – Trout Unlimited Modeling

Trout Unlimited 2017 report including hydraulic capacity modeling for non-tidal crossings.

Trout Unlimited, 2017. *Parker-Ipswich-Essex Watersheds Stream Crossing Vulnerability Assessment Project: Final Report*

Available for download at: http://pie-rivers.org/documents/TUPIEBarriers-2017.pdf