Broad Meadow Brook Restoration Project
Ecological Restoration Roadmap

Broad Meadow Brook Wildlife Sanctuary
Worcester, Massachusetts

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This project was funded by an agreement (CE00A00004) awarded by the United States Environmental Protection Agency (USEPA) to the NEIWPCC on behalf of the Narragansett Bay Estuary Program (NBEP). Although the information in this document has been funded wholly or in part by the USEPA under agreement CE00A00004 to NEIWPCC, it has not undergone the Agency's publications review process and therefore, may not necessarily reflect the views of the USEPA and no official endorsement should be inferred. The viewpoints expressed here do not necessarily represent those of the NBEP, NEIWPCC, or USEPA nor does mention of trade names, commercial products, or causes constitute endorsement or recommendation for use.

1.0 INTRODUCTION

The goal of the Broad Meadow Brook Restoration Project (the Project) is to achieve a self-sustaining, native riparian and wetland ecosystem providing a full suite of ecosystem services and available for the enjoyment and benefit of neighbors, residents, and visitors. Desired outcomes include a reduction in localized flooding in the upper Broad Meadow Brook watershed through increased flood storage capacity, increased climate resilience, improved water quality and streamflow, increased wetland habitat value and function, and heightened appreciation for urban river and wetland ecosystems in Worcester and beyond. Partners hope the Project inspires increased support for urban ecosystem restoration projects throughout the Northeast. To succeed, the Project will require:

- informed planning supported by site investigation and data collection;
- coordination with project partners, landowners, Sanctuary users, neighbors, and the community;
- financial and other resource support; and
- regulatory oversight from local, state, and federal regulatory agencies.

With meaningful public participation, the restoration effort within the Broad Meadow Brook Wildlife Sanctuary (including education and outreach activities) can inspire stewardship and lead to future ecological restoration endeavors.

Mass Audubon and other project partners, including the City of Worcester and the Massachusetts Division of Ecological Restoration (DER), have identified the following project components for the Broad Meadow Brook Restoration Project:

- Restoration of a severely degraded wetland complex by improving hydrological function and native habitat with particular interest in increasing flood storage capacity and improving water quality.

- Improving climate resilience and reducing, to the extent practicable, flooding issues in the surrounding environmental justice neighborhoods.

- Alleviating land use-related impairments to water quality and quantity in the upper Broad Meadow Brook watershed/storm drain system.

- Re-naturalization of thousands of linear feet of stream channel to improve both streamside and in-channel habitat features and connectivity for fish and wildlife and long-term riparian function and ‘dynamic’ stream stability.

- Enhancing the Sanctuary visitor experience through improved trails and wildlife viewing opportunities.

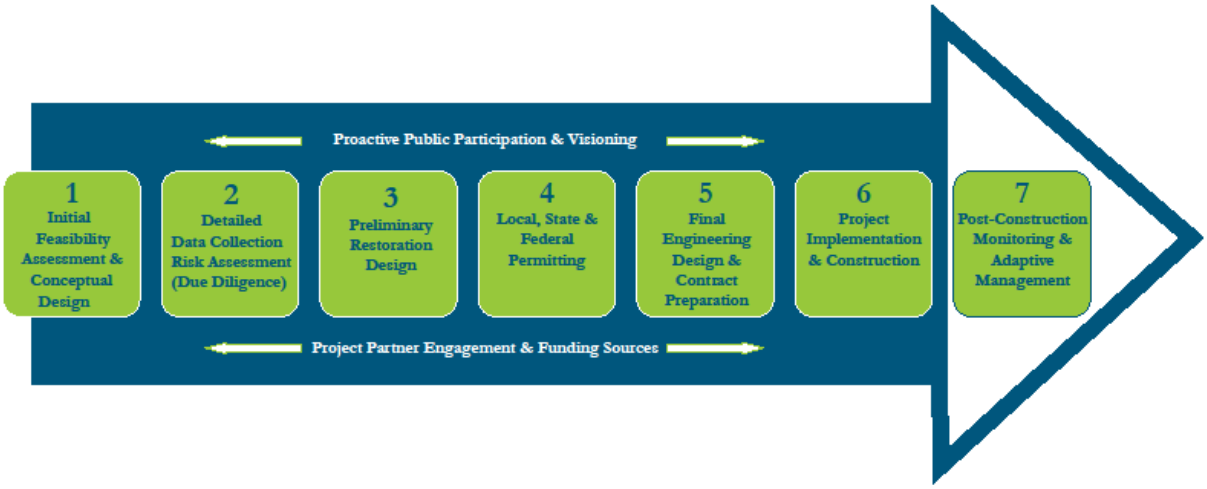
- Inspiring stewardship and future restoration projects through education and outreach activities.

As the restoration measures listed above will increase the capacity of the wetland complex to buffer climate-related environmental changes within the upper Broad Meadow Brook watershed, the restoration project will actively contribute to climate change adaptation and resilience. Mass Audubon recognizes proper planning and informed design will be the key to successfully restoring the Broad Meadow Brook stream and wetland complex. Through this process, the project partners will be positioned to engage interested stakeholder groups and regulators to work together to assess restoration options. A collaborative process

will facilitate selection of the optimal restoration and access components allowing Project Partners to identify project needs and potential funding and other resources to meet project needs.

The Broad Meadow Brook Restoration Project conceptual project roadmap outlines a suggested path toward achieving the stated project goals. The basis for this roadmap has been used on several ecological restoration projects (Figure 1).

Figure 1. Broad Meadow Brook Restoration Project Conceptual Roadmap



The work on the Broad Meadow Brook Restoration Project that has been performed to date by ESS, Mass Audubon, and the City of Worcester focused on completing Step 1: Initial Feasibility Assessment & Conceptual Design. To complete Step 1, some aspects of Step 2: Detailed Data Collection were performed where needed to provide necessary information.

During the work on Step 1, it was determined that opportunities to implement potential water quality or other improvements within the developed upstream portions of the Broad Meadow Brook watershed (e.g., increased use of Low Impact Development techniques, green infrastructure, and stormwater system maintenance procedures) will require participation from additional Project Partners and landowners. As a result, the concepts for restoration are focused on areas immediately surrounding Broad Meadow Brook that are also within the Broad Meadow Brook Sanctuary.

2.0 WORK COMPLETED TO DATE

The work completed by ESS, Mass Audubon, and the City of Worcester, as described in this section, was funded by an agreement (CE00A00004) awarded by the USEPA to the NEIWPCC on behalf of the Narragansett Bay Estuary Program.

2.1 Initial Data Collection Efforts

To support assessment of potential restoration concepts, certain information on the Brook and the surrounding area were collected using publicly available data and field efforts. This information includes the following:

- **Detailed photogrammetry** of the project site with a professional UAS drone flight was obtained in May 2020 to assist in the development of resource area limits, vegetation community mapping, and

restoration concepts (Appendix A). This high-resolution orthoimagery combined with LiDAR-derived topographic data from public sources serves as the project base mapping for presenting existing conditions and conceptual design components. No topographic or property survey was performed as a part of this project phase.

- **Field reconnaissance** efforts included an evaluation of the extent of habitat impairment and invasive plant species; soil types and hydrology; size, composition, and structure of the wetland complex; and a comparison of environmental factors and elevations on either side of the existing causeway. Other initial data collection involved observations of streambed materials, the types and integrity of stream grade controls, longitudinal profile features, and bankfull dimensions. The field reconnaissance also included an assessment of past and ongoing beaver activities, which appears to vary over time depending on the availability and growth of their food sources..

- **Geospatial data** was acquired from publicly available sources including LiDAR data, assessor's parcel data, and area hydrography. The LiDAR data was analyzed and processed to develop topographic contours.

A list of the existing data sources reviewed by ESS is presented in Table A.

Table A. Reviewed Documents and Data Sources Related to Broad Meadow Brook

Document	Author/Source	Year
Land-use History: A Study of Anthropogenic Impacts on the Past, Present, and Future Landscape of Broad Meadow Brook Wildlife Sanctuary	DeGasperis	No Date
Aerial Photographs of Broad Meadow Brook: #55, #82, #84, and #86	City of Worcester	1954
Ecological Management Plan for Broad Meadow Brook Wildlife Sanctuary	Mass Audubon	1993
Final Draft Brightwood Avenue Area and Broad Meadow Brook Drainage Study	CDM	2009
Project Evaluation Form. Clean Water State Revolving Fund (CWSRF) CY 2010. Brightwood Avenue Area and Broad Meadow Brook Drainage System Improvements	CDM	2009
Final Letter Report on Brightwood Avenue Area and Broad Meadow Brook Drainage Study – Flood Storage Area Alternative	CDM	2010
1-foot LiDAR elevation contours	MassGIS	2010
Flood Insurance Rate Map #25025C0807E, Panel 807 (Worcester and Millbury)	FEMA	2011
Brightwood Avenue Area Flood Storage Improvements (Construction Documents)	CDM Smith	2013
Broad Meadow Brook Wildlife Sanctuary – Ecological Management Report	Mass Audubon	2016

2.2 Initial Feasibility Assessment and Conceptual Design

The initial feasibility and conceptual design process involved ESS engineers and scientists, working in collaboration with Mass Audubon and the City of Worcester to identify creative, self-sustaining, and cost-effective approaches to address the ecological and water quality goals and objectives of the Project described above while minimizing potential negative environmental impacts and risks. This work included a conceptual level assessment of resource area impacts, construction costs, permit constraints, and management requirements, among others. Available HEC-RAS modelling data of the drainage system was

reviewed for water surface elevations and flooding frequencies with either ecological or regulatory significance.

Conceptual design plans were prepared to present the design intent and identify additional planning steps necessary to refine the design for permitting. These plans were developed using field reconnaissance observations, interpretation of the high resolution UAS orthoimagery, LiDAR elevations, and anticipating flooding regime with and without climate change predictions.

2.3 Design Basis Summary

This section summarizes the basis of the conceptual designs that were prepared. After submittal of this Roadmap to NBEP, ESS and Mass Audubon will compile a more detailed report on the conceptual designs to create an expanded Roadmap that the Project Partners can use as they advance the Project and potentially seek to expand the coalition's breadth.

2.3.1 Guiding Principles for Conceptual Design

The conceptual design process involved ESS working in collaboration with Mass Audubon and the City of Worcester to identify creative, self-sustaining, and cost-effective approaches that effectively address the Project goals while minimizing potential negative environmental impacts and risks.

Through this process, the project team developed guiding principles for the conceptual design of the Broad Meadow Brook Restoration Project, which include the following:

1. Re-establish floodplain connectivity at all flood stages by removing segments of the bifurcating causeway.
2. Re-establish a stable low-gradient channel using the reference reach geometry as a guide.
3. Reduce area of exotic *Phragmites australis.*
4. Daylight portion of the Brook that currently flows through the stone box culvert.
5. Enhance trail connectivity.
6. Look for opportunities to reduce stormwater-driven impacts on water quality.

These guiding principles are closely aligned with the primary restoration components included in the Project. These include measures to address the severely degraded nature of portions of the wetland complex, provide an enhanced Sanctuary trail experience for visitors, and improve ecological services by restoring hydrological functions, flood storage capacity, wildlife habitat, and water quality.

2.3.2 Summary of Conceptual Design Alternatives and Components

The initial feasibility assessment and conceptual design process, informed by the Project's guiding principles, resulted in two conceptual design alternatives (Appendix A):

- Option 1. Focuses on restoration of sections of the Brook, creation of new open water areas with elevated wooded zones, and limited trail improvements.

- Option 2. Focuses on restoration of sections of the Brook and creation of new open water areas with elevated upland wooded zones. Also includes more comprehensive trail improvements, new wildlife observation platforms, and the creation of turtle nesting habitat.

Each conceptual design alternative included opportunities for channel daylighting and naturalization, floodplain reconnection, fill removal, trail network connectivity, and habitat enhancement actions to broadly improve ecosystem services. The design also recognized the key role that beaver play in creating and augmenting aquatic habitats.

Brief descriptions of each primary design component are provided in Table B.

Table B. Summary of Conceptual Design Components

Component	Sub-Component	Description
Ecological Restoration	Constructed Channel	• Realignment of channel using planform morphology, cross-section, and longitudinal profile of "reference" channel reach downstream of the stone box culvert as a model. • Portions of existing channel abandoned and plugged at either end but otherwise remain as open water features within the wetland complex.
	Causeway Removal	• Removal of segments of existing causeway and abandoned sewer pipe to allow for greater hydrologic exchange between areas east and west of the causeway.
	Stone Box Culvert Removal	• Removal of high-gradient, straight stone box culvert and rerouting of streamflow into constructed channel. • Restoration of native vegetation in demolition area.
	Excavated Open Water	• Excavation of existing invasive *Phragmites australis* beds and underlying soils/sediments to create areas of open water marsh on the eastern side of the causeway.
	Cut/Fill Transition	• Removal of rhizome layer of existing invasive *Phragmites australis* beds with minimal alteration of underlying soils. • Restoration of native wetland vegetation with targeted management of invasive species to allow for establishment of transition zone between Excavated Open Water and Elevated Wooded Zones.
	Elevated Wooded Zones	• Fill of existing invasive *Phragmites australis* beds using excavated onsite soils/sediments to create elevated "islands" of native upland vegetation. • Restoration of native vegetation in these zones.
	Invasive Species Control	• Areas of existing *Phragmites australis* beds to be managed using permitted chemical or mechanical means.
Trail Improvements	Boardwalk	• Installation of elevated wooden boardwalk to connect remaining portions of the causeway in existing or restored wetlands and to span the Broad Meadow Brook. • Installation of wildlife observation platforms for improved viewing of restored wetlands and adjacent habitats.
	Trail Connectivity	• Rerouting of existing trails and creation of new trails or extensions to improve trail connectivity and visitor experience.
Stormwater Improvements	Stormwater Pre-treatment	• Stormwater pre-treatment chamber installed in Woodcliffe Ave drainage system to minimize maintenance required in the receiving gravel wetland.
	Stormwater Treatment	• Woodcliffe Ave stormwater discharge directed to an approximately 4,000 square foot gravel wetland below the outfall to provide water quality improvement and potentially infiltration (depending on soil types present).

2.3.3 Concept-Level Cost Estimates

To assist with planning and future funding of the project, ESS developed an order-of-magnitude Opinion of Probable Costs for both conceptual options (Table C). The costs are based on conceptual design assumptions, the concept/feasibility/planning stage of the Project (10-15% design level), MassDOT published Weighted Average Bid Prices, and estimated costs of generally comparable elements of reference projects. The estimated cost range represents -40% to +100% range, which is typical for a concept study in the planning phase as described in the Washington State Department of

Transportation "Cost Estimating Manual for Projects", dated April 2015[1]. These ranges will decrease as design is advanced and a more refined estimate can be made.

Table C. Concept-Level Opinion of Probable Costs

Item	Option 1	Option 2
Boardwalk	$800,000 - $2,600,000	$1,500,000 - $4,900,000
Restoration	$1,400,000 - $4,700,000	$1,500,000 - $5,000,000
Stormwater Treatment	$90,000 - $300,000	$90,000 - $310,000
Design and Permitting	$120,000 - $400,000	$130,000 - $420,000
Total	**$2,400,000 - $8,000,000**	**$3,220,000 - $10,630,000**

Disclaimer: This Opinion of Probable Cost is made on the basis of ESS's experience and judgment and is based on concept level drawings. The stated probable costs are opinions only and are not a formal construction estimate. ESS makes no warranty, expressed or implied, that proposals, bids, or actual construction cost will not vary from this Opinion of Probable Cost.

3.0 NEXT STEPS

To advance the Project beyond conceptual design (Step 1) to Preliminary Restoration Design (Step 3, Figure 1)., a number of steps must be taken. This section describes the expected process that will be necessary to design, permit, and construct the Project. Based on the concept designs identified, the process would largely be the same for both options. The differences will likely be in the matter of degree or complexity of certain elements (e.g., the more limited trail improvements in Option 1 would require a lesser degree of stakeholder outreach with recreational groups and require less design and permit application detail than the more complex Option 2, but the permits required would likely be the same for both options).

3.1 Detailed Data Collection and Due Diligence (Step 2)

More detailed survey data of existing structures, utilities, and channel geometry will be necessary to support preliminary design efforts during the data collection phase, regardless of which design concept option is selected for advancement.

Supplementing field data collection beyond the information described in Section 2.1 will be necessary to support the restoration design and permitting process. Specific data requirements are anticipated to include macroinvertebrate and fish sampling, supplemental topographic survey, discharge and water quality measurements, sediment sampling to evaluate bed material composition, and resource area delineation. The exact scope and extent of these surveys will be determined after pre-application meetings are held with the relevant regulatory agencies that will permit the Project. The following supplemental data collection efforts are recommended as the Project advances:

- **Supplemental field survey** of existing structures, utilities, channel geometry (i.e., width, depth, slope), and topography to support future design efforts. More detailed measurements of bankfull elevations (channel-forming discharge) will support channel restoration design and to understand ground elevations in the adjacent wetland complex. The available LiDAR data set is anticipated to be sufficient to support floodplain modelling.

[1] MassDOT estimating guidance begins at the 25% design level and does not provide guidance on estimate ranges for the different stages of design.

- **Discharge measurements** during bankfull and low flow conditions is recommended for hydrodynamic model calibration as well as channel design.

- **Sediment sampling to** determine bed material size distributions will be used for describing existing and future channel type, transport, and flow resistance.

- **Resource area field delineations** will be performed to support permitting of the Project under the Wetlands Protection Act and the Worcester Wetlands Protection Ordinance and Regulations. The timing of the delineations would be dependent on the anticipated timing of permit application filings.

The following supplement data collection efforts could provide additional useful information to support the project if desired:

- **Fish, herpetofauna, and macroinvertebrate sampling** to assess habitat improvements for aquatic organisms.

- **Water quality sampling** to identify the presence/absence of constituents of concern in the Brook flow and to target potential water quality improvement methods.

The project area contains the remains of a former small mill and a stone box culvert approximately 500 feet in length. As details on past land uses in this portion of the site are unclear, a due diligence assessment of potential or existing environmental contamination concerns is necessary to ascertain whether further soil and sediment testing is warranted. This assessment will likely begin with either an environmental screening analysis or an ASTM Phase I Environmental Site Assessment, depending on the needs of the Project. Depending on the outcome of this work, further desktop, and field assessment of the Project Site in accordance with MGL c. 21E (Massachusetts Oil and Hazardous Material Release Prevention and Response Act) and the Massachusetts Contingency Plan (MCP; 310 CMR 40.0000) could be required.

A broad-based risk-benefit assessment of the potential for alteration to floodwater flow patterns, increased flood storage, reimagining local stormwater management infrastructure, channel modifications and beaver management strategies may be necessary to address potential stakeholder concerns about conveyance of flood events, channel migration, headcutting potential or channel instability. The need for a risk-benefit assessment will be determined after pre-application meetings with regulatory agencies and initial stakeholder conversations are held to identify issues that may be of concern to stakeholders.

Using the data collected, a hydrology and hydraulic (H&H) model of Broad Meadow Brook and its watershed will be prepared to evaluate existing and predicted climate change scenarios and inform selection of restoration options that will be advanced to preliminary design and permitting. The H&H model can also be used to validate existing flood-prone areas and predict how restoration options may reduce flooding risks by providing additional flood storage capacity. The model can also be extended to quantify the benefits of adding green infrastructure elements to augment the restoration project.

Timing: Begin as soon as funding is secured and continue through the design and permitting phase.

3.2 Preliminary Restoration Design (Step 3)

While data collection is ongoing, discussions will be held among Mass Audubon and the City of Worcester to review the conceptual design options identified using the funding from agreement CE00A00004, evaluate

potential new restoration options or design ideas, and to determine the restoration components that will make up the Broad Meadow Brook Restoration Project. Each option will be evaluated for its ability to achieve a self-sustaining, native riparian and wetland ecosystem providing a full suite of ecosystem services and enjoyment and benefit of neighbors, residents, and visitors. Each's options ability to meet the Project's stated goals (flood storage capacity increase; climate resilience; wetland and waterway re-naturalization; increased wetland habitat value and function; water quality and streamflow improvement; interpretation/outreach; and recreational access opportunities) will be evaluated along with the perceived benefits and the potential challenges of implementing each option. Opportunities to further enhance the use of Low Impact Development, Green Infrastructure, and Best Management Practices, if any, will be identified.

Another fundamental decision that must be made at the beginning of the design process is whether Mass Audubon or the City of Worcester want to put forward a restoration project that could receive a certification for sustainability or similar certification. As examples, the Institute for Sustainable Infrastructure provides third-party verification that projects meet certain sustainability criteria outlined in its Envision framework, and the Society of Ecological Restoration maintains a database of restoration projects. Stakeholder project reception and funding opportunities may be improved by committing to meet the required criteria or seeking such certifications. However, pursuing such a certification may also constrain the project design process to some degree.

Once these decisions are made, the Project can advance to the preliminary or (permit-level) design phase (Step 3).

The preliminary design will incorporate the results of refined H&H modeling to assess the suitability and sustainability of the proposed channel geometry. This is likely to be an iterative process, with design adjustments made in response to modeling results until a solution is identified. Mass Audubon and the City of Worcester should anticipate at least two preliminary design iterations before the Project is ready for permitting. The result of the preliminary design work will be design plans, basis of design technical memorandum, supporting data and materials, accompanying renderings or visualizations, and revised cost estimates that will be used to further engagement with partners, stakeholders, and funding sources. This information will also serve as the basis for preparing regulatory permit applications.

Timing: Start once collected data is analyzed and initial stakeholder discussions are underway. The preliminary design process for this type of project typically requires 4 to 10 months to complete, depending on the level of stakeholder involvement and interim design reviews.

3.3 Local State and Federal Permitting (Step 4)

Local, state, and federal agencies will have permitting authority over this restoration project. The efforts included to support permitting include pre-application meetings; completing application forms and supporting documents; and attending hearings, meetings, and site visits. As a component of partner engagement, regulatory agencies will be consulted prior to beginning the permitting process to identify agency concerns up front. Based on the two conceptual design options prepared, it is anticipated the following regulatory program permit authorizations would be required for project implementation, regardless of which option is advanced.

- **Massachusetts Environmental Policy Act (MEPA):** The concept designs include alteration of one or more acres of bordering vegetated wetlands. Under MEPA, this level of impact requires a mandatory Environmental Impact Report (EIR); however, based on our experience, the Project could possibly be submitted as an Expanded Environmental Notification Form (Expanded ENF) with a waiver request of mandatory EIR. This approach has been successfully applied on other projects. *Timing: First Project submittal to regulatory agencies that confirms need for state level permits.*

- **Water Quality Certification:** The Massachusetts Water Quality Certification regulations (314 CMR 9.00) include provisions that apply to Ecological Restoration Limited Projects. As an Ecological Restoration Limited Project, the project is required to obtain Water Quality Certification prior to submitting the wetlands NOI described below. A Major Fill/Excavation Project Certification (BRP WW 10) would be required for the Project since it would result in alteration 5,000 square feet or more of bordering and isolated vegetated wetlands and land under water. *Timing: Submit after MEPA process is completed and prior to initiating wetlands permitting.*

- **Wetlands Permitting:** The restoration work will take place within wetland resource areas and their buffer zones, and therefore will be subject to the jurisdiction of the Massachusetts Wetlands Protection Act (WPA) as well as the City of Worcester Wetlands Protection Ordinance and Wetlands Protection Regulations. Therefore, the Project will need to file a Notice of Intent (NOI) with the Worcester Conservation Commission for the construction, operation, and maintenance (e.g., herbicide application) of the Project, with a copy provided to the Massachusetts Department of Environmental Protection (DEP) Regional Office. It is anticipated that the Project would be eligible for review as an Ecological Restoration Limited Project pursuant to 310 CMR 10.53(4)(e)(5). Upon Project approval from the Worcester Conservation Commission, the applicant will need to record the issued Order of Conditions at the Worcester Registry of Deeds. *Timing: Submit after Water Quality Certification process is substantially complete.*

- **Federal Permitting:** As the work will result in a discharge of material to Waters of the United States, the Project will require authorization from the United States Army Corps of Engineers (USACE) under Section 404 of the Clean Water Act. The project is expected to be eligible for coverage under the Massachusetts General Permit through the submittal of a Pre-Construction Notification (PCN) to the USACE New England District. The Project would likely fall under General Permit 23: Aquatic Habitat Restoration, Establishment and Enhancement Activities. *Timing: Confirm ability of USACE to authorize Project under MA General Permit 23 during MEPA review process. Submit GP 23 PCN after wetlands permitting process is substantially complete. If an Individual Permit authorization is necessary, submit at same time Water Quality Certification application is submitted.*

Timing: Start pre-application meetings with regulatory agencies as early as possible to inform Project design. The regulatory permitting process could require approximately 12 months to complete if MEPA grants the waiver from the EIR requirement for the Project. If the waiver is not granted, the MEPA EIR process could add another 12-18 months to the permitting timeframe.

Prior to initiating project construction, notifications to regulatory agencies such as the USACE, MassDEP, and the Worcester Conservation Commission will likely be required. Additionally, as the Project will likely entail over one acre of land disturbance, the work will require the development of a Stormwater Pollution Prevention Plan (SWPPP) and submittal of a Notice of Intent to the USEPA seek coverage under the

National Pollutant Discharge Elimination System (NPDES) Construction General Permit (CGP). *Timing: Submit after contractor is selected for Project construction and at least 14 calendar days before commencing construction activities.*

3.4 Final Engineering Design and Contract Preparation (Step 5)

The final design plan development process begins when regulatory permitting is substantially complete. The final design package is prepared to provide the necessary information for the contractor to successfully execute the work and incorporate permit conditions that have been placed on the Project. This involves modifying the preliminary drawings and details to include bid and construction level detail, preparing the final itemized cost estimate, and preparing technical specifications.

The final design package would then be incorporated into bid documents meeting the requirements of Mass Audubon or the City of Worcester, depending on which entity would bid and contract the work.

Timing: Start when the regulatory permitting process is substantially complete. Preparation of final designs and bid documents for a project like this one typically requires about 2-6 months to complete.

3.5 Project Implementation and Construction (Step 6)

Construction of the Project would be bid out to qualified contractors. There are a growing number of contractors that specialize in construction of ecological restoration projects and have prior experience in Massachusetts. Steps during the bid phase for construction typically include advertising and distributing the bids documents to potential bidders, a pre-bid conference, preparation of addenda as needed to clarify the scope for contractors, completing bid tabulations and evaluations, conducting reference checks, and selecting a bidder for contract award.

Once the contractor is selected, a consultant typically provides construction management and oversight including shop drawing reviews, addressing contractor requests for information, regulatory agency notifications and coordination, and field monitoring to help assure successful project construction in accordance with the requirements of the contract documents. Diligent oversight by experienced construction engineers and scientists is critical to ensuring compliance with contract plans, contract specifications, issued permit conditions, and good engineering practices.

The final step in the process is preparing “as-built” Record Drawings, turning the site over to the owner, and initiating the post-construction monitoring.

Timing: Start after bid documents are complete and ready for distribution to potential bidders. The bidding and contracting process typically requires less than 6 months to complete. The duration of construction will depend on the level of construction effort required, project phasing decisions, timing of construction in relation to seasons and regulatory agency time of year restrictions (if imposed), and availability of funding.

3.6 Post-Construction Monitoring and Adaptive Management (Step 7)

Post-construction monitoring is important to evaluate the performance of restoration measures implemented as part of the restoration project and provides useful information for future restoration efforts. It is important that monitoring plans are feasible in terms of costs and technology, and provide information relevant to meeting the project goals. (USEPA, 2000)

Maintenance of the constructed Project may require the use of herbicides to control the growth of invasive species. Any herbicide application must be conducted by a Massachusetts pesticide-licensed applicator with a valid license from the Massachusetts Department of Agricultural Resources. For herbicide treatments applied to waterbodies, a License to Apply Herbicides to the Waters of the Commonwealth (BRP WM 04) from MassDEP Bureau of Resource Protection is also required annually prior to undertaking herbicide applications. Such work would be performed as maintenance under the Order of Conditions issued for the restoration project. *Timing: Submit on an annual basis prior to herbicide use.*

As a component of the restoration design process, project partners will identify a suite of measurable criteria to evaluate restoration implementation in light of project goals, identify the need for intervention to influence system response, and determine if changes to operations and/or management are warranted. The specifics of the monitoring program and the length of monitoring period will be influenced by the elements included in the final design plans as well as input from project partners and regulatory or funding agencies. The monitoring plan is anticipated to focus on biological monitoring, including assessments of physical habitat and fish and benthic macroinvertebrate communities as well as physical habitat assessments to evaluate substrates, habitat availability, water quality, presence of invasive plants, and streambank stability conditions. Additional post-construction monitoring and reporting requirements may also need to be met for compliance with the conditions of issued permits and approvals.

Post-construction adaptive management is an iterative process involving predictions of management actions, system response monitoring, comparisons to predicted outcomes, and using the results to guide future management actions. The knowledge gained through post-construction monitoring improves the ability to predict future outcomes and make better decisions regarding the selection of appropriate future management actions.

Unlike reactive processes, adaptive management seeks to compare predicted outcomes to observed system responses to improve decision making over time, rather than trial and error. Adaptive management allows for flexibility in adjusting decisions as outcomes from management actions and other events become better understood. Characteristics of the Broad Meadow Brook Restoration Project provide the conditions appropriate for using an adaptive management approach.

Timing: Start pre-construction monitoring before work begins at the site. Post-construction monitoring is typically performed at pre-defined intervals after construction is completed and may extend for several years depending on permit conditions and stakeholder/funding source requirements.

3.7 Engagement, Visioning, and Funding

3.7.1 Partner Engagement and Funding Sources

Building consensus among the people and organizations potentially affected by the project is an important early step to build the broad support needed to get the project moving and ensure long-term protection and stewardship. Partnering with stakeholders can lead toward funding opportunities and technical expertise with implementation and monitoring. To date, project partners have been limited to the City and DER. If participation from additional Project Partners and landowners can be obtained, there may be opportunities to implement potential water quality or other improvements within the developed upstream portions of the Broad Meadow Brook watershed. Determining if it is possible to expand this coalition should be an early step in the process as this step is tied to developing the overall restoration plans that will be advanced and the fundraising strategy for the Project.

Complex ecological restoration projects often require funding from multiple sources for project design and implementation. Engaged project partners are critical to identifying and securing highly competitive funding. In general, projects with multiple partners along with strong local and state agency support are more likely to receive support. Mass Audubon has recently secured provisional Priority Project designation from DER. One of the objectives of work described in Section 2 was positioning the Project to receive full Priority Status to continue the technical assistance from DER staff; technical services from consultants under contract to DER; and/or direct grant funding. With Priority Project status, the agency can work in partnership with Mass Audubon and other project partners to advance the project. DER staff are particularly adept at working with other partners to identify additional funding possibilities from national, state, local, non-profit, and private sources.

Potential funding sources that should be investigated for the Project include:

- Federal funding through USEPA grants administered by MassDEP, NEIWPCC, and NBEP.
- Federal funding through USEPA grants administered by Restore America's Estuaries through the Southeast New England Program (SNEP).
- Federally funded assistance through the SNEP Network, which provides training and assistance to municipalities, organizations, and tribes to advance stormwater and watershed management, ecological restoration, and climate resilience in Rhode Island and Massachusetts.
- Federal funding through the NFWF Five Star and Urban Waters Restoration Program
- Federal funding through USACE In-Lieu Fee Program administered by the Massachusetts Department of Fish & Game
- Federal funding that may be directed to Massachusetts projects from the Infrastructure Bill currently in development in Congress.
- State funding through DER.
- State funding through the Municipal Vulnerability Preparedness (MVP) Program.

- Federal/state hazard mitigation funding if modeling can demonstrate significant reductions in flooding impacts resulting from the Project.

- City of Worcester budget appropriations or other funding sources. The City of Worcester has not adopted the Massachusetts Community Preservation Act, so CPA would not be a source of funding for the Project

- NGO funding through the Barr Foundation or similar organizations.

Timing: Start immediately and maintain ongoing progress throughout project development and implementation.

3.7.2 Public Participation/Engagement and Visioning

As stated in its 2015-2020 Strategic Plan, "Mass Audubon is uniquely positioned to build lasting bonds between people and the natural environment and inspire adults and children alike to form positive, personal connections to nature." An effective public participation program tailored for the Broad Meadow Brook restoration project creates an ideal opportunity to forward this broad goal (especially with urban audiences in mind) through engaging students, volunteers, and experts. The following discussion provides a suggested framework and guiding principles to implement an effective public participation and visioning program for the Broad Meadow Brook project. With the current high level of visitation to the Sanctuary, a proactive approach is critical to help the community understand the need to undertake restoration and the landscape changes that may result.

Mass Audubon and the City of Worcester will develop an active stakeholder engagement process that will seek input from Broad Meadow Brook abutters, the citizens of Worcester, and interested environmental stakeholder groups. The process will seek meaningful involvement of all interested people so they may participate in making the Broad Meadow Brook Restoration Project something that can provide environmental and recreational benefit to as many people as possible.

Mass Audubon is presently considering public opinion surveys as a way to seek input on topics such as recreational uses in the Sanctuary, alignment with the Project overall objectives, and understanding of the Project benefits.

The community becomes involved with restoration projects through the regulatory hearing process as well as through proactive public participation throughout the life cycle of a project. Maintaining an open dialogue and a sustained close relationship with the community is critical to building credibility. This trust is often critical to receiving the necessary approvals to undertake projects on both private and public land. The approach would be to present the Project Partners' vision for the Project to the surrounding neighborhood prior to submitting permit applications. This would allow the neighbors to feel engaged in the process and provide their feedback. The Project Partners can then assess the feedback/suggestions received and incorporate them into the Project where warranted. At this point, broader outreach to the Worcester community could be made to present the project and solicit support.

Opportunities may also exist to include neighboring residents in monitoring and maintenance (e.g., control of invasive plants) to foster public engagement to better understand the benefits the Project would bring, provide a tangible benefit to ecosystem improvement, and cultivate a sense of ownership or long-term buy-in within the community.

After the Project is constructed, direct community involvement offers the potential for tremendous opportunities for the public to learn about the health of this urban ecosystem and water quality and habitat improvements over time. The possibility of involving local school systems in these learning opportunities should not be overlooked as an extension of current outreach efforts at the Sanctuary. While sustained and responsive face-to-face communication with the community can take an incredible amount of work, it can produce transformative effects for community and their waterways when done well (Druschke and Hychka 2015).

Timing: Start immediately and maintain ongoing progress throughout project development and implementation.

4.0 LITERATURE CITED

Druschke, C. G., and K. C. Hychka. 2015. Manager perspectives on communication and public engagement in ecological restoration project success. Ecology and Society 20(1): 58.

USEPA, 2000. Principles for the Ecological Restoration of Aquatic Resources. EPA841-F-00-003. Office of Water (4501F), United States Environmental Protection Agency, Washington, DC.

Appendix A

Existing Cover Types and Conceptual Restoration Design Alternatives

Legend

- Culvert
- Broad Meadow Brook Sanctuary Boundary
- Parcel (City of Worcester, 2019)
- Watershed
- Shallow Marsh
- Shrub Swamp
- Wooded Swamp
- Phragmites
- Upland

Cover Type

- Deep Marsh

0 100 200 Feet

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No.	REVISION	DATE	APP BY

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DESIGNED BY: CW	APPROVED BY: CW

MASS AUDUBON
BROAD MEADOW BROOK
WILDLIFE SANCTUARY

WORCESTER, MASSACHUSETTS

EXISTING COVER TYPES

RESTORATION ROAD MAP

SHEET 1 OF 1

Path: C:\Users\SDetterhead.ESSGROUP\Documents\GIS\MXD_000_ConceptualDesign_Fig01_Limited.mxd

Section A

Section B

Section C

Existing Trail to Remain

MATCH LINE

Legend

- Existing Trail
- Terrain Contour (1' Interval)
- Terrain Contour (10' Interval)
- Section Line
- Parcel
- Constructed Channel
- Cut/Fill Transition
- Elevated Wooded Zones
- Excavated Open Water
- Invasives Control
- Broad Meadow Brook Sanctuary Boundary
- Timber Boardwalk

0 100 200 Feet

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MASS AUDUBON
BROAD MEADOW BROOK
WILDLIFE SANCTUARY

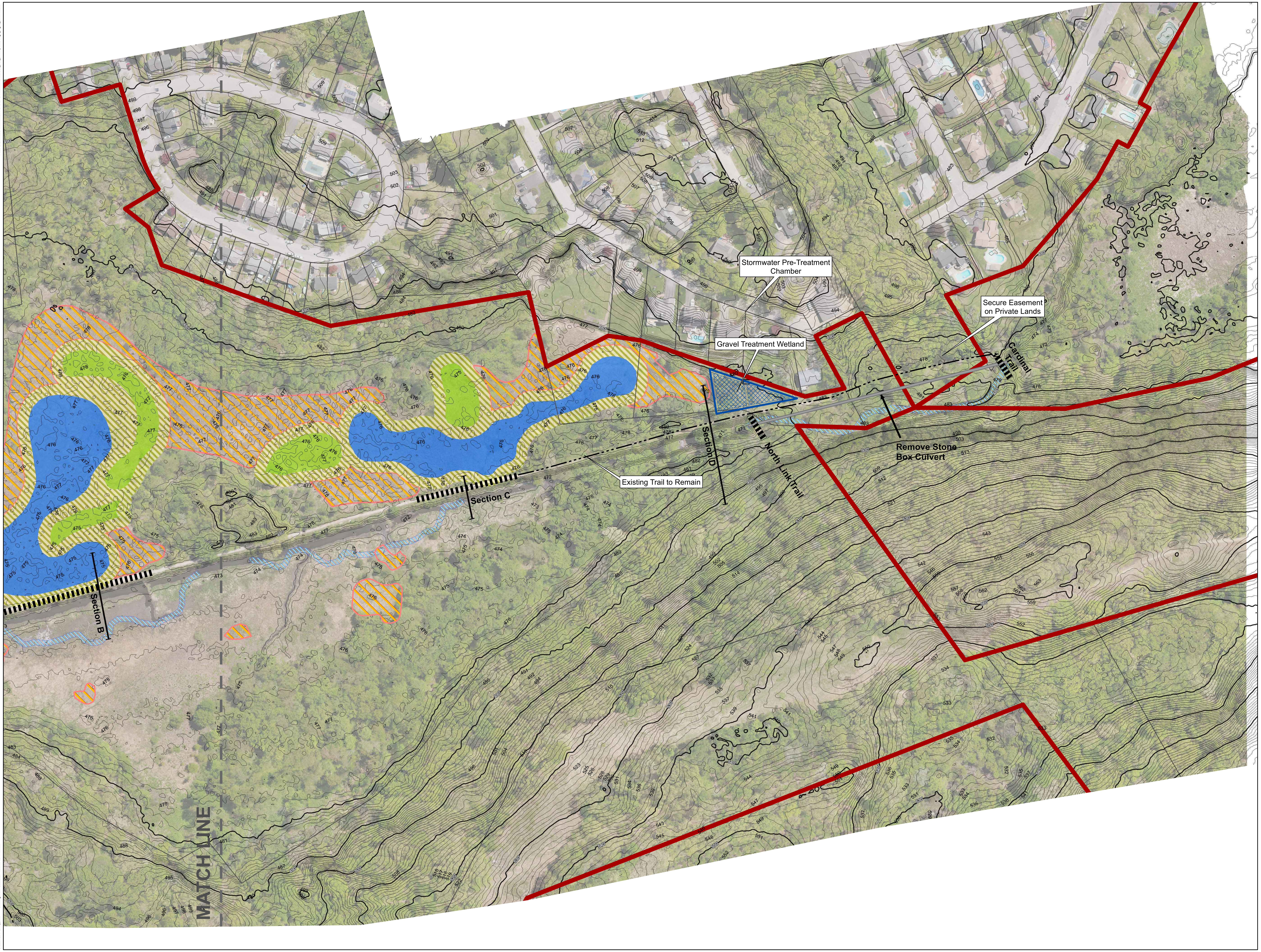
WORCESTER, MASSACHUSETTS

CONCEPTUAL RESTORATION DESIGN

OPTION 1 - RESTORATION WITH LIMITED TRAIL IMPROVEMENTS

SHEET 1 OF 2

 Drawing Date: 8/23/2021 Author: SDetterhead



Legend

- Existing Trail
- Terrain Contour (1' Interval)
- Terrain Contour (10' Interval)
- Section Line
- Parcel
- Constructed Channel
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0 100 200 Feet

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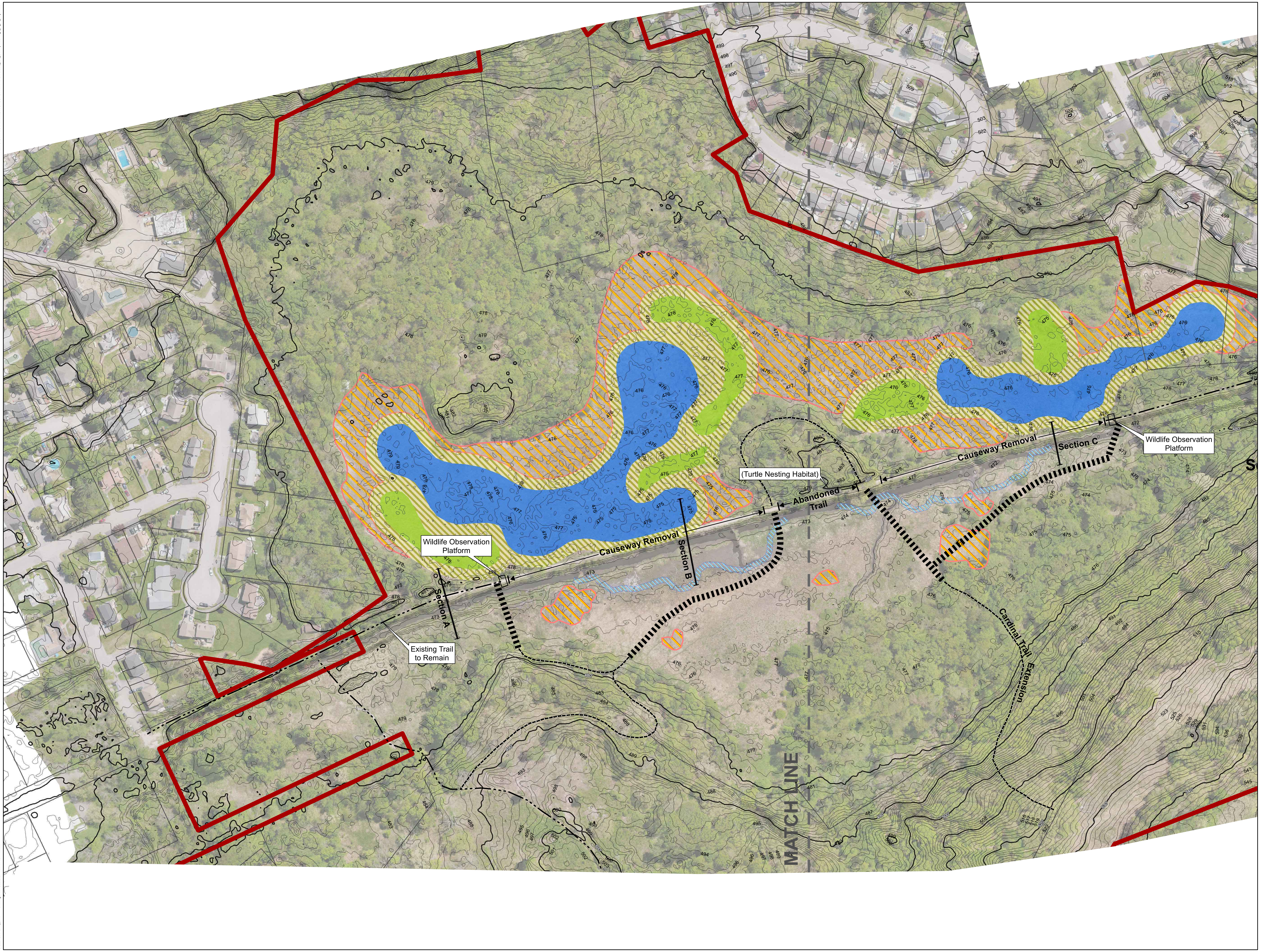
WORCESTER, MASSACHUSETTS

CONCEPTUAL RESTORATION DESIGN

OPTION 1 - RESTORATION WITH LIMITED TRAIL IMPROVEMENTS

SHEET 2 OF 2



Legend

- Existing Trail
- Terrain Contour (1' Interval)
- Terrain Contour (10' Interval)
- Section Line
- Parcel
- Constructed Channel
- Cut/Fill Transition
- Elevated Wooded Zones
- Excavated Open Water
- Invasives Control
- Broad Meadow Brook Sanctuary Boundary
- Proposed Trail Extension
- Timber Boardwalk

0 100 200 Feet

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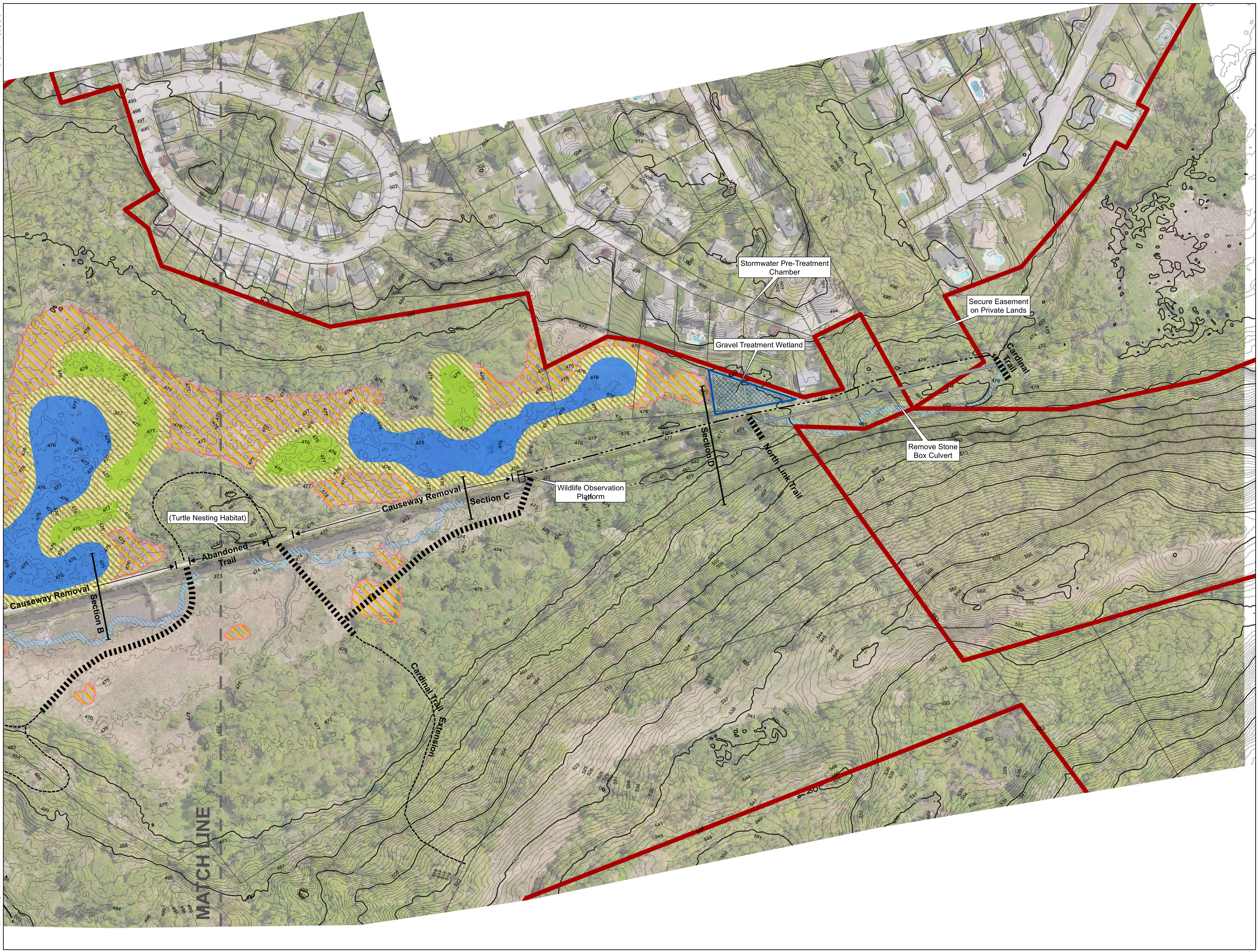
MASS AUDUBON
BROAD MEADOW BROOK WILDLIFE SANCTUARY

WORCESTER, MASSACHUSETTS

CONCEPTUAL RESTORATION DESIGN

OPTION 2 - RESTORATION WITH MAJOR TRAIL IMPROVEMENTS

SHEET 1 OF 2



Legend

- Existing Trail
- Terrain Contour (1' Interval)
- Terrain Contour (10' Interval)
- Section Line
- Parcel
- Constructed Channel
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0 100 200 Feet

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MASS AUDUBON BROAD MEADOW BROOK WILDLIFE SANCTUARY

WORCESTER, MASSACHUSETTS

CONCEPTUAL RESTORATION DESIGN

OPTION 2 - RESTORATION WITH MAJOR TRAIL IMPROVEMENTS

Appendix B

May 2020
UAS Orthoimagery
Metadata

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Broad Meadow Brook Restoration Project

May 2020 UAS Orthoimagery Metadata

Capture Date: 5/22/2020 by ESS Group, Inc.

File Creation Date: 9/14/2021

File Resolution: 0.1ft/pixel

Camera: DJI Xenmuse X5S (FC6520)

Ground Sampling Distance: 2.00cm/0.79in

Projected Coordinate System: NAD83 State Plane (Mass Mainland, FIPS 2001) US Feet

Coverage Area: 202.63acres

Bounds: WEST LONGITUDE=71.7773496590° W, NORTH LATITUDE=42.2437436089° N, EAST LONGITUDE=71.7693425490° W, SOUTH LATITUDE=42.2324858524° N

Orthophotography was cloud processed using DroneDeploy and georeferenced using Ground Control Points (GCPs) collected with Trimble Geo7X (5996 positions collected at 10 locations) and corrected using GPS Pathfinder Office (average accuracy <30cm).

Attachment C

May 2020
UAS Orthoimagery

Available for Download at:
https://1drv.ms/u/s!AlpAB0XvpN4trC1sNkl5eHXh3fmd?e=Vfl61B
Until October 15, 2021