Phase 1

Adaptive Management Plan

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January 28, 2008

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Job File:

GENfd1:138

January 28, 2008

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List of Abbreviations

CD	Consent Decree
CU	Certification Unit
EPA	United States Environmental Protection Agency
ESUH	Especially Sensitive or Unique
FCI	Functional Capacity Index
GE	General Electric Company
HD Report	Habitat Delineation Report
HDA Work Plan	Habitat Delineation and Assessment Work Plan
HSI	Habitat Suitability Index
NRC	National Research Council
OM&M Scope	Operation, Maintenance, and Monitoring Scope
Phase 1 AM Plan	Phase 1 Adaptive Management Plan
Phase 1 Cap/ Habitat OM&M Plan	Operation, Maintenance, and Monitoring Plan for Phase 1 Caps and Habitat Replacement/ Reconstruction
Phase 1 FDR	Phase 1 Final Design Report
Phase 1 HA Report	Habitat Assessment Report for Candidate Phase 1 Areas
Phase 2 HA Report	Habitat Assessment Report for Phase 2 Areas
RD AOC	Remedial Design Administrative Order on Consent
RD	Remedial Design
ROD	Record of Decision
SAV	Submerged Aquatic Vegetation
SHAWP	Supplemental Habitat Assessment Work Plan
SHO	Shoreline
SOW	Statement of Work
UCB	Unconsolidated Bottom
WET	Wetlands

SECTION 1
INTRODUCTION

This *Phase 1 Adaptive Management Plan* (Phase 1 AM Plan) describes the adaptive management process for habitat replacement and reconstruction in areas to be dredged in Phase 1 of the remedial action for the Upper Hudson River. It has been prepared on behalf of General Electric Company (GE) as part of the remedial design for Phase 1 of the remedy selected by the United States Environmental Protection Agency (EPA) and in accordance with: 1) the *Habitat Delineation and Assessment Work Plan* (HDA Work Plan; BBL 2003a), which is part of the Administrative Order on Consent for Remedial Design and Cost Recovery (RD AOC), effective August 18, 2003 (Index No. CERCLA-02-2003-2027); 2) GE's *Habitat Assessment Report for Candidate Phase 1 Areas* (Phase 1 HA Report; BBL and Exponent 2005a), which was approved by EPA in November 2005; and 3) Section 4 of the *Operation, Maintenance, and Monitoring Scope* (OM&M Scope), which is Attachment E to the Statement of Work (SOW) that is part of the Consent Decree (CD) executed by GE and EPA and entered by the federal district court on November 2, 2006 (EPA and GE 2006). This Phase 1 AM Plan is part of the Phase 1 Final Design, consistent with the Remedial Design Work Plan (BBL 2003b).

1.1 BACKGROUND AND OVERVIEW

In the 2002 Record of Decision (ROD) for the Site (EPA 2002), EPA divided the Upper Hudson River into three sections, illustrated on Figure 1-1, as follows:

- River Section 1: Former location of Fort Edward Dam to Thompson Island Dam (approximately 6.3 River Miles);
- River Section 2: Thompson Island Dam to Northumberland Dam (approximately 5.1 River Miles); and
- River Section 3: Northumberland Dam to the Federal Dam at Troy (approximately 29.5 River Miles).

The ROD calls for sediment remediation to be undertaken in two distinct phases. Phase 1 of the remedial action will consist of the first year of dredging and will occur within River Section 1. Phase 2 of the remedial action will consist of the remainder of the dredging project. The Phase 1 dredge areas are shown on Figure 1-2 and were discussed in detail in the *Phase 1 Final Design Report* (Phase 1 FDR; BBL 2006).

Following submittal of the Phase 1 FDR, the final Phase 1 design continued through numerous exchanges of information between GE and EPA and additional submittals by GE. These exchanges and additional submittals included several that related to the design of the habitat replacement and reconstruction program.[1] As discussed in the HDA Work Plan, that program relates to the replacement or reconstruction of the four habitat types within the Upper Hudson River: unconsolidated river bottom, aquatic vegetation beds (sometimes referred to as submerged aquatic vegetation or SAV), shorelines, and riverine fringing wetlands. A Habitat Decision Matrix (Figure 1-3) was used to identify the locations and types of habitats to be replaced/reconstructed. (The SAV Model referenced in that matrix is described in Exhibit C.) In particular, the designs for backfill, SAV, and shoreline progressed after the Phase 1 FDR was submitted. Technical memoranda submitted to EPA that provide a description for these designs include:

- Design of Backfill and Submerged Aquatic Vegetation (J. Haggard of GE to D. Garbarini of EPA, June 4, 2007);
- Backfill Availability (S. Blaha of GE to D. Garbarini of EPA, July 5, 2007); and
- Shoreline Design (S. Blaha of GE to D. Garbarini of EPA, July 16, 2007).

Comments and responses regarding these technical memoranda are summarized in three matrices that EPA transmitted to GE on November 30, 2007 (EPA 2007b). The final design for dredging operations and habitat construction, including the designs for backfill, capping, shoreline restoration, and planting (as described in the above memoranda and comment response matrices), was approved by EPA on November 30, 2007. The scope and location of the habitat

[1] For the purposes of the contracting and design specifications developed to support this program, habitat replacement and reconstruction is referred to as "habitat construction."

types are designated in the contract documents. A summary of the remediation quantities (acres or linear feet) for each habitat type is given in Table 1-1. Subsequent field response actions as part of OM&M shall consist of those actions listed in the OM&M Scope (p. 4-13 through p. 4-14), plus any additional actions that are agreed upon by GE and EPA as appropriate for adaptive management, based on field experience. Also, as stated in the OM&M Scope (p. 4-14), the adaptive management program will not require the implementation of changes in the type of habitat from the types designed and implemented as part of the habitat replacement/reconstruction program. However, as discussed in Section 4.3 of this Phase 1 AM Plan, a reevaluation of site-specific goals may be an option as part of an additional adaptive management response action, provided that EPA and GE agree.

In addition to these design activities, habitat delineation and assessment activities were conducted, beginning in 2003, to:

- document the nature and distribution of the four types of habitats potentially affected by remediation;
- identify reference habitat locations representing the range (i.e., distribution) of existing conditions; and
- document physical and biological characteristics of the existing habitats to develop criteria for determining when post-remediation habitat conditions fall within the ranges of reference conditions.

Details on habitat delineation and assessment activities can be found in the following documents:

- *Habitat Delineation Report* (HD Report; BBL and Exponent 2006) (which will be revised and resubmitted based on comments received from EPA on May 2, 2007).
  - Describes the methods used to delineate the four habitat types in River Sections 1, 2, and 3 of the Upper Hudson River.
  - Provides large scale maps of delineated habitats.

- *Habitat Assessment Report for Candidate Phase 1 Areas* (Phase 1 HA Report; BBL and Exponent 2005a).
  - Describes the results of the habitat assessments completed in Phase 1 areas.
  - Lists the species for which habitat suitability index (HSI) model scores will be calculated.
- *Habitat Assessment Report for Phase 2 Areas* (Phase 2 HA Report; QEA 2007) (revised and resubmitted on July 11, 2007, based on comments from EPA on a prior version).
  - Describes the results of the habitat assessments completed in Phase 2 areas.
  - Provides the results for the reassessments of Phase 1 areas.
- *Supplemental Habitat Assessment Work Plan* (SHAWP; BBL and QEA 2006)
  - Describes the process used to select habitat assessment station locations.
  - Provides the standard operating procedures for calculating HSI model scores.
- *Hudson River Remedial Design - 2007 Habitat Assessment Field Work* (GE 2007)
  - Describes the process used to select the 2007 field season habitat assessment locations.

1.2 HABITAT REPLACEMENT AND RECONSTRUCTION AND ADAPTIVE MANAGEMENT

Following sediment remediation, habitat replacement and reconstruction will be implemented. The ROD specifies, “A habitat replacement program will be implemented in an adaptive management framework to replace SAV communities, wetlands, and river bank habitat” (EPA 2002, p. A-3). The HDA Work Plan explains that the primary goal of this program is “to replace the functions of the habitats of the Upper Hudson River to within the range of functions found in similar physical settings in the Upper Hudson River, in light of changes in river hydrology, bathymetry, and geomorphology that will result from the implementation of the USEPA-selected remedy and from possible independent environmental changes that may occur from other factors.”

As described in the Phase 1 FDR, Phase 1 of the remedial action is designed to remove a target volume of 265,000 cubic yards of sediments from over 90 acres of the Upper Hudson

River, followed by backfilling or engineered capping. Dredging and backfilling/capping activities will necessarily disturb the existing habitats. Adaptive management provides a framework for design and monitoring of the habitat replacement and reconstruction. It will be used in a systematic manner to maximize the probability that the areas impacted by Phase 1 of the remedy will be brought within the range of conditions in similar physical settings in the Upper Hudson River, as specified in the above-quoted goal.

Adaptive management is a suite of assessment and management tools most appropriately applied where uncertainty exists and where decisions are best made on the basis of accumulated information – which is precisely the case for the Upper Hudson River habitat replacement and reconstruction. Since ecosystems are not machines that can be engineered to yield precisely determined outcomes, the habitat replacement and reconstruction program is a challenge best met by a "design with nature" approach (Kangas 2004). In this situation, adaptive management is the process by which ecological processes, also known as "natural engineering", are fostered to assist habitat replacement and reconstruction following the "hard engineering" of the remedial action.

In adaptive management, the goal of achieving a desired range of habitat characteristics is met by applying site-specific habitat information in an iterative framework of measurement and response (Holling 1978; Thom 1997). In this framework, no single goal determines success or failure. Rather, if certain goals are not being met, additional monitoring is conducted and decisions are made regarding the need for and approach to particular adaptive responses. Flexibility is an important component of adaptive management, so the potential responses cover a broad range of possibilities. These potential responses include additional monitoring, literature research, experiments, consultations with discipline experts, re-evaluation, and restatement of goals and success criteria, and/or active intervention (such as planting desired species or removing invasive plant species). Potential responses and applications are identified and discussed in greater detail in Section 4.

As described in the OM&M Scope and this Phase 1 AM Plan, adaptive management at the Upper Hudson River will include frequent and routine reporting of habitat monitoring data collected under the OM&M program. Specifically, this program will include monthly reporting of monitoring data collected as part of the habitat OM&M program and annual reporting of the habitat monitoring data collected, the results of adaptive management evaluations, and any actions performed during the current year and previous years.

As stated in the OM&M Scope (p. 4-9 through p. 4-10):

> [W]hen parameters(s) from target areas within an appropriate scale (i.e., River Section or reach) are within the range of parameter(s) from reference areas, considering overall distribution of values within habitats and within the relevant river section or reach, the habitat replacement/reconstruction within those target areas shall be considered successful. . . Given the changes in river conditions that will result from the dredging, the objective for a specific dredged area cannot be established *a priori* as either the "low end" or "high end" of the range of parameters based on reference areas, since physical conditions in each area will determine where the post-dredging habitat falls within these bounds. GE will establish a mix of habitats, taking account of physical conditions in the post-remediation environment, and that habitat mix shall be evaluated against the mix of habitats in reference sites with similar physical conditions. This evaluation of success shall be made for each habitat type and shall be based on comparing the overall distribution of the relevant parameters from the dredged areas within a given spatial extent of the river to the overall distribution of such parameters in the pertinent reference areas, using appropriate statistical tests.

As further stated in the OM&M Scope (p. 4-3):

> [I]t is anticipated that comparisons of the range of conditions in reference and remediated areas will be made by statistical tests appropriate for the collected data. A 'spatially-weighted average' and use of negative null hypotheses are possible techniques that will be considered. The appropriate spatial scale for these comparisons will be determined by the data, and may consist of comparisons on a reach basis or on an overall river section basis. The spatial scale for these

comparisons and the specific statistical techniques to be used in the comparisons will be included in the Adaptive Management Plan, which will be part of the Final Design Report, for each phase of dredging.

In addition, as stated in the OM&M Scope, general narrative descriptions of success criteria and hypotheses will be provided in the Adaptive Management Plans that will accompany the Final Design Reports (OM&M Scope, p. 4-12). Regarding success criteria, the OM&M Scope states, "[i]t is the parties expectation that the success criteria will not be biased to the high or low ends of the bounds of expectations" (OM&M Scope, p. 4-8). These concepts are addressed in more detail in Section 2. The range of characteristics will be established by measuring specific physical and biological parameters, as described in the HDA Work Plan (Attachments A to D) and the OM&M Scope (p. 4-4 through p. 4-6).

1.3 CONTENTS OF THE ADAPTIVE MANAGEMENT PLAN

This plan provides the detail for addressing elements commonly found in adaptive management programs used for water resource management (National Research Council [NRC] 2004), natural biological resource management (Lee 1999), and ecosystem restoration (Thom 1997). According to the NRC (2004), adaptive management is not a one-size-fits-all process. Instead, each project's adaptive management plan contains unique features that are dependent on the type of project, the process for developing the project, and a variety of other factors. At the same time, adaptive management plans typically contain certain common elements, summarized by the NRC (2004) as follows:

- management objectives that are regularly revisited and revised as needed;
- a model of the ecosystem being managed;
- a range of management options;
- monitoring and evaluation of outcomes of management actions;
- mechanisms for incorporating learning into future decisions; and
- a structure for incorporating stakeholder involvement and learning.

Consistent with the NRC (2004) description, this Phase 1 AM Plan provides an Upper Hudson-specific adaptive management design, while generally including the common elements listed above. The remainder of this Phase 1 AM Plan consists of the following five sections:

- Section 2 describes the general narrative criterion that will be used to determine if the habitat replacement/reconstruction is successful (for each habitat type and for the Phase 1 areas as a whole), the primary and secondary quantitative success criteria that will be used to implement the narrative criterion for each habitat type, and certain adaptive management benchmarks that will be used to assist in achieving the success criteria by triggering specific response actions where appropriate.
- Section 3 describes the type of monitoring that will be conducted during the adaptive management program.
- Section 4 describes the types of adaptive responses that may be used if habitats do not meet success criteria or if certain field conditions exist.
- Section 5 describes the schedule for submitting the Adaptive Management Reports.
- Section 6 lists the references used in preparing the Adaptive Management Plan.

In addition, several exhibits are included in this plan to provide more detailed information on certain aspects of the habitat replacement/reconstruction design or of the adaptive management program described in this Plan. These exhibits are:

- Exhibit A – describes the roadmap or framework to be used for selecting the final quantitative success criteria for each habitat.
- Exhibit B – describes the current status of the Habitat Suitability Index (HSI) models.
- Exhibit C – describes the SAV model used to identify planting and contingency areas.
- Exhibit D – describes the pre-planting inspections that will be completed to determine the suitability of reconstructed riverine fringing wetland and SAV areas for planting.

- Exhibit E – describes the Invasive Species Management Plan for Phase 1.
- Exhibit F – contains maps provided by the natural resource trustees depicting areas that they regard as "especially sensitive or unique habitats."[2]

[2] These maps are provided as an exhibit to this Phase 1 AM Plan at EPA's request. GE does not accept the designation of these areas as "especially sensitive or unique" (ESUH), and has not used these maps (or their underlying concept) in the development of the habitat replacement/reconstruction design, the success criteria for habitat replacement/reconstruction, or the adaptive management program. The ESUH maps were used by EPA in developing the guiding principles to allocate placement of the 15% additional backfill for SAV beds in the Phase 1 Final Design (EPA, November 22, 2006).

SECTION 2
SUCCESS CRITERIA

There are two kinds of success criteria that will be used to determine whether habitat replacement/reconstruction is complete – a general narrative criterion and the final quantitative criteria. The narrative success criterion is simply a general statement that describes when the overall program will be considered successful. As applied to a given habitat type, the narrative success criterion is a general statement of attainable or attained conditions of biological integrity for that habitat and establishes a positive statement about what should occur within a given biological entity (see EPA 2007a). In accordance with the OM&M Scope (pp. 4-9, 4-12), this AM Plan includes the general narrative criterion, as well as general descriptions of success criteria and hypotheses. In addition, this AM Plan provides a general description of the quantitative criteria that will be used to implement the narrative criterion for each habitat type. GE and EPA are currently engaged in collaborative efforts to develop specific quantitative success criteria for each habitat type. Quantitative success criteria will be set forth in the *Operation, Maintenance, and Monitoring Plan for Phase 1 Caps and Habitat Replacement/ Reconstruction* (Phase 1 Cap/Habitat OM&M Plan). As stated in the OM&M Scope (p. 4-12), "[s]pecific numerical criteria will be developed when post-remediation monitoring is initiated, to account for contemporaneous conditions in the reference areas as well as pre-remediation conditions throughout each river section." The discussion of success criteria in this section is limited to Phase 1 of the remedial action.

2.1 OVERALL APPROACH

For the Upper Hudson River habitat replacement/reconstruction program for each Phase 1 habitat type and for Phase 1 areas as a whole, the narrative success criterion is as follows (based on, for example, the HDA Work Plan (pp. 1-2, 1-4) and the OM&M Scope (pp. 4-1, 4-8, 4-9):

Narrative Success Criterion

When the characteristics of the replaced/reconstructed habitats within a River Section or reach (or an alternate spatial scale agreed upon by GE and EPA based on the data) fall within the range of characteristics in similar physical settings in the Upper Hudson River, as defined by reference conditions (including both pre-remediation conditions and conditions in post-remediation reference areas), considering the overall distribution of those characteristics within such habitats in the relevant River Section or reach (or alternate spatial scale agreed upon by the parties based on the data), and the length of time over which the characteristics in each replaced/reconstructed habitat type falls within the range of the reference conditions for that habitat type, the habitat construction will be considered successful. The characteristics of each habitat type consist of both physical and biological parameters that represent structure and function.

To determine whether this narrative success criterion has been met, quantitative success criteria for each habitat type will be applied. The primary quantitative success criteria for each habitat type will be based on specific parameters for which field data have been or will be collected and on functional equivalence. The OM&M Scope listed the structural and functional parameters for which such quantitative success criteria were to be developed (OM&M Scope, p. 4-10), as well as the specific parameters to be sampled in each habitat type (OM&M Scope, p 4-4 through p. 4-6) to support application of those criteria. Based on these parameters, collaborative working group efforts by GE and EPA over the past several months have resulted in a technical approach that will be used, if GE and EPA agree, to develop appropriate quantitative success criteria for each of the four habitat types of interest: unconsolidated bottom (UCB), SAV, shoreline (SHO), and riverine fringing wetlands (WET). The process for development of quantitative success criteria is described in Exhibit A in what has been referred to as a "road map." This process strives to develop a statistically based approach for each habitat type, to the extent feasible given the type(s) of data.

Note that the OM&M Scope anticipated that the primary success criteria for each habitat type would be based on the specific measured parameters listed on page 4-10 of the OM&M

Scope and on functional equivalence as defined by habitat-specific Functional Capacity Index (FCI) models and Habitat Suitability Index (HSI) models calculated from the parameters listed on pages 4-4 to 4-6 of the OM&M Scope. The derivation and potential use of FCI models have been the subject of much discussion between GE and EPA and led to the alternative approach described in Exhibit A. Thus, the FCI models are not discussed in this Phase 1 AM Plan or its exhibits. If collaborative efforts to develop or reach consensus on such alternative success criteria are not successful, then the FCI model approach as discussed in the OM&M Scope (p. 4-8 through p. 4-12), including model calibration, validation and verification, will be used to develop the success criteria for one or more habitat types. Any such calibration, validation and verification would be completed in accordance with Section 6.3.3 of the EPA-approved Phase 1 HA Report. In that event, the results of analyses performed for the Exhibit A "roadmap" would be applied to the FCI model output if appropriate and agreed to by EPA and GE.

For each of the four habitat types – unconsolidated bottom, aquatic vegetation beds, natural shorelines, and riverine fringing wetlands – the primary quantitative criteria will focus on the measured parameters listed on page 4-10 of the OM&M Scope, as well as a measure(s) of habitat functionality (i.e., FCIs and HSIs, or functional equivalent). The functional equivalent for each habitat type is expected to be based on some or all of the individual parameters of the FCIs and/or HSIs. Data for the specified parameters may be collected in both target and reference areas, before and after dredging, if those data do not exist. These criteria will involve a statistical evaluation, if feasible, of whether the values for such parameters in the replaced/reconstructed habitats fall within the range of the reference condition, and they will include a specification of the length of time over which those values must be in that range to achieve success. As noted above, the final specifics for these criteria will be provided in the Phase 1 Cap/Habitat OM&M Plan.

In addition to the primary success criteria, the HSI models for the indicator species listed in the Phase 1 HA Report, as well as wildlife observations, may be used as optional, secondary success criteria (see Exhibit B for a description of the HSI models). These HSI models and wildlife observations will not be used in the first instance to judge success (i.e., if the primary success criteria are met, the habitat replacement/reconstruction will be considered successful without further consideration of the secondary criteria). However, if the primary quantitative criteria are not met, these direct measures of habitat functions may be used to inform adaptive management options or to determine success. If the data are sufficient to show that these measures in dredged areas fall within the range of those in reference areas (see OM&M Scope, p. 4-8) and to indicate that such conditions are likely to be sustainable, then the habitat replacement/reconstruction will be considered successful. To obtain the information necessary to apply the secondary success criteria, data collected under existing programs (e.g., wildlife observations from the HDA program, fish data from the Baseline Monitoring Program) will be used, as appropriate. If GE and EPA agree, specifications will be developed for the collection of additional data to evaluate the secondary criteria, and if agreed upon, such data will be collected under the OM&M program, as appropriate.

The success criteria (primary, or secondary (if applied)) for all four habitats (UCB, SAV, SHO and WET) will be applied at the river reach scale (or an alternate spatial scale as determined by the data, if agreed to by GE and EPA). That is, success will be evaluated relative to the ecological functioning of habitats present in each river reach (or alternate spatial scale if the parties agree) relative to reference conditions. The Upper Hudson River is composed of eight river reaches, with upstream and downstream limits defined by the navigational locks. All Phase 1 dredge areas are located in River Section 1, which constitutes one river reach. Once all quantitative success criteria have been met for that reach (or alternate spatial scale if the parties agree) and the habitat conditions meeting those criteria are considered sustainable, the overall narrative criterion will be deemed to have been met and GE's obligations for OM&M monitoring for habitat replacement/reconstruction will end (OM&M Scope, p. 4-12). The length of time over which the parameters in the replaced/reconstructed habitats must fall within the range of the reference conditions to demonstrate sustainability of the replaced/reconstructed habitats will be specified as part of the final quantitative success criteria (for example, two consecutive years or three out of five years). The time frames for achievement of the final quantitative success criteria will be developed and proposed to EPA in one or more technical memoranda in accordance with the roadmap (Exhibit A). These time frames will be included, as part of the final quantitative success criteria, in the Phase 1 Cap/Habitat OM&M Plan.

The primary quantitative success criteria are discussed in Sections 2.2 through 2.4 and will be based on the parameters listed for such criteria in Table 2-1. Monitoring for these criteria will begin in the year after dredging. However, achievement of the success criteria may not occur on such a short time scale and may take years. During this period, if the success criteria are not achieved in a given year, the available adaptive management options will include the continuation of monitoring (without other action) to assess trends over time, the performance of immediate response actions, and consideration of additional responses. Additional responses may consider, in some cases, a re-evaluation of the habitat type for a given target area or areas if monitoring and any prior response actions conducted over several years demonstrate to the satisfaction of both GE and EPA that the habitat in such area(s) is unlikely to meet the success criteria even with further action. These potential adaptive responses are discussed further in Section 4 below. In any event, success criteria monitoring will continue until the primary success criteria (or if those criteria are not met, the secondary success criteria) are achieved.

In addition to the success criteria, Adaptive Management Benchmarks (hereafter referred to as “benchmarks”) have been developed for each habitat type to assist in achieving the primary success criteria. These consist of a series of specific objectives for certain parameters of these habitats at certain specified years after completion of the habitat replacement/reconstruction. These benchmarks are based on non-destructive measurements to be collected each year for several years after habitat replacement/reconstruction and to be applied at the scale of the reconstructed areas within a Certification Unit (CU). The parameters for which such benchmarks have been derived are also shown in Table 2-1.[3] These benchmarks are linked with specific response actions if the benchmarks are not met. Benchmarks are not alternative success criteria, but rather are tools for managing the replaced/reconstructed areas, and taking corrective

[3] One of those benchmarks, plant species composition, was identified in the OM&M Scope as one of the parameters on which the primary success criteria would be based (OM&M Scope, p. 4-10), but is now also included in the program as a benchmark, specifically to monitor for percent invasive species in the reconstructed areas.

action where appropriate, to assist in achieving success. Benchmarks are discussed in Section 2.5.

2.2 PRIMARY SUCCESS CRITERIA FOR UNCONSOLIDATED RIVER BOTTOMS

Reconstruction of unconsolidated river bottom habitat will be accomplished through the placement of backfill material (or cap material if necessary to meet the engineering performance standards) in accordance with the drawings and specifications provided in Contract 4 of the Phase 1 Final Design. The physical characteristics of the backfill and cap material have been modified, based on discussions with EPA, to incorporate finer-grained material for habitat considerations than originally proposed in the design. The OM&M Scope provided that the primary success criteria for unconsolidated river bottom are to be based on substrate type and FCIs (OM&M Scope, p. 4-10). Since the substrate types will be replaced by the EPA-approved backfill materials, the primary success criteria for UCB will include the placement of the backfill materials in accordance with the backfill plans and specifications.

In addition, EPA and GE will implement a collaborative process to address the functions performed by UCB habitat. Measures of function (e.g., FCIs, individual parameters of the FCIs, benthic invertebrate data, fisheries data) and the appropriate methods to evaluate functional equivalence will be discussed and agreed upon by EPA and GE and included in the primary success criteria. For example, primary quantitative criteria may be developed for a subset of the agreed-upon parameters, and may rely on data collected in both target and reference areas, before and after dredging. Under this approach, an effort will be made to identify the final parameters and develop a technical basis for their selection, as well as an appropriate quantitative or qualitative method for determining achievement of the success criteria. These discussions are anticipated to conclude within the same time period as the development of success criteria for other habitats (see Table A-1 of Exhibit A). If EPA and GE do not develop an approach for UCB pursuant to Exhibit A, the success criteria will be finalized in accordance with the OM&M Scope. The final success criteria for this habitat type will be set forth in the Phase 1 Cap/Habitat OM&M Plan.

2.3 PRIMARY SUCCESS CRITERIA FOR AQUATIC VEGETATION BEDS

The primary success criteria for aquatic vegetation beds will be based on the parameters listed for such criteria in Table 2-1. The strategy for designing the success criteria for this habitat type has been the subject of considerable collaborative efforts of GE and EPA, forming the basis for the general roadmap presented in Exhibit A. The overall approach, statistical framework, and alternatives currently under evaluation for application of that framework are described in Exhibit A. The final success criteria will be set forth in the Phase 1 Cap/Habitat OM&M Plan.

2.4 PRIMARY SUCCESS CRITERIA FOR NATURAL SHORELINES AND RIVERINE FRINGING WETLANDS

The primary success criteria for natural shorelines and riverine fringing wetlands will be based on the parameters listed for such criteria in Table 2-1. The strategy for developing specific quantitative success criteria for these habitats, along with the resulting quantitative criteria, will be developed through the same collaborative process described in Exhibit A. These criteria will also include the time frame over which success must be achieved to be considered sustainable (i.e., the number of years in which success must be demonstrated). The final success criteria for shorelines and riverine fringing wetlands will be described in the Phase 1 Cap/Habitat OM&M Plan.

2.5 ADAPTIVE MANAGEMENT BENCHMARKS

As noted above, in addition to the success criteria, adaptive management benchmarks have been developed for each of the habitats. These benchmarks consist of a series of specific objectives for certain parameters of these habitats at certain specified years after completion of the habitat replacement/reconstruction. They are based on non-destructive measurements that will be taken at individual reconstruction areas within the CUs to determine if response actions may be required. The purpose of the benchmarks for aquatic vegetation beds, shorelines, and riverine fringing wetlands is to ensure that the material planted in those areas remains viable and increases in coverage, so as to assist in achieving the success criteria. For unconsolidated river bottoms, the benchmark is to ensure that the backfill materials have been placed in accordance with the backfill specifications. Additional benchmarks for unconsolidated river bottom habitat may be determined, as agreed to by EPA and GE. The parameters for which benchmarks were derived are listed in Table 2-1, and the benchmarks are presented in Table 2-2. To facilitate the ability to make decisions and implement actions relatively quickly, the comparison criteria listed for the benchmarks are straightforward, bright-line comparisons of the data collected from replacement/reconstruction areas with a specified percentage, many of which are based on the arithmetic mean of the reference data (i.e., total plant cover and occurrence of invasive species). Use of the arithmetic mean of the reference data to determine whether corrective actions are warranted at habitat replacement sites has been used elsewhere (Balsam et al. 1993). Complex statistical analyses are not warranted for the purposes of applying the benchmarks.

If the planted material does not show sufficient survival and expansion to cover the disturbed areas, these areas may potentially be colonized by invasive species. Therefore, in addition to criteria for plant survival and percent cover, the benchmarks include criteria relating to invasive species. It should be noted, however, that invasive species are present in the Upper Hudson River and there is a chance that invasive species may colonize a Phase 1 area. While monitoring and response actions will be implemented to minimize the potential for establishment of invasive species, elimination of invasive species from Phase 1 areas is not an ultimate project goal and is not a requirement for meeting the success criteria. The Invasive Species Management Plan is provided as Exhibit E.

As also specified in Table 2-2, the benchmarks are linked with associated "immediate response actions" if the benchmarks are not met in a given year. These are actions that will be taken within a short time of the measurements (within the same season), after consultation with EPA oversight personnel, to address certain deficiencies, unless GE shows that doing so is not warranted (e.g., based on the results of prior efforts indicating that the specified actions would be futile and/or based on review of trajectories toward the overall reach-wide success criteria). It should be noted that not every possible response action is presented in Table 2-2, because response actions depend on the specific conditions in the field. Finally, because the benchmarks are tools to assist in meeting success criteria and are not success criteria themselves, it will not be necessary to meet every benchmark for the planted areas. Success of the habitat reconstruction program will be determined by the success criteria at the river reach scale (or an alternate spatial scale if agreed to by GE and EPA).

Other incidental observations of changes in the river system may be included in the evaluations as well, such as uncharacteristic high flows during the growing season, changes in the direction or velocity of flow, loss of downed trees or other vegetation previously providing protection of shorelines and riverine fringing wetlands, or changes in the character of the substrate or cover as it may affect the species present. These observations may assist in providing a solution for an area not attaining a benchmark(s).

Benchmark monitoring for planted areas is to begin in the year following dredging and may continue for five years or longer after planting (see Table 2-2), unless success criteria have been met sooner. Monitoring will be conducted for each area where planting of aquatic vegetation beds, shoreline, and riverine fringing wetlands has occurred, as well as for aquatic vegetation beds designated for natural recolonization. For unconsolidated river bottom habitats, benchmark monitoring will occur only at the end of the dredging contract, as noted in Table 2-2. Additional benchmarks for unconsolidated river bottom habitat may be determined, as agreed to by EPA and GE.

SECTION 3
MONITORING AND EVALUATION

A basic tenet of adaptive management is that collecting information and learning about the system while the program is underway are continuous activities, and that revisions and modifications should be made as suggested by project needs and findings. When field data indicate that success criteria are not being met, the first response is to evaluate the existing data and determine if additional data collection can help address the issue. To accommodate this aspect of adaptive management, ongoing data collection, evaluation and documentation are built into the program. The data collection will include habitat monitoring to assess the adaptive management benchmarks and success criteria, as well as monitoring to collect data to evaluate design, implementation, and habitat recovery uncertainties.

3.1 HABITAT MONITORING

With the exception of conducting reassessments in accordance with the Phase 1 HA Report, the pre-dredging data collection in the Phase 1 dredge areas and associated reference areas is complete, subject to any modification as a result of ongoing discussions regarding the selection of appropriate reference areas. Post-dredging habitat monitoring in the Phase 1 areas and associated reference areas will be conducted annually, starting in the first year after Phase 1 dredging has been completed. The results of the monitoring are expected to provide the information needed to evaluate the adaptive management benchmarks, as well as the primary and secondary success criteria.

The data collection program is described in the OM&M Scope (Section 4.2.2, p. 4-4 through p. 4-6). Monitoring will include data collection in target areas and on-site reference areas. It will also include monitoring at off-site reference areas upstream in the Upper Hudson River and in the Lower Mohawk River. The data from these off-site areas will not be used in evaluating the habitat replacement/reconstruction success, but to evaluate the impacts (if any) of broad, watershed-wide or regional changes that may extend beyond the project area and to determine whether such changes have affected the habitat replacement/reconstruction.

The parameters to be sampled in each habitat type during this monitoring are listed in the OM&M Scope (p. 4-4 through p. 4-6). The locations of the collection stations, sample numbers, and sampling methodologies will be the same as those used for the pre-dredging data as defined in the SHAWP. Any changes or additions to the parameters to be sampled or to the data collection locations or procedures will be implemented only through agreement by both EPA and GE.

In each year after the completion of Phase 1 dredging, an Adaptive Management Report will be prepared, summarizing the work performed, the monitoring results for each habitat type, and the evaluations conducted. These reports are described further in Section 5.

3.2 MONITORING TO EVALUATE DESIGN UNCERTAINTIES

The habitat construction designs include certain aspects to address design, implementation, and habitat recovery uncertainties, and monitoring will be conducted to evaluate those uncertainties – for example, to assess whether the survival and expansion of aquatic vegetation are related to planting method (adult plants, tubers, or natural recolonization), water depth, and/or backfill type. This monitoring information will be used in evaluating adaptive responses.

SECTION 4
ADAPTIVE RESPONSES

Under the adaptive management approach, there are four general management alternatives if success criteria are not being met:

1. continue current monitoring;
2. enhance data gathering;
3. implement active response action(s) that will help the recovery process; or
4. re-evaluate goals.

These alternatives may be used individually or in combination and are discussed below. Decisions regarding the need for adaptive responses, and a description of any response(s) taken or recommended, will be documented in the annual Adaptive Management Reports (see Section 5).

4.1 CONTINUED OR ENHANCED DATA GATHERING

One possible response is to gather additional information, including continued or expanded monitoring under the existing program, additional monitoring using revised protocols, a review of relevant literature, consultation with experts, and experiments to evaluate specific aspects of habitat recovery that are not currently addressed by monitoring data. Field response actions shall consist of those actions listed in the OM&M Scope (p. 4-13 through p. 4-14), plus any additional actions that are agreed upon by GE and EPA as appropriate for adaptive management, based on field experience.

Additional information gathering may be appropriate to evaluate the extent to which reconstructed habitats are on a trajectory towards success. This is especially true early in the process. It is reasonable to assume that success will not be achieved in the first year or first few years after habitat construction.

Additional information-gathering may also be appropriate to investigate potential causes for unsatisfactory progress towards meeting success criteria. This could include additional monitoring or experiments aimed at designing adaptive responses to accelerate the recovery process or to correct deficiencies.

4.2 ACTIVE RESPONSE ACTIONS

There are two classes of active response actions, “immediate” and “additional,” as further described below.

4.2.1 Immediate Response Actions

Immediate response actions will be conducted to correct obvious deficiencies. These are actions that will be undertaken at the time the condition is observed or within the appropriate planting window. The adaptive management benchmarks are linked with certain immediate responses designed to address the reasons for failing to meet the benchmarks in a given area (Table 2-2). These response actions will be implemented on a near-term basis, after consultation with EPA oversight personnel, unless GE shows and EPA agrees that taking such actions is not warranted (e.g., because prior efforts indicate that the specified actions would be futile). Immediate responses may also occur in response to other types of field observations during the adaptive management program.

In accordance with the OM&M Scope (p. 4-12), immediate response actions will include the following (where pertinent to correct observed deficiencies), as well as others listed in Table 2-2, plus any additional actions that are agreed upon by GE and EPA, as appropriate for adaptive management, based on field experience:

- Where bank slope failure has occurred and structural integrity is needed to support infrastructure or habitat, bank stabilization measures will be taken, including placement of riprap or vegetated material, to stabilize riverbanks where necessary and/or return them to grade. Preferred bank stabilization measures will have both physical stabilization and habitat benefits. Examples include placement of natural or manufactured ("bio") logs, cobble, gravel, and protective or plant-growth matting. Riprap (e.g., Type P armor stone) will be used where additional stabilization is required to withstand waves or wakes. Consistent with the OM&M Scope (p. 4-13), "[r]egrading banks shall only be considered if access has been or is obtained for the area in question."

- Invasive species in replaced/reconstructed areas will be removed as necessary to maintain the extent of invasive species below the levels specified in Table 2-2. An Invasive Species Management Plan is included as Exhibit E. As noted in Section 2.5 above, however, successful habitat replacement/reconstruction does not require the complete elimination of invasive species from replaced/reconstructed areas. After the immediate response actions are discontinued and the success criteria have been met, native Hudson plant species are expected to be sustainable without continued maintenance.

- Targeted plantings in aquatic vegetation beds, wetlands, and shoreline habitats will be implemented where warranted based on the benchmarks. This field response action will not include complete replanting of a site unless the cause(s) for the initial failure of the plantings has been identified and corrected/controlled. Targeted planting will be undertaken only with non-invasive species and will be subject to EPA approval. Target plantings will occur within the planting windows specified in the designs. The amount of material replanted will not exceed 50% of the material initially installed at any area, unless the reason(s) for planting failure have been evaluated and GE and EPA agree on the response action.

- Maintenance of habitat replacement/reconstruction structures consistent with design specifications and as appropriate under this Adaptive Management Plan will be implemented.

- Actions will be taken, as appropriate, to respond to the impacts of unforeseen anthropogenic (i.e., non-natural) events. For example, if vessel groundings or unusually low water levels (e.g., due to maintenance activities on locks or hydrofacilities) reduce plant survival, targeted plantings may be needed.

Such immediate response actions, as well as any others listed in Table 2-2 or agreed upon by GE and EPA, will be implemented in consultation with EPA oversight personnel.

4.2.2 Additional Response Actions

Additional response actions are those that are appropriately performed at some point after the condition is observed, either to meet the required seasonal planting window (e.g., fall planting of tubers) or to consider additional data. All responses to the success criteria evaluations are considered to be additional responses, as they will be based upon the entire year's worth of data and will in general be performed in the following growing season.

Additional responses will be recommended for discussion with EPA in the annual Adaptive Management Report based upon the outcome of the annual data evaluation of benchmarks and success criteria and will be consistent with the requirements provided in the Phase 1 Cap/Habitat OM&M Plan. The selection of appropriate actions will be based on the nature and extent of the identified problem(s). Table 2-3 provides a list of potential additional response actions by habitat type. The response actions listed in this table are not exhaustive, because response actions depend on the specific conditions in the field. Field response actions shall consist of those actions listed in the OM&M Scope (p. 4-13 through p. 4-14), plus any additional actions that are agreed upon by GE and EPA as appropriate for adaptive management, based on field experience. Except as otherwise provided in Section 4.3 below, the OM&M program shall not require the implementation of changes in the type of habitat from the types designed and implemented as part of the habitat replacement/reconstruction program; however, as indicated in Section 4.3, the specific goals for some locations may need to be re-evaluated. Moreover, if dictated by natural processes occurring in the river and based on field conditions in the river, additional response actions may also include evaluating the feasibility of shifting the habitat to an alternative area, provided that EPA and GE agree.

4.3 REEVALUATION OF GOALS

Site-specific goals (i.e., designated habitat types for specific areas or even the benchmarks or success criteria themselves) may turn out to be unrealistic for some locations. Reevaluating the appropriateness of such goals may occur when monitoring has shown that the benchmarks or success criteria have not been met or are not likely to be met, despite efforts to achieve the benchmarks and success criteria. For example, if a portion of the site is determined not to be suitable for aquatic vegetation, the goals for that area may need to be altered. Any change to the habitat type for an area or to the benchmarks listed in Table 2-2 will require agreement between EPA and GE.

4.4 SUCCESS AND CLOSURE

When habitat conditions in target Phase 1 areas achieve the success criteria for each habitat type and are sustained for the number of years to be specified by those criteria, adaptive management and its associated habitat monitoring, will end.

SECTION 5
SCHEDULE AND REPORTING

As stated in the OM&M Scope, GE will submit annual Adaptive Management Reports to EPA by January 31 of each year following habitat replacement/reconstruction (OM&M Scope, p. 4-14). Each report will present the habitat monitoring data collected during the prior calendar year, including the database used to develop the report, and the results of the adaptive management evaluations conducted (including an analysis of habitat trends and recovery trajectories). As required by the OM&M Scope, the habitat data will be collected annually: "[s]ampling of the replaced and reconstructed unconsolidated river bottom, aquatic vegetation bed, shoreline and riverine fringing wetland habitats shall be conducted annually, between June 1 and September 30, focused on peak growth times for aquatic vegetation and wetlands and appropriate times for identification of riparian plant species in shoreline habitats" (OM&M Scope, p. 4-4). In addition, "[c]ollected data shall be evaluated on an ongoing basis (at a minimum, annually) to determine if modifications to the sampling design are warranted" (OM&M Scope, p. 4-4).

Each year's Adaptive Management Report will document evaluations of the adaptive management benchmarks (where relevant), assess progress toward meeting success criteria, and summarize any adaptive responses taken during the previous year. Each such report will also include recommendations, as appropriate, for additional adaptive response actions, continuation or revision of the data collection program, termination of monitoring in successful habitats, or revisiting the habitat goals for specific areas. The format of the annual Adaptive Management Report is anticipated to include:

- Introduction – summary of work completed and goals for the specific year;
- Methods – describing the location and number of stations sampled and statistical methods used for data evaluation, and describing the methods used for any adaptive responses;

- Results – graphs and tables summarizing the results of the data collection (similar to those provided in the Habitat Assessment Reports) and adaptive responses (if implemented); and
- Discussion – summary of progress towards success criteria and the effectiveness of any adaptive responses (if implemented), and recommendations for adaptive responses for the following year(s) (if necessary).

In addition, during the OM&M program, GE will provide the data from the habitat replacement and reconstruction monitoring program to EPA, including data files, shape files, and photodocumentation, in the monthly progress reports and database updates under the Consent Decree.

SECTION 6
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TABLES

Table 1-1. Habitat design specifications and estimated acreages or linear feet.

Design Specification	Area or Length[1]	Units
Type 3 – RFW Planting	2.0	acre
Type 1 – SAV Planting	3.1	acre
Type 1 – SAV Contingency Planting Areas[2]	2.3	acre
Type 1 – SAV Natural Recolonization	2.9	acre
Type 1 – UCB	4.1	acre
Type 2 – SAV Planting	5.7	acre
Type 2 – SAV Contingency Planting Areas[2]	6.7	acre
Type 2 – SAV Natural Recolonization	1.2	acre
Type 2 – UCB	64.1	acre
Total	**92.0**	**acre**
Type 1 Nearshore Backfill at Shoreline	60	lf
Type 2 Nearshore Backfill at Shoreline	250	lf
Biolog and Type 1 Backfill at Shoreline	4700	lf
Biolog and Type 2 Backfill at Shoreline	3300	lf
Armor stone (Type P) at Shoreline	6400	lf
Total	**14,700**	**lf**

Notes:

[1]*The areas and lengths shown in this table are approximate.*
[2]*Contingency planting areas that are not ultimately planted will be natural recolonization areas.*

Table 2-1. Parameters included in success criteria and adaptive management benchmarks.

Habitat	Parameter	Adaptive Management Benchmarks [1]	Primary Success Criteria	Secondary Success Criteria
Aquatic Vegetation Bed	Survival of Planted Materials	√		
	Stem Density		√	
	Percent Cover	√	√	
	Plant Species Composition	√	√	
	FCIs and HSIs - or Functional Equivalents [2]		√	
	Wildlife observations			√
Shoreline	Survival of Planted Materials	√		
	Percent Cover	√		
	Bank Assessment		√	
	Plant Species Composition	√	√	
	FCIs and HSIs - or Functional Equivalents[2]		√	
	Wildlife observations			√
Wetlands	Survival of Planted Materials	√		
	Percent Cover	√	√	
	Plant Species Composition	√	√	
	FCIs and HSIs - or Functional Equivalents[2]		√	
	Wildlife observations			√
Unconsolidated River Bottom	Substrate Type		√	
	FCIs and HSIs - or Functional Equivalents and HSIs [2]		√	
	Wildlife observations			√

Notes:

[1] Adaptive management benchmarks have been added to the program since completion of the OM&M Scope. The benchmarks focus on survival of planted material, percent cover, and plant species composition (monitored as percent invasive species).

[2] FCIs were included in the OM&M Scope as one of the bases for the primary success criteria; the use of FCIs and HSIs is currently under discussion with EPA (see Section 2.1). Alternate functional equivalent measures (listed in this table as Functional Equivalents) may be used instead of FCIs and/or HSIs as a basis for primary success criteria only upon agreement between GE and EPA on the specific functional measures (or, alternatively, if the parties agree, HSIs may be used as secondary success criteria).

Table 2-2. Adaptive management benchmarks and potential immediate response actions for habitat replacement and reconstruction in the Upper Hudson River following dredging in Phase 1 Areas.

Habitat Type	Benchmark[1]	Immediate Response Action[2]
Riverine fringing wetlands	1. At the end of the habitat construction contract period, 100% of the installed material will meet the acceptance criteria stated in the contract specifications. This condition will be documented on the Final CU Completion Certification (Form 3).	1. Replace missing or dead plant material. 2. Implement actions outlined in Section 4.2.1, as needed.
	2. Within the first full growing season in the year following planting, at least 90% of the planted species and planting units are present. Percent cover has increased from the initial planting density. Invasive species are not present.	1. Replace missing or dead plants to achieve 90% survival. 2. Remove observed invasive species. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed.
	3. After 2 years, total plant cover is at least 70% of the average plant cover at reference sites, with 20% of the total coverage by native volunteer species. Invasive species are not present.	1. Remove observed invasive species. 2. Install plant material to achieve 70% cover. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed.
	4. After 3 years, total plant cover is at least 85% of the average plant cover at reference sites, with 40% of the total coverage by native volunteer species. Percent of invasive species is less than or equal to the average percent invasive species at reference condition.	1. Remove observed invasive species, if above average percentage at reference condition. 2. Install plant material to achieve 85% cover. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed.
	5. After 4 years, total plant cover is at least 85% of the average plant cover at reference sites. Percent of invasive species is less than or equal to the average percent invasive species at reference condition.	1. Install additional plant material, as needed. Plant species and/or vegetative form that have shown the highest level of success at the site should be used if significantly below goal. 2. Remove observed invasive species, if above average percentage at reference condition. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed.

Habitat Type	Benchmark[1]	Immediate Response Action[2]
	6. After 5 years, total plant cover is at least 85% of the average plant cover at reference sites. Percent of invasive species is less than or equal to the average percent invasive species at reference condition.	1. Install additional plant material, as needed. Plant species and/ or vegetative form that have shown the highest level of success at the site. 2. Remove observed invasive species, if above average percentage at reference condition. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed.
Submerged aquatic vegetation – active planting	1. At the end of the habitat construction contract period, 100% of the installed material will meet the acceptance criteria stated in the contract specifications. This condition will be documented on the Final CU Completion Certification (Form 3).	1. Replace missing or dead plant material.
	2. Within the first full growing season in the year following planting, total plant cover is at least 20% of the average plant cover of the reference condition. Invasive species are not present.	1. Remove observed invasive species 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed.
	3. After 2 years, total plant cover is at least 30% of the average total plant cover of the reference condition. Invasive species are not present.	1. Remove observed invasive species 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed.
	4. After 3 years, total plant total cover is at least 40% of the average total plant cover of the reference condition. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	1. Remove observed invasive species, if above average percentage at reference condition. 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed.
	5. After 4 years, total plant total cover is at least 50% of the average total plant cover of the reference condition. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	1. Remove observed invasive species, if above average percentage at reference condition. 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed.

Habitat Type	Benchmark[1]	Immediate Response Action[2]
	6. After 5 years, total plant cover is at least 70% of the average total plant cover of the reference condition. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	1. Remove observed invasive species, if above average percentage at reference condition. 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed
Submerged aquatic vegetation - natural recolonization	1. At the end of the habitat construction contract period, no invasive species are present at the natural recolonization areas. This condition will be documented on the Final CU Completion Certification (Form 3).	1. Remove observed invasive species.
	2. Within the first full growing season following habitat construction, native plants have reappeared in the area and invasive species are not present.	1. Remove observed invasive species.
	3. After 2 years, total plant cover is at least 20% of the average total plant cover of the reference condition. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	1. Remove observed invasive species, if above average percentage at reference condition.
	4. Within 3-4 years, total plant cover is at least 20% of the average total plant cover of the reference condition. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	1. Remove observed invasive species, if above average percentage at reference condition.
	5. Within 5-6 years, total plant cover is at least 50% of the average total plant cover of the reference condition. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	1. Remove observed invasive species, if above average percentage at reference condition.

Habitat Type	Benchmark[1]	Immediate Response Action[2]
Shoreline vegetation	1. At the end of the habitat construction contract period, 100% of the installed material will meet the acceptance criteria stated in the contract specifications. This condition will be documented on the Final CU Completion Certification (Form 3).	1. Replace missing or dead plant material.
	2. Within the first full growing season in the year following planting, the following conditions will be met. Seeded Areas: Total plant cover for the seeded areas will be 85%. Invasive species are not present. Planted area: 90% of the installed material will be present and show signs of growth. Invasive species are not present.	Seeded Areas: 1. Reseed all open areas. 2. Remove invasive species. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed. Planted Areas: 1. Replace missing or dead plant material. 2. Remove observed invasive species. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed.
	3. After 2 years, the following conditions will be met. Seeded Areas: 100% of the seeded area will be covered with vegetation. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition. Planted area: Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	Seeded Areas: 1. Reseed all open areas. 2. Remove invasive species, if above average percentage at reference condition. 3. Implement herbivory control, if necessary. 4. Implement actions outlined in Section 4.2.1, as needed. Planted Areas: 1. Remove observed invasive species, if above average percentage at reference condition. 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed.

Habitat Type	Benchmark[1]	Immediate Response Action[2]
	4. Within 3-4 years, the following conditions will be met. Seeded Areas: 100% of the seeded area will be covered with vegetation. Percent of invasive species is less than or equal to the average percent invasive species of the reference condition. Planted area: Percent of invasive species is less than or equal to the average percent invasive species of the reference condition.	Seeded Areas: 1. Remove invasive species, if above average percentage at reference condition. 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed. Planted Areas: 1. Remove observed invasive species, if above average percentage at reference condition. 2. Implement herbivory control, if necessary. 3. Implement actions outlined in Section 4.2.1, as needed.
Unconsolidated River Bottom[3]	1. At the end of the dredging contract, 100% of the installed material will meet the contract specifications. This condition will be documented on the CU Backfill/Engineered Cap Completion Approval (Form 2).	1. Take actions as necessary to meet the contract specifications.

Notes:

1. *Benchmarks will be applied at the scale of the individual habitat replacement/reconstruction areas within a CU. Where such areas affect more than one CU, the response action(s) will be recorded for each affected CU.*
2. *The indicated response action(s) will be implemented promptly, after consultation with EPA oversight personnel, unless GE demonstrates and EPA agrees that such action is not warranted in the circumstances. In addition, other immediate response actions (i.e., bank stabilization, invasive species removal, targeted plantings, actions to respond to unforeseen anthropogenic events) are discussed in Section 4.2.1. All applicable actions described in that section may be applied as appropriate to correct deficiencies.*
3. *Additional benchmarks for UCB habitat will be added if necessary specific to any functional measures agreed to by EPA and GE.*

Table 2-3. Potential additional adaptive response actions for habitat replacement and reconstruction in the Upper Hudson River following dredging in Phase 1 Areas.[1]

Habitat Type	Potential Responses To Be Implemented if Necessary Based on Evaluation of the Monitoring Data and/or Field Experience[2]
Riverine fringing wetlands	1. Evaluate monitoring data to determine if progression towards the success criteria is occurring and, if not, whether the specific cause can be identified. Determine if corrective action is necessary. 2. Consider conducting site-specific focused studies to evaluate, for example: a. Elevations, inundation frequency, water depth, plant zonation, plant survival; b. Soil properties; c. Species planted and/or vegetative form planted (e.g., seed vs. potted plant vs. bare root plant); d. Age or size of plants; and/or e. Source of material or nursery propagation method(s). 3. Based on above evaluation and/or studies (if agreed to by GE and EPA and conducted), apply appropriate corrective actions if necessary. Such actions may include: a. Plant open areas within the riverine fringing wetland using the non-invasive species that have shown success at that location. b. Apply nutrient amendments. c. Implement increased herbivory control (if not taken as immediate response action). 4. Consider whether to restore, enhance or create riverine fringing wetland habitat elsewhere within Phase 1 dredge areas.
Submerged aquatic vegetation – active planting	1. Evaluate monitoring data to determine if progression toward the success criteria is occurring and, if not, whether the specific cause can be identified. Determine if corrective action is necessary. 2. Consider conducting site-specific focused studies to evaluate, for example: a. Suitability of site conditions to support growth and survival of SAV; and/or b. Species planted and/or vegetative form planted (e.g., tuber vs. potted plant). 3. Based on above evaluation and/or studies (if agreed to by GE and EPA and conducted), apply appropriate corrective actions if necessary. Such actions may include: a. Conduct additional planting if necessary. If warranted, consider use of alternate species, modification of vegetative form planted, and/or change in planting density. b. Evaluate whether additional tubers should be placed in the fall and whether the tuber size or age should be modified. c. Apply nutrient amendments.
Submerged aquatic vegetation - natural recolonization	1. Evaluate monitoring data to determine if progression toward the success criteria is occurring and, if not, whether the specific cause can be identified. Determine if corrective action is necessary. 2. Consider conducting site-specific focused studies to evaluate, for example: a. Suitability of site conditions to support growth and survival of SAV. b. Availability of propagules (e.g., seeds, tubers, turions, vegetative fragments) for natural recolonization. 3. Based on above evaluation and/or studies (if agreed to by GE and EPA and conducted), apply appropriate corrective actions if necessary. Such actions may include:

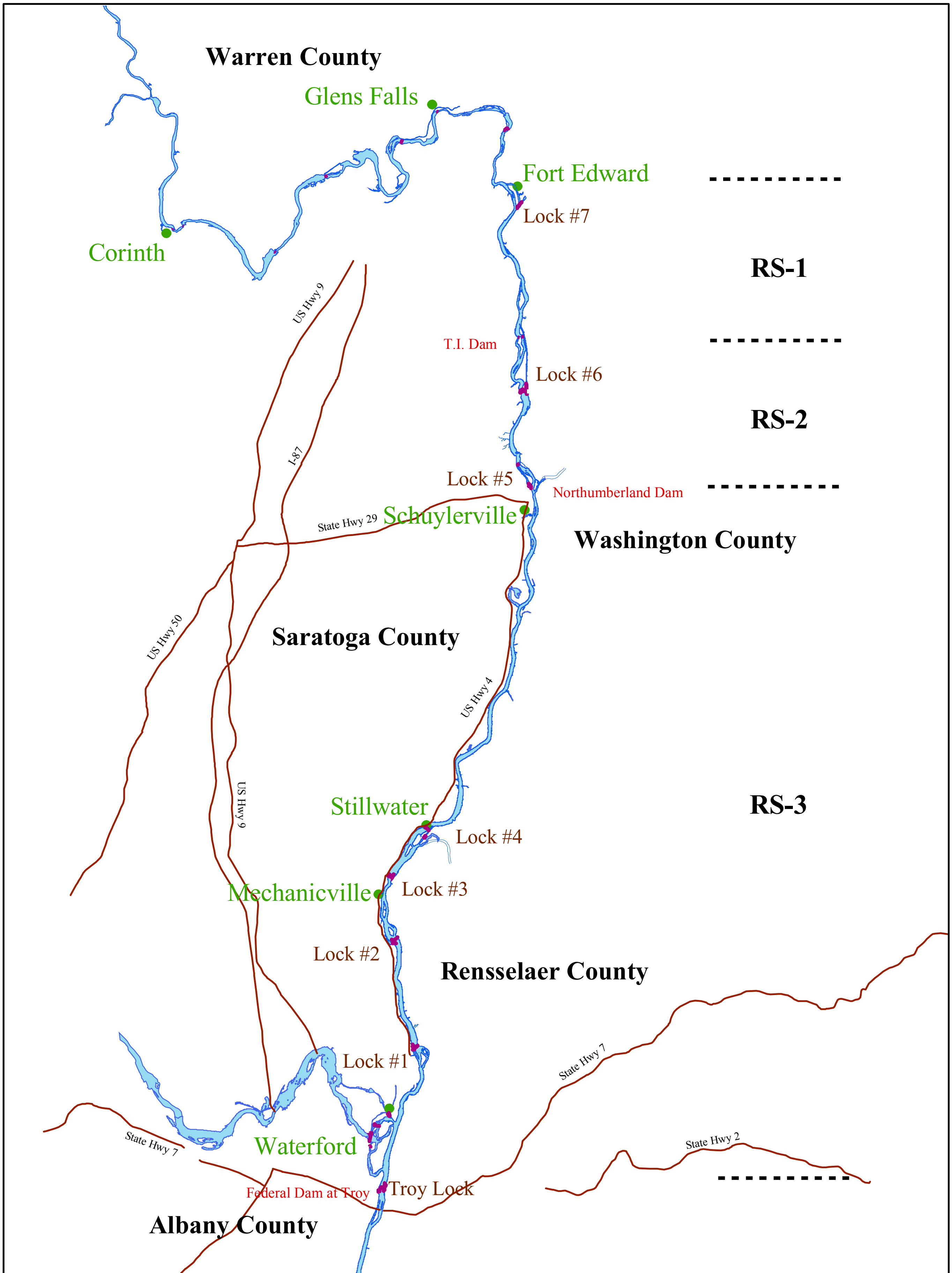
Habitat Type	Potential Responses To Be Implemented if Necessary Based on Evaluation of the Monitoring Data and/or Field Experience[2]
	a. Identify most successful areas and evaluate for planting or seeding. If warranted, conduct planting or seeding. Once planted, follow benchmarks for submerged aquatic vegetation, active planting. b. Implement increased herbivory control (if not taken as immediate response action).
Shoreline vegetation	1. Evaluate monitoring data to determine if progression towards objective is occurring and, if not, whether the specific cause can be identified. Determine if corrective action is necessary. 2. Consider conducting site-specific focused studies to evaluate, for example: a. Suitability of site conditions to support planted/seeded material; b. Seed mix or seed germination rates; c. Vegetative form (e.g. live stake vs. potted plant vs. bare root vs. seed mix); and/or d. Age or size of plants. 3. Based on above evaluation and/or studies (if agreed to by GE and EPA and conducted), apply appropriate corrective actions if necessary. Such actions may include: a. Conduct additional planting if necessary. If warranted, consider use of alternate species, modification of vegetative form planted, and/or change in planting density. b. Apply nutrient amendments. c. Implement increased herbivory control (if not taken as immediate response action).
Unconsolidated River Bottom	Following final agreement on success criteria and appropriate monitoring data for UCB habitat, consider the following: 1. Collect monitoring data for UCB habitat. 2. Evaluate monitoring data to determine if progression toward the success criteria is occurring and, if not, whether the specific cause can be identified. Determine if corrective action is necessary. 3. Consider conducting site-specific focused studies to evaluate appropriate parameters (e.g., suitability of site conditions to support benthic invertebrates). 4. Based on above evaluation and/or studies (if agreed to by GE and EPA and conducted), apply appropriate corrective actions if necessary.

Notes:

1. This table lists some of the potential response actions that may be taken or considered, in addition to the immediate response actions listed in Table 2-2, as a means to facilitate meeting success criteria. These additional response actions can be implemented in any year based on an evaluation of the monitoring data and/or field experience. Any potential response actions will be proposed in the Annual Adaptive Management Monitoring Report for EPA's consideration. Field response actions shall consist of those actions listed in the OM&M Scope (p. 4-13 to p.4-14), plus any additional actions that are agreed upon by GE and EPA as appropriate for adaptive management, based on field experience.

2. The design for dredging operations and habitat construction, including backfill, capping, shoreline restoration, and planting, was approved by EPA on November 30, 2007. The scope and location of the habitat types are designated in the contract documents. Field response actions shall consist of those actions listed in the OM&M Scope (p. 4-13 to p.4-14), plus any additional actions that are agreed upon by GE and EPA as appropriate for adaptive management, based on field experience. Also, as stated in the OM&M Scope (p. 4-14), the OM&M program will not require the implementation of changes in the type of habitat from the types designed and implemented as part of the habitat replacement/reconstruction program.

FIGURES



General Electric Company
Hudson River Project

0 2.5 5 Miles

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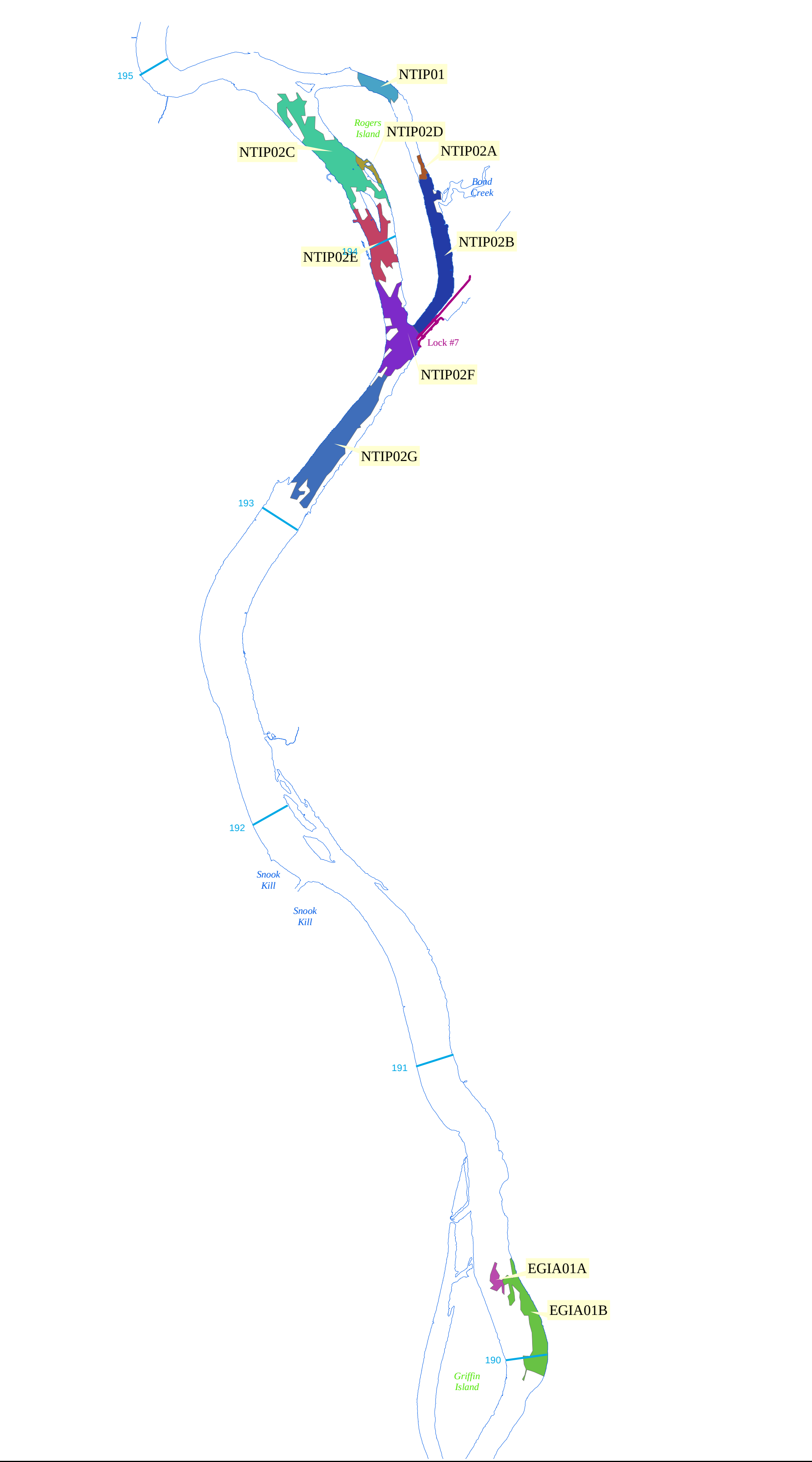
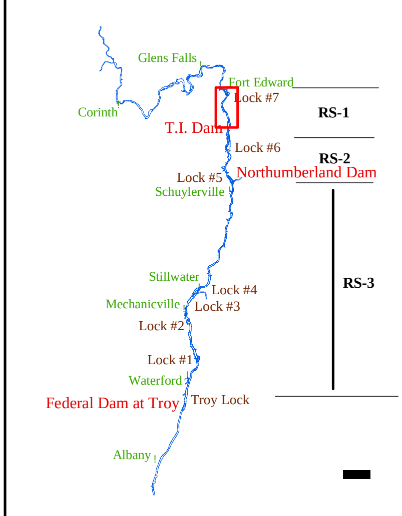
Figure 1-1.



LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 1,000 2,000 Feet

LEGEND

Dredge Areas

- EGIA01A
- EGIA01B
- NTIP01
- NTIP02A
- NTIP02B
- NTIP02C
- NTIP02D
- NTIP02E
- NTIP02F
- NTIP02G
- Shore Line
- Dams and Locks

Notes:
- EGIA = East Griffin Island Area
- NTIP = Northern Thompson Island Pool

Figure 1-2

Phase 1 Dredge Areas

QEA Quantitative Environmental Analysis, LLC

GENfd1:138

January 2008

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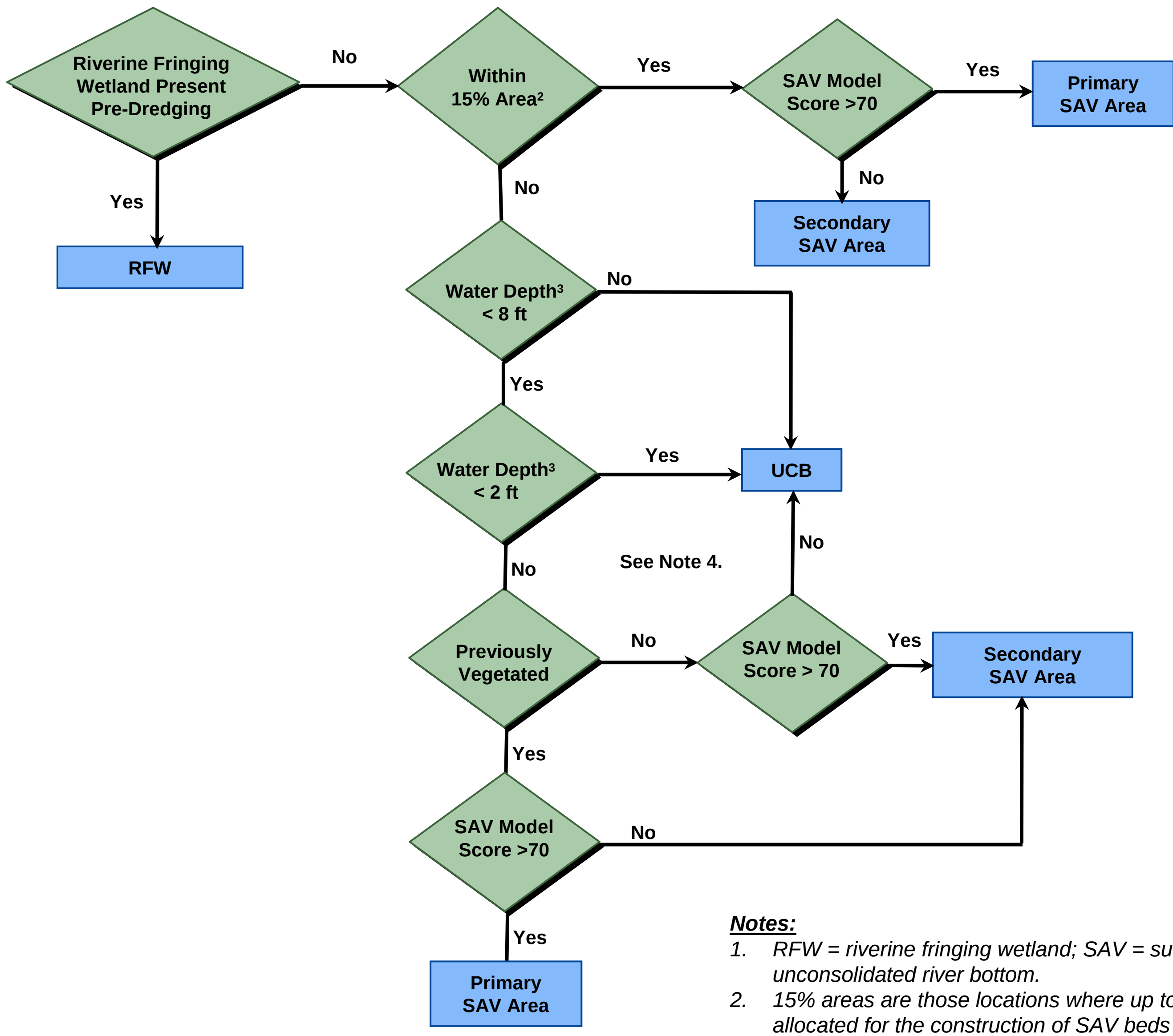

Figure 1-3. Habitat Decision Matrix.

Notes:

1. *RFW = riverine fringing wetland; SAV = submerged aquatic vegetation; UCB = unconsolidated river bottom.*
2. *15% areas are those locations where up to 15% additional backfill material will be allocated for the construction of SAV beds developed based on EPA's Guiding Principles from February 16, 2007.*
3. *Water depth based on post-dredging, post-backfilling (including additional 15%) elevation at 5000 cfs.*
4. *At the locations where the dredge prism extends to the shoreline (defined as elevation 119), shoreline habitat and nearshore areas will be reconstructed in accordance with the shoreline design approved by EPA on November 30, 2007.*

EXHIBIT A

Development of Success Criteria for Unconsolidated River Bottom, Aquatic Vegetation Beds, Shoreline, and Riverine Fringing Wetland Habitats

Quantitative Environmental Analysis, LLC

∂c/∂t

EXHIBIT A
DEVELOPMENT OF SUCCESS CRITERIA FOR UNCONSOLIDATED RIVER BOTTOM, AQUATIC VEGETATION BEDS, SHORELINE, AND RIVERINE FRINGING WETLAND HABITATS

This exhibit provides a description of the additional steps that will be completed to develop the final quantitative success criteria for unconsolidated river bottom (UCB), aquatic vegetation beds (SAV), natural shoreline (SHO), and riverine fringing wetland (WET) habitats. The steps in this exhibit differ from the steps set forth in the OM&M Scope (Section 4.3) for development of success criteria. In the event that acceptable success criteria for UCB, SAV, SHO, and/or WET cannot be developed by following the steps in this exhibit, then EPA and GE will finalize the success criteria in accordance with the OM&M Scope.

The strategy for designing the success criteria for SAV has been the subject of considerable collaborative efforts of GE and EPA. Taking advantage of this extensive effort, a modified version of the overall approach and statistical framework (if feasible and agreed upon by the parties) will be applied to the other three habitat types to arrive at final success criteria. These methods are described, as a general road map or framework, in this exhibit. This exhibit also includes brief sections describing specific details relevant to each of the four habitats, including the remaining steps to finalize the success criteria for SAV. The development of success criteria for the remaining habitats will follow a similar process to that used for SAV, as described in this exhibit. The anticipated schedule to complete this process is provided in Table A-1. The final success criteria for all habitats will be set forth in the Phase 1 Cap/Habitat OM&M Plan.

A.1 FRAMEWORK OR ROAD MAP

The primary success criteria for each habitat type will be based on the parameters listed for such criteria in Table 2-1 of the main text of this Phase 1 Adaptive Management (AM) Plan. Demonstration of success will be based upon a technical analysis of both the pre-dredging data and the post-dredging data from the target areas, where appropriate, and, for some habitats, from reference areas (application of reference areas may vary by habitat type). A statistically based approach will be the preferred method, unless alternative methods are determined to be more appropriate based on the types of data as discussed in A.1.1 below. The guiding principle is to minimize the probability of making errors in judging habitat replacement/reconstruction success. The two types of errors are: inappropriately declaring success when in fact habitats have not been sufficiently restored; and inappropriately declaring that habitat reconstruction is not complete when in fact success has been achieved. These are commonly called "Type I" and "Type II" errors (although which error is of which type depends on the choice of null hypothesis: see below). The statistical approach (if used), as well as the values for the critical parameters of the analysis, will be chosen based upon a simulation analysis designed to estimate the error rates using the available data pre-dredging data.

Final decisions regarding the methodology to be used for evaluating achievement of the success criteria and the numerical criteria themselves will be determined on the basis of the statistical evaluation (or other technical analysis if agreed upon), and the final criteria will be specified in the Phase 1 Cap/Habitat OM&M Plan. Those criteria will also incorporate a final specification of the time frame over which success will be evaluated (i.e., the number of years in which success must be demonstrated, spread over a specified period of time).

A.1.1 Preliminary Technical Analysis

Some habitats such as the SAV areas clearly lend themselves to a rigorous field sampling design and statistical analysis approach for demonstration of success. However, because of differences in the size and nature of other habitats in Phase 1 areas of the project (e.g., wetlands), it may not be necessary or feasible to employ for such habitats such a data-intensive approach as that anticipated for SAV. To investigate this possibility, the first step in the framework is to develop some simple technical analyses to evaluate the need for and feasibility of more rigorous statistical methods for the other habitats. This analysis will result in a technical description of the need for and feasibility of the rigorous "Before/After Control/Impact" (BACI) approach described below and will point out any alternative analyses that may be under consideration. For example, in earlier collaborative discussions between GE and EPA, methods such as control charts were discussed as a less data-intensive procedure for evaluating smaller areas that may be better assessed with a combination of qualitative and quantitative methods. The details of this preliminary analysis will be discussed collaboratively and will serve as an initial filter in the success criteria road map for each habitat. Where this preliminary analysis indicates that the BACI approach discussed below (or an alternative statistical approach) would be feasible and appropriate for a given habitat, that habitat will be evaluated using such approach, as agreed upon by the parties.

A.1.2 BACI Statistical Framework

The discussions of quantitative criteria to date (which have related principally to SAV) have focused on a statistical framework designed to make use of the fact that the data are stratified both with respect to reference and target sites and with respect to before and after dredging. This framework is commonly called “Before/After Control/Impact” or BACI in the ecological literature. BACI is an accepted approach in ecology (Smith 2002); such evaluations have a history in the evaluation of habitat impacts (Smith 2002) and the statistical aspects of designing and evaluating a BACI study have been much discussed (Stewart-Oaten 2001). The BACI approach is appropriate here, at least for SAV, because it is specifically designed to accommodate temporal variation (i.e., seasonal, annual, climatic) that affects both target and reference sites and is not related to the dredging and/or the habitat reconstruction effort.

With a BACI design, the goal of the statistical test is to evaluate whether the relationship between Reference and Target sites changes between the Before-dredging and After-dredging time periods. Success is achieved if this relationship has not changed. Adaptive management will be required if the habitat quality of the target areas is lower than the reference areas in the After data set relative to the Before data set. This evaluation will be on a reach-wide basis unless GE and EPA agree that, based on the data, an alternative scale is appropriate for the evaluation.

Two-way analysis of variance (ANOVA) with interaction will be employed, using the interaction term to assess the relationship between Before/After and Control/Impact. Success will be declared based on the statistical significance of the interaction term at some predetermined probability (α), and the direction of effects as described in detail below. Multivariate ANOVA (MANOVA) will provide the statistical tool for the multivariate analysis. For the univariate cases, a method to integrate the ANOVAs for the individual parameters will be incorporated into the final success criteria. Tests of bioequivalence and the classical null hypothesis will be considered within the BACI experimental design.

A.1.3 Application of the Framework

The BACI approach can be applied in a variety of ways. Table A-2 depicts the alternative statistical tests available to complete this evaluation in the BACI framework for SAV, shoreline, and riverine fringing wetland habitats. Considerations include the treatment of data (i.e., parametric, non-parametric), type of test (i.e., univariate or multivariate) and hypotheses (i.e., classical or bioequivalence). Each of these elements is briefly described below.

Parametric vs. Non-parametric

The SAV data collected to date are not, in general, normally distributed. It is anticipated that data collected from shoreline and riverine fringing wetland habitats will also be non-normally distributed. Both parametric and nonparametric analyses will be evaluated. Parametric analyses will be performed using data transformed to normality or near-normality using an optimized Box-Cox transformation. For the nonparametric methods, an analysis of variance will be performed on untransformed data (Gibbons 1985). The nonparametric (M)ANOVA will be performed using an aligned rank test to test for significant one-tailed interaction. This is because a standard rank transformation approach can increase the Type 1 error when testing interaction effects (Seaman et al. 1994).

Multivariate vs. Univariate Analysis

For each habitat type, multiple parameters were measured in the field. There are two ways in which multiple parameters can be incorporated in statistical tests. First, all parameters can be evaluated in a single multivariate analysis. Alternatively, each parameter can be evaluated separately (i.e., in a univariate way) and a rule or a set of rules can be developed that incorporate(s) all of the results to achieve interpretation of the whole system. These rules must include a basis for deciding how many parameters must pass their tests for success to be declared. Individual parameters may be given different weights in the decision-making process.

Choice of Null Hypothesis

As with any statistical approach based upon hypothesis testing, it is necessary to choose a null and an alternative hypothesis. For example, under the assumption that target areas have been successfully restored, the null hypothesis (H_0) and alternative hypothesis (H_1) can be stated as:

- H_0: There is no significant difference between the before and after condition. That is, the difference between target and reference stations does not change; both come from the same distribution of values.
- H_1: There is a significant difference between the before and after condition. That is, the difference between target and reference stations changes after dredging.

The analysis can also be framed with these hypotheses reversed, in which case, the null hypothesis would state that there is a significant difference between the before and after condition. The alternative hypothesis would state that the difference between the before and after condition is less than a specified amount (termed a "bioequivalence factor", *B*). The bioequivalence approach has been used extensively in the pharmaceutical industry, particularly in testing the effectiveness of generic drugs against name-brand drugs (Westlake 1988). It has also been applied in the field of habitat restoration (McDonald et al. 2003). This approach has the benefit of resting on the null hypothesis that restoration has not been successful: it is necessary to have collected sufficient data, those data must have a sufficiently small variance, and the post-dredging target habitats must be of sufficient quality, for success to be declared. Both the classical and the bioequivalence null hypotheses will be evaluated using the available habitat data. The final hypotheses will be described in the Phase 1 Cap/Habitat OM&M Plan.

Simulation Analysis

As shown in Table A-2, there are a total of eight possible statistical approaches. Six of these will be evaluated. Multivariate analysis based on the bioequivalence approach is at present a research-level approach for which published information is very limited. In the interests of clarity and defensibility, this approach will not be evaluated further. Choice of the final method, as well as the setting of the numerical criteria, will depend upon the results of simulation analyses that will be performed using data already collected from each habitat. GE and EPA will work collaboratively in an effort to plan and conduct these simulation analyses. These analyses will be used to select one of the statistical methods and to determine values of the key parameters (i.e., alpha level, α and bioequivalence factor, B). The final criteria will be described in the Phase 1 Cap/Habitat OM&M Plan.

Contingency

It is possible that reasonable Type I and Type II error rates cannot be attained based on the existing sampling designs and data distributions. In this situation GE and EPA will work collaboratively to develop feasible alternative approaches that may include consideration of qualitative approaches, use of the Functional Capacity Index (FCI) models, or other indexing methods.

A.2 UNCONSOLIDATED RIVER BOTTOM

The OM&M Scope provided (Section 4.3, at p. 4-10) that the parameters for application of the primary success criteria for unconsolidated river bottom are substrate type and FCIs and Habitat Suitability Indices (HSIs). Since the substrate type is the EPA-approved backfill, the primary success criteria for UCB will include the placement of the backfill materials in accordance with the backfill plans and specifications. In addition, to address the FCI/HSI criterion, alternative measures will be considered. GE and EPA will continue collaborative efforts to develop the final parameters and a technical basis for their selection, as well as an appropriate quantitative or qualitative method for determining achievement of the success criteria for those parameters. GE will also continue discussions with EPA regarding the potential collection of data for the direct measure of habitat function (e.g., benthic invertebrate data, fisheries data) as an alternative to using the FCIs and/or HSIs. These discussions are anticipated to conclude within the same time period as the development of success criteria for other habitats (see Table A-1). The final success criteria for this habitat type, including any additional data collection agreed to by GE and EPA, will be described in the Phase 1 Cap/Habitat OM&M Plan.

A.3 AQUATIC VEGETATION BEDS

As discussed above, the quantitative primary success criteria for SAV habitats are being developed within the BACI framework. As provided in the OM&M Scope (Section 4.3 at p. 4-10) and shown in Table 2-1, the specific parameters on which these criteria will be based for Phase 1 are stem density, percent cover, and plant species composition.[1] Based on discussions with EPA, the experimental design for collecting and analyzing SAV data was revised to use the individual sampling quadrat as the experimental unit instead of the sampling station (comprised of 9 or 18 quadrats depending on size of the SAV bed). Following receipt of the 2007 habitat assessment data and updates to the habitat database, simulation plots will be run to incorporate the 2007 data and submitted to EPA. GE and EPA will review the data simulations to select the appropriate test(s), including alpha level or bioequivalence factor, for evaluating SAV replacement/reconstruction.

[1] In this Phase 1 AM Plan, GE has included plant species composition, which is focused on monitoring for invasive species, as an adaptive management benchmark, in addition to its use as a success criterion, to facilitate early monitoring and management of invasive species. The use of FCIs and HSIs is under discussion with EPA; HSIs as well as wildlife observations may also be used as optional, secondary success criteria.

A.4 SHORELINE AND RIVERINE FRINGING WETLANDS

The following subsections outline the process for selecting the data sets and statistical analyses to be evaluated in selecting success criteria for shoreline and riverine fringing wetland habitats.

Parameters to be used to evaluate success

For natural shoreline habitats, as provided in the OM&M Scope (Section 4.3, at p. 4-10) and shown in Table 2-1, the specific parameters on which the quantitative primary success criteria for Phase 1 will be based are: (1) bank assessment components; and (2) plant species composition.[2] The use of FCIs and HSIs is under discussion with EPA; and HSIs as well as wildlife observations may also be used as optional, secondary success criteria.

For riverine fringing wetlands, as provided in the OM&M Scope (Section 4-3, at p. 4-10) and shown in Table 2-1, the specific parameters on which the quantitative primary success criteria will be based are: (1) percent cover; and (2) plant species composition.[3] Again, for WET, the use of FCIs is under discussion with EPA; HSIs as well as wildlife observations may also be used as optional, secondary success criteria.

Selection of the Data Set

Data have been collected from both Phase 1 and Phase 2 areas and from all three river sections. Simulations will be performed including data collected through 2007. The target dataset will include Phase 1 and River Section 1 only. A separate evaluation will be performed to determine the composition of the reference dataset, in particular whether Phase 2 data are to be included, which river sections are to be included, and whether correction factors should be incorporated for portions of the dataset (as was done in the SAV analysis). An additional evaluation will be performed to determine the appropriate experimental unit for completing the

[2] As with SAV, plant species composition is also included as an adaptive management benchmark to facilitate early monitoring and management of invasive species.

[3] As for SAV and SHO, plant species composition, which is focused on monitoring for invasive species, is also included as an adaptive management benchmark

simulations, i.e., the habitat assessment station *vs.* individual transects (for shoreline) or quadrats (for riverine fringing wetland). The composition of the reference dataset will be agreed to by GE and EPA before beginning the data simulations.

Preliminary Technical Analyses

As described in Section 1.1.1 above, data for WET and SHO will be subjected to preliminary technical analyses to determine the need for and feasibility of applying the BACI framework to these habitat types. A technical justification will be developed to assess the appropriateness of the full BACI framework. If data suggest that these habitats do not lend themselves to the full BACI approach, then alternative procedures may be proposed. If the preliminary analyses suggest that the BACI approach is appropriate, then the remainder of the BACI framework will be applied to data from these habitats. These analyses will follow the approach that has been taken thus far for SAV habitats.

A.5 ADDITIONAL TASKS AND SCHEDULE

It is anticipated that it will take approximately 4 to 6 months to complete the necessary tasks and finalize quantitative success criteria for all habitats.

As previously stated, the final quantitative success criteria will be provided in the Phase 1 CAP/Habitat OM&M Plan. The items that remain to be completed and the anticipated schedule for their completion are provided in Table A-1.

Table A-1. List of remaining tasks and anticipated timeframe for the development of final quantitative success criteria.

Habitat	Item	Anticipated Schedule
SAV	Submit updated simulation plots using quadrats as the experimental unit	30 days after approval of the Phase 1 Adaptive Management Plan
SAV	Review SAV simulation plots with EPA	15 days after submittal of updated simulation plots to EPA
SAV	Select statistical test and alpha or bioequivalence factor for final SAV success criteria	15 days after review of SAV simulation plots with EPA
SAV, UCB	Submit Technical Memorandum #1 to summarize approach to SAV habitat and status of UCB discussions and any UCB-related work products.	30 days after selection of final quantitative success criteria for SAV
SHO, WET[1]	Submit raw data plots for discussion of reference condition	15 days after completion of habitat database updates
SHO, WET[1]	Select data sets and define reference condition	Latest of 15 days after submittal of data plots to EPA; or agreement on composition of reference dataset with EPA
SHO, WET[1]	Develop final matrix of statistical tests	15 days after agreement on data sets and reference condition
SHO, WET[1]	Create R code to perform agreed upon statistical tests; submit data simulation results to EPA for review / discussion	30 days after agreement on statistical tests
SHO, WET[1]	Discuss data simulation results and agree on appropriate test (may required code revisions and creation of additional data plots)	30 days after submittal of initial data simulation plots
SHO, WET[1,]	Select final quantitative success criteria for SHO and WET habitats	15 days after submittal of updated data simulation plots
SHO, WET, UCB[1]	Submit Technical Memorandum #2 to summarize approach to SHO and WET habitats and status of UCB discussions and any UCB-related work products.	30 days after selection of final quantitative success criteria for SHO and WET habitats
SAV, SHO, WET, UCB[1]	Submit draft text for the Phase 1 Cap/Habitat OM&M Plan, to EPA describing the results of the simulation analysis and agreements between GE and EPA on the final success criteria.	30 days after agreement on appropriate tests

Note:

[1] *It is anticipated that preliminary analyses for UCB habitats (including discussions regarding the use of specific parameters for success criteria and quantitative or qualitative methods for evaluating those parameters), as well as discussions regarding the potential use of a direct measure of function in UCB habitat, will occur within the same time period as the development of success criteria for the other habitats.*

Table A-2. Statistical approaches to evaluating success of SAV, natural shoreline, and riverine fringing habitat reconstruction in the Hudson River.

	Classical Null Hypothesis		**Bioequivalence Approach**	
	Parametric[1, 2]	Nonparametric[1, 3]	Parametric[1, 2]	Nonparametric[1, 3]
Univariate[1]	ANOVA	ANOVA	ANOVA	ANOVA
Multivariate[1]	MANOVA	MANOVA[3]	Research-Level[4]	Research-Level[4]

Notes:

[1] *In all cases, the statistical test to be performed will be a one-tailed test for significant interaction between Before/After and Control/Impact. Other tests, for example the t-test, may also be evaluated if agreed to by EPA and GE.*

[2] *Parametric cases: data will be transformed to near-normality using an optimized Box-Cox transformation.*

[3] *Nonparametric cases: (M)ANOVA to be performed using an aligned rank test.*

[4] *Research-level techniques will not be included in the evaluation of alternative approaches.*

EXHIBIT B

HSI Development

Quantitative Environmental Analysis, LLC
∂c/∂t

EXHIBIT B
HSI DEVELOPMENT

The objective of this Exhibit to the Phase 1 Adaptive Management Plan (Phase 1 AM Plan) is to document the data sources used to calculate Habitat Suitability Index (HSI) model values for the representative species specified in the Phase 1 HA Report.

The HSI models and associated parameters that are used in those models provide the information that may be used as part of the secondary success criteria to assess whether the overall program goals have been met once the habitat replacement and reconstruction designs have been implemented. Secondary success criteria are described in Section 2 of the Phase 1 AM Plan.

B.1 HABITAT SUITABILITY INDEX (HSI) MODELS

Data were collected under various programs to calculate HSI model scores for River Section 1 (Thompson Island Pool). HSI values were calculated for the entire reach and separately for target and reference areas and are reported in the Habitat Assessment Report for Phase 1 Candidate Areas (Phase 1 HA Report, BBL and Exponent 2005b) and the Habitat Assessment Report for Phase 2 Areas (Phase 2 HA Report, QEA 2007).

Selected Species

The representative species for which HSI models have been calculated are shown in Table B-1, below. The rationale for the selection of these representative species was provided in the Phase 1 HA Report.

Where models exist for both lacustrine and riverine environments, the riverine models were used. In some cases, such as with the great blue heron, only one index of the overall HSI will be used (the foraging index) as the remaining variables are specific to habitats unlikely to be impacted by remedial activities (i.e., forested wetlands off the river). A rationale for the exclusion of certain variables from the HSI models was provided in Appendix I of the Phase 1 HA Report.

Table B-1. List of species for HSI models.

Species (Scientific Name)	Associated Habitat	Rationale
Birds		
Belted Kingfisher (*Ceryle alcyon*)	SHO, UCB	• Habitat potentially impacted by dredging • Forested habitat along edge of the river provides foraging and nesting • River likely provides suitable prey population
Great Blue Heron (*Ardea herodius*)	SHO, UCB, WET, SAV	• Habitat within range of nesting sites • River likely provides suitable prey population • HSI model for Upper Hudson River will only use the foraging index within the overall HSI
Wood Duck (*Aix sponsa*)	SHO, UCB, WET, SAV	• Forested wetlands along river provide potential nesting sites • Overhang and downfall along natural shorelines provide potential cover
Mammals		
Mink (*Mustela vison*)	SHO, WET	• Portions of potential mink habitat in near-shore areas could be impacted by remedial activities; therefore mink has been retained as requested by the United States Environmental Protection Agency (EPA)
Muskrat (*Ondatra zibethicus*)	SHO, WET, SAV	• Abundant herbaceous vegetation on shoreline and in wetlands • Low flow conditions of Upper Hudson River still provide surface water • Tracks frequently observed during assessment of fringing wetlands
Fish		
Yellow Perch (*Perca flavescens*)	UCB, SAV	• Habitat potentially impacted by dredging • Recreational species • Predator/invertivore
Largemouth Bass (*Micropterus salmoides)*	UCB, WET, SAV	• Habitat potentially impacted by dredging • Recreational species • Top predator
Smallmouth Bass (*Micropterus dolomieui*)	UCB, SAV	• Habitat potentially impacted by dredging • Recreational Species • Predator/invertivore
Common Shiner (*Notropis cornutus*)	UCB, WET, SAV	• Habitat potentially impacted by dredging • Representative HSI species for Cyprinidae • Forage base for predatory fish and piscivorous wildlife
Bluegill (*Lepomis macrochirus*)	UCB, WET, SAV	• Large woody debris and SAV provide cover • Recreational species • Forage base for predatory fish and piscivorous wildlife
Reptiles/Amphibians		
Snapping Turtle (*Chelydra serpentina*)	SHO, UCB, WET, SAV	• Small tributaries and backwaters present along river edge • Depths in river exceed ice depth; provides overwintering

Notes:
1. *UCB = Unconsolidated river bottom*
2. *SAV = Submerged aquatic vegetation*
3. *SHO = Shoreline*
4. *WET = Wetland*

Data Sources

In accordance with the EPA-approved Supplemental Habitat Assessment Work Plan (SHAWP; BBL and Exponent 2005c), data collected as part of ongoing monitoring programs were used to complete the HSI models for the selected species. Data sources included: water quality data from the Hudson River Baseline Monitoring Program (QEA 2004), water quality and habitat assessment data from the Habitat Delineation and Assessment Program (BBL and Exponent 2005a), bathymetric survey data (QEA 2003), habitat delineation data (BBL and Exponent 2005b), and aerial photography (BBL and Exponent 2005a). Some suitability indices were determined based on defined categories (such as soil type or specific pH range); while others were based on calculated values (i.e., mean temperature). Once variables were calculated, the suitability index for that variable was obtained by interpolation using curves provided in each HSI model. The suitability indices for individual variables were then used to compute component suitability indices (e.g., food, cover, reproduction) from which the final HSIs were calculated. A summary of final HSI values for all species is shown in Table B-2.

The HSI model for yellow perch was modified due to temporal data limitations. Specifically, the calculated HSI for yellow perch for River Section 1 was 0.0 using the entire set of variables. The low HSI value was the result of the winter degree days variable (number of days with water temperature between 4 and 10°C during the winter). The temperature data available from the Upper Hudson River is sparse during the winter due to ice cover, thus giving an estimate of winter degree days that is likely biased low. However, based on the Baseline Monitoring Program (BMP) fish sampling data, yellow perch are common in River Section 1. Since winter degree days are unlikely to be changed by dredging, this variable was removed from the HSI calculations for yellow perch. This approach has been used for the application of HSI models elsewhere (Madsen et al. 1998).

B.2 REFERENCES

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QEA, 2007. *Habitat Assessment Report for Phase 2 Areas* (Phase 2 HA Report). Hudson River PCBs Superfund Site. Prepared for General Electric Company, Albany, NY.

Table B-2. Suitability indices calculations for representative fish indicator species.										
Variable	**Description**	**Calculation**	**Target Areas**		**Reference Areas**		**All Areas**		**Data Source**	**Comments**
			Value	**SI**	**Value**	**SI**	**Value**	**SI**		
Yellow Perch										
V2	% pool and backwater during average summer flow	Determined in GIS: pool area as a % of reach area	99.77	0.31	96.25	0.39	97.20	0.37	Summer 2003 aerial photography	
V3	% cover during summer within pools and backwaters	Determined in GIS: vegetative and nonvegetative cover as % of pool and backwater area	30.71	1.00	25.34	1.00	26.82	1.00	2003 habitat survey and OSI RS1 SSS debris* data	
V4	Most suitable temperature (^oC) during midsummer - adults, juveniles, and fry	Find the temperature closest to 22^{o}C between July 1 and August 31	22.00	1.00	22.00	1.00	22.00	1.00	BMP and Habitat Assessment data (2003 - 2005)	
V5	Most suitable temperature (^oC) during spawning and embryo development within pools and backwaters	Find the temperature closest to 10.5^{o}C in April to June	11.13	1.00	11.13	1.00	11.13	1.00	BMP data	
V6	Minimum D.O. (mg/L) during the growing season at the locations where the most suitable temperatures were observed	Find minimum D.O. between May 1 and October 1 - at the same locations as the most suitable temperature observations (V4 & V5)	8.76	1.00	8.76	1.00	8.76	1.00	BMP and Habitat Assessment data (2003 - 2005)	
V7	Degree days (4-10^{o}C) from October 30 to April 1	Multiply average of weekly temperature measurements in RS1, between 4 and 10^{o}C, by 7 days; calculate total	215.20	0.00	215.20	0.00	215.20	NA	BMP data	variable was removed due to gaps in temperature data during mid-winter
V8	pH range throughout year	Determine max and min pH and 2 standard errors (stderr) from the mean: SI = 1.0 if mean-2stderr > 6.5 and mean+2stderr < 8.5; SI = 0.5 if pH is 5.5 - 6.5 or 8.5 - 9.5; SI = 0.25 if mean+2 stderr < 6.5 and mean-2stderr > 4.5 and min <4.5 or mean+2 stderr < 9.5 and mean-2stderr ge 8.5 and max > 9.5; SI = 0.1 if mean-2stderr < 4.5 or mean+2stderr > 9.5		1.00		1.00		1.00	BMP data	Excluded extreme low measurement on 5/16/05 and values > 12; Habitat Assessment data was not used due to pH probe issues
HSI	Habitat suitability index	Minimum SI value		0.00		0.00		0.37		

Table B-2. Suitability indices calculations for representative fish indicator species.

Variable	Description	Calculation	Target Areas		Reference Areas		All Areas		Data Source	Comments
			Value	SI	Value	SI	Value	SI		
Largemouth Bass										
V1	% pool and backwater during summer	Determined in GIS: pool area as a % of reach area	99.77	1.00	96.25	1.00	97.20	1.00	Summer 2003 aerial photography	
V3	% bottom cover during summer - vegetative and non-vegetative for adults and juveniles	Determined in GIS: vegetative and non-vegetative area as % of pool area	30.71	0.81	25.34	0.71	26.82	0.74	2003 Habitat delineation and OSI SSS debris data	
V4	% bottom cover - vegetative and non-vegetative for fry	Determined in GIS: vegetative and non-vegetative area as % of pool area	30.71	0.77	25.34	0.63	26.82	0.67	2003 Habitat delineation and OSI SSS debris data	
V6	Minimum D.O. during midsummer	Examine D.O. values during July and August: SI = 0.1 if more than 5 measurements are < 2.0; SI = 0.4 if 75% of D.O. measurements are between 2 and 5 ; SI = 0.4 if 75% of D.O. measurements are between 5 and 8; SI = 1.0 87.5% of measurements are greater than 8		1.00		1.00		1.00	BMP data	Assumed values < 4.0 were erroneous and the river was not anoxic during these periods (C. Yates)
V7	pH range throughout the growing season	Find whether 85% of pH measurements fall within the following ranges: SI = 0.1 if pH < 5.0 or pH > 10.0; SI = 0.5 if range is 5.0 < pH < 6.5 or 8.5 < pH < 10.0; SI = 1.0 if range is 6.5 < pH < 8.5		1.00		1.00		1.00	BMP data	Habitat Assessment data was not used due to pH probe issues
V8	Average water temperature during growing season (adult and juvenile)	Mean temperature between May and October	20.35	0.59	20.39	0.60	20.38	0.60	BMP and Habitat Assessment data (2003 - 2005)	
V9	Mean weekly average water temperature during spawning and incubation (embryo)	Mean weekly average water temperature between May 1 and June 15	16.24	0.46	16.24	0.46	16.24	0.46	BMP data	
V10	Average water temperature during growing season (fry)	Mean temperature between May 1 and October 1	20.35	0.49	20.39	0.49	20.38	0.49	BMP and Habitat Assessment data (2003 - 2005)	

Table B-2. Suitability indices calculations for representative fish indicator species.

Variable	Description	Calculation	Target Areas		Reference Areas		All Areas		Data Source	Comments
			Value	SI	Value	SI	Value	SI		
V11	Maximum monthly average turbidity during growing season	Maximum of monthly average turbidity between May and October: SI = 1.0 if max >= 5 ppm and max <= 25 ppm; SI = 0.7 if max > 25 ppm and max <= 100 ppm; SI = 0.3 if max < 5 ppm or max > 100 ppm		0.30		0.30		0.30	BMP and Habitat Assessment data (2003 - 2005)	Converted from turbidity units NTU to ppm according to Dahlgren et al. (2004)*. 1 ppm = 1-2 NTU
V12	Maximum salinity during summer (adult and juvenile)	Maximum salinity between June 15 to September 15	0.99	1.00	0.99	1.00	0.99	1.00	BMP and Habitat Assessment data (2003 - 2005)	
V13	maximum salinity during summer (fry)	Maximum salinity between June 15 to September 15	0.99	1.00	0.99	1.00	0.99	1.00	BMP and Habitat Assessment data (2003 - 2005)	
V14	maximum salinity during spawning and incubation (fry)	Maximum salinity between May 1 to June 15	0.11	1.00	0.11	1.00	0.11	1.00	BMP data	
V15	Substrate composition within pools and backwaters (embryo)	Looked at overall description and primary sediment type data in top segment of cores: SI = 0.3 if predominant sediment type is rock; SI = 0.5 if predominant sediment type was sand; SI = 0.8 if predominant sediment type is silt or clay; SI = 1.0 if predominant sediment type is gravel		0.30		0.30		0.30	SSAP sediment data (in Locations (probing data) and Description tables)	only found which primary sediment type was most prevalent, not necessarily > 50%
V16	Average water level fluctuation (m) during growing season (adult and juvenile)	Average maximum water level fluctuation between May 1 and October 1	1.68	0.83	1.68	0.83	1.68	0.83	water level data from Canal Corp. (2001 - 2003)	
V17	Max water level fluctuation (m) during spawning (embryo)	Maximum water level fluctuation between May 1 and June 15	1.23	0.96	1.23	0.96	1.23	0.96	water level data from Canal Corp. (2001 - 2003)	

Table B-2. Suitability indices calculations for representative fish indicator species.										
Variable	**Description**	**Calculation**	**Target Areas**		**Reference Areas**		**All Areas**		**Data Source**	**Comments**
			Value	**SI**	**Value**	**SI**	**Value**	**SI**		
V18	Average water level fluctuation (m) during growing season (fry)	Average maximum water level fluctuation between May 1 and October 1	1.68	1.00	1.68	1.00	1.68	1.00	water level data from Canal Corp. (2001 - 2003)	
V19	Average current velocity at 60% depth during summer (adults and juveniles)	Average current at 60% depth between June 15 and Sept. 15	0.27	1.00	0.32	1.00	0.31	1.00	Habitat Assessment data (2003 - 2005)	
V20	Maximum current velocity at 80% depth during spawning in pools and backwaters (embryo)	Maximum current at 80% depth between May 1 and June 15	1.22	1.00	1.22	1.00	1.22	1.00	Habitat Assessment data (2003 - 2005)	Not from spawning period
V21	Average current velocity at 60% depth during summer (fry)	Average current at 60% depth between June 15 and September 15	0.27	1.00	0.32	1.00	0.31	1.00	Habitat Assessment data (2003 - 2005)	
V22	Stream gradient in reach (m/km)	Determined in GIS: measured elevation difference from north of reach to south of reach (m) and total reach length (km): gradient in m/km	0.27	1.00	0.27	1.00	0.27	1.00	2001 OSI RS1 bathymetry data	
SIF	Food Suitability Index	(SI1 * ((SI3+SI4)/2)^(1/2)		0.89		0.82		0.84		
SIC	Cover Suitability Index	(SI1 * ((SI3+SI4)/2) * ((SI16+SI18)/2))^(1/3)		0.90		0.85		0.86		
SIWQ	Water Quality Suitability Index	((2 * SI6) + SI7 +(2 * SI8) + SI10 +SI11)/7		0.71		0.71		0.71		SI12 or SI13 = 1.0
		((2 * SI6) + SI7 +(2 * SI8) + SI10 +SI11 + ((SI12 + SI13)/2))/8								SI12 and SI13 < 1.0
		minimum(SI6, SI8, SI10, SIWQ)								SI6, SI7, SI8, or SI10 < 0.4
SIR	Reproduction Suitability Index	(SI1 *SI9 * SI15 * SI17 * SI20)^ (1/5)		0.67		0.67		0.67		SI4 = 1.0
		(SI1 *SI9 * SI14 * SI15 * SI17 * SI20)^ (1/6)								SI4 < 1.0
SIO	Other Suitability Index	SI22		1.00		1.00		1.00		
HSI	Habitat Suitability Index	(SIF * SIC * SIWQ * SIR * SIO)^(1/5)		0.82		0.80		0.81		

Table B-2. Suitability indices calculations for representative fish indicator species.										
Variable	**Description**	**Calculation**	**Target Areas**		**Reference Areas**		**All Areas**		**Data Source**	**Comments**
			Value	**SI**	**Value**	**SI**	**Value**	**SI**		
Smallmouth Bass										
V1	Dominant substrate type within pools and backwaters	Looked at overall description and primary type sediment data in top segment of cores: SI = 0.2 if predominant sediment type is silt or sand; SI = 0.3 if predominant sediment type is pebbles; SI = 1.0 if predominant sediment type is gravel; SI = 0.2 if predominant sediment type is rock		0.20		0.20		0.20	SSAP sediment data in Locations and Description tables	Predominant sediment type only means the most common, not necessarily > 50%
V2	% pools	Determined in GIS: pool area as % of reach area	99.77	0.21	96.25	0.32	97.20	0.29	Summer 2003 aerial photography	
V4	Average depth (m) of pools during midsummer	Determined in GIS: mean of all bathymetry grid cells in reach at 3,661 cfs	3.05	1.00	2.90	1.00	2.93	1.00	QEA hydrodynamic model grid	
V5	% cover nonvegetative (adults) or vegetative (fry)	Determined in GIS: vegetative and nonvegetative cover as % of reach area	30.71	1.00	25.34	1.00	26.82	1.00	2003 Habitat delineation and OSI side-scan sonar debris data*	
V6	Average pH during year	Average of all pH measurements	7.57	0.91	7.57	0.91	7.57	0.91	BMP data	Excluded extreme low value on 5/16/05 and values > 12; Habitat Assessment data was not used due to pH probe issues
V8	Minimum D.O. (ppm) throughout the year	Minimum D.O. (ppm) measurement	4.18	0.47	4.18	0.47	4.18	0.47	BMP and Habitat Assessment Data (2003 - 2005)	Assumed values < 4.0 were erroneous and the river was not anoxic during these periods (C. Yates)
V9	Maximum monthly average turbidity (JTU) during summer	Maximum of monthly average turbidity between June 15 and Sept 15	3.64	1.00	3.64	1.00	3.64	1.00	BMP and Habitat Assessment Data (2003 - 2005)	BMP and Habitat data are in NTU; JTU is approximately equal to NTU
V10	Water temperature (^{o}C) in selected habitat during May-Oct. (adults)	Mean water temperature May 1 to Oct 1	21.26	0.91	21.21	0.91	21.15	0.90	BMP and Habitat Assessment Data (2003 - 2005)	Temperature measurements were not all collected in the specific habitat

Table B-2. Suitability indices calculations for representative fish indicator species.										
Variable	**Description**	**Calculation**	**Target Areas**		**Reference Areas**		**All Areas**		**Data Source**	**Comments**
			Value	**SI**	**Value**	**SI**	**Value**	**SI**		
V11	Water temp. (^oC) in selected habitat during spawning and 45 after (embryo)	Mean water temp between April 15 and July 31	20.08	1.00	20.08	1.00	20.08	1.00	BMP data	Due to limited temperature data measurements are not all taken in selected areas
V12	water temperature in selected habitat during May-Oct. (fry)	Mean water temp May 1 to Oct 1	21.26	0.92	21.21	0.92	21.15	0.92	BMP and Habitat Assessment Data (2003 - 2005)	
V13	Water temperature (^oC) in selected habitat during May-Oct. (juvenile)	Mean water temp May 1 to Oct 1	21.26	0.93	21.21	0.93	21.15	0.93	BMP and Habitat Assessment Data (2003 - 2005)	
V14	Water level fluctuation (m) during spawning and 45 days afterward	Determined water level difference between beginning and end of three time periods: (prior to May 1 = before); during spawning (May 1 - June 15 = spawn); after spawning (June 15 - July 31 = after). SI = 0.3 if spawn >= 1m and spawn <= 2 m; SI = 0.0 if spawn <= -0.5 m and after <= -0.5 m; SI = 1.0 if (0.5 m < before < 1.0 m) and -1.0 m < spawn < 1.0 m and -1.0 m < after < 1.0 m		1.00		1.00		1.00	Water level data from Canal Corp (2001 - 2003)	
V15	Stream gradient in reach (m/km)	Determined in GIS: measured elevation difference from north of reach to south of reach (m) and total reach length (km): gradient in m/km	0.27	0.41	0.27	0.41	0.27	0.41	2001 OSI RS1 bathymetry data	
SIF	Food Suitability Index	(SI1 * SI2 * SI5)^(1/3)		0.35		0.40		0.39		
SIC	Cover Suitability Index	(SI1 + SI2 + SI4 + SI5)/4		0.60		0.63		0.62		
SIWQ	Water Quality Suitability Index	((SI6 + SI8 + SI9 + (2 * ((SI10 * SI12 * SI13)^(1/3))))/5		0.84		0.84		0.84		
SIR	Reproduction Suitability Index	((SI11^2) * SI14 * SI1 * SI5 * SI8 * SI9)^(1/7)		0.71		0.71		0.71		
SIO	Other Suitability Index	SI15		0.41		0.41		0.41		
HSI	Habitat Suitability Index	(SIF * SIC * SIWQ * SIR * SIO)^(1/5)		0.55		0.57		0.57		SIWQ and SIR > 0.6
		Minimum(SIWQ, SIR, HSI)								SIWQ or SIR < 0.6

Table B-2. Suitability indices calculations for representative fish indicator species.

Variable	Description	Calculation	Target Areas		Reference Areas		All Areas		Data Source	Comments
			Value	SI	Value	SI	Value	SI		
Bluegill										
V1	Percent pool area during average summer flow	Determined in GIS; pool area as % of the reach area	99.77	1.00	96.25	1.00	97.20	1.00	Summer 2003 aerial photography	
V2	Percent cover - nonvegetative	Determined in GIS; nonvegetative cover as % of pool area	6.77	0.47	8.23	0.53	7.82	0.51	OSI side-scan sonar debris data	
V3	Percent cover - vegetative only	Determined in GIS; vegetative cover as % of pool area	24.71	1.00	17.86	1.00	19.75	1.00	2003 habitat survey GIS data	
V6	Maximum monthly average turbidity (ppm) during average summer flows	Maximum of monthly average turbidity between June 15 and Sept. 15	2.44	1.00	2.44	1.00	2.44	1.00	BMP data	Converted from NTU to ppm by multiplying by 0.67. (1-2 NTU/ ppm [Dahlgren et al. 2004])
V7	pH range during growing season	Find whether 85% of pH measurements (May 1 to Oct. 1) fall within the following ranges: SI = 0.1 if pH < 5.0 or pH > 10.0; SI = 0.2 if range is 5.0 < pH < 6.0 or 9.0 < pH < 10.0; SI = 0.5 if range is 6.0 < pH < 6.5 or 8.5 < pH < 9.0; SI = 1.0 if range is 6.5 < pH < 8.5		1.00		1.00		1.00	BMP data	Eliminated extreme low values from 5/16/05 and values > 12; Habitat Assessment data was not used due to pH probe issues
V8	D.O. (ppm) range during summer	Determined +/- 2 stderr of the mean from June 15 to Sept. 15: SI = 1.0 if -2stderr ge 5; SI = 0.7 if -stderr < 3 and +stderr > 5; SI = 0.25 if -stderr < 1.5 and +stderr > 3; SI = 0.1 if +stderr < 1.5		1.00		1.00		1.00	BMP and Habitat Assessment Data (2003 - 2005)	
V9	Maximum average monthly salinity (ppm) during growing season	Maximum of monthly average salinity between May 1 and October 1	0.10	1.00	0.10	1.00	0.10	1.00	BMP and Habitat Assessment Data (2003 - 2005)	Optional
V10	Maximum midsummer temperature (^oC) (adults)	Maximum temperature between July 1 and August 31	26.56	0.99	26.56	0.99	26.56	0.99	BMP data	

Table B-2. Suitability indices calculations for representative fish indicator species.

Variable	Description	Calculation	Target Areas		Reference Areas		All Areas		Data Source	Comments
			Value	SI	Value	SI	Value	SI		
V11	Average mean weekly water temperature (^{o}C) during spawning (embryo)	Mean weekly temperature between May 15 to July 15	20.60	0.65	20.60	0.65	20.60	0.65	BMP data	
V12	Maximum early summer temperature (^{o}C) (fry)	Maximum temp between June 1 and July 1	24.45	0.96	24.45	0.96	24.45	0.96	BMP data	
V13	Maximum midsummer temperature (^{o}C) (juveniles)	Maximum temp between July 1 and August 31	26.56	0.79	26.56	0.79	26.56	0.79	BMP data	
V14	Average current velocity (cm/s) during growing season in pools and backwaters (adult)	Average current velocity throughout water column (May 1 to Oct. 1)	0.32	1.00	0.35	1.00	0.33	1.00	Habitat Assessment Data (2003 - 2005)	Habitat data is from late summer
V15	Average current velocity (cm/s) in spawning areas (embryo)	Average current velocity throughout water column May 15 to July 15	0.32	1.00	0.35	1.00	0.33	1.00	Habitat Assessment Data (2003 - 2005)	Habitat data is from late summer
V16	Average current velocity (cm/s) in pools during early summer (fry)	Average current velocity throughout water column June 1 to July 1	0.32	1.00	0.35	1.00	0.33	1.00	Habitat Assessment Data (2003 - 2005)	Habitat data is from late summer
V17	Average current velocity (cm/s) during the growing season (juvenile)	Average current velocity throughout water column May 1 to Oct. 1	0.32	1.00	0.35	1.00	0.33	1.00	Habitat Assessment Data (2003 - 2005)	Habitat data is from late summer
V18	Stream gradient in reach (m/km)	Determined in GIS: measured elevation difference from north of reach to south of reach (m) and total reach length (km): gradient in m/km	0.27	1.00	0.27	1.00	0.27	1.00	2001 OSI RS1 bathymetry	
V20	Substrate composition within pools (embryo)	SI = 1.0 b/c gravel and fines are present in all river sections		1.00		1.00		1.00		
SIF	Food Suitability Index	(SI1 * SI2 * SI3)^(1/3)		0.78		0.81		0.80		
SIC	Cover Suitability Index	(SI2 + SI3)/2		0.74		0.76		0.76		
SIWQ	Water Quality Suitability Index	(SI6 + SI7 + (2 * SI8) + SI9 + (2 * [(SI10 * SI12 * SI13)^(1/3)]))/7		0.97		0.97		0.97		SI8 or (2 * [(SI10 * SI12 * SI13)^(1/3)]) > 0.4
		Minimum(SI8, (2 * [(SI10 * SI12 * SI13)^(1/3)]), SI9)								SI8 or (2 * [(SI10 * SI12 * SI13)^(1/3)]) < 0.4
SIR	Reproduction Suitability Index	(SI11 * SI15 * SI20)^(1/3)		0.87		0.87		0.87		
SIO	Other Suitability Index	(((SI14 + SI16 + SI17)/3) + SI18)/2)		1.00		1.00		1.00		
HSI	Habitat Suitability Index	(SIF * SIC * (SIWQ^2) * SIR * SIO)^(1/6)		0.88		0.89		0.89		SIWQ or SIR > 0.4
		Minimum(SIF, SIC, SIWQ, SIR, SIO)								SIWQ or SIR < 0.4

Table B-2. Suitability indices calculations for representative fish indicator species.

Variable	Description	Calculation	Target Areas		Reference Areas		All Areas		Data Source	Comments
			Value	SI	Value	SI	Value	SI		
Common Shiner										
V1	Maximum summer temp. persisting for > 1 week	Determined the first and last day within each year where the temperature was > each unique temperature and found the maximum temperature with a duration greater than 7 days	26.00	0.30	26.00	0.30	26.00	0.30	BMP data	Could not use Habitat data because dates were not kept in data, just years
V2	Least suitable pH occurring during year	Determined the pH with the greatest absolute difference from 7.5	8.57	1.00	8.57	1.00	8.57	1.00	BMP data	Excluded 5/16/05 extreme low values and values > 12; Habitat Assessment data was not used due to pH probe issues
V3	Average turbidity in JTU	Mean of turbidity throughout year	1.74	1.00	1.71	1.00	1.75	1.00	BMP and Habitat Assessment Data (2003 - 2005)	BMP and Habitat data are in NTU; JTU is approximately equal to NTU
V4	Predominant substrate in riffles or shoals	Examined overall description and sediment type data in top 12 inches of cores in riffle areas masked out in GIS: SI = 0.1 if predominant sediment is silt or organic; SI = 0.5 if predominant sediment type is fine sand; SI = 1.0 if sediment is predominantly gravel and sand; SI = 0.8 if predominant sediment type is rubble; SI = 0.2 if predominant sediment type is rock		0.10		0.50		0.50	SSAP sediment data in Locations and Description tables	Predominant sediment type only means the most common, not necessarily > 50%
V5	Percent pools	Determined in GIS: pool area as a % of reach area	99.77	0.60	96.25	0.64	97.20	0.63	Summer 2003 aerial photography	
V6	Average current velocity at 60% of depth in pools	Average current velocity at 60% of depth in pools	8.26	0.97	9.90	1.00	9.34	0.99	Habitat Assessment data (2003-2005)	
V7	Predominant pool class	SI = 0.4 b/c the predominant pool class is large and deep		0.40		0.40		0.40		
V8	Average water temp. (^{o}C) in spawn habitat during spawn	Average temperature from May 1 to July 1	18.02	0.89	18.02	0.89	18.02	0.89	BMP data	Data are not specifically from spawning habitat
V9	Average current velocity (cm/s) just above substrate in riffle	Used average current velocity from 10 cm above the substrate in UCB stations where water depth was less than 200 cm	14.49	0.90	16.22	1.00	13.27	0.65	Habitat Assessment data (2003-2005)	There was no velocity data from riffle areas; UCB stations with water depth < 200 cm were used as an approximation

Table B-2. Suitability indices calculations for representative fish indicator species.

Variable	Description	Calculation	Target Areas		Reference Areas		All Areas		Data Source	Comments
			Value	SI	Value	SI	Value	SI		
SIFC	Food and Cover Suitability Index	(SI4 + SI5 + SI6 + SI7)/4		0.10		0.63		0.63		All suitability indices are > 0.4
		Minimum(SI4,SI5,SI6,SI7)								Any of the suitability indices are < 0.4
SIWQ	Water Quality Suitability Index	(SI1 * SI2 * SI3)^(1/3)		0.30		0.30		0.30		All suitability indices are > 0.4
		Minimum(SI1,SI2,SI3)								Any of the suitability indices are < 0.4
SIR	Reproduction Suitability Index	((SI8^2) * SI4 * SI9)^(1/4)		0.52		0.79		0.71		All suitability indices are > 0.4
		Minimum(SI4,SI8,SI9)								Any of the suitability indices are < 0.4
HSI	Habitat Suitability Index	(SIFC * SIWQ * SIR)^(1/3)		0.10		0.30		0.30		SIFC, SIWQ or SIR > 0.4
		Minimum(SIFC,SIWQ,SIR)								SIFC, SIWQ or SIR < 0.4

Notes:
1. ** Dahlgren, R., E. VanNieuwenhuyse, and G. Litton. July-September 2004.* Transparency tube provides reliable water quality measurements. *California Agriculture. University of California Division of Agriculture and Natural Resources. http://CaliforniaAgriculture.ucop.edu.*

Table B-2 - Suitability Indices Calculations for Non-Fish Representative Indicator Species

Variable	Target Areas Value	Target Areas SI	Reference Areas Value	Reference Areas SI	All Areas Value	All Areas SI	Description	Calculation	Data Source	Comments
Mink										
V1		1.00		1.00		1.00	% of year with surface water present	SI = 1.0 b/c surface water is always present in the Upper Hudson		
V2	100.00	1.00	89.00	0.89	96.00	0.96	% shoreline cover within 1 m of shoreline	Estimated using photography from 2005 habitat assessment	2005 field photos	Pertinent transect data was not taken in the field; photos were used as a substitute
V3	46.30	0.66	68.40	0.92	58.00	0.80	% tree and/or shrub canopy cover within 100 m of water's edge	Determined in GIS: visual estimate	Summer 2003 aerial photography and QEA Hudson River shoreline	
SIW		1.00		1.00		1.00	Water Suitability Index	SI1		
SIC		0.81		0.91		0.87	Cover Suitability Index	(SI2 * SI3)^(1/2)		
HSI		0.81		0.91		0.87	Habitat Suitability Index	Minimum SIW and SIC		
Wood Duck										
V3	1419.83	1.00	1419.83	1.00	1419.83	1.00	Density of potential nesting sites per 0.4 ha (1 acre)	((0.18*cavities)+(0.95*nest boxes)/nesting area)*100	Habitat Assessment data (2005)	
V4	8.46	0.17	9.73	0.19	9.39	0.19	% of water surface covered by potential brood cover	Determined in GIS: area of wetlands and overhanging trees as a percent of total reach area	Summer 2003 aerial photography and QEA Hudson River shoreline at 5000 cfs	
HSI		0.17		0.19		0.19	Habitat Suitability Index	Minimum(SI3,SI4)		
Snapping Turtle										
V1	21.97	0.77	21.84	0.76	21.73	0.74	Water temp at mid-depth during summer	Mean water temperature between June 15 and September 15	BMP data and habitat assessment data (2003 - 2005)	Used 60% depth measurements from Habitat Assessment Data
V2	8.26	0.88	9.90	0.85	9.34	0.86	Mean current velocity at mid-depth during mid-summer (cm/s)	Current velocity at 60% of depth	Habitat assessment data (2003 - 2005)	
V3	30.81	0.31	25.65	0.26	27.04	0.27	% aquatic vegetation in littoral zone	Calculated the % cover of aquatic vegetation for the entire reach	2003 Habitat delineation GIS data	See Section III E. of Attachment A of SHAWP
V4		1.00		1.00		1.00	Maximum water depth greater than ice depth during winter	SI = 1.0 b/c water depth is always greater than ice depth		
V5	24.01	0.24	24.01	0.24	24.01	0.24	% silt in substrate	Average % silt in top 12" of cores within the reach	SSAP Results_NonPCBs table	
V6	4.42	0.56	4.61	0.54	4.54	0.55	Distance to small stream	Determined in GIS: mean of measured distances to small streams from wetlands and shoreline stations	2003 Habitat delineation and shoreline transect GIS data	
V7		1.00		1.00		1.00	Distance to permanent water	SI = 1.0 b/c Hudson River is permanent water		
SIF		0.59		0.55		0.56	Food Suitability Index	(SI1 * SI2 * SI3)^(1/3)		
SIWC		0.24		0.24		0.24	Winter Cover Suitability Index	SIWC = SI4 * SI5		
SIR		0.56		0.54		0.55	Reproduction Suitability Index	SIR = SI6		
SII		1.00		1.00		1.00	Interspersion Suitability Index	SII = SI7		
HSI		0.43		0.41		0.42	Habitat Suitability Index	((SIF*SIWC*SIR)^(1/3))*SII		

Table B-2 - Suitability Indices Calculations for Non-Fish Representative Indicator Species										
	Target Areas		Reference Areas		All Areas					
Variable	Value	SI	Value	SI	Value	SI	Description	Calculation	Data Source	Comments
Muskrat										
V2		1.00		1.00		1.00	% of year with surface water present	SI = 1 because surface water is present in the Hudson River year-round		
V3	0.27	1.00	0.27	1.00	0.27	1.00	Percent stream gradient	Determined in GIS: measured elevation diff. from north of reach to south of reach (m) and total reach length (km): gradient in m/km	2001 OSI RS1 bathymetry	
V4		1.00		1.00		1.00	% of river channel with water present during typical minimum flow	SI = 1 because there are no large drawdowns in the Hudson River		
V5	1.09	0.23	1.46	0.25	1.36	0.24	% of river channel dominated by emergent herbaceous veg	Determined in GIS (wetland cover as a % of total reach area)	2003 Habitat delineation	
V6	66.86	0.67	70.94	0.71	69.29	0.69	% herbaceous veg. cover within 10 m of water's edge	Mean % herbaceous cover of all shoreline stations in reach	Habitat Assessment Shoreline Data (2003 - 2005)	
SIF		0.62		0.62		0.62	Food Suitability Index	(((SI2 * SI3 * SI4)^(1/3)) + SI5)/2		
SIC		0.57		0.60		0.59	Cover Suitability Index	(SI6 + 2(SI5)) / 2		if SIF gt 1.0 then SIF = 1.0
HSI		0.57		0.60		0.59	Habitat Suitability Index	Minimum(SIF,SIC)		
Great Blue Heron										
V1	7.15	0.39	8.34	0.27	7.76	0.32	Distance between heronry areas and foraging sites	Calculated average distance between heronries and potential forage areas within reach	NYSDEC et al. 2004	
V2		1		1		1.00	Presence of water body with suitable prey population and foraging substrate	SI set to 1.0 because the Upper Hudson is assumed to support a suitable fish population and foraging substrate		
V3		1		1		1.00	A disturbance free zone up to 100 m around potential foraging areas	Determined in GIS areas within the reach with water depth < 0.5 meters and a 100 m exclusion zone were identified	2001 OSI RS1 Bathymetry, Spring 2002 aerial photos	Suitable foraging areas were identified in RS1 therefore variable was set to 1.0
SIF		0.39		0.27		0.32	Forage Suitability Index	SI1 *SI2 * SI3		
HSI		0.39		0.27		0.32	Habitat Suitability Index	SIF		

Table B-2 - Suitability Indices Calculations for Non-Fish Representative Indicator Species

Variable	Target Areas		Reference Areas		All Areas		Description	Calculation	Data Source	Comments
	Value	SI	Value	SI	Value	SI				
Belted Kingfisher										
V2	273.66	1.00	258.93	1.00	261.63	1.00	Average water transparency (secchi depth in cm)	Average of secchi depth readings for all stations in reach	Habitat Assessment Shoreline Data (2003 - 2005)	
V3	25.89	0.74	25.35	0.75	24.46	0.76	% water surface obstruction	Average percent of water surface obstruction for all stations in reach	Habitat Assessment Shoreline Data (2003 - 2005)	Obstructions are areas covered by emergent and floating vegetation, logs, leaves, or overhanging shore vegetation < 1.0 m above the water's surface
V4	6.21	0.29	8.12	0.30	7.61	0.30	% of water area that is < 60 cm	Determined in GIS by creating polygons of areas where water depth < 60 cm during the breeding season (May 1 to June 31) and calculating its percentage of the total reach	OSI 2001 RS1 bathymetry and QEA Hudson River shoreline at 5000 cfs	
V6	64.58	1.00	33.79	0.88	62.15	1.00	Availability of fishing perches - average number of stream subsections that contain one or more perches	Calculated the # of perches per km of shoreline sampled	Habitat Assessment Shoreline Data (2003 - 2005)	
V7	0.00	1.00	0.00	1.00	0.00	1.00	Distance to nearest suitable soil bank from river	Measured the distance from the reach to the nearest soil bank suitable for kingfisher nesting in GIS	NYSDEC et al 2004	
SIW		0.40		0.41		0.41	Water Suitability Index	((SI2 * SI4)^(1/2)) * SI3		Note - The equation for SIW that included % riffles (SI5) was not used because that variable was deemed to be not applicable for the Upper Hudson.
SIC		1.00		0.88		1.00	Cover Suitability Index	SI6		
SIR		1.00		1.00		1.00	Reproduction Suitability Index	SI7		
HSI		0.40		0.41		0.41	Habitat Suitability Index	Minimum(SIW,SIC,SIR)		

EXHIBIT C

Aquatic Vegetation Model

Quantitative Environmental Analysis, LLC
∂c/∂t

EXHIBIT C
AQUATIC VEGETATION MODEL

This Exhibit to the *Phase 1 Adaptive Management Plan* (Phase 1 AM Plan) describes the model developed for aquatic vegetation (also referred to as submerged aquatic vegetation or SAV) for River Section 1 of the Upper Hudson River.

C.1 SAV MODEL DEVELOPMENT

Data from areas where the aquatic vegetation beds currently exist were combined in a general linear model to determine which variables, and/or interactions among the variables, had a statistically significant correlation with the presence of SAV. A general linear model (or multivariate regression model) is a linear model with multiple measurements per object. In this case, the multiple measurements are the variables listed below and the object is the presence of SAV. The model was created in the R programming language using the following data:

- water depth (used as a surrogate for light availability), as determined from bathymetry measured during the Sediment Sampling and Analysis Program (SSAP) based on a water surface elevation at 5,000 cfs at Fort Edward;
- sediment type from the SSAP;
- current velocity from the hydrodynamic model (described in Attachment F of the Phase 1 FDR); and
- presence of SAV as determined by field delineation and assessments.

The results of the model indicated that all variables and all interactions were determined to be statistically significant, with the exception of the interaction between rocky substrate and water depth (Table C-1). Table C-1 lists the significance level of the correlation between each individual measurement, and interactions among them, to the presence of SAV.

The model is currently specific to River Section 1 (RS1; including both Phase 1 and Phase 2 areas), where high resolution bathymetry and hydrodynamic model output are available. Sediment type was treated as a categorical variable in the general linear model while the other variables were continuous. Categories of sediment type were organized alphabetically and the base regression was calculated for the first category, fine sediment, with coefficients calculated for additional sediment types and their interactions with the other variables. As a result, the coefficient for fine sediment and its multiplicative interaction with water depth and velocity was 1.0, while the effects of other sediment types were calculated as adjustments to the initial regression. The model was applied to the RS1 grid to predict SAV presence in each cell, the result of which is a probability value ranging from 0 to 1, with higher values representing a greater likelihood of SAV being present. Figures C-1 through C-5 show the model output for pre-dredging conditions.

The model was also run using post-dredging depth, current velocity, and substrate type data. Post-dredging model results were used in the habitat decision matrix to determine whether specific areas that currently support aquatic vegetation should be planted as part of habitat construction. For this purpose, a model score was selected to minimize to the probability for false positives to ensure that SAV planting, contingency and recolonization areas are located in areas most likely to support SAV (i.e., the areas with model scores above the cutoff value have a high probability to support SAV). A model cutoff score of 0.7 was selected to minimize the probability for false positive while still selecting sufficient acreages for implementing the SAV construction plans.

C.2 SENSITIVITY ANALYSIS

A series of tests were used to assess the accuracy of the general linear predictions of the SAV model. Model scores were compared to the actual aquatic vegetation cover in each cell to determine the number of times the model predicted vegetation correctly. Multiple model score cut-off values were used (0, 0.4, 0.5, 0.6, 0.7, and 0.8) to assess model prediction (e.g., for a cut-off value of 0.4, no cells with a model score of 0.4 or less should have aquatic vegetation). These tests assessed the following:

- percent correct;
- percent of false negatives – model score is less than or equal to the cutoff value and aquatic vegetation cover is greater than 0 %;
- percent of false positives – model score is greater than the cutoff value and there is no aquatic vegetation cover;
- specificity – the probability that cells that do not contain SAV are not predicted to contain SAV;
- sensitivity - the probability that cells that contain SAV are predicted to contain SAV;
- positive predictive value – the probability that cells predicted to contain SAV do contain SAV; and
- negative predictive value – the probability that cells predicted not to contain SAV do not contain SAV.

The objective of this series of tests was to find the model score cutoff that maximized the number of correct classifications. A scoring cutoff of 0.4 yielded the highest percentage of correct classifications for RS1 subsections, with 78% correct predictions. Accuracy, while similarly high in most subsections, was lower in others; specifically in West Rogers Island and near Thompson Island Dam where the false negative predictions rose to 20% and between RM 191 and 192 where the false positive predictions were between 25-35% (see Table C-2). Figure C-6 shows the percent correct, the percent of false negatives, and the percent of false positives for all of RS1 and for the model subsections within RS1 (which are depicted on Figures C-1 through C-5). On Figure C-6, the X-axis shows the cut-off value. The Y-axis is percent (correct, false negative, false positive).

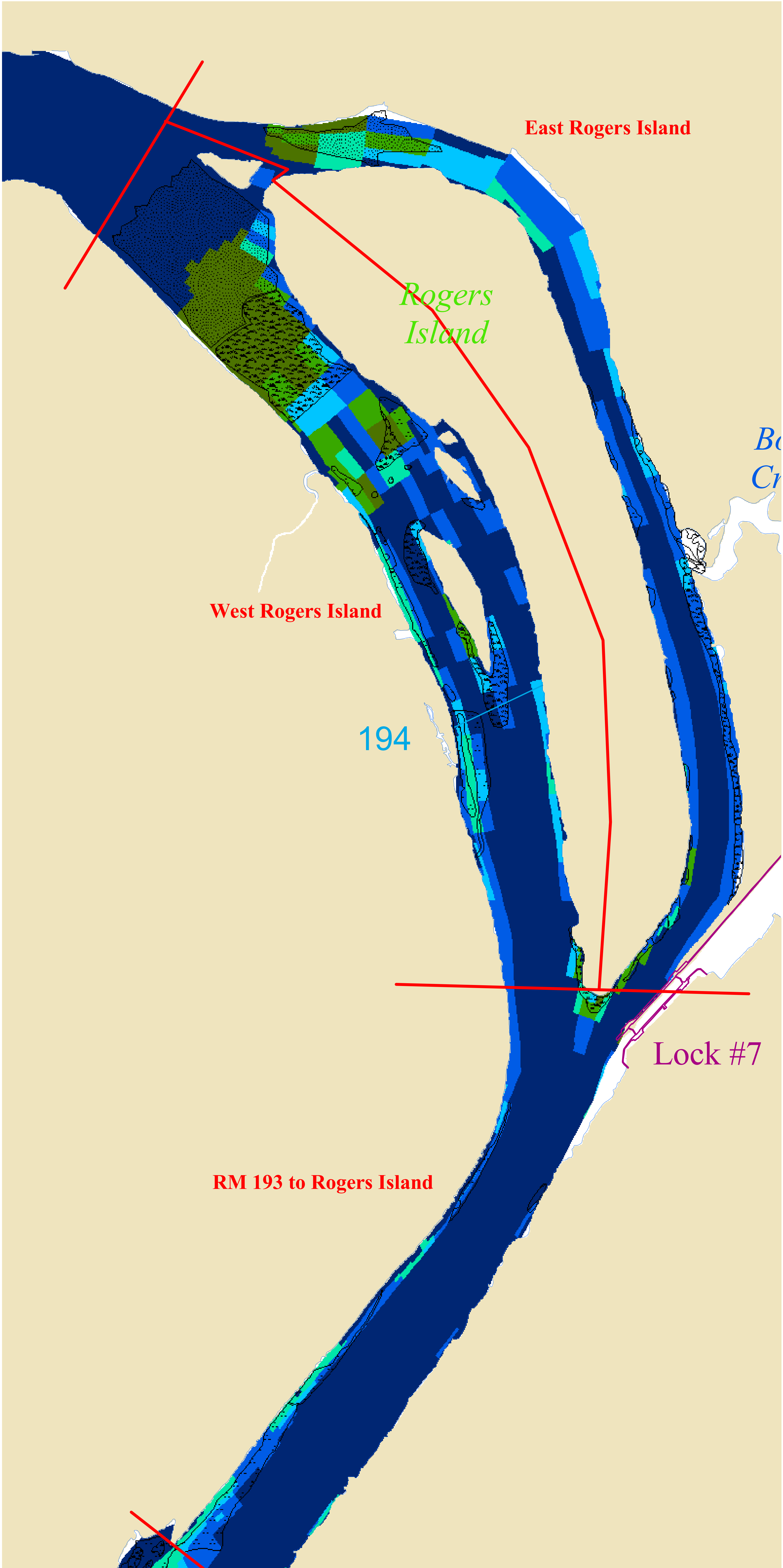
The model was run using post-dredging depth, current velocity, and substrate type data. Post-dredging model results were used in the habitat decision matrix (which is Figure 1-3 in the main text of this Phase 1 AM Plan) to determine whether specific areas that currently support aquatic vegetation should be planted as part of habitat construction. For this purpose, a model score was selected to minimize the probability of false positives, so as to ensure that SAV planting, contingency and recolonization areas are located in areas most likely to support SAV (i.e., the areas with model scores above the cutoff value are considered to have a higher probability to support SAV). A model cutoff score of 0.7 was selected to minimize the probability of false positives while still selecting sufficient acreages for implementing the SAV construction plans.

Table C-1. Significance of SAV model variables.

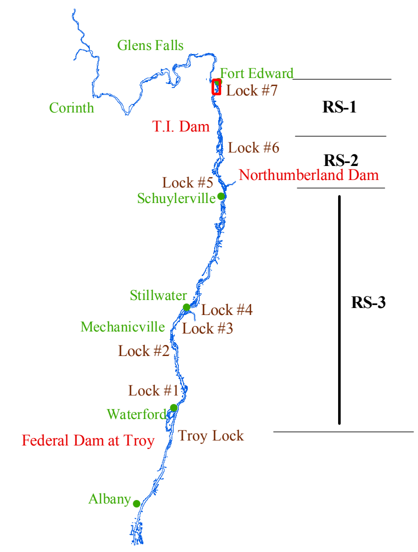
	Estimate	Std. Error	z value	Pr(>|z|)	Significance Level
(Intercept)	0.904	0.095	9.52	< 2.00E-16	0.0001
Gravel	-4.322	0.333	-12.97	< 2.00E-16	0.0001
Mixed	-2.598	0.139	-18.65	< 2.00E-16	0.0001
Rocky	1.332	0.386	3.45	0.000559	0.001
Sand	1.269	0.210	6.05	1.43E-09	0.0001
Unknown	-3.204	0.109	-29.40	< 2.00E-16	0.0001
Velocity	0.045	0.010	4.64	3.44E-06	0.0001
Depth	-0.097	0.017	-5.87	4.28E-09	0.0001
Gravel:velocity	0.231	0.019	12.43	< 2.00E-16	0.0001
Mixed:velocity	0.102	0.011	9.26	< 2.00E-16	0.0001
Rocky:velocity	-0.062	0.024	-2.65	0.008047	0.01
Sand:velocity	-0.091	0.016	-5.76	8.61E-09	0.0001
Unknown:velocity	0.023	0.011	2.20	0.027622	0.05
Gravel:depth	0.249	0.052	4.76	1.96E-06	0.0001
Mixed:depth	0.467	0.023	19.94	< 2.00E-16	0.0001
Rocky:depth	0.074	0.050	1.47	0.141269	1.0
Sand:depth	0.109	0.028	3.91	9.35E-05	0.0001
Unknown:depth	0.929	0.030	30.78	< 2.00E-16	0.0001
velocity:depth	-0.006	0.001	-4.58	4.66E-06	0.0001
Gravel:velocity:depth	-0.023	0.003	-8.30	< 2.00E-16	0.0001
Mixed:velocity:depth	-0.021	0.002	-13.90	< 2.00E-16	0.0001
Rocky:velocity:depth	-0.009	0.003	-2.80	0.005122	0.01
Sand:velocity:depth	-0.006	0.002	-3.54	0.0004	0.001
Unknown:velocity:depth	-0.026	0.002	-13.94	< 2.00E-16	0.0001

Table C-2. Performance summary of the logistic regression model for RS1.

Area	True Negative	True Positive	False Negative	False Positive	Count	Specificity (%)	Sensitivity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)	Percent Correct
All RS1	33095	11019	5808	6426	56348	84	65	63	85	78
West Rogers Island	2482	1061	982	217	4742	92	52	83	72	75
East Rogers Island	902	372	210	128	1612	88	64	74	81	79
RM 193 to Rogers Island	4065	430	345	281	5121	94	55	60	92	88
RM 192-193	5213	2167	664	1100	9144	83	77	66	89	81
RM 191-192	8290	2307	678	3523	14798	70	77	40	92	72
RM 190-191	5726	2093	898	428	9145	93	70	83	86	86
RM 189-190	4278	1298	574	301	6451	93	69	81	88	86
Thompson Island Dam to RM 189	2139	1291	1457	448	5335	83	47	74	59	64



LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

- Shore Line
- River Miles
- Dams and Locks
- Land

2007 Habitat Survey

- SAV (0 - 25%)
- SAV (25 - 50%)
- SAV (50 - 75%)
- SAV (75 - 100%)
- SAV (unclassified)
- Trapa

SAV Model Score

- 0 - 40
- 40 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- SAV Model Boundaries

General Electric Company
Hudson River Project

Figure C-1
General Linear Model Output
River Mile 193-194

QEA Quantitative Environmental Analysis, LLC

GENhab:120

January 2008

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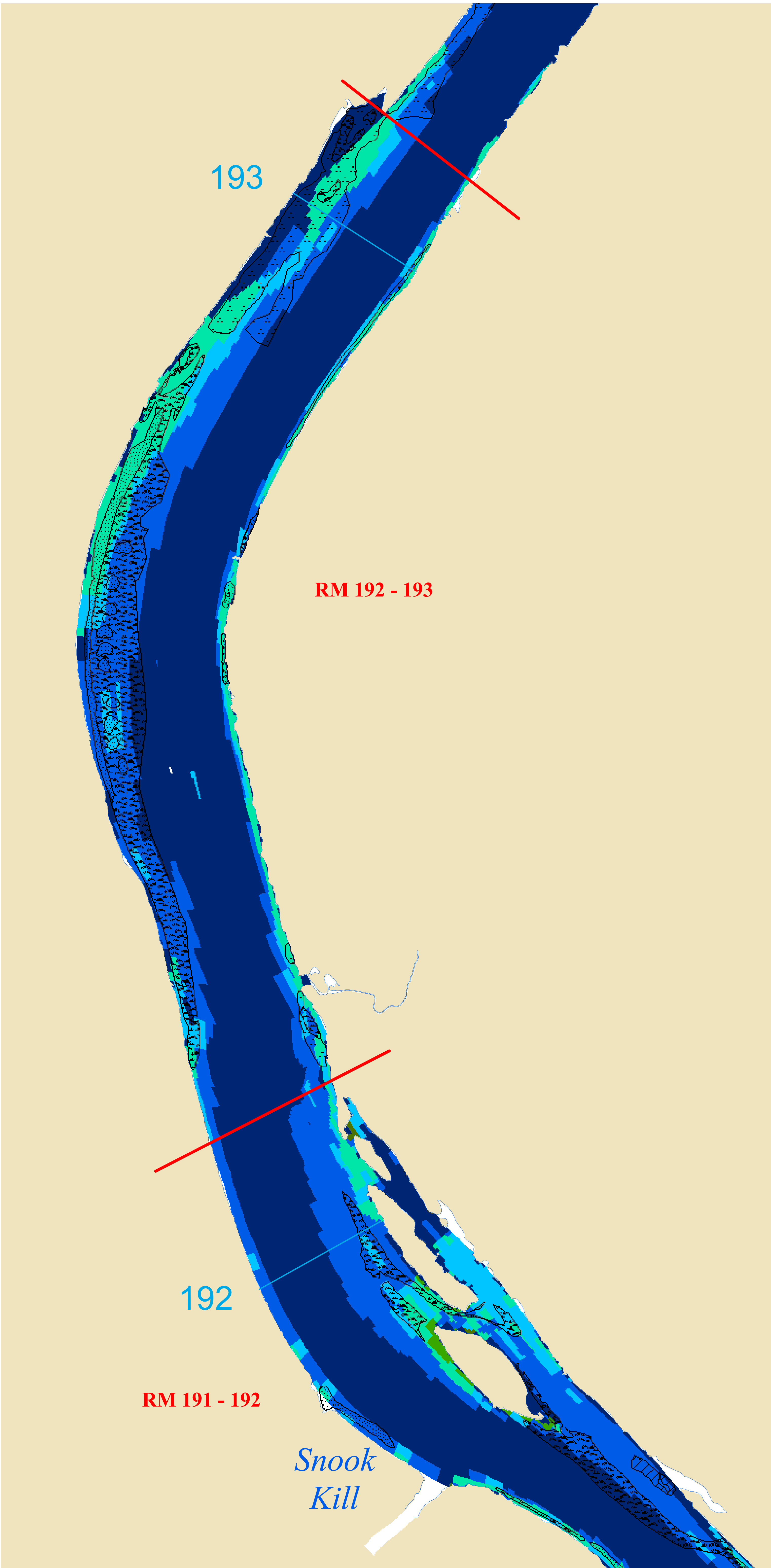
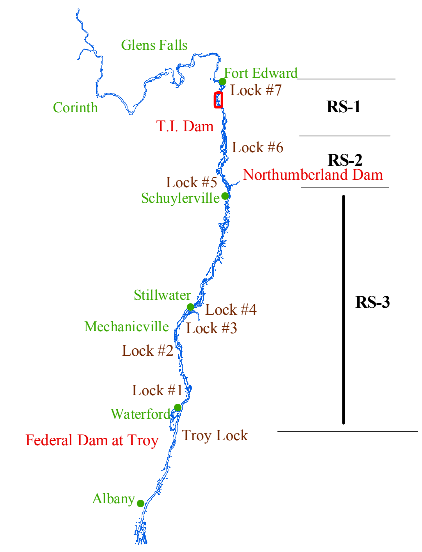


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

Shore Line

River Miles

Dams and Locks

Land

2007 Habitat Survey

SAV (0 - 25%)

SAV (25 - 50%)

SAV (50 - 75%)

SAV (75 - 100%)

SAV (unclassified)

Trapa

SAV Model Score

0 - 40

40 - 60

60 - 70

70 - 80

80 - 90

90 - 100

SAV Model Boundaries

General Electric Company
Hudson River Project

Figure C-2
General Linear Model Output
River Mile 191-193

QEA Quantitative Environmental Analysis, LLC

GENhab:120

January 2008

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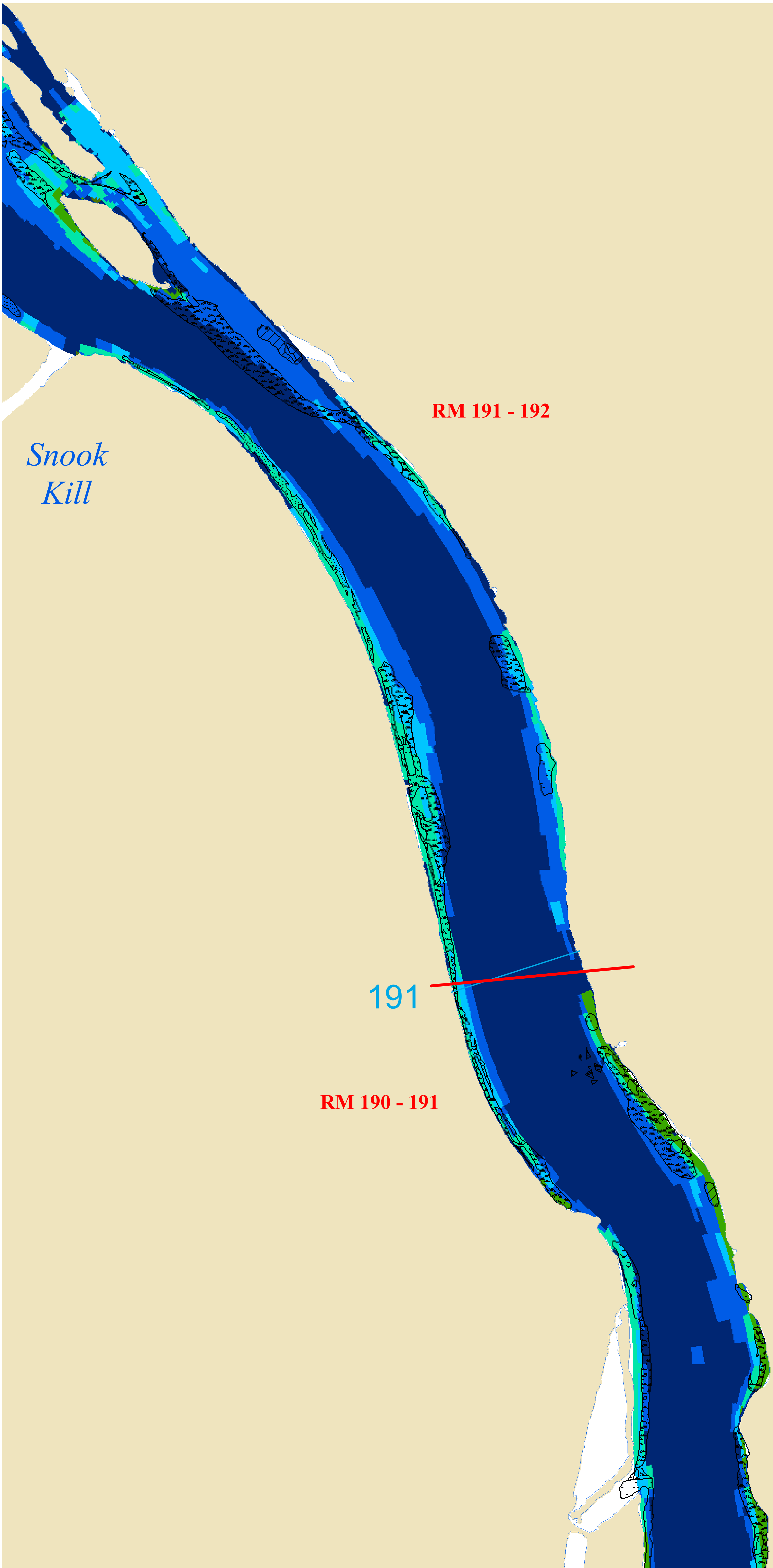
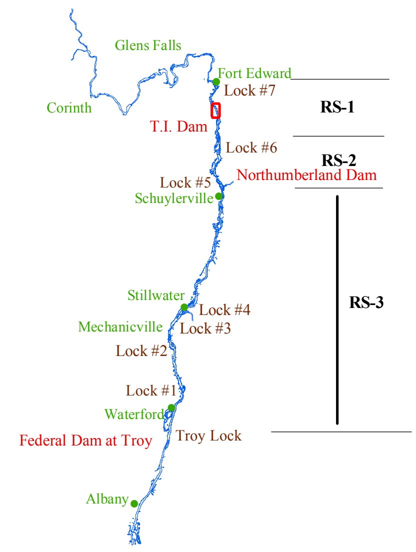


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

- Shore Line
- River Miles
- Dams and Locks
- Land

2007 Habitat Survey

- SAV (0 - 25%)
- SAV (25 - 50%)
- SAV (50 - 75%)
- SAV (75 - 100%)
- SAV (unclassified)
- Trapa

SAV Model Score

- 0 - 40
- 40 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- SAV Model Boundaries

General Electric Company
Hudson River Project

Figure C-3
General Linear Model Output
River Mile 190-191

QEA Quantitative Environmental Analysis, LLC

GENhab:120

January 2008

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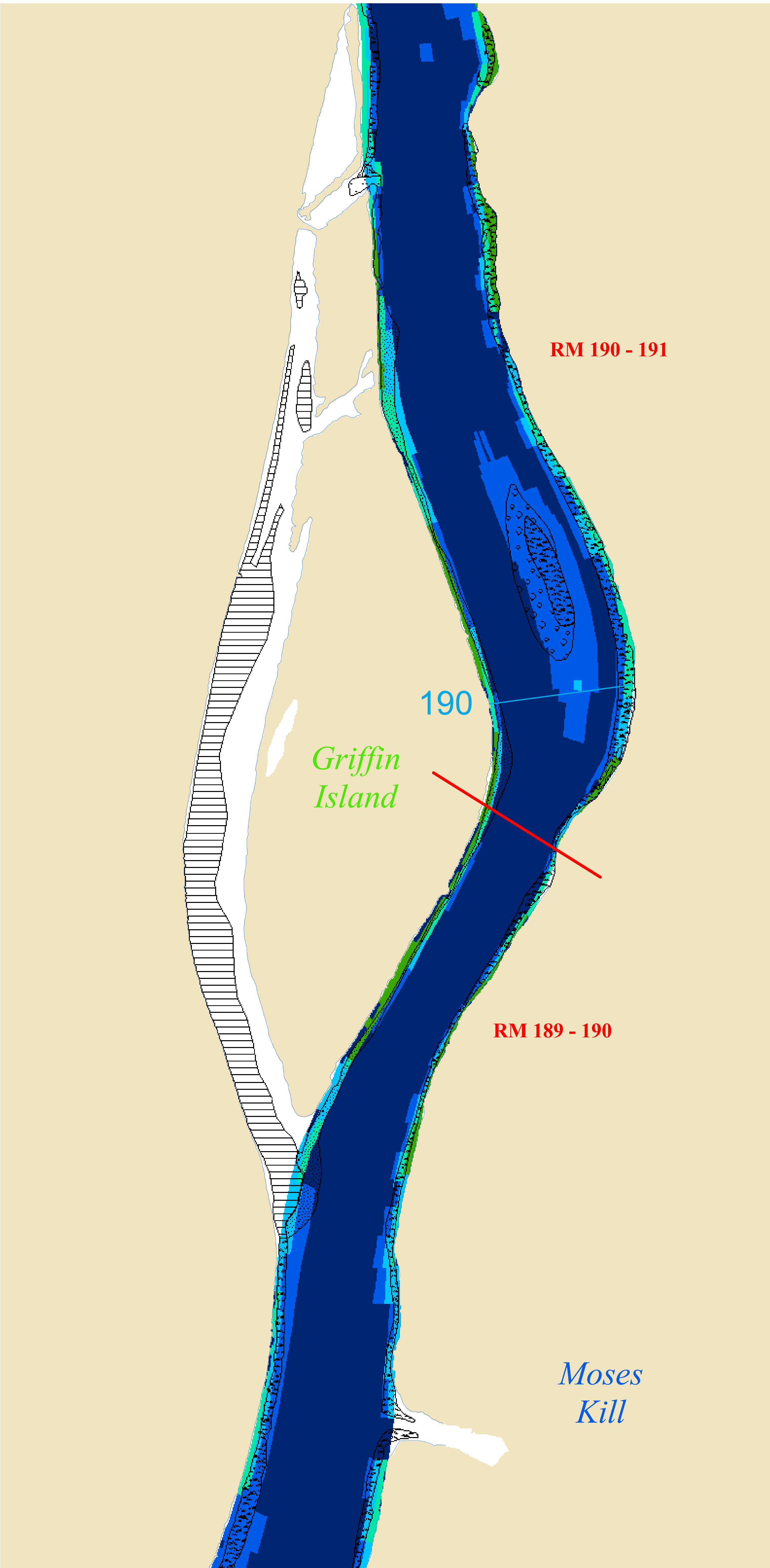
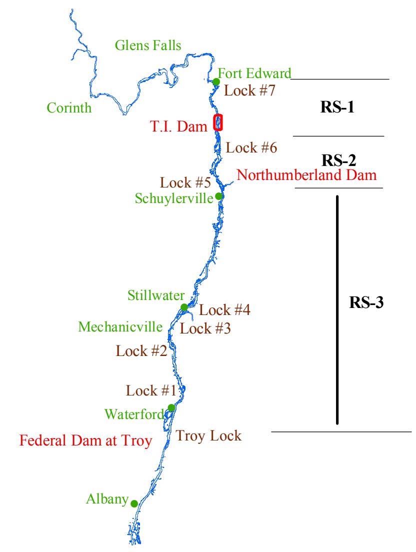


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

Shore Line
River Miles
Dams and Locks
Land
2007 Habitat Survey
SAV (0 - 25%)
SAV (25 - 50%)
SAV (50 - 75%)
SAV (75 - 100%)
SAV (unclassified)
Trapa
SAV Model Score
0 - 40
40 - 60
60 - 70
70 - 80
80 - 90
90 - 100
SAV Model Boundaries

General Electric Company
Hudson River Project

Figure C-4
General Linear Model Output
River Mile 189-190

GENhab:120

January 2008

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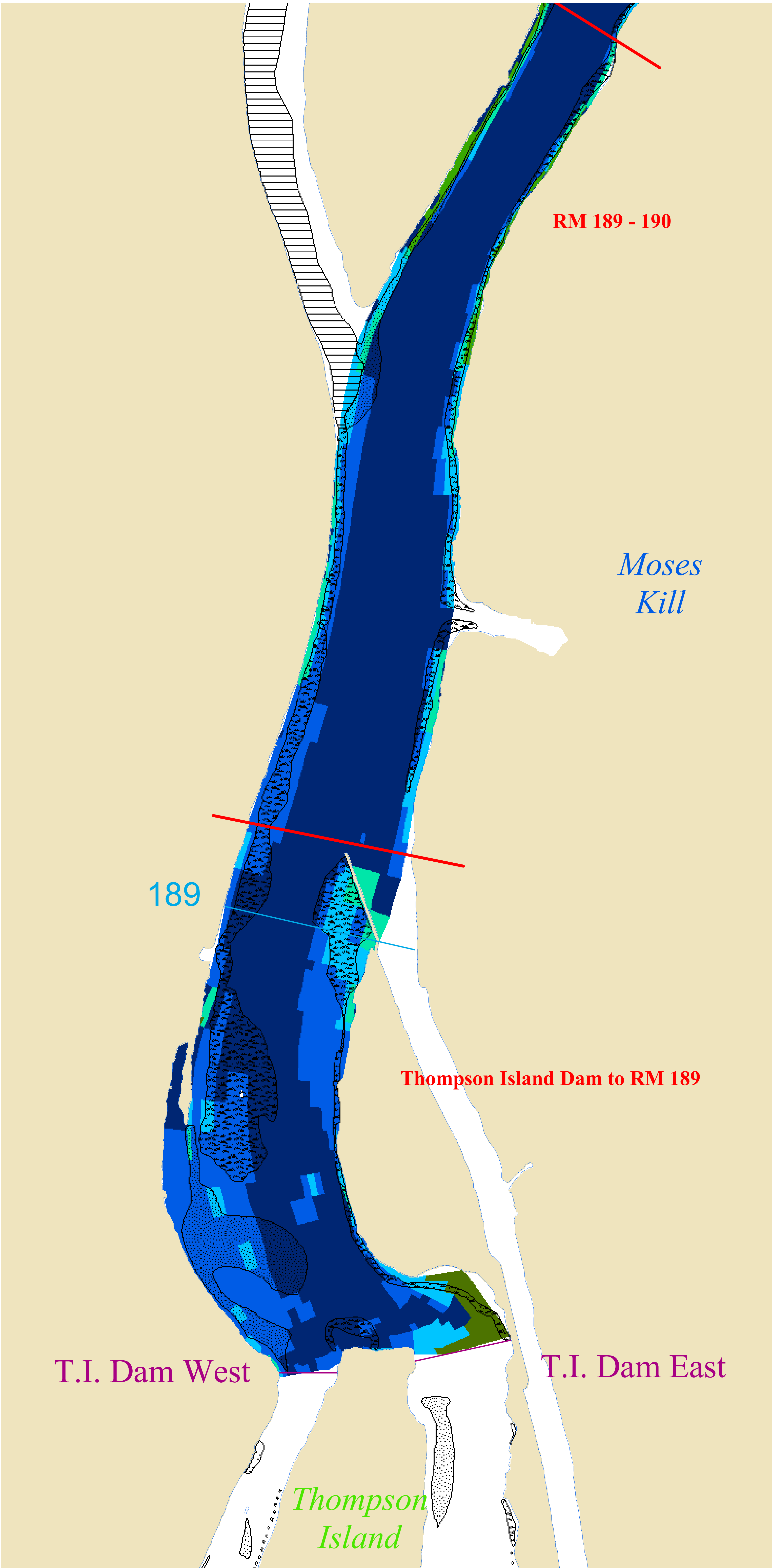
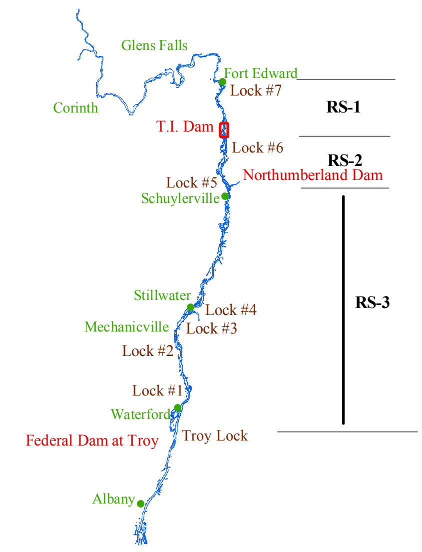


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

- Shore Line
- River Miles
- Dams and Locks
- Land

2007 Habitat Survey

- SAV (0 - 25%)
- SAV (25 - 50%)
- SAV (50 - 75%)
- SAV (75 - 100%)
- SAV (unclassified)
- Trapa

SAV Model Score

- 0 - 40
- 40 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- SAV Model Boundaries

General Electric Company
Hudson River Project

Figure C-5
General Linear Model Output
River Mile 188-189

QEA Quantitative Environmental Analysis, LLC

GENhab:120

January 2008

NDK- Q:\GENhab\GIS\maps\ArcGIS8\logistic_regression\GENhab_portrait_11x17_SAV_Model_PH1_20070726.mxd

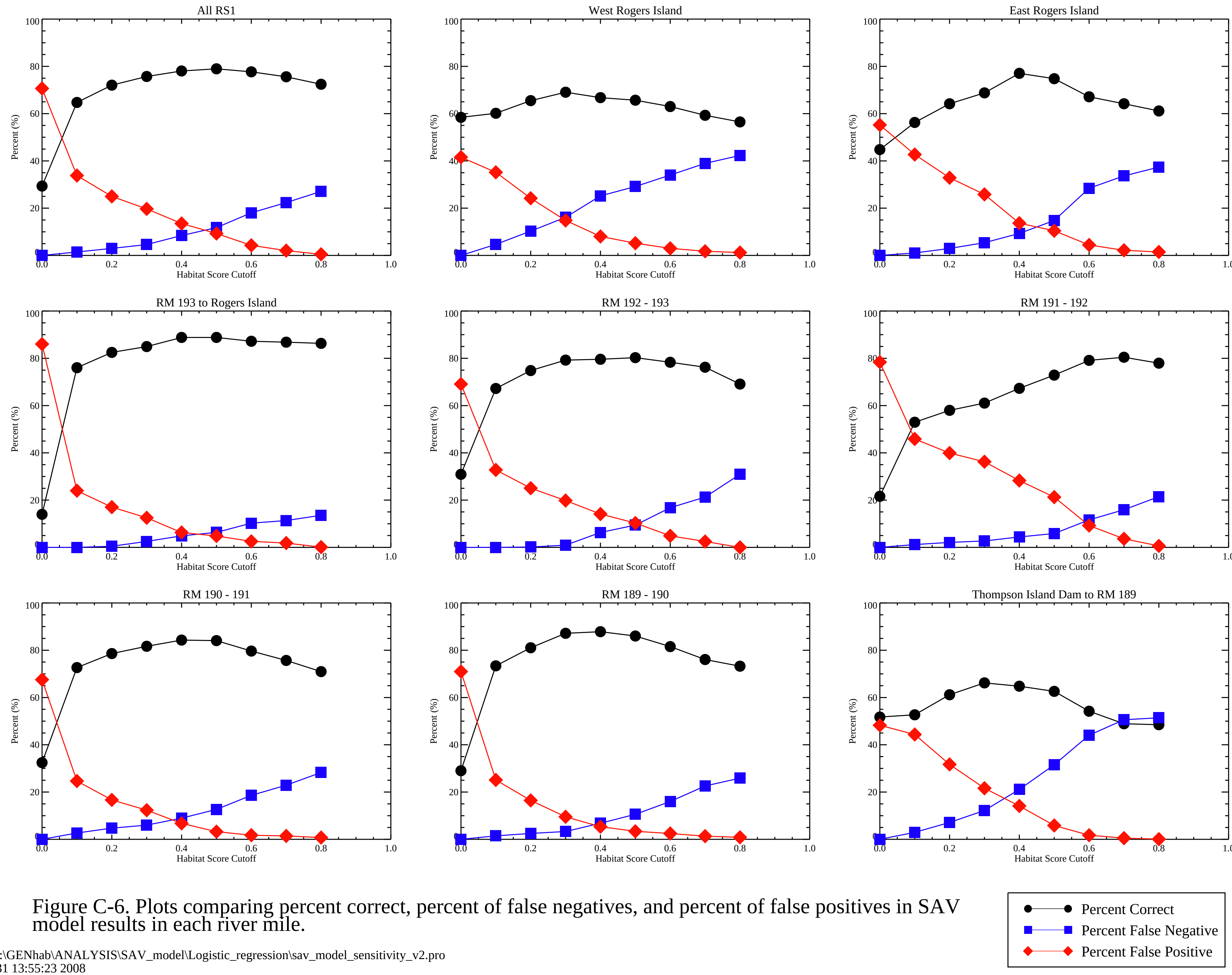


Figure C-6. Plots comparing percent correct, percent of false negatives, and percent of false positives in SAV model results in each river mile.

NDK - Q:\GENhab\ANALYSIS\SAV_model\Logistic_regression\sav_model_sensitivity_v2.pro
Thu Jan 31 13:55:23 2008

EXHIBIT D

Phase 1 Pre-Planting Inspection Plan for Submerged Aquatic Vegetation and Riverine Fringing Wetlands

Quantitative Environmental Analysis, LLC

EXHIBIT D
PHASE 1 PRE-PLANTING INSPECTION PLAN FOR SUBMERGED AQUATIC VEGETATION AND RIVERINE FRINGING WETLANDS

D.1 OBJECTIVE

Confirm that the submerged aquatic vegetation (SAV) and riverine fringing wetland (RFW) planting areas, which are designated in the Contract 5 plans, meet the acceptance criteria for planting.

D.2 BACKGROUND

The dredging operations contractor (Contract 4) will construct the SAV and RFW planting areas. The construction of these areas will be documented in accordance with the specifications in Contract 4 and certified using the Certification Unit (CU) Backfill/Engineered Cap Completed Approval (Form 2). The following spring, the habitat construction contractor (Contract 5) will install the plants in these areas. Ideally, these areas will remain suitable for planting in the period between their construction and the beginning of planting. However, that will be evaluated through the inspections and acceptance criteria specified herein.

The SAV will be planted as live adult plants in a peat pot or as tubers. The RFW planting will be from seed and containerized plants. When planting is completed and accepted under the terms of Contract 5, the Final CU Construction Certification (Form 3) will be completed in accordance with Section 5.2.3 of the Statement of Work in the Consent Decree. This form includes record drawings of the location and type of habitat replacement/reconstruction (including species and spacing) and final elevation and profile.

The Contract 5 plans show the limits of the planting areas and also provide contingency areas for SAV planting in the event that the designated planting areas do not meet the acceptance criteria outlined below.

D.3 SAV PLANTING AREAS

As indicated by the SAV model (see Exhibit C of the AM Plan), water depth, velocity, and sediment type are the controlling factors for SAV growth. These factors have been considered in developing the acceptance criteria.

- Water depth is a surrogate for light penetration. A conservative estimate for the depth of the photic zone supporting SAV beds (2 feet to 8 feet) has been assumed to account for potential changes in light availability. Light penetration is highly variable due to changes in weather and river conditions over short timeframes. Therefore, light availability measurements will not be explicitly considered in the decision to plant in designated areas or contingency areas. Rather, water depth will be used as an indicator of long-term light penetration.
- Water velocity, as indicated by the hydrodynamic model, influenced the location of the SAV planting and contingent areas. Both planting and contingency areas have been pre-determined to be in the acceptable velocity regime. Planting and contingency areas are located where SAV currently exists or where the SAV model (which includes water velocity) indicates a high probability for SAV to occur under post-dredging conditions. Therefore, river velocity measurements will not be explicitly considered in the decision to plant in designated areas or contingency areas.
- Sediment type for the SAV will be either Type 1 or Type 2 backfill. Both of these materials are acceptable substrate for planting and a peat pot will surround the roots of individual plants. Therefore, backfill type will not be considered in the decision to plant in designated areas or contingency areas.

Acceptance Criteria

The criterion for the acceptance for planting in Phase 1 areas will be that the elevation of the area is not greater than 117 ft. (NAVD 88) and not less than 111 ft. (NAVD 88). This criterion is consistent with the Habitat Decision Matrix (Figure 1-3 in the AM Plan).

Record drawings will be reviewed. If a designated planting area has become unconsolidated bottom (based on elevations of cap armor stone or sub-bottom of the dredge cut) due to changes in elevation, then a contingency area will be selected for SAV planting if those areas meet the acceptance criteria using the same inspection method described below.

The inspection data and acceptance decisions will be provided to EPA oversight staff for review.

Inspection Method

The pre-planting inspection will consist of a single beam bathymetric survey of the planting areas and any contingency areas to be planted to offset the primary planting areas that do not meet the acceptance criteria. Point measurements of water depth in areas designated as passive recolonization areas will be collected during habitat assessment activities in subsequent years. The number of water depth point measurements for all SAV areas (primary planting areas, contingency areas, and passive areas) will be consistent with those collected during habitat assessment activities in 2007 (i.e., 164 water depth point measurements). The water depth point measurements will be collected following procedures outlined in the Habitat Delineation and Assessment Work Plan (BBL, 2003) and will be distributed among SAV areas as agreed upon by EPA and GE. The single beam bathymetric survey will have a maximum track line spacing of 30 ft. At a minimum, three track lines will be run for each discrete SAV planting area. The outside track line will be within 10 ft. of the edge of the planting area (parallel to the direction of river flow). This survey will provide the final elevation and profile that is to be recorded on Form 3. The gradients between the data points will be used to assess the slope of the planting area.

The single beam bathymetry data will be used in the following manner. A quality control (QC) review of data associated with each track line will be completed. Following the United States Army Corps of Engineers (USACE) Hydrographic Survey Manual (EM 1110-2-1003, January 2002), the digital soundings will be compared to the paper readout from the fathometer to identify valid measurements to be kept and invalid measurements (due to fish, air bubbles, passing vessels, SAV etc.) to be deleted. Using the Triangular Irregular Network (TIN) method contours will be created using the resulting data set. The data will be provided as .dwg files. These contours will be compared with the acceptance criteria described above to identify areas that are acceptable for planting. If the designated areas that are specified in the Contract 5 plans are not suitable for planting, contingency areas will be selected for planting, using the same inspection method and acceptance criteria described above and starting at the most upriver contingency area.

GE will also measure and record the river velocity and light attenuation at the center and the riverside edge of each planting area once during this pre-planting inspection period. Velocity and light attenuation will also be measured daily during the installation of the plantings. As stated above, these parameters are highly dependent on weather, seasonal flow conditions, and upstream releases of water; and thus these data will be not be used as acceptance criteria.

D.4 RFW PLANTING AREAS

The Phase 1 habitat construction plans include reconstruction of approximately 2.0 acres of RFW at the locations shown in Appendix C of the Habitat Assessment Report for Phase 2 Areas. Elevation, water velocity, and inundation period are the controlling factors used in the RFW model. In addition to these controlling factors, substrate type and slope, which can also influence the establishment of the vegetation, have been considered in developing the acceptance criteria.

- The average elevations of the wetland open water and upland interfaces are given in Table D-1.
- River velocity can be used to identify potential alternative locations for RFWs if they cannot be reconstructed in the locations where they currently exist. Under present conditions, some riverine fringing wetlands occur in areas where current velocity exceeds 1.5 ft./s. These riverine fringing wetlands will be replaced at their existing locations, if feasible, given the constraints of the remedy. However, for habitat replacement and reconstruction, the model specifies that current velocity must be less than 1.5 ft./s so that the finer-grained material used as backfill will be stable under the two-year event. Thus,

if replacement or reconstruction of riverine fringing wetlands in River Section 1 is needed in areas other than where they currently exist, those areas must have current velocities less than 1.5 ft./s (during a two-year flood event).

- Since the acceptance criteria for elevation are consistent with the average elevations of delineated wetlands and since the average seasonal water levels in Thompson Island Pool are not expected to change, the predicted inundation period will not be used as an acceptance criterion (but see the discussion of slopes below). Furthermore, the ability to predict changes in inundation period in years after planting is uncertain.
- Type 3 backfill has been specified as the substrate. To verify that this material is present prior to planting, a survey of the elevation will be conducted before planting and the results will be compared to the survey data collected after the backfill was placed. If pre-planting elevations are consistent with post-backfilling elevations, then Type 3 backfill material or finer material that has deposited can be assumed to be present.
- The range of slopes of the wetlands delineated in Phase 1 areas is 3.42% to 15.43%, with an overall average of 10.07%. Slopes can influence the inundation period for the RFW. Water drains more quickly from steeper slopes resulting in a shorter inundation period when compared to a similar wetland with shallower slopes. Slopes in the reconstructed RFW will be similar to the slopes measured in the existing RFWs to provide the appropriate inundation period. The final elevations will be used to inform where plant species will be installed.

Acceptance Criteria

The criteria for the acceptance of Phase 1 RFW areas for planting will be:

1. Elevation of the RFW area is not greater than 122.75 ft. (NAVD 88) and not less than 118.75 ft. (NAVD 88). This range is consistent with existing wetland elevations based on NYS Canal Corporation water level data.

2. The river velocity is less than 1.5 ft./s.

3. Slope is no greater than 10%.

The inspection data and acceptance decisions will be provided to EPA oversight staff for review.

Inspection Method

Three transect locations will be randomly selected along the axis of the wetland parallel to the shoreline. A transect line perpendicular to the long axis at each location will be established. A survey stake and transit will be used to record the elevation at the following three locations on each transect:

1. The shoreward edge of the constructed RFW area;
2. The approximate center of each transect; and
3. The riverward edge of the constructed RFW area.

The average elevation of the RFW will be calculated from the nine transect measurements for comparison to the acceptance criterion for elevation. The individual elevation measurements will be used to determine which species will be planted. The selection of the final plant species (from those shown on the drawings) will be made in consultation with EPA oversight personnel. In addition, the elevations at the shoreward edge and riverward edge, and the distance between those two locations, will be used to calculate slope for comparison to the acceptance criteria for slope.

As stated in the EPA approved Phase 1 Habitat Assessment Report, riverine fringing wetlands affected by the remediation will be replaced at their current locations, to the extent practicable and appropriate. If the acceptance criteria are met, the contractor will be released to plant the area according to the plans.

In the event that the RFW location does not meet the acceptance criteria for planting, the area will be evaluated for measures that could make it acceptable (e.g., grading and/or placement of Type 3 backfill) and alternate locations will be reviewed against the acceptance criteria. If the original RFW location is not and cannot be made suitable for planting, an alternate location will be selected for the construction of RFW. The selection of the final RFW locations will be made in consultation with EPA oversight personnel and the construction manager.

Table D-1. Inundation period for riverine fringing wetlands in the Thompson Island Pool based on frequency of water levels between the average elevations of the wetland/open water interface and the wetland/upland interface.

Average Inundation Period (days)	Average Elevation of Wetland/Open Water Interface (feet)[1]	Average Elevation of Wetland/Upland Interface (feet)
66.07	118.86	122.88

Note:
[1]River water surface elevation, relative to North American Vertical Datum (NAVD) 1988.

D.5 REFERENCES

BBL, 2003. Habitat Delineation and Assessment Work Plan (HAD Work Plan). Hudson River PCBs Superfund Site. Prepared for General Electric Company, Albany, NY.

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EXHIBIT E

Invasive Species Management Plan

Quantitative Environmental Analysis, LLC

EXHIBIT E
INVASIVE SPECIES MANAGEMENT PLAN

E.1 INTRODUCTION

This *Phase 1 Invasive Species Management Plan* (ISM Plan) has been prepared as part of the remedial design (RD) program for the remedy selected by the United States Environmental Protection Agency (EPA) for the Upper Hudson River, located in New York State. Additional discussion of the RD program can be found in the *Remedial Design Work Plan* (RD Work Plan) (Blasland, Bouck & Lee, Inc. [BBL] 2003a). The ISM Plan builds upon objectives described in the *Habitat Delineation and Assessment Work Plan* (HDA Work Plan; BBL 2003b), and was developed to provide a framework for invasive species control in the project area, to be implemented as part of the *Phase 1 Adaptive Management Plan* (Phase 1 AM Plan) and monitoring programs for this project. The *Operation, Maintenance, and Monitoring Scope* (OM&M Scope) states (p. 4-13) "For the OM&M activities under this Scope, field response actions shall consist of the following:...[2nd Bullet] Invasive species management in replaced/reconstructed areas to maintain the extent of invasive species below specific levels (percent of a site) as specified in the Final Design Reports. This field response action does not include the complete elimination of invasive species from replaced/reconstructed areas." The specific levels or percentages (relative to those in the reference condition) of invasive species in a given area above which invasive species removal actions will be taken after a specific number of years are specified in Table 2-2 of the Phase 1 AM Plan. In other cases, invasive species management will be performed as necessary and appropriate to achieve the quantitative success criteria for plant species composition that are developed in accordance with the Phase 1 AM Plan.

Spread of invasive species is a widely recognized environmental problem. Such species can reduce local biodiversity, disrupt ecosystem processes, and constrain habitat functions (NISC 2001). Habitat replacement and reconstruction efforts in the Upper Hudson River will, to the degree possible within the parameters of the selected remedy, include measures designed to control the potential spread of invasive species. The habitat replacement and reconstruction program emphasizes the establishment of appropriate macrophyte plant communities as the key to ecosystem functions in areas designated for aquatic vegetation. Remediation (dredging, capping) and habitat replacement/reconstruction (substrate reconstruction, active planting and natural recolonization) in such areas have their greatest potential effect on plants. Invasive animal species (e.g., mammals such as Norway rat, birds such as starling and house sparrow, fish such as carp, and invertebrates such as the Asiatic clam) tend to be ubiquitous and their distribution will not be greatly affected by the dredging/capping or habitat replacement and reconstruction activities.

E.2 INVASIVE SPECIES

Four habitat types are present within the Upper Hudson River project area: unconsolidated river bottom, aquatic vegetation beds, shoreline, and riverine fringing wetland habitats. Beginning in 2003, habitat delineation and assessment activities were completed in accordance with the HDA Work Plan. These investigations documented 11 invasive plant species within the Upper Hudson River and one invasive invertebrate species. Table E-1 summarizes the invasive species documented and the habitats in which they were found.

Table E-1. Invasive species in Upper Hudson River habitats.

Common name	Scientific name	# Obs
Unconsolidated River Bottom		
Zebra Mussel	*Dreissena polymorpha*	1
Aquatic Vegetation Beds		
Water Chestnut	*Trapa natans*	8
Yellow Floating Heart	*Nymphoides peltata*	4
Curly Pondweed	*Potamogeton crispus*	2
Eurasian Water Milfoil	*Myriophyllum spicatum*	9
Riverine Fringing Wetlands		
Purple Loosestrife	*Lythrum salicaria*	122
Common Reed	*Phragmites australis*	2
Shoreline		
Japanese Knotweed	*Polygonum cuspidatum*	4
Tatarian Honeysuckle	*Lonicera tatarica*	110
Bittersweet spp.	*Celastrus* spp.	13
Black Locust	*Robinia pseudoacacia*	21
Common Buckthorn	*Rhamnus cathartica*	6

Of these 12 invasive species, only the following six species are known to exist in habitats that overlap Phase 1 dredge areas:

- Purple Loosestrife (*Lythrum salicaria*);
- Tatarian Honeysuckle (*Lonicera tatarica*);
- Bittersweet spp. (*Celastrus spp.*);
- Black Locust (*Robinia pseudoacacia*);
- Common Buckthorn (*Rhamnus cathartica*); and
- Zebra Mussel (*Dreissena polymorpha*).

This list includes species actually observed in the Phase 1 dredge areas during field activities associated with remedial action planning; these are the species that are likely to be of principal concern for the success of habitat replacement and reconstruction efforts. Zebra mussels do not appear to have successfully colonized in Phase 1 areas. The one observation was of a single mussel in an unconsolidated river bottom habitat within the navigational channel. Upon further inspection, this mussel had an extremely soft shell and no other mussels were found in the area. During ongoing monitoring and adaptive management activities following remediation, observations will be made in all habitats and the presence of additional species noted, should they occur. Under the adaptive management process, control measures for such additional species will be taken as necessary and will be described in the annual Adaptive Management Reports. For example, if other invasive plant species that may have been observed in the vicinity of Phase 1 dredge areas are found in the reconstructed/replaced areas during the adaptive management process, they will be addressed and controlled, as necessary under the Phase 1 AM Plan, consistent with the methods described in Section E.2.4.2 of this Exhibit.

The following subsections provide a brief introduction to the potentially invasive species recorded in the Phase 1 dredge areas, along with corresponding methods that have been used in the literature to control each species. Section D.3 discusses the control methods potentially appropriate for the Upper Hudson River and how such methods will be incorporated in the adaptive management program.

E.2.1 Invasive Animals in Phase 1 Unconsolidated River Bottoms

Zebra mussel (Dreissena polymorpha)

Zebra mussels are a native of Eurasia and spread to the United States through the Great Lakes in the mid-1980s. They have moved throughout the Great Lakes and are also found within the Ohio River drainage and Mississippi River drainage. They were first observed in the Hudson River estuary in 1991 (Strayer et al. 1999). Zebra mussels are filter feeders and feed on phytoplankton within the system often filtering enough to significantly increase water clarity. Larvae are free swimming (veligers) and eventually settle on a hard surface with byssal threads. They will readily attach to any hard surface, including native mussels, which can reduce those populations. Zebra mussels have specific environmental requirements for population sustainability including low salinity, mean summer water temperature between 17 and 23^{o}C, pH 7.4 to 9.0, and calcium concentration of 20 to 125 mg/L to support shell formation and growth (Ludyanskiy et al. 1993).

Zebra mussels are primarily transported between waters by commercial and recreational boaters. Control methods include draining and cleaning bilge tanks, fish live wells, and bait buckets prior to traveling to a new water body. Juveniles and adults can also attach to boat hulls, engine units, and trailers. Prior to launch, boats should be left out of the water and dried in the sun for several days and/or the hulls, engine, and trailers thoroughly cleaned to remove any zebra mussels. If zebra mussels are observed in Phase 1 dredge areas, that will be noted in the monthly reports. As noted above, only a single zebra mussel was identified in Phase 1 areas. This mussel was found in an unconsolidated river bottom habitat within the navigational channel. Upon inspection, it was noted that the shell was extremely soft. Clusters of zebra mussels were not encountered in any of the Phase 1 habitats.

E.2.2 Invasive Plants in Phase 1 Riverine Fringing Wetlands

Purple loosestrife (Lythrum salicaria)

Purple loosestrife is a native of Eurasia that has spread throughout the United States since its first report in 1814. Purple loosestrife prefers to colonize portions of disturbed wet areas such as ditches, wetlands, or areas along streams, rivers, and lakes that are exposed to full sunlight. The plant is grows to 0.5 to 2.0 meters in height, and has a well developed taproot. Vegetative reproduction is minimal, as most of the root system is centered around the taproot, although stem and root fragments can act as vegetative propagules to establish new plants, particularly in disturbed areas. Reproduction is primarily through seeds, which are dispersed by wind and (to a lesser degree) by animals. Prolific seed production, high seed viability, high germination density, and rapid growth help purple loosestrife out-compete native plants when colonizing new areas. Purple loosestrife can create monotypic stands by crowding and shading out competitors (Bender and Rendall 1987).

Control methods for purple loosestrife have exhibited varying degrees of success. Because stands over three acres in size may not be effectively eradicated, containment of these stands to their present size and location is often a management objective. Stands of less than three acres or plants extending beyond the boundaries of a contained stand may be controlled by hand-pulling or chemical application. Purple loosestrife stands under three acres may also be controlled by cutting. Purple loosestrife can be removed by hand prior to seed set; however, the entire rootstock must generally be removed to prevent regeneration. Recommended herbicides include glyphosate applied after August or broadleaf herbicide applications in late spring (Bender 1987).

Biological controls also have been developed for purple loosestrife. Under certain environmental conditions, the beetle species *Galerucella calmariensis* and *G. pusilla* have been effective at dramatically decreasing purple loosestrife populations, enabling native species to recolonize. The beetles are effective for stands that are located in sunny areas that are not permanently flooded. Studies indicate that the beetles have minimal effects on non-target species (Adirondack Park Invasive Plant Program [APIPP] 2004).

E.2.3 Invasive Plants in Phase 1 Shorelines

Tatarian honeysuckle (Lonicera tatarica)

The tatarian honeysuckle ranges (*Lonicera tatarica*) from the central Great Plains to southern New England, and belongs to the family of bush honeysuckles that includes seven species in the genus Lonicera. Bush honeysuckles originated in Eurasia. Historically, these plants were used as ornamentals, wildlife cover, and erosion control shrubs. Bush honeysuckles tend to be intolerant of shade, occurring in forest edges, fields, and other open upland habitats. Woodland areas disturbed by grazing or other activities can be susceptible to colonization by this genus. The plants reproduce primarily through seeds, as the fruits are attractive to wildlife; however, vegetative reproduction enables the plant to persist and spread (Swearingen et al. 2002).

Control methods that have been used for tatarian honeysuckle include harvest, herbicide application, stump cutting combined with herbicide application, and basal bark herbicide application. Hand removal of plants or seedlings may be effective for small areas that are ecologically sensitive. Biological control agents have not been identified (SEPPC 2006; WAPM 2006).

Bittersweet spp. (Celastrus orbiculatus)

Bittersweet is a woody vine that occupies open woods or thickets, and can climb to 18 meters. It is native to temperate eastern Asia, and is believed to have appeared in North America prior to 1879. By the 1970s, the documented range extended from Maine to Georgia, and west to Iowa. The vine reproduces primarily through seeds. Animals are the primary vector of seed dispersal, but humans can be important dispersal agents as well by using the vine in dried arrangements and conservation plantings. Bittersweet can also reproduce by rootsuckering, which results in large patches of the plant. Dense canopies of bittersweet are believed to shade out desirable native plants (Dreyer 1994).

Control methods include chemical and mechanical techniques. Combinations of cutting and chemical treatments have been used to control bittersweet. Triclopyr is a recommended herbicide, as it will not kill beneficial monocots. Mowing alone is not recommended, as poorly scheduled mowing events can stimulate rootsuckering (Dreyer 1994).

Common buckthorn (Rhamnus cathartica)

Common buckthorn is a deciduous shrub or small tree between two to six meters in height; it is found in wooded areas, hedgerows, and pastures. The plant is native to Europe and Asia, and is believed to have arrived in North America before 1800. It now ranges in the eastern portions of Canada and the United States.

Common buckthorn reproduces sexually. Fruits are dispersed by wildlife, and the plant is also spread through horticulture. Seedlings will invade apparently stable habitats where there are ample light and exposed soils. The plants will form thickets that create dense shade through lateral crown spread (Converse 1984b).

Potentially successful control options for common buckthorn include mowing, girdling, excavation, underplanting, and chemical application. Repeated mowing maintains open areas to prevent seedling establishment, and can reduce vigor of existing plants. Girdling can successfully kill plants, and will not disrupt soil or affect non-target plants. Excavation has been recommended for low density areas, where root or soil disturbance will not promote recolonization. Chemicals such as glyphosate, fosamine, picloram, and 2,4-D may be effective for stump and wick application, mist application, frill application, and basal application, respectively. Establishment of common buckthorn may also be prevented by underplanting viable desirable species (Converse 1984b).

Black locust (Robinia pseudoacacia)

Black locust has extended beyond its natural range in the Appalachian and Ozark Mountains to areas throughout the world. The tree can grow up to 25 meters in height. Most reproduction occurs vegetatively through root suckering or stump sprouting. Black locust is most successful where it has room to grow, and its rapid growth allows it to out-compete other trees (Converse 1984a).

The powerful potential for vegetative reproduction in black locust hinders the effectiveness of many control methods, as cutting or burning can stimulate root suckering or stump sprouting. Chemical control using glyphosate, picloram, AMS, triclopyr, or 2,4-D have demonstrated some success; however, plants can re-sprout years after treatment. Combinations of chemical treatment, burning, basal application, and plant removal have demonstrated varying degrees of success (Converse 1984a).

E.2.4 Invasive Species Control in Phase 1 Areas

River Section 1 does not include large areas or monospecific stands of invasive plant species or zebra mussel colonies. In this river section, it is anticipated that controls will be implemented for small stands and isolated patches of invasive species. The following invasive species control program components are intended to operate in this context.

E.2.4.1 Controls during Dredging

As discussed above, many of the invasive plant species can spread via the dispersal of fragments of roots, rhizomes or stems, and/or seeds. Zebra mussels disperse as free floating larvae or can be transported on boats. The potential for plant and zebra mussel dispersal during dredging will be managed for each habitat as follows.

Unconsolidated Bottom Habitat

Zebra mussels are the only invasive species identified within unconsolidated bottom habitats and, if present, are expected to be removed during dredging. It is not anticipated that many zebra mussels will be located within these areas due to the lower habitat suitability in these areas. As indicated in Section E.2.1, if zebra mussels are observed in Phase 1 dredge areas, that will be noted in the monthly reports.

Aquatic Vegetation Beds

No invasive species have been identified in the aquatic vegetation beds within the areas to be dredged during Phase 1 or in the immediately adjacent areas. If invasive species do occur within the areas to be dredged, they are expected to be removed in their entirety by dredging. In the event that dispersal of vegetative fragments occurs and results in colonization of invasive plant species in passive SAV recolonization areas, response actions to address invasive species in these areas will be implemented consistent with the adaptive management benchmarks and success criteria and with the controls described in Section E.2.4.2 of this Exhibit.

Shorelines

As described in the Phase 1 Final Design Report (BBL 2006), the shoreline is defined as the 119-foot elevation contour. As such, disturbance to terrestrial vegetation during dredging will be minimal and the inadvertent dispersal of invasive species is unlikely. Any invasive species that occur within the areas to be dredged are expected to be removed in their entirety by dredging. Stands or patches of invasive species identified adjacent to the areas to be dredged will be marked in the field and will be avoided, to the extent practicable, to minimize the potential for the displacement of invasive plant parts or fragments.

Riverine Fringing Wetlands

Invasive species that occur within the riverine fringing wetlands to be dredged are expected to be removed in their entirety by dredging. Stands or patches of invasive species identified adjacent to the areas to be dredged will be marked in the field and will be avoided, to the extent practicable, to minimize the potential for the displacement of invasive plant parts or fragments.

E.2.4.2 Controls during Post-Remediation Adaptive Management

After habitat replacement and reconstruction has been completed for Phase 1, the presence of invasive species will be monitored as part of the Operations, Maintenance, and

Monitoring program. Invasive species control will be implemented as an adaptive management response as described in Section 6 of the Adaptive Management Plan.

As appropriate, adaptive response measures to be implemented in the above instances will be in accordance with the Aquatic Ecosystem Restoration Foundation (AERF 2005) and New York State Department of Environmental Conservation (NYSDEC 2005) and will include some or all of the following:

1. Continued monitoring: If invasive species are present but not spreading or thriving, continued monitoring will be conducted to document ongoing patterns of dispersal.

2. Hand harvesting: If appropriate and useful, hand-harvesting and disposal of limited areas of dense stands of invasive species will be considered.

3. Herbicide application: If appropriate and useful, herbicide application will be considered, and discussed with EPA.

4. Other methods as appropriate: A range of alternate control methods is available, including mechanical harvesting, burning, dye additions, isolation barriers, biological controls, and substrate amendments. Most of these are inappropriate for flowing waters or for small patches or scattered individuals of invasive species. However, should success of the reconstruction be impeded by the presence of invasive species, all available control methods will be evaluated and considered for adaptive management response.

E.3 REFERENCES

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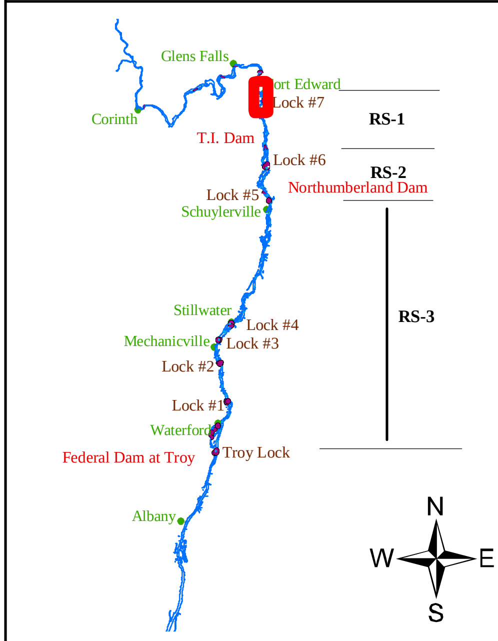
EXHIBIT F

Especially Sensitive or Unique Habitats Identified by Regulatory Agencies in River Section 1

Quantitative Environmental Analysis, LLC

LOCATOR MAP OF THE UPPER HUDSON RIVER

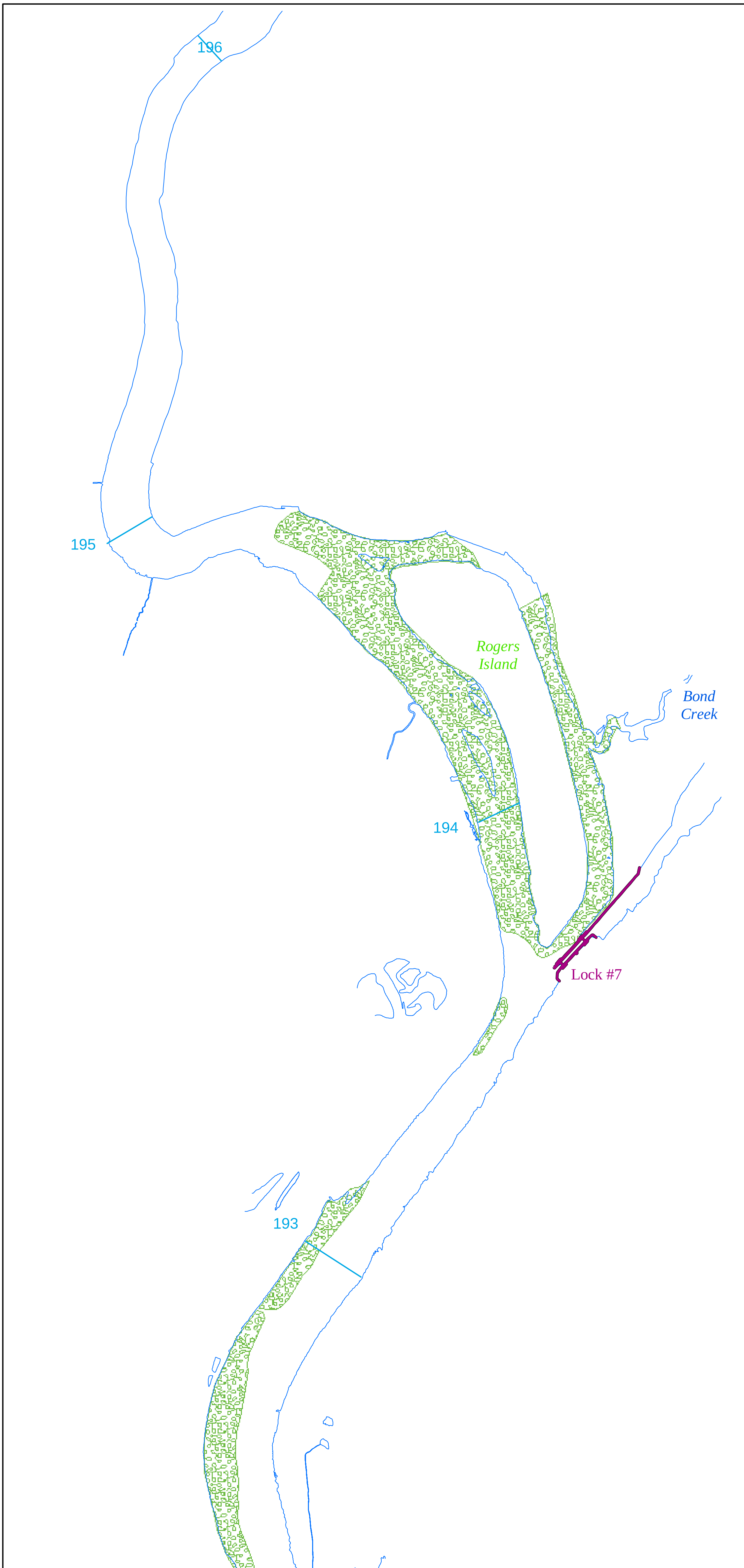


GRAPHIC SCALE

Miles
0 0.05 0.1 0.2

LEGEND

- ESUH Areas
- **River Miles**
- **Dams and Locks**
- **Shoreline**



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Hudson River Project

Figure F-1

Especially Sensitive and Unique Habitat in the upper Hudson River identified by natural resource agencies

RM 195 to 192.5

GENhab

Jan. 2008

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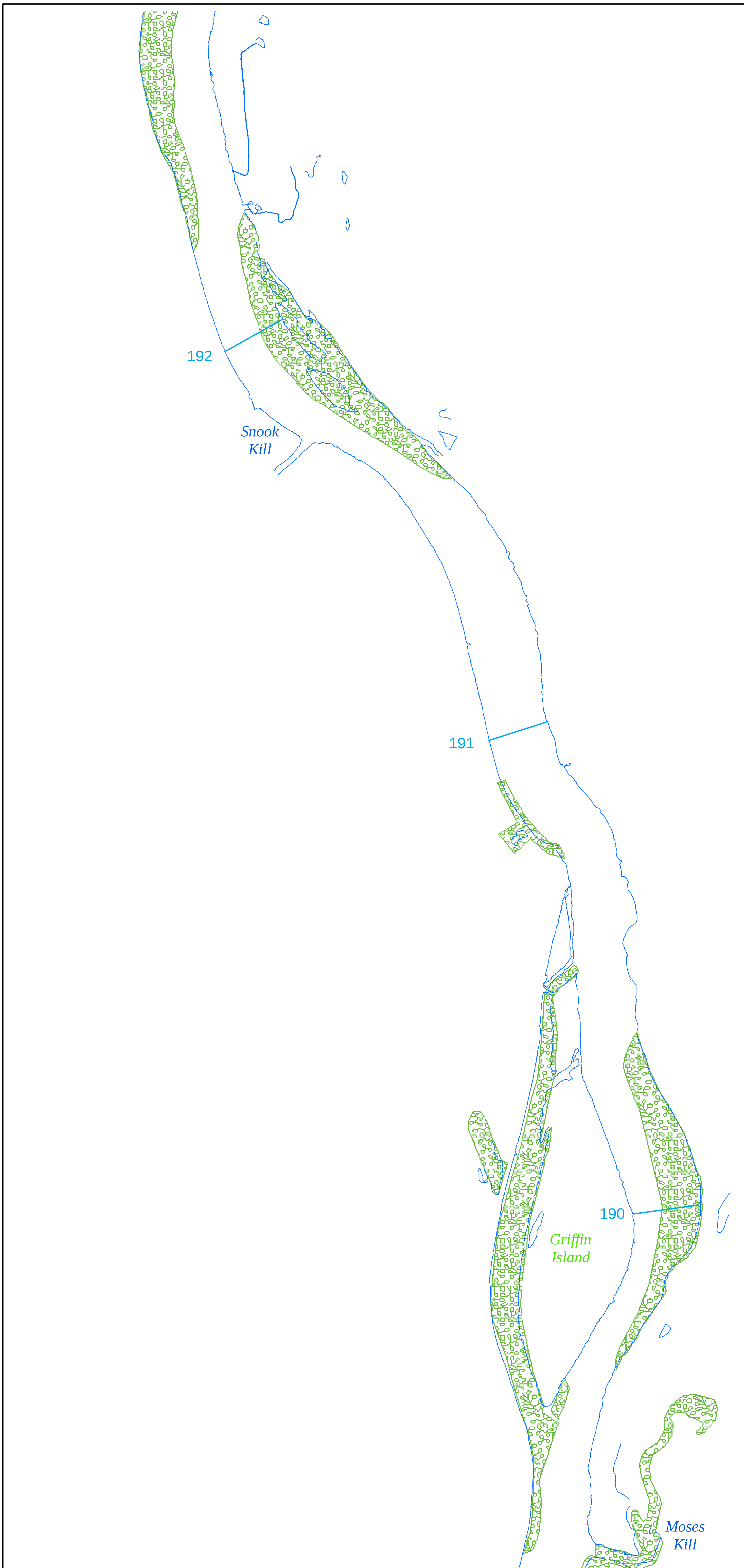
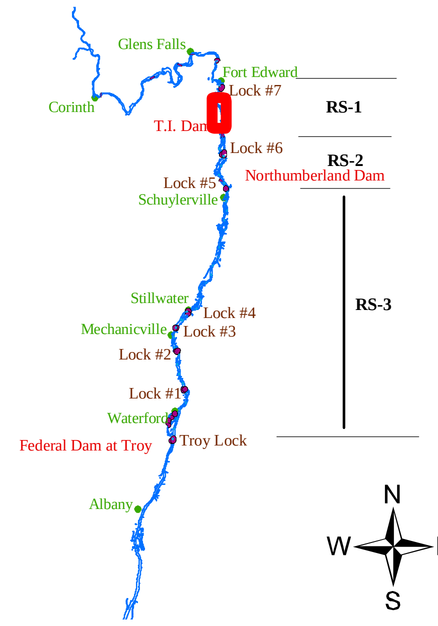


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

Miles
0 0.05 0.1 0.2

LEGEND

ESUH Areas
River Miles
Dams and Locks
Shoreline

General Electric Company
Hudson River Project

Figure F-2

Especially Sensitive and Unique Habitat in the upper Hudson River identified by natural resource agencies

RM 192.5 to 189.5

GENhab

Jan. 2008

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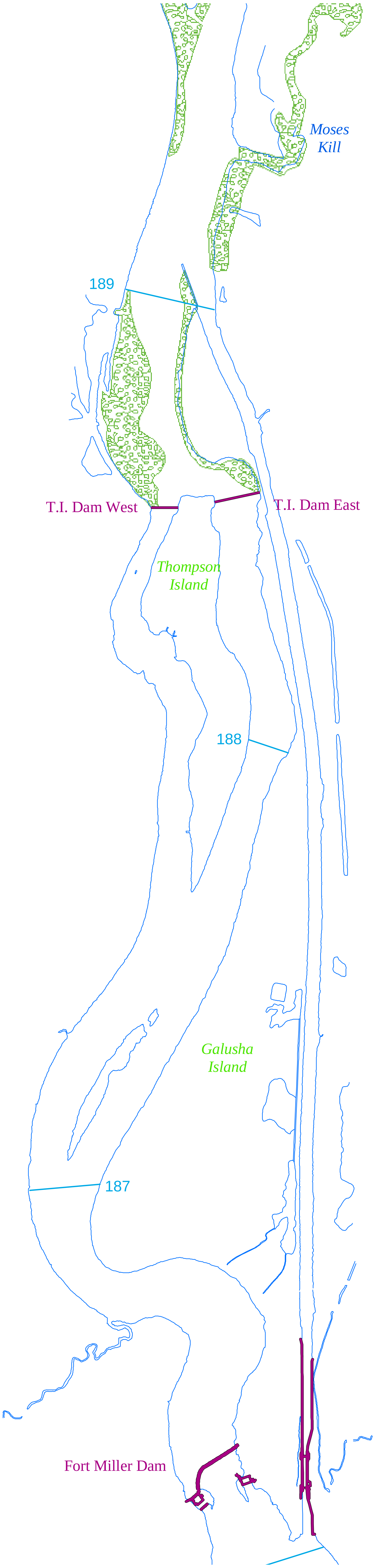

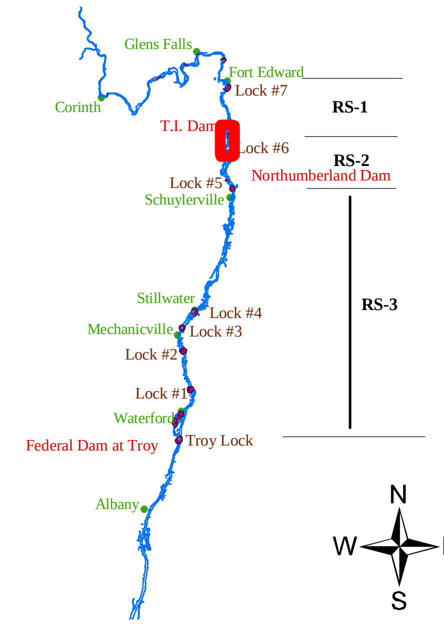

GRAPHIC SCALE

Miles

0 0.05 0.1 0.2

LEGEND

- ESUH Areas
- **River Miles**
- **Dams and Locks**
- **Shoreline**

General Electric Company
Hudson River Project

Figure F-3

Especially Sensitive and Unique Habitat in the upper Hudson River identified by natural resource agencies

RM 189.5 to 186.5

GENhab

Jan. 2008

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