DETERMINATION OF INJURY TO NATURAL RESOURCES FROM REMEDIAL ACTIVITIES ON THE HUDSON RIVER:

RIVERINE FRINGING WETLANDS, AQUATIC VEGETATION BEDS, SHORELINE TREES, AND NATIVE FRESHWATER MUSSELS

HUDSON RIVER NATURAL RESOURCE DAMAGE ASSESSMENT

HUDSON RIVER NATURAL RESOURCE TRUSTEES

STATE OF NEW YORK
U.S. DEPARTMENT OF COMMERCE
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EXECUTIVE SUMMARY

The Hudson River PCBs Superfund Site extends almost 200 miles between Hudson Falls and the Battery in New York City and consists of 4 operable units (OU): the Remnant Deposits (OU-1), the Upper Hudson River (UHR) (OU-2), Rogers Island (OU-3), and the floodplains (OU-4). The U.S. Environmental Protection Agency (EPA) 2002 Record of Decision (ROD) for OU-2 selected targeted dredging for 40 miles of the UHR between Fort Edward and the Federal Dam at Troy to remove approximately 500 acres of PCB-contaminated sediment hotspots. As a result of remedy implementation by the General Electric Company (GE), the natural resources of the Hudson River sustained significant ecological injuries. The focus of this injury determination report is the impact to natural resources from the remediation of the river proper. As described in this injury determination, the dredging and subsequent capping and/or backfilling of the UHR destroyed riverine fringing wetlands, aquatic vegetation beds, woody shoreline, and native freshwater mussels.[1] Each of these natural resources plays an important role in the environment of the Hudson River.

Pursuant to the 2002 ROD, 2006 Consent Decree, 2011 Consent Decree Modification (No. 2), and subsequent remedial design, action, operations, and maintenance and monitoring documents, GE was required to design, reconstruct, monitor, and adaptively manage habitat disturbed or destroyed during the OU-2 remediation. The Trustees primarily used GE's 2016 Habitat Reconstruction Ledger to conduct the injury determination to riverine fringing wetlands and submerged aquatic vegetation, but supplemented this effort with other GE technical documents when necessary. As part of the dredging remedy, GE trimmed and removed trees to safely access nearshore areas. Prior to remedy implementation, GE recorded the location, species, condition, and size of trees to be removed and a subset of this information for trees to be trimmed. The Trustees used GE's and New York State Department of Environmental Conservation's records of tree removal in the injury determination to shoreline habitat. In 2013 and 2015, the Hudson River Natural Resource Trustees conducted surveys of the native freshwater mussel community in five of the eight UHR pools affected by remediation and in an upstream reference pool. The results from these surveys provide the basis for determining an injury to the native freshwater mussels.

GE's dredging remedy injured the natural resources of the Hudson River to varying degrees. The Trustees present this report as a determination of injury to riverine fringing wetlands, aquatic vegetation beds, shoreline trees, and native freshwater mussels. A final quantification of the amount of injury, including interim losses, will be provided in a subsequent report.

Destruction of these resources constitutes a natural resource injury under federal law and regulation, and this report constitutes the Natural Resource Trustees' determination that GE's dredging remedy injured, in some instances in perpetuity, Hudson River natural resources as a result of GE's response actions. Furthermore, GE's failure to adequately

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[1] The Trustees recognize that other habitats and resources were potentially injured or could be injured in the future by GE's remedial actions, including the removal of large woody debris, direct effects to the benthic community other than mussels, disturbance of upland forests, and any remedial actions disturbing the floodplain.

reconstruct habitat destroyed during the remedial action has extended the time until those resources recover, if at all, and has increased injuries to these resources.

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CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CY	Cubic Yards
CU	Certification Unit
DBH	Diameter at Breast Height
ECL	New York State Environmental Conservation Law
EPA	U.S. Environmental Protection Agency
FAV	Floating Aquatic Vegetation
GE	General Electric Company
HRNRT	Hudson River Natural Resource Trustees
LHR	Lower Hudson River
NRDA	Natural Resource Damage Assessment
NYSDEC	NY State Department of Environmental Conservation
OU	Operable Unit
PCBs	Polychlorinated Biphenyls
RFW	Riverine Fringing Wetland
ROD	Record of Decision
RS	River Section
SAV	Submerged Aquatic Vegetation
SSAP	Sediment Sampling and Analysis Plan
UHR	Upper Hudson River

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1.0 INTRODUCTION AND APPROACH

Discharges of polychlorinated biphenyls (PCBs) have contaminated the natural resources of the Hudson River. The Hudson River Natural Resource Trustees (Trustees or HRNRT) – New York State, the U.S. Department of Commerce/National Oceanic and Atmospheric Administration, and the U.S. Department of the Interior – are conducting a natural resource damage assessment for the Hudson River PCBs Superfund Site to assess and restore those natural resources injured by PCBs (HRNRT 2002). These agencies are responsible for evaluating the injuries to natural resources, including injuries related to the dredging remedy ordered by the U.S. Environmental Protection Agency (EPA) and implemented by the General Electric Company (GE) to remove PCB-contaminated sediments from the Hudson River (USEPA and GE 2006a,b, USEPA and GE 2011). The Trustees are also responsible for determining appropriate actions to restore those injured resources. This report was developed as part of the Hudson River Natural Resource Damage Assessment to assess injuries to natural resources from GE's dredging remedy.

To determine injury, the Trustees examined the extent and scope of GE's remedial work undertaken on the Upper Hudson River (UHR), identified the ecological significance and value of certain natural resources in those areas, and determined the nature of "injury" within the meaning of the U.S. Department of Interior Natural Resource Damages Regulations, 43 C.F.R. Part 11. Sections 5.0 – 8.0 of this report address those affected resources. Each of these sections describes the resource, sets forth the methodology for measuring injury, describes the impact of the dredging on the resource, and describes the injury analysis and determination. As described in this injury determination, the dredging, capping and backfilling of the targeted PCB dredging remedy destroyed entire sections of riverine fringing wetlands, aquatic vegetation beds, substantial areas of woody shoreline, and beds of freshwater mussels. The Trustees believe that GE's dredging remedy injured other habitats and natural resources, including the woody debris within the river, the benthic invertebrate community (aside from mussels) living on or in the sediments, the invertebrate community living on aquatic vegetation, upland forests disturbed to create dredging support areas, and armored and hardened river banks. The decision whether to characterize injuries to these additional resources or to resources harmed in other operable units will be made in the future.

The injury determination for each resource in this report is based upon the direct impact of the dredging remedy.[2]

2.0 THE HUDSON RIVER ENVIRONMENT

The Hudson River originates in Lake Tear of the Clouds in the Adirondack Mountains and flows south for 315 miles, past many of New York State's major cities, including Troy, Albany, Poughkeepsie, and New York City. In total, about 13,390 square miles of land drain to the Hudson River; this drainage basin encompasses about one-quarter of New York, as well as portions of Connecticut, Massachusetts, New Jersey, and Vermont. The river reaches a maximum depth of 216 feet and is over three miles wide in some places (Stanne *et al.* 2007).

The Hudson River PCBs Superfund Site includes a nearly 200 mile stretch of the river from the Village of Hudson Falls to the Battery in New York City (USEPA 2002a). EPA has divided the Hudson River PCBs Superfund Site into the Upper and Lower Hudson River (UHR and LHR, respectively), which are separated by the Federal Dam at Troy (USEPA 2002a). The UHR extends from Hudson Falls to the Federal Dam at Troy, a distance of approximately 40 miles. Land use along the UHR is dominated by forests and agriculture interspersed with towns and cities. The UHR has been extensively modified by dams that create a series of interconnected impoundments with relatively slow currents. The focus of this Remedial Injury Determination is on those parts of the UHR, from Fort Edward downstream to the

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[2] The dredging remedy included clamshell dredging followed by backfill or cap placement to sequester residual PCB contamination and to expedite habitat recovery. Reconstruction of some of the disturbed habitats including potential placement of additional backfill was a component of the remedial action (USEPA 2002a,b).

Federal Dam at Troy, where the sediment dredging, backfilling, capping, and support operations occurred (USEPA 2002a).

The UHR is a freshwater non-tidal ecosystem. The Federal Dam, approximately 154 miles upstream of the Battery in New York City, is the first significant barrier to upstream fish movement on the mainstem of the Hudson River (Limburg *et al.* 1986) and divides the UHR and the LHR. Dams located upstream of the Federal Dam further impede fish passage, although almost all of the dams are associated with the locks of the Champlain Canal that allow for some limited fish movement both upstream and downstream. A few diadromous species such as blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), gizzard shad (*Dorosoma cepedianum*), and American eel (*Anguilla rostrata*) have been collected in the UHR (Smith 1985, Waldman *et al.* 2006). The LHR extends from just below the Federal Dam at Troy downstream to the Battery in Manhattan. This 154-mile estuary is a mix of tidal marine, brackish, and freshwater habitats influenced by both the freshwater that flows from the river's upper reaches as well as by seawater that moves upstream with the ocean's tide (Stanne *et al.* 2007).

The UHR is on average less than eight feet deep nearshore, approximately 18 feet in the Champlain Canal (USEPA 2019), and supports a rich array of ecological communities that interact in complex ways (HRNRT 2002). Emergent marshes, also referred to as riverine fringing wetlands (RFW), occur along the edges of coves, along shorelines, in backwater areas, in the vicinity of islands and near the mouths of some tributaries. Several wetland communities were identified during the baseline (pre-dredge) assessment (BBL and Exponent 2005, Anchor QEA 2009). Along with RFW, the UHR supports aquatic vegetation beds comprised of submerged aquatic vegetation (SAV) and floating aquatic vegetation (FAV). Numerous species of native SAV and FAV can be found in the UHR (Anchor QEA 2018, CDM 2018) where water clarity allows sunlight to penetrate and support plant growth. In vegetated and unvegetated river bottom, the sediments support benthic invertebrates (Exponent 1998 a,c,d; HRNRT 2016), including native freshwater unionid mussels (Strayer and Jirka 1997, Strayer 1987, Strayer 2012a,b, HRNRT 2020) and the aquatic vegetation supports a community of invertebrates that live on it (Exponent 1998 a,c,d).

Floodplain forests are closely associated with the river and are subject to a wide range of inundation. Some may be flooded after every severe storm, while others only flood during exceptional runoff events. Scrub-shrub, RFW, backwater wetlands, vernal pools and hardwood swamps are associated with these floodplain forests (HRNRT 2002). All of these shoreline and floodplain communities occur in patches on both sides of the river and are interspersed with stretches where uplands come right to the banks.

The aquatic, shoreline, and floodplain vegetation of the UHR provide many critical ecosystem functions. At a most basic level, these plant communities are serving as producers of organic carbon through the process of photosynthesis. Also, through the photosynthetic process, the plants remove carbon dioxide from the atmosphere and produce oxygen both to the water and the air. RFW and SAV/FAV are consumed directly by invertebrates, fish, reptiles, waterfowl, and mammals (Thunhorst 1993, Batzer *et al.* 2015). RFW and SAV/FAV support invertebrates, living in association with the aquatic vegetation, that are important prey for many aquatic species of fish and wildlife (Exponent 1998 a,c,d, Feldman 2001, Stevenson and Davis 2001, Batzer *et al.* 2015). RFW and SAV/FAV provide critical nursery habitat for juvenile fish, as well as important feeding areas for certain sport fish such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), yellow perch (*Perca flavescens*), brown bullhead (*Ameiurus nebulosus*), and northern pike (*Esox lucius*) (Smith 1985, Stanne *et al.* 2007). RFW areas are spawning habitat for northern pike, common carp (*Cyprinus carpio*), and frogs, and breeding habitat for reptiles, mammals (such as mink, *Neovison vison*), and waterbirds such as bitterns, and rails (Smith 1985, Batzer *et al.* 2015). Waterfowl also feed and reproduce here (McFarland 2006, Korschgen and Green 1988, Thunhorst 1993). RFW and SAV/FAV beds can moderate river flows, flooding and sediment transport, allowing fine sediments to accumulate, enhance water quality, and are important areas for nutrient cycling (Bullock and Acreman 2003).

Wetlands and floodplain forests help to moderate the effect of damaging floods after spring snow melt and extreme storm events (Gregory *et al.* 1991). The trees of the shoreline and floodplain provide an important source of organic material and nutrients to the river through the annual shedding of leaves from deciduous trees (Grubaugh and Anderson 1989). The trees themselves are important producers of wildlife food; they also provide habitat for many species of insects, which are an important food source for birds (Harris and Gosselink 1990, Taylor *et al.* 1990). Overhanging branches of live trees serve as perches for birds and basking platforms for turtles if those branches are in contact with the river. The trees provide shade and moderate river and riparian habitats (Gregory *et al.* 1991). Dying trees provide important habitat for cavity-nesting birds, such as wood ducks (*Aix sponsa*), tree swallows (*Tachycineta bicolor*), and screech owls (*Megascop asio*) (Budliger and Kennedy 2005). Dying trees also fall into the river creating structure that benefits fish and that alters water flow and sediment deposition, adding to the diversity of microhabitats in the river (Gregory *et al.* 1991).

Native freshwater mussels are recognized as a globally imperiled group of species (Strayer *et al.* 2004, Strayer 2006). Freshwater mussels are often overlooked, but critical components of the ecosystem including the UHR. Native freshwater mussels (Unionidae) can be the primary contributor of benthic macroinvertebrate biomass (Strayer *et al.* 1999; Raikow and Hamilton 2001). They provide important ecosystem functions such as water filtration and nutrient cycling that improve water clarity and water quality (Strayer 2017, Kreeger *et al.* 2018). They inhabit a variety of substrates and can be found in vegetated and unvegetated areas (Haag 2012). In addition, freshwater mussels help stabilize sediment, provide structure to the river bottom, support conditions that sustain aquatic, floating and emergent vegetation, and are an important food source to fish and wildlife (Spooner and Vaughn 2008, Vaughn and Spooner 2006, Vaughn *et al.* 2008, Owen *et al.* 2011, Haag 2012, and Strayer 2017). Mussels are also important bioturbators and oxygenators of sediment as they move within the sediment column and pump overlying water through the sediment (Schwalb and Pusch 2007 and McCall *et al.* 1979).

3.0 THE REMEDIAL WORK

3.1 Background

The Hudson River PCBs Superfund Site was listed on the National Priorities List in 1984 and consists of four operable units (OU1 to OU4): the Remnant Deposits, the river proper, Rogers Island, and the floodplains, respectively. The focus of this injury determination report is OU2, or the remediation of the river proper (USEPA 2002a). The primary contributors of PCBs to the Hudson River are two former electrical capacitor-manufacturing plants located at Hudson Falls and Fort Edward, NY, which are owned by GE (USEPA 1984). GE began using PCBs in its manufacturing processes at the Fort Edward and Hudson Falls plants in 1947 and 1952, respectively (Hetling *et al.* 1978). Between 1946 and 1977, GE purchased almost 190 million pounds of PCBs (Aroclors 1016, 1221, 1242 and 1254) for use at these two plants (Shifrin 2014 a, b, c). Both plants discharged manufacturing process wastewater containing PCBs directly to the Hudson River until 1977 (USEPA 2002a). GE also discharged PCBs from the Hudson Falls plant to the sanitary sewer system leading to the Hudson Falls Village Sewage Treatment Plant, and PCB-contaminated storm water discharges to the Hudson River from both plants (Clark, Dietz and Associates 1975). In 1991, EPA estimated that the amount of PCBs released from these plants to the sediments and waters of the Hudson River between 1947 and 1977 ranged from 209,000 to 1,330,000 pounds (USEPA 2002a); however, the actual amount of PCBs discharged into the river is likely significantly higher.

In February 2002, EPA issued a Record of Decision (ROD) for the Hudson River PCBs Superfund Site OU2 that called for the targeted environmental dredging of approximately 2.65 million cubic yards (cy) of PCB-contaminated sediment from approximately 500 acres within a 40-mile section of the UHR.

3.2 Geographic Scope

As previously described, EPA has divided the Hudson River PCBs Superfund Site into the UHR and LHR, which are separated by the Federal Dam at Troy (USEPA 2002a). The UHR portion of the site is defined as the freshwater non-tidal river from Hudson Falls (RM 198) downstream to the Federal Dam at Troy, New York. The LHR consists of the Hudson River estuary from the Federal Dam at Troy, New York downstream to the Battery (RM 0) at the southern tip of New York City. The focus of this injury determination report is the UHR, where remedial actions (sediment dredging, backfilling, and capping) and associated remedial support activities (i.e., shoreline armoring, tree removal and trimming, construction for access) have been implemented in the river, along the shoreline, and in the uplands.

The UHR consists of three river sections comprising eight river reaches or pools (Figure 1). The river sections and pools are separated by dams and locks associated with the Champlain Canal, which runs through the Hudson River from the Federal Dam at Troy to Lock 7 in Fort Edward. Seven of the eight pools are navigable through this channel.

River Section 1 is the Thompson Island Pool, an area of river from the former Fort Edward Dam in Fort Edward downstream to the Thompson Island Dam. This section is about six miles long and extends from approximately river mile RM 195 to RM 189.

River Section 2 consists of two pools, Fort Miller and Northumberland. The Fort Miller Pool extends from the Thompson Island Dam downstream to the Fort Miller Dam (RM 186) and is the only pool not navigable via the Champlain Canal. The Fort Miller Pool is often referred to as the "land-locked section." The Northumberland Pool is about three miles long and extends from the Fort Miller Dam downstream to RM 183 at the Northumberland Dam.

The 29.5-mile long River Section 3 consists of the Stillwater, Upper and Lower Mechanicville, Waterford and Troy Pools. The Stillwater Pool (approximately RM 183 to RM 168), which is the longest pool on the UHR, is bounded by the Northumberland Dam at the upstream end and the Stillwater Dam at the downstream end. The Upper Mechanicville Pool is formed by the Stillwater Dam at RM 168 and the Upper Mechanicville Dam at RM 166. The Lower Mechanicville Pool is formed by the Upper Mechanicville Dam at RM 166 and the Lower Mechanicville Dam at RM 163. The Waterford Pool is the area from RM 163 at the Lower Mechanicville Dam to RM 159 at the Waterford Dam. The Troy Pool extends from the Waterford Dam at RM 159 to the Federal Dam at Troy (RM 154).

3.3 Dredging

For purposes of the UHR dredging project, EPA divided the three river sections, described above, into 100 "certification units", or "CUs", each CU being approximately five acres in size, but some were as small as 0.4 acres and as large as 7.9 acres (Parsons 2011, Parsons 2019).

The ROD specifies numeric and other criteria for delineating areas to be dredged. Numeric triggers used in the delineation of dredged areas were based upon surface (defined as the top 12 inches) PCB concentration and PCB "mass-per-unit area", or "MPA", which is a way to sum the amount of PCBs within a given area based on PCB concentrations, sampling depth, and density of the sediment (USEPA 2004). The numerical trigger used in the upper-most (most upstream) River Section 1, the Thompson Island Pool, was about three times more stringent than the trigger for River Sections 2 and 3, further downstream. The result of the application of these triggers is that more than half of River Section 1 was dredged, in many places from one bank of the river to the other, while dredging occurred in a more targeted manner in River Sections 2 and 3, leaving much higher levels of contamination behind in seven of the eight pools compromising the OU2 remedy. Slightly more acres were dredged in River Section 3 than River Section 2 but the relative total area dredged in River Section 3 relative to River Section 2 was substantially less because of its much larger size. Based on the dredging criteria, much of the sediment dredged out of the UHR was finer grained than the material left undredged outside of the CUs (USEPA 2019).

GE performed the dredging, under EPA oversight, pursuant to the terms of the 2006 Consent Decree, 2011 Consent Decree Modification (No. 2), and remedial design, action, operations, and maintenance and monitoring documents. The dredging of the Hudson River was designed and performed in two phases. The first year of dredging (Phase 1) occurred between May and November 2009. During Phase 1, approximately 286,000 cy of contaminated sediment was removed from 10 CUs within River Section 1 (LBI 2010b). After an extensive evaluation by an independent panel of scientists and input from a broad range of stakeholders in 2010 (Bridges *et al.* 2010), EPA developed plans for the second part of the cleanup. In December 2010, General Electric elected to implement the remainder of the dredging project (Phase 2; USEPA and GE 2011).

Phase 2 dredging began in June 2011 (Parsons 2012) and was conducted at full production to remove the contaminated river sediment meeting the cleanup criteria that was targeted for dredging (LBI 2010a). During the five years of Phase 2 dredging, between June 2011 (Parsons 2012) and October 2015 (Parsons 2016), approximately 2.5 million cy were dredged (Parsons 2019).

Between 2009 and 2015, which constituted the totality of the dredging project (Phase 1 combined with Phase 2), GE – under EPA's oversight – removed PCB-contaminated sediment meeting the ROD cleanup criteria from 493 acres of Hudson River bottom (Parsons 2019). In all, over six seasons of dredging, approximately 2.75 million cy of PCB-contaminated sediment was removed from the river bottom (Parsons 2019). GE dredged approximately 307 acres in River Section 1; 88 acres in River Section 2; and 96 acres in River Section 3 (Table 1). Approximately 27,000 cy of additional dredging was needed to allow dredging equipment to access shallow areas (USEPA 2019), but information on exactly how much occurred in each pool outside of CU's was not clearly reported and was therefore left out of Table 1.

Table 1. Scope of OU-2 Remedial Dredging

Remedy Phase	River Section	Reach #	River Pool	CUs	Pool Acres	Acres Dredged	% of Pool Dredged
1 and 2	1	8	Thompson Island	1-60	545.5	306.7	56.2
2	2	7	Fort Miller	61-66	239.8	29.3	12.2
2	2	6	Northumberland	67-78	293.6	58.5	19.9
2	3	5	Stillwater	79-91	1310.5	57.9	4.4
2	3	4	Upper Mechanicville	92-93	339.7	13.1	3.9
2	3	3	Lower Mechanicville	94-96	280.6	16.1	5.7
2	3	2	Waterford	97-98	439.1	4.1	0.9
2	3	1	Troy	99-100	591.1	5.3	0.9
TOTAL				**1-100**	**4,040**	**491**	**12.2**

Note: "Pool Acres", including the navigation channel, were derived from "HudsonRiverPolygon_Reach.shp" and Hudson_River_Shoreline_Coveville20190319.shp"; "Acres Dredged" tabulated from Phase 1 and Phase 2 RA Completion Report Form 1s, Form 2s and Figures 2-1 to 2-31 (Parsons 2019). The acres dredged differs slightly from 491.6 acre total reported in Table A8-2 of USEPA (2019) for River Section (RS)1 (307.8), RS2 (87.7) and RS3 (96.1) and the 493 total acres dredged reported on page 2-13 of Parsons (2019).

Dredging removed PCBs to an average depth of 3.5 feet and at maximum depths up to 15 feet (USEPA 2019). Backfill or cap material was placed on top of the sediments exposed following dredging, but the volume placed back in the river was less (approximately 51.5% of volume removed) than the amount of sediment dredged (Parsons 2011, Parsons 2019, USEPA 2019). Capping is discussed further in Section 3.4.1 immediately below. Remedial backfill is described in Section 3.4.2.

3.4 Remedial Backfill and Capping

EPA estimated that 1,362,266 cy[3] of backfill and cap were placed in the river as part of the remedial action following dredging.[4] Hence, approximately 48.5% of the sediment dredged from the UHR was not replaced with backfill or cap. After dredging, backfill and capping, the bed of the river was generally deeper, and the substrate was firmer and more angular (USEPA and GE 2006b, BBL 2006, LBI 2010b, Parsons 2019). The constructed remedy modified river bottom topography and elevation, and modified or removed habitat; those modifications harmed habitat functionality and the natural resources of the UHR.

3.4.1 Remedial Capping

Due to logistical, seasonal, and engineering realities, GE was unable to fully dredge some targeted areas to the required 1 ppm Tri+ PCB cleanup goal set forth in the 2002 ROD. In those areas, subaqueous caps were installed in lieu of backfill (MPI *et al.* 2004, LBI 2010a, Parsons 2019). Subaqueous caps were designed in a way that the top of the cap is flush with adjacent sediment or at a lower elevation whereby the constructed cap would not reduce water depths. The purpose of the caps was to physically isolate benthic invertebrates from the residual PCB contamination, minimize bioturbation (mixing by biological activity) of the contaminated sediment under the cap, prevent resuspension and migration of the contaminated sediments, and eliminate or reduce flux of PCBs from the isolated sediment into the water column (USEPA and GE 2006b).

Several different cap types were designed and placed to isolate contaminated sediment remaining in the CUs. The thickness, construction materials, and degree of armoring of the different cap types depended on the level of PCBs in the sediment post-dredging, the velocity of the river (low, medium, high) that the cap was designed to withstand and the phase of dredging. (MPI *et al.* 2004, LBI 2010a). The 12-15-inch thick caps were not specifically designed to return the river bottom to its pre-dredge contour or condition.

During Phase 1 and Phase 2 remediation, caps were required in portions of 83 of the 100 CUs. Approximately 111 of 493 acres were capped, representing 22.4% of the total dredged area (Table 2). No caps were placed in areas dredged for access located outside of the CU boundaries (Parsons 2011, 2019).

3.4.2 Remedial Backfilling

Backfill was placed in some of the areas dredged during remedy construction consistent with the 2002 ROD. The backfill designs and material specifications changed as the remedy progressed over the six years of work, but the backfill was generally a variant on a non-angular sandy substrate derived from run of bank material and thus generally coarser than what was removed. In shallow water areas supporting RFW, backfill type included more fined grained material and organic content (BBL 2006; Arcadis 2011, 2012a, 2013b, 2014, 2015).

Backfill was placed in the river to achieve an approximately one-foot thick cover to isolate the remaining PCBs not addressed by cap placement and to expedite habitat recovery (EPA 2002a). The design also specified that the nearshore and the riverine fringing wetlands be restored to pre-dredge elevations, but there were some modifications to this procedure (e.g., deeper open water allowing higher flows) to improve plane or boat access (e.g., West Griffin Island Area, north of the Snook Kill) or to reduce recolonization by water chestnut (e.g., West Griffin Island Area) (Arcadis

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[3] Table A8-4 of USEPA 2019 lists the reported volume for backfill, but Table A8-6 suggests the volume represents both backfill and cap materials

[4] Table A8-2 of USEPA 2019 estimated 2,641,926 cy of sediment dredged from OU2 per the 2002 while Parsons (2019, pg.2-9) reported a higher removal volume of 2,754,324 cy.

2012b, 2013a, Parsons 2019). In many areas of the river the thickness of backfill or cap was insufficient for restoring the river bottom to pre-existing elevations. (BBL 2003, USEPA and GE 2006b, Parsons 2019, USEPA 2019).

Table 2. Extent of UHR (OU-2) Capping in the Three River Sections (RS) Following Dredging

River Section	Reach #	River Pool	CUs	Acres Capped*	% of Dredged CU/Section Capped**	% of Pool Capped ***
1	8	Thompson Island	1-60	54.7	17.8	10.0
RS 1 – Subtotal			*1-60*	*54.7*	*17.8*	*10.0*
2	7	Fort Miller	61-66	6.2	21.2	2.6
2	6	Northumberland	67-78	20.4	34.9	6.9
RS 2 –Subtotal			*61-78*	*26.6*	*30.3*	*5.0*
3	5	Stillwater	79-91	15.3	26.2	1.2
3	4	Upper Mechanicville	92-93	5.1	38.9	1.5
3	3	Lower Mechanicville	94-96	7.0	43.5	2.5
3	2	Waterford	97-98	0.7	17.1	0.2
3	1	Troy	99-100	1.1	20.8	0.2
RS 3-SubTotal			*79-100*	*29.1*	*30.3*	*0.1*
TOTAL			**1-100**	**110.4**	**22.4**	**2.7**

* Form 2s from Parsons 2011 and Parson 2019.
**Percent Dredged CU (Section) Capped = Acres within CU (Section) Capped (from Table 2) /Acres within CU (Section) Dredged (from Table 1).
***Percent Pool Capped = Acres within CU (Section) Capped (from Table 2) /Total Acres in Pool (Section) (from Table 1).

Supplemental backfill was also placed in areas that supported aquatic vegetation beds destroyed by the remedy if the post-dredge elevation was below the photic zone (where sufficient light penetrates to support plant growth). While this raised the bottom elevation closer to pre-dredge conditions, it did not return all of the river bottom that supported aquatic vegetation or could potentially support aquatic vegetation in the future to original bathymetry (Parsons 2011, Parsons 2019).

During Phase 1, GE placed no more than 15% additional backfill for aquatic bed construction based on the total volume of backfill to isolate residuals (USEPA and GE 2006b, BBL 2006). During Phase 2, GE used a different formula for calculating how much backfill was available for reconstructing the aquatic vegetation beds destroyed by the dredging (Arcadis 2011, 2012a, 2013b, 2014, 2015). In an effort to reconstruct the SAV/FAV beds where required, additional "habitat layer" backfill was placed on top of the one-foot backfill or capped surface within CUs that supported SAV/FAV beds at water depth between two and eight feet[5] prior to dredging but that was deeper than eight feet after dredging. The "habitat layer" backfill was designed to either return aquatic vegetation areas with pre-dredging depths of greater than five to eight feet to their pre-dredging bathymetry or to a five foot water depth, for areas with water depths greater than two to five feet pre-dredging. No additional backfill was placed in areas that previously supported aquatic vegetation beds at depths greater than eight feet. Areas targeted for dredging that were adjacent to SAV/FAV beds, but not supporting vegetation at the time of habitat delineation received no additions of "habitat layer" backfill (Arcadis 2011, 2012a, 2013b, 2014, 2015), although those areas might have supported SAV sometime in the past or future.

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[5] Assumes a design flow of 5000 feet per second.

GE's approach to backfill after dredging left the river deeper in many areas: (a) that previously supported SAV/FAV beds; (b) where no vegetation was present, but where existing beds had the potential to spread and expand; or (c) where natural recolonization by dispersal of upstream seed, turion[6] or vegetative fragment might have occurred sometime in the future. The deeper water column, and firmer, and sometimes more angular river bottom harmed habitat and the natural resources of the UHR.

3.5 Shoreline Remedial Activity

GE conducted tree trimming and tree removal in 2009 and 2011-2014 in preparation of dredging of the river (see Appendix A). This was preceded by an evaluation by a certified arborist of trees requiring removal or pruning. The intent of the tree trimming and removal activities along the shoreline was to permit safe access and effective operation of dredging and stabilization equipment without interference from overhanging branches. Trees to be trimmed or removed were adjacent to or overhung an access area or a dredge area (e.g., certification unit, access dredge area). The root ball and tree stumps ≥ 6 inches diameter at breast height (DBH) required construction manager approval for removal and generally were left in place to minimize shoreline erosion (BBL 2006, Arcadis 2011, Parsons 2015). Other shoreline vegetation was also pruned or removed. GPS coordinates were provided prior to the trim or removal activities (Parsons and Anchor 2008, Parsons 2019). Maps and lists of trees targeted for trimming or removal were generally developed by GE, although NYSDEC prepared the records for trees to be impacted in Saratoga County (see Appendix A). These lists identified the CU, tree species or genus, tree condition (e.g., poor, dead, fail, decayed), general tree size (e.g., <6", 6-16", >16", ≥ 6" DBH), action (trim or remove) and coordinates (eastings and northings).

3.6 Habitat Reconstruction

Before the dredging began in the river, GE delineated habitat in the UHR into four major categories: unconsolidated river bottom, riverine fringing wetlands (RFW), aquatic vegetation beds, and shoreline. The delineation of the aquatic vegetation bed included native, non-native, and invasive SAV and FAV (Arcadis and QEA 2008). In areas where RFW, FAV, and SAV were present within the CUs, those natural resources would be completely removed and, under the ROD, the 2006 Consent Decree, and 2011 Consent Decree Modification No. 2, GE was responsible for a certain level of reconstruction of those habitats.

GE's habitat reconstruction program focused on RFW, SAV, and FAV, and to a more limited degree, shoreline areas. A variety of RFW species were seeded and or planted. SAV and FAV were planted in some areas and allowed to naturally recolonize in others. The species seeded and or planted and the specific protocols used for reconstructing wetlands and aquatic vegetation beds were adaptively managed over the course of the remedy. Live stakes of a short list of tree and shrub species were to be installed in any shoreline hardened by the remedy (BBL 2006, Arcadis 2011, 2012a, 2013b, 2014). The placement of backfill, discussed in the previous section above, was intended in part, to provide habitat for benthic invertebrates to recolonize (USEPA 2002a). No other efforts were specifically undertaken to address benthic habitats or natural resources, e.g., freshwater mussels, inhabiting river sediments adversely impacted by the remedy.

GE recognized that the design for habitat reconstruction would not return the river and ecosystem to how it was prior to remediation. According to GE, the primary goal of the habitat reconstruction program, is "to replace the functions of the habitats of the UHR to within the range of functions found in similar physical settings in the UHR, in light of changes in river hydrology, bathymetry, and geomorphology that will result from the implementation of the EPA-

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[6] A turion or winter bud is a dormant storage organ of some perennial aquatic plants that gives rise to new plants (Adamec 2018). Anchored or buried in sediment, turions are not as likely to disperse by wind or water to the degree seeds are (McFarland 2006).

selected remedy and from possible independent environmental changes" that "may occur from other factors" (USEPA and GE 2006b, Parsons 2011, 2019).

RFW, SAV/FAV, shoreline areas and unconsolidated (unvegetated) river bottom are all important components of the UHR ecosystem and have inherent value as habitat for a diversity of invertebrate, fish and wildlife species and for the various ecosystem functions they provide., e.g., provision of food, sediment and shoreline stability, nutrient and organic carbon cycling, shade and cover, surface water exchange, energy dissipation (BBL and Exponent 2005). These habitats support various trophic levels of organisms that comprise the food web. Many of the remediated habitats contained native freshwater mussels and other macroinvertebrate communities that lived on or in the sediment and on plants (RFW, SAV, FAV) prior to dredging (Feldman 2001, Exponent 1998a,b,c,d, HRNRT 2016, HRNRT 2020). The quality, quantity, success, sustainability and resiliency of these reconstructed habitats has implications for the natural resources that use them at various points in their life history for feeding, breeding, and shelter.

4.0 DEFINITION OF INJURY

Section 107(a) of the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"), 42 U.S.C. § 9607(a) establishes liability for damages for injury to, destruction of, or loss of natural resources resulting from the release of hazardous substances to the environment. The term "damages" is defined as "the amount of money sought by the natural resource trustee as compensation for injury, destruction, or loss of natural resources as set forth in section 107(a) or 111(b) of CERCLA." 43 C.F.R. § 11.14(l). The term "injury" means:

> a measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a discharge of oil or release of a hazardous substance, or exposure to a product of reactions resulting from the discharge of oil or release of a hazardous substance. As used in this part, injury encompasses the phrases "injury," "destruction," and "loss." Injury definitions applicable to specific resources are provided in § 11.62 of this part. (43 C.F.R. § 11.14(v)).

The term "destruction" means the total and irreversible loss of a natural resource (43 C.F.R. § 11.14(m)). The term "loss" is a measurable adverse reduction of a chemical or physical quality or viability of a natural resource (43 C.F.R. § 11.14(x)).

The term "natural resources" means land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States or any State or local government, any foreign government, or any Indian tribe (42 U.S.C. § 9601(16); 43 C.F.R. § 11.14(z)).

In addition to injuries sustained directly as a result of the release of hazardous substances to the environment, Trustees are also entitled to recover "any increase in injuries that are reasonably unavoidable as a result of response actions taken or anticipated" (43 C.F.R. § 11.15(a)(1)). This provision, along with the fact that injury is defined to include adverse changes resulting indirectly from an exposure to hazardous substances (i.e., from remedial activities), means that the impact of targeted PCB removal in various habitats of the Hudson River resulted in natural resource injuries that the Trustees should include in the Hudson River NRDA. In a separate report, the Trustees will quantify the amount of natural resource services that were lost due to the remedy and GE's failure to adequately reconstruct adversely-affected habitat.

5.0 THE INJURY TO RIVERINE FRINGING WETLANDS

5.1 Habitat Description and Ecological Services

Riverine fringing wetlands (RFW) in the UHR that are usually flooded during most of the growing season support plants such as spatterdock (*Nuphar luteum*), pickerelweed (*Pontedaria cordata*), arrowhead (*Sagittaria* spp.), cattail (*Typha* spp.), giant burreed (*Sparganium eurycarpum*), wild rice (*Zizania aquatica*), arrow arum (*Peltandra virginica*) and soft-stem bulrush (*Schoenoplectus tabernaemontani*, formerly *Scirpus validus*); those flooded only during high water periods support a mix of plant species depending on elevation and flooding such as rice cutgrass (*Leersia oryzoides*), purple loosestrife (*Lythrum salicaria*), wool grass (*Scirpus cyperinus*), spike rush (*Eleocharis* spp.) and various sedges (*Carex* spp.) (Reschke 1990, HRNRT 2002). Northern pike and carp (*Cyprinus carpio*) use these flooded areas as spawning habitat, and many prey and game fish use wetlands as important foraging and nursery areas (Smith 1985). Frogs, reptiles, mammals (such as mink), waterbirds (such as herons, bitterns, and rails), and waterfowl feed and reproduce in the river's wetlands (Thundhorst 1993, Batzer *et al.* 2015). Wetlands contribute to flood resiliency, sediment stability, and help moderate sediment transport by slowing water velocity and allowing deposition. Along with wetlands' obvious role in photosynthesis, as plants die back at the end of each growing season, wetlands provide a major source of carbon and other nutrients into the aquatic food web (Batzer *et al.* 2015).

5.2 Methodology for RFW

As part of the remedial design under the ROD (USEPA 2002a), GE was required to delineate RFW and aquatic vegetation beds, including SAV and FAV, along the Hudson River dredging project area. During the remedial action, GE (2016) developed and submitted to the EPA a 2016 "Habitat Reconstruction Ledger," based on Form 2 and Form 3 packages approved by EPA as of September 13, 2016, or were in draft form at the time of its preparation, and from designs submitted to EPA as of August 4, 2016. Upon completion of Phase 1 and Phase 2 remediation, Record Drawings were prepared memorializing, by certification unit delineated, designed and reconstructed RFW habitat destroyed by dredging (Parsons 2011, Parsons 2019). In certain areas, like the West Griffin Island Area in River Section 1, GE reconstructed wetlands as "RFW-FAV/SAV," a mix of all aquatic vegetation types (GE 2016, Parsons 2019). For this injury determination, delineated RFW areas (GE 2016) that were removed during remediation were counted among the total acres of RFW injured, even if those areas were reconstructed as SAV or FAV. Fringing wetlands are dynamic communities and can vary in size and exact location from year to year depending on water levels in the river (Levine and Willard 1990). GE delineated wetlands over several years before dredging began, including Phase 1 areas in 2006 (QEA 2008) and Phase 2 areas in 2008, 2009, and 2011 (Anchor QEA 2011, 2012). The number of acres of RFW and RFW-SAV/FAV listed in GE's (2016) Habitat Reconstruction Ledger was used as the measure of the acres of RFW habitat injured during the dredging project. While GE's habitat reconstruction of RFW areas will offset some of the initial injury, the wetlands will take years to return to the full ecological function of the pre-dredge wetland habitat (Moreno-Mateos *et al.* 2012). These interim losses will be evaluated in a subsequent injury quantification and are beyond the scope of this report.

5.3 The Impact of the Dredging Remedy on RFW

Overall the dredging made the river deeper, changed the substrate, and modified the depositional patterns (USEPA 2019, Parsons 2011, 2019). The West Griffin Island area (WGIA) provides a clear example of the effects of the dredging remedy on Hudson River wetlands. The west channel of Griffin Island was a backwater area in River Section 1, which prior to being dredged provided spawning and nursery habitat for Largemouth bass (Arcadis 2012b) and other fish (Sloan *et al.* 2005). The area consists of 31.5 acres of mapped wetlands regulated by New York State under ECL Article 24 (ECL §§24-0301; NYCRR Part 664) and included 9.5 acres of water chestnut and 13 acres of RFW-FAV/SAV that provided a nearly continuous, dense cover of emergent and floating wetland vegetation before dredging (Arcadis 2012b, Seggos 2017). After dredging, 3.17 acres of RFW and 3.23 acres of RFW-FAV/SAV were replanted in the WGIA. The post-remediation WGIA is currently dominated by open water with a narrow band of fringing wetlands compared to a channel dense with vegetation prior to remediation. Because the remedial action and reconstruction occurred in a New York State regulated wetland, and the changes to bathymetry and wetland composition were in violation of the substantive requirements of state regulations (NYCRR Part 663, Seggos 2017), both the removal and failure to adequately restore the wetlands represent an injury to state resources. Another example of the effects of dredging and inadequate reconstruction on RFW is the area around CUs 67-70 in the Northumberland Pool, River Section (RS)2. Areas close to the channel east of the wetland were left deeper than original bathymetry. While this may benefit adjacent property owners by allowing better boat access, deeper water may limit the recovery of RFW. Both the WGIA and CUs 67-70 comprised a significant percentage of the total wetland acres destroyed by the remedy.

Aside from the physical removal of wetlands, the dredging remedy also had effects to wetlands outside the dredge areas through disturbance caused by boat traffic (prop wash, wakes, etc.) and increased turbidity and sedimentation from dredging and backfilling activities. Dredging removed seed bank within existing wetland areas and potentially in unvegetated areas within a CU and at least temporarily impacted overall water quality, but these effects were not captured in our measurement of injury.

In areas where wetlands (RFW and RFW-FAV/SAV) were located in CUs targeted for dredging, dredging activities completely destroyed any wetlands present resulting in a complete loss. Based upon GE's delineations of RFW, the footprint of the dredging CUs, and the information in GE's Habitat Reconstruction Ledger, the remedy directly affected an estimated 24 acres of RFW and almost 6 acres of RFW-FAV/SAV, for a total of approximately 30 acres of wetlands destroyed by dredging.

5.4 Summary of Injury to RFW

An injury to wetlands (RFW and RFW-FAV/SAV) on the Hudson River has resulted from GE's dredging remedy. The dredging remedy removed approximately 30 acres of fringing and backwater wetlands which represents a complete loss of natural resources. Habitat reconstruction activities began one year after the dredging, capping and backfilling in a CU, so the loss of RFW and its associated ecological services continued for at least one year. In many instances, whether the habitat was planted and/or seeded, reconstruction efforts failed or was poor and complete or major loss of wetlands continued for multiple years. Even in places where the river bottom was returned to pre-dredge bathymetry, the potential effect of the remedy on water quality and GE's approach to reconstruction (e.g., seeding vs planting, species composition, absence of herbivory control) and changes in native sediment type to backfill can affect wetland plant recovery and the structure and functionality of the reconstructed wetlands.

The number of wetland acres destroyed by the remedial action, as described by the Trustees in this injury determination report, are presented for the sole purpose of documenting injury from the remedial action. These wetland acres will subsequently be refined for injury quantification and may differ from the approximately 30 acres discussed here. A separate effort is being undertaken to further review relevant remedial design, remedial action, and remedial monitoring documentation to support quantification of the injury resulting from remedy implementation. The quantification of the direct losses to RFW from the remediation and the interim losses that occur until those reconstructed RFW areas return to baseline will be described in detail in subsequent reports on injury quantification, restoration options, and costs to implement that restoration (i.e., damages).

6.0 THE INJURY TO AQUATIC VEGETATION BEDS[7]

6.1 Habitat Description and Ecological Services

Aquatic vegetation beds (aquatic beds) can be comprised of SAV and FAV as well as algal and aquatic mosses (Cowardin *et al.* 1979). Aquatic vegetation beds of the UHR consist of SAV and FAV for the purposes of this injury report and are used interchangeably. SAV includes rooted aquatic plants in which part or all of the plant is under water. The leaves and stems of most SAV are limp and rely on water and internal structural features for buoyancy and support. In the freshwaters of the UHR, SAV communities often include native species, such as water celery (*Vallisneria americana*), pondweeds (*Potamogeton* spp.), waterweed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), water nymphs (Najadeace), and non-native species, such as Eurasian water milfoil (*Myriophyllum spicatum*) and curly pondweed (*Potamogeton crispus*) (Law Environmental 1991, Anchor QEA 2018, BBL and Exponent 2005, Arcadis and QEA 2008, Anchor QEA 2009). Light penetration is usually the principal driver of SAV communities, but they can also be influenced by other physical parameters, such as flow, substrate, and water depth, as well as chemical parameters, such as nutrient concentration, salinity, and level of acidity (pH) (Titus and Stephens 1984, Barko *et al.* 1988, Batiuk *et al.* 1992, QEA 2008). In addition to SAV, the UHR also supports native FAV, such as white water lily (*Nymphaea odorata*) and watershield (*Brasenia schreberi*), and non-native FAV such as yellow floating heart (*Nymphoides peltata*), and water chestnut (*Trapa natans*) (BBL and Exponent 2005, Arcadis and QEA 2008, Anchor QEA 2009). Since native and non-native FAV have similar ecological function to SAV, they are combined with and treated as SAV in this injury determination.

In the UHR, aquatic vegetation beds were a common habitat type in waters providing sufficient light for photosynthesis prior to dredging. GE delineated approximately 26 acres of FAV, 157 acres of water chestnut, and 573 acres of SAV in the UHR (Arcadis and QEA 2008). *Vallisneria* was the most common native SAV plant in the UHR prior to the remedy, but some beds were more densely vegetated than others (Exponent 1998b, BBL 2003, Arcadis and QEA 2008). Similarly, *Vallisnernia* is the dominant SAV species in the LHR. SAV covered 6% of the estuary (below the Federal Dam at Troy) in the 1990's; coverage was 18% in the shallows. The coverage of *Vallisneria* in the LHR declined by more than 90% in the aftermath of two major storms in the summer of 2011, likely due to increased sediment deposition that impacted plant tubers (Hamberg *et al.* 2017).

SAV[8] provides many important ecological functions (Heck and Crowder 1991, Stevenson and Davis 2001). At a most basic level, as photosynthesizing plants, SAV serve as primary producers and important contributors to the Hudson River's energy budget. SAV beds serve as filters and traps for sediment and cycle nutrients. SAV beds are important nursery areas for larval and juvenile fish, providing cover from potential predators and ample food resources. The vegetation also serves as important habitat for many invertebrate species, which are an important food source for larger species. The plants themselves may also serve as a food source for fish and waterfowl. SAV dampen wave energy thereby protecting shorelines from erosion. Epiphytic organisms also use the plants as substrate to grow on. Even non-native and invasive species like water chestnut and Eurasian water milfoil are not without ecological value. Although water chestnut and Eurasian water milfoil can crowd out native species, they still provide important habitat for invertebrates and juvenile fish (Exponent 1998b, Feldman 2001, Tinoco *et al.* 2017). Studies have also documented the important role *Trapa* beds can play in the cycling of nitrogen (Tall *et al.* 2011).

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[7] Aquatic beds are a type of wetland (Cowardin *et al.* 1979), but are treated separately in this injury determination report, consistent with Hudson River PCBs Superfund Site documents.

[8] Used interchangeably with SAV/FAV.

6.2 Methodology for Aquatic Vegetation Beds

In accordance with the ROD (USEPA 2002a), GE was required to delineate SAV along the Hudson River dredging project area. Aerial extent and spatial location of SAV beds can vary over time because of flooding, low flow events, changes in sedimentation rates, turbidity, chemistry, or physical disruption (Findlay 2014). GE used aerial photography, side-scan sonar, Sediment Sampling and Analysis Plan (SSAP) data and ground-truthing to map SAV beds over several years prior to the start of the dredging remedy in 2009 (BBL 2003, Arcadis and QEA 2008).

As previously described, GE (2016) developed a Habitat Reconstruction Ledger based on delineated and designed habitat and Form 2 and Form 3 packages, which tracks what habitat was destroyed during dredging and where habitat reconstruction activities occurred (Parsons 2016). The acres of SAV delineated within the 100 CUs in GE's Habitat Reconstruction Ledger provides a preliminary estimated measure of the acres of SAV habitat injured during the dredging project for the purposes of this determination of remedial injury to SAV. GE's habitat reconstruction of SAV areas may accelerate the recovery from the initial injury in the subset of areas that were replanted. However, more acres (approximately 56 acres or 58.5%) were designated for natural recolonization (i.e., no active planting) than were actively planted (approximately 39 acres or 41.5%). Destroyed SAV habitat, whether replanted or recovering passively, may take years to return to full ecological function of the original habitat. These interim losses are beyond the scope of this report but will be evaluated in a subsequent injury quantification.

6.3 The Impact of the Dredging Remedy on Aquatic Vegetation Beds

Aside from the physical removal of SAV within the dredged areas, the dredging remedy also had effects on SAV beds outside the dredge areas through disturbance caused by boat traffic (prop wash, wakes, etc.), increased turbidity and sedimentation from dredging, capping and backfilling activities and changes in the river fluvial geomorphology (river not returned to pre-dredge contours). The potential for SAV to colonize unvegetated areas or areas that previously supported SAV could be also be impaired by the alteration of bathymetry, the removal of SAV and likely removal of seed banks within dredged areas. These effects were not captured in this determination of injury.

Based upon GE's delineations of aquatic vegetation beds (including native and non-native SAV and FAV), the footprint of the dredging CUs, and the information in GE's (2016) Habitat Reconstruction Ledger, the remedy directly removed an estimated 133 acres of SAV, many of which were densely vegetated beds with *Vallisneria* ($\geq$50% cover). Of the estimated 133 acres removed during the dredging remedy, GE reconstructed approximately 95 acres of SAV, including planting approximately 39 acres of SAV and designating an additional 56 acres for SAV natural recolonization, primarily in the two- to eight-feet water depth range. However, this is 38 fewer acres of SAV than what was removed during dredging because EPA generally did not require GE to reconstruct SAV through active or passive methods or to monitor their recovery in dredged areas: (a) at depths of two feet or shallower; (b) at depths of greater than eight feet; (c) in the navigation channel; (d) in areas smaller than 0.1 acres; or (e) in isolated areas based on modeling (Parsons 2019, Arcadis 2011). These excluded SAV areas, delineated prior to remediation, were not included in the habitat ledger as reconstructed SAV habitat acres.

SAV reconstructed through active planting or passively through natural recolonization were completely destroyed during dredging and represent a complete loss of this habitat type from within CUs until reconstruction activities commenced. Generally, habitat reconstruction began one year after dredging and was completed for a specific CU, but in some areas SAV was replanted when initial plantings were unsuccessful. SAV reconstruction consisted of planting mostly *Vallisneria* supplemented with *Potamogeton* spp. and the FAV *Nymphaea odorata* in a subset of areas while the remainder of the destroyed aquatic vegetation bed was to be recovered passively through natural recolonization (no plantings installed by contractor) (Parsons 2019).

Based on GE's (2016) habitat ledger, the dredging remedy directly affected an estimated 133 acres of SAV. GE was required to plant approximately 39 acres, slightly less than half of the total SAV acres it destroyed during the dredging remedy.

6.4 Summary of Injury to Aquatic Vegetation Beds

An injury to aquatic vegetation beds in the UHR has resulted from GE's dredging remedy. The dredging remedy altered physical conditions of the river that promoted colonization, growth, and expansion of SAV and FAV prior to remediation and removed biomass and diversity in areas where SAV existed at the time of dredging. The removal of SAV during the implementation of the remedy represents a complete loss of natural resources and the ecological services they provide. Habitat reconstruction resulted in planting of submerged and floating vegetation in about 30% of delineated SAV acres dredged. This generally began one year after the dredging, capping and backfilling. Reconstruction was limited to passive natural recolonization for 42% of the delineated SAV acres destroyed by the remedy. The remaining 28% of the delineated SAV acres dredged were excluded from the habitat reconstruction program - no additional backfill was placed to adjust bed elevation, no planting occurred to jump-start recovery, and no post-remediation monitoring was required. In many instances, whether the habitat was planted or left to natural recolonization, reconstruction efforts failed or were poor and incomplete or major loss continued for multiple years and is ongoing. The Trustees generally have no data on the recovery of SAV in areas with water depths of two feet or less and greater than eight feet, in the navigation channel, or in isolated areas of <0.1 acres, where habitat was not reconstructed in some manner. The number of SAV acres destroyed by the remedial action, as described by the Trustees in this injury determination report, are presented for the sole purpose of documenting injury from the remedial action. A separate effort is being undertaken to further review relevant remedial design, remedial action, and remedial monitoring documentation to support quantification of the injury resulting from remedy implementation. The number of directly affected SAV acres will subsequently be refined during the injury quantification phase and may be different than the approximately 133 acres of SAV discussed here. The quantification of the direct losses from remediation and the interim losses until those planted and naturally recolonizing SAV areas reach baseline, and the compensation for areas that were excluded from habitat reconstruction, will be described in detail in subsequent reports on injury quantification, restoration options, and the cost to implement that restoration (i.e., damages).

7.0 THE INJURY TO SHORELINE

7.1 Habitat Description and Ecological Services

The UHR shoreline is a mix of land uses, including agricultural, residential, commercial, and public lands, but the shoreline also includes stretches of forest generally characterized as a northern floodplain forest, with overstory species such as box elder (*Acer negundo*), eastern cottonwood (*Populus deltoides*), black willow (*Salix nigra*), green ash (*Fraxinus pennsylvanicum*), and silver maple (*Acer saccharinum*), as well as a diverse understory (Arcadis and QEA 2008, Anchor QEA 2009). Floodplain forests and shoreline trees are important parts of the Hudson River ecosystem for terrestrial and aquatic organisms. They produce flowers, which attract pollinators and later produce an abundant seed crop that feeds a wide variety of birds as well as small mammals (Harris and Gosselink 1990, Taylor *et al.* 1990). In addition, shoreline buffers between agricultural land, suburban lawns, and impervious surfaces improve water quality, filter nutrients, reduce soil erosion, buffer storm surge, and increase bank stability (Gregory *et al.* 1991). Palatable bark and foliage are also important food sources for biota. Shoreline trees provide shelter, breeding grounds, and nesting sites for vertebrates and invertebrates. Benthic invertebrates and aquatic systems are affected by the stage of growth of the surrounding terrestrial habitat. Shoreline tree roots, overhanging branches and canopy cover provide shade and create important structure critical to many sportfish. Overhanging branches provide perches for passerine birds, cover for waterfowl, and basking platforms for turtles. Even after shoreline trees decay and die or when they shed leaves and branches, they still play important roles by providing new habitat for birds, fishes, fungi, and other organisms as well as contributing to energy flow and nutrient cycling (Gregory *et al.* 1991). The debris influences soil and sediment transport and storage in both aquatic and terrestrial systems. In aquatic systems, leaf litter and both coarse and fine woody debris are major contributors of carbon to the food web (Grubaugh and Anderson 1989, Gregory *et al.* 1991, Strayer and Findlay 2010).

7.2 Methodology for Shoreline

In nearshore areas where GE dredged, it was necessary to trim branches and cut down trees that hindered the maneuverability of the dredging excavators or limited access for barges. Prior to dredging, GE and DEC identified which trees were to be trimmed or removed. GE identified the species of tree, the condition, diameter and coordinates. All the trees assessed for condition by GE were described as either "poor," "dead," "dying", "decay," "decayed", "fail", "failed", "fair" or in combination with or without qualifiers. Where no condition was described, the Trustees added "not reported" (NR). GE generally limited its description of tree diameter at breast height to "greater than 6 inches" and "less than six inches," the exception being 2009 when GE and NYSDEC reported tree diameter as <6", 6-16", or >16 inches. For this injury determination, the injury is based as the number of trees removed as derived from NYSDEC and GE's design documents, which are listed in Appendix A.

7.3 The Impact of the Dredging Remedy on Shoreline

GE recorded the trimming and removal of 3,287 trees during the design of dredging project between 2009 and 2015. One hundred and fifty-two (152) trees were identified for trimming and 3,135 trees were identified for removal during the dredging remedy. All of the trees that GE removed were deciduous species, with silver maple and ash making up the largest percentage (54% and 17%, respectively). With the exception of 815 live stakes, including black willow (300), button bush (*Cephalanthus occidentalis*) (352), and silver maple (163) planted as part of habitat reconstruction in the West Griffin Island Area (Parsons 2019), GE planted no other trees or shrubs as part of habitat reconstruction, and the trees it removed represent a complete loss and the trees it trimmed represent a functional loss.

Although trimming trees can have negative effects, such as decreased shade, increased water temperatures, reduced wildlife habitat, and decreased input of organic matter into the ecosystem, for this injury determination we only considered trees that were removed. In addition, the number of trees trimmed along the shoreline were only a small percentage (4.6%) of the total of trees impacted by the dredging remedy when compared to the number of trees removed.

7.4 Summary of Injury to Shoreline

An injury to shoreline trees occurred when GE removed over 3,000 trees during the dredging remedy. While the stumps left behind after the trees were cut have some ecological value as habitat for insects and small mammals and also continue to stabilize shorelines, the trees that were not replaced have lost most of the ecological services they originally provided. The number of shoreline trees removed as part of the remedial action, as described by the Trustees in the current injury determination report, are presented for the sole purpose of documenting injury from the remedial action. The number of injured trees could subsequently be refined during the injury quantification phase and may be different than the 3,135 removed trees referenced in this report. A separate effort is being undertaken to further review relevant remedial design, remedial action, and remedial monitoring documentation to support quantification of the injury resulting from remedy implementation.

8.0 THE INJURY TO NATIVE FRESHWATER MUSSELS

8.1 Habitat Description and Ecological Services

Freshwater pearly mussels (Unionidae) are among the most imperiled groups of animals in North America (Strayer *et al.* 2004). Historically, 51 species of mussels have been described in the state of New York. Currently, 39 species are listed by the New York State Department of Environmental Conservation (NYSDEC) as Species of Greatest Conservation

Need (NYSDEC 2018a) including those designated as extinct, threatened, or endangered (NYSDEC 2018b).[9] However, since mussel assemblages in many rivers and lakes in New York including the Hudson River have never been surveyed or have limited information on species diversity, density and distribution, substantial assemblages may exist, waiting to be characterized. In the UHR prior to the Trustee-supported 2013 and 2015 surveys, some records of mussels existed (Strayer 1987), and general surveys of benthic organisms (Exponent 1998 a,c,d; BBL and Exponent 2005, Anchor QEA 2009) confirm that mussel assemblages inhabit the UHR, but no quantitative studies had been conducted that estimated their populations and species diversity (Strayer 1987). At least 20 species each of unionid and sphaeriid freshwater mussels have been reported in the Hudson River Basin (Strayer 1987). The eastern Elliptio (*Elliptio complanata*) was the dominant unionid species (Strayer 1987, Strayer 1994). In the UHR, five species of freshwater mussels have been documented between Corinth and Troy, New York, two of which are on NYSDEC's list of Species of Greatest Conservation Need. Another 14 species might utilize this habitat, including one species designated by NYSDEC as threatened and five as Species of Greatest Conservation Need (Strayer 2012a,b).

During 2013 and 2015, the Trustees conducted quantitative mussel surveys in 5 of the 8 pools impacted by the remediation and in one pool upstream of the dredging (HRNRT 2020). Eight of the nine native Unionid species collected during these surveys were found between Fort Edward and Mechanicville. The dominant mussel in the UHR was the eastern elliptio, similar to the tidal Hudson (Strayer *et al.* 1994). Other species found during the surveys included *Lampsilis cariosa*, *Lampsilis radiata*, *Leptodea fragilis*, *Ligumia nasuta, Strophitus undulatus, Lasmigona costata, Utterbackianna implicata* and *Pyganodon cataracta* (HRNRT 2020).

Freshwater mussels can be the most abundant benthic organisms in terms of biomass in some systems, often occurring in high-density beds of multiple species (Strayer *et al.* 1999; Raikow and Hamilton 2001). Freshwater mussels serve as couplers of nutrient and energy flows between pelagic and benthic communities (Welker and Walz 1998; Raikow and Hamilton 2001; Nalepa *et al.* 1991; Vaughn and Hakenkamp 2001) and can be important in removing suspended particles (Newton *et al.* 2011). Freshwater mussels are voracious filter feeders, filtering up to 11 liters per day, depending on species and size (Naimo 1995). Historically, 1.1 billion freshwater mussels filtered five billion gallons of Hudson River water per day below Troy (Strayer 2012a). In addition, the shells of native mussels provide habitat for other benthic organisms (Sephton *et al.* 1980; Beckett *et al.* 1996) and epiphyton (Vaughn and Hakenkamp 2001; Gutiérrez *et al.* 2003). Changes to the diversity, abundance, and long-term viability of native freshwater mussel communities affect the ecosystem services that these communities perform. Freshwater mussels also provide an important food source to fish and wildlife (Haag 2012). These services are also important for the preservation of natural freshwater ecosystems that provide drinking water and recreational opportunities for residents and visitors to New York.

8.2 Methodology for Freshwater Mussels

In 2013 and 2015, the Trustees supported surveys of native freshwater mussels in five pools in the UHR to assess impacts from the remedy. Surveys in 2013 were conducted in the Fort Miller Pool (RS2) and the Stillwater Pool (RS3) before dredging occurred both inside (before-remediation) and outside (non-remediated) of CUs. Surveys in 2015 were implemented in the Thompson Island Pool (RS1) and the Northumberland Pool (RS2) in non-remediated areas and in CUs after remediation (dredging, backfilling, and capping) had already occurred. Two additional pools were sampled in 2015: the Feeder Dam Pool (a reference area upstream of the GE plants), and the Upper Mechanicville Pool (RS3), which is downstream of the Stillwater Pool (non-remediated areas only) (HRNRT 2014a, b, c, 2015, 2019). Because the Feeder Dam Pool is the upstream reference pool, it is not included in the calculation of the total mussels lost due to remediation. Remediation would have removed mussels present in the CUs within the more downstream pools of RS3, Lower Mechanicville, Waterford and Troy.

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[9] In October 2019, under 6 NYCRR Part 182.5, New York State proposed changes to their list of state endangered, threatened and species of special concern, including 23 species of freshwater mussels (NYSDEC 2019).

In each pool, sampling was conducted in a random stratified design, where sample sites were randomly selected across two strata: "dredged"[10] (or "to be remediated"[11]) and "non-remediated" areas. The random sampling allows for calculations of population estimates of live freshwater mussels in each pool as a whole, and across the before-remediation, after-remediation and non-remediated strata. For the Fort Miller Pool and the Stillwater Pool, the data were collected before dredging occurred in those pools ("to be remediated" and "non-remediated"), so there is a clear, direct measure of the mussel densities present in the CUs prior to the remedy and estimates of the number of mussels lost to dredging. For the Thompson Island Pool and the Northumberland Pool, the data were collected after dredging occurred, so the mussel densities in non-remediated areas were used by the Trustees as a surrogate for estimating what was present prior to remediation and therefore lost from remediated areas in these two pools. The similarities in mussel densities between non-remediated and before-remediation areas in the Fort Miller and Stillwater Pools prior to dredging support this approach. To calculate injury in the "before-remediated" areas of the Fort Miller Pool and the Stillwater Pool, the Trustees applied a 92.4% loss from dredging within CUs ("after-remediation"), based upon the average percent change in total mussel densities between dredged and non-remediated areas in the Thompson Island Pool and the Northumberland Pool.

Mussel densities were converted to population estimates (Newton *et al.* 2011, HRNRT 2020). The Trustees applied the ratio of the density of all mussel species in before-remediation areas to non-remediated areas from Fort Miller Pool and Stillwater Pool (0.771) to calculate the number of mussels injured in Thompson Island Pool and Northumberland Pool, as follows:

*(Density of mussels in non-remediated * 0.771) * after-remediation survey area = Estimated number of mussels before dredging*

Since some mussels were found in remediated areas within the Thompson Island Pool[12] and the Northumberland Pool[13] (one to six years after dredging), the Trustees subtracted the post-dredging population estimate in remediated areas from our calculated population estimate before dredging to determine the number of injured mussels for these two pools. This is a conservative estimate because dredging likely removed all mussels within a CU or suffocated the few that remained through the subsequent placement of backfill and cap. Any mussels collected one to six years after dredging likely recolonized the remediated area from nearby non-remediated areas, were transported into the remediated area during high flow events, or were reseeded after transformation of glochidia[14] into juvenile mussels and releasing from host fish.

8.3 The Impact of the Dredging Remedy on Freshwater Mussels

Freshwater pearly mussels live at least partially embedded in sediments where they filter the water column for food. While freshwater mussels can move vertically in the sediment and migrate horizontally in response to changing environmental conditions, those movements are slow and limited (Balfour and Smock 1995, Amyot and Downing 1997, 1998) and would render mussels located in CUs vulnerable to removal by sediment dredging and subsequent backfill and cap placement. Even mussels adjacent to dredge areas could be smothered by backfilling and capping activities during construction, through backfill and cap realignment post-dredging or impacted by the turbid conditions outside of CUs

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[10] "Dredged" is synonymous with "remediated" and "after-remediation" areas and are used interchangeably.

[11] "To be remediated" is synonymous with "before-remediation" areas and are used interchangeably.

[12] The Thompson Island Pool (TIP) was dredged in 2009, 2011-2015. Although the mussel survey for the TIP was conducted in 2015 and remediation in that year targeted CU60, no strata immediately downstream of the dam guide wire (CU59 and CU60) but upstream of the Thompson Island Dam were sampled due to safety concerns.

[13] The Northumberland Pool was dredged in 2013.

[14] Glochidia are the parasitic microscopic larval stage of freshwater mussels the size of a sand grain. Glochidia typically attach to a fish host prior to transforming into juvenile mussels and falling off and settling on the bottom substrate.

that occurred in portions of the river downstream of backfill/capping operations. This injury determination focuses on the live mussels removed from the river by dredging or subsequently smothered by backfill and/or cap materials within CUs resulting in mortality and a loss of natural resources.

In the Fort Miller Pool, data were collected prior to remediation stratified by areas inside and outside of CU boundaries. Prior to remediation, 62 of the 98 surveyed quadrats (63.3%) in areas to be remediated in the Fort Miller Pool had mussels present, and in the Stillwater Pool, 59 of 99 surveyed quadrats (59.6%) in areas to be dredged had mussels. Quadrats recorded with mussels in the non-remediated areas of the Fort Miller Pool is 64.4% in the Fort Miller Pool, and 67% in the Stillwater Pool, comparable to the before remediation survey results (HRNRT 2020).

Relatively similar densities of mussels were recorded from the before-remediation (36.2 and 19.6 mussels/m^2) and non-remediated areas (40.6 and 30.0 mussels/m^2) of the Fort Miller and Stillwater Pools, respectively (HRNRT 2020). These UHR mussel densities were greater than those reported for the tidal Lower Hudson River (Strayer *et al.* 1994).

In the Thompson Island Pool and the Northumberland Pool, data were collected in the non-remediated and remediated portion of the pools. The density of mussels in the remediated areas (3.1 and 6.1 mussels/m^2, respectively) were at least an order of magnitude lower than in the non-remediated areas (51.1 and 66.7 mussels/m^2, respectively), representing a 94% and 91% lower density, respectively, in remediated areas compared with non-remediated areas of the Thompson Island and Northumberland Pools. No mussels were detected in 72.2% of the remediated Thompson Island Pool quadrats and in 58.2% of the remediated Northumberland Pool quadrats.

The data from the 2013 survey in Fort Miller Pool and Stillwater Pool provide support that the mussel community was similar in areas targeted for dredging (i.e., CUs before-remediation) and non-dredge areas (outside of CUs). For example, the percent of sites with mussels before remediation and non-remediated is 63.3 % and 64.4%, respectively for Fort Miller Pool and 59.6% and 67.0%, respectively for Stillwater Pool. The densities in the non-remediated areas of the Thompson Island and Northumberland Pools were 51.1 and 66.7 mussels per m^2, respectively, the same order of magnitude found for non-remediated areas (40.6 and 30.0 mussels per m^2) of the Fort Miller and Stillwater Pools (HRNRT 2020).

A high percentage of quadrats with mussels were found in non-dredge areas in Thompson Island Pool and Northumberland Pool (70.4%, 84.7%, respectively) and pool-wide (non-remediated and before-remediation) in Fort Miller Pool and Stillwater Pool (63.8%, 64.7%, respectively) (HRNRT 2020). We are aware of no physical or chemical parameters that would suggest that the mussel community would be significantly different between the four uppermost pools (Thompson Island, Fort Miller, Northumberland, Stillwater), and the survey data for mussels (HRNRT 2020), as well as decades of fish sampling (Sloan *et al.* 2005, Maceina and Sammons 2015) supports commonalities between these pools.

For purposes of this injury determination, an estimated 3.84 million and 4.17 million mussels were destroyed during the remediation of the Fort Miller Pool and Stillwater Pool, respectively. This is a preliminary estimate of the mussel population lost based on the mean percent change (92.4%) in density calculated for the Thompson Island Pool and Northumberland Pool non-remediated and after-remediation areas. Using the ratio between the density in before-remediation areas to non-remediated areas from the Fort Miller Pool and Stillwater Pool as described in the methods section (*[Density of mussels in non-remediated * 0.771] * after remediation survey area*), an estimated 35 million mussels in Thompson Island Pool and 11 million mussels in Northumberland Pool were destroyed during the dredging remedy. We then subtracted the estimated mussel population in dredged areas of the Thompson Island Pool (2.7 million) and the Northumberland Pool (1.3 million), observed one to several years after the dredging was conducted, from the total mussels destroyed in these 2 pools (35 million and 11 million, respectively). Thus, the adjusted estimated loss of live pearly mussels from these two pools is approximately 32 million and greater than 9 million mussels, respectively. Using the same calculation, the preliminary estimated loss of live pearly mussels in the Upper Mechanicville Pool is approximately 30,000 mussels.

Using this preliminary method selected for purposes of this injury determination, the total estimated number of live pearly mussels lost across the five pools that were sampled is approximately 50 million. This represents a substantial injury to freshwater mussels of the UHR. These preliminary losses do not account for mussels dredged from the Lower Mechanicville (Reach 3), Waterford (Reach 2) and Troy Pools (Reach 1), or from areas excluded from any of the surveys for safety purposes (e.g., mussels in the navigation channel and in CUs located between dam safety barriers and dams).

Freshwater native mussels can be long-lived (often on the order of decades) and have a complex lifestyle typically involving specific host fish species for their parasitic glochidia life stage (Haag 2012). For example, the most commonly collected mussel from the UHR, *Elliptio complanata*, was recorded as living close to 100 years in another northeastern waterbody (Schneider and Strayer 2006). Even with the presence of mussels in non-remediated areas, the time to recolonize in remediation areas without intervention for a stable mussel community could be decades (Strayer 2012a, Watters 1999). In particular, in the Thompson Island Pool where dredging occurred on a large scale relative to the total area of the pool (about two-thirds of the pool dredged), the losses to the mussel community could pose an even greater challenge for natural recovery.

8.4 Summary of Injury to Freshwater Mussels

The UHR supported a dense freshwater mussel community prior to implementation of the dredging remedy. An injury to freshwater mussels occurred in the UHR when GE remediated the river removing sediments and the mussels that lived in those sediments and then capped and backfilled those areas). Our preliminary calculations, based upon quantitative mussel surveys, estimate that approximately 50 million live native freshwater mussels were destroyed from five pools during the dredging remedy. We have not yet estimated the number of mussels removed from the other three pools. The preliminary estimate of freshwater mussels destroyed by the remedial action, as described by the Trustees in this injury determination report, are presented for the sole purpose of documenting injury from the remedial action. A separate effort is being undertaken to support quantification of the injury resulting from remedy implementation. The number of injured mussels will subsequently be refined during the injury quantification phase and may be differ from the 50 million mussels discussed here. The quantification of the direct losses to native freshwater mussels of the Hudson River from the remediation and the interim losses that occur until mussel populations return to baseline will be described in detail in subsequent reports on injury quantification, restoration options, and the cost to implement that restoration (i.e., damages).

9.0 CONCLUSIONS

The dredging remedy to remove PCBs from the UHR sediments between Hudson Falls and Troy, NY was historic for its scale. GE removed approximately 2.75 million cy of sediment from 493 acres over an approximately 40-mile stretch of river and then capped and/or backfilled the dredged surface (Parsons 2019). However, the dredging remedy was not without a cost to natural resources. Dredging activities included trimming or cutting down trees, removing wetlands and aquatic vegetation beds, and destroying millions of the live freshwater mussels in the UHR (Table 3), as well as other impacts to in-river and terrestrial habitats not covered by this report.

Table 3. Preliminary Determination of Injuries Associated with Direct Losses to Natural Resources of the UHR from GE's Dredging Remedy.

(A final quantification of the amount of injury, including direct and interim losses, will be provided in another report.)

Resource	Preliminary Scope of Injury
Riverine Fringing Wetland*	30 acres
Submerged Aquatic Vegetation**	133 acres
Shoreline***	> 3,000 trees removed and/or trimmed
Native Live Freshwater Mussels****	>50 million live mussels destroyed

* Includes Form 3 constructed RFW (24.21 acres) and RFW-FAV/SAV (5.68 acres) within all CUs (RFW Tab of EPA Habitat_Reconstruction_Ledger_2016-09-13_R7.xlsx).

** Sum of delineated pre-dredge SAV excluded from SAV habitat reconstruction (38.5 acres), adjusted by SAV added at EPA's request (0.6 acres), Form 3 Record Drawing SAV planted areas (39.41 acres), and natural recolonization areas (55.61 acres) (Summary and SAV Design Tab of EPA Habitat_Reconstruction_Ledger_2016-09-13_R7.xlsx).

*** Based on GE (2009), Cashman (2009, 2011-2014), GLDDC (2012), DEC (undated), see Appendix A.

**** Does not include mussels removed from navigation channel, behind dam safety barriers, or Reaches 1-3 (HRNRT 2020).

This "destruction" constitutes an injury under the DOI regulations. Even when and where GE was required to perform habitat reconstruction, the resources have yet to fully recover ecological function and are still years away from a return to baseline (pre-dredging) conditions.

As a result of GE's dredging remedy on the UHR between Ft. Edward and Troy, New York, injuries to wetlands, vegetated beds, shoreline, and freshwater mussels have occurred. The Trustees will quantify these injuries and develop restoration options to compensate the public for these resources that we hold in trust for the public.

10.0 REFERENCES

Adamec, L. 2018. Ecophysiological characteristics of turions of aquatic plants: a review. *Aquatic Botany* 148:64-77.

Amyot, J. P., and J. A. Downing. 1997. Seasonal variation in vertical and horizontal movement of the freshwater bivalve *Elliptio complanata* (Mollusca: Unionidae). *Freshwater Biology* 37:345-354.

Amyot, J. P., and J. A. Downing. 1998. Locomotion in *Elliptio complanata* (Mollusca: Unionidae): a reproductive function? *Freshwater Biology* 39:351-358.

Anchor QEA, LLC. 2009. Habitat Assessment Report for Phase 2 Areas Hudson River PCBs Site. Prepared for General Electric Company, Albany, NY, June 2009.

Anchor QEA, LLC. 2011. Wetland Delineation Report for Phase 2 Areas. Prepared for General Electric, January 2011.

Anchor QEA, LLC. 2012. Wetland Delineation Report for Griffin Island Hudson River PCBs Site. Prepared for General Electric, October 2012.

Anchor QEA. 2018. Monitoring, Maintenance, and Adaptive Management Report for 2017, Hudson River PCBs Superfund Site. Prepared for General Electric, January 2018.

Arcadis. 2011. Phase 2 Final Design Report for 2011, Hudson River PCBs Superfund Site. Prepared for General Electric, Revised April 2011.

Arcadis. 2012a. Phase 2 Final Design Report for 2012, Hudson River PCBs Superfund Site. Prepared for General Electric, Revised May 2012.

Arcadis. 2012b. Phase 2 Final Design Report for 2012 Addendum No. 1 – West Griffin Island Area Hudson River PCBs Superfund Site, Revised October 2012.

Arcadis. 2013a. Documentation Report for 2012 Short Term Response Actions, Upper Hudson River Floodplains Project. Prepared for General Electric Company, March 2013.

Arcadis. 2013b. Phase 2 Final Design Report for 2013, Hudson River PCBs Superfund Site. Prepared for General Electric, Revised April 2013.

Arcadis. 2014. Phase 2 Final Design Report for Reach 7 (the Landlocked Area), Hudson River PCBs Superfund Site, Revised June 2014.

Arcadis. 2015. Supplemental Design Revisions for 2015, Hudson River PCBs Superfund Site, Revised September 2015. Company, December 2008.

Arcadis and QEA. 2008. Habitat Delineation Report Hudson River PCBs Superfund Site. Prepared for General Electric, December 2008.

Balfour, D. L., and L. A. Smock. 1995. Distribution, age structure, and movements of the freshwater mussel, *Elliptio complanata* Mollusca: Unionidae) in a headwater stream. *Journal of Freshwater Ecology* 10(3):255-288.

Batiuk, R. A., R. J. Orth, K. A. Moore, W. C. Dennison, J. C. Stevenson, L. W. Staver, V. Carter, N. B. Rybicki, R. E. Hickman, S. Kollar, S. Bieber, and P. Heasly. 1992. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets, A Technical Synthesis, CBP/TRS 83/93, December 1992.

Batzer, D. P., R. Cooper, and S. A. Wissinger. 2015. Ecological roles of animals in wetlands. In Batzer, D. P, and R. R. Sharitz (Eds.), Ecology of Freshwater and Estuarine Wetlands 2nd edition (pp. 242-284). Oakland, CA: University of California Press.

Barko, J. W., M. S. Adams, and N. L. Clesceri. 1986. Environmental factors and their consideration in the management of submersed aquatic vegetation: a review, *Journal of Aquatic Plant Management* 24:1-10.

BBL (Blasland, Bouck & Lee, Inc.). 2003. Habitat Delineation and Assessment Work Plan, Hudson River PCBs Superfund Site. Prepared for General Electric Company, August 2003.

BBL (Blasland, Bouck & Lee, Inc.) and Exponent. 2005. Habitat Assessment Report for Candidate Phase 1 Areas, Hudson River PCBs Superfund Site. Prepared for General Electric Company, November 2005.

BBL (Blasland, Bouck & Lee, Inc.). 2006. Phase 1 Final Design Report, Hudson River PCBs Superfund Site, General Electric Company, Albany, New York, March 21, 2006.

Beckett, D.C., B.W. Green, S.A. Thomas, and A.C. Miller. 1996. Epizoic invertebrate communities on upper Mississippi River unionid bivalves. *American Midland Naturalist* 135:102-114.

Bridges, T., R. Fox, P. Fuglev, and, G. Hartman, V. Magar, P. Schroeder, and T. Thompson. 2010. Hudson River PCBs Site Peer Review of Phase 1 Dredging, Final Report. September 10, 2010.

Budliger, R. E., and G. Kennedy. 2005. *Birds of New York State.* Auburn, WA: Lone Pine Publishing International, Inc.

Bullock, A., and M. Acreman. 2003. The role of wetlands in the hydrological cycle. *Hydrology and Earth System Sciences* 7(3): 358-389.

CDM (CDM Smith). 2018. Hudson River PCBs Superfund Site, 2017 Submerged Aquatic Vegetation Reconstruction Inspections Report, March 12, 2018.

Clark, Dietz, and Associates. 1975. Wastewater Monitoring Program and Evaluation of Control Measures for Polychlorinated Biphenyl Discharges to the Hudson River, prepared for General Electric Company, Hudson Falls, NY, June 1975.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D. C. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/1998/classwet/classwet. htm (Version 04DEC98)

Exponent. 1998a. Macroinvertebrate Communities and Diets of Selected Fish Species in the Upper Hudson River, Volume I-Data Report, May 1998.

Exponent. 1998b. Data Documentation and Interpretation Report. Submerged Aquatic Vegetation and Fish Community Analysis. Prepared for General Electric Company, April 1998.

Exponent. 1998c. Data Report Macroinvertebrate Communities and Diets of Selected Fish Species in the Upper Hudson River, Volume II-Tables, May 1998.

Exponent. 1998d. Macroinvertebrate Communities and Diets of Selected Fish Species in the Upper Hudson River, Spring 1998: Data Report, October 1998.

Feldman, R. S. 2001. Taxonomic and size structures of phytophilous macroinvertebrate communities in *Vallisneria* and *Trapa* beds of the Hudson River, New York. *Hydrobiologia* 452:233-245.

Findlay, S. C., D. L. Strayer, S.D. Smith, and N. Curri. 2014. Magnitude and patterns of change in submerged aquatic vegetation of the tidal freshwater Hudson River. *Estuaries and Coasts* 37:1233-1242.

GE (General Electric Corporation). 2016. Habitat Reconstruction Ledger EPA_Habitat_Reconstruction_Ledger_2016-09-16_R7. xlsx.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. *BioScience* 41(8):540-551.

Grubaugh, J. W., and R. V. Anderson. 1989. Upper Mississippi River: Seasonal and floodplain forest influences on organic matter transport. *Hydrobiologia* 174:235–244.

Gutiérrez, J.L., C.G. Jones, D.L. Strayer, and O.O. Iribarne. 2003. Mollusks as ecosystem engineers: the role of shell production in aquatic habitats. Oikos 101:79-90.Haag, W. R. 2012. *North American Freshwater Mussels: Natural History, Ecology, and Conservation*. Cambridge University Press, New York. 538 pp.

Haag, W.R. 2012. North American Freshwater Mussels: Natural History, Ecology, and Conservation. Cambridge University Press, New York, NY. 505 pp.

Hamberg, J., S. E. G. Findlay, K. E. Limburg, and S. A. W. Diemont. 2017. Post-storm sediment burial and herbivory of *Vallisneria americana* in the Hudson River estuary: mechanisms of loss and implications for restoration. *Restoration Ecology* 25(4):629-639.

Harris, L. D., and J. G. Gosselink. 1990. Cumulative impacts of bottomland hardwood conversion on hydrology, water quality, and terrestrial wildlife. In J. G. Gosselink, L. C. Lee, and T. A. Muir (Eds.), *Ecological processes and cumulative impacts: illustrated by bottomland hardwood wetland ecosystems* (pp. 260–322). Chelsea, MI: Lewis Publishers.

Heck, K. L. Jr., and L. B. Crowder. 1991. Habitat structure and predator-prey interactions in vegetated aquatic systems. In S. S. Bell, E. D. McCoy, and H. R. Mushinsky (Eds.), *Habitat Structure: The Physical Arrangements of Objects in Space* (p. 281-299). Chapman and Hall, London and New York.

Hetling, L., E. Horn, and J. Tofflemire. 1978. Summary of Hudson River PCB Study Results. New York State Department of Environmental Conservation. Technical Paper #51. July.

HRNRT (Hudson River Natural Resource Trustees). 2002. Hudson River Natural Resource Damage Assessment Plan. September 2002. U. S. Department of Commerce, Silver Spring, MD. https://www.dec.ny.gov/docs/wildlife_pdf/HRNRDAPlan.pdf

HRNRT (Hudson River Natural Resource Trustees). 2014a. Responsiveness Summary for the Study Plan for Freshwater Mussel Injury Determination Population Assessment and Potential Functional Roles of Native Mussels in Multiple Sections of the Upper Hudson River: 2014 Remedial Injury Study Hudson River Natural Resource Damage Assessment, September 2, 2014. https://pub-data.diver.orr.noaa.gov/admin-record/6306/Hudson_River_Mussel_Work_Plan_Responsiveness_Summary_09022014.pdf.

HRNRT (Hudson River Natural Resource Trustees). 2014b. Population Assessment and Potential Functional Roles of Native Mussels in Select Reaches of the Upper Hudson River: 2013 Remedial Injury Pilot Study, Hudson River Natural Resource Damage Assessment, Public Version Final, September 10, 2014. https://pub-data.diver.orr.noaa.gov/admin-record/6306/2013HudsonRiverMusselSurvey_PublicRelease.pdf.

HRNRT (Hudson River Natural Resource Trustees). 2014c. Study Plan for Freshwater Mussel Injury Determination Population Assessment and Potential Functional Roles of Native Mussels in Multiple Sections of the Upper Hudson River**:** 2014 Remedial Injury Study, Public Release Version Final, August 15, 2014. https://pub-data.diver.orr.noaa.gov/admin-record/6306/2014HudsonRiverMusselSurveyWorkPlan_For_Public_Release_081514.pdf.

HRNRT (Hudson River Natural Resource Trustees). 2015. Study Plan for Freshwater Mussel Injury Determination Population Assessment and Potential Functional Roles of Native Mussels in Multiple Sections of the Upper Hudson River: 2015 Remedial Injury Study, Amendment 1, Hudson River Natural Resource Damage

Assessment, Final, May 26, 2015. https://pub-data.diver.orr.noaa.gov/admin-record/6306/mussel-study-plan-amendment-1-final-may-26-2015.pdf.

HRNRT (Hudson River Natural Resource Trustees). 2016. Data Report Pilot Study for The Characterization of Sediment Chemistry, Sediment Toxicity, and Benthic Invertebrate Community Structure for PCB-Contaminated Sediments from the Upper Hudson River, New York Hudson River Natural Resource Damage Assessment, Public Release Version, October 13, 2016. https://pub-data.diver.orr.noaa.gov/admin-record/6306/HR_BenthicStudyDataReport10-13-16.pdf.

HRNRT (Hudson River Natural Resource Trustees). 2019. Study Plan for Freshwater Mussel Injury Determination, Population Assessment and Potential Functional Roles of Native Mussels in Multiple Sections of the Upper Hudson River: 2015 Remedial Injury Study Amendment 2, Public Version, March 14, 2019. https://pub-data.diver.orr.noaa.gov/admin-record/6306/Mussel%20Study%20Plan%20Amendment031419Final.pdf

HRNRT (Hudson River Natural Resource Trustees). 2020. Population Assessment and Potential Functional Roles of Native Mussels in the Upper Hudson River. Hudson River Natural Resource Damage Assessment, July 2020. https://pub-data.diver.orr.noaa.gov/admin-record/6306/Population%20Assessment%20and%20Potential%20Functional%20Roles%20of%20Native%20Mussels%20in%20the%20Upper%20Hudson%20River%20-Final.pdf

Kreeger, D.A., C.M Gatenby, and P. Bergstrom. 2018. Restoration Potential of Several Native Species of Bivalve Molluscs for Water Quality Improvement in Mid-Atlantic Watersheds, *Journal of Shellfish Research*, 37(5) : 1121-1157, https://bioone.org/journals/Journal-of-Shellfish-Research/volume-37/issue-5/035.037.0524/Restoration-Potential-of-Several-Native-Species-of-Bivalve-Molluscs-for/10.2983/035.037.0524.short

Korschgen, C. E., and W. L. Green. 1988. American Wild Celery (*Vallisneria americana*): Ecological Considerations for Restoration. Report 19, Washington, DC: U. S. Department of the Interior, Fish and Wildlife Service.

Law Environmental, Inc. 1991. Submerged and Emergent Aquatic Plant Survey of the Upper Hudson River. Prepared for General Electric Company, October 11, 1991.

LBI (Louis Berger Group, Inc.). 2010a. Revised Engineering Performance Standards for Phase 2, Hudson River PCBs Site. Prepared for: U. S. Environmental Protection Agency, Region 2 and U. S. Army Corps of Engineers, Kansas City District, December 2010.

LBI (Louis Berger Group, Inc.). 2010b. EPA Phase 1 Evaluation Report, Hudson River PCBs Site. Prepared for: U. S. Environmental Protection Agency, Region 2 and the U. S. Army Corps of Engineers, Kansas City District, March 2010.

Levine, D. A. and D. E. Willard. 1990. Regional analysis of fringed wetlands in the Midwest: creation and restoration, In Kusler, J. A. and M. E. Kentula (Eds.), *Wetland Creation and Restoration, The Status of the Science* (pp. 299-319). Island Press, Washington, D.C.

Limburg, K. E., M. A. Moran, and W. H. McDowell. 1986. *The Hudson River Ecosystem*. New York, NY: Springer-Verlag.

Maceina, M. J., and S. M. Sammons. 2015. Polychlorinated biphenyl exposure and fish recruitment from 1988 to 2002 in the upper Hudson River, New York, USA. *Fisheries Research* 170: 228-236.

McCall, P. L. 1979. Sediment mixing by *Lampsilis radiata siliquoidea* (Mollusca) from western Lake Erie. *International Association of Great Lakes Research* 5(2): 105-111.

McFarland, D. G. 2006. Reproductive Ecology of *Vallisneria americana* Michaux. ERDC/TN SAV-06-4, December 2006. http://www.dtic. mil/dtic/tr/fulltext/u2/a460686.pdf

Moreno-Mateos, D., M. E. Power, F. A. Comín, and R. Yockteng. 2012. Structural and functional loss in restored wetland ecosystems. *PLoS Biology*, 10 (1):e1001247.

MPI (Malcolm Pirnie, Inc.), TAMS Consultants, Inc. and Earth Tech Company. 2004. Engineering Performance Standards, Technical Basis and Implementation of the Residuals Standard, Hudson River PCBs Superfund Site. Prepared for the U. S. Army Corps of Engineers, April 2004.

Naimo, T. J. 1995. A review of the effects of heavy metals on freshwater mussels. *Ecotoxicology* 4:341-362.

Nalepa, T.F., W.S. Gardner, and J.M. Malczyk. 1991. Phosphorus cycling by mussels (Unionidae: Bivalvia) in Lake St Clair. *Hydrobiologia* 219:230-250.

NYSDEC (New York State Department of Environmental Conservation). 2018a. Species of Greatest Conservation Need. Accessed from: http://www.dec.ny.gov/animals/9406.html

NYSDEC (New York State Department of Environmental Conservation). 2018b. *List of Endangered, Threatened and Special Concern Fish & Wildlife Species of New York State.* Accessed from: https://www.dec.ny.gov/animals/7494.html

NYSDEC (New York State Department of Environmental Protection) 2019. Draft List Under Part 182.5 Pre-proposal—October 2019. Accessed from: https://www.dec.ny.gov/docs/wildlife_pdf/preproposal182.pdf

Newton, T. J., S. J. Zigler, J. T. Rogala, B. R. Gray and M. Davis 2011. Population assessment and potential functional roles of native mussels in the upper Mississippi River. *Aquatic Conservation:Marine and Freshwater Ecosystems* 21(2):122-131.

Owen, C. T., M. A. McGregor, G. A. Cobbs, J. E. Alexander. 2011. Muskrat predation on a diverse unionid mussel community: impacts of prey species composition, size and shape. *Freshwater Biology* 56(3): 554-564.

Parsons. 2011. Phase 1 Construction Completion Report, Hudson River PCBs Superfund Site. Prepared for General Electric, October 2011.

Parsons. 2012. Phase 2 Year 1 Annual Progress Report, Hudson River PCBs Superfund Site. Prepared for General Electric, February 2012.

Parsons 2015. Remedial Action Work Plan for Phase 2 Dredging and Facility Operations in 2015, Hudson River PCBs Superfund Site. Prepared for General Electric, Revised June 2015, Public Release Version.

Parsons. 2016. Phase 2 Year 5 Annual Progress Report, Hudson River PCBs Superfund Site. Prepared for General Electric, April 2016.

Parsons. 2019. Remedial Action Completion Report, Hudson River PCBs Superfund Site. Prepared for General Electric, Initial -December 2016, Updated March 2019.

Parsons and Anchor Environmental, LLC. 2008. Remedial Action Work Plan for Phase 1 Dredging and Facilities Operations, Hudson River PCBs Superfund Site. Prepared for General Electric Company, August 2008.

QEA (Quantitative Environmental Analysis LLC). 2008. Hudson River PCBs Site Habitat Reassessment Data Summary Report. Prepared for General Electric Company, July 9, 2008.

Raikow, D. F., and S. K. Hamilton. 2001. Bivalve diets in a Midwestern U. S. stream: a stable isotope enrichment study. *Limnology and Oceanography* 46(3): 514-522.

Reschke, C. 1990. Ecological Communities of New York State. New York Natural Heritage Program, New York State Department of Environmental Conservation. Albany, NY. 96 pp.

Schneider, R. and D.L. Strayer 2006. The Age Structure and Decline of the Freshwater Mussel *Elliptio complanata* in Webatuck Creek in Amenia, New York, Institute of Ecosystem Studies, Undergraduate Ecology Research Reports, https://www.caryinstitute.org/sites/default/files/public/reprints/Schneider_2006_REU.pdf

Schwalb, A. N. and M. T. Pusch. 2007. Horizontal and vertical movements of unionid mussels in a lowland river. *Journal of North American Benthological Society* 26(2):261–272.

Sephton, T.W., C.G. Paterson, and C.H. Fernando. 1980. Spatial interrelationships of bivalves and nonbivalve benthos in a small reservoir in New Brunswick, Canada. Canadian Journal of Zoology 58:852-859.

Seggos, B. 2017. Hudson River PCBs, GE request for Certificate of Completion, letter from Commissioner Seggos, New York State Department of Environmental Conservation, to Mr. Scott Pruitt, Administration, U. S. EPA, November 22, 2017.

Shifrin, N. 2014a. Exhibit 4 (Excerpts from "Expert Report of Neil Shifrin, Ph. D. "), Declaration of Benjamin Hill in Support of Town of Halfmoon's Motion *in Limine. Town of Halfmoon et. al. v. General Electric,* Index No. 1:09-cv-0228 (N. D. N. Y. filed August 8, 2014).

Shifrin, N. 2014b. Exhibit 72 (Excerpts from "Expert Report of Neil Shifrin, Ph. D."), Declaration of William Bachman in Support of General Electric's Motion for Summary Judgment against Saratoga County and Saratoga County Water Authority. *Town of Halfmoon et. al. v. General Electric,* Index No. 1:09-cv-0228 (N. D. N. Y. filed August 8, 2014).

Shifrin, N. 2014c. Exhibit EE (Excerpts from "Expert Report of Neil Shifrin, Ph. D."), Declaration of David Engel in Support of Plaintiff Town of Halfmoon's Motion *in Limine. Town of Halfmoon et. al. v. General Electric*, Index No. 1:09-cv-0228 (N. D. N. Y. filed August 8, 2014).

Sloan, R. J., M. W. Kane, and L. C. Skinner. 2005. *Of Time, PCBs and the Fish of the Hudson River.* NY State department. of Environmental Conservation Environ. Conserv, Albany, NY.

Smith, C. L. 1985. *The Inland Fishes of New York State.* New York State Department of Environmental Conservation, Albany, NY.

Spooner, D. E., and C. C. Vaughn. 2008. A trait-based approach to species' roles in stream ecosystems: climate change, community structure, and material cycling. *Oecologia* 158(2): 307-317.

Stanne, S. P., R. G. Panetta, and B. E. Forist. 2007. *The Hudson: An Illustrated Guide to the Living River.* Piscataway, NJ: Rutgers University Press.

Stevenson, J. C., and R. C. Davis 2001. Assessment of EPA's Habitat Replacement Program for the Hudson River Proposed Remedial Plan (REM3/10/Select), Expert Report, April 2001, Appendix D-1 of General Electric (GE) 2001. Comments of General Electric Company on the Feasibility Study and Proposed Plan for the Hudson River PCBs Superfund Site (December 2000), April 17, 2001.

Strayer, D. L. 1987. Ecology and zoogeography of the freshwater mollusks of the Hudson River Basin. *Malacological Review* 20:1-68.

Strayer, D. L. 2006. The Benthic Animal Communities of the Tidal-Freshwater Hudson River Estuary. In J. S. Levinton, J. R. Waldman (Eds.), *The Hudson River Estuary* (pp. 266-278). Cambridge University Press, New York, NY.

Strayer, D. L. 2012a. An introduction to the pearly mussels of the middle Hudson River (Corinth to Troy). Presentation the Hudson River CAG.
http://www.hudsoncag.ene.com/files/D%20Strayer%20Mussels%20Presentation%20062812.pdf

Strayer, D. L. 2012b. Notes on the pearly mussels (Unionidae) of the middle Hudson River (Corinth to Troy) and their possible role in the ecosystem, Report prepared for Scenic Hudson, Poughkeepsie, NY, June 2012.

Strayer, D. L. 2017. What are freshwater mussels worth? *Freshwater Mollusk Biology and Conservation* 20:103–113.

Strayer, D. L., N. F. Caraco, J. J. Cole, S. Findlay, and M. L. Pace. 1999. Transformation of freshwater ecosystems by bivalves. *BioScience* 49: 19-27.

Strayer, D. L., J. A. Downing, W. R. Haag, T. L. King, J. B. Layzer, T. J. Newton, and S. J. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. BioScience 54(5):429-439.

Strayer, D. L., and S. E. G. Findlay. 2010. Ecology of freshwater shore zones. *Aquatic Sciences* 72:127-163.

Strayer, D. L. D. C. Hunter, L. C. Smith, and C. K. Borg. 1994. Distribution, abundance, and roles of freshwater clams (Bivalvia, Unionidae) in the freshwater tidal Hudson River. *Freshwater Bio*logy 31:239-248.

Strayer, D. L., and K. J. Jirka. 1997. *The Pearly Mussels of New York State*. New York State Museum Memoir 26. New York State Education Department, Albany, NY.

Taylor, J. R., M. A. Cardamone, and W. J. Mitsch. 1990. Bottomland hardwood forests: their functions and values. In J. G. Gosselink, L. C. Lee, and T. A. Muir (Eds.), Ecological processes and cumulative impacts: illustrated by bottomland hardwood wetland ecosystems (pp. 13–73). Chelsea, MI: Lewis Publishers.

Tall, L., N. Caraco, and R. Maranger 2011. Denitrification hot spots: dominant role of invasive macrophyte Trapa natans in removing nitrogen from a tidal river, *Ecological Applications*, 21(8), 2011, pp. 3104–3114.

Thunhorst, G. A. 1993. *Wetland Planting Guide for the Northeastern United States: Plants for Wetland Creation, Restoration and Enhancement*. St. Michaels, MD: Environmental Concern, Inc.

Tinoco, A. I., B. T. Furman, K. M. Darnell, and B. J. Peterson. 2017. Submerged aquatic vegetation, topography and flow characteristics in the upper, tidal Hudson River: progress toward a predictive habitat model. Aquatic Botany 142: 53-60.

Titus, J. E. and M. D. Stephens. 1984. Neighbor influences and seasonal growth patterns for *Vallisneria americana* in a mesotrophic lake. *Oecologia* 56(1): 23-29.

USEPA (U. S. Environmental Protection Agency). 1984. Superfund Record of Decision: Hudson River PCBs Site, New York. EPA/ROD/R02-84/004.

USEPA (U. S. Environmental Protection Agency). 2002a. Hudson River PCBs Site New York Record of Decision. USEPA, February 2002.

USEPA (U. S. Environmental Protection Agency). 2002b. Responsiveness Summary, Hudson River PCBs Site Record of Decision. USEPA, January 2002.

USEPA (U. S. Environmental Protection Agency). 2004. Hudson River PCBs Superfund Site, EPA's Final Decision Regarding General Electric Company's Disputes on Draft Phase 1, Dredge Area Delineation Report and Draft Phase 1 Target Area Identification Report, July 26, 2004.

USEPA (U.S. Environmental Protection Agency). 2019. Final Second Five-Year Review Report for Hudson River PCBs Superfund Site. April 2019.

USEPA (U. S. Environmental Protection Agency) and GE (General Electric Company). 2006a. Consent Decree in *United States v. General Electric Company*, Civil Action No. 1:05-cv-1270, lodged in the United States District Court, for the Northern District of New York, on October 6, 2005; entered by the Court on November 2, 2006.

USEPA (U. S. Environmental Protection Agency) and GE (General Electric Company). 2006b. Consent Decree (*United States v. General Electric Company*, Civil Action No. 1:05-cv-1270, lodged in the United States District Court for the Northern District of New York, on October 6, 2005; entered by the Court on November 2, 2006), Appendix B, Hudson River PCBs Site, Statement of Work (SOW) for Remedial Action and Operations, Maintenance, and Monitoring, Attachment A to Statement of Work Hudson River PCBs Site Critical Phase 1 Design Elements, September 2005.

USEPA (U. S. Environmental Protection Agency) and GE (General Electric Company). 2007. Administrative Settlement Agreement and Order on Consent for Removal Action, CERCLA Docket No. 02-2007-2008, July 2007.

USEPA (U. S. Environmental Protection Agency) and GE (General Electric Company). 2011. Consent Decree in *United States v. General Electric Company*, Civil Action No. 1:05-cv-1270, Consent Decree Modification 2, filed in United States District Court for the Northern District of New York, on August 15, 2011.

Vaughn, C. C., S. J. Nichols and D. E Spooner. 2008. Community and foodweb ecology of freshwater mussels. *Journal of North American Benthological Society*. 27(2):409–423.

Vaughn, C. C. and C. C. Hakenkamp. 2001. The functional role of burrowing bivalves in freshwater ecosystems. *Freshwater Biology* 46:1431-1446.

Vaughn, C. C. and D. E Spooner. 2006. Unionid mussels influence macroinvertebrate assemblage structure in streams *Journal of North American Benthological Society*. 25(3):691–700.

Waldman J. R., K. E. Limburg, and D. L. Strayer. 2006. Hudson River Fishes and their Environment. American Fisheries Society Symposium 51. *Proceedings of the Hudson River Fishes and their Environment*, March 2003, Poughkeepsie, NY.

Watters, G. T. 1999. Freshwater mussels and water quality: a review of the effects of hydrologic and instream habitat alterations. *Proceedings of the First Freshwater Mollusk Conservation Society Symposium*: 261-274.

Welker, M. and N. Walz. 1998. Can mussels control the plankton in rivers? – a planktological approach applying a Langrangian sampling strategy. *Limnology and Oceanography* 43:753-762.

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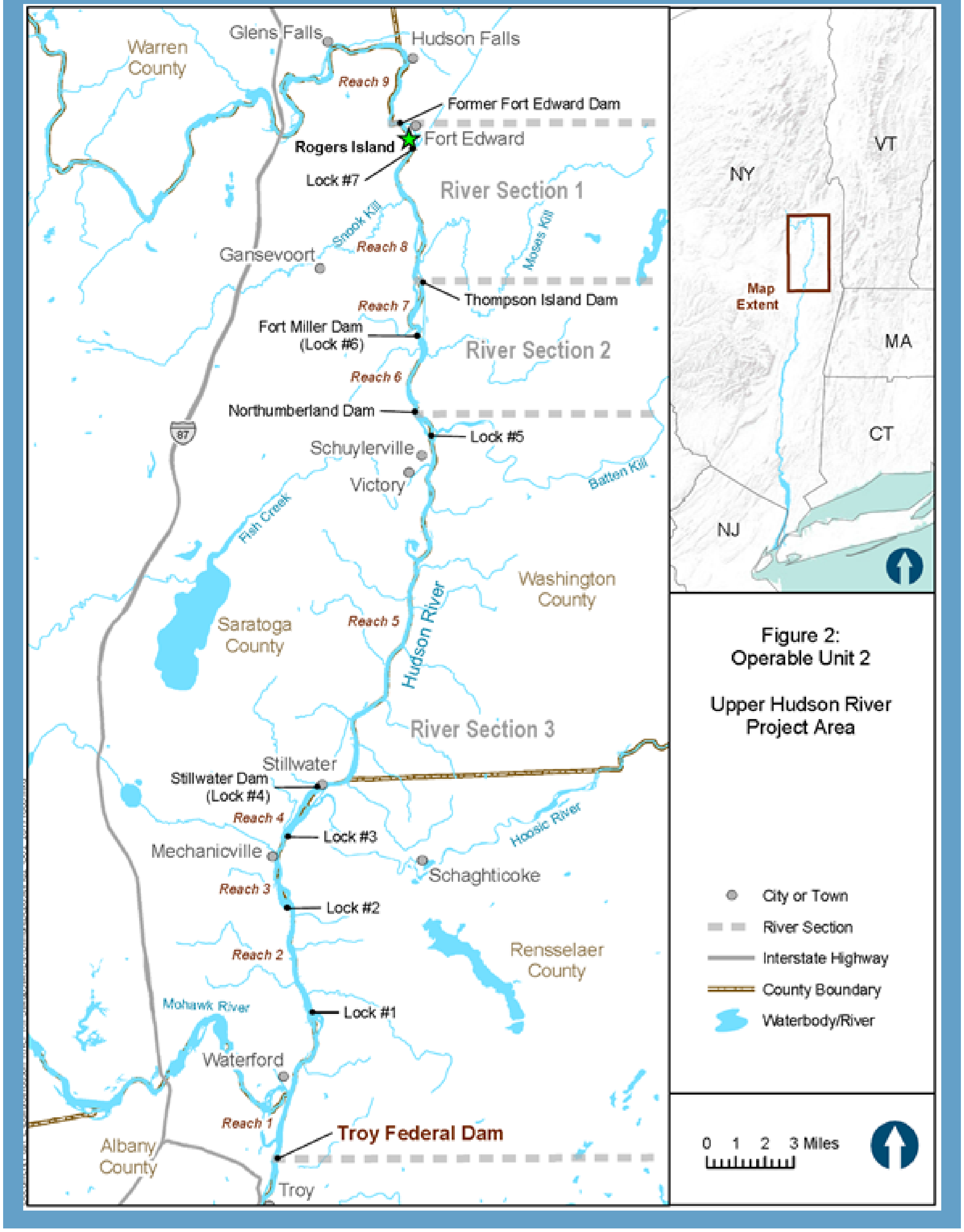
FIGURES

Figure 1. Map of the UHR Superfund Site Showing River Sections, River Pools, and Important Landmarks. From USEPA (2019).



APPENDICES

APPENDIX A. GE and NYSDEC Documents Used to Assess Tree Removal and Trimming During the Hudson River PCB Superfund Site Dredging Remedy

- GE 2009. Tree Trimming/Removal Survey, Cashman Submittal 13893-04-01 Tree Removal Survey 4-16-09.pdf.
- NYSDEC (undated). DEC Tree Removal List.pdf.
- Cashman Dredging and Marine Contractors (Cashman) 2009a. CU-11.pdf, April 16, 2009.
- Cashman Dredging and Marine Contractors 2009b. CU-12.pdf, April 16, 2009.
- Cashman Dredging and Marine Contractors 2009c. CU-13.pdf, April 16, 2009.
- Cashman Dredging and Marine Contractors 2009d. CU-14.pdf, April 16, 2009f.
- Cashman Dredging and Marine Contractors 2009e. CU-15.pdf, April 16, 2009.
- Cashman Dredging and Marine Contractors 2011a,. 2011 Shoreline Trimming Survey List w condition.pdf.
- Cashman Dredging and Marine Contractors 2011b.. 2011 Shoreline Trimming Survey List.pdf, April 4-11, 2011.
- Cashman Dredging and Marine Contractors Cashman Dredging (Cashman) 2011v. 2011 Shoreline Trimming Survey Maps.pdf, April 5, 2011.
- Cashman Dredging 2012a. 2012 Tree Trimming Maps and List of Trees, April 13, 2012.
- Cashman Dredging 2012b. Plan_with_Parcels.pdf, April 13, 2012.
- Cashman Dredging 2012c. Cashman Submittal K42A-113A 13893-04 Tree Trimming West Griffin Island.pdf, August 21, 2012.
- Cashman Dredging 2012d. CU55 thru 58 Tree Trimming Maps and List of Trees w condition.pdf, August 1, 2012.
- Cashman Dredging 2013a. 2013 CU51 additional tree removal.pdf, March 29, 2013.
- Cashman Dredging 2013b. 2013 CU59-60 tree removal.pdf, September 6, 2013.
- Cashman Dredging and Marine Contracting Co., LLC (Cashman) 2013c. 2013 CU67-75 tree removal.pdf, March 29, 2013.
- Cashman Dredging 2013c. 2013 CU76-77 tree removal.pdf, May 7, 2013.
- Cashman Dredging 2013e. 2013 CU79-84 tree removal.pdf, August 20, 2013.
- Cashman Dredging 2013f. 2013 CU97-100 tree removal.pdf, September 27, 2013.
- Cashman Dredging 2013g. 2013 Partial CU60 tree removal.pdf, September 3, 2013.
- Cashman Dredging 2013h. 2013 Saratoga Barge Loading Area tree removal.pdf, March 5, 2013.
- Cashman Dredging 2013i. dredge maps 1014001.pdf, August 20, 2013.

- Cashman Dredging 2014a. 2014 CU 51 Tree Trimming Map and Table.pdf, September 10, 2014.
- Cashman Dredging 2014b. 2014 CUs 85-91 Tree Trimming Map and Tables.pdf, April 28, 2014.
- Cashman Dredging 2014c. 2014 CUs 94 and 96 Tree Trimming Maps and Table.pdf, June 12, 2014.
- Cashman Dredging 2014d. 2014 ITA Tree Trimming Map and Tables.pdf, February 14, 2014.
- Great Lakes Dredge and Dock Company (GLDDC) 2014a. 2014 LBLA Tree Trimming Map and Table_20may14.pdf, May 15, 2014.
- Great Lakes Dredge and Dock Company (GLDDC) 2014b. CU61-66 Tree Survey.pdf, June 4, 2014.

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