Final Second Five-Year Review Report for the Hudson River PCBs Superfund Site

APPENDIX 2

MASS REDUCTION EVALUATION

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FINAL SECOND FIVE-YEAR REVIEW REPORT FOR THE HUDSON RIVER PCBs SUPERFUND SITE

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1 BACKGROUND

The remedy selected for the Upper Hudson River polychlorinated biphenyls (PCBs) Superfund Site required the development of enforceable Performance Standards, with multiple interrelated objectives: to ensure that the clean-up would meet human health and environmental protection objectives, including reduction of Site risk and downstream transport of PCBs, and also to satisfy criteria for dredging productivity. An independent peer review panel reviewed Phase 1 performance relative to the Engineering Performance Standards (EPS) that governed that first year of dredging, and made recommendations that resulted in revised 2010 EPS for Phase 2 (EPA, 2010c; EPA, 2010b). The 2010 EPS presented performance standards for dredging residuals, resuspension, and productivity that embodied specific requirements for Phase 2 dredging activities. An important component of the 2010 EPS was the accurate determination of the volume of sediment dredged and the mass of PCBs removed, and these two metrics provided a link among all three standards. The 2010 Productivity Standard specified the minimum volumes of sediment that were expected to be dredged during each year of Phase 2. The Resuspension Standard contained specific PCB load thresholds, as measured at various downstream stations as well as the Waterford far-field station, intended to limit resuspended PCBs to a percentage of the total mass of PCBs removed. Thus, accurate determination of the volume and mass of PCBs removed during Phase 2 was an important component of determining whether Phase 2 dredging activities were in overall compliance with the 2010 Productivity and Resuspension Standards. The Residuals Standard contained directives that affected the volume of sediment dredged (*e.g.*, limiting the number of dredging passes) and how dredged areas were to be closed out (*i.e.*, requiring cover with clean backfill material or an engineered cap), to limit post-dredging exposure and resuspension of residuals.

The Residuals Standard presented in the 2010 EPS was designed to detect and manage contaminated sediment that might remain after the initial dredging of a 'Certification Unit' (CU) and to confirm that the depth of contamination (DoC) was accurately identified. The standard incorporated "lessons learned" from Phase 1 dredging that occurred in 2009 (EPA, 2010b). In particular, the peer review of Phase 1 concluded that the full depth of PCB contamination in sediments in CUs was not accurately defined prior to commencement of Phase 1 dredging, resulting in PCB mass left behind. The incomplete characterization of the vertical extent of PCB contamination for the original dredging design became apparent during Phase 1 dredging in 2009, when as many as five dredging passes were required to remove PCB-contaminated sediment within a single CU. The recognition that existing core data were inadequate to properly delineate the vertical extent of PCB contamination was an important factor driving modifications incorporated in the Phase 2 Residuals Standard. As a result of the findings of the peer review panel, General Electric Company (GE) was instructed to conduct the Supplemental Engineering Data Collection (SEDC) program, which collected additional sediment cores in Phase 2 CUs prior to dredging in order to more accurately define the elevation of the bottom of contamination (General Electric 2011b). Similarly, GE was required to dredge six inches below the design DoC elevation and collect sediment cores (hereinafter referred to as Residuals Cores) after each dredging pass that followed removal of the original design dredging volume, to verify whether additional PCB-containing sediment remained below the design DoC elevation. Based on the PCB concentration of sediments below the dredged surface, the Residuals Standard provided specific directives on whether additional dredging passes would be required or whether the dredged area could be closed out with clean backfill or an engineered cap. The maximum area allowed to be capped was also outlined in the Residuals Standard using a nodal capping index (NCI). Additional details regarding the NCI can be found in the 2010 EPS (EPA, 2010b). GE was also required to carry out bathymetric surveys after each dredging pass that followed removal of the original design dredging volume to confirm the volume of sediment dredged, confirm that the design DoC was reached in at least 95 percent of the dredging area, and to verify that the rate of removal of sediment volume was in compliance with the Productivity Standard.

The sediment and bathymetric data collected during implementation of the Phase 2 Residuals Standard provided a means to assess whether Phase 2 dredging was in compliance with the Standard; these data also allow verification of estimates of dredging volume and PCB mass present in the CUs as estimated in the 2002 Record of Decision

(ROD) (EPA, 2002), as well as values reported by GE during Phase 2 dredging activities. Finally, these data can also facilitate estimates of the PCB mass that remains within the CUs now that Phase 2 dredging has been completed.

Volumes of sediment and mass of PCBs removed were estimated from predesign and post-dredging core data, as well as pre- and post-dredging bathymetry. Volume removed in each year of Phase 2 was found to be in compliance with the Productivity Standard. Total sediment volume and masses of Total PCB (TPCB[1]) and Tri+ PCB[2] removed in Phases 1 and 2 were found to be much greater than anticipated at the outset of the remedy, due to prior underestimates of DoC that were corrected by coring that GE performed in 2010-2012 to support Phase 2 remedial design. The estimated masses of PCBs removed were also used to help assess compliance with the Resuspension Standard, which limited downstream transport to a percentage of dredged PCBs. Estimates of capped and backfill-covered areas demonstrate compliance with limits set in the Residuals Standard, and the estimated PCB mass left in place in capped or backfill-covered areas is small relative to the mass removed by dredging.

[1] TPCBs represents the sum of all measured PCB congeners. PCBs are a group of chemicals consisting of 209 individual compounds known as congeners. The congeners can have from one to ten chlorine atoms per molecule, each with its own set of chemical properties.

[2] Tri + PCBs represents the sum of all measured PCB congeners with three or more chlorine atoms per molecule. PCBs are a group of chemicals consisting of 209 individual compounds known as congeners. The congeners can have from one to ten chlorine atoms per molecule, each with its own set of chemical properties.

2 PRODUCTIVITY AND RESIDUALS STANDARDS FOR PHASE 2 DREDGING

Full details of the Phase 2 EPS Productivity Standard can be found in the 2010 EPS (EPA, 2010d). Briefly, the Productivity Standard set goals for the volume of sediment to be dredged each year. While subordinate to the Residuals and Resuspension Standards, the Productivity Standard was implemented to monitor dredging progress and encourage a pace of work intended to complete dredging activities in a timely manner (within approximately 6 years). The 2010 Productivity Standard recognized that estimates of the anticipated total volume of sediments to be dredged were uncertain, and therefore set the dredging productivity goal at 350,000 cubic yards/year based on actual productivity results from the Phase 1 dredging activities in 2009, as recommended by the peer review panel in 2010 (EPA, 2010c). The updated productivity goal of 350,000 cubic yards/year was above the original productivity goal of 319,000 cubic yards/year, as presented in the 2009 Phase 1 Performance Standards Compliance Plan (General Electric 2009e).

As described in the previous section, the Residuals Standard provided specific directives and decision logic on whether additional dredging passes would be required to reduce sediment PCB concentration or whether the dredged area could be closed out by either covering the dredged surface with clean backfill or an engineered cap. Each dredging area was referred to as a CU, and each CU was divided into nodal areas, based on the location of the Residuals Cores (the “nodes”) collected after each dredging pass. Residuals Cores collected sediment samples to 48 or 96 inches (depending on DoC) or bedrock, whichever was encountered first. The cores were segmented into 6-inch lengths and a subset of the segments was analyzed for PCB Aroclors using Method 8082. Method 8082 was demonstrated to be equivalent to the sum of PCB congeners based on the results of performance evaluation samples, and Tri+ PCB (sum of detected PCBs in the tri-homologue and higher groups) concentrations were calculated from measurements of PCB Aroclors and a site-specific regression equation relating PCB Aroclors to Tri+ PCB concentrations (Appendix 5, Section 2.2.4).

Whether an area associated with an individual residuals core (*i.e.,* a nodal area) needed to be re-dredged depended on the detected TPCB and Tri+ PCB concentrations in the Residuals Core samples from that node. With few exceptions, if a Residuals Core contained $\geq$ 6 milligrams per kilogram (mg/kg) Tri+ PCB in any 6-inch segment below the surface core segment, or the surface core segment had a Tri+ PCB concentration $\geq$ 27 mg/kg, or any segment had a TPCB concentration > 500 mg/kg, the associated nodal area was required to be re-dredged. In addition, nodal areas that yielded Residuals Cores that did not meet the above criteria but caused the average surface concentration within the CU to be greater than 1 mg/kg Tri+ PCB were required to be either re-dredged or covered with an engineered cap, in order to achieve an average surface concentration within the CU of 1 mg/kg Tri+ PCB or less. The remaining nodal areas containing cores that did not exceed the above criteria were deemed compliant and were covered with clean backfill material. If a nodal area was re-dredged, the associated node was re-occupied and a new Residuals Core collected, and the above steps were repeated in order to determine whether the nodal area was in compliance.

The total amount of capping was limited by additional provisions in the Residuals Standard, formulated with the intention that the mass of PCBs left in place within the CU be minimized such that 96-98 percent of PCB mass would be removed from the CU areas (EPA, 2002). Compliance with the Phase 2 Residuals Standard required that no more than 11 percent of the total dredged area be capped, and no more than 3 percent of the total area be capped with inventory present, as calculated using the NCI. Inventory was defined as nodes with sediment segments below the 0-6-inch surface core segment that contained Tri+ PCB concentrations equal to or greater than 6 mg/kg. The nodal capping index (NCI) was developed to facilitate timely tracking of the approximate extent of capping and backfilling within dredged areas on an area-weighted basis. The NCI acted as a surrogate for the rigorous and continuous recalculation of the river bottom area and PCB mass subject to capping and backfilling. Briefly, each node was categorized according to sediment texture, location within the river bottom (*i.e.*, shoreline, bedrock, glacial clay) and whether the node was capped or backfilled. Based on this classification, the NCI calculated the total area capped within each CU, and formed the measurement basis for compliance with the capping criterion of the Residuals Standard. Full details regarding the classification scheme and equations involved in the NCI are presented in the 2010 EPS (EPA, 2010d).

3 METHODS

3.1 Determination of Volume of Sediment Removed and Mass of PCBs in Sediment Removed

In order to calculate the sediment volume and PCB mass removed by dredging activities during Phase 2, chemistry and bulk density data from the remedial design sediment sampling and analysis program (SSAP) (General Electric 2002a), the SEDC program described above, and Phase 2 residuals cores were utilized, along with bathymetry data collected prior to and after each dredging pass. The methods employed are based on the equations and methodologies presented in the 2010 EPS. Briefly, differencing of bathymetric data collected after each dredging pass was used to calculate the total volume of sediment removed. In order to estimate the mass of PCBs removed, both the dry bulk density and PCB concentration within the dredging volume were determined using the following steps:

1) Because no dry bulk density data were available for the Residuals Cores collected during Phase 2, dry bulk density values measured on SSAP core segments were utilized. For each residuals dredging pass, the subset of SSAP cores that fell within the dredging pass area were identified. The mean dry bulk density of this subset of SSAP cores was used as the dry bulk density value for the entire residuals dredging pass volume. It is recognized that in certain instances, the depth of the dredging cut exceeded the depth of the SSAP cores that fell within the boundary of the dredging pass. However, the SSAP cores still provide the best available estimate of dry bulk density for the dredging volume and were included in the calculations presented here.
2) PCB concentrations (both TPCB and Tri+ PCB) were available for both the SSAP cores and the Residuals Cores. In the case of the initial volume removal to the design elevations (accomplished by one or more dredging passes), the SSAP core segments that fell within the dredging volume were used. For subsequent dredging passes, Residuals Core segments that fell within the residuals dredging volume were used to calculate a PCB concentration. By differencing the bathymetry after each dredging pass, the depth of dredging at each Residuals Core can be obtained,

and only the core segments that fell within the dredging depth interval were included in the mass calculation, thereby avoiding the inclusion of PCB mass that was outside the dredged volume and double counting PCB mass. Residuals cores collected in dredged areas that were subsequently deemed compliant with the residuals standard (thus representing areas that did not require further dredging) were not used in the mass removed calculation but were used in the calculation of PCB mass remaining in dredged areas.

Once the appropriate core segments were identified, the length of the segments, the PCB concentration (both TPCB and Tri+ PCB), and the dry bulk density were used to calculate a length-weighted PCB mass per unit volume (denoted as *m*) for each dredging pass using the following equation:

$$m_i = \frac{B_i \sum_{j=1}^{n_i} L_{ij} C_{ij}}{\sum_{j=1}^{n_i} L_{ij}} \qquad (1)$$

where i is an individual core, j is a core segment within core i, n_i is the number of core segments within core i, L_{ij} is the length of the core segment, C_{ij} is the concentration (TPCB or Tri+ PCB) for the core segment, and B_i is the bulk density of the core (note in the calculation presented here, all cores within the dredging volume are assumed to have the same dry bulk density).

For calculating the mass of PCBs removed as a result of dredging, a recovery correction was applied to each core section in cores with less than 100 percent core depth recovery. The length of each core section was corrected for less than 100 percent core recovery by dividing the measured length by the fraction of sediment recovered. The core correction compensated for loss of recovery, which results in under-sampling of some sediment strata during the core collection process. Additional details on the use of recovery correction are provided in Section 3.4 below. Once the PCB mass per unit volume (*m*) has been calculated for all cores located within the dredging volume, a length-weighted average mass per unit volume (*MPUV*) can be calculated as:

$$\overline{MPUV} = \frac{\sum_{i=1}^{n} L_i m_i}{\sum_{i=1}^{n} L_i} \quad (2)$$

where *Li* represents the total length of core segments within core *i*.

The $\overline{MPUV}$ for each dredging pass is multiplied by the associated dredging pass volume (*V*) to determine the mass of PCBs (TPCB or Tri+ PCBs) dredged (*M*) per dredging pass, per CU, during Phase 2:

$$M = V \times \overline{MPUV} \quad (3)$$

As noted earlier, volume (*V*) calculations are based on differencing of bathymetric data collected after each dredging pass, while MPUV values are based on either SSAP/SEDC cores or residuals cores. It should be noted that the calculations of MPUV (Equation 2) for residuals dredging passes include the surface core segment (0-6") of the residuals cores. It may be expected that during dredging, some of the dredged sediment will escape the dredge bucket and resettle on the river bottom. As such, PCB mass in the surface core segment of the residuals cores may represent a mixture of *in-situ* PCB contamination and PCB mass from overlying, dredged sediment. As it is not possible to determine with certainty the fraction of these two PCB sources in the surface core segment, the surface core segment was included in calculations and, therefore, the TPCB and Tri+ PCB mass removed values likely represent upper bounds on the mass removed.

Dredging activities conducted within CUs included dredging that targeted removal of PCB contaminated sediment, dredging for navigation purposes, and daylight dredging (dredging conducted to prevent collapse of dredging area walls during dredging and backfill activities). Outside of CUs, navigational dredging and access dredging (dredging for the purpose of allowing barge and boat traffic to reach areas to be dredged) was also performed. While mass and volume of dredging activities outside CUs were not included in the volume and mass estimates presented below, they do constitute additional removal of river sediment and PCB mass. Estimates of mass removed during navigational and access dredging is discussed in Section 4.1 and in Table A2-5.

3.2 Determination of Mass of PCBs in Sediment Capped in Certification Units Following Dredging

In order to estimate the mass of PCBs (both TPCB and Tri+ PCB) capped within each CU after dredging activities were completed, similar methods and equations to those described above were utilized with slight modification, because the volume (*V*) in equation (3) is unknown. To estimate volume, we can express V as:

$$V = A \times \bar{L} \tag{4}$$

where $\bar{L}$ represents the average DoC measured in the residuals cores (corrected for recovery) collected within the capped areas of a CU after the final dredging pass (thus representing a direct sample of the top of the sediment profile remaining after dredging was complete). *A* represents the area of the cap in the CU.

We can also re-express the $\overline{MPUV}$ as:

$$\overline{MPUV} = \frac{\sum_{i=1}^{n} L_i m_i}{\sum_{i=1}^{n} L_i} = \frac{\sum_{i=1}^{n} L_i m_i / n}{\sum_{i=1}^{n} L_i / n} = \frac{\overline{MPA}}{\bar{L}} \tag{5}$$

where $\overline{MPA}$ is the average PCB (TPCB or Tri+ PCB) mass per unit area in the capped areas, *i.e.*,:

$$\overline{MPA} = \frac{\sum_{i=1}^{n} L_i m_i}{n} = \frac{\sum_{i=1}^{n} MPA_i}{n} \tag{6}$$

and MPA_i is the mass per unit area determined for an individual core.

Combining equations (3), (4), and (5), the mass remaining after dredging (*M*) can be expressed as:

$$M = A \times \overline{MPA} \quad (7)$$

For all calculations of mass in the CU, both the capped mass as well as the mass remaining under backfilled areas (see discussion in Section 4.3 for the latter mass estimate), B_i in equation (1) is calculated as the mean dry bulk density for all SSAP core segments collected within the CU. Values of C_{ij} and L_{ij} in equation 1 were the results from the Residuals Cores that were collected following the final dredging pass in each capped area of the CU. In this way, C_{ij} and L_{ij} represent direct sampling of sediment that was left in place and subsequently covered with an engineered cap. The above calculations were carried out for the capped area in each CU dredged in Phase 2.

3.3 Determination of Mass of PCBs in Sediment Remaining Outside Certification Units

Unlike the calculation of PCB mass removed within dredged areas (Section 3.2), the volume of PCB-bearing sediment is unknown. To estimate the PCB mass outside the CUs, the calculations integrate PCB mass on an area basis, based on the mass per unit area (MPA, grams per square meter [g/m^2]) results for cores collected outside the CUs. To accomplish this, the area of the non-dredged river bottom was multiplied by the average MPA based on the cores collected within the non-dredged areas to produce an estimate of PCB mass remaining. Core-based MPA values were calculated using a formula that is essentially the numerator in Equation (1) above:

$$MPA_i = \sum_{j=1}^{n_i} L_{ij} C_{ij} B_{ij} \quad (8)$$

where i is an individual core, j is a core segment within core i, n_i is the number of core segments within core i, L_{ij} is the length of the core segment, C_{ij} is the concentration of TPCBs for the core segment, and B_i is the bulk density of the core segment.

In order to avoid over-representing a given area of the river, clusters of cores within 20 feet (ft) of one another were averaged, with the average MPA of the core cluster applied to the centroid of the cluster. Core-based (or cluster-based) MPA values were first grouped by river section. Given the relatively small size of non-dredged areas in River Sections 1 and 2 (RS 1 and RS 2, respectively), as compared to River Section 3 (RS 3), a single estimate of the mean MPA was calculated for each of these River Sections, and multiplied by the corresponding non-dredged area within the river section to obtain an estimate of the PCB mass remaining, using Equation 7 above.

For RS 3, given the large extent of non-dredged area, the non-dredged areas were first stratified by sediment type (gravel, fine sand/silt, sand, transitional, and "unclassified") derived from the side-scan sonar survey conducted by GE in 2002 and 2003 (General Electric 2003d, 2003a); a mean MPA was subsequently calculated for each stratum. PCB mass estimates were obtained by the product of area and MPA (Equation 7), and the estimates were summed to calculate a TPCB mass remaining outside dredged areas in RS 3.

As mentioned above, "unclassified" sediment was treated as a fifth stratum. This stratum was required for three reasons, first the lack of side-scan sonar coverage, second, the lack of sediment cores to characterize these areas except in a few very limited areas, and third, the large amount of river bottom that fell into this category.

There are several reasons why certain areas of river bottom could not be classified using boat-mounted side-scan sonar equipment, including unsafe conditions either immediately upstream or downstream of dams, shallow water that did not allow sufficient draft for the survey vessel, and vegetative cover in some locations (*e.g.*, water chestnut) that posed a boating hazard. A review of unclassified areas in RS 3 indicates that greater than 80 percent of unclassified area is likely associated with gravel, cobble, or bedrock. This assessment included evaluation of classified sediment texture in the immediate vicinity of unclassified areas, evaluation of the proximity of unclassified areas to dams (which create downstream, high energy tail races that limit deposition of fine-grained material), and the observations of long-term project personnel who routinely navigate the Upper Hudson River by boat.

The high percentages of gravel, cobble, and bedrock in unclassified areas impacted the spatial distribution of cores. A review of cores located in unclassified areas of RS 3 indicated that 95 percent (224 out of 236 cores) were clustered together in well-defined areas bounded by a combination of shoreline, dredging area boundaries, or a classified sediment type (Figure A2-1a through A2-1aw). The well-defined areas that contained the vast majority of cores tended to be fine-grained, and thus were not representative of the sediment texture of the unclassified areas as a whole.

The well-defined areas where high numbers of cores are clustered are referred to here as high-density core (HDC) areas (13 in total, comprising 55.4 acres). PCB mass remaining was calculated separately for each HDC area using an average MPA value derived solely from cores within the respective HDC area.

The remaining unclassified areas not part of the HDC areas (396 acres in total) were identified as likely containing gravel, cobble, and bedrock, based on field observations and their proximity to dams and coarse-grained areas. The PCB mass remaining in these unclassified areas was estimated by creating an average MPA using the twelve remaining core-based MPA values in unclassified areas (but not inside HDC areas) along with the 728 core-based MPA values located in the gravel sediment areas of RS 3. This MPA average was then multiplied by the unclassified area (396 acres) to obtain an estimate of PCB mass. The estimated PCB mass in HDC areas was summed with the estimated PCB mass in the non-HDC areas to determine the TPCB mass in "unclassified" sediment of RS 3.

3.4 Assessing Applicability of Recovery Correction to Sediment Cores with Less than Complete Sample Recovery

As discussed in Section 3.1, a recovery correction can be applied to sediment cores to account for low sample recovery. The application of a recovery correction affects the core-based MPA value in a linear fashion, basically by accounting for the length of unrecovered material left behind during core collection. The Fraction Recovery for an individual core *i* is calculated as defined in the EPS as:

$$Fraction\ Recovery_i = \frac{length\ of\ core\ material\ recovered}{depth\ of\ core\ barrel\ penetration} \qquad (9)$$

The correction was applied by dividing the length of each core segment by the percent of core recovered, as follows:

$$MPA_{i,corrected} = \sum_{j=1}^{n_i} \frac{L_{ij}}{Fract.Recovery_i} C_{ij} B_{ij} = \frac{1}{Fract.Recovery_i} \sum_{j=1}^{n_i} L_{ij} C_{ij} B_{ij} \quad (10)$$

which reduces to the following for each core:

$$MPA_{i,corrected} = \frac{1}{Fract.Recovery} MPA_{i,orig} \quad (11)$$

Where: $MPA_{i,corrected}$ = is the recovery corrected MPA for an individual core *i*

$MPA_{i,orig}$ = is the original MPA calculated for the individual core *i*

While recovery correction is a straightforward means to adjust for missing sample material and prevents underestimation of MPA as a result of low recovery, it is possible for the recovery correction to over-correct MPA values (*i.e.,* to produce an MPA estimate – and hence a PCB mass remaining estimate - that is greater than the true value). This is because the recovery correction is applied proportionately to each section of the core, recognizing that it is not possible to determine which section(s) of the core were actually missing sample material. In order to assess the appropriateness of recovery correction with respect to MPA values, an analysis was carried out that compared SEDC cores with high recovery (≥ 90 percent) with co-located SSAP cores with low recovery (≤ 70 percent). In total, 102 core pairs were identified that satisfied this criteria. In this analysis, the high recovery SEDC core was assumed to represent the best estimate of MPA at the sampled location, and the SEDC MPA was compared with the recovery-corrected and non-recovery corrected SSAP MPA value (Figure A2-2 and A2-3).

Figures A2-2 and A2-3 demonstrate that for cores with MPA values greater than 10 g/m^2, the recovery correction tends to improve the MPA value (*i.e.,* recovery-corrected SSAP MPA values in Figure A2-3 are evenly distributed about the 1:1 line, matching their co-located SEDC core). MPA values in Figure A2-2 tend to fall below the 1:1 line for MPA > 10 g/m^2. On the other hand, for cores with MPA values less than approximately 10 g/m^2, recovery correction tends to over-correct the MPA values (points in this region tend to fall above the 1:1 line in both figures but are clearly more distant from the line in Figure A2-3), indicating that no correction is necessary. The reasons for this are not entirely understood. It may be that in the low MPA cores (<10 g/m^2), high TPCB concentrations are concentrated in only one or a limited number of segments (whereas the calculation assumes that poor recovery is distributed proportionately across all segments). In this situation, if the contaminated segment(s) were, in fact, properly sampled (i.e., 100 percent of the contaminated segment(s) were recovered), then low recovery may be inferred to be a result of not recovering the section(s) of the core that were either low or non-detect for PCBs. In this case, applying the recovery correction to all segments would not be appropriate, and would produce an overestimate of the MPA. In contrast, in cores with high MPA values (>10 g/m^2), where TPCB concentrations are likely to be detected in a majority (or all) of the core segments, it is more likely that a segment with a high or detectable concentration of PCBs would be recovered at less than 100 percent. In this case, recovery correction is appropriate and improves the estimate of MPA for the core.

Based on the analysis presented above, applying the recovery correction to cores inside the dredged areas where 63 percent of cores yielded MPA values greater than 10 g/m^2 (the median non-recovery corrected MPA value was 19.9 g/m^2) was deemed appropriate when estimating the PCB mass removed. Outside the dredged area, where approximately 84 percent of cores had non-recovery corrected MPA values less than 10 g/m^2 (the median non-recovery correct MPA value was 1.6 g/m^2), estimates of PCB mass remaining in RSs 1, 2, and 3 are presented using both recovery corrected and non-recovery corrected MPA values in order to provide the likely range. These results indicate that non-recovery corrected MPA values likely provide the best estimate of PCB mass remaining outside dredged areas, while recovery-corrected MPA values likely produce an upper bound estimate.

3.5 Determination of Dredged Area Capped Using the Nodal Capping Index (NCI)

The post-dredging surfaces were first categorized as to their level of compliance with the Residuals Standard and then as to the areas of the river in which they fell. The level of compliance is defined by the categories below:

A. Inventory capped in place (*i.e.*, the node contained sediment below 6 inches containing Tri+ PCB concentrations equal to or greater than 6 mg/kg).

B. Elevated residuals capped (*i.e.*, the node caused the average surface concentration in the CU or sub-unit to exceed 1 mg/kg Tri+ PCB or had a surface concentration of 27 mg/kg Tri+ PCB or greater).

C. Compliant areas backfilled (*i.e.*, the node was part of a CU or sub-unit area whose average Tri+ PCB concentration was 1 mg/kg or less).

As required by the standard, the level of compliance was tracked for each category of river bottom area listed below. Note that the first three categories represent specific geographic settings, whereas the latter three represent river bottom types:

1) Structural offsets;
2) Cultural resource areas;
3) Shoreline areas;
4) Exposed bedrock areas;
5) Exposed glacial Lake Albany clay areas; and
6) River bottom not falling into any of the above categories (typically silt, sand, and gravel areas).

The extent of capping in a single CU for use in calculating the NCI is defined as follows:

$$A_{capped} = A_{CU} \times \left[\frac{\Sigma(N_{field\ capped})}{\Sigma(N_{field})+\frac{1}{2}\Sigma(N_{shoreline})}\right] \qquad (12)$$

where A_{capped} is the area capped within the CU as determined by the NCI,[3] A_{CU} is the total area of the CU, $N_{field\ capped}$ is the number of nodes within the CU that were capped and

[3] Note that the actual area capped in a CU is generally greater than the A_{capped} value calculated in this formula. This is because the NCI determines the area capped based on the fraction of nodes that required capping and not on the actual area. Because of the geometries involved between sampling nodes and the requirements of the EPS itself, the actual area capped is nearly always greater than A_{capped}. As discussed in the EPS, this simplified method was designed to provide a basis to determine dredging compliance in real

in category 6 above and in compliance categories A or B, N_{field} is the total number of nodes within the CU that are not specifically identified as boundary nodes (river bottom categories 1 and 2) or shoreline nodes, including all nodes from categories 4, 5 and 6, irrespective of their compliance category. Finally, $N_{shoreline}$ is the sum of nodes in the shoreline area of a CU; this includes all shoreline nodes irrespective of their compliance category.

Once A_{capped} is determined for all CUs, the total percentage of area capped, based on the NCI, is calculated as:

$$Nodal\ Capping\ Index\ (NCI) = \frac{\sum A_{capped}}{\sum A_{CU}} \times 100 \qquad (13)$$

The NCI formed the measurement basis for compliance with the capping criteria of the Residuals Standard.

time, given the much more extensive analyses and resulting delays that would have been required to track the exact amount of area capped in real time.

4 RESULTS AND DISCUSSION

4.1 Volume of Sediment Removed and Mass of PCBs in Sediment Removed

The results of the United States Environmental Protection Agency's (EPA's) calculation of the volume of sediment removed and the mass of PCBs in sediment removed on a CU-by-CU basis are presented in Tables A2-1a-b and A2-2a-d. The calculations indicate that 2,360,000 cubic yards of sediment were removed from CUs in the Upper Hudson River during Phase 2, which facilitated the removal of 136,000 kilograms (kg) of TPCB and 43,100 kg of Tri+ PCB. Using values of volume and mass of TPCB and Tri+ PCB removed during Phase 1 dredging (268,000 cubic yards, 20,000 kg and 5,460 kg for volume dredged, TPCB mass removed, and Tri+ PCB mass removed, respectively) from the 2010 Phase 1 Evaluation Report (EPA, 2010d), the totals removed during both Phases 1 and 2 were 2,630,000 cubic yards of sediment, 156,000 kg of TPCB, and 48,600 kg of Tri+ PCB. On a yearly basis (Tables A2-2a and A2-2b), 2012 had the highest total with respect to volume dredged, while 2015 had the lowest dredging total. Note that some CUs were dredged over 2 consecutive years. In these situations, in order to present annual values, CUs dredged over multiple years were included in the year in which the CU was first dredged. As a result of this grouping, annual values presented in Tables A2-2a and A2-2b may differ from the values presented in Annual Reports provided by GE during Phase 2 dredging activities. Total volume removed (summed over all Phase 2 years) calculated for this analysis was within 4 percent of values calculated by GE for the Phase 2 activities, and TPCB and Tri+ PCB masses removed calculated for this analysis were within 6 percent of values calculated by GE for the Phase 2 dredging activities. Combining Phase 1 and Phase 2, GE estimates of TPCB mass removed were within 8 percent of those calculated by EPA.

Estimates of volume dredged and PCB mass removed rely not only on accurate measurements of volume and area dredged, but also on the extrapolation of the concentrations of TPCB and Tri+ PCB measured in cores (*i.e.*, point estimates) to concentrations over relatively large areas and volumes (*i.e.*, areal and volume estimates). Further, bulk density was not directly measured on residuals cores collected during dredging activities, and assumptions were required regarding estimation of the bulk density of sediments dredged. Therefore, differences between values calculated by GE and EPA are likely related to small differences in calculation of area and volume dredged on a CU-by-CU basis, estimates of MPUV and MPA using SSAP and residuals core data on a CU-by-CU basis, and estimation of bulk density values for the residuals cores where no bulk density was directly measured. EPA's and GE's values for volume of sediment and PCB mass removed should be considered as best estimates of the actual volume and mass removed given the data available, and the observation that both values agree well provides confidence that these values reflect the true volume and mass removed.

A comparison of the volume and mass of sediment removed during each dredging pass of Phase 2 indicates that 75 percent of the TPCB mass and 80 percent of the total sediment volume were removed during the first dredging pass. Based on the Residuals Cores collected after the first pass, 88 out of the 91 CUs dredged in Phase 2 required a second pass. 24 percent of the TPCB mass and 19 percent of the total sediment volume were removed during the second pass. 20 CUs required a third pass, with 1 percent of the TPCB mass and 1 percent of the total volume of sediment removed during the third pass. On an individual CU basis, the first dredging pass removed between 23 and 100 percent of the TPCB dredged within a respective CU, while the second dredging pass removed between 2 and 73 percent of TPCB mass within a CU and the third dredging pass removed between 0 and 10 percent of TPCB mass within a CU. Further, we identified two CUs (CU-16, CU-26) that had more PCB mass removed during the second pass than during the first pass.

Compared to the 2010 Productivity Standard's target volumes, Phase 2 dredging years 2011 through 2014 met or exceeded the volume of sediment to be dredged. For the years 2011 to 2014, dredging volumes were approximately 100, 155, 180, and 175 percent, respectively, of the stated goal of 350,000 cubic yards to be removed each year. In 2015, only 237,000 cubic yards of sediment were dredged, which represented the volume in CUs remaining to be dredged in the final year.

To put these results into context, the actual volume of sediment and mass of PCBs dredged in Phases 1 and 2 were compared with the estimated volume of sediment and mass of PCBs to be removed, as presented in the 2002 ROD and the 2007 Phase 2 Dredge Area Delineation (DAD) Report (EPA 2002; General Electric 2007e). Table A2-3 presents estimates of the mass of TPCB and Tri+ PCB to be removed from the Upper Hudson River during Phase 1 and 2 dredging activities. Using values calculated in this report, along with values presented in the Phase 1 Evaluation Report (EPA, 2010a), the actual dredged volume (2,630,000 cubic yards) was within 1 percent of the predicted 2,650,000 cubic yards presented in the 2002 ROD, and 47 percent more than the 1,800,000 cubic yards predicted in the 2007 DAD Report. With regard to the TPCB mass removed, actual TPCB mass removed (156,000 kg) was 123 percent more than the 69,800 kg predicted in the 2002 ROD and 38 percent more than the 113,100 kg predicted in the 2007 DAD report. While the 2007 Phase 2 DAD Report did not estimate a specific amount of Tri+ PCBs to be removed, the actual amount of Tri+ PCBs removed (48,600 kg) was 123 percent more than the 21,700 kg predicted in the 2002 ROD.

It should be noted that dredging volumes and mass presented above include dredging required to maintain a navigable channel within the dredging areas. Data provided by GE (Table A2-5) indicate that approximately 444,000 cubic yards were dredged inside CUs and 7,300 cubic yards were dredged outside CUs specifically for navigation channel access. Dredging resulted in the removal of 18,900 kg of TPCB and 6,400 kg of Tri+ PCB mass from the navigation channel withinCUs. Further, additional dredging took place in the Upper Hudson River that was not included in the above volume and mass estimates. In particular, access dredging was conducted to allow access for barges and other dredge-related ship traffic to reach CUs, and “daylight” dredging was conducted where dredging depths were such that additional dredging was required within and along the border of CUs to prevent the collapse of dredging area walls prior to the placement of clean backfill or cap material. While exact values for the volume and mass removed as a result of access and daylight dredging were not tracked during Phase 2 dredging, GE estimates that approximately 4,000 cubic yards of sediment were removed for these purposes, and this represents additional volume and PCB mass removed beyond the values calculated above.

It follows from this analysis that the predictions in the 2002 ROD and 2007 Phase 2 DAD Report of the *in-situ* mass of PCB-contaminated sediments in the Upper Hudson River were underestimates. The mass removed values for both TPCB and Tri+ PCB calculated by EPA were within 6 percent of the values calculated by GE during Phase 2 dredging. While some differences between EPA's and GE's estimates are expected, both values exceeded the mass removal objectives laid out in the 2002 ROD. Similarly, the close agreement between EPA's and GE's estimates for the volume of sediment and PCB mass removed (less than 6 percent difference) indicate that GE correctly implemented these metrics for determining compliance with the Phase 2 Productivity, Resuspension, and Residuals Standards.

4.2 Proportion of Phase 2 Dredged Area Covered by Engineering Cap and Percentage of Dredged Area Capped with Inventory present

The total area within each CU covered by an engineered cap was determined using the NCI and compared with the actual area capped, based on analysis of EPA-approved capping design plans for each CU. The total area closed out with engineered caps based on the NCI formulation was 34 acres, and the total area closed out with engineered caps that contained non-dredged inventory (*i.e.*, the node contained sediment below 6 inches containing Tri+ PCB concentrations equal to or greater than 6 mg/kg), based on the NCI, was 2.2 acres.

When compared with the compliance thresholds for percentage of dredged area capped and area capped with non-dredged inventory, the NCI-calculated area capped (the area used for determination of compliance) was 7.7 percent of the total area dredged in Phase 2 (34 out of 442 acres), and the NCI-calculated area capped with inventory was 0.5 percent of the total area dredged in Phase 2 (2.2 out of 442 acres). Both of these areas were below the compliance thresholds set out in the Residuals Standard (*i.e.*, 11 and 3 percent for total area capped and area capped with inventory, respectively). These percentages were specifically designed for comparison with the NCI criteria calculation, essentially requiring that no more than 11 percent of the residual sampling nodes fail to meet the Residual Performance Standard criterion, and that no more than 3 percent of residual sampling nodes identify remaining sediment inventory. An important factor in the decision to use the NCI as a measure of dredged area capped was the need to expeditiously determine compliance with capping limitations in the Residuals Standard while active dredging was taking place, to avoid delaying the closure of dredged areas and potentially increasing the amount of sediment resuspension. The index also served to keep the operation moving forward smoothly, by facilitating compliance decisions on each CU. As noted in Section 2, the NCI acted as a surrogate for the exact extent of capping and backfilling.

The actual area capped as a result of residuals cores in Phase 2 that did not comply with the Residuals Standard was 56 acres, which is larger than the NCI-calculated area capped. The larger area of actual capping was the direct result of the Residuals Standard requirement that capped areas extend out to the surrounding compliant nodes, and not just the area of influence associated with a non-compliant core. This protective capping approach was intended to further isolate any residual contamination in the vicinity of a non-compliant sampling node. Thus, the NCI approach was a strict tally of the known non-compliant area, as opposed to the more conservative total area capped for non-compliance. Per the requirements of the Residual Performance Standard, the total area capped was designed to be greater than the NCI area. The 11 percent capping criterion was pointedly based on the NCI (the percentage of failing nodes) and not the actual area capped. This was done in recognition of the difficult geometries of the various CU areas, as well as the need to make expeditious decisions during the remediation, enabling the rapid closure of CUs and isolation of any remaining disturbed PCB-bearing sediment. As it turned out, the actual area capped due to non-compliant nodes in Phase 2 (56 acres), was just slightly more than the 11 percent capping criterion of area dredged in Phase 2 (49 acres).

In addition, certain dredged areas were capped due to presence of non-compliant cores in areas that could not be further dredged. These areas included shoreline stability areas, structural offsets, cultural resources, exposed bedrock or exposed Lake Albany clay. These capped areas were not included in the NCI area calculation as per the Standard, specifically because they represented engineering limitations and not a failure to remove PCB contamination. These engineering limitations resulted in an additional 33 acres of capped area. In total, 88 acres of dredged areas were capped in Phase 2 as a result of non-compliant residuals cores or for the reasons listed above, and 3.9 acres were capped with inventory present.

4.3 Mass of PCBs Remaining in Sediment in Certification Units Following Phase 2 Dredging

Tables A2-4a and A2-4b present the mass of PCBs (both TPCB and Tri+ PCB) remaining in sediments within CU boundaries subsequently covered by engineered caps. Based on the data from the Residuals Cores, the upper bound mass of TPCB and Tri+ PCB remaining in Phase 2 dredged areas capped after dredging is estimated to be 3,900 kg and 1,100 kg, respectively. This represents 3.0 and 2.5 percent of the TPCB and Tri+ PCB removed during Phase 2, respectively. It should be noted that the mass associated with capped areas is not simply left behind in the river but rather the mass has been permanently isolated from interactions with humans and the environment.

Of the 3,900 kg of TPCB capped, 600 kg were capped as exceeding the *inventory threshold* of the Residuals Standard, while the remaining mass was capped as a result of exceeding the *elevated residuals threshold*. The value of 3,900 kg TPCB (or 1,100 kg Tri+ PCB) capped represents an upper bound, as this value is based on the assumption that all underlying sediment within a capped area has the mean concentration of the associated non-compliant cores. However, this assumption disregards the uncertain boundary of non-compliant contamination between non-compliant cores and surrounding compliant cores that delineate the outer edge of the cap (see Section 4.2). Very likely, the actual average concentration of sediment underneath a cap falls somewhere between the concentration of the non-compliant core at the center of the cap and the surrounding compliant core concentrations, and thus the actual mass capped would be lower than the 3,900 kg TPCB (or 1,100 kg Tri+ PCB) reported here.

Remaining areas of CUs that were dredged but not capped (such as areas covered with clean backfill[4]) were required to have surface sediment concentrations equal to or less than 1 mg/kg Tri+ PCB (with the allowance that concentrations be rounded to the nearest whole number). Of the approximately 442 acres dredged in Phase 2, 354 acres were not covered with an engineered cap. An analysis of the likely amount of mass remaining in the non-capped areas, using an average Tri+ PCB concentration of 1.38 mg/kg[5], the average DoC in these areas of 6 inches, and a bulk density of 0.9 grams per cubic centimeter (g/cm^3), indicates the Tri+ PCB mass in these areas would be approximately 300 kg. Given that the non-capped areas and capped areas are both part of the CU areas, it is likely that the proportion of Tri- and higher PCB homologues relative to TPCB homologues in non-capped areas is the same as was observed in capped areas (3,900 kg TPCB / 1,100 kg Tri+ PCB = 3.5). Using this relationship, approximately 1,000 kg of TPCB mass remains in the non-capped Phase 2 areas.

Thus, the calculation of PCB mass remaining within the CUs indicates that the dredging activities were carried out in a manner that not only met the Productivity and Residuals Standards for Phase 2, but also removed 136,000 kg of TPCB mass within the targeted dredging areas, which equates to removal of approximately 96 percent of all PCB mass within the Phase 2 dredged areas themselves. This result is in line with the Residuals Standard goal of removal of 96 to 98 percent of PCBs within the dredged areas.

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[4] The term "non-capped areas" is used here to refer to the combination of backfilled areas as well as areas that were dredged to compliance but subsequently were neither backfilled nor capped. In the latter instance, the areas were not capped because they lay within the navigation channel or there were other engineering limitations. Note that the areas that were dredged and backfilled make up approximately 90 percent (~315 acres) of the 354 non-capped acres.

[5] The Tri+ PCB concentration representing the weighted average surface Tri+ PCB concentration in non-capped areas of each CU after dredging, with weighting based on the number of final compliant cores collected in each CU.

4.4 Amount of TPCB Mass Removed from the Upper Hudson River

The 2002 ROD presented prediction of the percentage of TPCB mass that would be removed at the conclusion of dredging activities (EPA, 2002, Table 363334). Using sediment data from 1984, 1991, and 1994, the 2002 ROD predicted that 65 percent of TPCB mass would be removed from the Upper Hudson River. At the river section scale, the 2002 ROD predicted that 80 percent, 86 percent, and 26 percent of TPCB mass would be removed from RSs 1, 2, and 3, respectively. In order to assess whether dredging activities achieved these targets, the mass of TPCB outside CUs was estimated for each river section (as described in Section 3.3), and combined with mass dredged and mass remaining inside CUs (incorporating dredging activities for both Phase 1 and Phase 2) to estimate the total inventory of TPCBs in each river section. As described in Section 3.3, two methods were used to estimate the TPCB mass remaining in RSs 1, 2 and 3: 1) recovery correction was applied to all cores to address low sample recovery, and 2) no recovery correction was applied to cores. As described in Section 3.4, the first method represents a likely upper bound on the mass of TPCBs remaining in the Upper Hudson River, while the second method represents a likely best estimate. Note that while the analysis in Section 3.3 shows that recovery correction provides an upper bound on the mass of PCBs remaining (*i.e.,* for low MPA cores), recovery correction provides a best estimate for the mass of PCBs removed, which is primarily based on high MPA cores. Thus, the calculations described below use the recovery-corrected estimates for mass removed but vary based on the use of recovery-corrected estimates and uncorrected estimates of PCB mass left behind.

Tables A2-6a and A2-6b present the results of this analysis using both estimates of mass left behind. As described above, estimates of the total mass dredged and the mass remaining in dredged areas (including both capped and non-capped areas) presented in Tables A2-6a and A2-6b incorporate both Phase 1 and Phase 2 dredging activities. The results indicate that 93 to 94 percent of TPCB mass was removed from RS 1 (using method 1 and method 2 described above, respectively), 76 to 82 percent of TPCB mass was removed from RS 2 (using methods 1 and 2, respectively), and 38 to 47 percent of TPCB mass was removed from RS 3 (using methods 1 and 2, respectively). Overall, the total TPCB mass removed in all three river sections was between 70 and 76 percent, using methods 1 and 2, respectively. The results of method 2 (76 percent overall), which is considered the best estimate, indicate that the remedy has readily exceeded the prediction of 65 percent of TPCB mass to be removed from the Upper Hudson River, as presented in the 2002 ROD. Examining the best estimate results on a river section basis, in RS 1, the ROD prediction of 80 percent was exceeded by 14 percent (actual removal estimated at 94 percent). In RS 3, the estimate of 47 percent removal actually achieved by the remedy was nearly double the ROD prediction of 26 percent, a difference of 21 percent. Only in RS 2 was the best estimate of actual percentage removed (82 percent) below the ROD prediction (86 percent), although these values agree within error.

Estimates of PCB mass removed and PCB mass remaining in the Upper Hudson River presented here can be integrated to compare with the 2002 ROD predictions of TPCB mass anticipated to be removed and mass likely to remain. The best estimates of actual mass removed and mass outside CUs presented in this appendix indicate that the actual mass removed (156,000 kg) was 123 percent more than the 69,800 kg predicted in the 2002 ROD (*i.e.*, the actual dredged mass was 2.2 times the 2002 ROD estimate), while the mass outside dredged areas (best estimate of 41,000 kg) was only 9 percent more than the 37,500 kg of TPCB mass outside dredged areas as predicted in the 2002 ROD. Essentially, the current best estimate and the ROD prediction agree within error. However, the agreement between the current best estimates and the ROD predictions varies more widely on a river section basis, as shown in Table A2-7.

The observation of a larger increase in the mass inside dredged areas compared to the mass outside dredged areas, relative to 2002 ROD predictions, is consistent with the observations made during the SSAP and SEDC core collection programs. Specifically, the highest concentrations of PCBs were found primarily in fine-grained sediment and in areas with high organic content (including wood debris) that were specifically targeted for removal during dredging, and these areas contained substantially more PCB than originally anticipated in the 2002 ROD. The areas outside the dredged areas generally were observed to be more coarse-grained in nature. The observation of a larger increase in mass inside dredged areas compared to outside dredged areas is largely the result of the difficulties in coring the fine sediments and associated woody debris, which were addressed by the SSAP and SEDC coring techniques.

These analyses were carried out in order to assess the success of dredging activities relative to estimates set forth in the 2002 ROD. The results indicate that mass of PCBs removed greatly exceeded predictions from the 2002 ROD and the largest increases in TPCB mass relative to 2002 ROD predictions were largely confined to the dredged areas themselves. While our confidence in estimates of TPCB mass outside dredged areas is higher for RS 1 and RS 2 compared with RS 3, the evidence does not support the concept that because of the significant increase in mass within the CUs targeted for removal, there must be a significant mass also left outside of the CUs. The fact that dredging removed twice the anticipated mass is unrelated to the observation of higher-than-anticipated surface concentrations. The higher-than-anticipated surface concentrations outside CUs based on the SSAP and SEDC cores do not constitute a substantively larger reservoir of PCB contamination than originally estimated, largely because contamination depth is typically much shallower in those areas than that within the dredged areas.[6]

4.5 Summary

The primary objective of these analyses was to determine whether Phase 2 dredging activities were in compliance with the Productivity and Residuals Standards presented in the Phase 2 EPS. The results indicate that dredging activities were in compliance with the Productivity Standard throughout Phase 2. Volumes dredged between 2011 and 2014 ranged from 100 to 175 percent of the stated annual Productivity Standard goal (350,000 cubic yards). In 2015, the last year of Phase 2 dredging, the remaining areas to be dredged contained less than the Productivity Standard goal of 350,000 cubic yards, and therefore, the total volume removed (237,000 cubic yards) was necessarily below the Productivity Standard. The total volume dredged as calculated by EPA (2,630,000 cubic yards) is within 5 percent of the values GE reported during Phase 2 dredging.

[6] As noted in Appendix 4, the surface concentrations estimated from the SSAP and SEDC cores have significantly declined since those surveys were completed.

Estimates of total mass removed during both Phase 1 and Phase 2 (156,000 kg of TPCB and 48,600 kg of Tri+ PCB) exceeded predicted amounts reported in both the 2002 ROD and the 2007 Phase 2 DAD Report (General Electric 2007e). This occurred in part because those earlier estimates were based on cores that did not fully characterize the vertical extent of contamination. Based on "lessons learned" from Phase 1 dredging, additional sediment sampling programs were carried out prior to Phase 2 dredging and revised standards were implemented for Phase 2.

The mass removed estimates for both TPCB and Tri+ PCB as calculated by EPA and GE for Phase 2 agreed within 6 percent. Combining both Phase 1 and Phase 2, mass-removed estimates for TPCB as calculated by EPA and by GE agreed within 8 percent.

Collection of additional cores in 2010 to better characterize the DoC within the CUs, along with the Phase 2 requirement to dredge six inches deeper than the identified DoC, minimized the number of dredging passes required within each CU while still removing approximately 96 percent of PCB mass within the dredged areas. Additionally, the observation that approximately 25 percent of the TPCB mass was removed during the second dredging pass highlights the effectiveness of the Residuals Performance Standard and the associated residuals coring requirements in identifying additional inventory for removal. Phase 2 dredging successfully removed approximately 136,000 kg of PCB while conducting a maximum of three dredging passes in a given area, reducing the amount of dredging-related resuspension of sediment. Despite the fact that the TPCB mass removed was more than twice that estimated in the ROD, the changes in the dredging requirements and the Residuals Performance Standard helped to ensure that the remedy still exceeded the ROD-anticipated percentage of overall mass removed (65 percent planned *vs*. 76 percent achieved) as well as achieve a mass removal efficiency of 96 percent in the dredging areas themselves.

5 CONCLUSIONS

Volumes of sediment and mass of PCBs removed were estimated from predesign and post-dredging core data, as well as pre- and post-dredging bathymetry. Volumes removed in each year of Phase 2 were found to be in compliance with the Productivity Standard. Total sediment volume and masses of TPCB and Tri+ PCB removed in Phases 1 and 2 were found to be much greater than anticipated at the outset of the remedy, due to prior underestimates of DoC, which were remedied by coring conducted in 2010 to 2012 to support the Phase 2 remedial design. The estimated mass of PCBs removed annually was used to help assess compliance with the Resuspension Standard, which limited downstream transport to a percentage of the total dredged PCB mass.

Estimates of PCB mass removed and areas capped and backfilled demonstrate compliance with limits set in the Residuals Standard. In Phase 1, approximately 93 percent of mass was removed in dredged areas (20,000 kg TPCB removed and 1600 kg remaining; EPA 2010a), while in Phase 2, 96 percent of PCB mass was removed from dredged areas (136,000 kg TPCB removed, 4900 kg remaining), demonstrating an improvement between Phase 1 and Phase 2, based on "lessons learned" from Phase 1 activities. In total, the estimated TPCB mass left in place in dredged areas across both Phase 1 and 2 (upper bound estimate of 6,500 kg of TPCB) is small relative to the mass removed by dredging in Phase 1 and 2 (156,000 kg of TPCB), and represents removal of 96 percent of PCBs in dredged areas. Of the 6,500 kg or less remaining, 3,900 kg were securely sequestered below engineered caps. A best estimate of 41,000 kg of PCB mass remaining outside dredged areas in the Upper Hudson. This value is within 9 percent of that predicted in the 2002 ROD (with the two values being within error of one another), however on a river section-by-river section basis, the estimates presented in this Appendix and predicted in the 2002 ROD can differ by more than 9 percent. Finally, 77 percent of TPCB mass was removed from the Upper Hudson River, which exceeded the predicted removal of 65 percent in the 2002 ROD.

Important objectives of the evaluation discussed here were to confirm that: (1) the expectations of PCB removal during dredging, as presented in the 2002 ROD, were achieved; (2) Phase 2 dredging activities were in compliance with the Productivity and Residuals Standards; and (3) GE correctly implemented the metrics (*e.g.*, calculation of PCB mass removed and the NCI) used to determine compliance with the Engineering Performance Standards during Phase 2. Based on EPA's calculations presented in this appendix, the amount of PCBs removed during Phase 1 and Phase 2 exceeded expectations in the 2002 ROD by more than a factor of 2. Targeting of surface sediment PCB concentrations, in combination with removal of PCB mass and natural recovery, served to reduce Tri+ PCB concentrations in surface sediments to an extent consistent with the post-remediation changes anticipated by modeling results presented in the 2002 ROD (Appendix 4, Table A4-5). Similarly, the close agreement between EPA's and GE's estimates for the volume of sediment and PCB mass removed (less than 6 percent difference) indicate that GE correctly implemented the metrics for determining compliance with the Phase 2 Productivity and Residuals Standards.

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Final Second Five-Year Review Report for the Hudson River PCBs Superfund Site

APPENDIX 2

MASS REDUCTION EVALUATION

Tables

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April 2019

Table A2-1a. Volume of Sediment Removed from Certification Units in Phase 2 by Certification Unit

CU	Year Dredged	Pass 1 (cy)	Pass 2 (cy)	Pass 3 (cy)	Total (cy)
CU01a	2015	9,640			9,600
CU09	2011	7,980	6,750		14,700
CU10	2011	12,900	4,000		16,900
CU11	2011	15,100	5,930		21,000
CU12	2011	15,000	5,250		20,200
CU13	2011	14,200	2,460		16,700
CU14	2011	21,900	3,060		25,000
CU15	2011	22,700	9,280	300	32,300
CU16	2011	17,800	6,450	800	25,000
CU19	2011	20,000	4,880		24,900
CU20	2011	19,000	4,570	400	24,000
CU21	2011	18,200	5,750	400	24,300
CU22	2011	19,300	5,880	700	25,900
CU23	2011	19,500	4,490	600	24,600
CU24	2011	30,400	2,000		32,400
CU25	2011	20,000	3,770		23,700
CU26	2012	16,700	7,170	600	24,500
CU27	2012	14,600	4,960	200	19,800
CU28	2012	18,200	6,400		24,600
CU29	2012	15,500	3,530		19,100
CU30	2012	16,400	3,030		19,500
CU31	2012	11,100			11,100
CU32	2012	12,800	1,310		14,100
CU33	2012	16,400	2,250		18,700
CU34	2012	11,800	1,630		13,400
CU35	2012	23,200	10,400		33,600
CU36	2012	21,200	2,890		24,100
CU37	2012	26,200	6,780		33,000
CU38	2012	21,400	4,590		26,000
CU39	2012	19,300	797		20,100
CU40	2012	21,900	6,080	300	28,400
CU41	2012	27,000	5,010		32,000
CU42	2012	22,900	4,540		27,400
CU43	2012	21,100	4,490	1,050	26,700
CU44	2012	18,600	6,750	600	26,000
CU45	2012	14,000	3,370	200	17,500
CU46	2012	15,200	2,260		17,500
CU47	2012	14,700	3,290		17,900
CU48	2012	16,100	4,230		20,400
CU49	2013	13,300	4,050		17,300
CU50	2012	22,200	4,910		27,100
CU51	2012/2013	27,400	1,980		29,400
CU52	2012/2014	32,100	1,080		33,200
CU53	2012/2015	26,400	2,090		28,500
CU54	2013	36,000	2,160		38,200

CU	Year Dredged	Pass 1 (cy)	Pass 2 (cy)	Pass 3 (cy)	Total (cy)
CU55	2013	10,600	2,480		13,100
CU56	2013	16,200	4,990		21,200
CU57	2013	16,700	6,400		23,100
CU58	2013	18,700	1,320		20,000
CU59	2013	9,790			9,800
CU60	2015	18,200	1,120		19,300
CU61	2014	20,800	2,930	800	24,500
CU62	2014	14,400	1,470		15,900
CU63	2014	24,100	1,750		25,900
CU64	2014/2015	17,700	4,810		22,500
CU65	2015	19,900	3,440		23,300
CU66	2015	21,600	1,730		23,400
CU67	2013	32,400	6,270	2,300	39,100
CU68	2013	27,700	9,800	2,670	40,200
CU69	2013	28,200	6,810		35,100
CU70	2013	34,900	14,200	400	49,500
CU71	2013	20,000	4,320		24,400
CU72	2013	17,100	6,240		23,400
CU73	2013	24,300	4,750	500	29,500
CU74	2013	14,900	5,350		20,200
CU75	2013	10,700	2,510		13,200
CU76	2013	34,800	19,700	1,630	56,100
CU77	2013	40,000	9,850	2,380	52,200
CU78	2013	15,500	2,550	200	18,200
CU79	2013	6,060	1,610		7,700
CU80	2014	13,400	1,950		15,300
CU81	2014	4,750	1,010		5,800
CU82	2014	39,000	7,160		46,200
CU83	2013/2014	44,000	9,400		53,400
CU84	2013	35,000	14,100		49,100
CU85	2014	15,200	5,700		20,900
CU86	2014	5,490	537		6,000
CU87	2014	39,700	10,200		49,900
CU88	2014	31,500	15,900		47,500
CU89	2014	41,900	19,000		60,800
CU90	2014	23,300	5,800		29,100
CU91	2014	25,200	4,360		29,600
CU92	2014	37,800	10,200		48,000
CU93	2014	28,500	6,260		34,800
CU94	2015	9,790	2,040		11,800
CU95	2015	38,000	5,190		43,200
CU96	2015	47,800	7,360		55,200
CU97	2014	5,000	1,240		6,200
CU98	2014	8,920	2,650		11,600
CU99	2013/2014	28,400	6,200		46,400
CU100	2013	1,440	1,000		2,400
Totals		**1,900,000**	**450,000**	**17,100**	**2,360,000**

Table A2-1b. Volume of Sediment Removed from Certification Units in Phase 1 and Phase 2 by Year

Year Dredged	Pass 1 (cy)	Pass 2 (cy)	Pass 3 (cy)	Pass 4 (cy)	Pass 5 (cy)	Total (cy)	GE Calculated Dredged Volume (cy)	2010 EPS Productivity Standard (cy)
2009	130,200	78,800	35,900	17,000	5,700	268,000	286,000	N/A
Phase 1 total	130,200	78,800	35,900	17,000	5,700	268,000	286,000	
2011	274,000	74,500	3,000	0	0	352,000	363,000	350,000
2012	438,000	101,000	3,000	0	0	542,000	663,000	350,000
2013	492,000	121,000	10,000	0	0	622,000	628,000	350,000
2014	484,000	127,000	1,000	0	0	611,000	583,000	350,000
2015	209,000	27,800	0	0	0	237,000	230,000	350,000
Phase 2 total	1,900,000	450,000	17,000	0	0	2,360,000	2,470,000	1,750,000
Phase 1 + 2 Total	**2,030,000**	**529,000**	**53,000**	**17,000**	**5,700**	**2,630,000**	**2,750,000**	

NOTE: Some CUs were dredged in multiple years, however for EPA calculation of dredged volumes by year, CUs were grouped by the initial year a CU was dredged, so values may not match up with GE values.

Table A2-2a. Mass of TPCB Removed from Certification Units in Phase 2

CU	Year Dredged	Pass 1 (kg)	Pass 2 (kg)	Pass 3 (kg)	Total (kg)
CU01a	2015	23			23
CU09	2011	276	244		520
CU10	2011	350	124		474
CU11	2011	680	410		1,090
CU12	2011	586	476		1,060
CU13	2011	597	118		716
CU14	2011	1,270	346		1,610
CU15	2011	2,580	1,290	2	3,880
CU16	2011	1,400	4,090	210	5,700
CU19	2011	1,260	153		1,420
CU20	2011	843	146	23	1,010
CU21	2011	553	200	18	771
CU22	2011	982	204	18	1,200
CU23	2011	935	369	43	1,350
CU24	2011	2,330	133		2,460
CU25	2011	1,590	310		1,900
CU26	2012	1,220	1,560	56	2,840
CU27	2012	1,250	560	1	1,810
CU28	2012	1,430	333		1,760
CU29	2012	806	301		1,110
CU30	2012	1,140	146		1,290
CU31	2012	241			241
CU32	2012	231	209		440
CU33	2012	395	72		467
CU34	2012	435	94		529
CU35	2012	2,890	1,110		4,000
CU36	2012	1,680	119		1,800
CU37	2012	1,450	175		1,630
CU38	2012	1,100	479		1,580
CU39	2012	1,350	71		1,420
CU40	2012	1,280	946	259	2,490
CU41	2012	1,290	611		1,900
CU42	2012	1,110	641		1,750
CU43	2012	1,710	360	102	2,180
CU44	2012	1,380	610	13	2,000
CU45	2012	780	217	1	998
CU46	2012	1,400	391		1,790
CU47	2012	583	81		664
CU48	2012	755	544		1,300
CU49	2013	644	141		785
CU50	2012	630	147		778
CU51	2012/2013	364	19		383
CU52	2012/2014	322	23		345
CU53	2012/2015	243	14		257
CU54	2013	1,260	31		1,290

CU	Year Dredged	Pass 1 (kg)	Pass 2 (kg)	Pass 3 (kg)	Total (kg)
CU55	2013	423	68		491
CU56	2013	1,340	742		2,090
CU57	2013	474	146		620
CU58	2013	663	30		693
CU59	2013	398			398
CU60	2015	747	18		765
CU61	2014	2,380	389	140	2,910
CU62	2014	982	118		1,100
CU63	2014	1,020	68		1,090
CU64	2014/2015	1,270	935		2,200
CU65	2015	1,650	902		2,550
CU66	2015	1,150	34		1,180
CU67	2013	3,240	190	34	3,470
CU68	2013	3,380	367	28	3,770
CU69	2013	2,610	273		2,880
CU70	2013	2,570	478	92	3,140
CU71	2013	1,333	215		1,550
CU72	2013	858	400		1,260
CU73	2013	1,390	246	21	1,660
CU74	2013	965	216		1,180
CU75	2013	728	117		845
CU76	2013	1,610	817	14	2,440
CU77	2013	1,360	618	95	2,080
CU78	2013	431	42	1.0	475
CU79	2013	315	64		378
CU80	2014	663	33		697
CU81	2014	146	11		157
CU82	2014	1,550	538		2,090
CU83	2013/2014	2,210	313		2,520
CU84	2013	1,770	865		2,640
CU85	2014	613	216		829
CU86	2014	227	11		238
CU87	2014	1,700	411		2,110
CU88	2014	1,730	674		2,410
CU89	2014	2,550	1,180		3,740
CU90	2014	927	235		1,160
CU91	2014	1,020	169		1,190
CU92	2014	1,550	392		1,940
CU93	2014	2,400	421		2,820
CU94	2015	251	46		298
CU95	2015	1,080	124		1,200
CU96	2015	1,310	351		1,670
CU97	2014	194	79		273
CU98	2014	179	79		258
CU99	2014	888	370		1,260
CU100	2013	14	6		20
Totals		**102,000**	**32,700**	**1,170**	**136,000**

Table A2-2b. Mass of Tri+PCB Removed from Certification Units in Phase 2

CU	Year Dredged	Pass 1 (kg)	Pass 2 (kg)	Pass 3 (kg)	Total (kg)
CU01a	2015	18			18
CU09	2011	119	82		200
CU10	2011	172	45		217
CU11	2011	292	142		435
CU12	2011	285	124		409
CU13	2011	230	35		265
CU14	2011	418	101		519
CU15	2011	722	351	1	1,070
CU16	2011	519	1,190	56	1,760
CU19	2011	358	47		406
CU20	2011	300	65	10	376
CU21	2011	248	82	10	340
CU22	2011	326	94	8	428
CU23	2011	312	148	17	476
CU24	2011	831	53		884
CU25	2011	541	133		674
CU26	2012	470	443	22	935
CU27	2012	415	160	0.4	576
CU28	2012	675	124		799
CU29	2012	284	81		365
CU30	2012	309	38		347
CU31	2012	97			97
CU32	2012	111	55		166
CU33	2012	173	30		203
CU34	2012	170	26		196
CU35	2012	627	248		875
CU36	2012	427	30		457
CU37	2012	419	46		465
CU38	2012	262	106		367
CU39	2012	326	15		341
CU40	2012	404	228	54	686
CU41	2012	471	255		726
CU42	2012	457	220		676
CU43	2012	552	104	36	692
CU44	2012	376	151	6	532
CU45	2012	216	58	0.5	274
CU46	2012	336	82		418
CU47	2012	173	22		195
CU48	2012	220	115		335
CU49	2013	279	35		314
CU50	2012	151	38		189
CU51	2012/2013	127	5		131
CU52	2012/2014	129	7		135
CU53	2012/2015	102	6		107
CU54	2013	349	7		356

CU	Year Dredged	Pass 1 (kg)	Pass 2 (kg)	Pass 3 (kg)	Total (kg)
CU55	2013	129	17		146
CU56	2013	354	204		558
CU57	2013	135	41		176
CU58	2013	188	8		196
CU59	2013	85			85
CU60	2015	198	5		203
CU61	2014	596	82	31	709
CU62	2014	212	24		236
CU63	2014	381	19		400
CU64	2014/2015	261	173		434
CU65	2015	459	222		681
CU66	2015	750	14		764
CU67	2013	930	51	8	989
CU68	2013	905	114	7	1,030
CU69	2013	639	70		708
CU70	2013	698	142	23	862
CU71	2013	368	59		426
CU72	2013	214	94		308
CU73	2013	371	67	5	443
CU74	2013	244	52		297
CU75	2013	209	30		240
CU76	2013	453	212	4	669
CU77	2013	534	175	28	737
CU78	2013	177	15	0.5	192
CU79	2013	89	18		107
CU80	2014	224	10		234
CU81	2014	60	4		65
CU82	2014	532	178		710
CU83	2013/2014	773	123		896
CU84	2013	551	278		829
CU85	2014	220	75		295
CU86	2014	73	5		77
CU87	2014	611	149		761
CU88	2014	731	302		1,030
CU89	2014	823	357		1,180
CU90	2014	349	74		423
CU91	2014	354	71		425
CU92	2014	539	124		663
CU93	2014	801	126		927
CU94	2015	131	21		152
CU95	2015	502	52		554
CU96	2015	714	156		870
CU97	2014	112	42		154
CU98	2014	160	63		224
CU99	2014	442	147		589
CU100	2013	16	4		20
Totals		**33,100**	**9,690**	**326**	**43,100**

Table A2-2c. Mass of TPCB in Sediment Removed from Certification Units in Phase 1 and 2 by Year

Year Dredged	Pass 1 (kg)	Pass 2 (kg)	Pass 3 (kg)	Pass 4 (kg)	Pass 5 (kg)	Total (kg)	GE calculated mass removed (kg)
2009	11,500	6,600	1,370	381	150	20,000	16,300
Phase 1 total	11,500	6,600	1,370	381	150	20,000	16,300
2011	16,200	8,620	314			25,200	27,200
2012	26,500	9,790	432			36,800	33,400
2013	28,200	6,090	285			34,500	32,500
2014	23,300	5,740	140			29,100	26,600
2015	7,700	2,430	0			10,100	8,190
Phase 2 total	102,000	32,700	1,170			136,000	128,000
Phase 1 + 2 Total	113,000	39,200	2,540	381	150	156,000	144,000

NOTE: Some CUs were dredged in multiple years; however, for EPA calculation of dredged volumes by year, CUs were grouped by the initial year a CU was dredged, so values may not match up with GE values.

Table A2-2d. Mass of Tri+PCB in Sediment Removed from Certification Units in Phase 1 and 2 by Year

Year Dredged	Pass 1 (kg)	Pass 2 (kg)	Pass 3 (kg)	Pass 4 (kg)	Pass 5 (kg)	Total (kg)	GE calculated mass removed (kg)
2009	3,040	1,800	413	150	64	5,460	N/A
Phase 1 total	3,040	1,800	413	150	64	5,460	N/A
2011	5,670	2,690	102			8,460	9,070
2012	8,120	2,670	119			10,900	10,100
2013	8,040	1,700	75			9,820	9,280
2014	8,120	1,980	31			10,100	8,920
2015	3,130	648	0			3,780	2,990
Phase 2 total	33,100	9,690	326			43,100	40,300
Phase 1 + 2 Total	36,100	11,500	739	150	64	48,600	N/A

NOTE: Some CUs were dredged in multiple years; however, for EPA calculation of dredged volumes by year, CUs were grouped by the initial year a CU was dredged, so values may not match up with GE values.

Table A2-3. Combined Phase 1 and Phase 2 PCB Mass and Volume Removal Estimated and Actual Values

Category	Source	Tri+ PCB Mass (kg)	Total PCB Mass (kg)	Total Area (acres)	Volume (cy)
Dredging Removal Estimates	2002 ROD Resp. Summ. (Table 363334-1 and 424851-1)	21,700	69,800	493	2,650,000
	2007 DAD report (Table 6-1)	N/A[1]	113,100	491	1,800,000
Actual Dredging Removal	2010 Phase 1 EPA Evaluation Report *and* Phase 2 Data	48,600	156,000	490	2,630,000

[1]: The 2007 DAD report did not report a Tri+PCB mass.

Table A2-4a. Capped Inventory of TPCB in Sediment Remaining in Certification Units after Phase 2 dredging

CU	Year Dredged	Inventory (kg)
CU01a	2015	0
CU09	2011	42
CU10	2011	5
CU11	2011	82
CU12	2011	25
CU13	2011	26
CU14	2011	47
CU15	2011	29
CU16	2011	9
CU19	2011	67
CU20	2011	0
CU21	2011	45
CU22	2011	19
CU23	2011	0
CU24	2011	15
CU25	2011	22
CU26	2012	249
CU27	2012	24
CU28	2012	58
CU29	2012	50
CU30	2012	17
CU31	2012	0
CU32	2012	42
CU33	2012	0
CU34	2012	0
CU35	2012	110
CU36	2012	106
CU37	2012	73
CU38	2012	0
CU39	2012	22
CU40	2012	709
CU41	2012	95
CU42	2012	189
CU43	2012	163
CU44	2012	56
CU45	2012	43
CU46	2012	42
CU47	2012	16
CU48	2012	0
CU49	2013	11
CU50	2012	14
CU51	2012/2013	29
CU52	2012/2014	0
CU53	2012/2015	17
CU54	2013	0

CU	Year Dredged	Inventory (kg)
CU55	2013	4
CU56	2013	17
CU57	2013	10
CU58	2013	0
CU59	2013	0
CU60	2015	12
CU61	2014	147
CU62	2014	4
CU63	2014	31
CU64	2014/2015	10
CU65	2015	13
CU66	2015	5
CU67	2013	30
CU68	2013	20
CU69	2013	29
CU70	2013	89
CU71	2013	13
CU72	2013	101
CU73	2013	46
CU74	2013	59
CU75	2013	12
CU76	2013	49
CU77	2013	45
CU78	2013	6
CU79	2013	2
CU80	2014	0
CU81	2014	0
CU82	2014	48
CU83	2013/2014	56
CU84	2013	37
CU85	2014	18
CU86	2014	0
CU87	2014	51
CU88	2014	113
CU89	2014	94
CU90	2014	26
CU91	2014	18
CU92	2014	42
CU93	2014	19
CU94	2015	4
CU95	2015	22
CU96	2015	35
CU97	2014	17
CU98	2014	0
CU99	2014	12
CU100	2013	0
Totals		**3,940**

Table A2-4b. Capped Inventory of Tri+PCB in Sediment Remaining in Certification Units after Phase 2 dredging

CU	Year Dredged	Inventory (kg)
CU01a	2015	
CU09	2011	15
CU10	2011	3
CU11	2011	27
CU12	2011	11
CU13	2011	9
CU14	2011	15
CU15	2011	11
CU16	2011	3
CU19	2011	16
CU20	2011	0
CU21	2011	21
CU22	2011	4
CU23	2011	26
CU24	2011	3
CU25	2011	5
CU26	2012	70
CU27	2012	5
CU28	2012	18
CU29	2012	18
CU30	2012	7
CU31	2012	0
CU32	2012	12
CU33	2012	0
CU34	2012	0
CU35	2012	28
CU36	2012	24
CU37	2012	16
CU38	2012	0
CU39	2012	5
CU40	2012	151
CU41	2012	21
CU42	2012	60
CU43	2012	38
CU44	2012	13
CU45	2012	10
CU46	2012	9
CU47	2012	4
CU48	2012	0
CU49	2013	2
CU50	2012	4
CU51	2012/2013	10
CU52	2012/2014	0
CU53	2012/2015	6
CU54	2013	0

CU	Year Dredged	Inventory (kg)
CU55	2013	1
CU56	2013	7
CU57	2013	3
CU58	2013	0
CU59	2013	0
CU60	2015	4
CU61	2014	37
CU62	2014	1
CU63	2014	9
CU64	2014/2015	2
CU65	2015	5
CU66	2015	2
CU67	2013	11
CU68	2013	5
CU69	2013	8
CU70	2013	27
CU71	2013	4
CU72	2013	23
CU73	2013	16
CU74	2013	13
CU75	2013	4
CU76	2013	16
CU77	2013	14
CU78	2013	4
CU79	2013	1
CU80	2014	0
CU81	2014	0
CU82	2014	16
CU83	2013/2014	18
CU84	2013	12
CU85	2014	8
CU86	2014	0
CU87	2014	17
CU88	2014	52
CU89	2014	29
CU90	2014	9
CU91	2014	6
CU92	2014	15
CU93	2014	5
CU94	2015	2
CU95	2015	9
CU96	2015	18
CU97	2014	9
CU98	2014	0
CU99	2014	5
CU100	2013	0
Totals		**1,140**

Table A2-5. Summary of Navigation Channel Volumes and PCB Mass Removed

Reach	Certification Unit	Area of CU w/in Channel (Acres)	%Area of CU w/in Channel	Volume Removed from Channel[1] (cy)	% CU Volume Removed in Channel	Average Depth of Cut in Channel (feet)	Tri+ PCB Mass Removed from Channel[4] (kg)	Total PCB Mass Removed from Channel (kg)
8	1[2]	2.72	80.1	47,142	87%	9.55	N/A	380
	1A[3]	---	---	7,392	---	2.12	10	20
	2	1.12	22.1	8,631	28%	4.78	N/A	660
	3	0.88	18.0	10,171	23%	7.18	N/A	1,330
	4	1.15	25.5	8,846	26%	4.77	N/A	640
	11	0.00	0.04	2	0%	0.73	0	0
	12	2.01	40.6	8,447	40%	2.61	120	280
	13	3.62	74.5	11,569	64%	1.98	180	540
	14	2.03	40.7	5,855	23%	1.78	90	240
	15	2.34	47.9	8,826	27%	2.34	270	750
	16	2.64	47.9	7,187	28%	1.69	160	440
	17	0.52	10.5	919	6%	1.09	N/A	10
	19	1.71	34.4	8,496	33%	3.07	160	310
	20	1.73	34.2	12,211	50%	4.37	240	510
	21	2.16	43.4	13,585	54%	3.89	210	390
	22	1.75	34.9	12,622	48%	4.46	250	490
	23	1.48	29.5	10,351	41%	4.34	220	460
	24	1.45	28.9	13,856	42%	5.90	460	920
	25	1.08	21.4	6,714	28%	3.86	170	360
	26	1.63	38.4	15,748	63%	6.00	500	1,330
	27	2.00	47.8	14,935	74%	4.63	430	1,220
	28	1.49	31.5	8,873	35%	3.70	230	570
	29	1.29	26.1	4,168	21%	2.00	40	90
	30	1.49	30.1	4,931	25%	2.05	50	130
	31	1.26	26.1	3,372	30%	1.66	30	70
	32	1.10	22.3	3,482	24%	1.96	40	90
	33	1.67	30.4	7,538	40%	2.80	100	230
	34	2.14	53.9	7,675	55%	2.22	90	180
	37	2.50	37.4	6,339	19%	1.57	80	190
	38	0.86	15.4	1,889	7%	1.36	30	110
	39	0.93	16.6	2,685	13%	1.80	50	120
	40	1.86	33.5	9,915	34%	3.31	160	390
	41	2.38	42.4	14,321	43%	3.73	220	490
	42	2.07	39.0	14,873	53%	4.44	220	580
	43	2.33	43.0	12,271	45%	3.26	200	530
	44	1.80	36.1	10,369	39%	3.57	170	370
	45	1.56	31.4	4,168	23%	1.65	50	110
	46	0.75	14.5	1,548	9%	1.28	20	80
	47	0.88	22.3	2,434	13%	1.71	30	50
	48	2.20	39.9	5,969	28%	1.68	70	170
	49	2.65	40.9	6,573	37%	1.54	70	150
	55	2.44	47.4	6,057	44%	1.53	60	110
	56	1.99	34.2	4,066	18%	1.27	30	80
	57	1.70	31.2	4,024	16%	1.47	30	90
	58	1.97	32.8	6,810	33%	2.14	70	280

Reach	Certification Unit	Area of CU w/in Channel (Acres)	%Area of CU w/in Channel	Volume Removed from Channel[1] (cy)	% CU Volume Removed in Channel	Average Depth of Cut in Channel (feet)	Tri+ PCB Mass Removed from Channel[4] (kg)	Total PCB Mass Removed from Channel (kg)
6	67	0.89	16.0	8,345	20%	5.82	200	700
	68	1.18	22.5	9,971	24%	5.22	180	560
	69	0.14	2.6	562	1%	2.51	10	40
	70	0.04	0.8	393	1%	5.92	0	10
	71	0.00	0.1	12	0%	2.78	0	0
	73	0.02	0.4	74	0%	1.98	0	0
	74	0.21	4.5	579	3%	1.67	10	20
	75	0.07	2.1	324	2%	3.04	10	20
	77	1.36	32.7	19,260	36%	8.75	200	460
	78	0.88	33.0	6,954	37%	4.91	60	160
5	80	0.16	6.2	492	3%	1.93	10	20
	82	0.00	0.02	4	0%	2.29	0	0
	83	0.55	8.4	4,151	7%	4.64	90	210
	88	0.84	13.8	4,347	9%	3.19	60	130
	91	0.30	5.6	486	1%	1.00	0	10
4	92	0.01	0.2	74	0%	3.76	1	5
3	96	0.08	1.1	303	1%	2.21	3	5
Total Inside CU		**82.1**	**16.7**	**444,186**	**16%**	**3.2**	**6,444 (excludes Phase 1 CUs)**	**18,890**
Outside CU[6]		---	---	7,286	---	---	---	---

Notes

Table compiled by and GE and provided to EPA.

1. Navigation channel removal volumes based on CU-wide volumes obtained from Parsons. For internal use only.

2. Combines 2009 and 2015 dredging within CU-1. Volume removed from within CU-1 (within the channel) by year: 2009 = 42,525 cy; 2015 = 4,617 cy

3. Data represent 2015 dredging outside the CU-1 boundary.

4. Tri+ PCB mass was not calculated for Phase 1 areas.

5. Water depths based on the design shoreline elevation (reach specific) and the final post-dredging/post-capping/backfill surveys. Phase 1 areas based on 2009 surveys.

6. Areas outside the CUs (excluding 1A) based on bathymetry survey extents to account for dredge-to-daylight areas; not representative of the navigation channel as a whole. Survey extents vary between the post-dredging and post-capping/backfill surveys.

CU - certification unit

CY - cubic yards; kg - kilograms; ft - feet

Table A2-6a. Estimate of Mass of TPCB in Sediment Outside Dredged Areas in Upper Hudson River (Method 1: Recovery Corrected)

River Section	Total area (acres)	Dredged area (acres)	Total non-dredged area (acres)[1]	Sediment type[2]	Subgroup[3]	Non-dredged area of sediment texture class (acres)	Number of SSAP/SEDC cores used to calculate mass outside CUs	Average mass per unit Area (MPA) (g/m2)[5]	Mass dredged (kg)[4]	ROD Estimate of Mass Removed (kg)	Mass remaining in engineered capped areas and non-capped dredged areas (kg)[6]	Mass outside CUs (kg)	ROD Estimate of Mass Remaining (kg)	Total PCB mass in River Section (kg)	Percent PCB mass removed (%)
1	553	307	219	All	N/A	N/A	970	2.27	90,000	36,000	4,800	2,000	9,200	96,800	93
2	474	85	329	All	N/A	N/A	877	8.27	36,000	24,300	900	10,400	3,800	47,300	76
3	2929	99	2487	Silt	N/A	327	1770	11.3	30,000	9,500	800	14,200	24,500	78,200	38
				Transitional	N/A	265	282	8.87				8,600			
				Silt and Sand	N/A	700	315	4.42				14,100			
				Gravel	N/A	728	99	2.15				4,500			
				Unclassified	High Density Core (HDC) Areas	55	224	1.68 (min) to 67.58 (max)				3,100			
					Non-HDC Areas	396	12	1.84				2,900			
Total:	3956	491	3035	-	-	-	-	-	156,000	69,800	6,500	59,800	37,500	222,000	70

[1]: CU areas and bedrock substrate removed from all River Sections.

[2]: River Section 1 and 2 were not stratified by sediment texture class; River Section 3 was stratified by sediment texture class.

[3]: Unclassified areas in River Section 3 were sub-divided into high density core (HDC) and non-HDC areas. See text for additional details on methodology.

[4]: The mass dredged in River Section 1 includes both Phase 1 (20,000 kg) and Phase 2 dredging (70,000 kg).

[5]: The average mass per unit area (MPA) for Non-HDC River Section 3 Unclassified sediment areas is calculated by averaging the 99 River Section 3 gravel cores and 12 Non-HDC cores.

[6]: Mass remaining in areas covered by engineered caps and non-capped dredged areas in River Section 1 CUs includes results from both Phase 1 and Phase 2 dredging activities (1,600 kg remained in Phase 1 CUs. EPA, 2010c).

Table A2-6b. Estimate of Mass of TPCB in Sediment Outside Dredged Areas in Upper Hudson River (Method 2: Non-Recovery Corrected)

River Section	Total area (acres)	Dredged area (acres)	Total non-dredged area (acres)[1]	Sediment type[2]	Subgroup[3]	Non-dredged area of sediment texture class (acres)	Number of SSAP/SEDC cores used to calculate mass outside CUs	Average mass per unit Area (MPA) (g/m2)[5]	Mass dredged (kg)[4]	ROD Estimate of Mass Removed (kg)	Mass remaining in engineered capped areas and non-capped dredged areas (kg)[6]	Mass outside CUs (kg)	ROD Estimate of Mass Remaining (kg)	Total PCB mass in River Section (kg)	Percent PCB mass removed (%)
1	553	307	219	All	N/A	N/A	970	1.60	90,000	36,000	4,800	1,400	9,200	96,200	94
2	474	85	329	All	N/A	N/A	877	5.36	36,000	24,300	900	7,100	3,800	44,000	82
3	2929	99	2487	Silt	N/A	327	1770	7.94	30,000	9,500	800	10,500	24,500	63,300	47
				Transitional	N/A	265	282	4.95				5,300			
				Silt and Sand	N/A	700	315	3.31				9,400			
				Gravel	N/A	728	99	1.03				3,000			
				Unclassified	High Density Core (HDC) Areas	55	224	1.23 (min) to 50.69 (max)				2,200			
					Non-HDC Areas	396	12	1.30				2,100			
Total:	3956	491	3035	-	-	-	4549	-	156,000	69,800	6,500	41,000	37,500	204,000	76

[1]: CU areas and bedrock substrate removed from all River Sections.

[2]: River Section 1 and 2 were not stratified by sediment texture class; River Section 3 was stratified by sediment texture class.

[3]: Unclassified areas in River Section 3 were sub-divided into high density core (HDC) and non-HDC areas. See text for additional details on methodology.

[4]: The mass dredged in River Section 1 includes both Phase 1 (20,000 kg) and Phase 2 dredging (70,000 kg).

[5]: The average mass per unit area (MPA) for Non-HDC River Section 3 Unclassified sediment areas is calculated by averaging the 99 River Section 3 gravel cores and 12 Non-HDC cores.

[6]: Mass remaining in areas covered by engineered caps and non-capped dredged areas in River Section 1 CUs includes results from both Phase 1 and Phase 2 dredging activities (1,600 kg remained in Phase 1 CUs. EPA, 2010c).

Table A2-7. Comparison of TPCB Mass Outside Dredged Areas - Best Estimate vs ROD (Method 2: Non-Recovery Corrected)

River Section	Total area (acres)	Dredged area (acres)	Total non-dredged area (acres)[1]	Actual TPCB Mass Removed (kg)	Actual TPCB Mass Remaining (kg)	ROD Estimate of Mass Remaining	Percent Difference from ROD
1	553	307	219	90,000	1,400	9,200	-85%
2	474	85	329	36,000	7,100	3,800	87%
3	2,929	99	2,487	30,000	32,500	24,500	33%
Total	3,956	491	3,035	156,000	41,000	37,500	9%

Final Second Five-Year Review Report for the Hudson River PCBs Superfund Site

APPENDIX 2

MASS REDUCTION EVALUATION

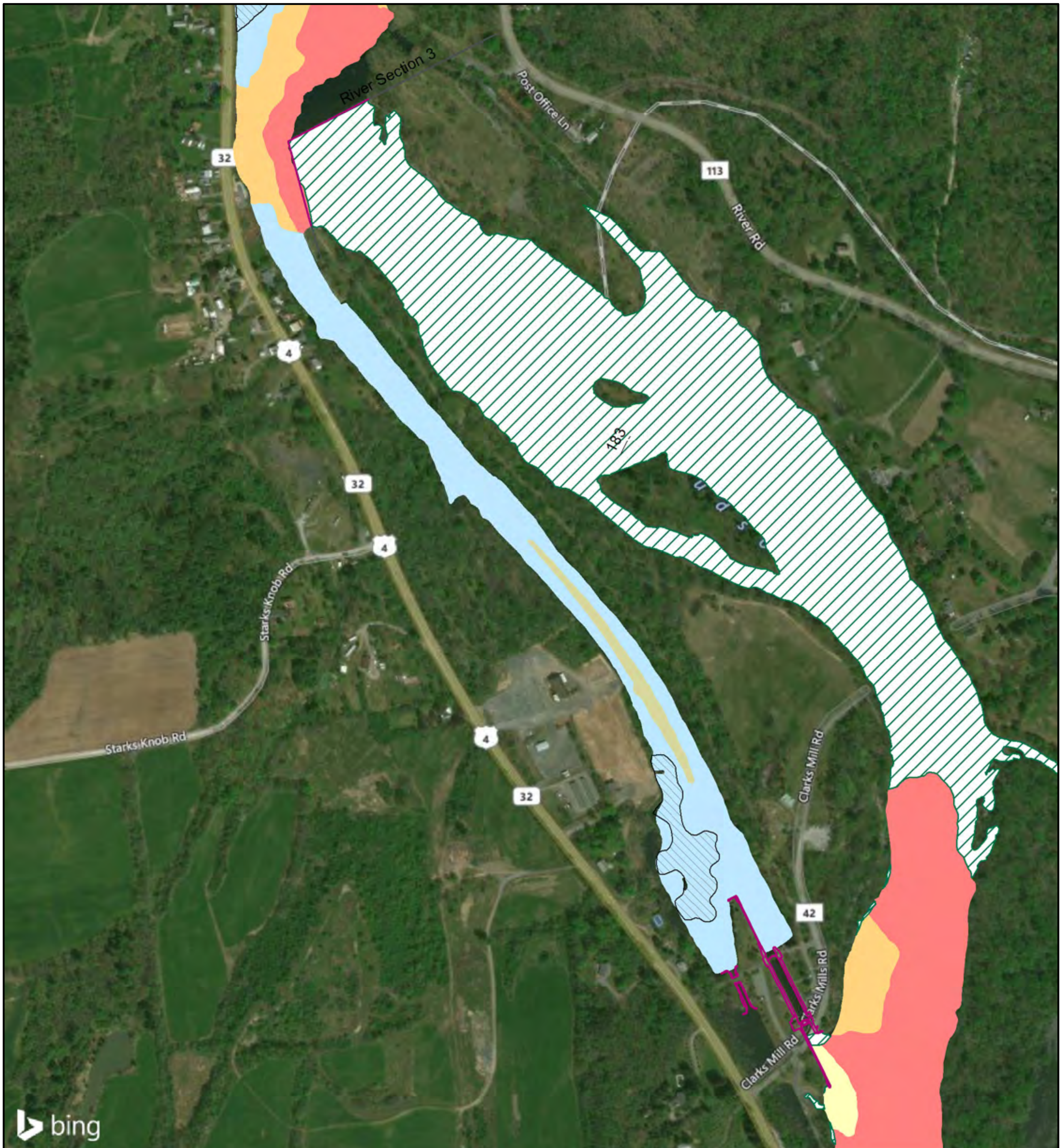
Figures

Prepared by:

Louis Berger US, Inc.

LimnoTech, Inc.

April 2019



SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

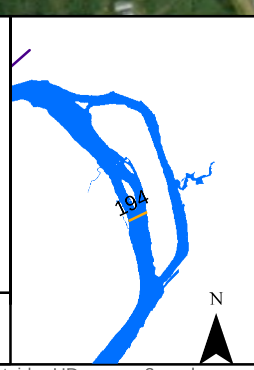
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1a

Louis Berger

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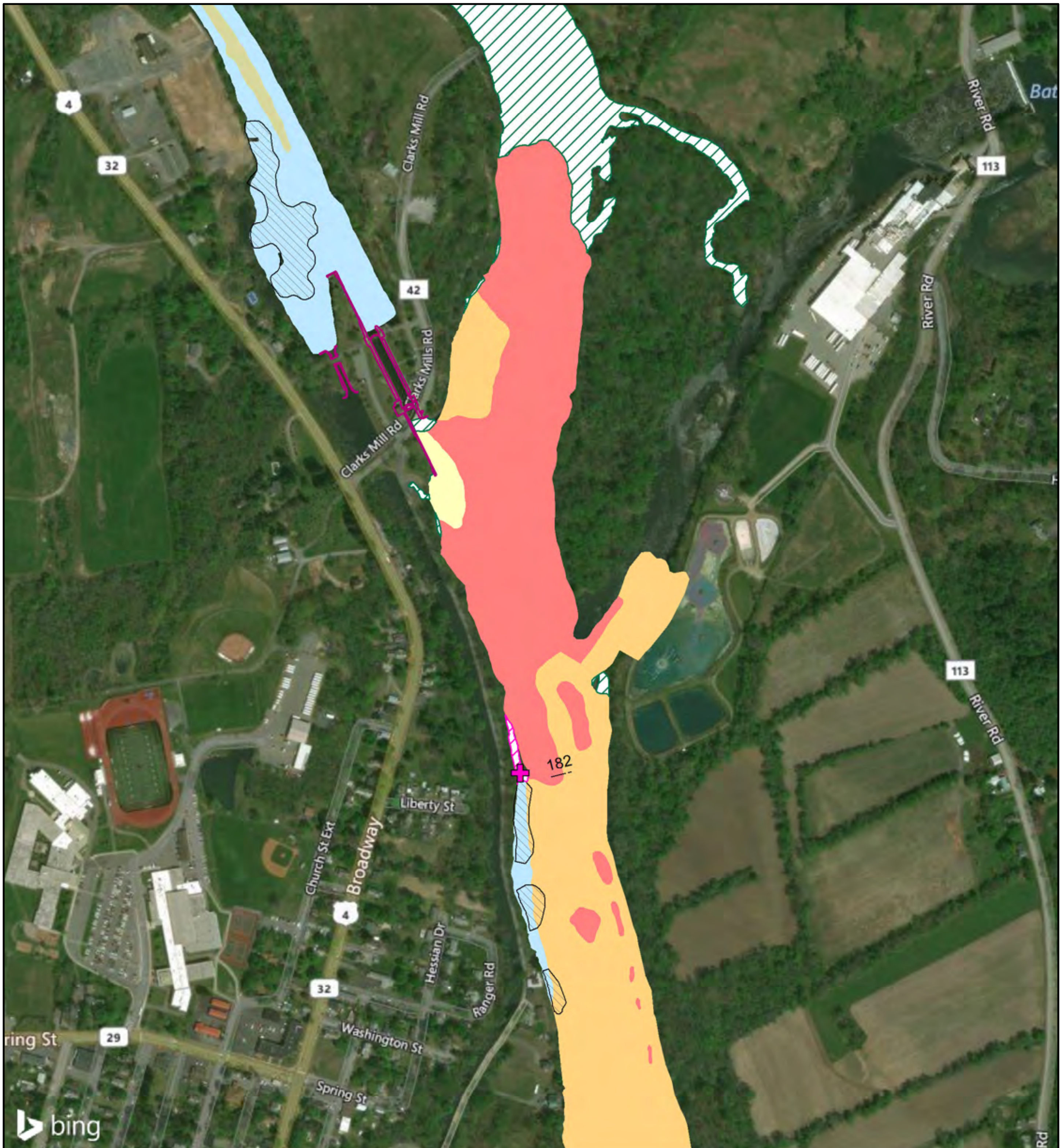


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

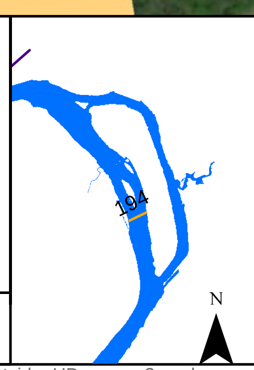
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1b

Louis Berger

0 250 500 Feet

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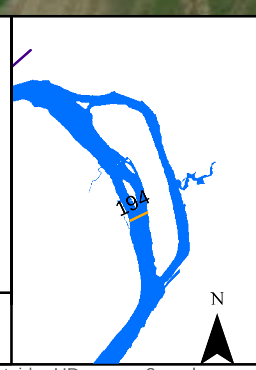
SSAP/SEDC Cores in HDC Areas	
SSAP/SEDC Cores in Non-HDC Areas	
RS3 Unclassified High Density Core (HDC) Areas	
RS3 Unclassified Non-HDC Areas	
Dams and Locks	
Mile Markers	
Certification Units	

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1c

Louis Berger

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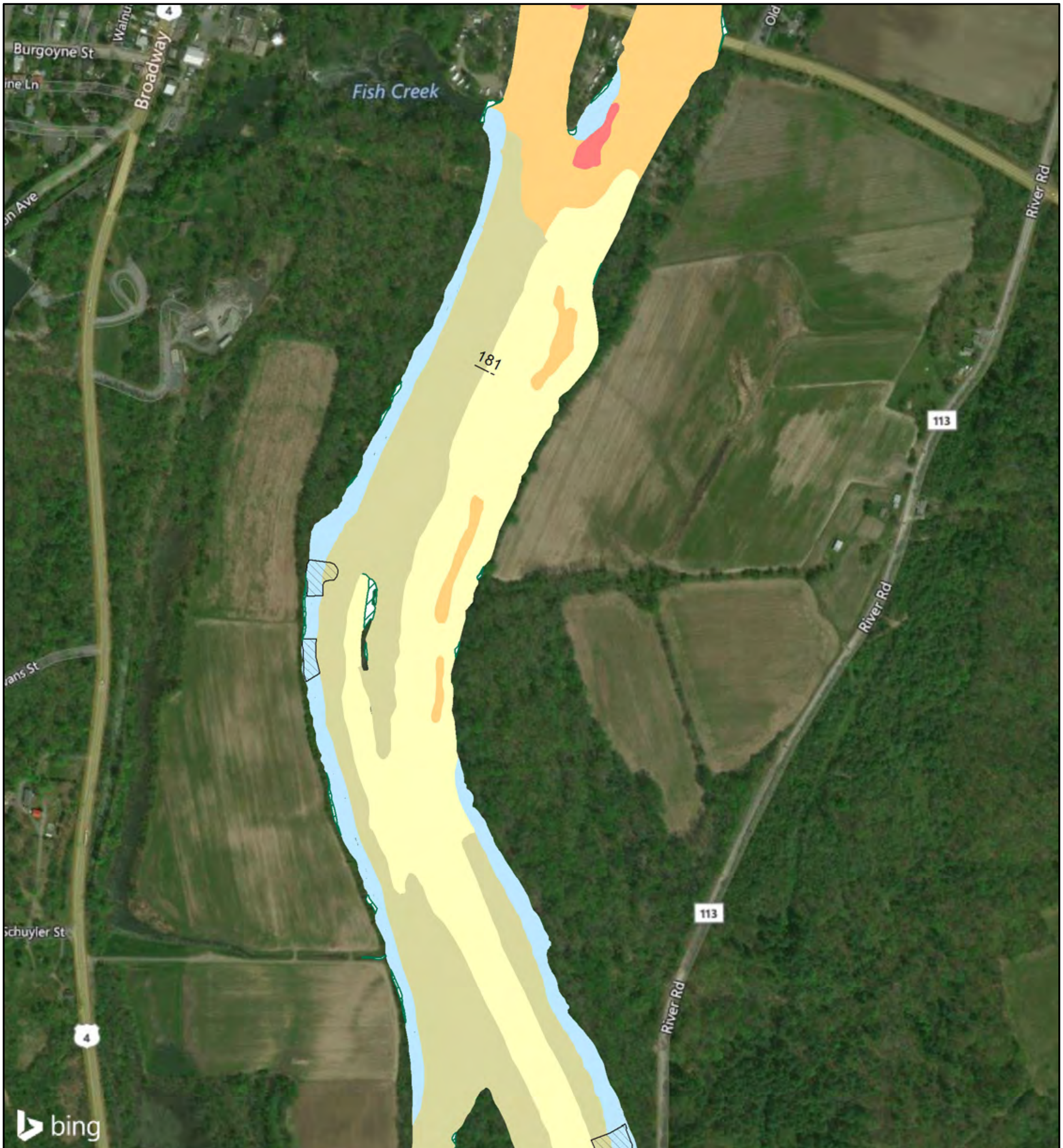
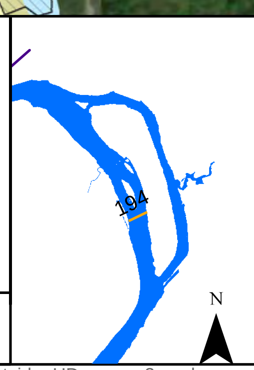


SSAP/SEDC Cores in HDC Areas
SSAP/SEDC Cores in Non-HDC Areas
RS3 Unclassified High Density Core (HDC) Areas
RS3 Unclassified Non-HDC Areas
Dams and Locks
Mile Markers
Certification Units

Sediment Type
Silt
Silt and Sand
Gravel
Transitional
Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1d

Louis Berger

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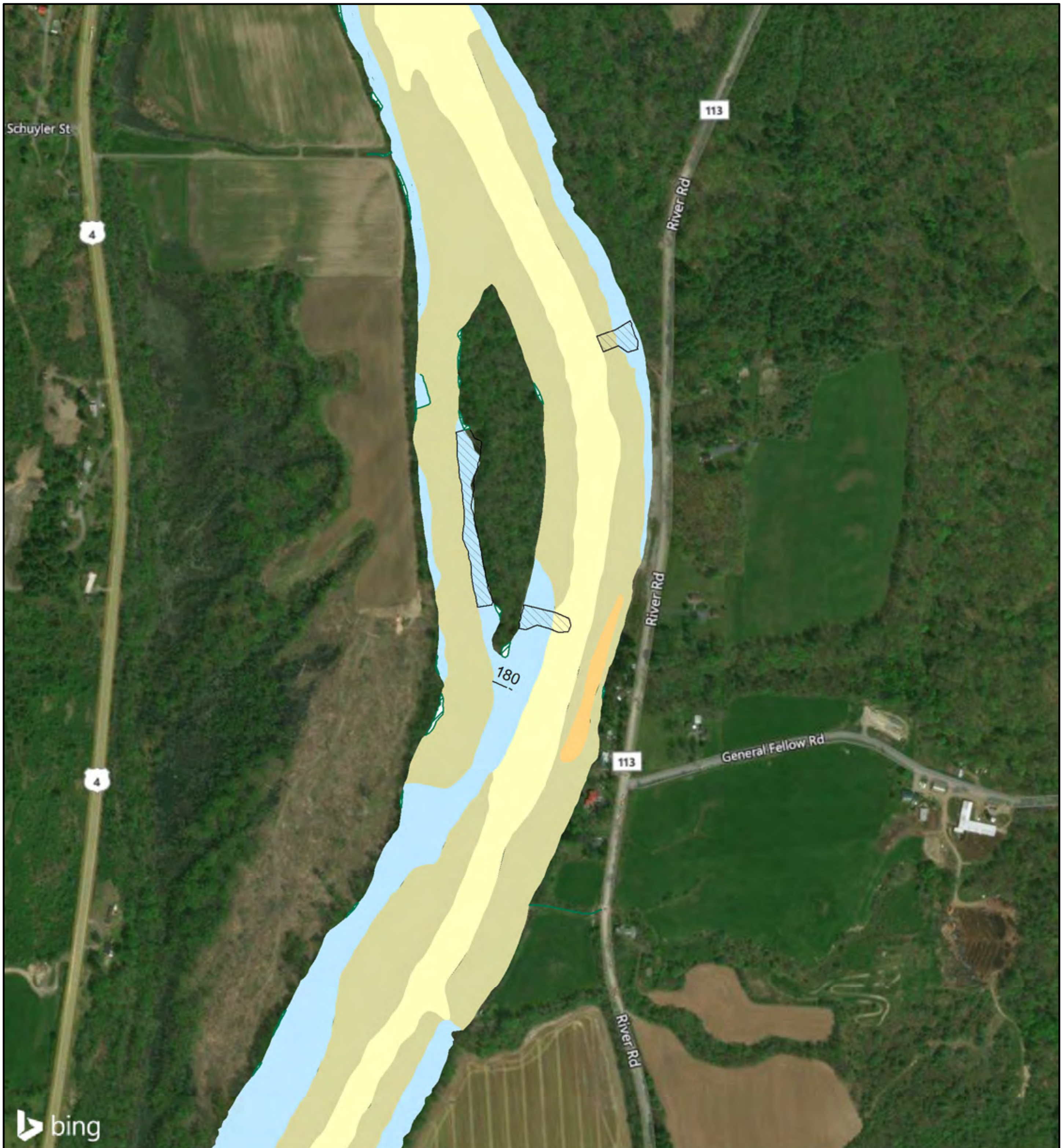


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

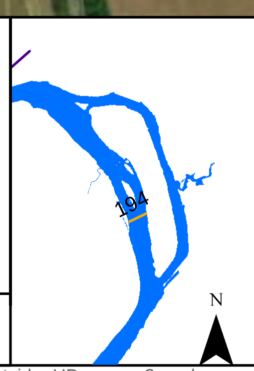
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1e

Louis Berger

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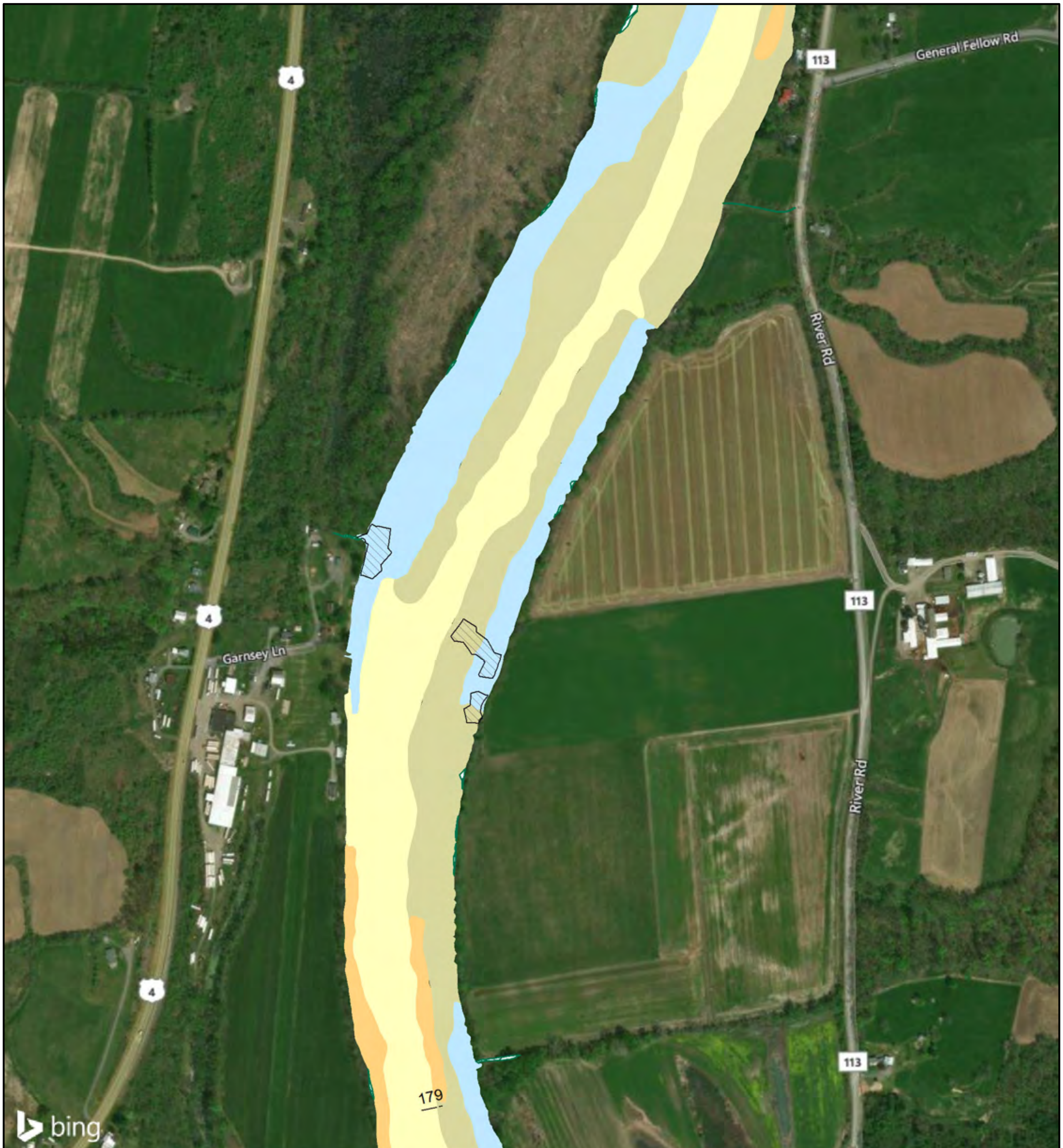
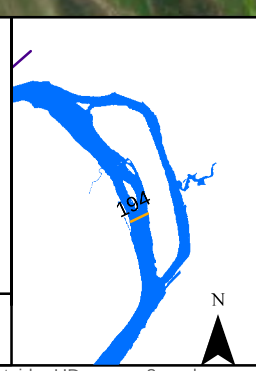


- SSAP/SEDC Cores in HDC Areas
- SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1f

Louis Berger

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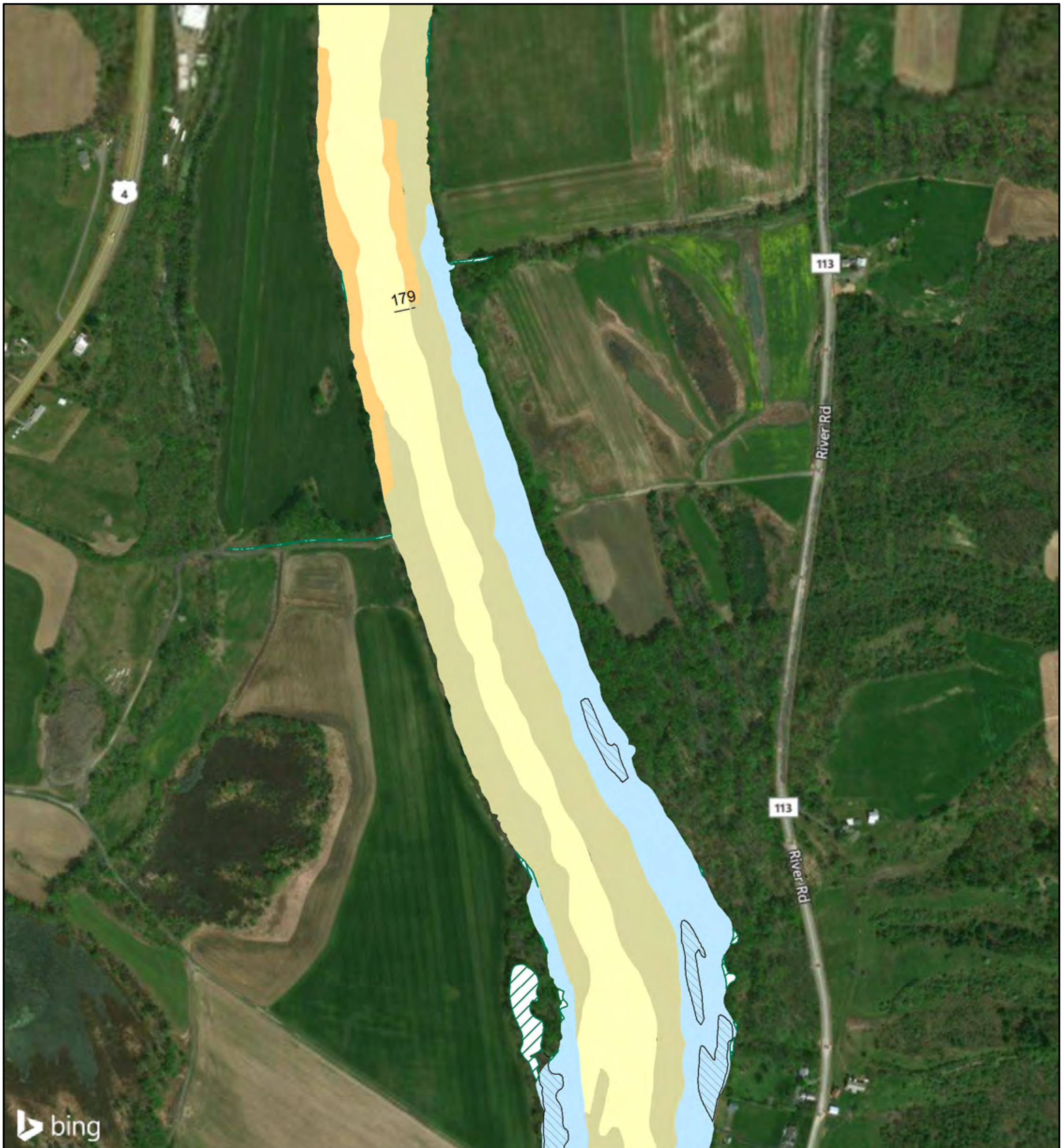


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

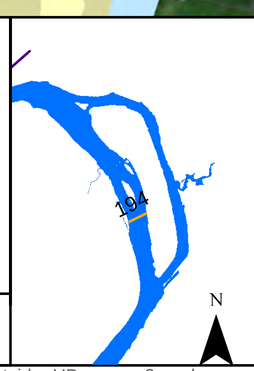
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1g

Louis Berger

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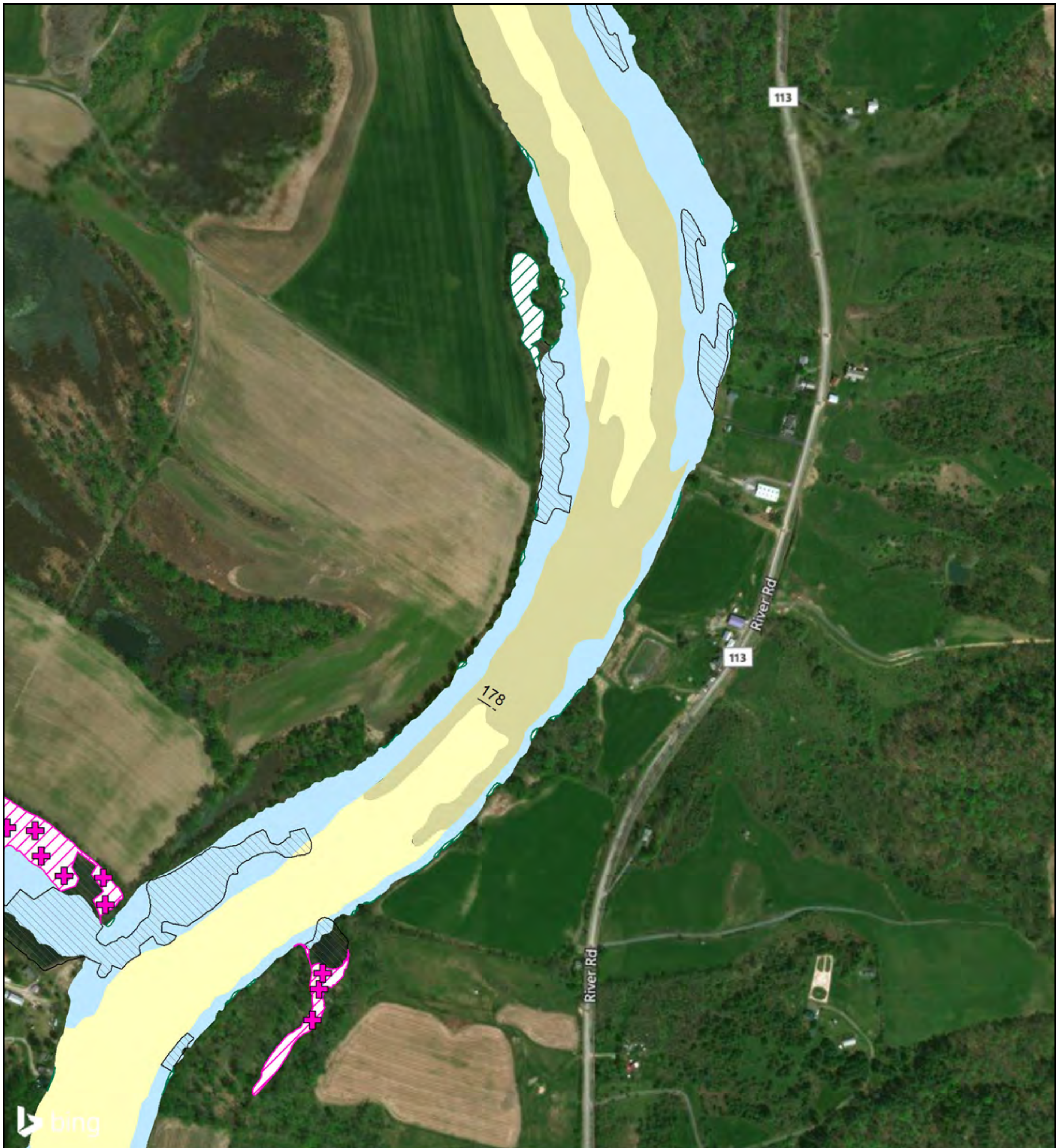


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

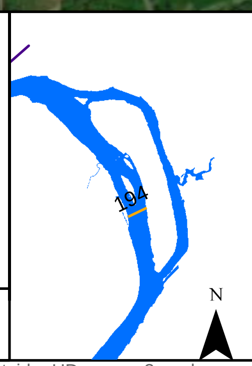
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1h

Louis Berger

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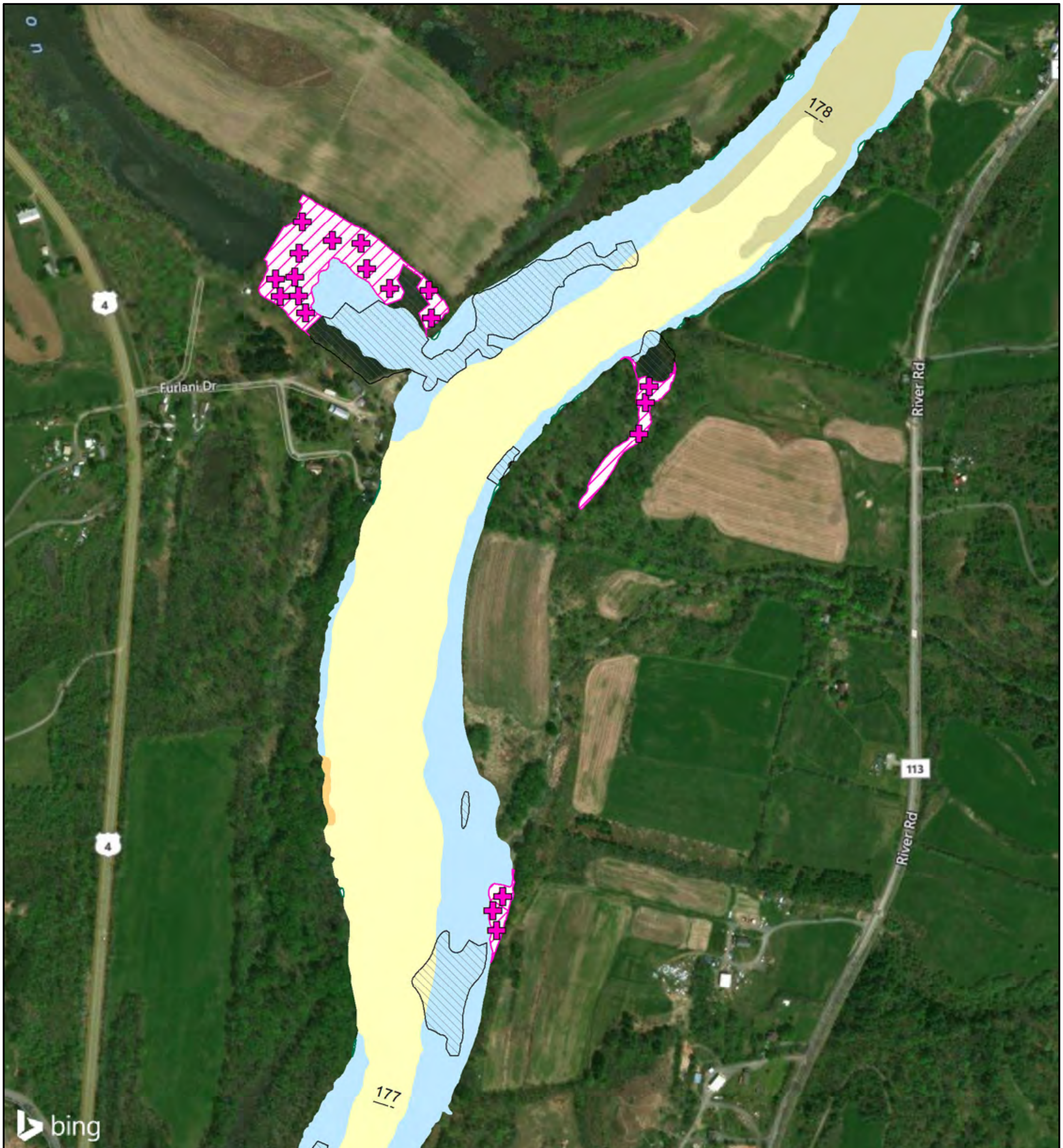

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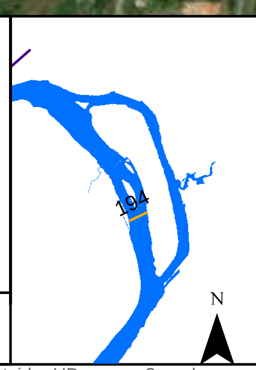
✚ (green)	SSAP/SEDC Cores in Non-HDC Areas
(magenta hatch)	RS3 Unclassified High Density Core (HDC) Areas
(green hatch)	RS3 Unclassified Non-HDC Areas
(magenta line)	Dams and Locks
(dash-dot line)	Mile Markers
(grey hatch)	Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1i

Louis Berger

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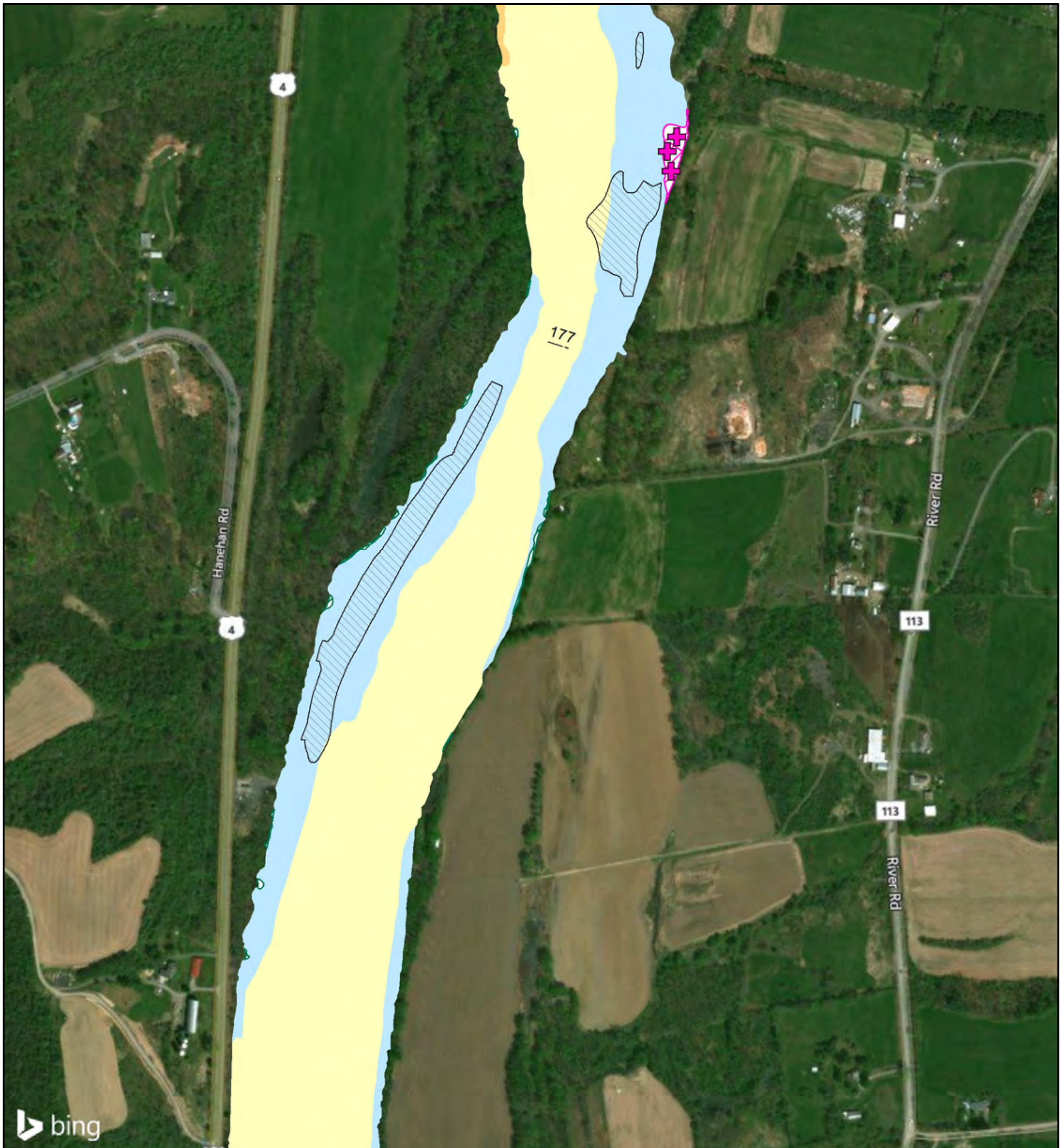

SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
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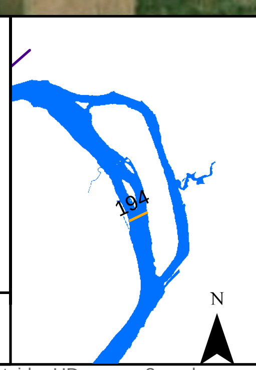
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1j

Louis Berger

0 250 500 Feet

SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

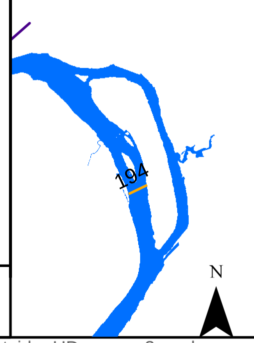
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1k

Louis Berger

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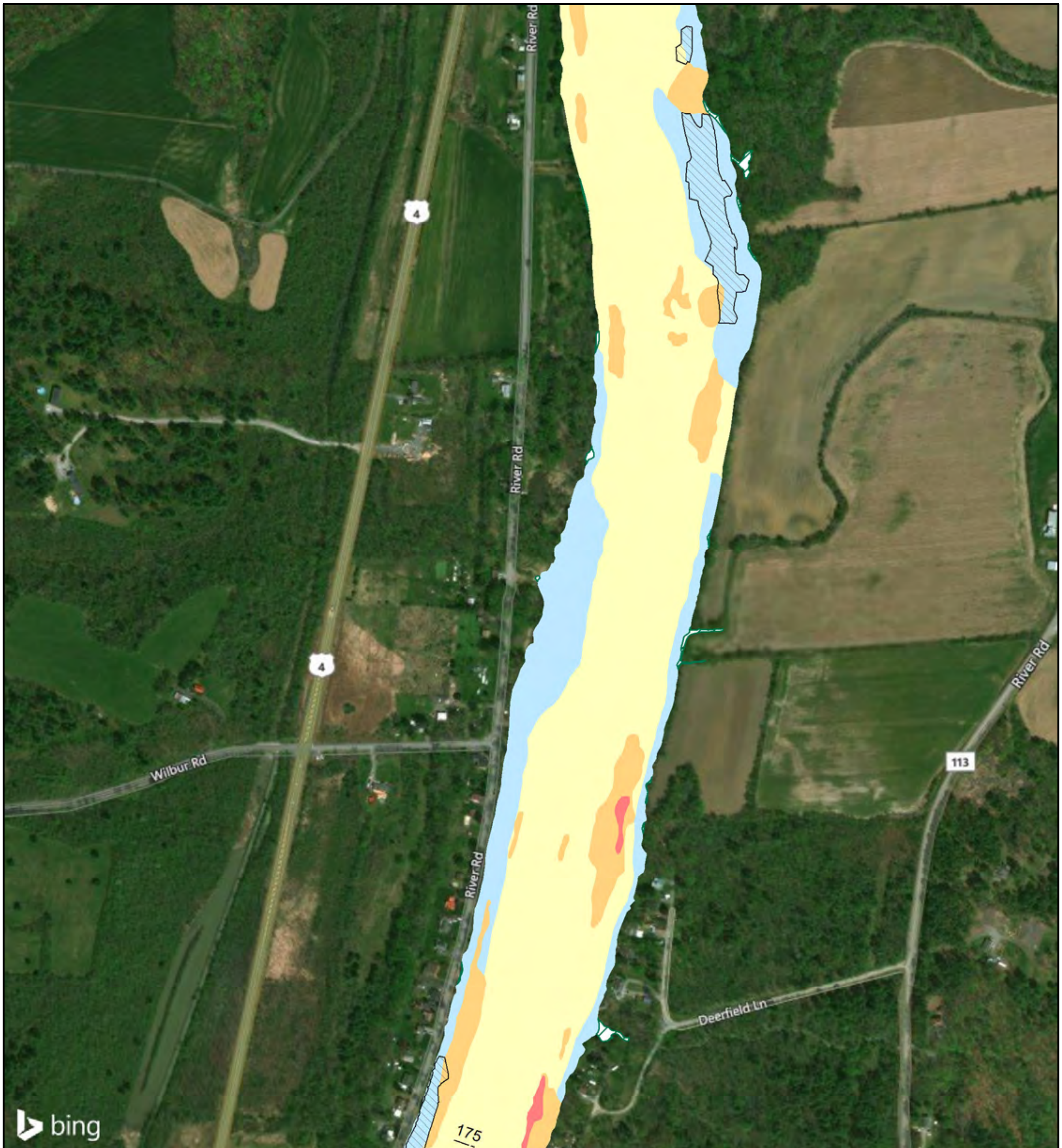
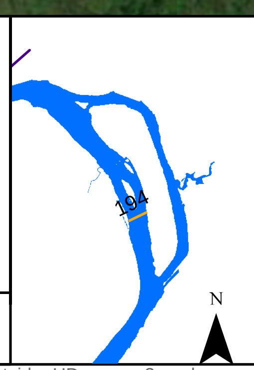


SSAP/SEDC Cores in HDC Areas
SSAP/SEDC Cores in Non-HDC Areas
RS3 Unclassified High Density Core (HDC) Areas
RS3 Unclassified Non-HDC Areas
Dams and Locks
Mile Markers
Certification Units

Sediment Type
Silt
Silt and Sand
Gravel
Transitional
Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1l

Louis Berger

0 250 500 Feet

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		Sediment Type	
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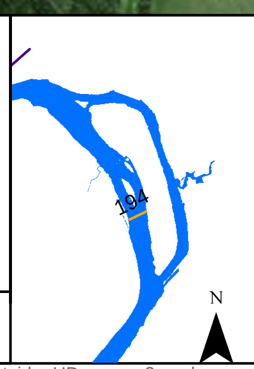
✚ (green)	SSAP/SEDC Cores in Non-HDC Areas	Silt and Sand	
	RS3 Unclassified High Density Core (HDC) Areas	Gravel	
	RS3 Unclassified Non-HDC Areas	Transitional	
	Dams and Locks	Bed Rock	
	Mile Markers		
	Certification Units		

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1m

Louis Berger

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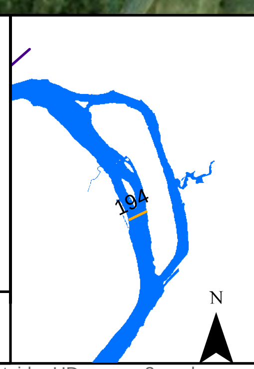


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1n

Louis Berger

0 250 500 Feet

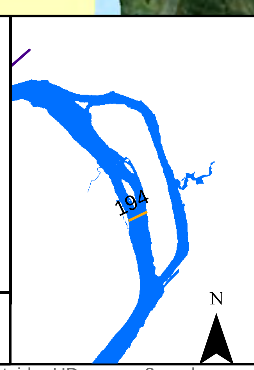
Document Path: U:\Hudson_River_Files\GIS\arcgis_mxds\FYR2017_Appendix_2_RS3_MassOutside_HDcores_v2.mxd

SSAP/SEDC Cores in HDC Areas	
SSAP/SEDC Cores in Non-HDC Areas	
RS3 Unclassified High Density Core (HDC) Areas	
RS3 Unclassified Non-HDC Areas	
Dams and Locks	
Mile Markers	
Certification Units	

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1o

Louis Berger

0 250 500 Feet

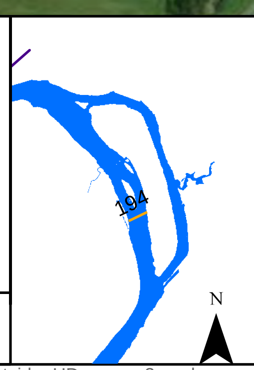
Document Path: U:\Hudson_River_Files\GIS\arcgis_mxds\FYR2017_Appendix_2_RS3_MassOutside_HDcores_v2.mxd

- SSAP/SEDC Cores in HDC Areas
- SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1p

Louis Berger

0 250 500 Feet

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SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

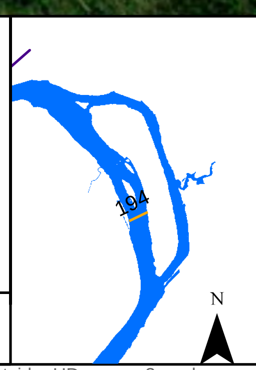
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1q

Louis Berger

0 250 500 Feet

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SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

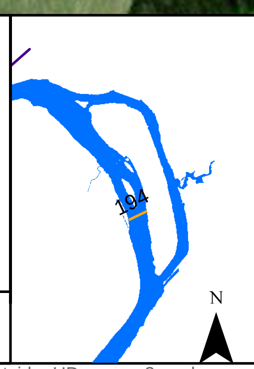
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1r

Louis Berger

0 250 500 Feet

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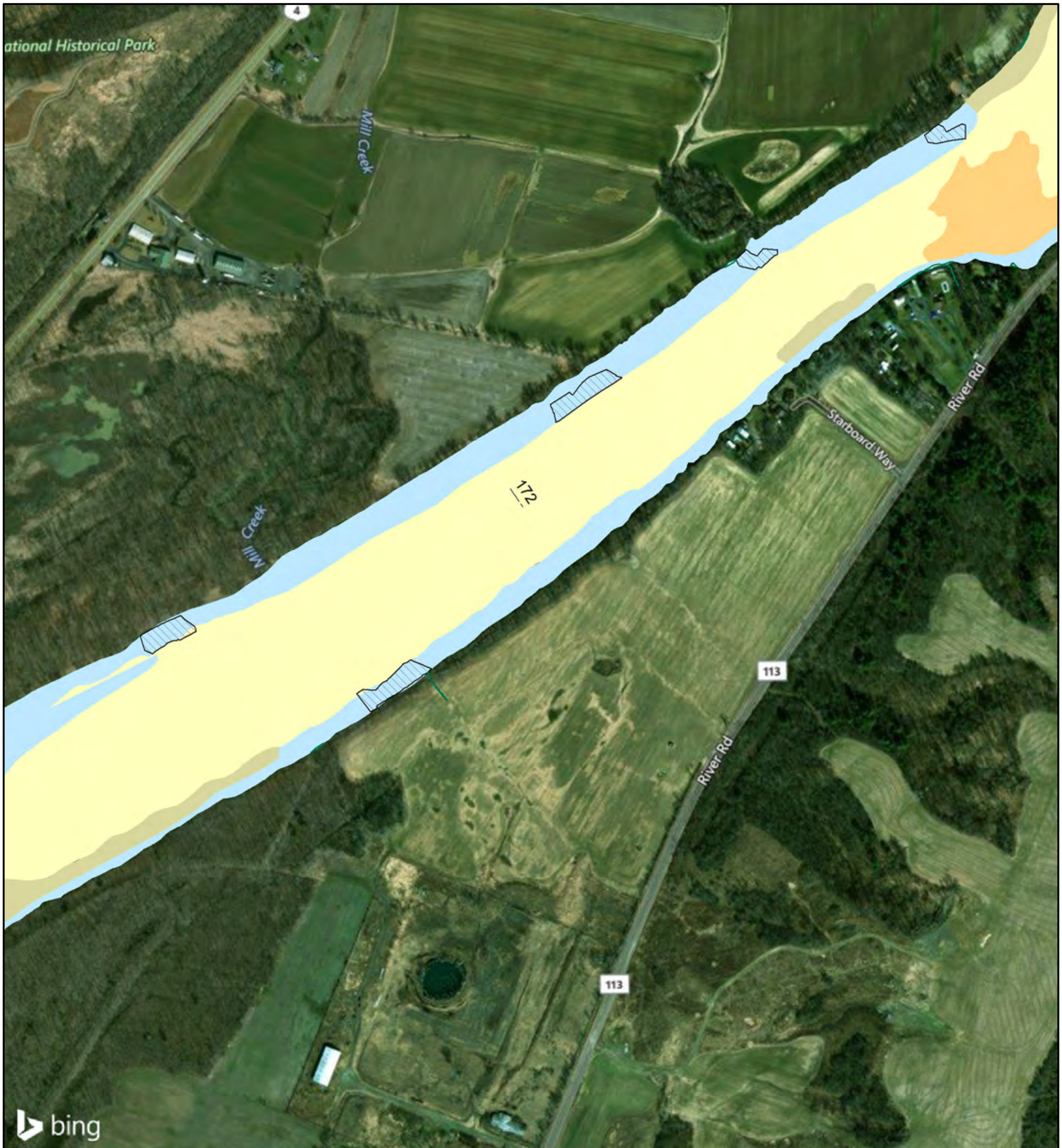

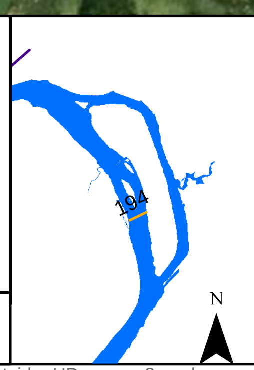

SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1s

Louis Berger

0 250 500 Feet

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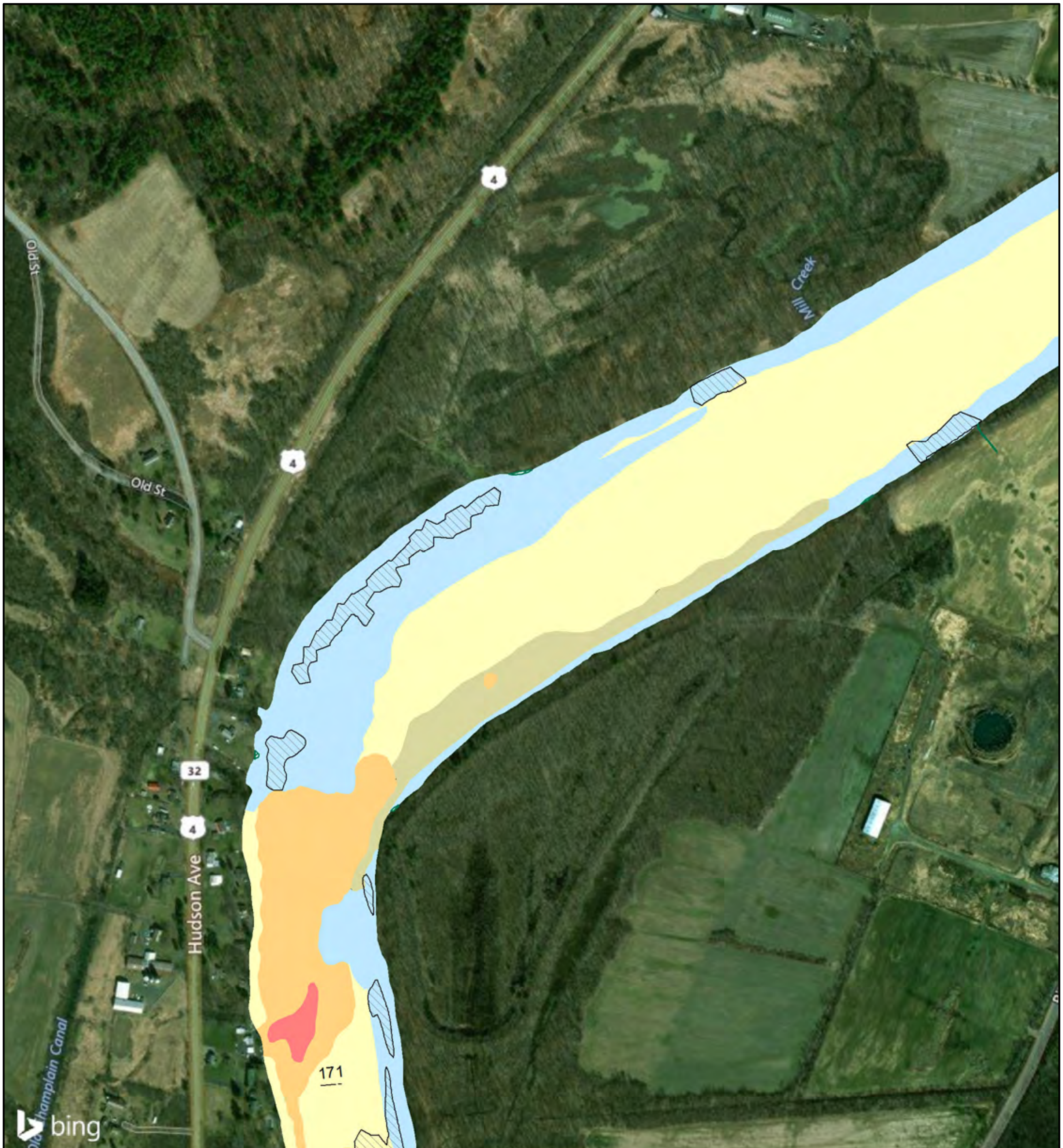


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

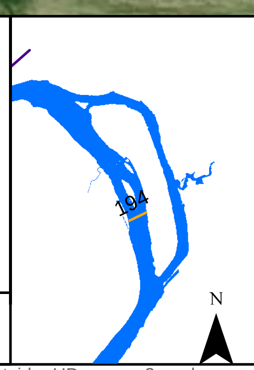
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1t

Louis Berger

0 250 500 Feet

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SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

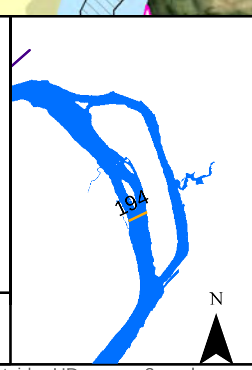
Silt

Silt and Sand

Gravel

Transitional

Bed Rock



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1u

Louis Berger

0 250 500 Feet

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

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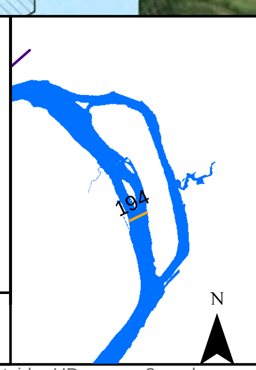
- SSAP/SEDC Cores in HDC Areas
- SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1v

Louis Berger

0 250 500 Feet

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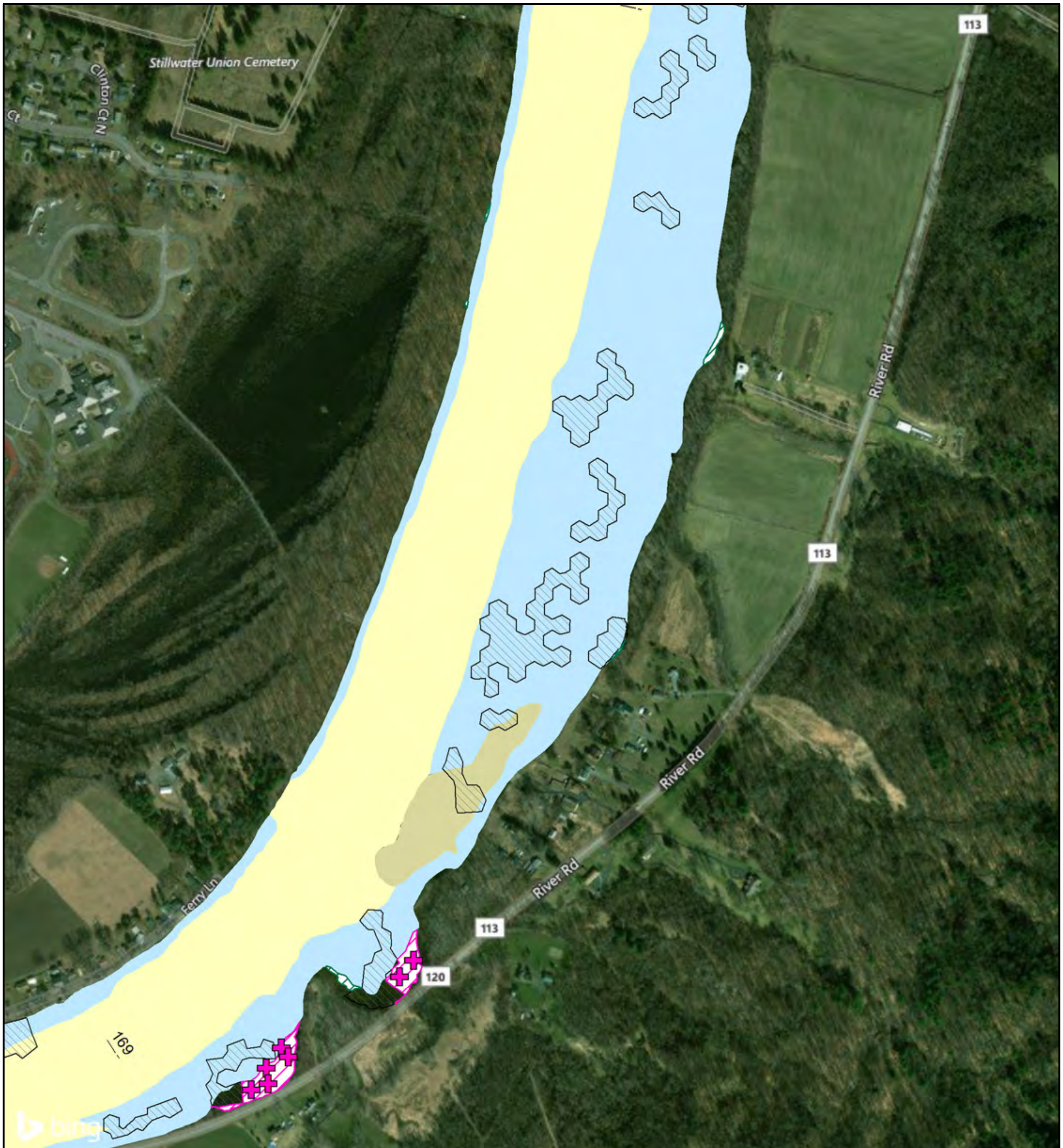
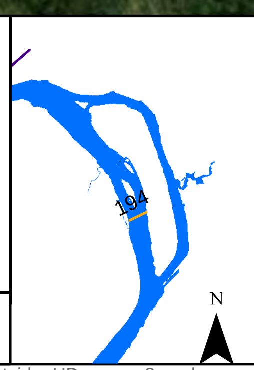


- ✚ SSAP/SEDC Cores in HDC Areas
- ✚ SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1w

Louis Berger

0 250 500 Feet

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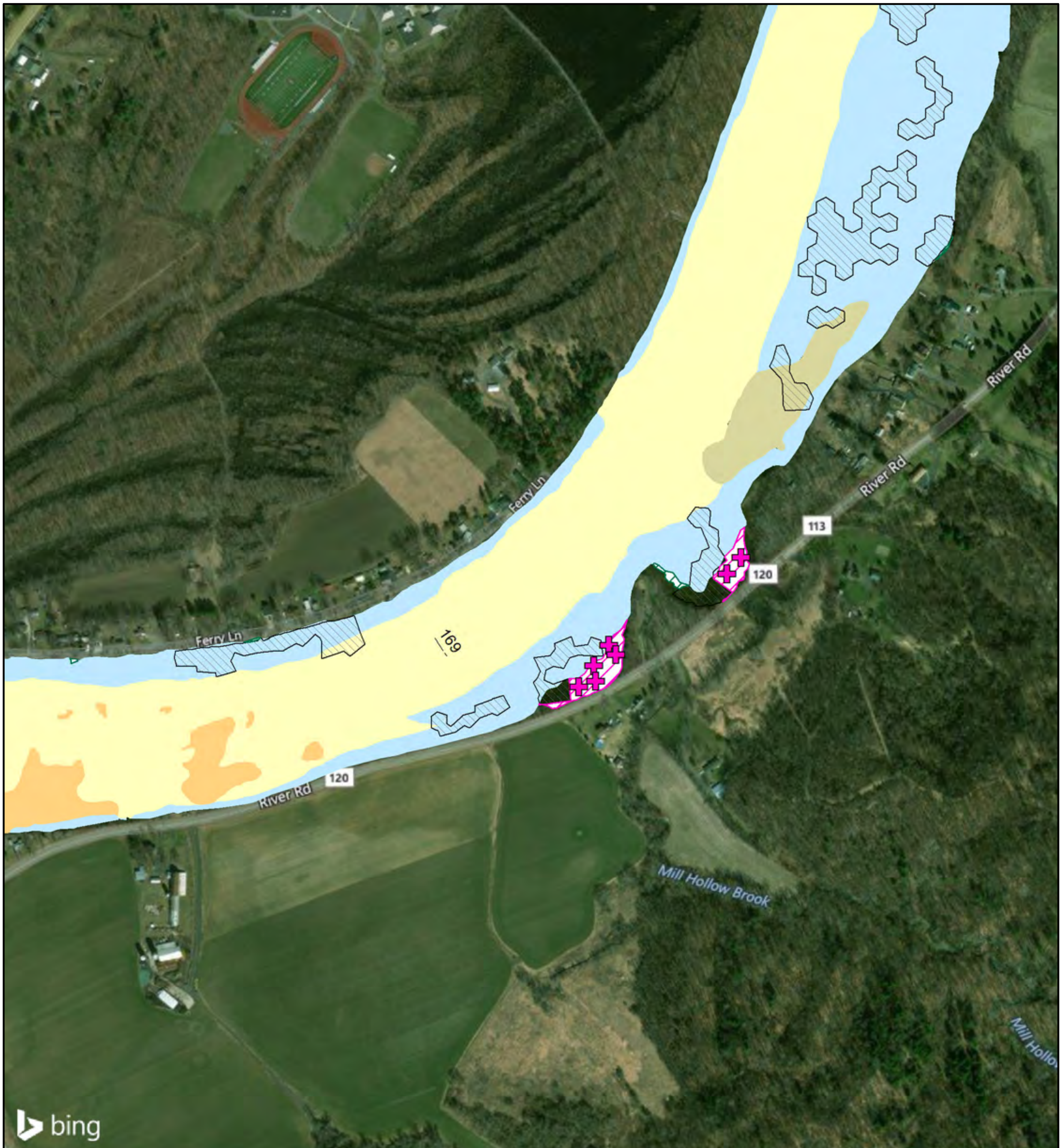
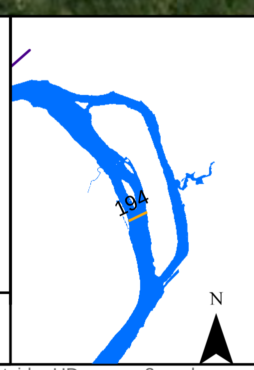


- SSAP/SEDC Cores in HDC Areas
- SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1x

Louis Berger

0 250 500 Feet

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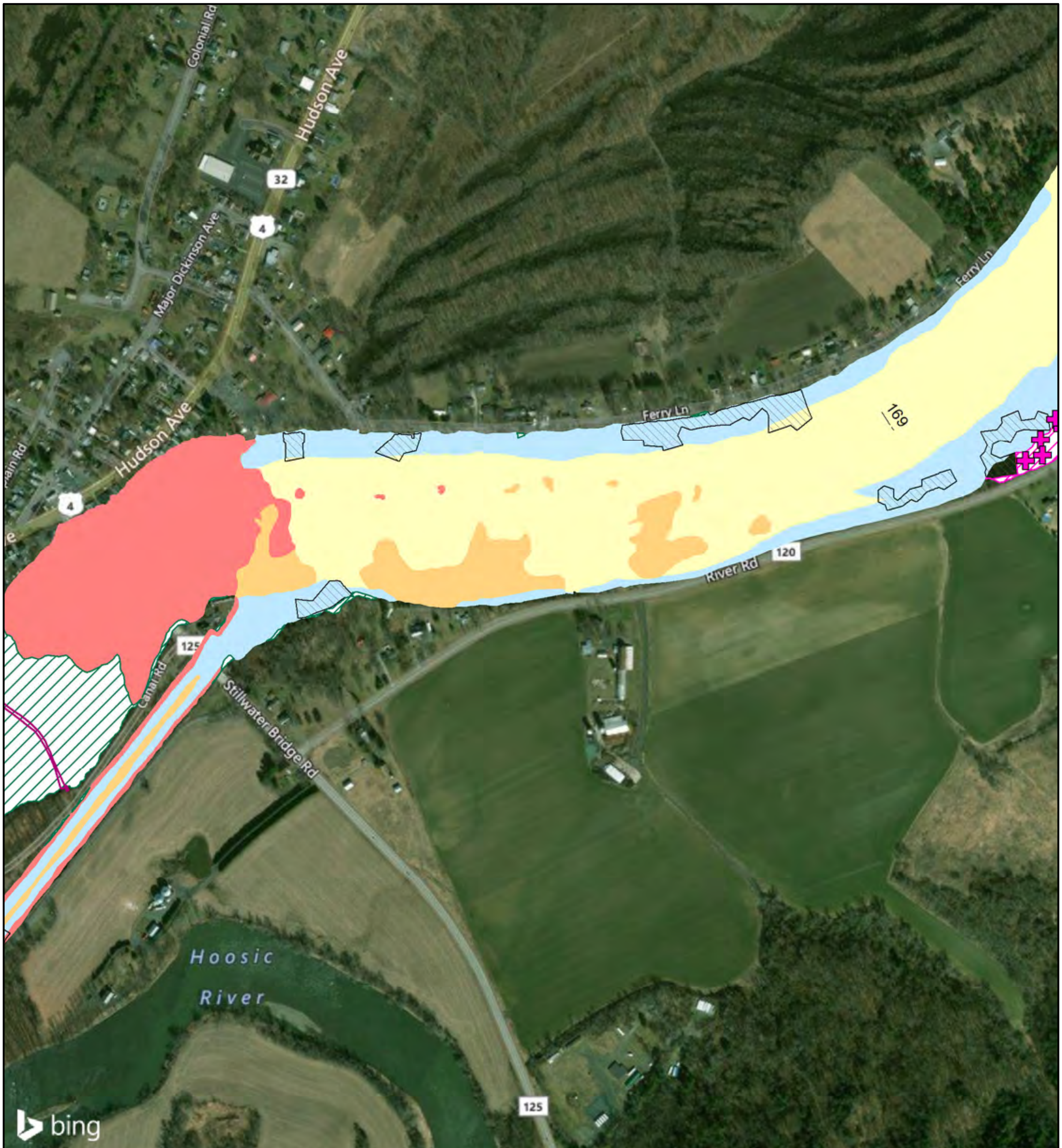


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

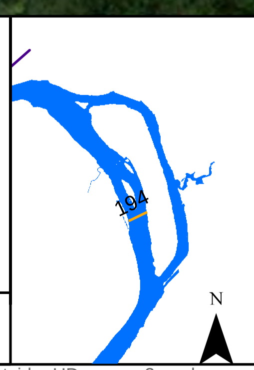
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1y

Louis Berger

0 250 500 Feet

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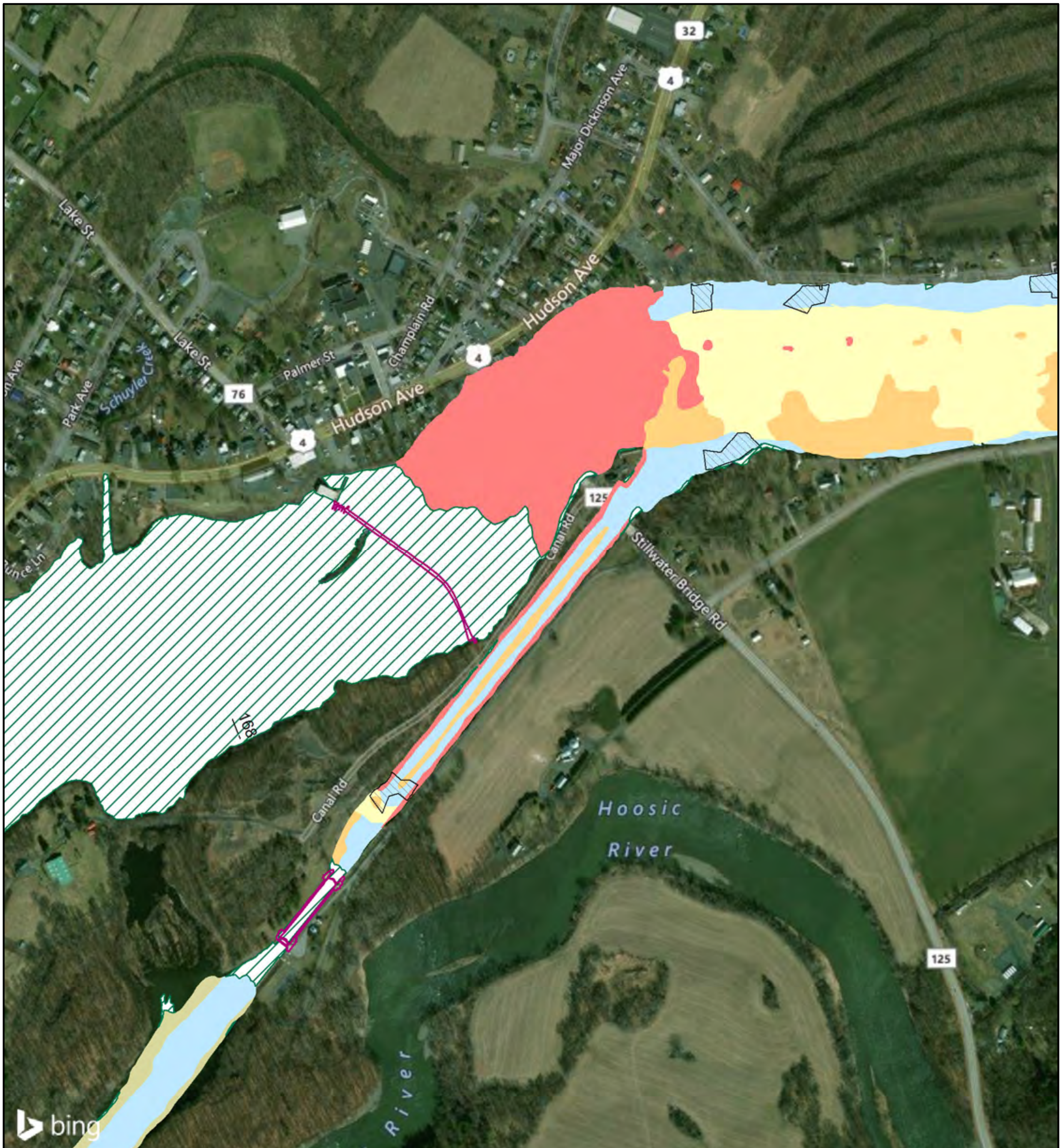


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

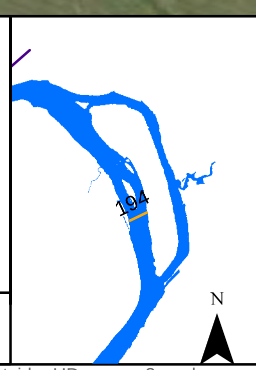
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1z

Louis Berger

0 250 500 Feet

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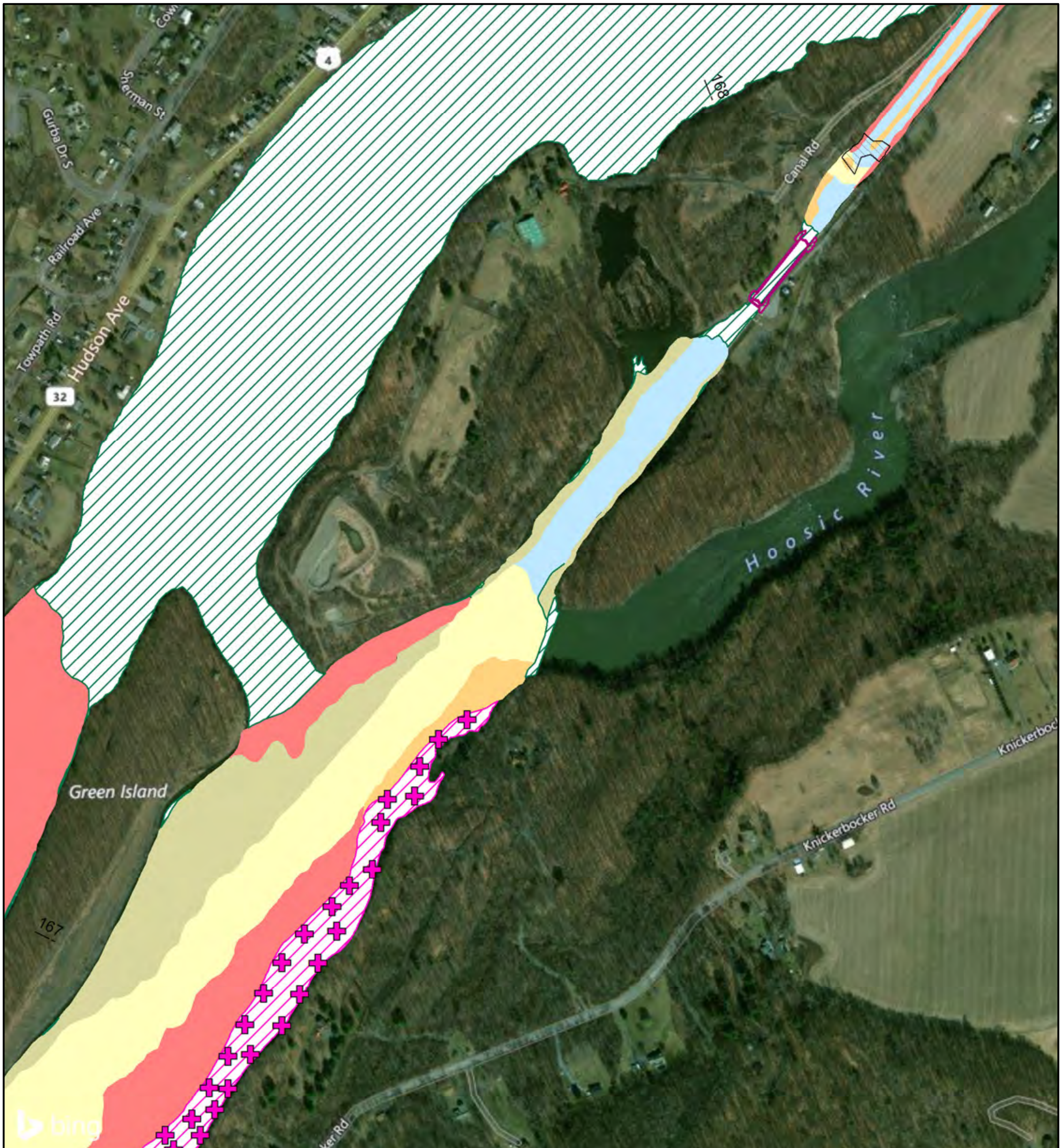


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

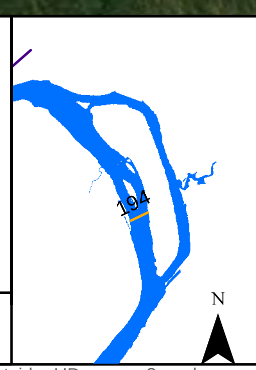
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1aa

Louis Berger

0 250 500
Feet

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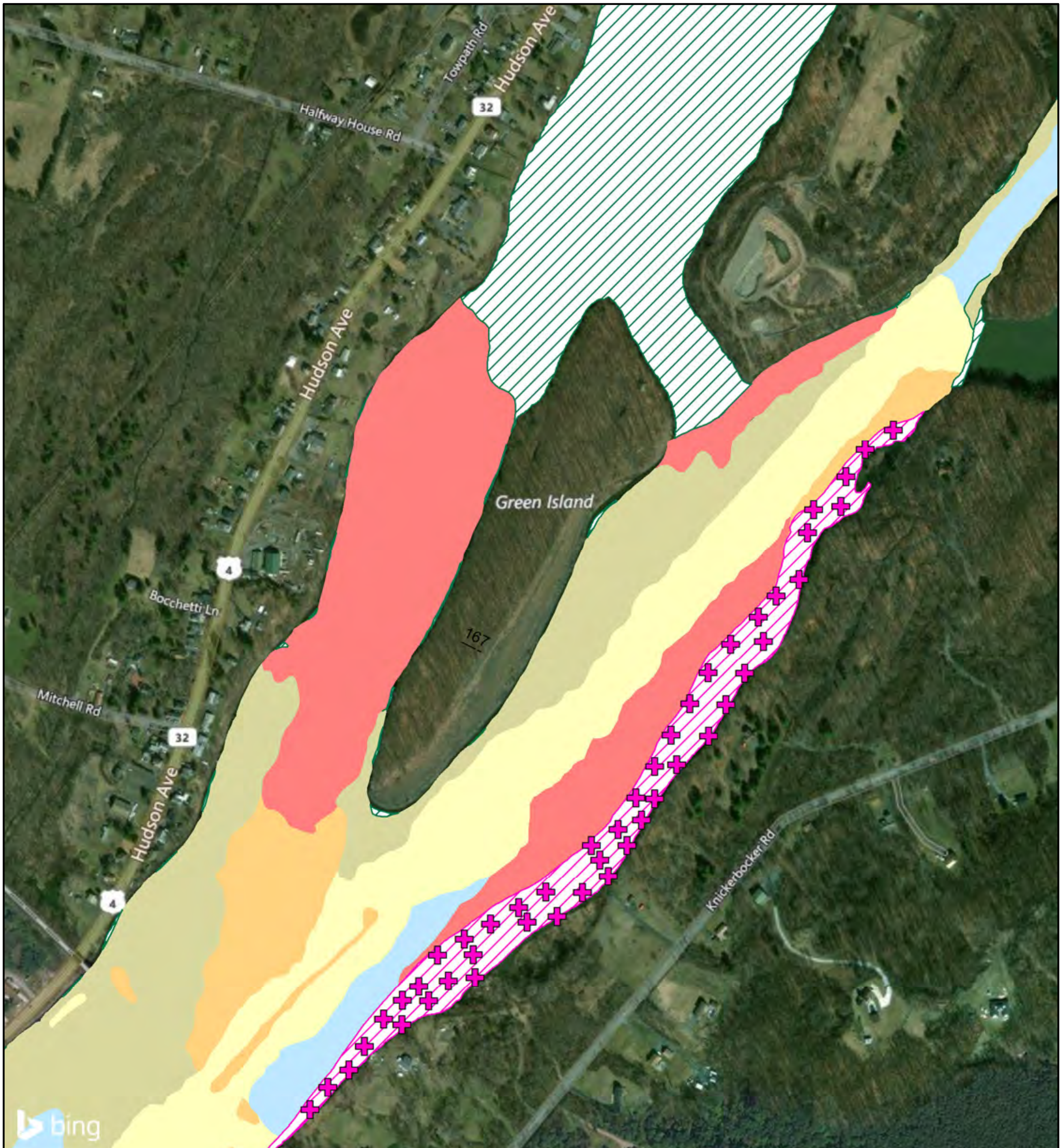
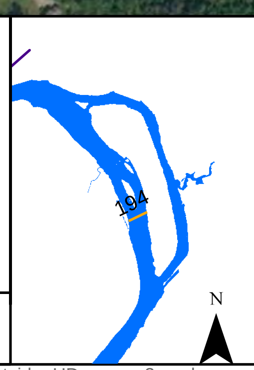


SSAP/SEDC Cores in HDC Areas
SSAP/SEDC Cores in Non-HDC Areas
RS3 Unclassified High Density Core (HDC) Areas
RS3 Unclassified Non-HDC Areas
Dams and Locks
Mile Markers
Certification Units

Sediment Type
Silt
Silt and Sand
Gravel
Transitional
Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ab

Louis Berger

0 250 500 Feet

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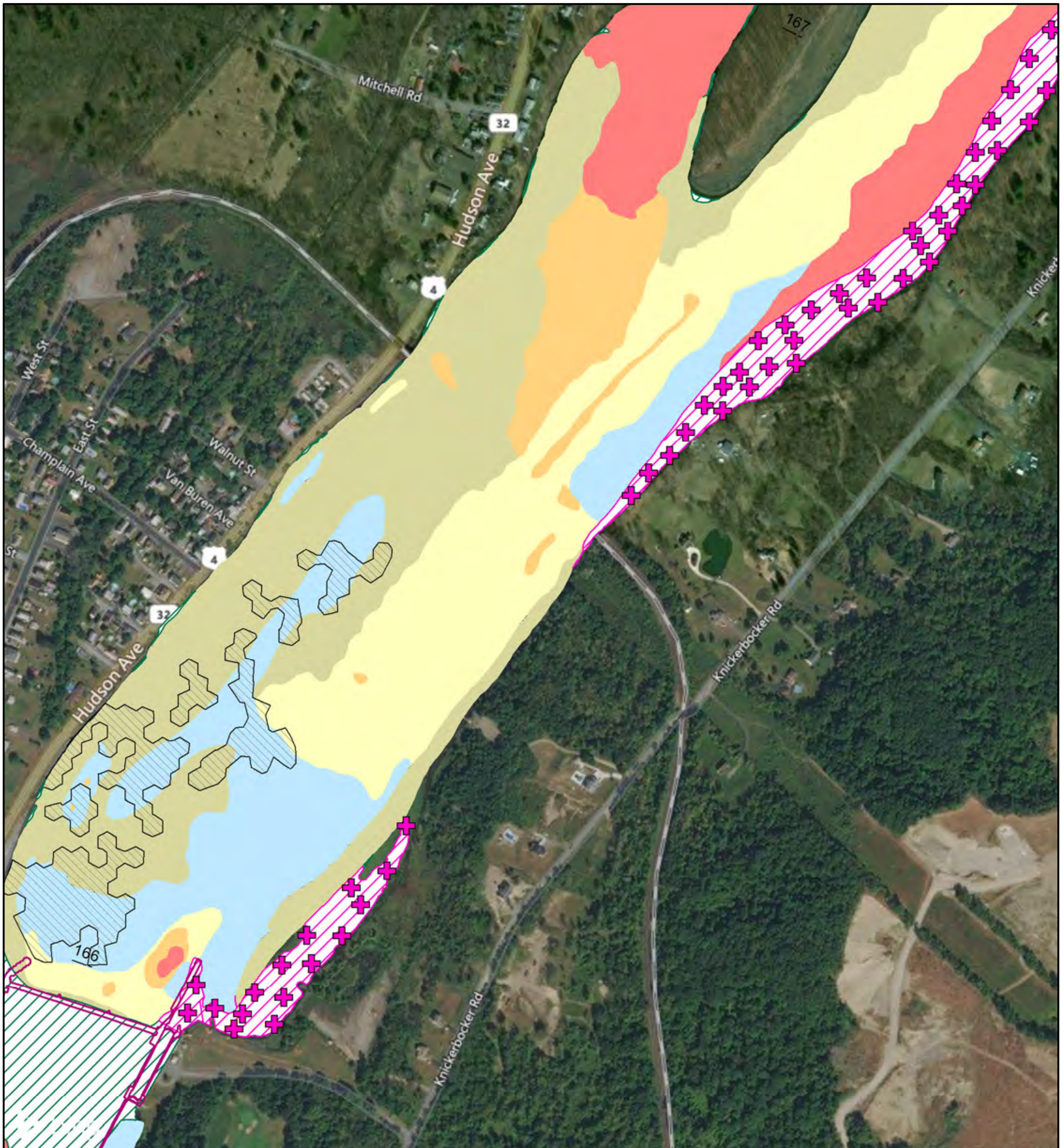


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

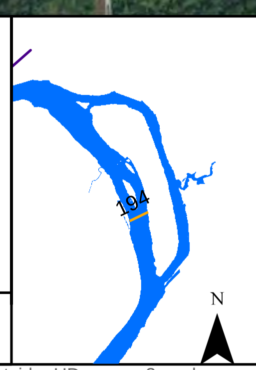
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ac

Louis Berger

0 250 500 Feet

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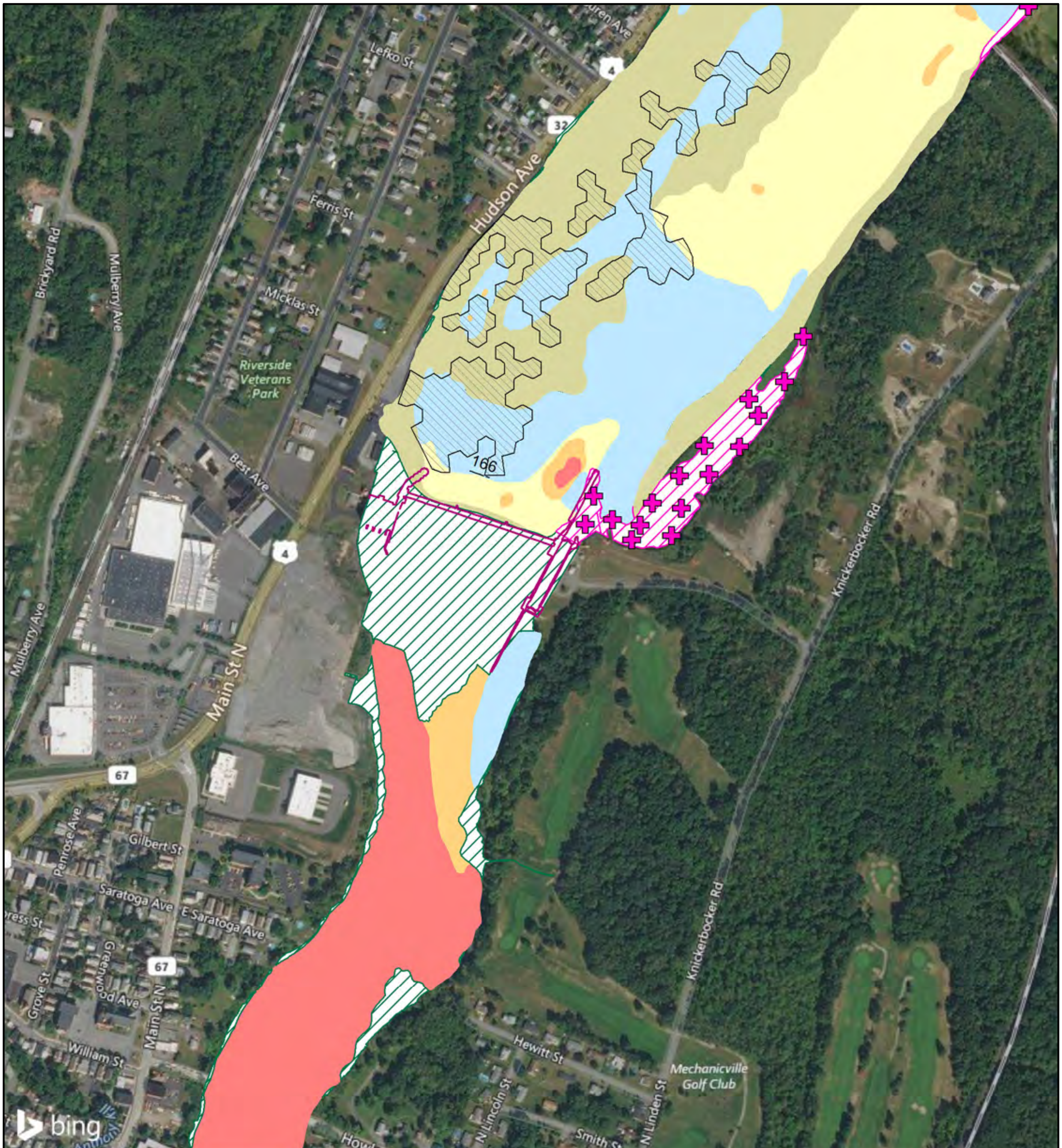
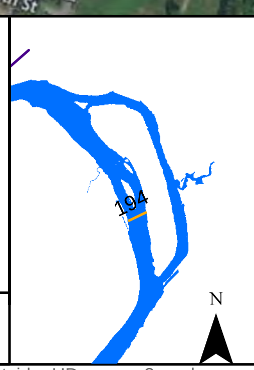


SSAP/SEDC Cores in HDC Areas	
SSAP/SEDC Cores in Non-HDC Areas	
RS3 Unclassified High Density Core (HDC) Areas	
RS3 Unclassified Non-HDC Areas	
Dams and Locks	
Mile Markers	
Certification Units	

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ad

Louis Berger

0 250 500 Feet

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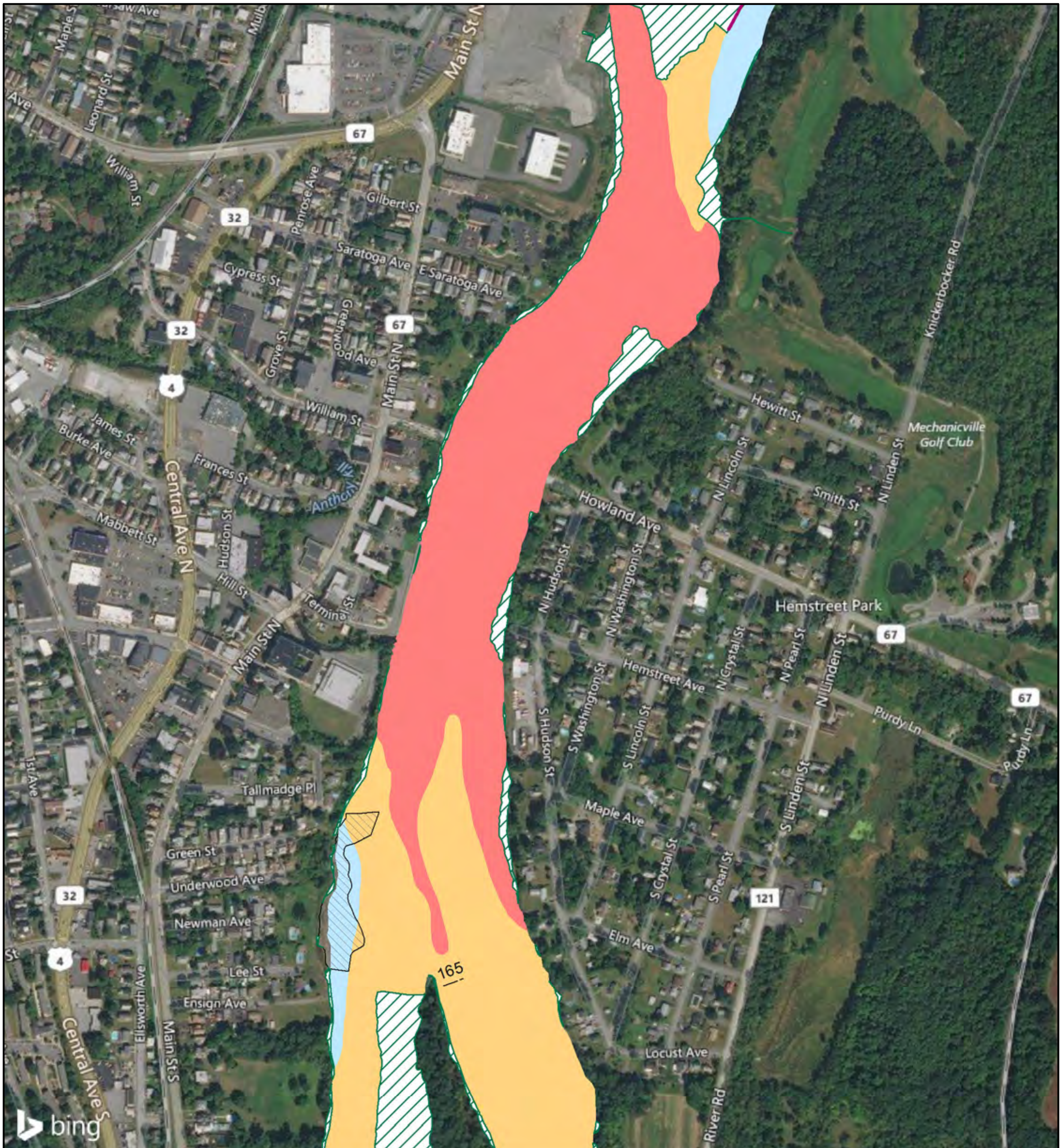


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

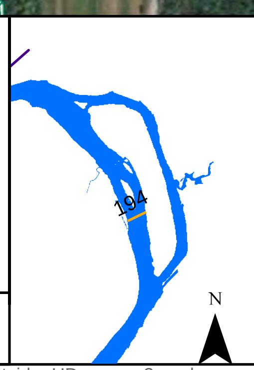
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ae

Louis Berger

0 250 500 Feet

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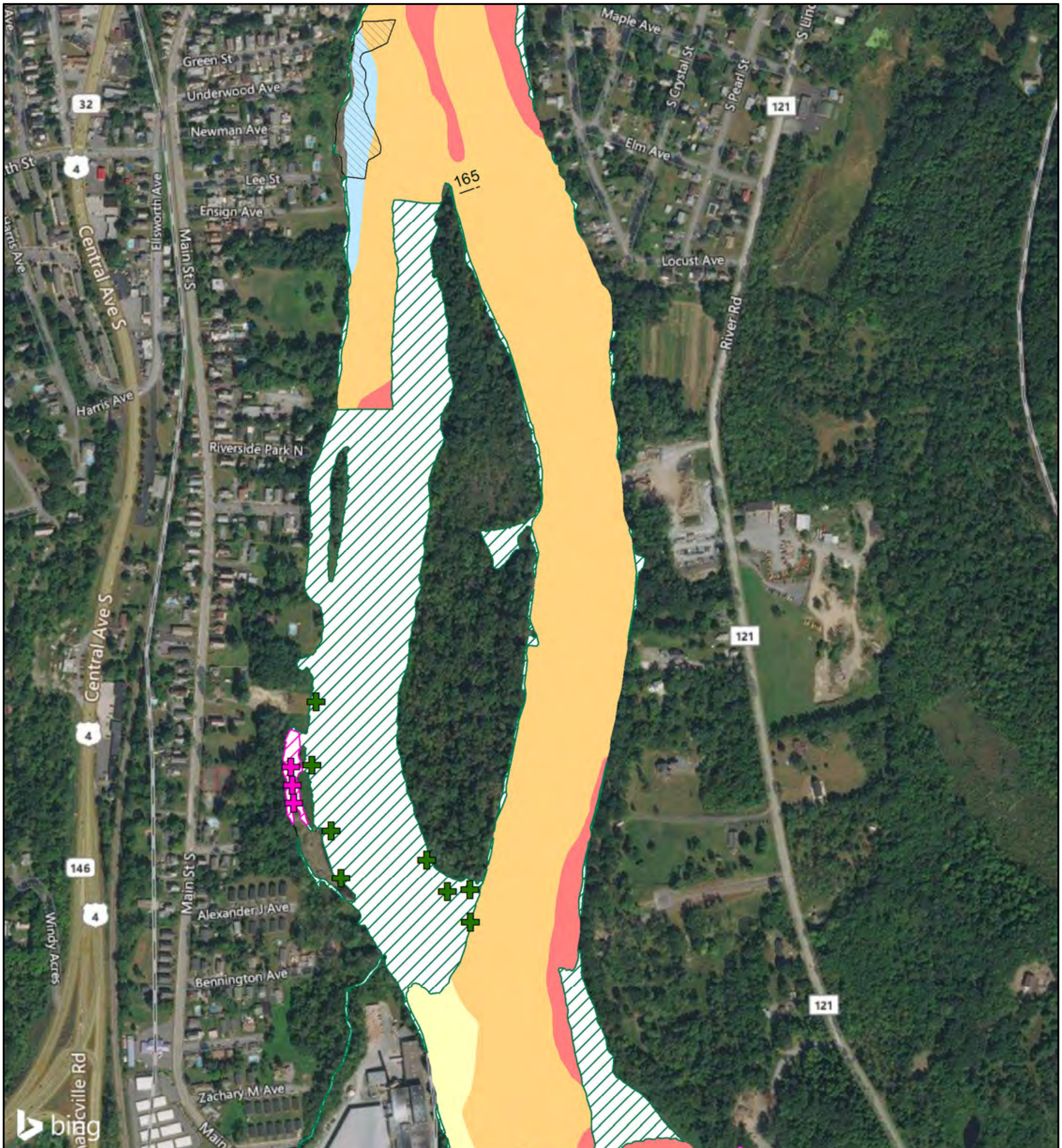


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

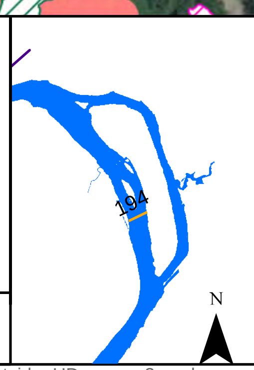
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1af

Louis Berger

0 250 500 Feet

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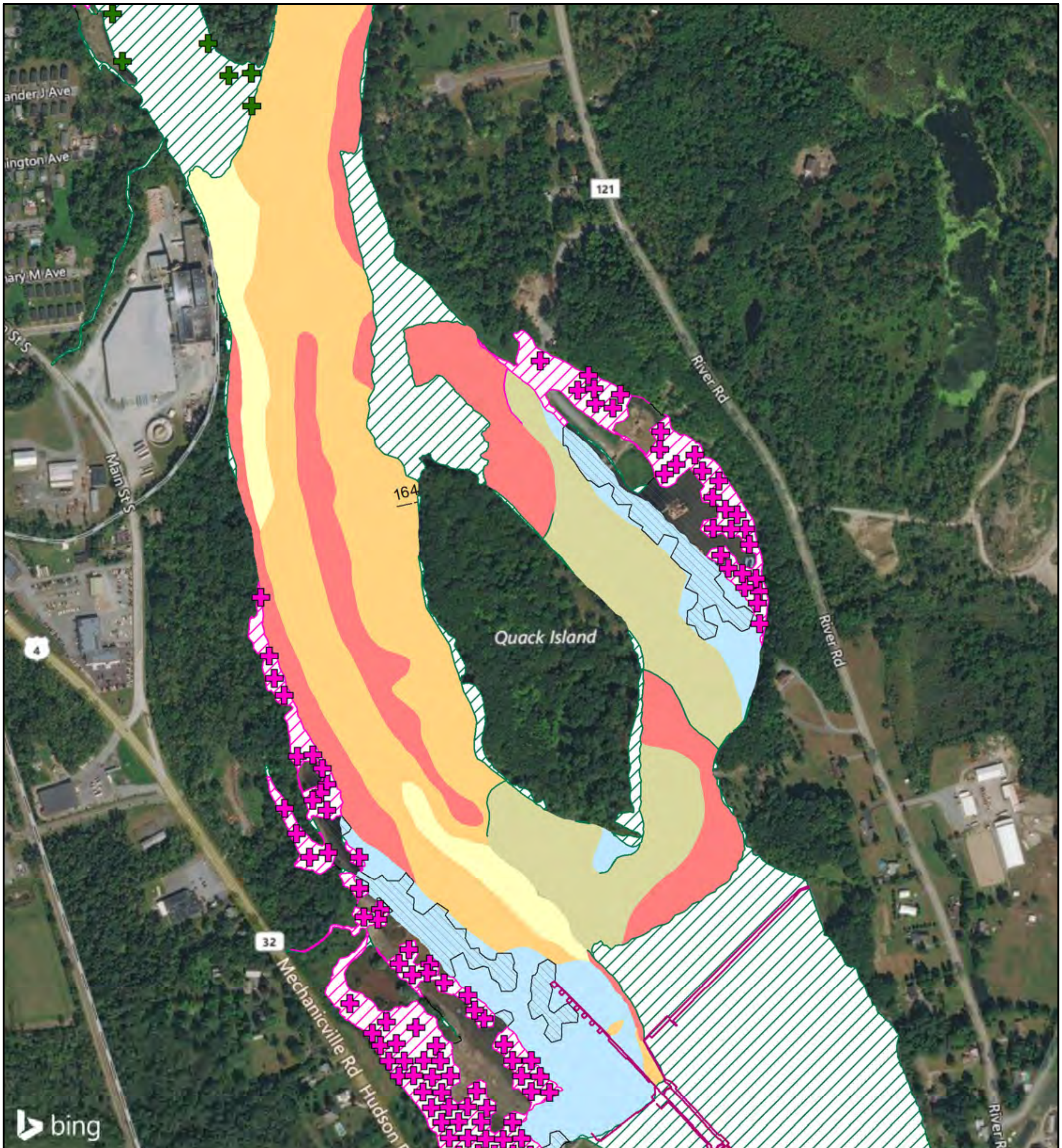
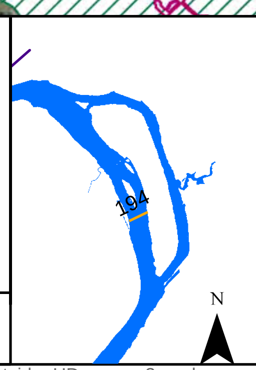


SSAP/SEDC Cores in HDC Areas
SSAP/SEDC Cores in Non-HDC Areas
RS3 Unclassified High Density Core (HDC) Areas
RS3 Unclassified Non-HDC Areas
Dams and Locks
Mile Markers
Certification Units

Sediment Type
Silt
Silt and Sand
Gravel
Transitional
Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ag

Louis Berger

0 250 500 Feet

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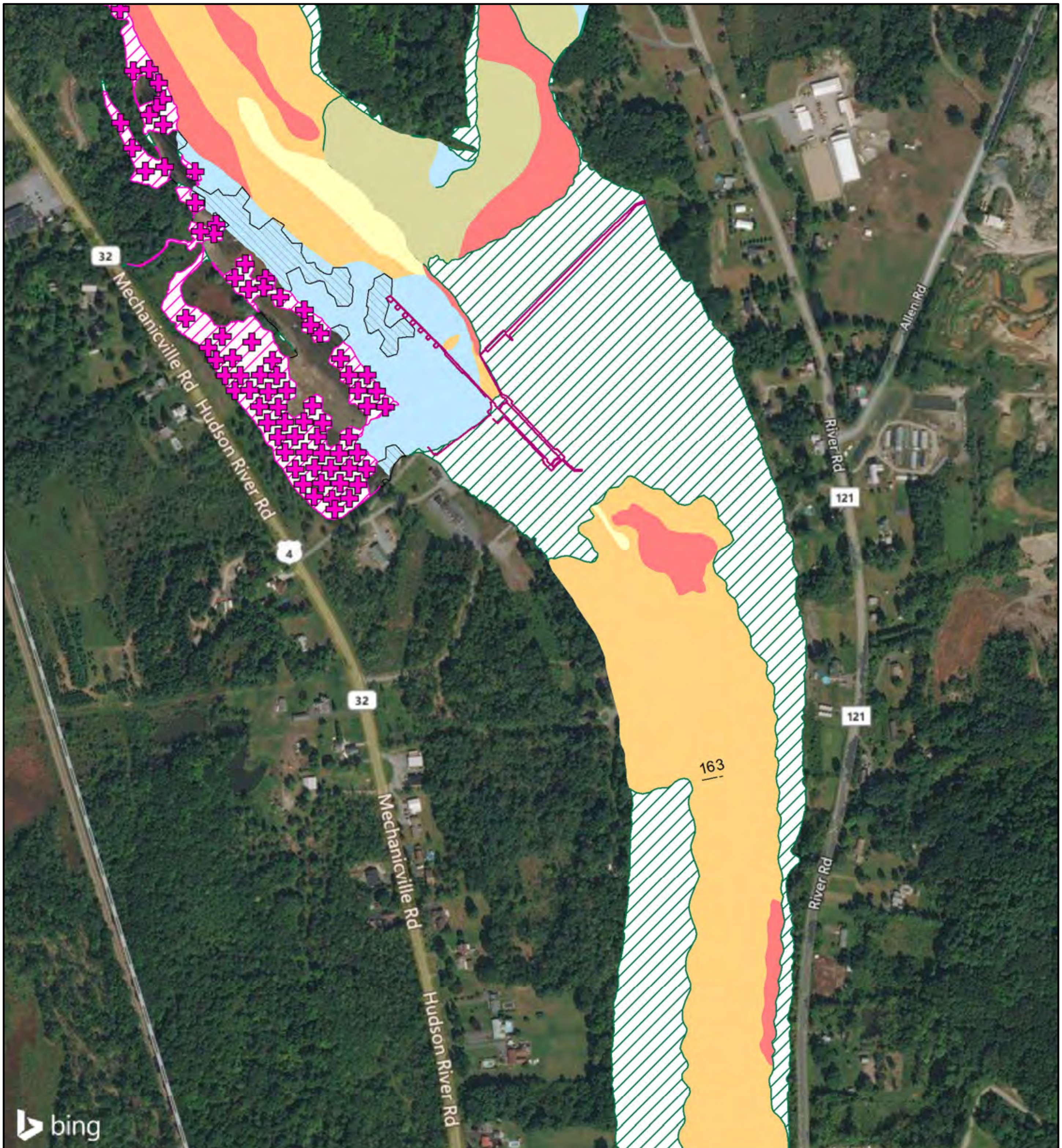

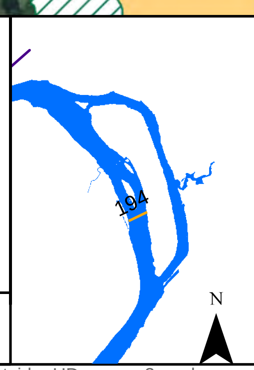

SSAP/SEDC Cores in HDC Areas	
SSAP/SEDC Cores in Non-HDC Areas	
RS3 Unclassified High Density Core (HDC) Areas	
RS3 Unclassified Non-HDC Areas	
Dams and Locks	
Mile Markers	
Certification Units	

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ah

Louis Berger

0 250 500 Feet

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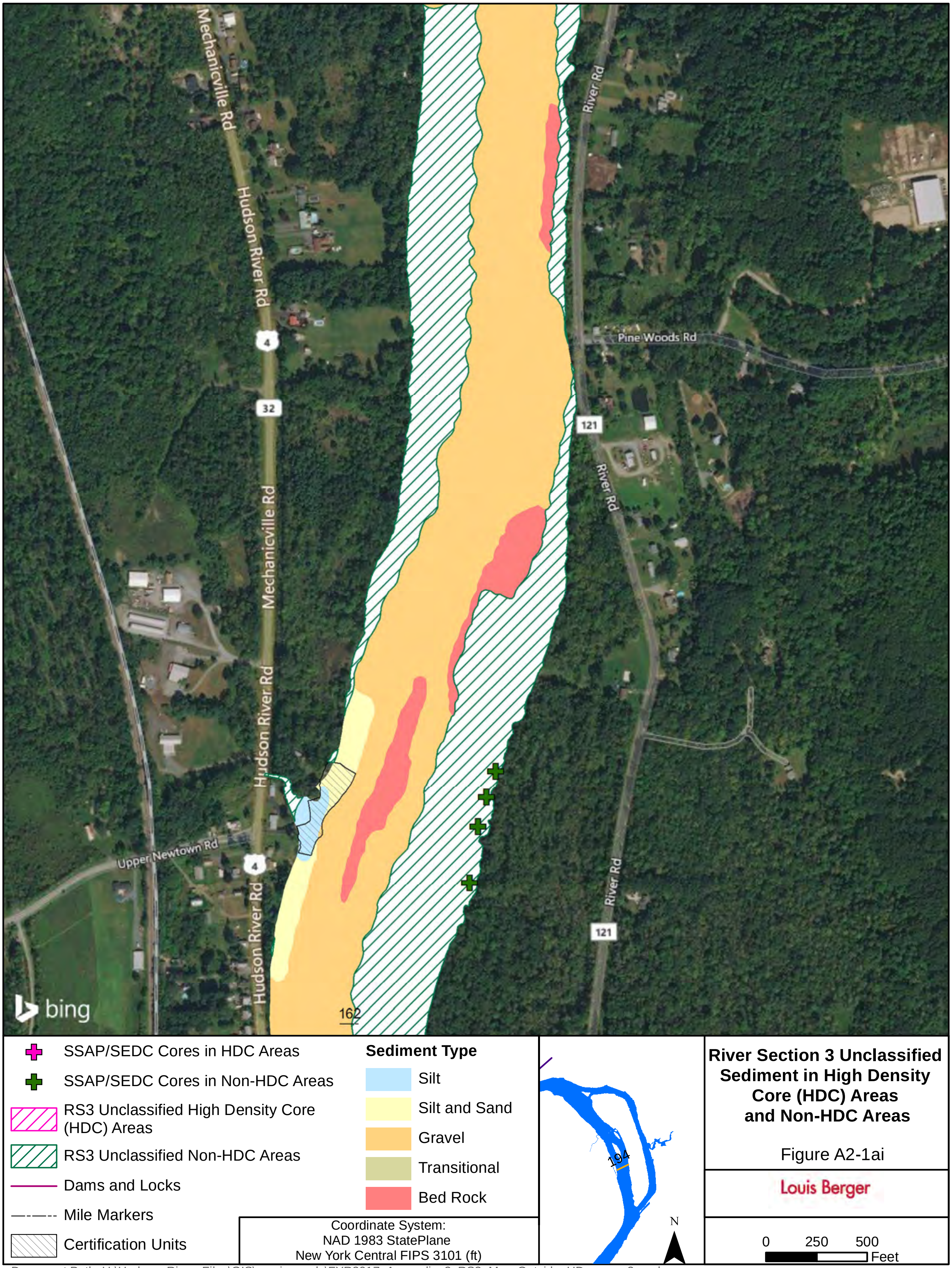

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ai

Louis Berger

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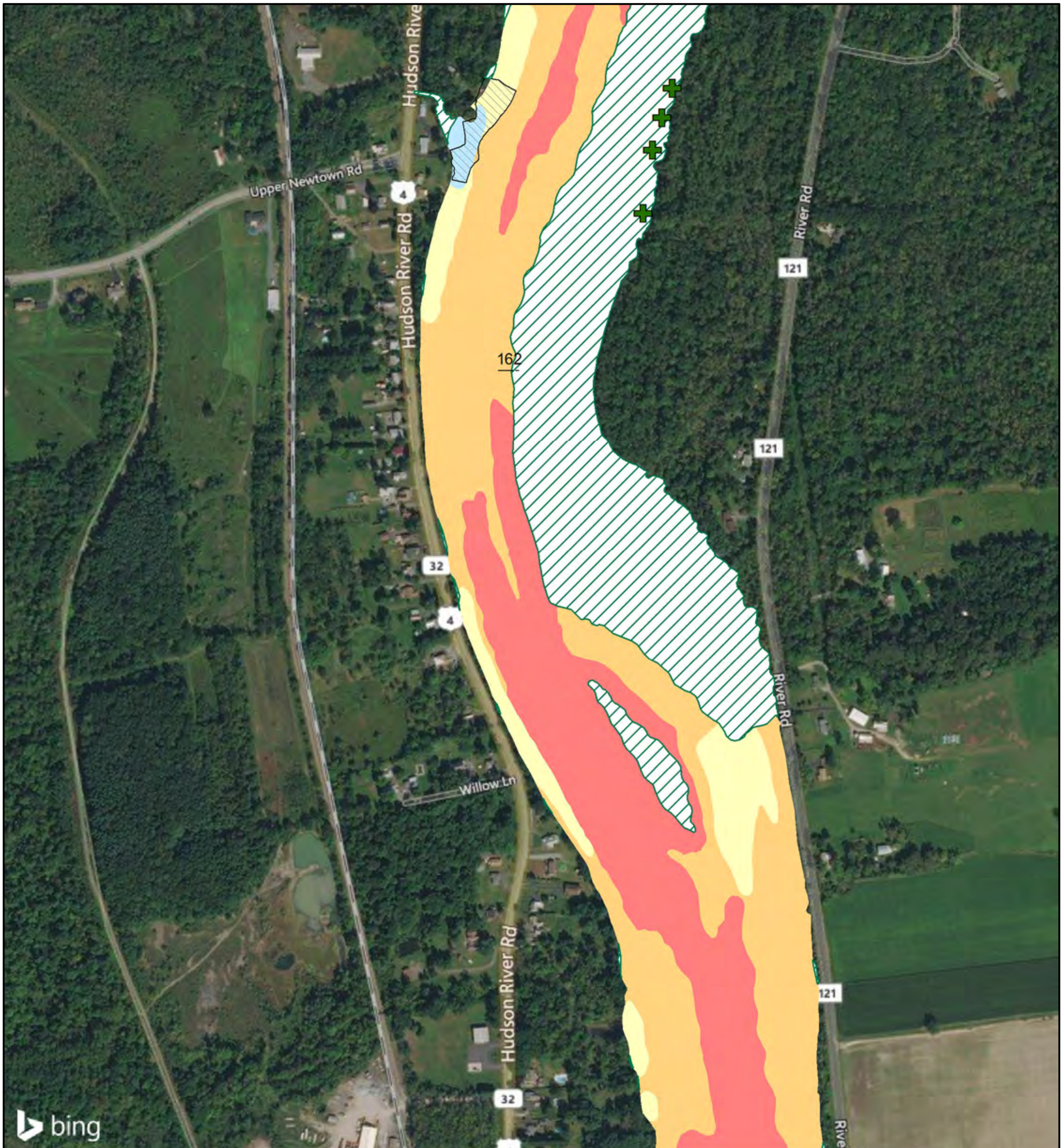
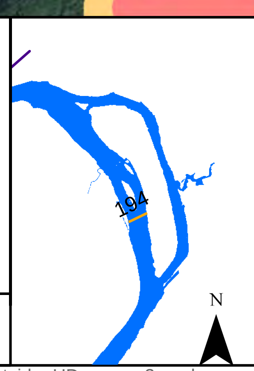


- SSAP/SEDC Cores in HDC Areas
- SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1aj

Louis Berger

0 250 500 Feet

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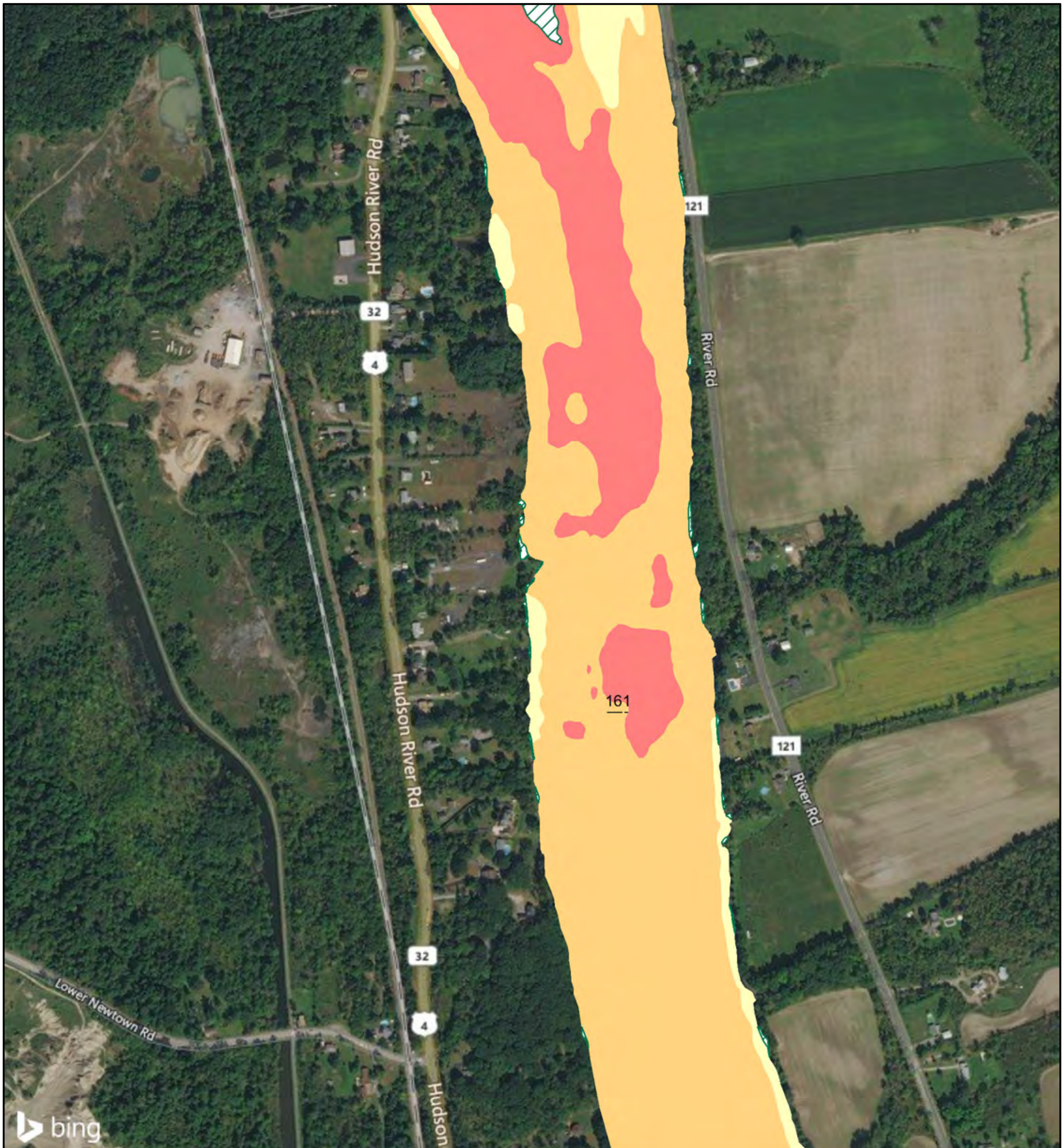
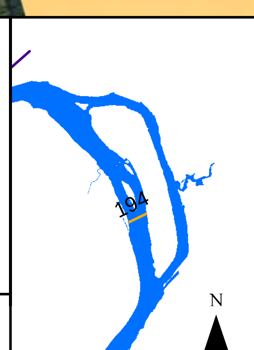


- SSAP/SEDC Cores in HDC Areas
- SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ak

Louis Berger

0 250 500 Feet

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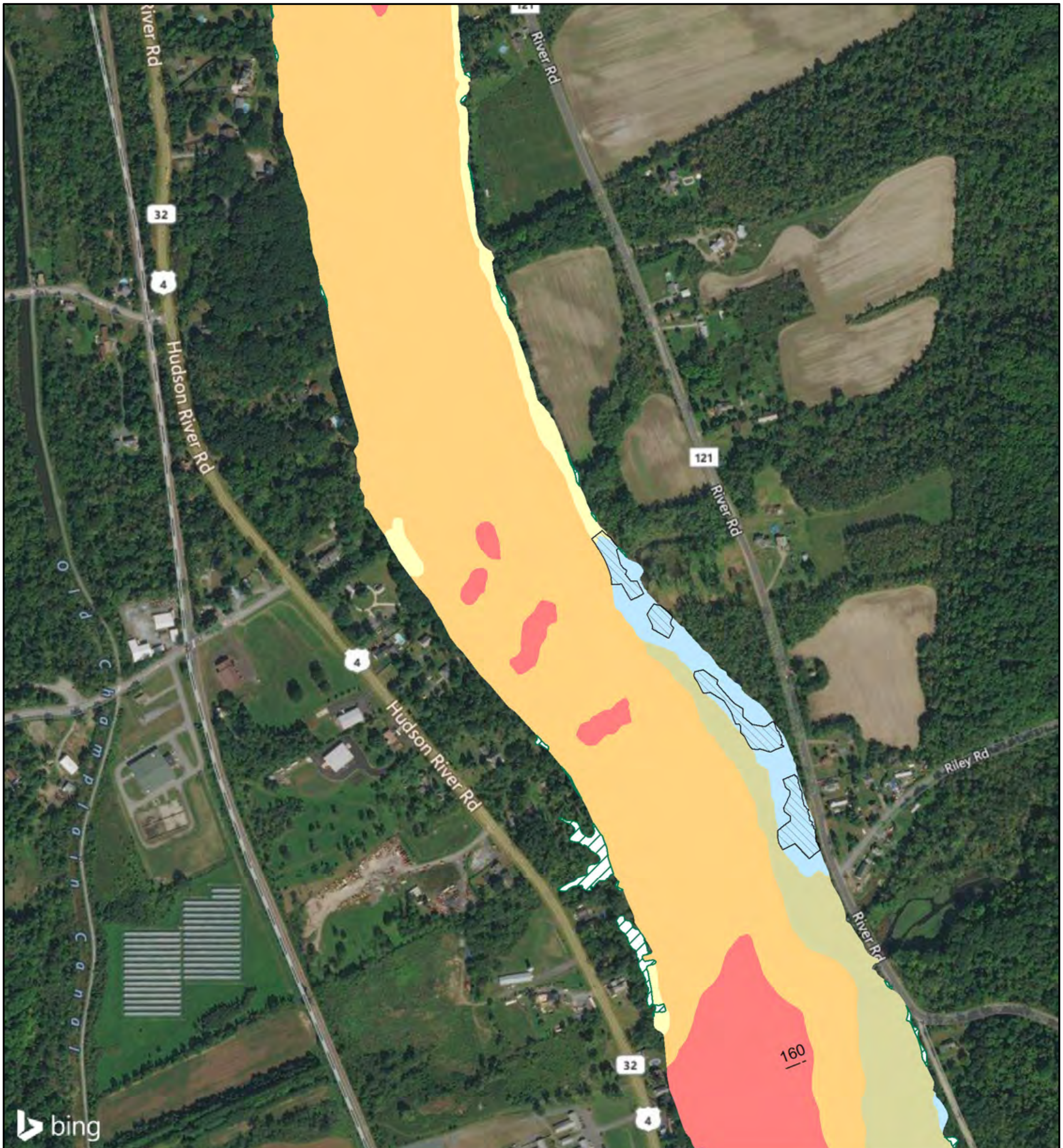


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

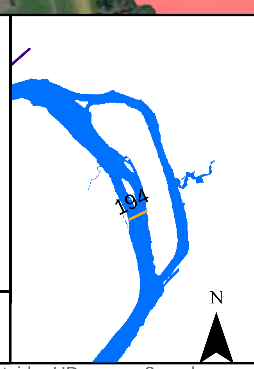
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1al

Louis Berger

0 250 500 Feet

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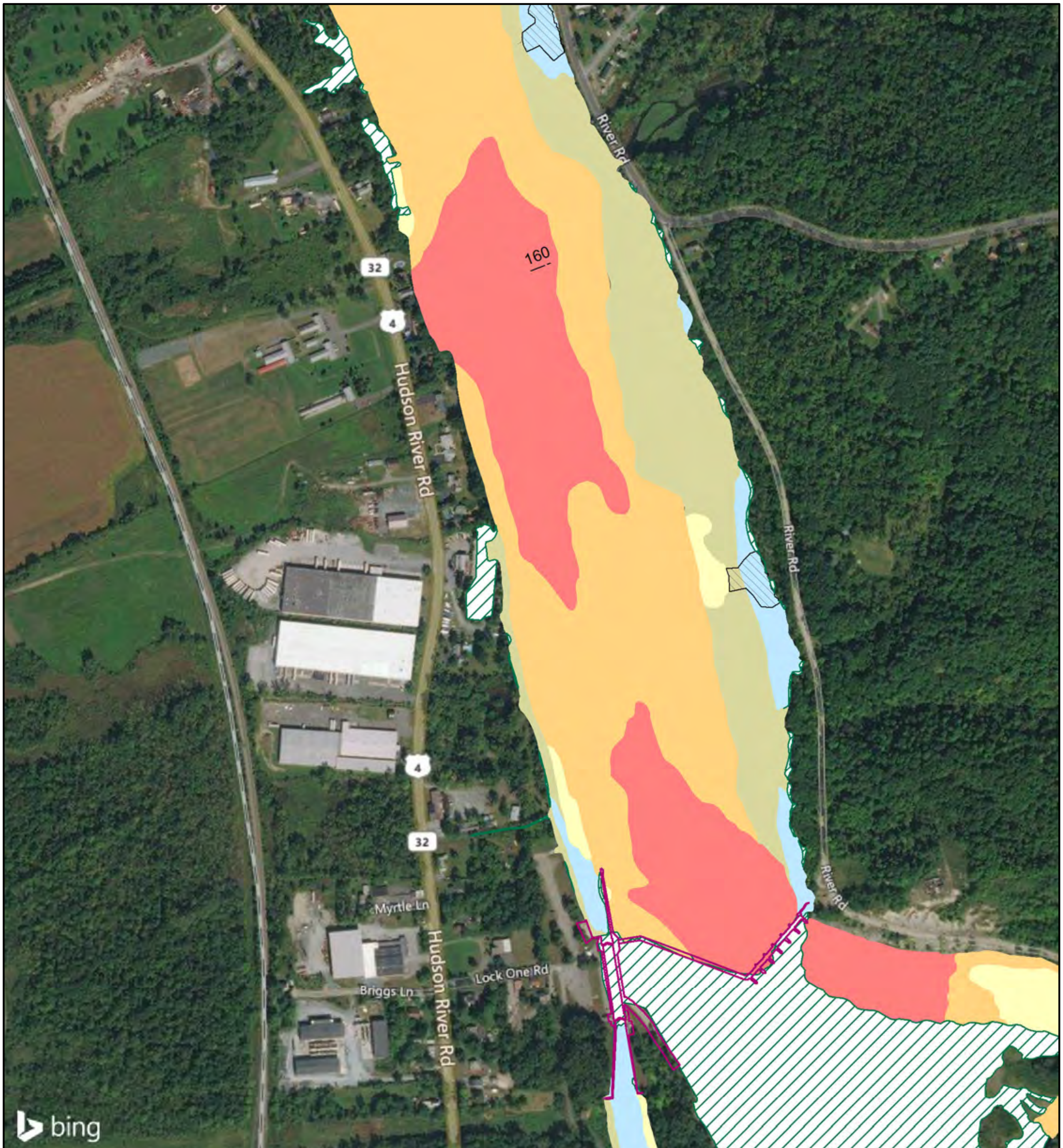


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

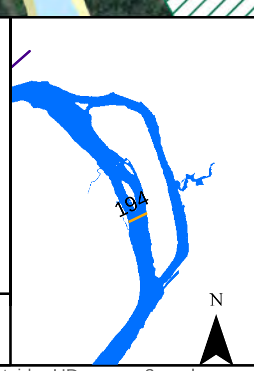
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1am

Louis Berger

0 250 500 Feet

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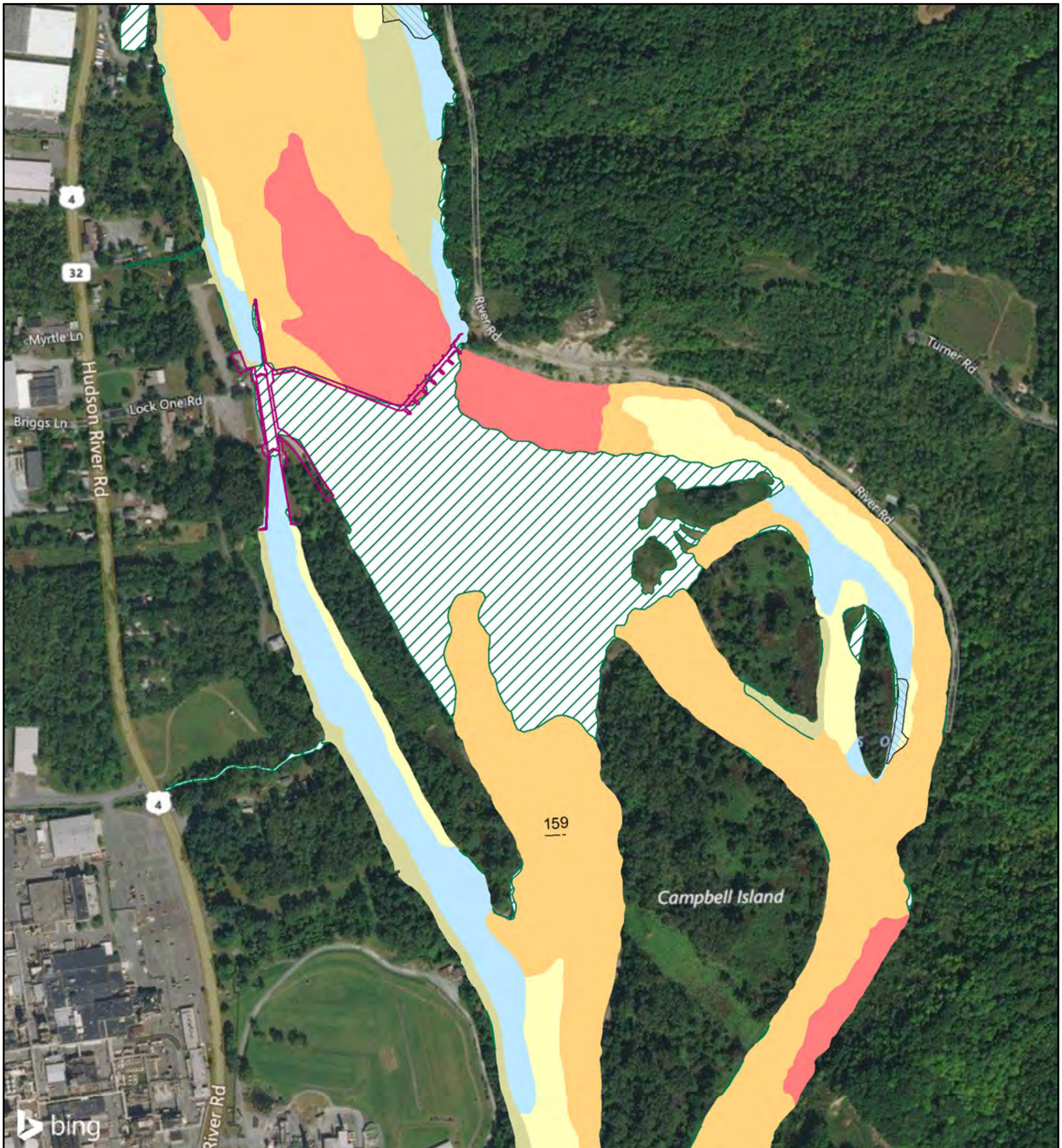


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

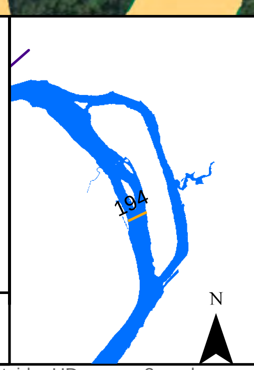
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1an

Louis Berger

0 250 500 Feet

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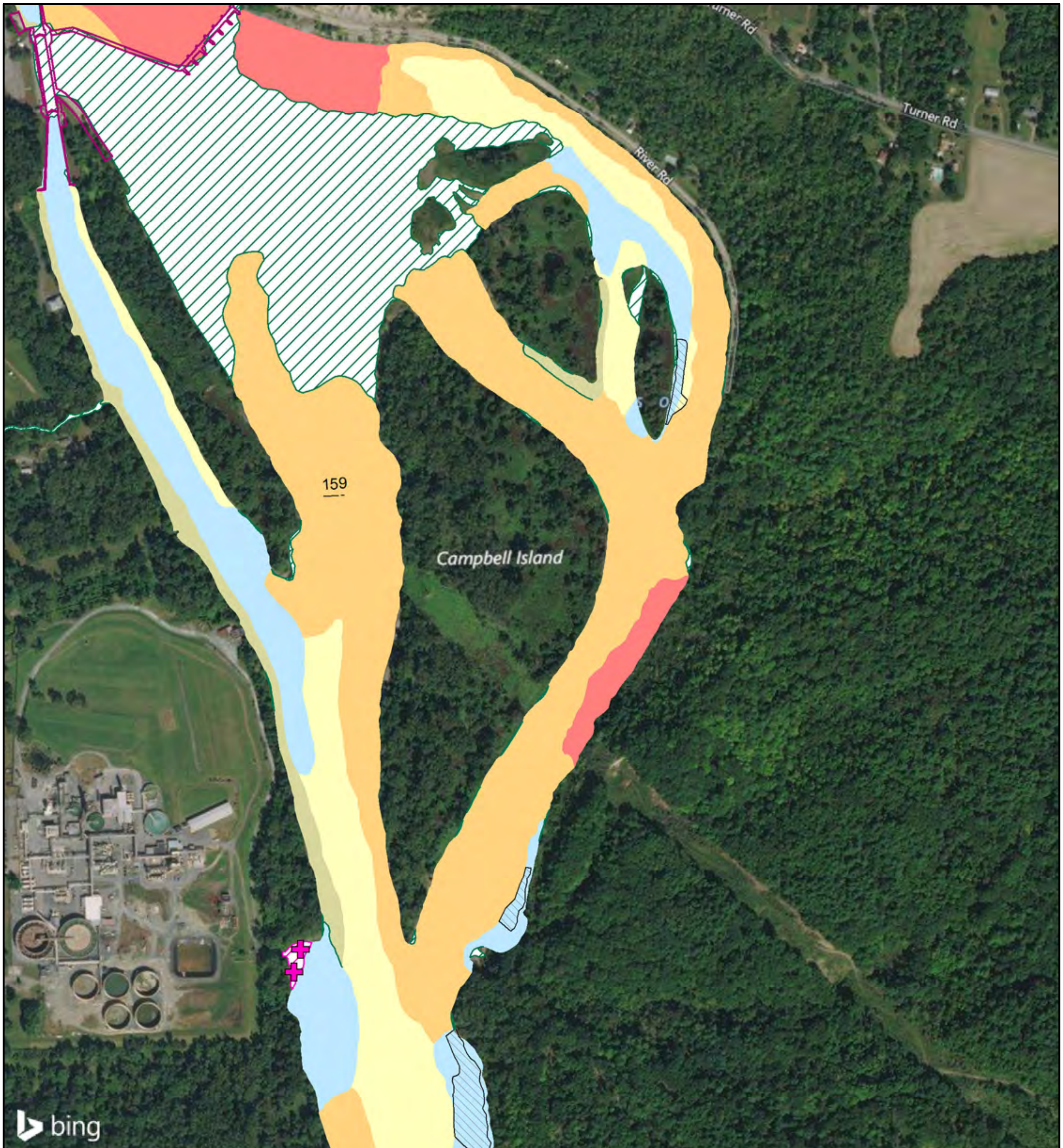


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

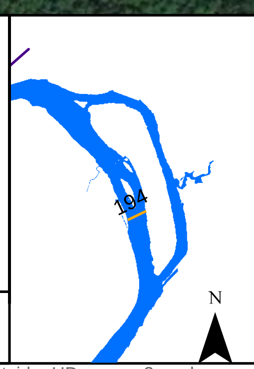
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ao

Louis Berger

0 250 500 Feet

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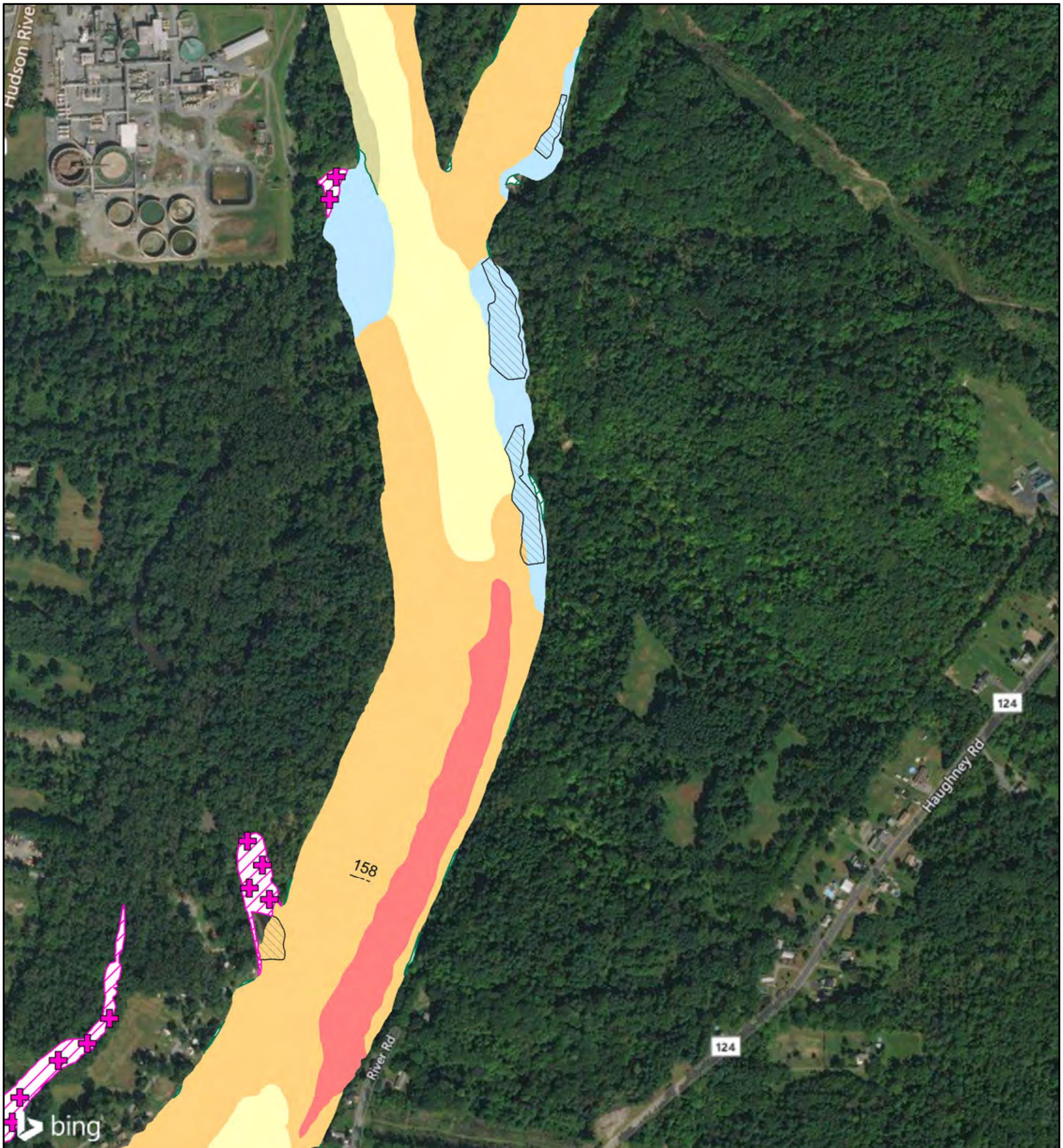

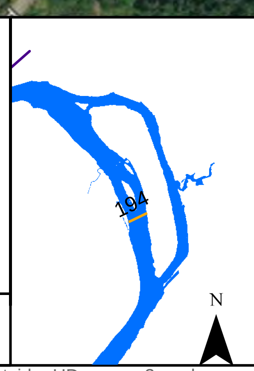

SSAP/SEDC Cores in HDC Areas
SSAP/SEDC Cores in Non-HDC Areas
RS3 Unclassified High Density Core (HDC) Areas
RS3 Unclassified Non-HDC Areas
Dams and Locks
Mile Markers
Certification Units

Sediment Type
Silt
Silt and Sand
Gravel
Transitional
Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ap

Louis Berger

0 250 500 Feet

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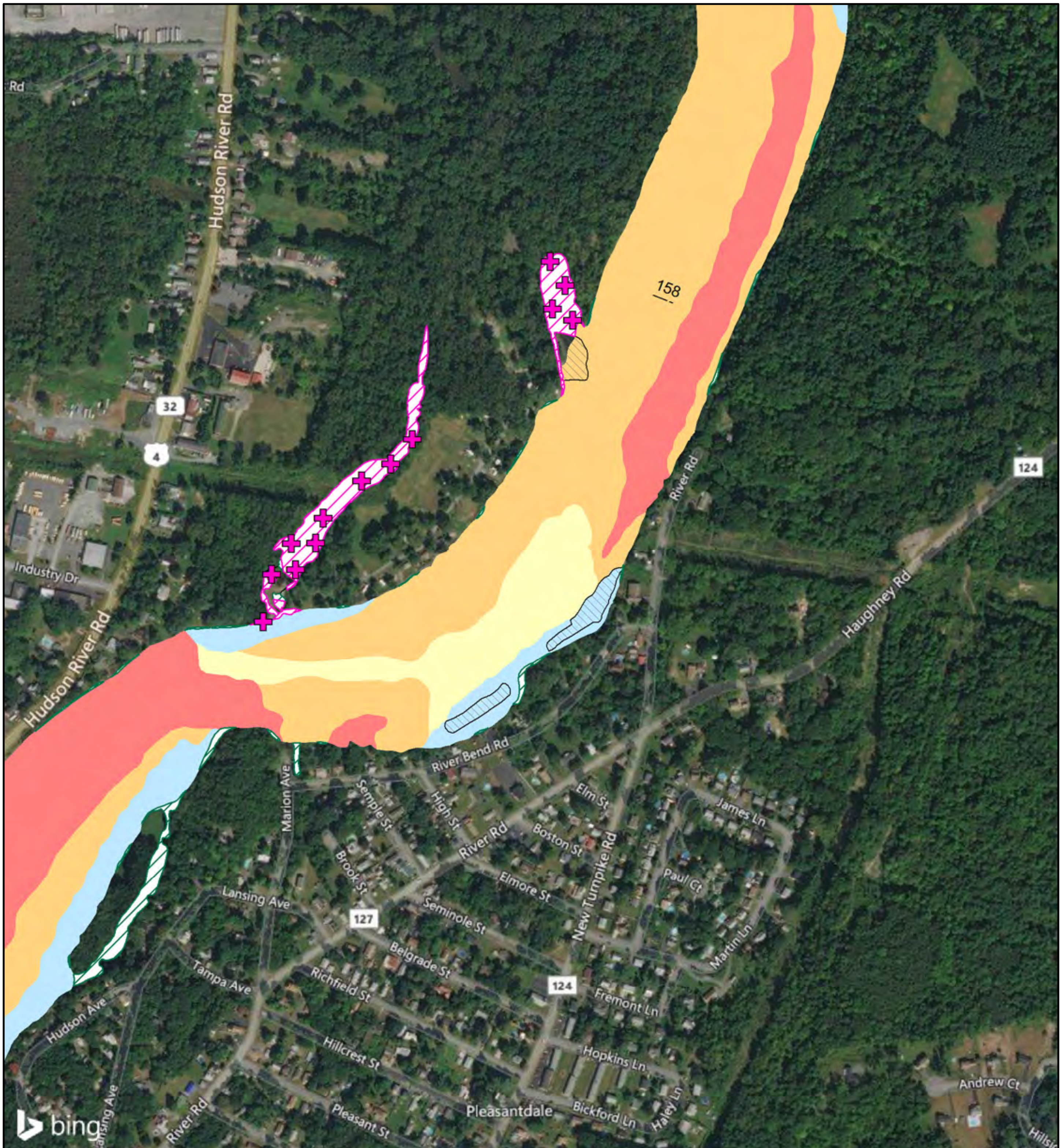


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

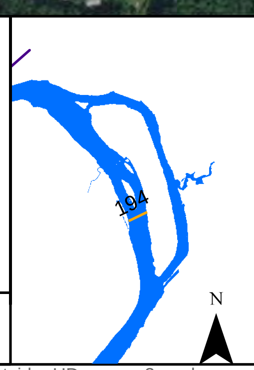
Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1aq

Louis Berger

0 250 500 Feet

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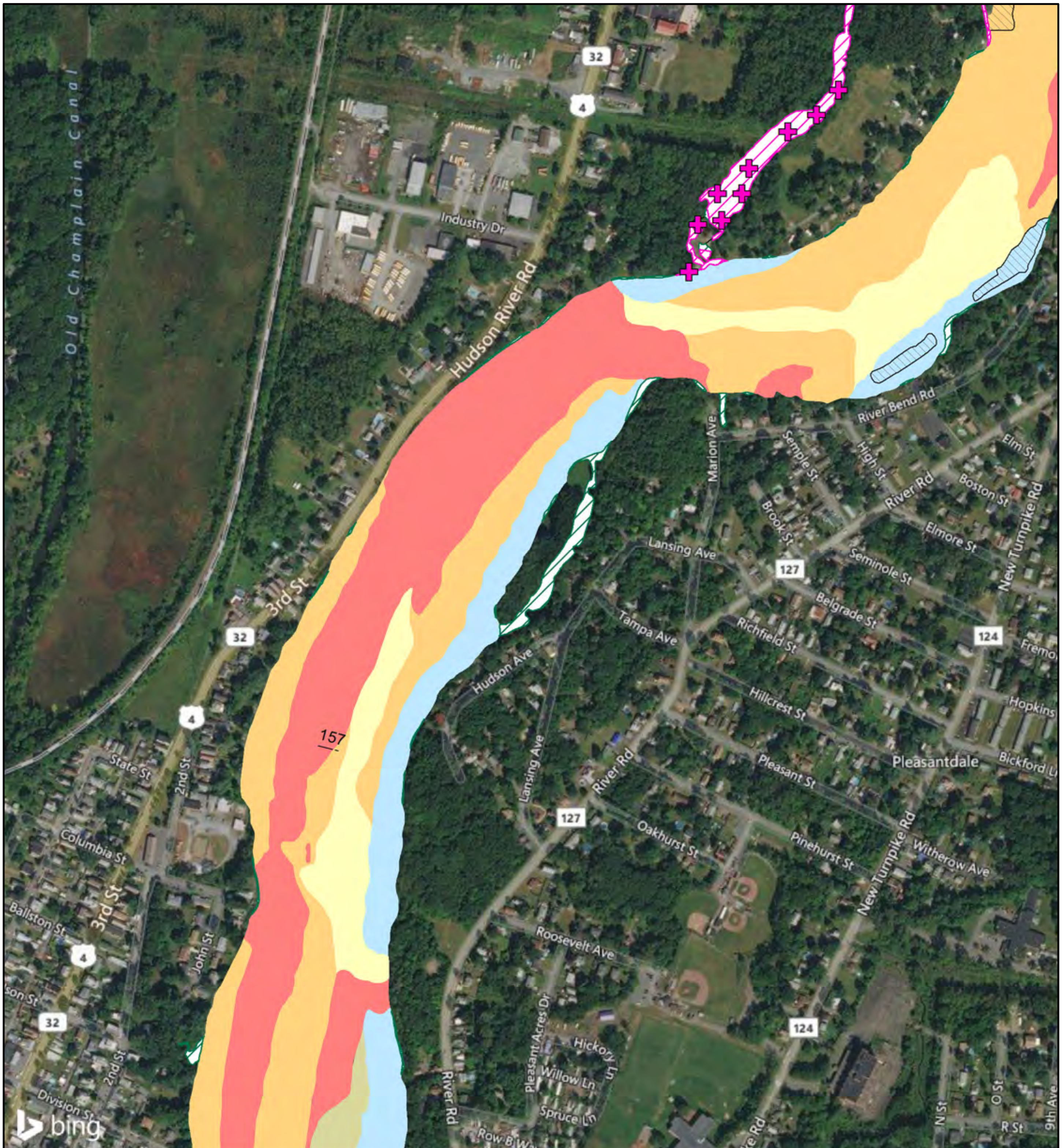

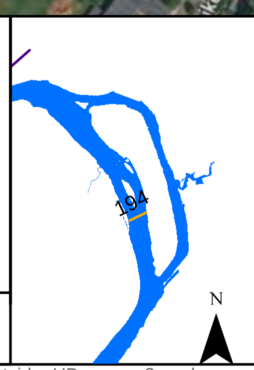

SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1ar

Louis Berger

0 250 500 Feet

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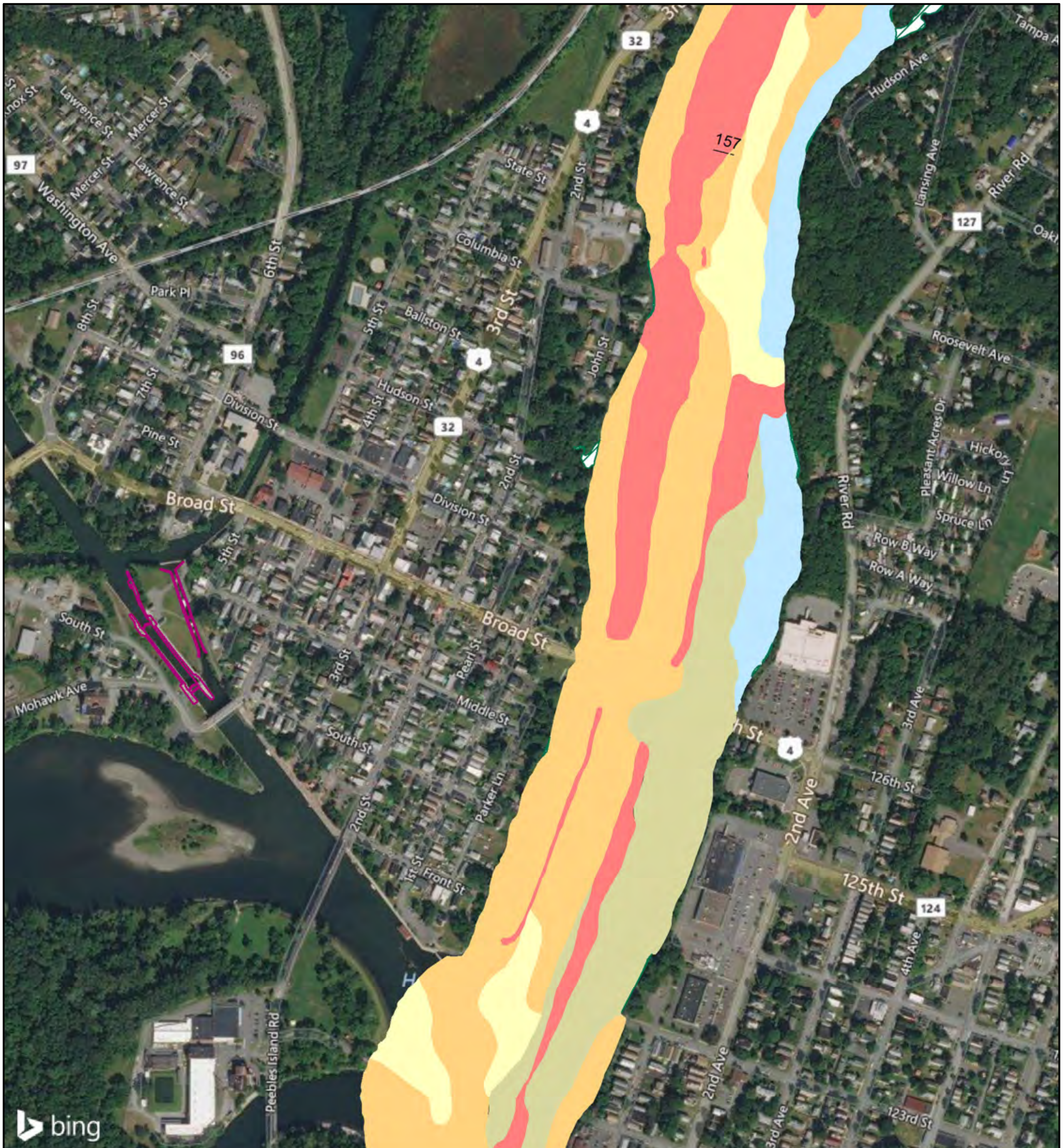

SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

Mile Markers

Certification Units

Sediment Type

Silt

Silt and Sand

Gravel

Transitional

Bed Rock

Coordinate System:
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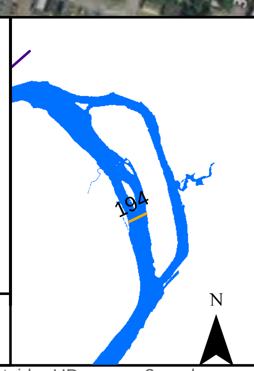
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1as

Louis Berger

0 250 500 Feet

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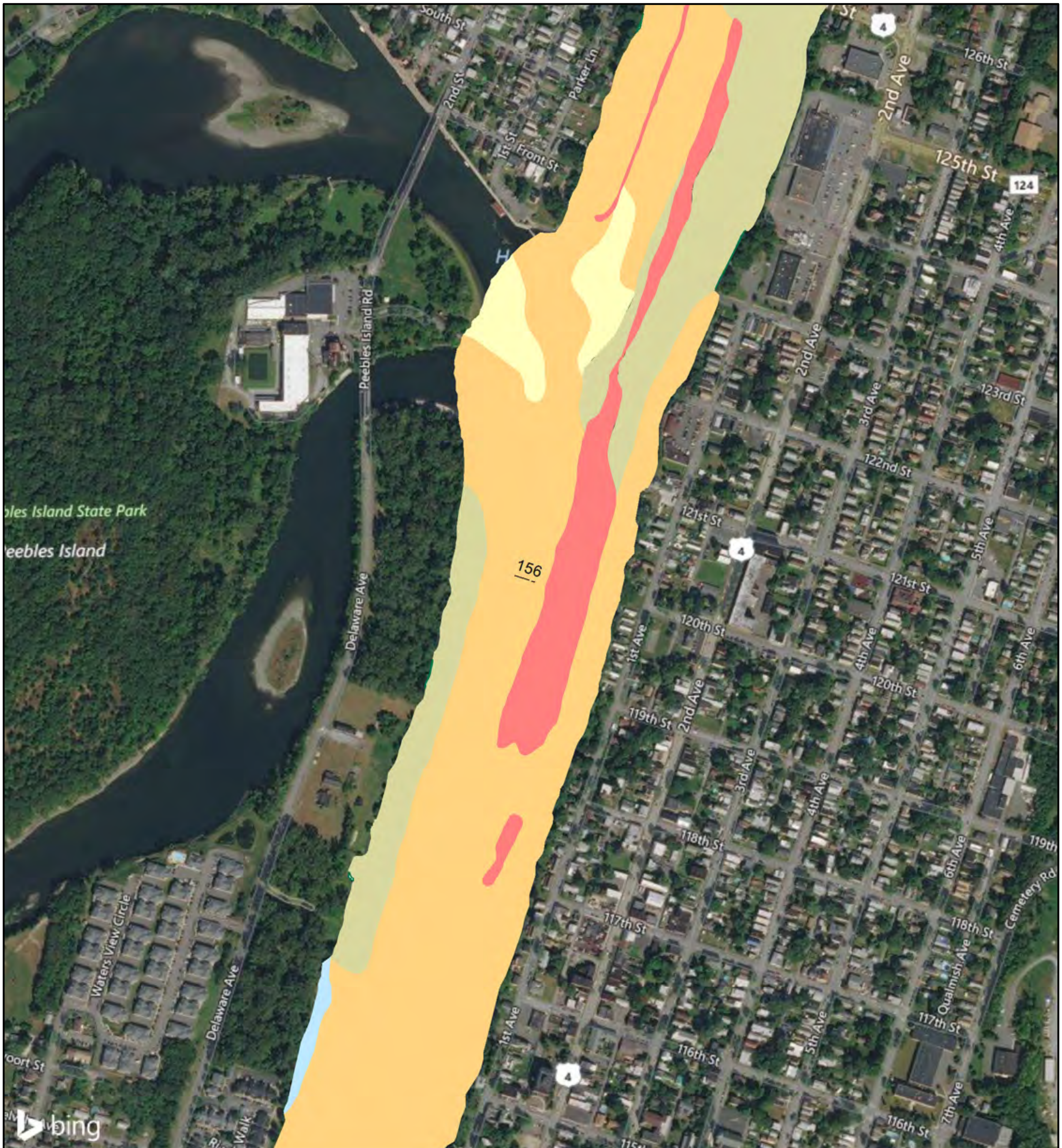


SSAP/SEDC Cores in HDC Areas

SSAP/SEDC Cores in Non-HDC Areas

RS3 Unclassified High Density Core (HDC) Areas

RS3 Unclassified Non-HDC Areas

Dams and Locks

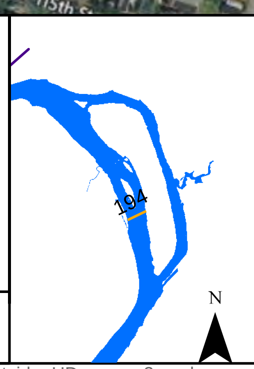
Mile Markers

Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1at

Louis Berger

0 250 500 Feet

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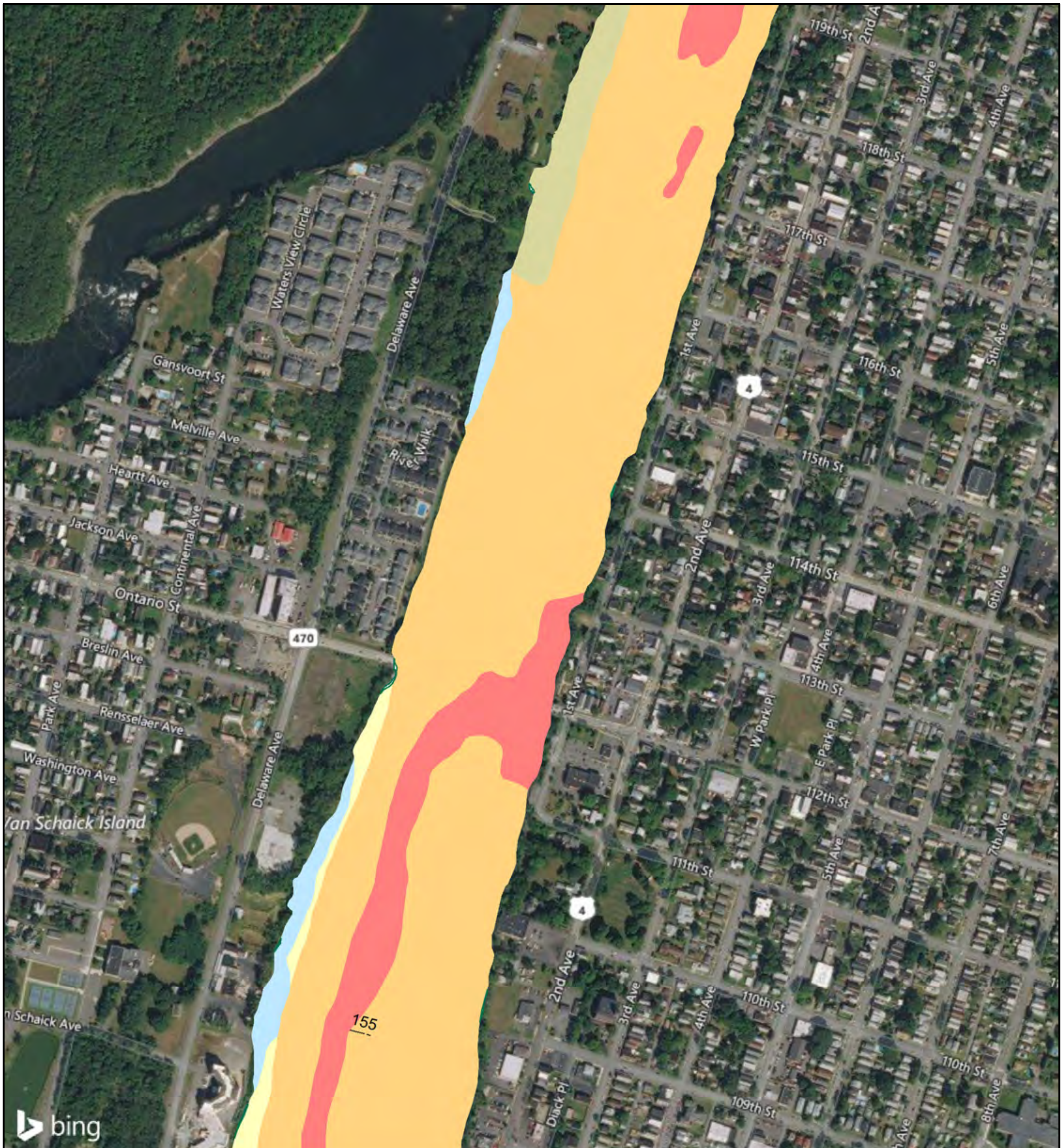

✚	SSAP/SEDC Cores in HDC Areas	**Sediment Type**	
✚	SSAP/SEDC Cores in Non-HDC Areas		Silt
	RS3 Unclassified High Density Core (HDC) Areas		Silt and Sand
	RS3 Unclassified Non-HDC Areas		Gravel
	Dams and Locks		Transitional
	Mile Markers		Bed Rock
	Certification Units		

Coordinate System:
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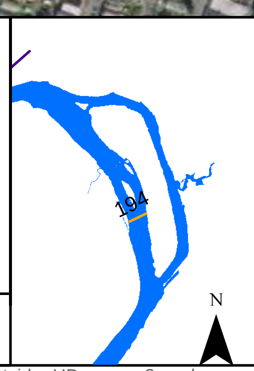
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1au

Louis Berger

0 250 500 Feet

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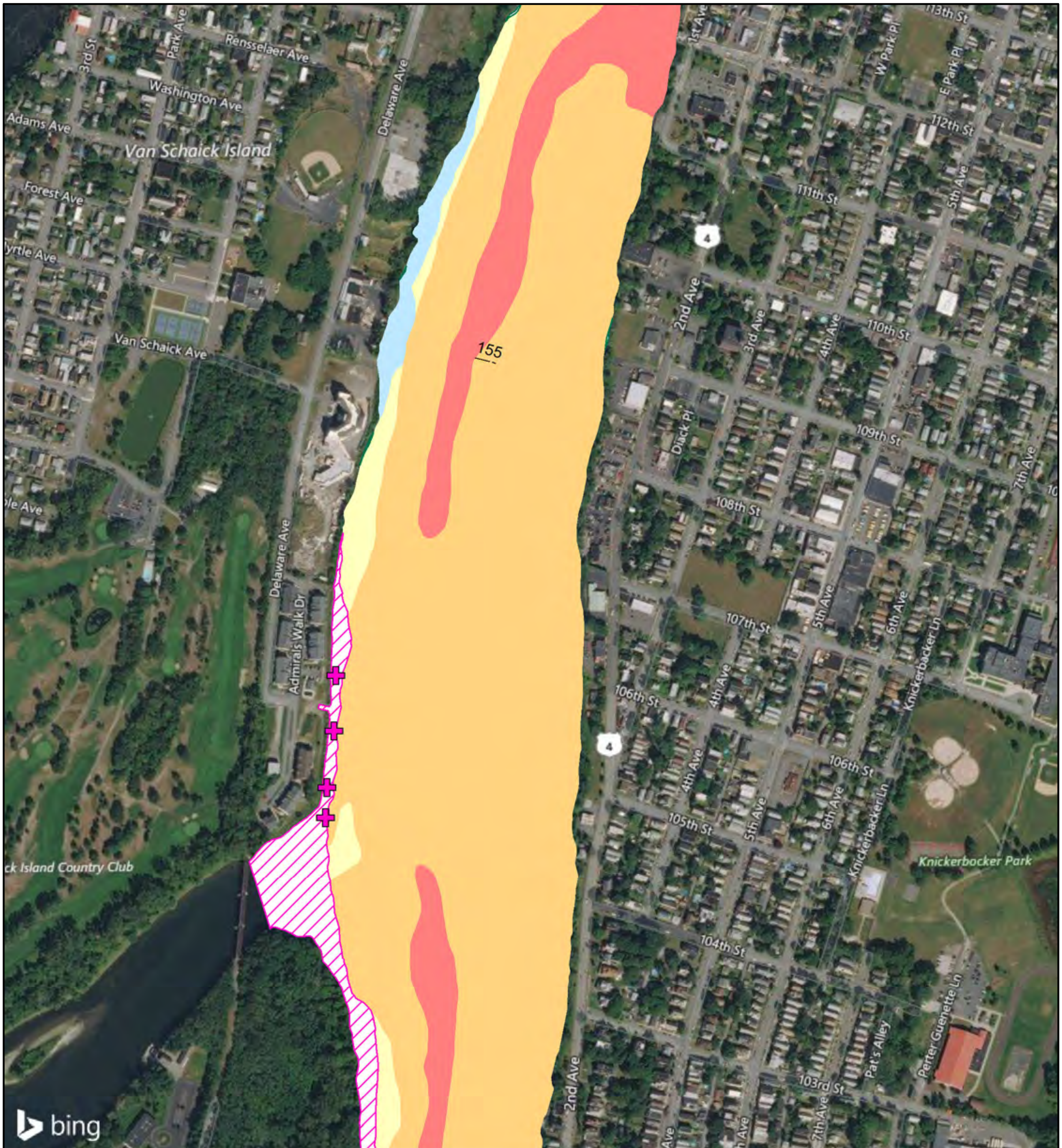
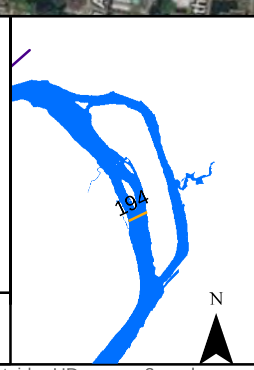


✚ (magenta)	SSAP/SEDC Cores in HDC Areas	**Sediment Type**	
✚ (green)	SSAP/SEDC Cores in Non-HDC Areas		Silt
	RS3 Unclassified High Density Core (HDC) Areas		Silt and Sand
	RS3 Unclassified Non-HDC Areas		Gravel
	Dams and Locks		Transitional
	Mile Markers		Bed Rock
	Certification Units		

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)



River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1av

Louis Berger

0 250 500 Feet

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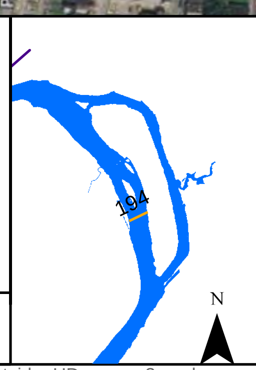

- SSAP/SEDC Cores in HDC Areas
- SSAP/SEDC Cores in Non-HDC Areas
- RS3 Unclassified High Density Core (HDC) Areas
- RS3 Unclassified Non-HDC Areas
- Dams and Locks
- Mile Markers
- Certification Units

Sediment Type

- Silt
- Silt and Sand
- Gravel
- Transitional
- Bed Rock

Coordinate System:
NAD 1983 StatePlane
New York Central FIPS 3101 (ft)

River Section 3 Unclassified Sediment in High Density Core (HDC) Areas and Non-HDC Areas

Figure A2-1aw

Louis Berger

0 250 500 Feet

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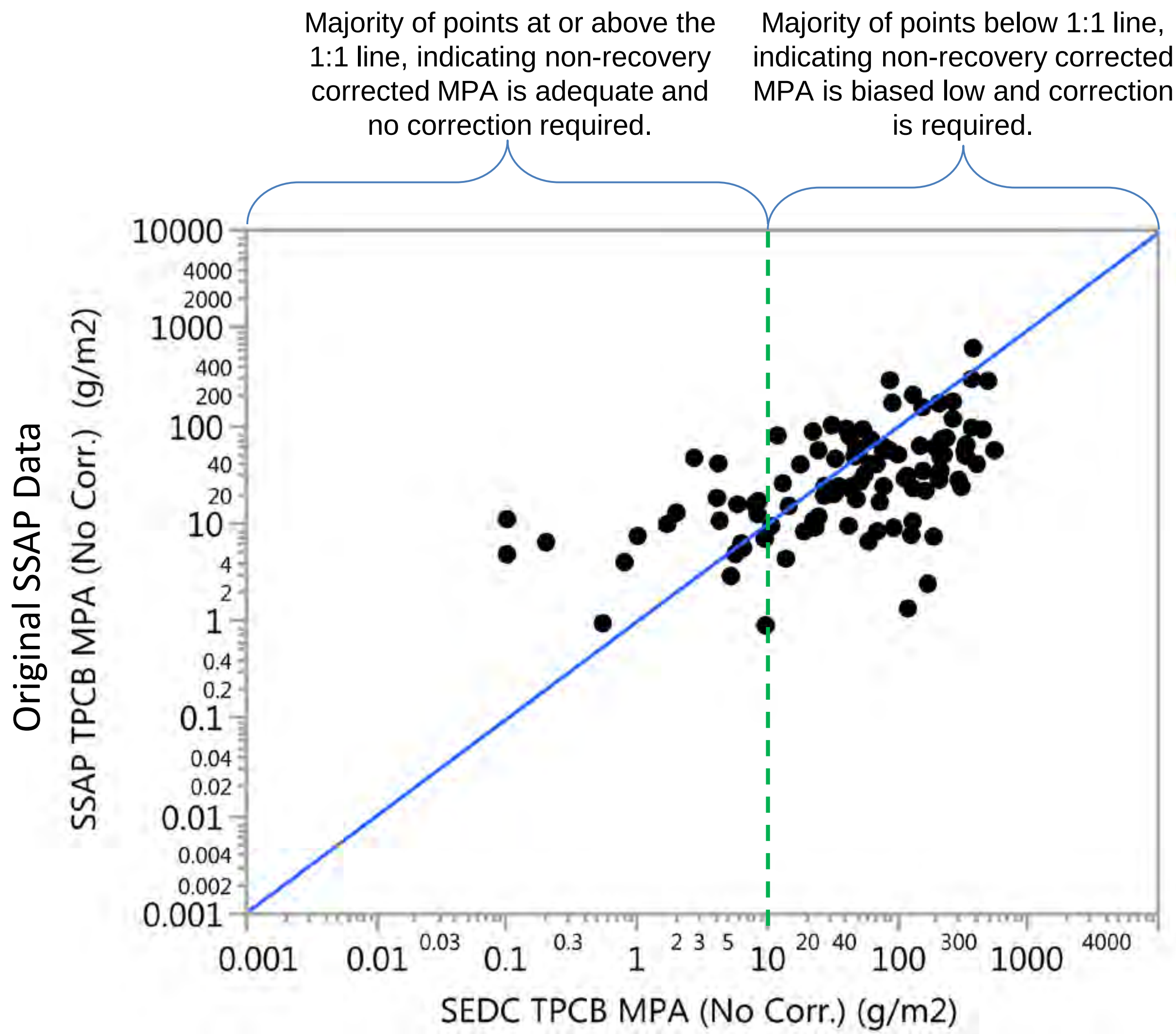
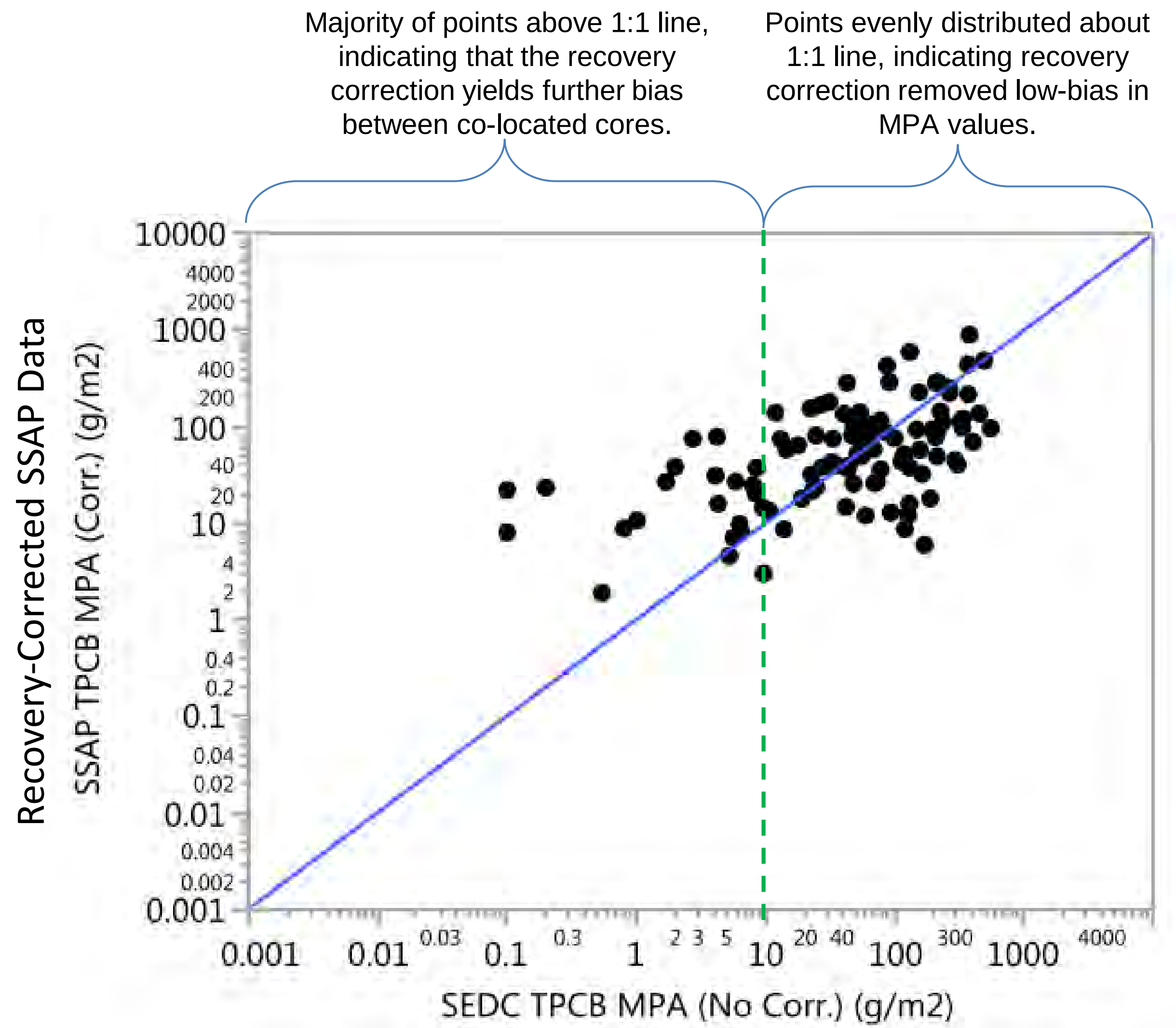


Louis Berger

Comparison of co-located low recovery (≤70%) SSAP non-recovery corrected MPA and high recovery (≥90%) SEDC non-recovery corrected MPA

Figure A2-2

April 2019



Louis Berger	Comparison of co-located low recovery (≤70%) SSAP recovery corrected MPA and high recovery (≥90%) SEDC non-recovery corrected MPA	Figure A2-3 April 2019