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Assessing Stability of Engineered Caps in the Upper Hudson River Impacted by a 100-year Flow Event

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Abstract

PCB contamination in the Hudson River extends back to the late 1940s. A 2002 Record of Decision (ROD) called for active remediation of PCB contamination in the Upper Hudson River (UHR, River mile 154 to 194). Of the 491 acres remediated, engineered caps were placed over approximately 15% of the river bottom: 17 acres during Phase 1 in 2009 and 56 acres during Phase 2 between 2011-2015. In April 2011, a storm with a recurrence interval of 100-years (i.e., 100-year flow event) occurred. Following the 100-year flow event, bathymetric surveys of the Phase 1 engineered caps were conducted in June 2011, which provided the project with the opportunity to validate performance of cap design and installation. A comparison of 2009 and June 2011 bathymetric surveys of Phase 1 caps indicated that one percent or less of each capped area (9 individuals caps) experienced greater than 3 inches of erosion, with the largest contiguous area of more than 3 inches of erosion being 530 square feet. Overall, the Phase 1 caps did not exhibit "Measureable Loss" as defined by the Operation, Maintenance & Monitoring (OM&M) program, a requirement under the 2002 ROD that outlines long-term monitoring activities (Table 4). Between 20% and 100% of Phase 1 capped areas experienced >3" of deposition, even under 100-year flow event conditions. These results demonstrate that the Phase 1 caps were largely successful in withstanding the Spring 2011 100-year flow event; during this event the dredged areas experienced net deposition, accumulating system sediment on top of the caps and further isolating material below the cap.

Introduction

PCB contamination in the Hudson River extends back to the late 1940s. A 2002 Record of Decision (ROD) called for active remediation of PCB contamination in the Upper Hudson River (UHR, River mile 154 to 194), including the removal of approximately 2.65 million cubic yards of contaminated sediment with the work to be performed in two phases. Dredging took place over a seven-year period (2009-2015). In accordance with the Residuals Engineering Performance Standard (EPS), targeted areas for which attaining the compliance threshold proved challenging were capped. Out of a total of 491 acres remediated, 17 acres were covered with an engineered cap during Phase 1 in 2009 and 56 acres were capped during Phase 2 dredging between 2011 and 2015. Dredging was performed in approximately 5-acre Certification Units (CUs) to aid tracking of dredging activities and to limit the amount of active dredging occurring at any one time. In April 2011, the UHR was subjected to a storm with a recurrence interval of 100-years (i.e., 100-year flow event) providing the opportunity to validate performance of cap design and installation.

Cap Design and Configuration in the Upper Hudson River

Cap design and configuration for dredged areas where required in Phase 1 were based on certain critical parameters within each Certification Unit (CU). Residual contaminant concentrations were used to determine the type and thickness of the isolation layer, while river flow velocity was used to determine the type and thickness of the armoring layer, as shown in Table 1:

Table 1. Summary of Cap Design and Configuration for Phase 1 Areas (2009)

Cap Type	Tri+ PCB[1] Residual Criteria for Use	Design Flow Event Interval	Construction
Type A	Nodal core conc. >1mg/kg and mean surface conc. ≤ 6mg/kg	Low Velocity (10-yr Flow Event)	12" layer of Type 2[2] Backfill (isolation layer)
		High Velocity (100-yr Flow Event)	6" layer of Type 2 Backfill (isolation layer) beneath a 6" layer of coarse gravel(armor layer)
Type B	Nodal core conc. > 6mg/kg	Low Velocity (10-yr Flow Event)	12" layer of Type 2 Backfill with 0.5% total organic carbon (TOC)
		Medium Velocity	9" layer of Type 2 Backfill with 0.5% TOC (isolation layer) beneath a 6" layer of coarse gravel (armor layer)
		High Velocity (100-yr Flow Event)	9" layer of Type 2 Backfill with 0.5% TOC(isolation layer) beneath a 6" layer of cobble stone (armor layer)

[1] Tri+ PCB refers to the sum of PCB congeners with 3 or more chlorine atoms per molecule.
[2] Type 2 backfill is defined as "run-of-bank" material with gravel no larger than 3 inches.

Table 2. Cap Types by CU for Phase 1 (2009)

Certification Unit	River Section	RM	Area Capped (acres)	Cap Type(s)[1]	Design Flood Interval
1	1	194	3.31	B	100-yr Flow Event
2	1	194	3.43	B	100-yr Flow Event
3	1	193	1.22	A	10-yr Flow Event
4	1	193	3.55	A/B	10-yr and 100-yr Flow Event
5	1	194	0.70	A	10-yr Flow Event
6	1	194	1.33	A	10-yr Flow Event
7	1	194	0.94	A	10-yr Flow Event
8	1	194	1.47	B	100-yr Flow Event
18	1	190	1.11	A	10-yr Flow Event

[1] Both A and B type caps were used in CU 4 as a result of residual concentrations exceeding 6 mg/kg in some locations but not others.

Phase 1 Cap Locations (2009)

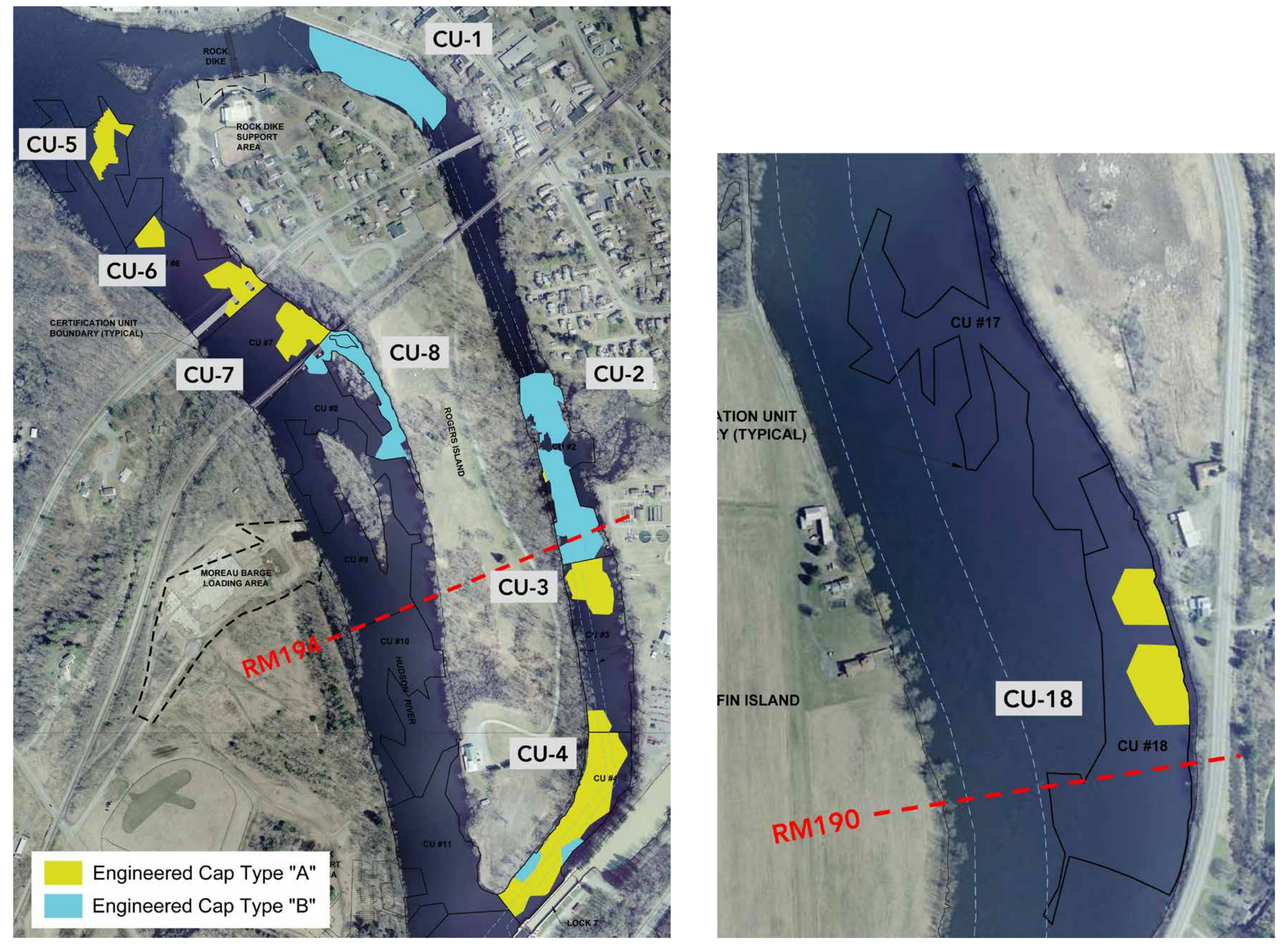

FIGURE 1. Cap Types and Locations Used in Certification Units (CUs) Dredged in Phase 1 (2009). Note that engineered caps were only installed in areas within a CU that contained residual PCB concentrations exceeding the Phase 1 Residuals EPS and thus were required to be permanently isolated from the overlying water column and biota. Dredging areas that were compliant with the Residuals EPS were backfilled with a thinner layer of material similar in composition to the cap material. These backfilled areas do not require long-term monitoring for stability.

Bathymetric Surveys to Monitor Cap Stability

A requirement of the 2002 ROD was the development of an Operation, Maintenance & Monitoring (OM&M) program that specifies the requirements for monitoring of caps in perpetuity. The OM&M specifies the use of multi-beam hydrographic surveys for surveying capped areas where feasible. In some cases backfill for habitat reconstruction was placed over the caps. For those areas the actual cap surface can't be measured but the backfill surface is monitored. Note that only Phase 1 caps were subjected to the 100-year flow event and therefore are the focus of this presentation. Stability of Phase 2 caps will be analyzed as multi-year bathymetric surveys for these caps become available.

Table 3. Summary of Bathymetric Survey Schedule for Areas Capped in Phase 1 (2009) and Phase 2 (2011 – 2015).

Dredging Activity	Year Capped	Post-placement Survey	Year 1 Survey	5-year Tier 1 Survey	10-year Tier 1 Survey	Additional Tier 1 Surveys
Phase 1	2009	**2009**	**2010**	**2014**	2018	Every 10 years until 2038
Phase 2 Year 1	2011	**2011**	**2012**	**2016**	2023	Every 10 years in perpetuity
Phase 2 Year 2	2012	**2012**	**2013**	2018	2023	
Phase 2 Year 3	2013	**2013**	**2014**	2018	2023	
Phase 2 Year 4	2014	**2014**	**2015**	2018	2023	
Phase 2 Year 5	2015	**2015**	**2016**	2018	2023	

Note: Bold indicates that the survey results are available.

April 2011—100-yr Flow Event

In April 2011, a 100-year flow event occurred, with a mean daily discharge reaching a maximum of 47,100 cfs on April 29, 2011. In response to this event, a high flow survey of Phase 1 caps installed in 2009 was performed in June 2011. The 2011 high flow survey data were compared with the 2009 post-placement survey data to determine whether any "Measurable Loss" of cap material had occurred as defined below.

Table 4. Metrics Used to Determine Degree of Cap Stability

Loss Metric[1]	Criteria	Actions Based on Metric
"Measurable Loss"	Loss of more than 3 inches of cap thickness over a contiguous 4,000 sq. ft. area or contiguous area representing 20% of the cap area, whichever is less.	Follow-up visual (and, as necessary, physical) investigations are to be conducted to develop other lines of evidence and determine whether there has been a "Significant Loss" of cap material.
"Significant Loss"	Confirmation of the "Measurable Loss" by additional lines of evidence as described above.	If "Significant Loss" is confirmed, affected areas of the cap will be repaired as necessary.

[1] "Measureable Loss" and "Significant Loss" are metrics defined in the OM&M program and applied to results of the bathymetric surveys described in Table 3. The specific actions listed in Table 4 are initiated if the criteria for a metric have been met.

Stability of Engineered Cap Following 100-year Flow Event

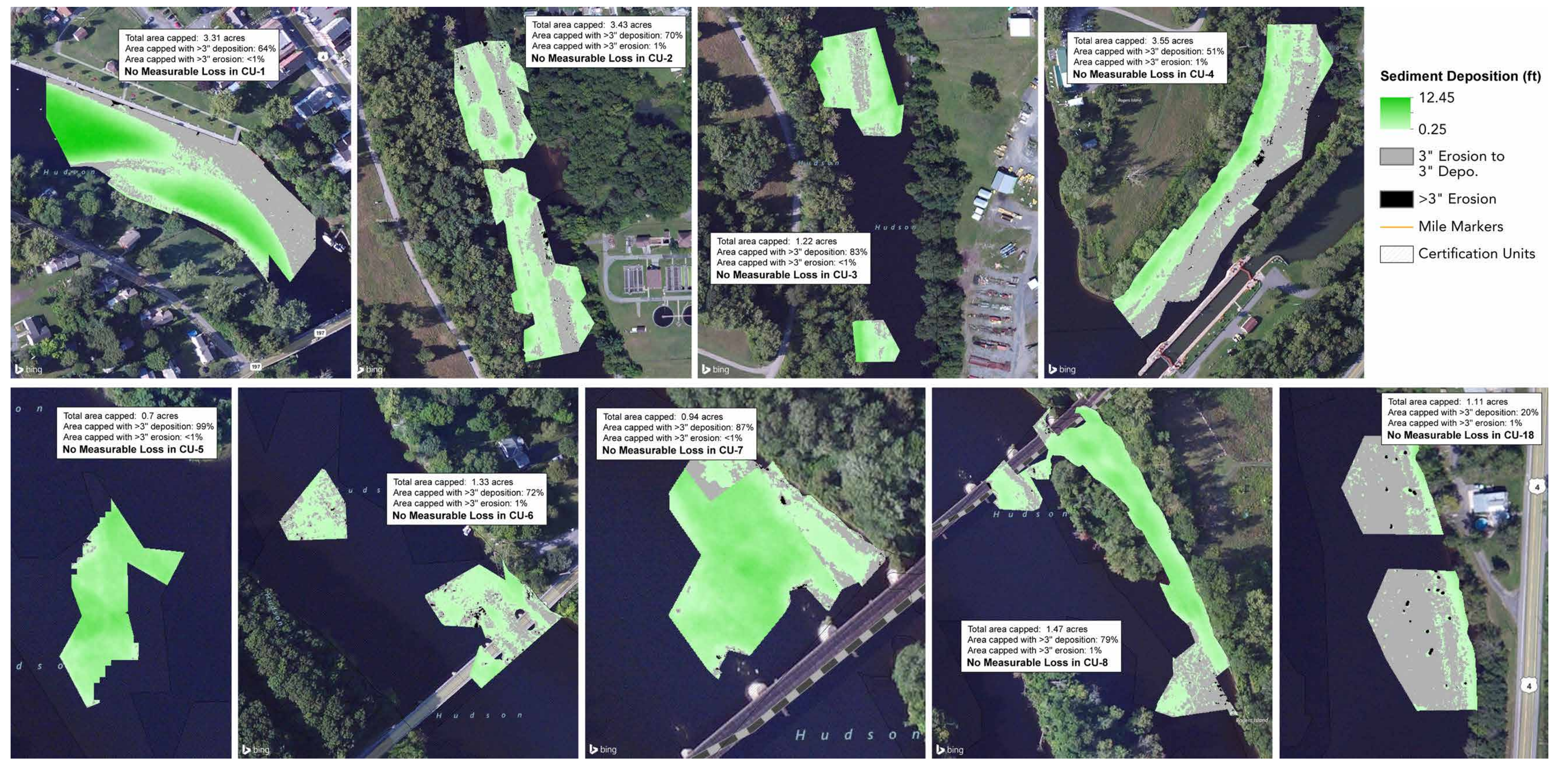

FIGURE 2. Results of the comparison of the June 2011 high flow survey and 2009 post-placement survey are shown in Figure 2. The measurement error for the bathymetric survey was assumed to be 6 inches. Therefore, if the difference in elevation between the 2009 and 2011 was within +/- 3inches, it was assumed that no erosion or deposition occurred.

Conclusions

The results of our analysis indicated that:

- Phase 1 caps withstood the impact of a Spring (April 2011) 100-year flow event, with minimal erosion and importantly, no "Measureable Loss" of cap material was identified in the 9 caps analyzed. The largest erosional area with more than 3" of cap material loss was 530 square feet (approximately 13 percent of the allowable impacted area under the EPS).
- Storm-related deposition of sediment occurred across extensive areas of the caps. This deposition further isolates the PCB residuals and provides greater confidence in long-term cap stability moving forward.
- For the single high-flow event analyzed here, it was notable that the performance of the caps designed for a 10-year flow event was similar to those designed for the 100-year flow events.
- While the analysis was limited to one Spring storm event and only caps installed in the Phase 1 capped areas of the river, it appears that the nominal dredging of 2 to 3 feet of contaminated sediment (typical removal thickness for the project) followed by placement of a properly designed cap 1 to 1.5 feet thick provides a fairly secure means of isolating residual PCB contamination.