Date: November 8, 2006

To: Doug Garbarini, USEPA

From: Malcolm Pirnie, Inc.

Subject: Maintenance of Pre-existing Shoreline Configuration and River Bathymetry

Summary In support of the recent discussions between EPA and GE concerning the reconstruction of the shoreline configuration and the river bathymetry, Malcolm Pirnie examined shoreline slopes in the Phase 1 areas. Additionally, Malcolm Pirnie also examined the relationship between river water elevation and the frequency of various flows. The results of these analyses indicate the existence of a natural break in shoreline slope occurring approximately 15 ft in-river from the 5,000 cfs shoreline. That shoreline corresponds to an elevation of 119 ft elevation NAVD 1988 and the break occurs at an elevation of 117.5 ft. Additionally, the analysis of the flow data indicates that the 117.5-ft elevation is exposed on a routine basis, probably multiple times per year due to the large daily flow cycle that occurs each day due to hydroelectric power generation. Based on these observations, the data support the definition of the shoreline area as the near-shore region down to an elevation of 117.5 ft.

Discussion Malcolm Pirnie conducted several separate analyses to support the selection of a near-shore boundary. Both the slope in the vicinity of the shoreline as well as the behavior and elevation of river flows were examined in this regard. The analyses supporting the recommendations to the EPA are described separately below.

<u>Examination of the river slope in the near shore area.</u> Shoreline slopes were examined on one-foot intervals along lines running parallel to shore. Lines parallel to shore were initially selected at 20, 40 and 80 ft off shore. Later in the analysis, a line at 14 ft off shore as well as the 117.5 ft contour were added to the analysis. The analysis was restricted to the Phase 1 areas that included a portion of the shoreline in their limits. Slopes were estimated perpendicular to the shoreline, providing a measure of the steepness of the bank for the various certification units (CU). To examine the shoreline profile, the slope was determined on one-foot intervals between each of the lines offshore. For example, the slope was estimated for one-foot intervals along the 20-ft offshore line, each time estimating the slope to the nearest one-foot interval point on shore (the 119-ft elevation). Similarly, the slope was measured between the 40-ft offshore line and the 20-ft offshore line, on one-foot intervals. These data were then compiled to determine the median and mean slope between each line for each certification unit. In this manner, nominally 1,000 slope estimates were generated for each CU. These data were then compiled to generate a median CU shoreline profile. These profiles are shown in Figure 1.

The initial evaluation of these profiles showed a marked change in slope near the 20-ft offshore line. Based on this, two additional lines were added, an offshore line at 14 feet off shore as well as the 117.5 ft contour. These were chosen given the height of the Thompson Island Dam, which would determine the ultimate minimum height of water in the TI Pool. These lines showed that the slope change actually occurred between 14 and 15 feet offshore, yielding a similar slope beyond this point out to approximately 40 ft offshore. 14 of the 18 Phase 1 certification units suggested this break, with median elevations within 6 inches of 117.5 ft at 14 feet offshore. Beyond this distance from shore, the river surface varies more widely and differences among the profiles at 20, 40 and 80 feet offshore are greater. This is shown in Figure 2 which is a box-and-whisker plot of the shoreline slopes at each distance. The break in slope at 14 feet off shore was confirmed as approximately the 117.5-ft contour by examining the distance between this contour and the 119-ft shoreline elevation. The median distance was 15 feet, which is within the precision of the analysis.[1]

These data indicate the presence of a natural shoreline break around 14 to 15 feet offshore, corresponding to the 117.5 contour. River bottom slope perpendicular to flow in this region is fairly shallow, at 10:1 (run: rise). While the exact cause of the prevalence of this slope and the natural break at 117.5 ft is unknown, it has two likely causes. First, it may be a break corresponding to a historical flood terrace, formed prior to the building of the Hudson-Champlain Canal. It may also be the result of the canal construction itself, since the height of the dam prevents lower elevations in the Pool. The presence of the dam also serves to focus wave action in this area, which would tend to flatten the area more than river flow alone. Regardless of whether the shallow sloped shoreline area was formed prior to the dam's construction, wave action and the daily oscillation of the river surface elevation serve to maintain the shallow slope of this area.

This observation has important implications for the reconstruction of the shoreline area. Given the energies available to move sediments in these areas, attempts to replace these shoreline areas at slopes steeper than 10:1 would require backfill materials much coarser than what is currently in place. Construction of such a slope would likely create a surface feature along the banks whose sediment texture and slope are coarser and steeper than what exists now. Given the daily oscillation in flow, this structure would be exposed daily under typical flow conditions.

Notably, the differences in slope along the cross sections are fairly large, with a median CU slope of 10:1 (run: rise) within 15 ft of shore, 6:1 between 15 and 40 feet offshore and 9:1 from 40 to 80 feet offshore. The four outlier CUs are 1, 6, 11, and 12. Of these, both 1 and 12 have man-made structures at the shoreline. CU 11 has had historical dredging by the NYSDEC during the late 1970s which may have affected the natural bank contours. There are no simple explanations for CU 6. The locations of the CUs along with bathymetric contours, habitat delineations and the median DOC at the shore are shown on Figures 3 and 4, representing all of the Phase 1 areas.

<u>Shoreline elevation and river flow.</u> The prior discussion documents the occurrence of a natural change in slope that occurs at or just above the height of the dam in the TI Pool. In the following discussion, the frequency of various flow events is examined to assess how often this elevation is exposed due to low water in the river.

As part of this analysis, the return frequency of daily flow and weekly flow events were determined. Table 1 lists the flow and elevation for several low flow events, including a 1 day (daily average) low flow event occurring once every 3 years (1Q3) and a 7-day low flow event (7Q10) occurring once every 10 years. These

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[1] In the initial examination of the shoreline slope, river bottom elevations were determined for distances of 20, 40 and 80 ft off shore for each of the CUs. Based on a rough calculation involving the elevation of the TI Dam and the median slope from the shoreline to 20 ft offshore, river bottom elevations were examined at a distance of 14 ft offshore, estimated as a low water condition approximately 6 inches over the top of the TI Dam. This distance had a median elevation of 117.5 ft, a mean elevation of 116.5 ft, (see Figure 2) and corresponded to an apparent change in bottom slope. To further support this observation, the distance from shore to the 117.5 ft contour was determined as a cross check on the calculations. The median distance of the 117.5-ft contour was found to be 15 ft Given the close agreement between the two calculations, the 117.5-ft contour with a median distance of 15 ft offshore was chosen as the demarcation of the natural break in slope

are flows of 1,100 cfs and 1,800 cfs, respectively.[2] Figure 5 shows a USGS rating curve for the Ft Edward gauge, relating flow at Ft Edward to river elevation. Note that this figure is referenced to the vertical datum USGS NGVD 1929. There is a difference between the USGS vertical reference frame and that used by GE. The difference between the two reference frames can be readily overcome by normalizing the USGS results to the 5,000 cfs shoreline condition, to which GE assigns a value of 119 ft, based on USGS NAVD 1988.[3] In this manner, the changes in elevation relative to the USGS vertical datum can be readily converted to the GE vertical reference frame. The two flow events discussed above correspond to elevations of 117.6 and 118.0 ft, respectively relative to the GE 119-ft, 5,000 cfs shoreline. The return frequency of these events indicates that the 117.5 elevation is approached fairly routinely, occurring at least every few years on a mean basis.

A further consideration is warranted here, however. Although the mean condition approaches the 117.5-ft contour on a frequency of one day every three years, there is a significant daily oscillation in flow that results from flow control to generate hydroelectric power. This daily flow variation is most pronounced at lower flows, causing the water elevation at Ft Edward and throughout the TI Pool to vary nearly a foot each day when the average flow drops below 3,000 cfs. As a result, typical low flow events occurring annually would serve to expose shoreline areas to close to the 117.5-ft contour. This can be seen in the most recent high frequency provisional data available from the USGS.

In Figure 6, the mean daily flow for the period August 11 to 31, 2006 is plotted against date. The figure shows August of 2006 to be a relatively dry month, as is typical for August, although this year has been a particularly wet one in the Upper Hudson. Nonetheless, flows reach the level corresponding to the annual one-day low flow event (1Q1), around 2,600 cfs, on several days. Even at this level, however, the daily oscillation in flow generates flows frequently under 2,000 cfs. This is shown in Figure 7, which shows the 15-minute interval data of the same period as Figure 6. Daily low flows below 2,000 cfs occur on 13 of the 20 days examined, for periods of 15 minutes to several hours. Hence the shoreline of the TI Pool is exposed to elevations approaching the 117.5-ft elevation on a regular annual basis.

<u>Shoreline cross section examples</u>**.** An example pre-dredge shoreline cross section is shown in Figure 8a, illustrating the typical shallow near-shore slope of approximately 10:1 out to the 117.5-ft elevation where the slope changes to approximately 6:1. The figure also represents the condition where the depth of contamination is greater than 2 feet at the shoreline; this situation would require a 2 foot initial cut followed by a cut on a 3:1 slope. Figure 8b depicts the same shoreline configuration subsequent to dredging with the backfilling proposed by GE in their April 28, 2006 letter from John Haggard to Doug Garbarini, as well as in Figure 2 of GE's August 4, 2006 Statement of Position. Figure 9a provides a similar cross section, except that the depth of contamination is less than 2 ft so the depth of cut and the depth of contamination are the same at the shoreline. Figure 9b depicts the cross section with GE's proposed backfill, similar to the illustration shown in Figure 8b.

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[2] The 1Q3 and 7Q10 events refer to periods of low flow occurring over differing lengths of time and at different frequencies of occurrence. The 1Q3 represents a lower flow condition for the Upper Hudson essentially because the river is less likely to experience a sustained flow event lasting 7 days at such a low level. The elevation for the low flow event (1Q3), rounded to the nearest 6 inches (i.e., to 117.5 ft), corresponds to the observed change in shoreline slope that occurs at 117.5 ft of elevation. Finer resolution than 6 inches is considered unwarranted given the nature of the earth moving equipment likely to be used in restoring the bathymetry.

[3] The difference in absolute elevation for the 5,000-cfs flow condition between the USGS staff gauge at Ft Edward and the GE shoreline is due to both the difference in the vertical reference frame (approximately 0.6 ft) and the typical change in river surface elevation that occurs between the USGS staff gauge and the TI Pool.

Recommendation. Figures 8c and 9c depict the recommended placement of backfill (or backfill/cap if capping is implemented) to maintain the pre-existing shoreline configuration and river bathymetry in the backfilled or backfilled/capped area. Figure 8c depicts backfilling/capping recommended in the situation where the DOC is extrapolated to be greater than 2 feet at the 5,000-cfs shoreline (as illustrated in figure 8a). Figure 9c represents backfill/cap recommended in shoreline areas where the depth of contamination lies between 1 ft and 2 ft.[4] These figures illustrate how the bathymetry should be restored to the 117.5 contour which approximates the 1Q3 flow. Beginning at the 117.5 elevation, backfill would be placed on a 3:1 slope until it intersects the 1 ft of backfill material typically required in areas not subject to this determination. This wedge of additional backfill is needed to prevent slumping on the river side edge of the bathymetric restoration of the near shore area. The change in slope at an elevation of approximately 117.5 ft would require a supporting wedge that would nominally extend horizontally to 12 ft beyond this elevation, given the median 6:1 slope.[5]

The shoreline areas in River Section 1, the TI Pool, show a natural break in slope at approximately 15 feet offshore, corresponding to an elevation of 117.5 ft. The area above this break is subject to wave action as well as the daily oscillation in river elevation, both of which probably serve to maintain a shallow near-shore slope. This elevation is also related to the top of the TI Dam, which effectively provides a lower bound on the shoreline elevation that might be exposed due to low flows. The frequency of low flow events in the Upper Hudson coupled with the daily flow oscillation for hydroelectric power production serves to expose the shoreline area to an elevation of 117.5 ft multiple times per year. Hence reconstructing the shoreline to the 117.5-ft contour would yield a smooth shoreline area regardless of the flow conditions. Due to the limitations of dam height and the frequent variation of the river elevation, it is reasonable to conclude, for purposes of this analysis, that the shoreline area extends to this elevation, approximately 15 ft from the 5,000 cfs shoreline.

Conversely, reconstructing the shoreline bathymetry to a more limited extent (*i.e.,* to a higher elevation) would necessitate the creation of a transitional zone (the transition from the reconstructed bathymetric surface to the 1-ft of backfill domain) that would need to be much "harder" than the existing sediments of the near shore area. The need for this arises from the higher energy levels in this near-shore area due to both wave action as well as the daily variation in river elevation, as already noted by GE in their Phase 1 Design. Reconstruction of the shoreline area out to the natural break at 117.5 ft would place the transitional zone out of this high energy area and into a region where less energy is available, as reflected by the steeper slopes beyond the 117.5-ft contour. In this manner, this transition would require less armoring and be more similar to the existing conditions.

Determination of the extent of shoreline reconstruction in this manner could be readily extended to the Phase 2 areas in River Section 1 since they are subject to the same energies and oscillations and likely have similar shoreline structures. The same general approach is also suited for the various river segments downstream. In the downstream river segments, information on flows and the dam elevations should provide a sufficient basis to support the use of a 1Q3 flow and river elevation condition as the limit of the shoreline reconstruction. Similar to River Section 1, the height of the dam in each river reach should provide a lower bound on the area for reconstruction. The higher flow energies at elevations greater than the dam height are again likely to

[4] Note that no additional backfill is required in shoreline areas where the depth of contamination is 1ft or less. This is because the required placement of up to 1 ft of backfill in these areas would restore the shoreline bathymetry directly.
[5] Note that while Figures 8c and 9c are expected to represent typical conditions, they are not representative of all conditions that may be encountered..

create shallow shoreline slopes akin to those in River Section 1. In this fashion, the decision on the Phase 1 areas should be applicable to regions downstream after identifying the 1Q3 flow event values. If sufficient bathymetric data are available to identify a natural break in slope in the shoreline areas of a given pool, and if the natural break is proximate to the 1Q3 flow shoreline, then it may be appropriate to consider utilizing the bathymetric contour for that pool that approximates the median bathymetric contour of the natural break in the shoreline area. If such a natural break is not generally found in a given pool, the 1Q3 flow should be used exclusively.

Table 1

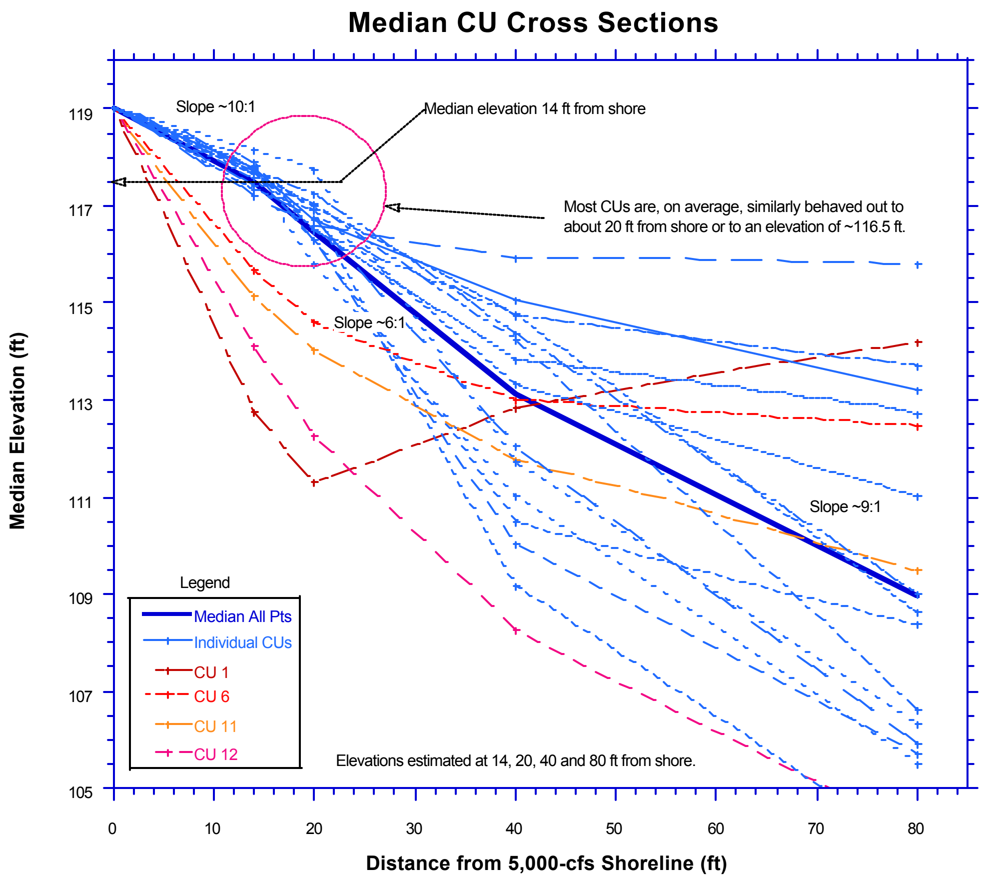
Estimation of Shoreline Elevation at Various River Flows

Flow Events	Event	Flow (cfs)	USGS Staff Gauge Height (NGVD29) (ft)	Elevation Relative to GE Shoreline (NAVD88) (ft)
Dredge Shoreline Elevation		5,000	121.7	119.0 **
1 day event annually	1Q1	2,570	121.0	118.3
7 day event once every 10 years	7Q10	1,800	120.7	118.0
1 day event once every 3 years	1Q3	1,100	120.3	117.6
1 day event once every 10 years	1Q10	700	120.0	117.3

Notes:

** For this calculation, the change in elevation at the Ft Edward gauge was applied directly to GE's shoreline elevation to estimate the water height at different flows. The difference in absolute elevation is due to both the difference in the vertical reference frame (approximately 0.6 ft) and the typical change in river surface elevation that occurs between the USGS staff gauge and the TI Pool.

Figure 1



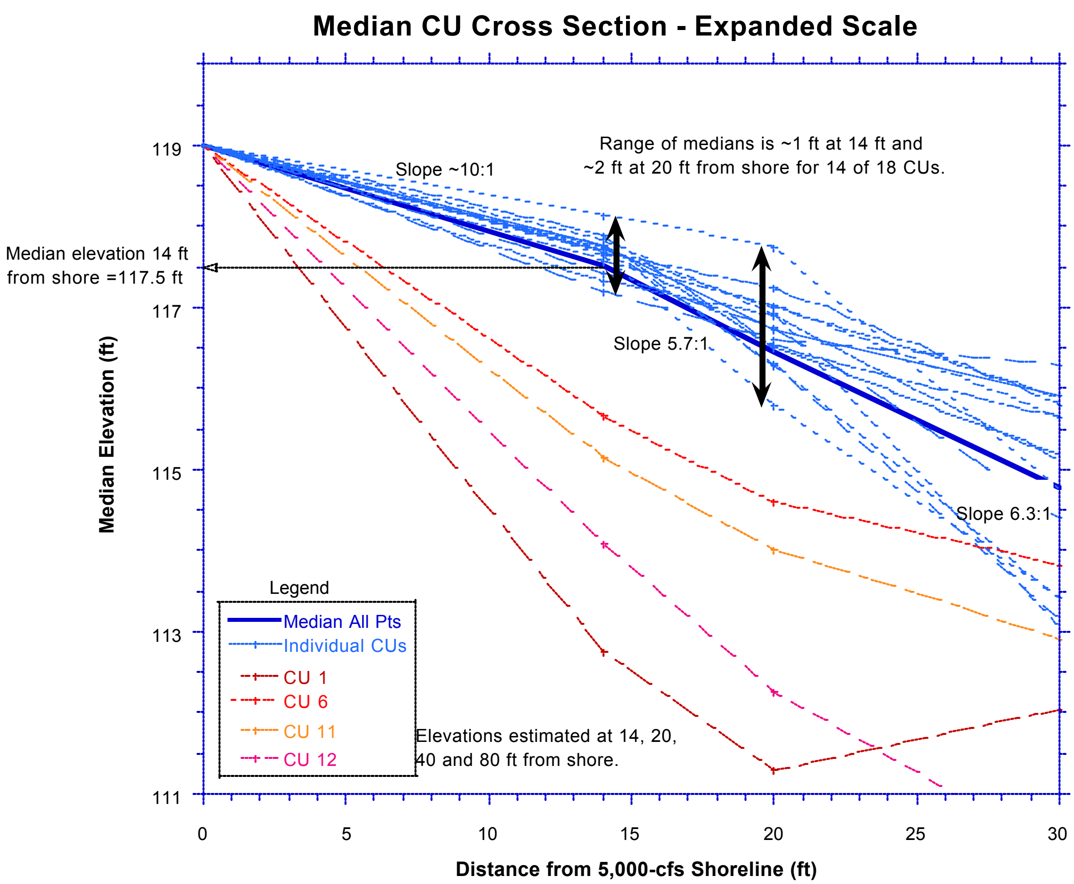


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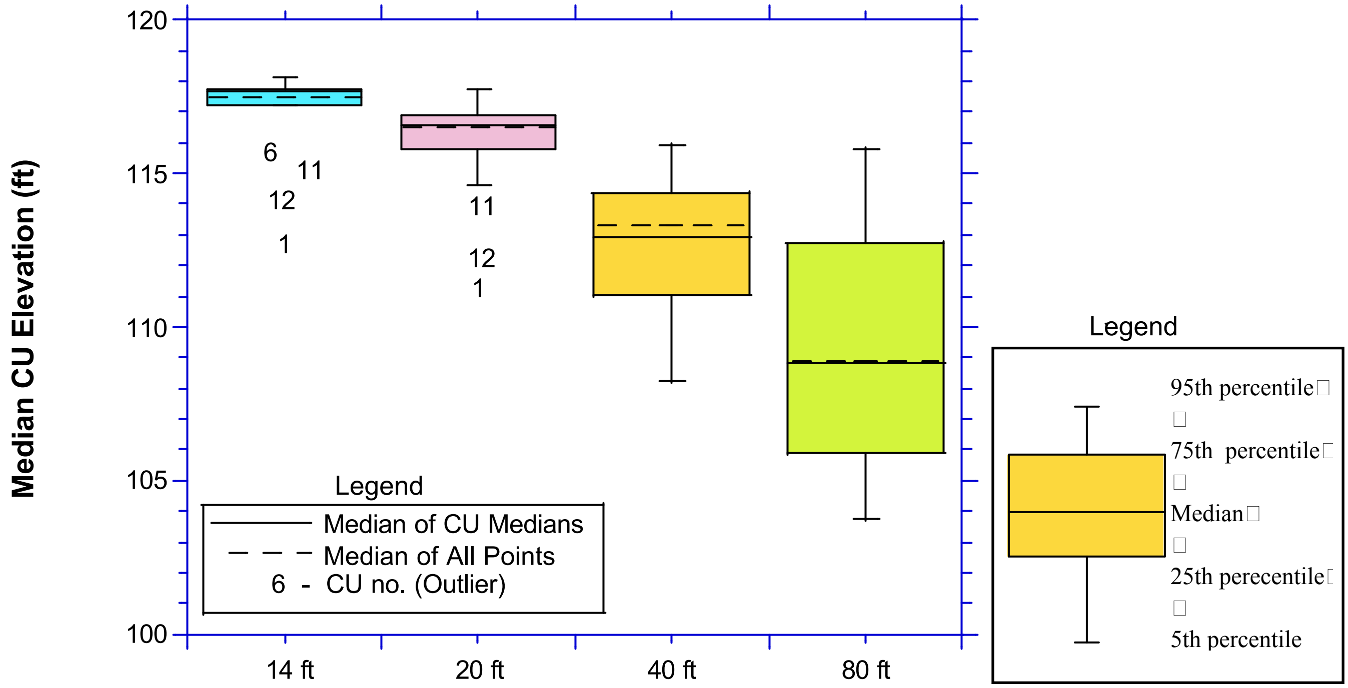
Figure 2

Comparison among Median CU Elevations

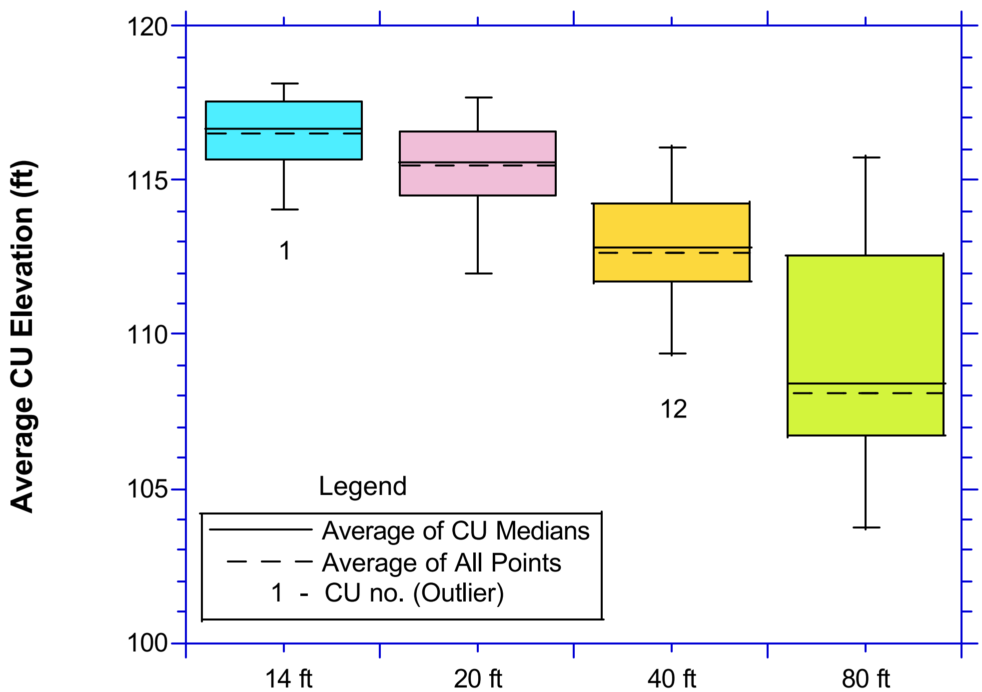


Distance from 5,000 cfs Shoreline (ft)

Median elevations are tightly grouped for 14 of the 18 Phase 1 CUs
for 14 ft off shore (117.5 ft elevation) and 20 ft off shore (116.5 ft elevation)

Note: See footnote in text for discussion on the 117.5 ft contour and distance from shore.

Comparison among Average CU Elevations



Distance from 5,000 cfs Shoreline (ft)

Average elevations are less tightly grouped but still show the least variation for 14 ft
off shore (116.5 ft mean elevation) and 20 ft off shore (115.5 ft mean elevation)
Note: See footnote in text for discussion on the 117.5 ft contour and distance from shore.

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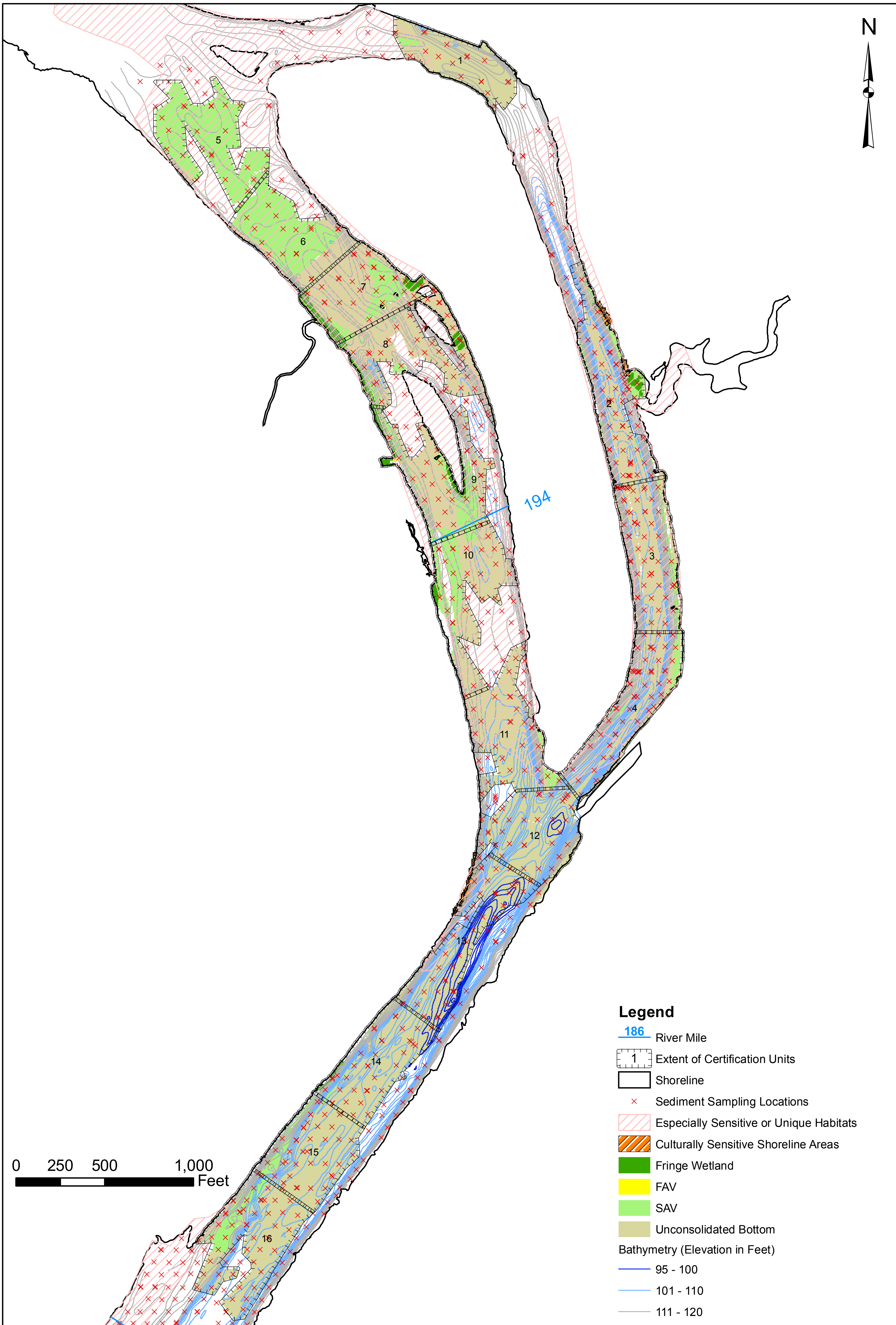

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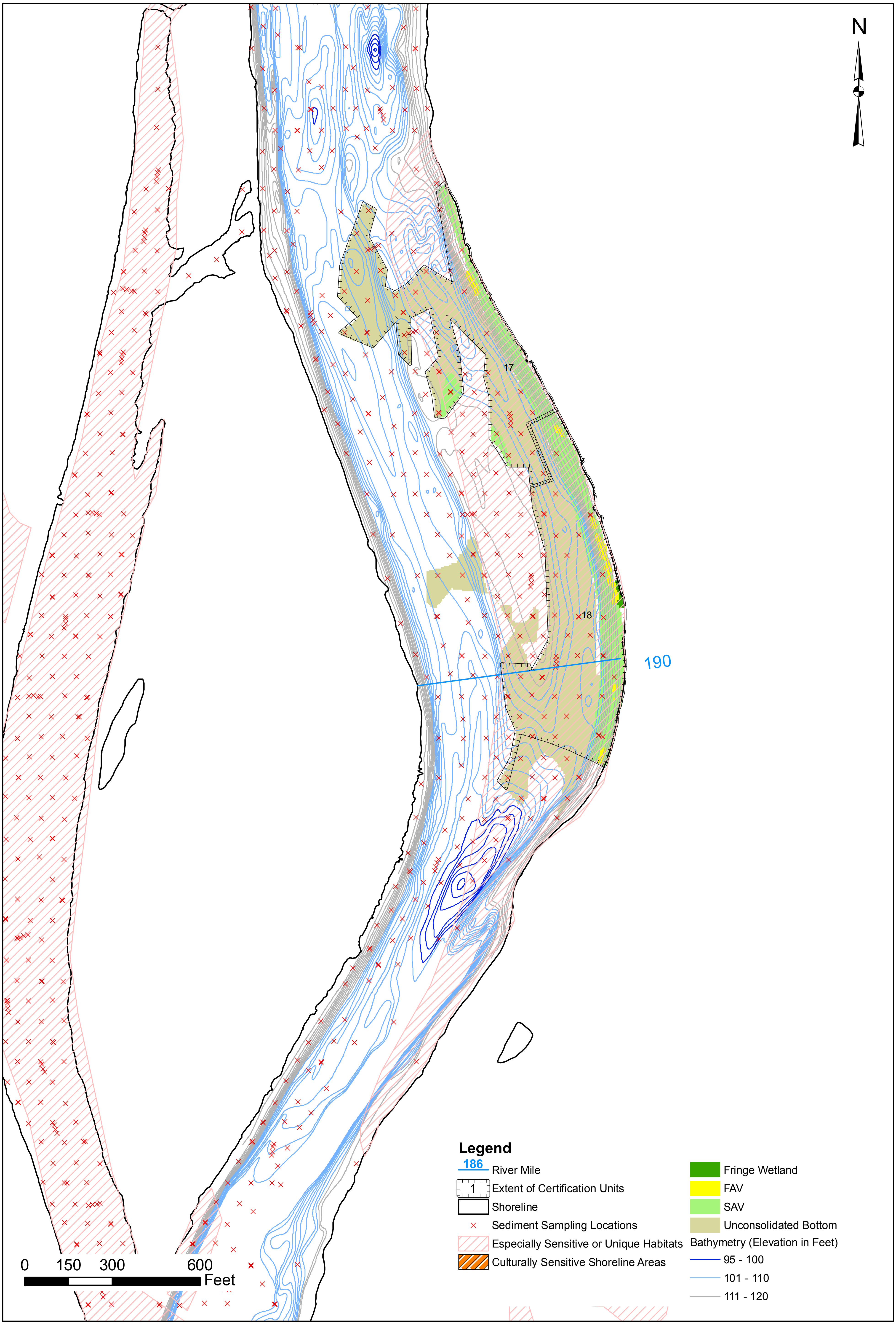
Bathymetry in Phase I Areas
Rogers Island

Figure 3



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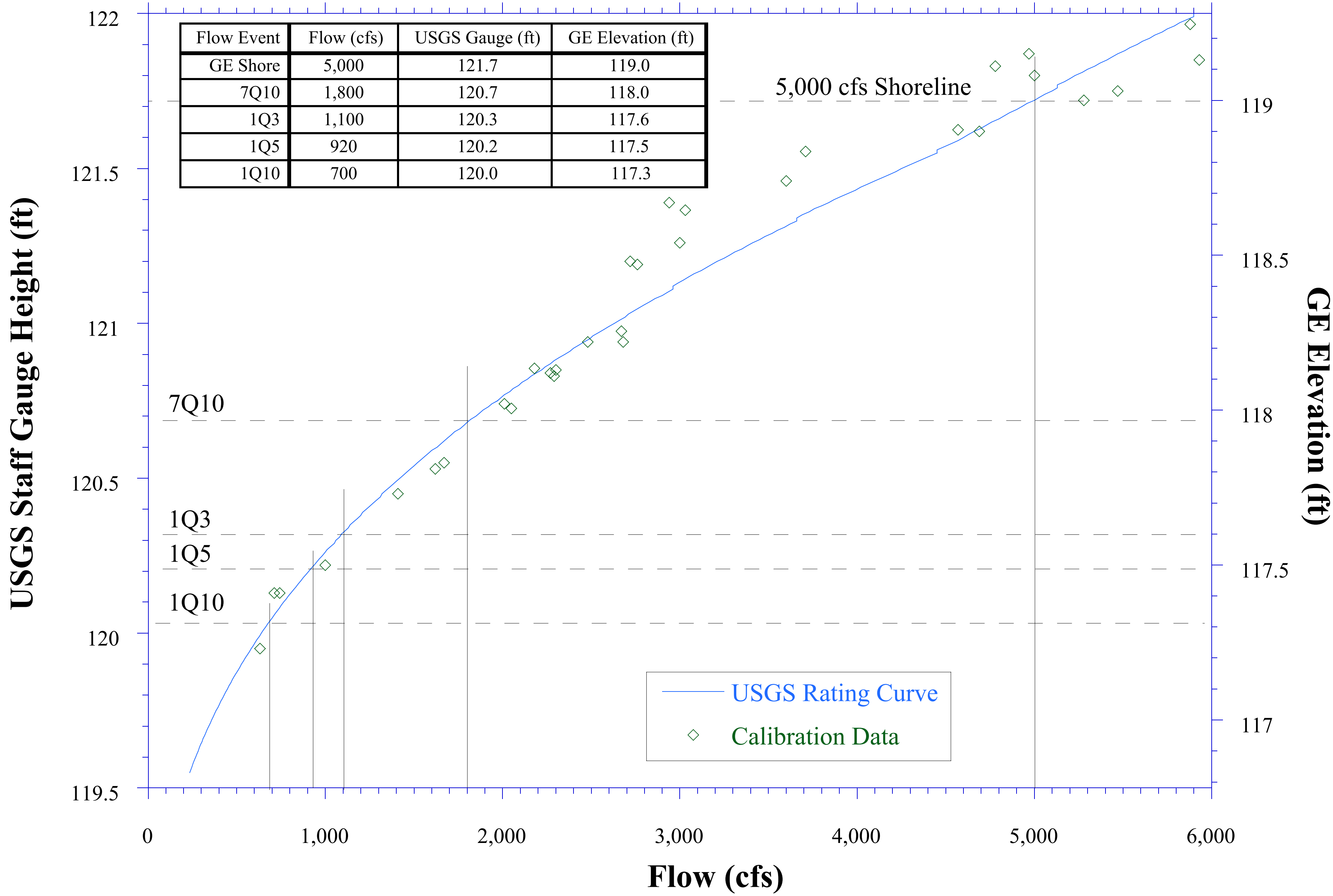
Bathymetry in Phase I Areas East of Griffin Island

Figure 4

Figure 5
USGS Rating Curve for Gauge at Ft Edward



Flow Event	Flow (cfs)	USGS Gauge (ft)	GE Elevation (ft)
GE Shore	5,000	121.7	119.0
7Q10	1,800	120.7	118.0
1Q3	1,100	120.3	117.6
1Q5	920	120.2	117.5
1Q10	700	120.0	117.3

Figure 6
Mean Daily Flow,
August 11, 2006 to August 31, 2006

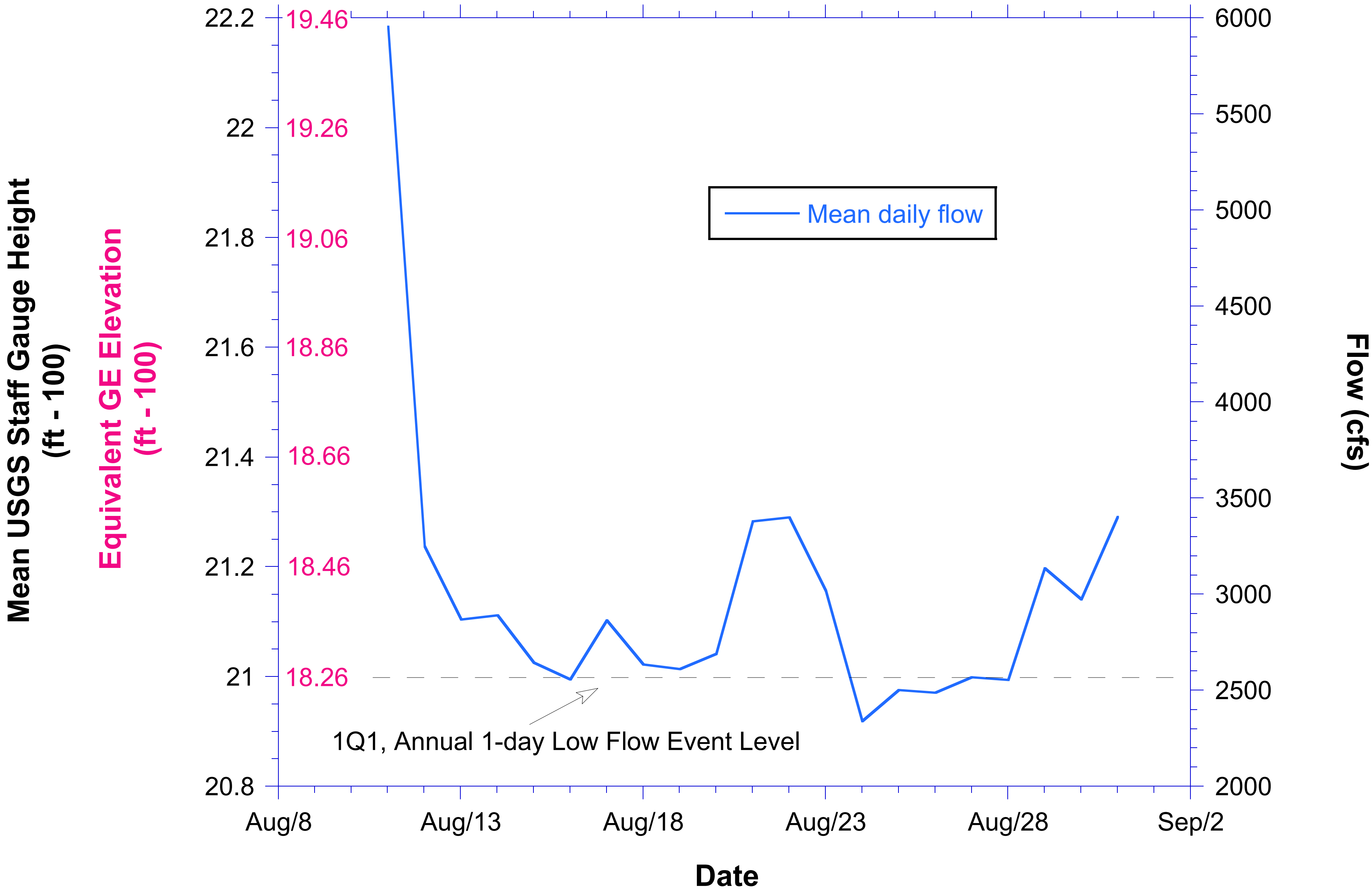


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Figure 7
Daily Variation in Flow at Ft Edward
August 11, 2006 to August 31, 2006

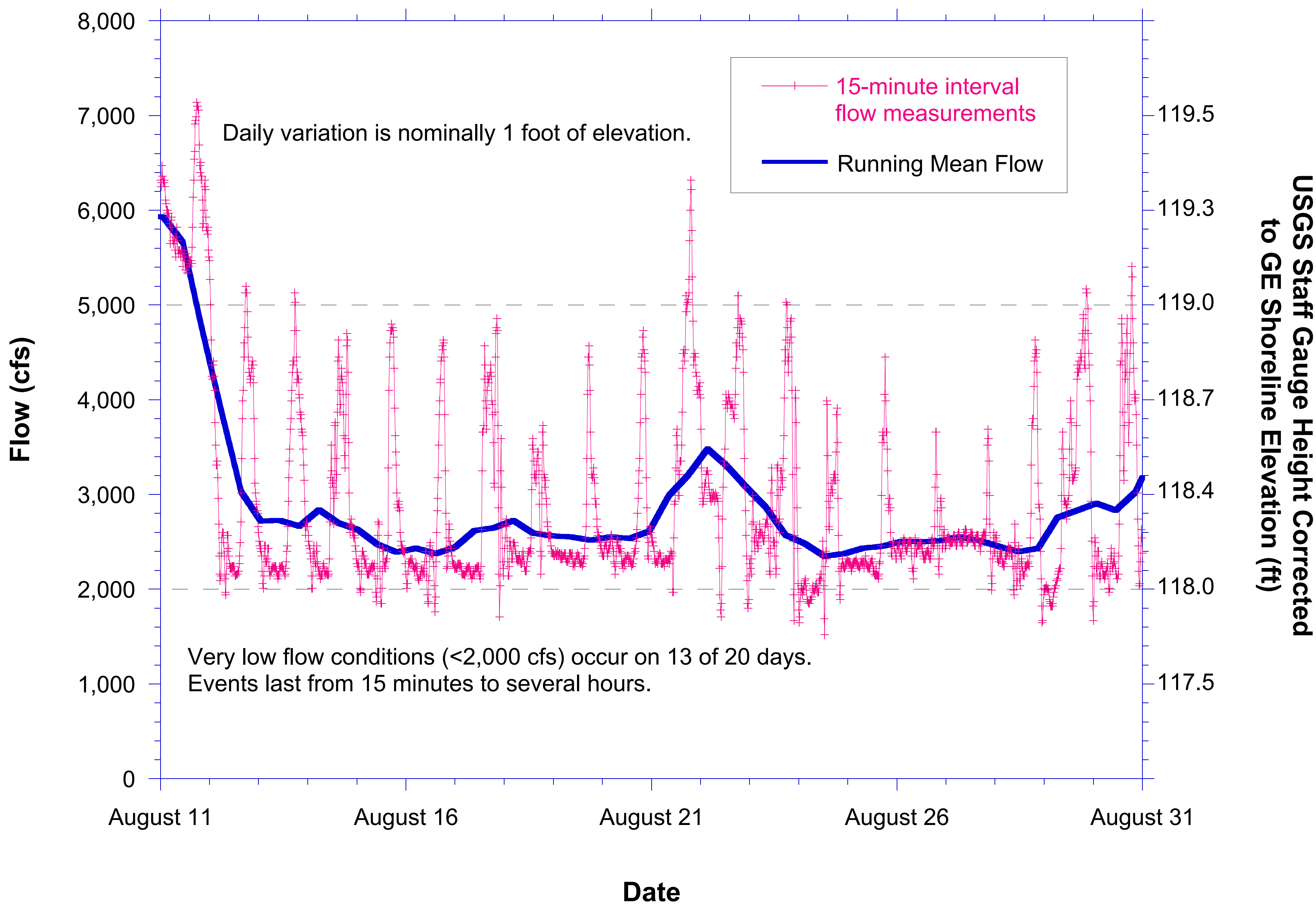

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Figure 8a
Pre-Dredge Condition

Typical Shoreline Cross Section
Depth of contamination = 3 ft

Typical Conditions (Actual conditions vary)
- Shoreline at 119-ft elevation, corresponding to 5,000-cfs flow.
- Median shoreline slope at 10(H):1(V).
- Slope change at 117.5 elevation, median offshore distance of 15 ft.
- Median slope below 117.5-ft elevation at 6(H):1(V)

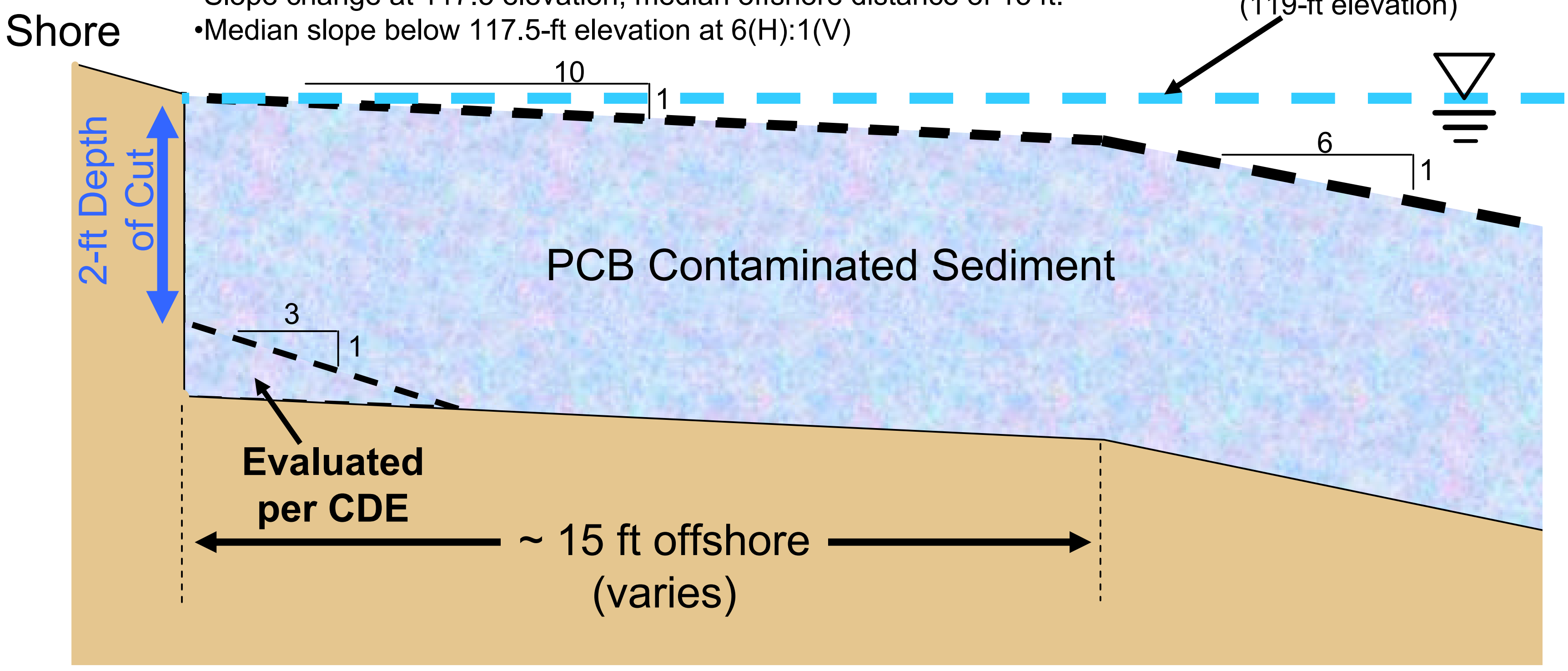

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Figure 8b
GE Proposed Backfill

Typical Shoreline Cross Section
Depth of contamination = 3 ft

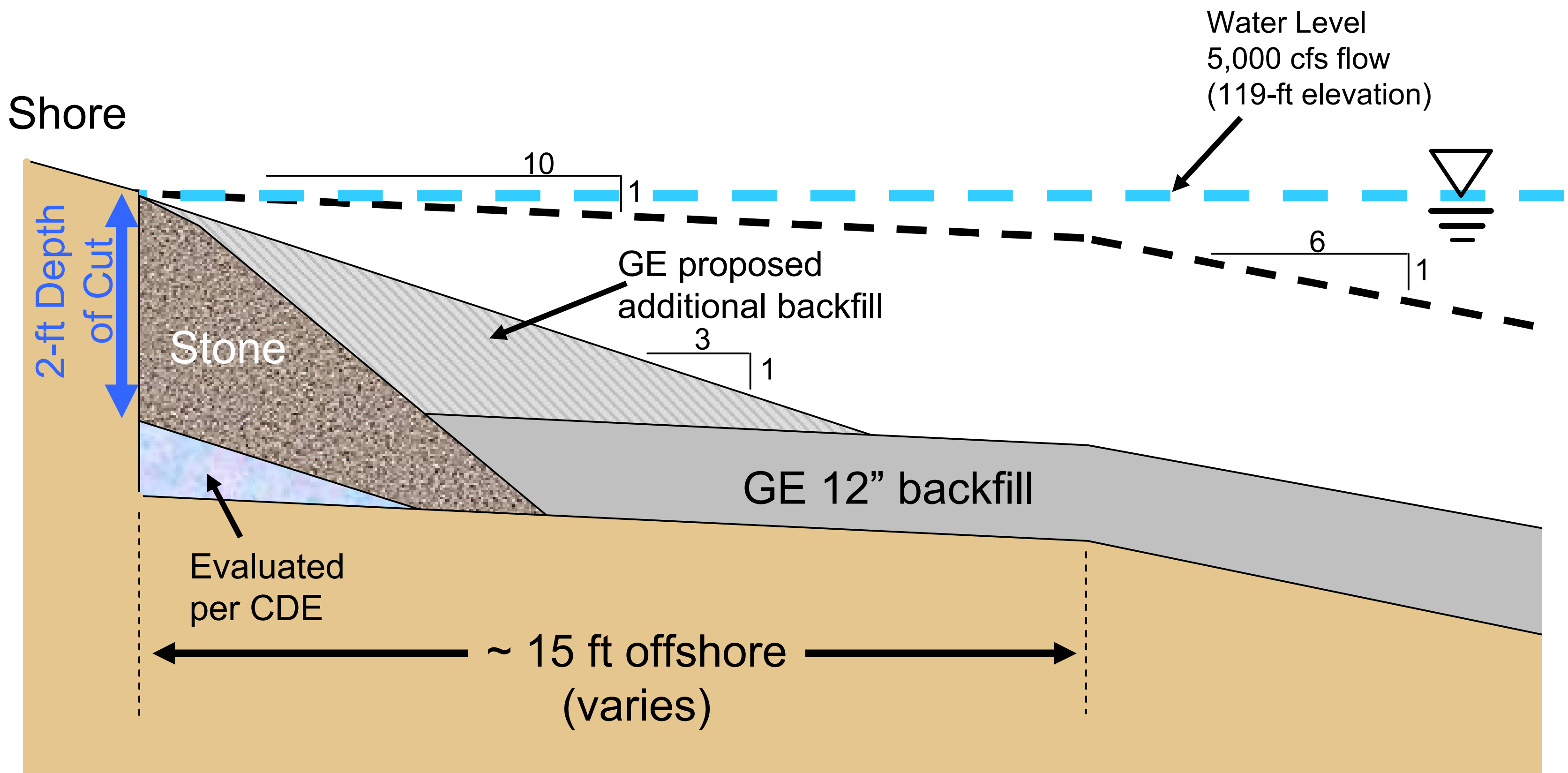

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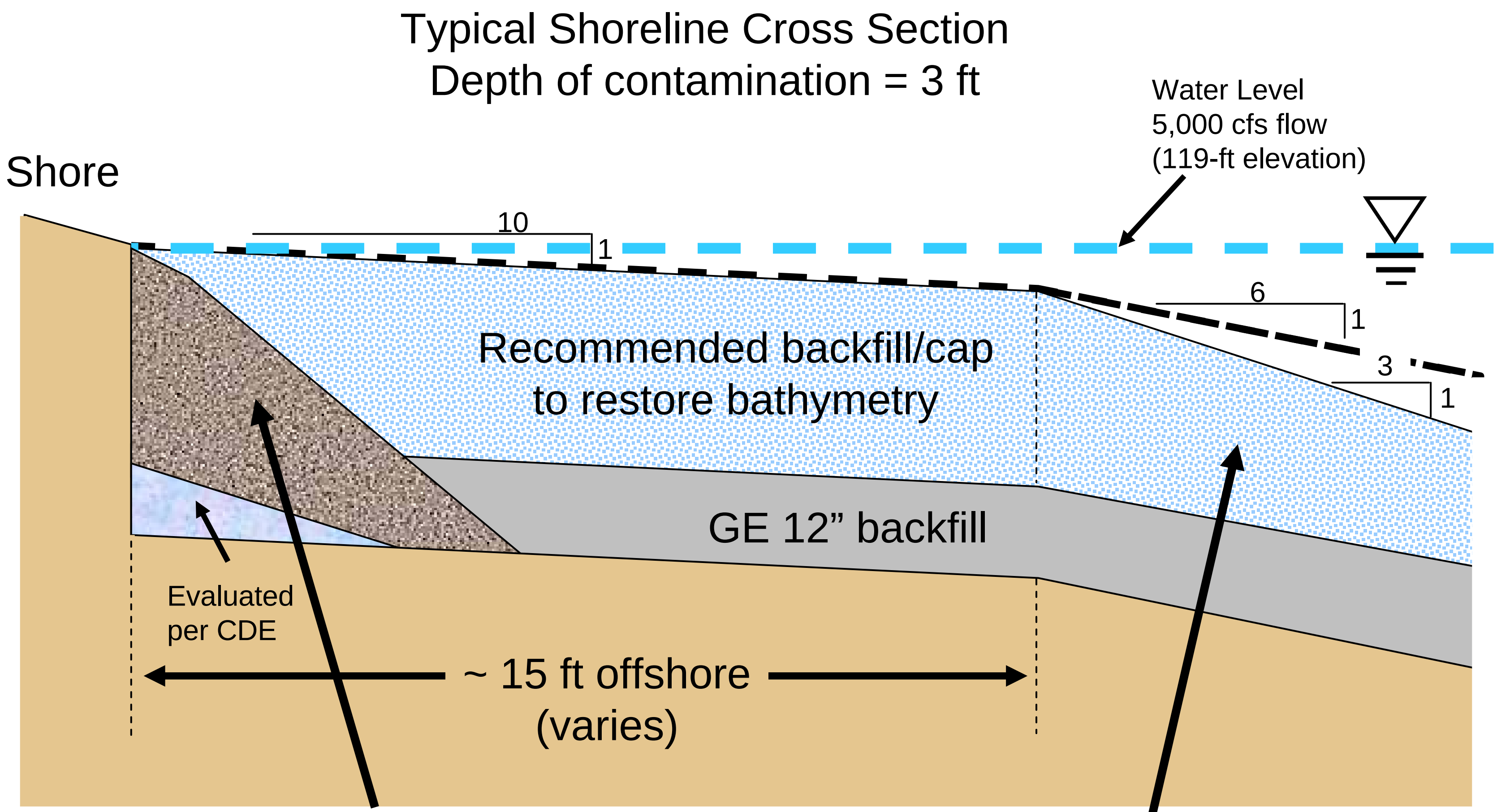
Figure 8c
Recommended Backfill



Bank treatment currently under discussion between EPA and GE, outside of the context of this dispute resolution; materials could include stone, biologs, backfill or a combination of these or other materials, to the extent approved by EPA.

Supporting “wedge” extends outward toward channel at 3:1 slope until upper surface intersects the surface of the 12-in backfill layer, ~12 ft (varies)

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Figure 9a
Pre-Dredge Condition

Typical Shoreline Cross Section
Depth of contamination = 2 ft or less

(Drawing for 2-ft condition)

Typical Conditions (Actual conditions vary)
- Shoreline at 119-ft elevation, corresponding to 5,000-cfs flow.
- Median shoreline slope at 10(H):1(V).
- Slope change at 117.5 elevation, median offshore distance of 15 ft.
- Median slope below 117.5-ft elevation at 6(H):1(V)

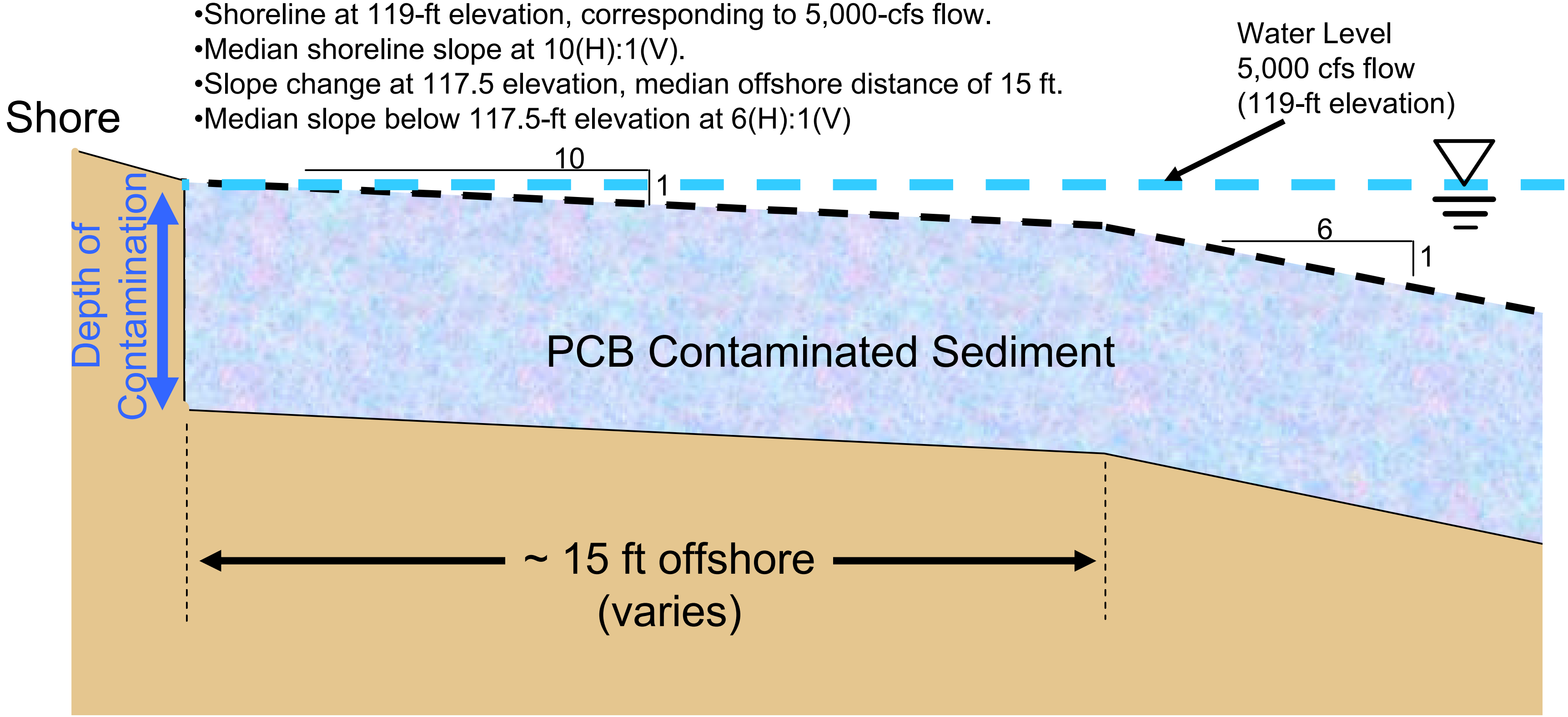

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Figure 9b
GE Proposed Backfill

Typical Shoreline Cross Section
Depth of contamination = 2 ft or less
(Drawing for 2-ft condition)

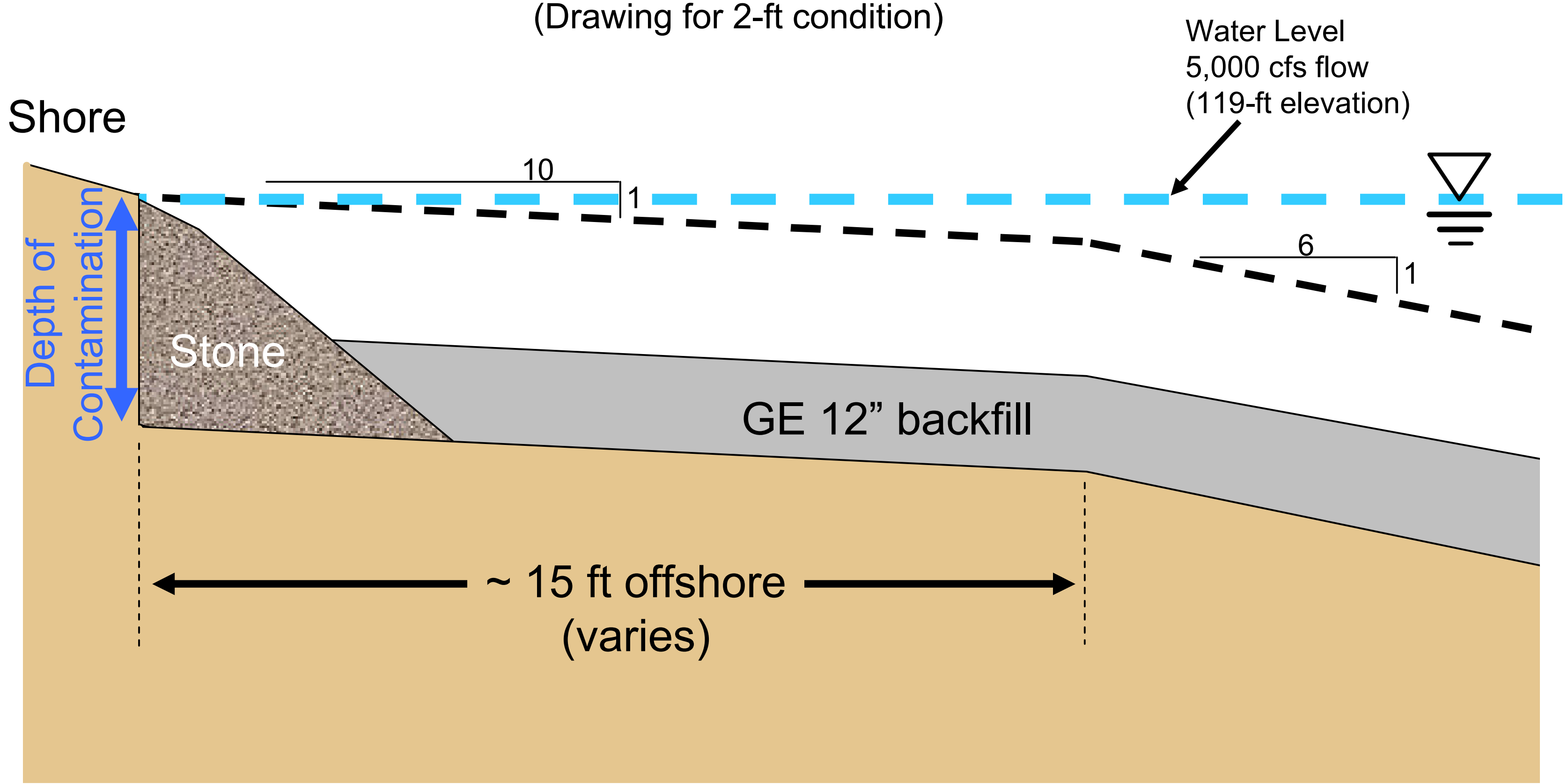

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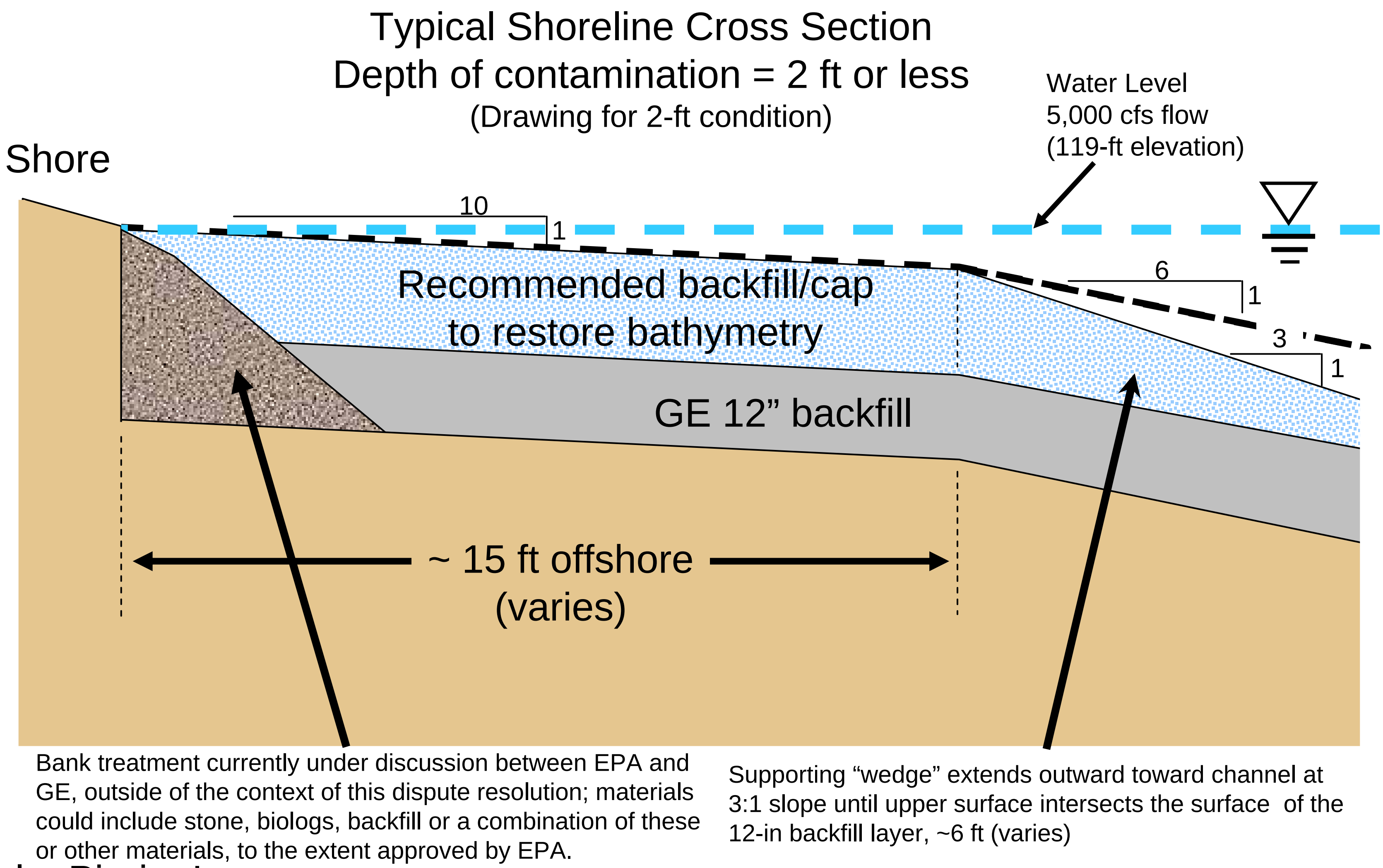
Figure 9c
Recommended Backfill



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