# Memorandum

**To:** Paul Ruesch, OSC, Region 5 EPA

**From:** John D. Jolly, GEI Consultants

**CC:** Bryan Heath, NCR Corporation

**Date:** 5/5/2023 (revised 5/9/2023)

**Re:** GEI Response to the “Area 4 TCRA Revised Design – Stability Review and “Area 4 TCRA Revised Design – Description of Modeling Errors and Inconsistencies” memos Dated February 15, 2023, Prepared by Jacobs

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This memorandum summarizes the responses of Kalamazoo River Areas 2, 3, and 4 Remediation LLC (LLC), on behalf of NCR Corporation, to the “Area 4 TCRA Revised Design – Stability Review” and “Area 4 TCRA Revised Design – Description of Modeling Errors and Inconsistencies” memoranda provided by Jacobs for EPA. It also documents the LLC’s response to the collaborative meeting attended by LLC, EPA, MDNR, and EGLE representatives on April 13, 2023. While working through this response, on May 2, 2023, three days before the due date of this memorandum, EPA provided a slide deck that contained additional notes.[1]

Below are GEI’s responses to the comments and meeting discussions. Note that the model results shown in the Jacobs’ memoranda are typically for the 10-year flood event. Unless otherwise specified, GEI’s modeling outputs discussed herein use the 100-year event, which is much more conservative and was part of the basis for the submitted design. Regarding the request for modeling a 200-year event, a figure was included in Appendix A of the August 15, 2022 Removal Work Plan (GEI, 2022a) that included the 200-year flood inundation extent and depth. The resulting shear stresses near or at the top of bank for the 200-year event generally resembled that of the 100-year event (see figures immediately below this paragraph). Any comments related to the design alluvial surface and its physical characteristics are discussed herein. GEI’s understanding of the alluvial contents and surface has been thoroughly communicated to EPA throughout the project, with the understanding that the EPA agreed with our approach through its acceptance of the PDI Phase 1 and Phase 2 Data Summary Report (GEI, 2022b), which provides those data.

[1] On May 2, 2023, EPA provided a slide deck that contained additional notes (a previous version of this memorandum incorrectly attributed the slide deck to an “agency huddle”). The slide deck acknowledges that an error was made in Jacobs’ previous shear analysis that reportedly caused a high bias in shear stress calculations. The slide deck also contained a comment that top-of-bank shear be modeled at the 200-year event or higher; a suggestion that the design withstand shear stress ranging from 10 to 30 dynes/cm2; and a recommendation for further analysis of scour during extreme floods due to EPA/State opinion on the characterization of alluvium. GEI provides preliminary responses to the notes in the slide deck in this memorandum. Since our last version of this memorandum, EPA has clarified that the deck was not intended to make any additional requests or provide scientific rationale, regulatory, or order-based justification for any action to be taken by NCR or GEI.

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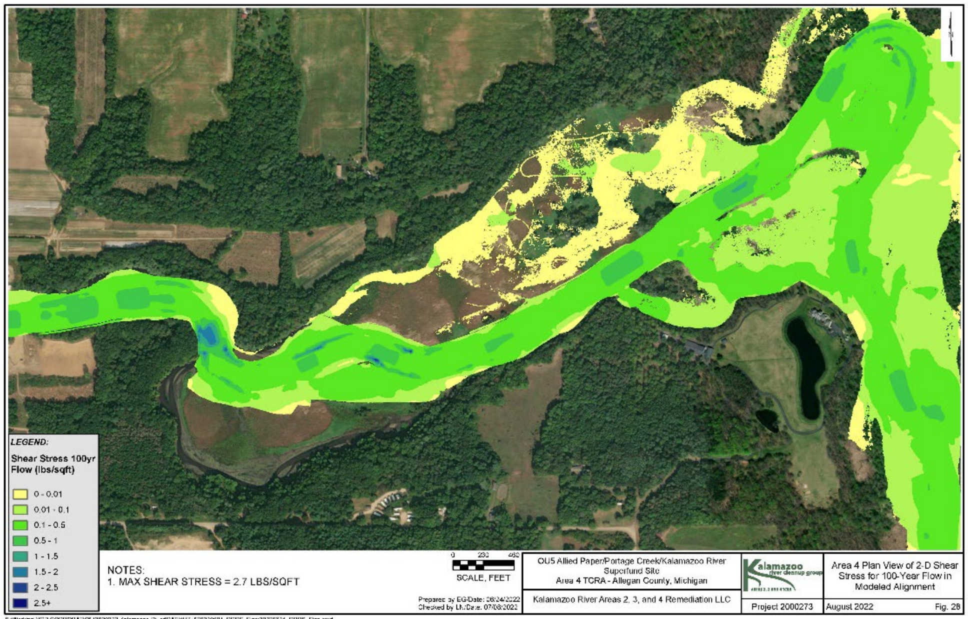


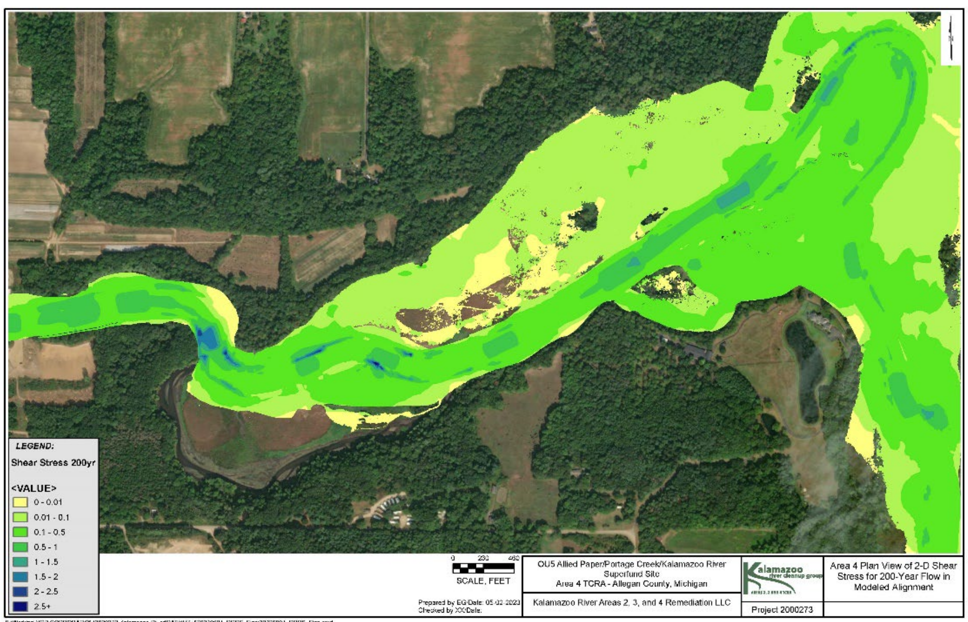


Following are summaries of EPA's comments in the two Jacobs memoranda and the LLC's responses to those comments.

1) *Stability Review Memo Section 1.0 Channel Bed Stability:* The comment on bed stability is based on the possibility of fine-grained sediments being exposed at the proposed riffle subgrade during construction or in the pools below the riffles. EPA's comment is that exposure of fine-grained sediments could cause riffle instability or headcutting from the pool back up through the riffle, ultimately impacting the elevation of riffle crests and upstream water surface elevations. During the April 13, 2023 meeting, a comment was made that

exposure of fine-grained sediments could also cause instability of the stone toe installed as part of the bank restorations.

***Response:***

This response is specific to comments by Jacobs regarding riffle, stone toe, and pool stability. Bed erosion and sediment mobilization estimates are responded to in number 8 and 9 below. As discussed in meetings with EPA on November 3, 2022 and April 13, 2023, GEI's intent is to construct the proposed riffles and stone toes on alluvial subgrade. Given the time-critical designation of this project, the field engineering team will evaluate riffle subgrades in conjunction with EPA oversight and improve as necessary (i.e., undercutting erodible material) until stable subgrade is achieved. This will be done during construction, which is consistent with standard practice for river restoration projects of this nature. Similar to the riffle subgrade preparation approach, the stone toe will also be keyed into alluvium at the banks, and the engineering team will likewise ensure stone toe will be installed on stable subgrade.

Extending the riffle and stone toe subgrades to alluvium is an approach consistent with a potential solution identified by Jacobs in Sec. 1.4 of the Area 4 TCRA Revised Design – Stability Review. GEI's understanding of the alluvial material is based on multiple core and poling investigations (GEI, 2022b); pebble counts at existing riffle locations (Appendix A of the Removal Work Plan [GEI, 2022a]); and the historical data sets, including supplemental remedial investigation (SRI) data and the report titled "Sediment Characteristics and Configuration within Three Dam Impoundments on the Kalamazoo River, Michigan, 2000" prepared for U.S. Geological Survey (Rheaume et al., 2000). The alluvial surface was developed using geostatistical approaches, was accepted by the EPA (GEI, 2022b), and was utilized in the sediment transport model and design documents.

Based on the sediment transport model including the proposed riffles, minimal pool erosion is possible. However, the model exhibited that post-dam-out bathymetry is predominantly controlled by stable riffles. With the proposed riffles being constructed on stable material, fine-grained sediment accumulation and pool erosion risk is adequately minimized.

2) *Stability Review Memo Section 2.2 Channel Bank Stability Risk (River Miles 45.7 to 46.2):* The comments are related to channel bank stability at 10-year events and greater, and the applied shear stresses from the GEI models exceed erosion thresholds for fine-grained sediment. The comments include that the "…treatment design will only be stable if the vegetation can establish and do so quickly."

***Response:***

It appears that Sections 2.2 and 2.3 of the bank stability memo were prepared with the assumption that both the installed erosion control blanket (ECB) and the proposed permanent vegetative cover either would not be installed in a timely fashion or would fail relatively quickly after installation, with the theory that raw and exposed banks could lead to failure. However, the design includes bank treatments that minimize risk of failure throughout the restoration phase through the use of best management practices (BMPs). As a result, except for a brief period during active construction between the start of work in a limited area (likely less than 150 linear feet) and installation of the engineered fill buffer and ECB, the banks will not have exposed fine-grained sediment to which this comment would be applicable.

The most important BMP to be used is sequencing bank construction so exposed areas are backfilled, graded, seeded, and protected as soon as practical to avoid exposing significant portions of subgrade (i.e., bare soil) to erosive conditions. This is a common BMP with earth work and erosion/sedimentation control, such as the bank work performed for the Area 3 TCRA



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and the restored banks along the Ceresco Dam Removal and Restoration project. The planned sequencing includes removing impacted bank soils vertically to remove greater than 5 mg/kg PCB, and landward to allow for the placement of a 10-foot engineered fill buffer. Once the buffer has been placed using engineered fill, restorative bank treatments will be installed expeditiously. As a matter of practice, we anticipate two different crews will complete bank construction, with a bank crew performing PCB removal and buffer installation, and a restoration crew installing bank treatments, which are commonly accepted BMPs for bank restoration work. The bank crew will lead the restoration crew by approximately 150 feet to maximize efficiency of temporary bank stabilization and limit the footprint of “exposed” disturbed banks. Temporary cofferdams will be installed along the toe of the bank as necessary to deflect concentrated flow away from the bank and encapsulate the work area from significant sediment migration. The intent of this process is to minimize the area of exposed bank soil and quickly cover the buffer area with erosion control measures (e.g., erosion control blankets). It is anticipated that the buffer area should be covered with the ECB within 1 to 2 days of final grading.

a) Exposed and graded surfaces along the banks will be seeded at appropriate seeding rates with a riparian/bank native Michigan plant seed mix that will include annual oat and rye seed. The annuals typically germinate in approximately 2 weeks during the active growing season and will establish fairly substantial roots and shoots within 2–3 months. Seeding will be watered as necessary to promote growth. During the first growing season, the native perennial plants will establish their root systems. By the second growing season the native species will be producing more shoots and roots. Within a couple growing seasons, the grasses, forbs, and woody plants will establish a nearly ubiquitous shoot and root cover that have proven to manage erosive stresses for the long-term.

b) The prepared seed bed and overall subgrade will be protected using a high-strength coir erosion control blanket. The ECB serves as bank protection until permanent vegetation has filled in. That fabric will be installed with 12-inch-long wooden stakes at intervals meeting the manufacture's spacing requirements. The blanket will be installed in a manner to minimize exposed edges that could catch and get pulled up by flowing water.

c) Careful maintenance and monitoring during the temporary erosion control period will verify the establishment of both temporary (annual) and permanent (perennial) vegetation. The banks will be closely monitored during this period and failures, if evident, will be addressed. For example, the monitoring will follow the substantive requirements of local Soil Erosion and Sediment Control (SESC) regulations, which include inspections after significant precipitation events and/or weekly for the first 12 months, with additional inspections occurring after documented bankfull flood events.

d) Both vegetated banks and banks with properly installed ECB are designed to withstand expected erosive forces. The shear stresses referenced in the memo were 5–15 N/m$^2$ or 0.1–0.3 lbs/ft$^2$ for the 10-year event near the banks (2D results). Additionally, the May 2, 2023 slide deck requests the top-of-bank resists shear ranging from 10 to 30 dynes/cm$^2$, or 0.02 to 0.06 lbs/ft$^2$, which our designed banks resist. The bank treatment design was developed to withstand the modeled 100-year shear stresses, which vary throughout the reach up to a maximum of 2.7 lbs/ft$^2$.

e) Bank treatments were designed to withstand 100-year velocities and shear stresses from the toe to the top of bank. As shown in the design, in areas of higher stresses, the bank lifts just above the stone toe will be constructed from Bio-D block, which has unvegetated shear stress and velocity thresholds 4.5 lbs/ft$^2$ and 12 ft/sec. The North American Green C-125BN ECB specifies unvegetated shear stress and velocity thresholds of 2.35 lbs/ft$^2$ (1,125 dynes/cm$^2$) and 10 ft/sec, respectively. Vegetated coir fabric has a permissible shear stress



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of 4–8 $lbs/ft^2$ and a permissible velocity of 9.5 ft/sec. The permissible shear and velocity thresholds from Fischenich are summarized in a 2001 US Army Corps of Engineers document titled: “Stability Thresholds for Stream Restoration Materials” (Fischenich, 2001).

3) *Modeling Memo Section 1.1 Near-bank Bathymetry Along Critical Reach:* The memo points out a “seam” or discontinuity in the geometric surface on which the 2D hydraulic model is built. This seam occurs near the banks, where the bathymetric surface ties in with the bank restoration grading surface. The memo suggests smoothing this seam located on the right descending bank (RDB) between river mile 45.7 and 46.3 to evaluate any changes in local velocities along the bank.

***Response:***

To address this comment, GEI smoothed the seam along the right bank using Civil 3D throughout the referenced stretch of river. The 100-year event in the 2D hydraulic model was then re-run. The results were compared to the modeled velocities and shear stresses included in the submitted work plan. Although there were some slight changes to modeled shears and velocities in the smoothed surface, the changes were negligible compared with original results, as shown in the table below. It is important to note that the results did not require modifications to proposed bank treatments.

| Modeled 100-Year Shear Stress ($lbs/ft^2$) at Vegetated Portion of Right Bank | | |
|---|---|---|
| River Mile (RM) | Design Submittal | Smoothed Surface from RM 45.7 to 46.3 |
| 46.36 | 2.3[1] | 2.3[1] |
| 46.26 | 0.4 | 0.4 |
| 46.16 | 0.8 | 0.9 |
| 46.07 | 0.4 | 0.3 |
| 46.00 | 0.6 | 0.7 |
| 45.89 | 0.4 | 0.4 |
| 45.83 | 0.2 | 0.3 |
| 45.77 | 0.6 | 0.7 |
| 45.72 | 0.4 | 0.4 |
| 45.68 | 0.3 | 0.3 |

[1]Location of max shear stress occurred at the elevation of the Bio D-block treatment, where permissible shear stress is 4.5 $lbs/ft^2$

4) *Modeling Memo Section 1.2: Critical Time Period for Instability Risk:* Jacobs comments that the roughness of the bank treatments in the model should be reduced to represent the interim condition with ECB and soil lifts in place but before the vegetative cover becomes established, using a Manning’s *n* roughness coefficient of 0.02.

***Response:***



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It is not common design practice to model interim conditions of the channel between completion of construction and the establishment of permanent erosion control measures. Instead, a more conventional approach is to model the permanent conditions and address interim conditions with a monitoring and maintenance plan that uses approved BMPs to control the risk of potential erosive forces during the interim condition.

Although GEI disagrees with the comment, GEI reduced the Manning's *n* value (roughness coefficient) for the planted area of the bank treatments from *n* = 0.07 to *n* = 0.02. The model was re-run using the 100-year event in the 2D hydraulic model (with the SWE-EM equation, see No. 5 response for further discussion and a table of results). Those modeled velocities and shear stresses were compared to modeled shears and velocities in the submitted workplan. As expected, velocities and shear stresses increased in the interim-condition run, particularly near the banks. However, the resulting velocities and shear stresses were still within the range that the designed bank treatments can withstand under the interim condition, as detailed in response #2. As a result, modifying the model to address this comment would not result in any change in the design.

5) *Modeling Memo Section 1.3 2D Hydraulic Model Equation:* The recommendation is to use the SWE-EM equation set recently added to the HEC-RAS software as a more conservative modeling approach than the equation set currently used for modeling.

***Response:***

The submitted workplan design uses an equation set called the SWE-ELM equations, which account for both conservation of mass (i.e., water coming into the model = water leaving the model) and conservation of momentum. The SWE-EM equation set first became available in the HEC-RAS software after GEI's model runs. Similar to the SWE-ELM, the new equation set also accounts for both conservation of mass and momentum. Although the SWE-EM equation operates more conservatively, GEI noted only small differences in results between the two equation sets, as described below. The HEC-RAS manual recommends using the new equations when detailed evaluations of water surfaces and velocities are needed, such as near hydraulic structures or piers, which is not the case in Area 4.

To address this comment, GEI re-ran the 100-year event in the 2D hydraulic model with the SWE-EM equations to evaluate model sensitivity to the equation. The 100-year velocities and shear stresses along both banks were evaluated using the SWE-EM equations and those results were compared to the submitted design velocities and shear stresses. Although the modeled shears changed compared to the submitted design (mostly increased), the changes were small enough that they would not change the overall bank treatments except at the following isolated locations: 1) RM 45.3, RM 45.32, and RM 46.36, where the bank treatments could be adjusted approximately 1 ft higher up the bank; and 2) RM 45.2, where the extent of Treatment "B" could be extended 100 ft farther downstream than what was submitted. These minor adjustments will be made to the design. The maximum near bank velocity was 7.2 ft/sec in the design submittal and 7.8 ft/sec in the SWE-EM run, compared to permissible velocities of 10 ft/sec for the ECB (data not included in table below). These velocity results indicate no design adjustments are necessary.

The table below compares modeled 100-year shear stresses along both banks between 1) the design submittal, 2) the SWE-EM sensitivity run, and 3) the interim condition sensitivity run (with SWE-EM equation). For the interim-conditions model run, the shear stresses were checked only at locations that were close to exceeding the permissible shear stress for the bank treatments and where the shear stress was higher than in the SWE-EM run.



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| Modeled 100-Year Shear Stress (lbs/ft$^2$) at Vegetated Portion of Left and Right Banks | | | | | | |
|---|---|---|---|---|---|---|
| River Mile (RM) | Design Submittal LDB | SWE-EM Equation LDB | Interim Condition (SWE-EM) LDB | Design Submittal RDB | SWE-EM Equation RDB | Interim Condition (SWE-EM) RDB |
| 47.27 | 0.7 | 0.7 | | 0.0 | 0.1 | |
| 47.14 | 0.6 | 0.6 | | 0.1 | 0.2 | |
| 47.07 | 0.3 | 0.4 | | 1.2 | 1.3 | |
| 47 | 0.8 | 1.0 | | 0.2 | 0.2 | |
| 46.92 | 0.0 | 0.1 | | 0.3 | 0.3 | |
| 46.84 | 0.3 | 0.3 | | 0.6 | 0.8 | |
| 46.8 | 0.2 | 0.2 | | 0.5 | 0.7 | |
| 46.67 | 0.6 | 0.7 | | 0.0 | 0.2 | |
| 46.46 | 0.7 | 0.6 | | 1.1 | 1.8 | 2.1[1] |
| 46.36 | 0.6 | 0.9 | | 2.3[1] | 3.0[1] | 4.0[1,2] |
| 46.26 | 0.2 | 0.2 | | 0.4 | 0.5 | |
| 46.16 | 0.8 | 1.8 | | 0.8 | 1.0 | |
| 46.07 | 0.5 | 0.5 | | 0.4 | 0.6 | |
| 46 | 0.8 | 0.7 | | 0.6 | 0.8 | |
| 45.89 | 0.3 | 0.4 | | 0.4 | 0.7 | |
| 45.83 | 0.3 | 0.4 | | 0.2 | 0.4 | |
| 45.77 | 0.3 | 0.4 | | 0.6 | 0.7 | |
| 45.72 | 0.6 | 0.8 | | 0.4 | 0.4 | |
| 45.68 | 1.2 | 1.6 | | 0.3 | 0.4 | |
| 45.64 | 1.0 | 1.2 | | 1.0 | 1.2 | |
| 45.59 | 2.0[1] | 2.4[1] | 2.6[1] | 2.6[1] | 3.1[1] | 3.7[1] |
| 45.56 | 2.2[1] | 2.7[1] | 2.6[1] | 0.1 | 0.1 | |
| 45.51 | 0.0 | 0.9 | | 1.0 | 1.1 | |
| 45.48 | 0.1 | 0.2 | | 1.5 | 1.6 | |
| 45.44 | 0.2 | 0.3 | | 1.4 | 1.4 | |
| 45.41 | 0.1 | 0.2 | | 0.5 | 0.5 | |
| 45.37 | 0.6 | 0.8 | | 0.6 | 0.6 | |
| 45.35 | 0.9 | 1.1 | | 1.6 | 2.0[1] | |
| 45.32 | 2.0[1] | 2.5[1] | | 4.1[1,2] | 3.8[1,2] | |
| 45.27 | 2.1 | 2.5[1,2] | | 0.1 | 0.1 | |
| 45.24 | 1.2 | 2.0[3] | | 0.3 | 0.4 | |
| 45.2 | 0.7 | 0.7 | | 0.8 | 0.9 | |
| 45.16 | 0.5 | 0.5 | | 0.8 | 0.9 | |
| 45.13 | 0.2 | 0.2 | | 0.3 | 0.3 | |
| 45.1 | 0.3 | 0.4 | | 0.4 | 0.5 | |
| 45.08 | 0.3 | 0.4 | | 0.7 | 0.8 | |



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| Modeled 100-Year Shear Stress (lbs/ft$^2$) at Vegetated Portion of Left and Right Banks | | | | | | |
|---|---|---|---|---|---|---|
| **River Mile (RM)** | **Design Submittal LDB** | **SWE-EM Equation LDB** | **Interim Condition (SWE-EM) LDB** | **Design Submittal RDB** | **SWE-EM Equation RDB** | **Interim Condition (SWE-EM) RDB** |
| 45.05 | 0.6 | 0.9 | | 0.9 | 1.0 | |
| 45.02 | 0.3 | 0.4 | | 0.9 | 1.0 | |
| 45 | 0.3 | 0.4 | | 0.8 | 0.9 | |
| 44.99 | 0.3 | 0.3 | | 0.5 | 0.6 | |
| 44.98 | 0.0 | 0.0 | | 0.3 | 0.3 | |
| 44.97 | 0.1 | 0.1 | | 0.2 | 0.2 | |
| 44.96 | 0.1 | 0.2 | | 0.1 | 0.1 | |
| 44.95 | 0.2 | 0.3 | | 0.1 | 0.1 | |
| 44.94 | 0.2 | 0.2 | | 0.0 | 0.0 | |
| 44.93 | 0.2 | 0.3 | | 0.0 | 0.0 | |
| 44.89 | 0.2 | 0.3 | | 0.0 | 0.0 | |

[1] Location of max shear stress occurred at the elevation of the Bio D-block treatment, where permissible shear stress is 4.5 lbs/ft$^2$.
[2] Adjust bank treatments approximately 1 ft higher on the bank.
[3] Extend bank treatment "B" approximately 100 ft farther downstream.

6) *Verbal feedback on mesh size sensitivity*: During the meeting on April 13, 2023, a comment was expressed that GEI's selected 2D model mesh resolution may be inadequate. The recommendation was to consider increasing mesh resolution in the channel and at the top of bank to improve model accuracy and reduce near-bank flow velocities.

***Response:***

GEI originally determined mesh size based on the need to accurately represent channel depths. This is important because channel depths dictate modeled velocities and shears. To determine the appropriate mesh size, initial sensitivity runs performed in SRH2D tested 10-ft, 25-ft, and 40-ft mesh spacing in the channel. Spacing at 40 ft was determined to inadequately capture small variations in bathymetry within the channel and was therefore not used. Negligible differences were found in both water surface elevations and velocities between the 10-ft and 25-ft mesh spacing. Initially a 10-ft channel mesh spacing was used for HEC-RAS 2D modeling, and based on comments received from the State of Michigan during 60% design, the mesh size was increased to 20 ft. The 20-ft mesh resulted in Courant numbers (a model performance measure) that were generally less than 1, which indicates the model has an acceptable combination of both mesh size and computation time step. Mesh sizing was then kept consistent throughout design iterations to compare the effectiveness of design alternatives more accurately. Because the current mesh size meets Courant numbers, and to acknowledge the time-critical nature of this removal action, GEI does not propose to reduce the mesh size (increase the mesh resolution).

7) *Modeling Memo Section 2.1 Differences Between Modeled and Measured Erosion at Critical Location:* The comment indicates that there are locations in the Area 4 model calibration profile plot where erosion occurred during the calibration period, but the model predicted deposition.



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***Response:***

Sand is moving and re-shaping the riverbed in the impoundment on a near constant basis. The model simulates movement of sand throughout the impoundment. The memo indicates that at specific locations (RM 45.3 to 46.2) the sediment transport model under-predicts erosion. However, at other locations, such as downstream of 45.3, the model over-predicts erosion. These “under-predictions” and “over-predictions” in discrete locations generally balance each other out, and that the model is biased neither high nor low as it relates to the potential for sediment migration through Area 4.

8) *Modeling Memo Section 2.1 and 2.3: Predictions of Sediment Mobilization:* The comment indicates that GEI’s sediment mobilization estimates are potentially biased low. The comment indicated that 1) bed substrate used in the model may not reflect actual bed substrate and 2) the sediment transport formula used in the submitted model was not the most appropriate formula to use. In particular, the comment requested that the Laursen-Copeland (LC) equation be used for sediment transport, rather than the Ackers-White (AW) equation that GEI had used in the model.

***Response:***

As discussed in Section 3.2.2 of the submitted work plan, GEI calibrated the hydrologic and sediment transport model using data from Area 3. The data from Area 3 provided a physical model of the effects of dam removal on the Kalamazoo River. Area 3 bathymetry data collected before and after dam removal was used to develop a dam-removal model that would confirm the validity of GEI’s proposed methods and approach in modeling this river system. This calibration allowed for a more robust and accurate model than is normally developed. Doing so not only validated that GEI’s sediment transport modeling was accurate for Area 3, but also reduced the uncertainty of the incoming sediment load into Area 4. From the beginning of data collection and modeling, GEI was transparent with the participating agencies regarding methods used and results obtained. The validation results exhibited less than a 17% volume difference between the model-predicted and bathymetric survey comparisons spaced 4 and 7 years apart for Area 3 and Area 4, respectively. This level of calibration demonstrates that the model can be used to adequately simulate sediment transport volumes following dam removal.

To address the comment about which equation to use, GEI completed a sensitivity analysis using the LC equation and finer pool sediment gradation. The sediment transport model was run using the 7-year dam-out hydrograph with riffle crest gradations reflecting those provided in the design drawings specifications ($D_{50}$ = 5 inches, 8 inches, or 12 inches) and using the LC transport equation. The model was run again under the same circumstances as above and with the assumption that the pool sediment particle size distribution was equivalent to the gradation observed in Phase 3 Core 4S-PC16-1(0-50), which has a $D_{50}$ of 0.18 mm and no particles larger than medium gravel.

Sediment volumes moving out of the TCRA area at the end of the 7-year simulation using the LC equation were within 1% of the volume moving out of the TCRA boundary using the AW equation. Using both a finer gradation in the pools (discussed further in response number 9) and the LC equation, mobilized sediment volumes were within 7% of the volume noted using the AW equation. See response 10 for further discussion on the LC equation. These small differences in modeled sediment transport do not warrant change to the TCRA design.



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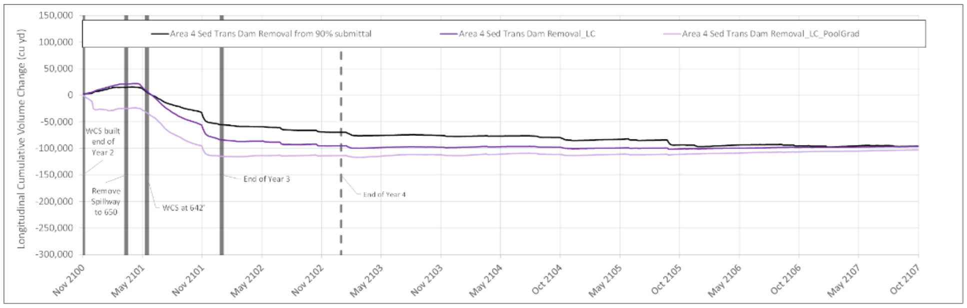


Longitudinal cumulative volume change for the Area 4 TCRA reach using the LC equation with and without a finer pool gradation over the 7-year simulation.

9) *Modeling Memo Section 2.2 and Stability Memo Section 1.2. Bed Substrate Based on Most Recent Core Data:* The comment relates to stability of the constructed riffles and potential undercutting.

***Response:***

The modeling work was completed before the most recent (Phase 3) core data were available. The model substrate is based on the data that was available at the time. The $D_{50}$ from the average surface gradation used in the design model is 0.6 mm, which is representative of the overall gradation of sediment in Area 4 (Area 4 TCRA Hydrology, Hydraulics, and Sediment Transport Modeling Technical Memo; GEI, 2022c). The average $D_{50}$ from Phase 3 cores is 0.57 mm. In several core samples from all three PDI phases, larger material was observed to fall out of the bottom of the core tube during collection and was therefore not included in the sieve analyses provided in the referenced reports. These observations support the actual gradation being larger than what was used for design. Thus the design constraints GEI used in the work plan are likely more conservative than actual field conditions.

To further assess stability, four additional sediment transport runs were performed in HEC-RAS version 5.0.7. Each run contained stone sizing at each riffle reflective of that specified in the design drawings ($D_{50}$ = 5 inches, 8 inches, or 12 inches). Each run used a 100-year hydrograph and assumed this event occurred after the completion of the overall channel, bank, and riffle construction. Two of the runs used the AW equation and two used the LC equation. To be conservative, one run with each equation used the gradation from Phase 3 core 4S-PC16-1(0-50) as the gradation for the cross sections in the critical reach rather than at the constructed riffle crests. This core had a $D_{50}$ of 0.18 mm and did not contain particles larger than medium gravel. In all four runs, the riffle crest elevations downstream of river mile 46.36 remained either at or slightly less than 0.5 ft of the design elevations. The pool and run elevations did show signs of erosion with the finer gradation but they did not erode down to the minimum elevation determined by poling data. In summary, the model using smaller particle sizes indicated some erosion within the proposed pools with negligible movement within the design riffle crests downstream of 46.36. The small amount of predicted movement in this sensitivity analysis does not indicate the need for change in the design.



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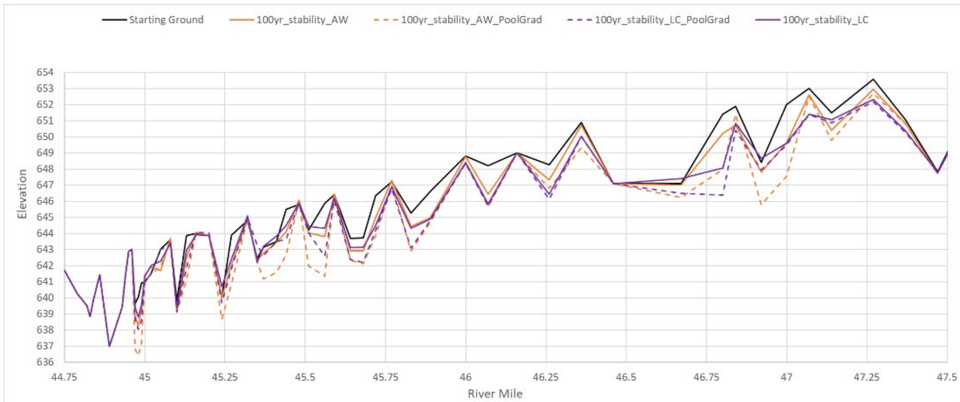


Longitudinal profile at the start and end of the 100-year event simulation for the Area 4 TCRA reach using the LC and AW equations with and without a finer pool gradation.

10) *Modeling Memo Section 2.3 Sediment Transport Equation:* The recommendation is to use the Laursen-Copeland (LC) equation for sediment transport instead of the Ackers-White (AW) equation.

***Response:***

In addition to the response provided in numbers 8 and 9 above, the fit of the LC equation with observed mobilization in the reach was also analyzed. The observed change in volume in Area 4 during the 7-year calibration period was 53,320 cubic yards ($yd^3$) of deposition. The original calibration with the Ackers-White equation simulated 44,070 $yd^3$ of deposition, or approximately 17% lower than observed. When calibrated using the LC equation, the simulated change in bathymetry was 12,990 $yd^3$ of *erosion*. These figures show that the AW equation predicted the observed amount of deposition more closely than the LC equation, which not only had a larger error but also predicted bathymetric change in the wrong direction. As a result, GEI continues to believe that the AW equation is more appropriate for modeling and that changes to the model are not warranted.

As noted in the response to number 9 above, the LC equation was used on additional runs with results showing riffle stability with limited pool erosion within the reach of concern.  The LC equation exhibited increased sediment mobilization rates earlier in the 7-year duration, however the overall sediment volume out was within 7% of the AW run at the end of the 7-year duration as discussed in response 7.

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