TECHNICAL REVIEW COMMENTS
April 2012 Kalamazoo River Hydrodynamic and Sediment Transport Model Report
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

BY USGS AND WESTON/START ON BEHALF OF U.S. EPA
August 22, 2012

The USGS and Weston/START have completed a review, on behalf of the U.S. EPA, of the report titled *Enbridge Line 6B MP 608, Marshall, MI Pipeline Release: Kalamazoo River Hydrodynamic and Sediment Transport Model* that was submitted on April 20, 2012, by Enbridge Energy, LP (Enbridge). The USGS and Weston/START team provided scientific expertise on geomorphology, hydrology, hydraulics, and sediment transport from the beginning of model development in the fall of 2011. This document describes the development of the model and related components of the "Consolidated Work Plan from Fall 2011 through Fall 2012" (Enbridge Energy, December 21, 2011), followed by a description of major technical concerns with the April 2012 version of the model and accompanying report, and a comprehensive list of review comments specific to the calibration and report.

The main finding of this review is that the April 2012 version of the hydrodynamic and sediment transport model is incomplete in terms of model development, calibration, and validation. The model must be rerun and updated in order to meet the four objectives of the modeling work as outlined in the CWP.

Overview and Background

Enbridge, USGS, and Weston/START personnel have met via web conferencing or on-site for model building and reviews of the modeling work, with such meetings started in fall 2011 and generally held weekly from January through June, 2012. Enbridge provided preliminary documentation for the model on February 10, 2012, followed by a Table of Contents for the Hydrodynamic and Sediment Transport Calibration Report on April 9, 2012. The calibration report was delivered on April 20, followed by an addendum containing calibration acceptance criteria on May 8, 2012, and a Tech Memo on rating curves for three dams on July 20, 2012 (e.g., by Tetra Tech, on behalf of Enbridge).

The modeling is considered as a tool for enhancing the adaptive management approach being applied for operations personnel in decisions and assessment regarding response activities related to active and passive recovery of submerged oil (CWP, Figure 4.3.1). The CWP describes four objectives for the model in regard to fate and transport of submerged oil (paraphrased): (1) successful calibration of a 3-D model capable of simulating spatial and temporal variations in the entrainment, transport, and deposition of sediment-oil mixtures, (2) simulate fate and transport of sediment-oil mixtures over a range of flow conditions, (3) simulate a variety of scenarios for containment, collection, and recovery of submerged oil-laden sediment, and (4) document the model results for use in planning, design, implementation, monitoring, and evaluation of future management methods. Descriptions regarding the scope and objectives; hydrodynamic model geometry, parameterization, and calibration; and phases and timeline of the modeling are described in the CWP.

The hydrodynamic and sediment transport characteristics of a 40-mile reach of the Kalamazoo River affected by the July 2010 oil spill were modeled using the numerical modeling program Environmental Fluid Dynamic Code (EFDC). Originally it was proposed as a 3-D model, but after considering the scale and the practical complexity of the river environment, and the questions to be addressed, it was agreed that a 2-D model was more appropriate. It was developed by Enbridge's modeling team in Atlanta, GA. A major assumption in the model was that the sediment transport model could be used as a surrogate for modeling submerged oil transport. Qualitative submerged oil assessments and field evidence suggest that residual globules of submerged oil are most closely transported with the fine-grained component (silt and organic matter) of the suspended sediment load.

For the Kalamazoo River, the model domain consists longitudinally of an approximately 40-mile reach of the Kalamazoo River (the study reach) from the Interstate 69 bridge (approximately 0.68 mile upstream of the confluence of Kalamazoo River and Talmadge Creek (MP 2.03)) to the upstream face of the Morrow Lake Dam (MP 39.85). [Mile post (MP) numbers increase in the downstream direction.] Laterally the domain extends to the 100-year floodplain boundaries on both sides of the channel, bounds that were estimated with a one-dimensional HEC-RAS model (initially developed by C.J. Hoard, USGS). In the study reach there are natural meandering channels, wide floodplains, regulated and straightened channels, dams and reservoirs, culverts, and bridges.

In terms of oil migration, the fate and transport of oil and oiled sediment through the natural and man-made storage compartments are important to understand in recovery efforts. Major storage compartments along the main stem include three impoundments: Ceresco Impoundment (upstream of the Ceresco dam), the Battle Creek millponds (upstream of the Kalamazoo Dam on Monroe Street, Battle Creek), and Morrow Lake (delta, alluvial fan, and lake) (upstream of the Morrow dam). Many channel margin features with slow or stagnant water, meander cut-off channels, side channels, tributary mouths, and backwater areas, also are effective storage sites. Off channel oxbow lakes, wetlands, and spring fed ponds have residual submerged oil. Tributaries also contribute flow and sediment loads into the study reach and seven of the largest were included in the model. Only one, of the seven tributaries has a USGS stream gauge (Augusta Creek near Augusta, USGS ID 04105700), and the inflows and sediment loads needed to be estimated for the other six. There are four other USGS stream flow gauging stations used either for specifying the boundary conditions or for model calibration. These are Kalamazoo River at Marshall (04103500), Battle Creek near Battle Creek (04105000), Kalamazoo River at Battle Creek (04105500), and Kalamazoo River at Comstock (04106000). Besides these long-term stream flow data, additional data used in the model development include those from reassessment of oil occurrence in overbank and submerged oil deposits (coordinates, local channel or floodplain elevations, and characterization of submerged oil and associated bed material), channel bathymetry and floodplain elevations from a HEC-RAS model, LiDAR data for floodplain topography, daily water level readings from Enbridge staff gages, point and transactional ADCP velocity measurement, high-water oil marks from the July 2010 flood, and the in-situ mapping of geomorphic surfaces.

Phases of the hydrodynamic model development (CWP, P 38) include grid setup, configuration for flow and velocity, analysis of sediment and cohesion data, complete model configuration including sediment processes, model calibration, preliminary and baseline model scenarios, and modeling of various flow events and changes in river conditions. The April 20, 2012 report corresponds to the last specified milestone in the CWP timeline for model simulation; and it consists of sections on *Introduction*, *Model Code Selection*, *Base Model Development*, *Model Calibration*, *Model Hydrodynamics Validation*, *Model Scenarios (Response to Historical Events)*, *Sediment Traps*, *Sensitivity Analysis*, *Base Model Limitations*, *Summary,* and *References*.

Technical Comments Pertaining to Model Development

Grid Setup and Model Configuration

Riverine and Floodplain Grids--The Enbridge model team spent significant time and effort refining the grid setup to make it representative of the complexity of river conditions by assigning grids to model tributary inflows, defining many islands, matching the grid system to the extent of the riverine geomorphic channel units, and extending the floodplain grid laterally to include the entire area included in the 100-year floodplain. The resulting model grids represent a very detailed computational configuration for simulating the fate and transport of sediment through the Kalamazoo River system. Two grids were developed – a curvilinear-orthogonal horizontal grid called "riverine" used for flows generally held within the channel banks, and a finer scale Cartesian grid cell network called "floodplain" was used for flows that extended beyond the channel and onto the floodplain. The Morrow Lake riverine model used the same scale Cartesian grids as the floodplain model.

Boundary Conditions—Boundary conditions for the Kalamazoo River hydrodynamic model include data for three main components: upstream/downstream and tributary flows, dam rating curves, and suspended sediment concentrations and particle size distribution. For the hydrodynamic component of the model, input and output flows are complete because of available data from USGS stream gauges, but questions remain for how tributary flows were estimated and the appropriateness of using simplified dam rating curves, especially for Morrow Lake dam. For sediment transport, less data were available and more questions remain for concentration and particle size distribution of suspended sediment. Data from other USGS stations on the Kalamazoo River suggest that sediment concentrations are generally low, less than 120 mg/L, even during floods. An assumption of bedload being negligible for the affected stretch is appropriate, (1) because data from downstream reaches shows that bedload makes up a small percentage of the total load, and (2) the many impounded reaches along the Kalamazoo River enhance storage of bedload. The table below gives more details on the source of data for boundary conditions, their status in the Consolidated Work Plan (CWP), and follow up that is needed.

Boundary conditions	Source	CWP Status	Follow-up
Flow boundaries	Discharge data USGS gauges	Complete	None.
Tributary flows	Drainage area weighted	Incomplete	Need to document uncertainty, compare with June 2012 USGS low flow measurements, and describe adjustments and implications for groundwater inputs. Need to adjust model conditions if needed.
Dam configurations and rating curves (Ceresco, Morrow)	Simplified weir with uniform crest	Incomplete	Updated dam rating curves provided by Enbridge in July 2012. USGS provided response in August 2012. Need to describe how the rating curves were used in model. The updated dam rating curves still seem to be in error. Not sure how the ratings were used in the model development and calibration. Simple weir not appropriate for subsurface intakes at Morrow power house. Need to update the weir equation for Ceresco as width of weir is too narrow. Need to rerun model. Need

			to develop a 3D model for Morrow lake with updated Morrow dam/intakes configuration to adequately account for subsurface draws.
Suspended sediment concentrations and particle sizes	Historical data outside affected reach; core data for particle size	Incomplete, identified as a data gap in calibration report	Need to collect suspended sediment concentration and particle size data at 5 USGS gauges in the affected reach in the summer 2012 (in progress). Use particle size data from Walling tube samples collected in fall 2011 and spring 2012 to help determine proportion of sand/silt/clay in suspended load. Use laser diffraction technique for particle size analysis of suspended load (in progress), Walling samples (in progress), and CSD samples (in progress). Need to reapportion particle distribution (and concentration) in the model based on new data. The proportion of sand used in the model is likely too high but effects on silt/clay sedimentation rates are likely negligible. Sensitivity tests (±50%) indicate that variations in input sediment concentrations affected sedimentation rates, and sediment mass and sediment loading outputs. Need to rerun model with updated particle size distribution.

Data Inputs -- The richness of available data associated with bathymetry, floodplain topography, channel and floodplain roughness, meteorological conditions, sediment characteristics, and critical shear stress are highly variable, depending on the source of the data. The modelers identified data gaps in the report that were incorporated into the hydrodynamic assessment component of the CWP based on fall/winter 2011 discussion among the modelers, USGS, and Weston/START. Data gaps included bathymetry (poling), sediment particle size classes (coring and laser diffraction analysis), submerged oil/silt representation, critical shear stress, aquatic vegetation influences on velocity and sediment erodibility, reach specific suspended sediment load and particle size data, and the effects of agitation and submerged oil recovery on sediment characteristics. In general, model bathymetry and topography are very detailed, especially for a 40-mile stretch of river, but more bathymetry data are needed for sediment transport through the Morrow Lake delta. Simplifications for channel roughness, critical shear stress, and sediment settling velocity used in the present model result in uncertainty and limitation of sediment transport results.

Data inputs	**Source**	**CWP Status**	**Follow-up**
Bathymetry	Multi-beam and poling	Incomplete, identified as a data gap in calibration report	Need more bathymetry data, especially in delta (done with spring 2012 poling). Need to incorporate additional data into model and rerun.
Floodplain topography	LiDAR	Incomplete, identified as a data gap in calibration report	Need additional data for islands (collected in spring 2012 poling). Need to report out acceptable standard error of the source DEM. Need to incorporate updated topography data into model and rerun.
Channel roughness	Simplified – used single	Incomplete, identified as	Need to explain why only one n value was chosen for channel but multiple were chosen for

	value of n = 0.02 for the channel in the riverine floodplain grids	a data gap in calibration report	the floodplain. Sensitivity testing (±50% base model value) showed that varying channel roughness in riverine and floodplain grids significantly affected sediment transport related outputs of shear stress, sedimentation rates, and sediment mass outputs, and sediment loading Hydrodynamic outputs were not as sensitive, but large discrepancies may have been caused by the simplification in roughness. Need to document that the simplification of channel roughness limits interpretations on sediment transport. Need to use more detailed roughness data for channel based on geomorphic units in future scenario runs, especially for subreaches such as sediment traps and the delta and fan. Need to adjust for possible agitation toolbox effects. Need to rerun model with updated channel roughness values.
Floodplain roughness	Floodplain land cover adjusted for irregularities and obstructions	Complete	The sensitivity testing for floodplain roughness was grouped with channel roughness for sensitivity testing making the sensitivity results inconclusive for determining if variations in floodplain roughness would affect sediment transport outputs. Need to document the process for determining values for vegetation, irregularities, and obstructions. Need to describe how floodplain roughness may have influenced large discrepancies in the WSE (oil marks) for the floodplain calibration.
Meteorological conditions	National Climate Data Center	Complete	Need additional wind data for 3D model of Morrow Lake and delta.
Riverine sediment physical characteristics (bulk density, particle size)	Fall 2011 cores	Incomplete	Need to update bulk density and particle size (sand, silt, clay) for geomorphic surface units with spring 2012 core data, including expanded particle size distribution. Bulk density values from 2011 cores were lower than expected. In addition, TOC data from Walling suspended sediment samples and cores suggest that a portion of the particle size data should be assigned a lower density for organic matter in future model runs. Areas of the river dominated by cohesive sediment or armored should also be identified.
Floodplain sediment physical characteristics	Cores and USDA soil surveys	Complete	
Critical shear stress for deposition	Assumed 0.1 Pa for silt	Incomplete	The sensitivity testing for critical shear stress (±50%) showed that variations in critical shear stress mainly affected sediment transport outputs of shear stress, sedimentation rates, and sediment mass output. Need to document that

			simplification of critical shear stress limits interpretations of sediment transport outputs. Need to gather additional field data and decide on methods (jet test or sedflume or other?). Need supporting information that using one value for silt for all geomorphic surface units is appropriate.
Sediment settling velocity	unknown	Not included	The calibration report does not describe derivation or assumptions associated with sediment settling velocity. The sensitivity testing for sediment settling velocity (±50%) showed that variations in settling velocity mainly affected sediment transport outputs of shear stress, particle size distribution, sedimentation rates, sediment mass output, and sediment loading. Need to document that unknowns associated with sediment settling velocity limits interpretations of sediment transport outputs. Need to check and possibly update assumed velocities with agitation effects experiment results.

Model Calibration

Time series for calibration – The riverine grid model was calibrated with flows from October 28 – November 9, 2011. Flows at the Kalamazoo at Battle Creek gauge were on the recessional limb of the runoff event from about 900 to 600 cfs. This flow range spans the annual mean flow at the gauge of 700 cfs (1937-2011). The floodplain model was calibrated with flows from July 23 – August 3, 2010 (flood during the time of the oil spill). Flows at the Kalamazoo at Battle Creek gauge were below 2000 cfs on July 23, rose to about 3,000 cfs on July 26, and fell to about 800 cfs by August 3.

These particular time series were selected for calibration because they had the most overlapping water surface elevation, velocity, and poling data. USGS gauging data were available prior to, during and following the spill. The selected time periods were approved through discussions among Enbridge, USGS, and Weston/START in the winter 2011-12.

Calibration sequence--The sequence for the model development described in the CWP was the following: calibrated model --> sensitivity analysis --> baseline model --> management scenarios. A "base model" is the model with all parameters properly calibrated and verified. The base model's parameters will not change further (CWP, p 37) and is the model for analyzing management scenarios outlined on p 39 & 40 of CWP. The April 2012 version of the model was developed with the best data available as of fall 2011 and it is recognized that calibration is an iterative process. However, regardless of the previously identified data gaps, the several discrepancies discussed above for boundary conditions and data inputs, such as the dam rating curves, the April 2012 version of the model should not be considered the final baseline model used for management scenarios. The model needs to be rerun with verified boundary conditions and updated model inputs from data collected in spring 2012, and recalibrated before further management scenarios are run.

Hydrodynamic Model Goodness-of-Fit – Model performance was checked for goodness of fit of flows, water surface elevations, and point velocities for the riverine and floodplain models. In the addendum, a comparison of the riverine and floodplain model results for October/November 2011 flows (Addendum Tables 1-2 and 1-4) indicate that the riverine modeled water surface elevations have a normalized root mean square error of ≤17 percent, whereas floodplain modeled elevations for the same time series have a normalized root mean square error of ≤23 percent.

Flows: The simulated discharge appeared to be within a reasonable range (within ± 10%); however, after having examined the rating curves for three dams in the system and the treatment of tributary inflows (discussed below), the results require further review.

Water-surface elevation: From the *Difference Normalized to Depth (%)* given in Figures 4-3 at the 10 Enbridge CSG stations, we observed that 8 CSGs generally showed differences larger than 10% on different days of the calibration event. If moderate differences are tentatively defined as those between 10% and 20%, and large differences are > 20%, reaches from MP 27.0 through 35.0 had moderate differences; and large differences existed in reaches from MP 5.25 to MP 21.5, for both riverine and floodplain models for the calibration events. The largest errors ranged from -25% to +31% for the riverine model, and from -44% to +55% for the floodplain model for water depth varied between approximately 3 and 7 feet.

Enbridge also made a comparison of high-flow calibration for the floodplain model using the oil makes surveyed after the July 2010 event. Understandably tracing back what actually happened in the field with the numerical modeling is challenging, the large differences in simulated water-surface elevation and oil marks, ranged from 9.51 feet (Transect 469) to -4.50 feet (Transect 77), and indicated the need for calibrating floodplain roughness values.

Velocities: The simulated velocities were evaluated with two types of measured data; the trans-sectional velocity (ADCP) and point velocity (ADV). Overall, the magnitudes of simulated velocity underestimated those of ADV and ADCP measurements and the underestimation is larger at higher values. The velocity direction was not discussed. Many of the modeled velocities above 0.5 ft/s were less than ½ the magnitude of the measured (*Figure 4-5; Addendum Attachment 1*). This is concerning as velocity forms the hydraulic backbone for the sediment transport model. A quick comparison of measured velocities in Morrow Lake in June 2012 (e.g., determined from preliminary USGS analysis of the data) with the riverine modeled velocities indicated that velocities in the lake may be double modeled velocities. Furthermore, preliminary acoustic velocity data from a temporary meter located in the neck area between the delta and lake indicate that the workings of the subsurface gates at Morrow dam affect water levels in the delta. More velocity data are needed to calibrate and validate the existing 2D model. The effects and interaction of three main external drivers -- opening/closing subsurface gates, wind, and incoming flows/sediment flux--need to be considered to adequately model sediment transport through Morrow Lake and delta. A 3-D model for Morrow delta and lake is needed that incorporates these factors into possible scenarios.

More specifically,

a. For riverine model and trans-sectional velocity in the riverine sections: The simulated velocities generally presented less lateral variations across the channel than the measured values; the magnitudes could match (or underestimate) the mean of the measured data. The model needs to be calibrated to match the cross sectional velocity pattern so the high velocity in the deep channel and low velocity at the edge where connection with the depositional areas exists are included. The quality of the ADCP data may be part of the mismatch but this is an unknown because no QA/QC data were included in the report.

b. For riverine model and trans-sectional velocity in the Delta, Fan, and Morrow Lake sections: The simulated velocities are the most under-estimated compared to the measured data. Was the downstream boundary properly described in the model? Or were there other mechanisms not captured in the model? Lacking QA/QC for the ADCP data also made the evaluation difficult.
c. For riverine model and point velocity data: Figure 4-5 showed that the simulated point velocity matched reasonably well for those magnitudes less than approximately 0.7 ft/sec, then became under-estimated. Need explanation of the source the measured velocity averages: are these measured values average over depth, or top/middle/ bottom velocities averaged over time (e.g., time interval should be specified). Also why were differences computed between simulated velocity and the "average minus standard deviation" for the riverine model but not the floodplain model (Figure 4-7)? It appears the differences would be larger if the "Averaged" magnitudes were compared. This error needs to be corrected.
d. For floodplain model and point velocity data: Figure 4-7 showed large scatters between the simulated and measured velocities, and the tendency was the simulation under-estimated the measured data. Criteria defining acceptance for the calibration and later verification need to be established.

Sediment Transport Model Goodness-of-Fit – No existing data for sediment concentration or loads were available for gauges in the 40-mi modeled section of the Kalamazoo River so that model results for critical shear stress, velocity, and sedimentation rates were instead compared to geomorphic surface units and qualitative field observations of depositional and erosional processes. Shortcomings in suspended sediment boundary inputs were discussed above.

Riverine model sediment mass flux: The calibration runs show sediment mass flux for six locations along the Kalamazoo River – Ceresco dam, Kalamazoo River dam, Kalamazoo River near Battle Creek gage, 35^{th} St. Bridge, Delta neck (MP 37.75), and Morrow Dam for the time period October 28 – November 9, 2011 during mean flow conditions. Overall, the sediment flux, especially the silt component seems high for a mean flow condition when water in the Kalamazoo River is generally clear. Turbidity data during this period could be checked for further order of magnitude type of documentation. The overly narrow weir design for Ceresco likely results in a conservative or minimum sediment flux.

The simulated results in Morrow Lake require further attention. Modeled sediment flux at the Morrow Lake delta neck was 60 megagrams/day (1 megagram (Mg) is about equal to 1 ton) at the start of the run and dropped to 20 Mg/day at the end of the run with even amounts of silt and sand (Figure 4-10). This would be equivalent to about a dump truck load of sediment a day passing the neck. At Morrow Dam, modeled sediment flux started at about 7 Mg/day and dropped to 1.5 Mg/day at the end of the run with only clay. Furthermore, the riverine model predicted no to very low sedimentation rates, and floodplain model predicted moderate sedimentation rates along the main channel in the upper part of the lake. These results are not capable of explaining the spread of oiled-sediment observed from the poling results of Spring 2012. This indicates that the mechanisms for moving sediment in the lake environment are not fully captured by the 2-D modeling. For the riverine sections, the lack of representative inflow sediment loads and particles, and not including the effects of dams at Marshall and Battle Creek need further attention.

Floodplain model sediment mass flux: For the July 2010 flood/oil spill run, sediment mass flux exceeds 350 Mg per day at the Morrow delta neck (equal portions of silt and clay) and 70 Mg per day at Morrow Dam (clay and some sand) on July 27th. It is confusing that a small portion of sand is shown to go over the dam (0.5 Mg) but no silt (Figure 4-12). This is further evidence that the sediment mass flux data should be used with caution, especially in using the model outputs to determine if oil transport past the dam is possible and the spread of oiled sediment in the lake.

Spatial patterns in velocities, shear stress, and sedimentation rates – The series of maps (Figure 4-18 through 4-28) should be used with caution given the above considerations and shortcomings in the sediment transport models. Relative differences in spatial extent are more appropriate than actual values. It is noteworthy that the model predicts silt deposition for the July 2010 run as far as MP 39.25 in Morrow Lake. It is likely that if a 3-D model were to be developed with the subsurface intakes at Morrow Dam the updated velocities would show transport of silt past Morrow Lake Dam during high flows.

Several parameters or statements that could be improved with currently available data but were not done are listed in the following bullets.

1. <u>Roughness coefficients (Manning's *n*-value)</u>: The riverine and floodplain models used one roughness coefficient to describe the resistance to flows in the channel. There is no explanation of how the $n = 0.02$ value was obtained, what type of bed or bank material it represented, and why it was considered a reasonable value to apply for the entire main stem of the river, especially with the large differences existed between the simulated and observed water-surface elevations and velocity magnitudes. Enbridge has developed the geomorphic polygons based on bed types where sediment sizes could be used to estimation of initial bed roughness; therefore, this is not a case of lack of data. On the other hand, the Enbridge team computed five different *n*-values for the floodplain grids based on vegetation types. Follow-up calibration steps need to be conducted to reduce the differences between the estimated water-surface elevations and surveyed high oil marks on the floodplain.
2. <u>Estimation of tributary flows</u>. The report stated that upstream boundary flow inputs and downstream flows were adjusted in the calibration process. This statement is not correct. Inflows are the most important boundary conditions for the correct hydrodynamic modeling in part because they maintain the continuity and balance of the system. These data need to come from trustworthy sources (e.g., gauge data), and one cannot adjust these data as part of the calibration process. It is a challenge that continuous inflows need to be estimated for ungauged tributaries in the system and estimation with the commonly used area ratio may result in large uncertainties. The Enbridge team described that the area ratio method was applied first to estimate the tributary inflows and the results were further adjusted to balance the flows; that is, the sum of incoming upstream inflow (using the Marshall gage) and tributary inflows from Talmadge, Bear, Minges Brook, and Battle Creeks were balanced at the Kalamazoo River near Battle Creek stream gage, and the downstream flows from Kalamazoo River near Battle Creek plus those from Wabascon, Seven Mile, Augusta, and Gull Creeks were balanced at the Kalamazoo River at Comstock stream gage. Re-balancing tributary inflows may be a legitimate

approach but it needs to be discussed in model development, as a method to be applied consistently to all events, not treated as part of the calibration process. At present, only the area ratio method was discussed, but no results were presented. Documenting the re-balancing work is important not only for referencing and use as a model check, but it also can become useful information for related studies. This is because the Kalamazoo River is a groundwater-fed river and receives significant groundwater contributions at low flow conditions. Hence the differences between the estimated and observed flows in this system may have implications for estimating incoming groundwater. It is also a concern in the review because questions arise about the rating curve for the three dams (see next comment); the errors in the ratings may introduce errors into the rebalanced flow and flows between dams and tributaries become questionable.

3. Rating curves developed for the Ceresco, Kalamazoo (near Monroe Street), and Morrow Dams. See above.

4. Demonstrate and support the 2-D modeling efforts. Understanding the effects of storage areas in the channel and along the channel margins, as well as on the floodplain, on the fate and transport of oiled sediment was one of the reasons for conducting the modeling in 2-D. The report should discuss mechanisms affecting storage versus transport at various locations and describe modeling considerations given that field data may not be available at present. On the other hand, the calibration and verification document needs to provide evidence of the need for 2-D modeling and demonstrate the capability of simulating 2-D flow patterns at these locations. At present the report presented comparisons of cross-sectional geometry between the HEC-RAS, riverine grids, floodplain grids, and LiDAR cutlines at 10 locations. The results showed differences in channel depth and width with the HEC-RAS cross sectional geometry. For transects, the simulated velocity tends to under-estimate and mismatch the location of the highest velocity, and also underestimates velocity magnitudes in the cross-sectional direction. No explanation about the discrepancies was provided. The calibration process and results need to be better documented, and further adjustment of important parameters is necessary.

5. Sediment inflows need to consider the effects of dam. Despite the fact that sediment loads and particle sizes are preliminary data, and known data gaps exist, the currently used values for sediment inflows should reflect the actual physical conditions to the extent possible where there are data available. There is a dam at Marshall and a dam on the Battle Creek near the junction with the Kalamazoo River. In the riverine calibration, the total sediment flux on 10/31/2011 dropped from around 40 mega grams/day (equivalent to one metric ton) at the inflow to around 20 at Ceresco Dam (MP 5.84), remained around 23 at Kalamazoo Dam (MP 15.65) but raised to about 79 at Kalamazoo River at Battle Creek (16.75) after the confluence with Battle Creek at MP 16.5. The cited high values appear to be artifacts resulting from likely erroneous choices of sediment inflows. Sediment inflows specified at these two major locations need to be adjusted considering the likely effects on sediment load and particle size.

Model Validation

The hydrodynamic model performance was evaluated for the riverine and floodplain grids over the time period of flows that included a flood event -- May 13 through June 8, 2011. For the riverine grid, flows from May 13 through May 24 were on the rising limb of the flood from about 900 to 1600 cfs at the

Kalamazoo at Battle Creek gauge. For the floodplain grid, flows from May 25 to June 8 continued to rise to a peak of about 3400 cfs on May 28 but then descended to 800 cfs by the end of the time period.

Hydrodynamic model – Modeled flows and water surface elevations were within 12% of measured flows at Battle Creek and Comstock gauges. The maximum difference between modeled and measured water surface elevations was about 2 ft.

Sediment transport – Modeled outputs of sediment mass flux for six locations along the river, as well as spatial distribution maps of velocity, bed shear stress, and sedimentation rates were compared qualitatively to measured flows and anticipated values based on the spatial distribution of geomorphic surface units.

For sediment mass flux, mass flux was highest on the first day of the riverine model for upstream locations, when flows were the lowest. This is likely an artifact of equilibration at the startup of the model as it did not carry through to Morrow Lake Dam (see below). Keeping in mind the limited interpretations that can be made from an uncalibrated, unvalidated sediment transport model, it is noteworthy that the riverine model shows sand, silt, and clay, totaling about 40 Mg/d, passing Morrow Lake Dam from May 15 to May 25, 2011 yet for the floodplain model virtually only 10 Mg/d of clay passes Morrow Lake Dam on May 25, 2011, rising to 100 Mg/d of clay on May 31, and falling to 20 Mg/d of clay on June 8. A comparison of the riverine and floodplain graphs below clearly illustrates why the sediment transport outputs from the April 2012 model need to be used with extreme caution and further justify the need for an updated model following the iterative process outlined in the CWP. These results presented below are especially critical in meeting objectives 1 and 2 of the model – successfully calibrating a model capable of simulating entrainment, transport, and deposition of sediment-oil mixtures and understanding the transport of submerged oil for different flow regimes--- in terms of providing supporting information for meeting the U.S. EPA order of "no oil past Morrow Lake Dam".

Figure 5-5 Riverine model validation Sediment Mass Flux

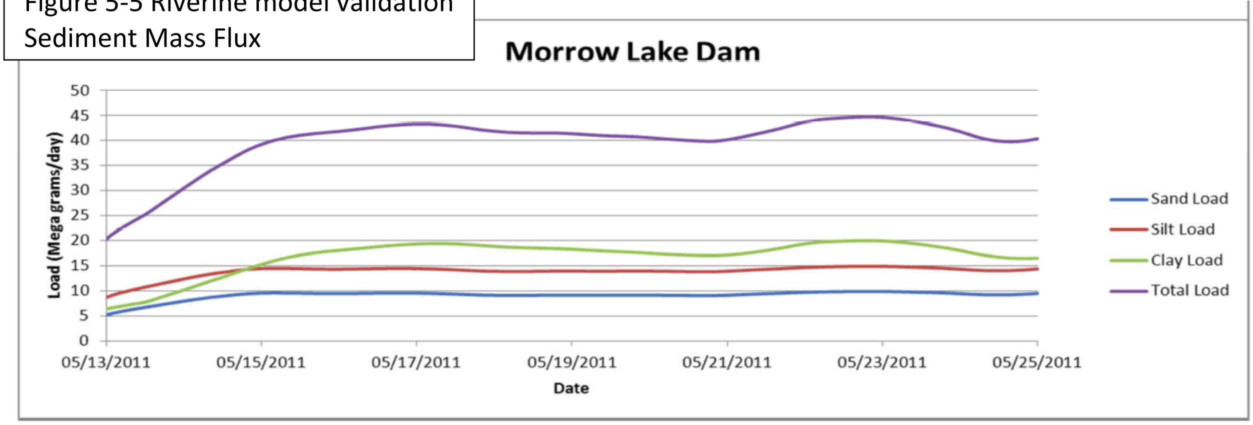
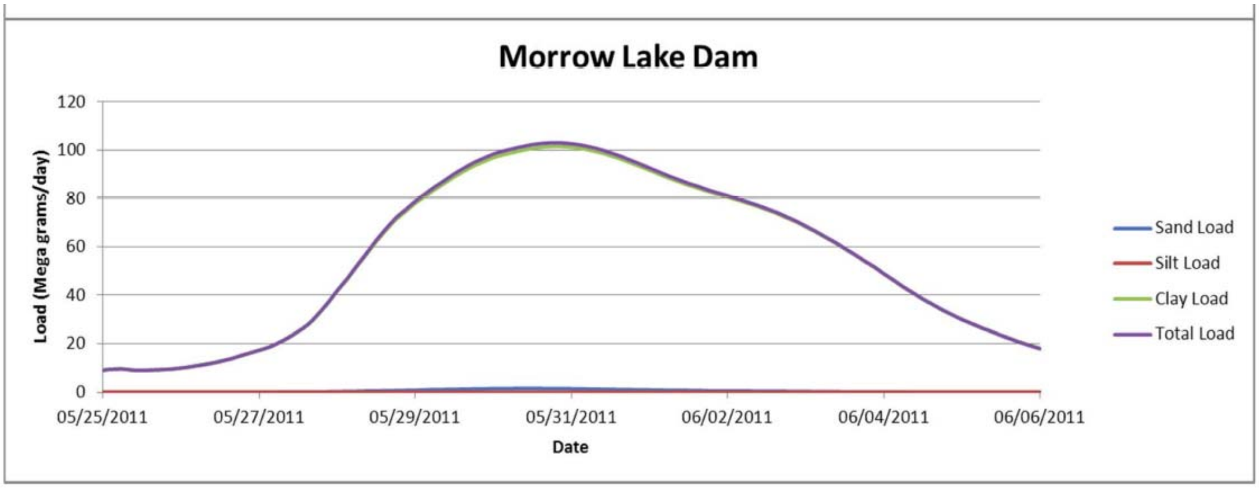
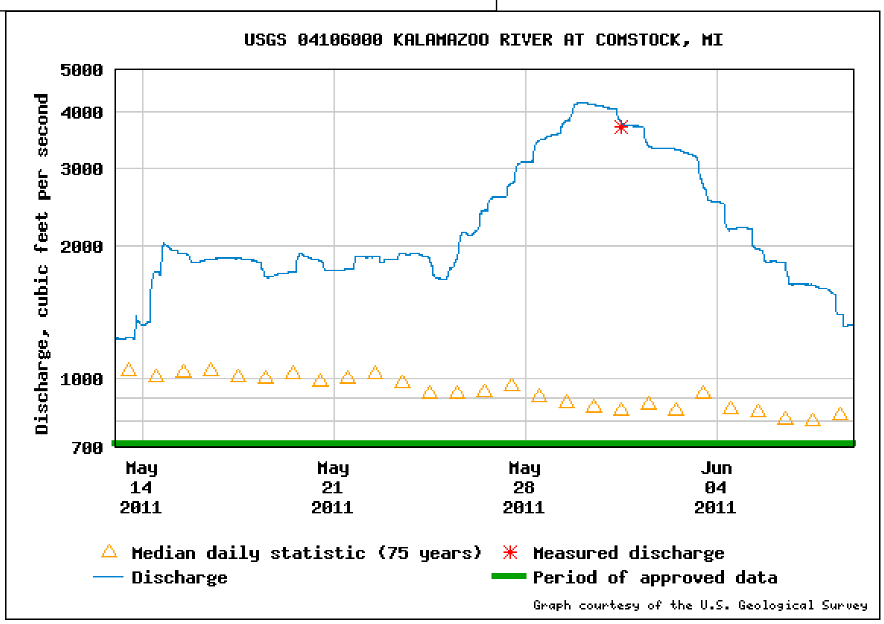


Figure 5-6 Floodplain model validation Sediment Mass Flux



Hydrograph for model validation period



Model Scenarios (Response to Historical Events)

The modeling team selected representative historical events and simulated floods to provide a range of hydrodynamic and sediment transport conditions over a range of flows as specified in the CWP. These included riverine models of a low flow event (<600 cfs; September 8-15, 2010) and a near bankfull event (about 1,200 cfs; April 6-17, 2011), and floodplain models for 100-yr (6,000-7,000 cfs) and 50-yr (5,000-6,000 cfs) events. Results in the calibration report included maps of the spatial distribution of velocity, bed shear stress, and erosion/deposition rates. From these maps general patterns of erosion/deposition can be gathered but are difficult to check for accuracy. Sediment flux graphs for the six locations along the river are needed as additional information, but based on the issues with the calibration and validation runs it would be more beneficial to rerun the model first.

Model Scenarios for Sediment Traps

The April 2012 model was used to determine the spatial distribution and rates of sedimentation in depositional settings along the Kalamazoo River with slow moving or stagnant flows and submerged oil accumulations. Several (19) of the depositional areas were proposed as passive sediment traps where sediment and submerged oil deposition could be enhanced with the addition of instream structures, such as bundled evergreen trees, that further decreased velocities. The instream structures were represented in the grid cells by reducing the porosity. In a smaller number of locations, coir log structures placed across the floodplain were represented in the grid cells by raising their elevations according to the height of the log structure. Four flow conditions were modeled – October/November 2011, May 2011, July 2010, and the 100-yr flow. Model results showed the spatial distribution of sedimentation rates in mm/day in the trap areas and the potential backup of water (height and extent) upstream caused by the structure for permitting purposes.

The spatial distribution and sedimentation rates are the most difficult to review because only observational data are available. Because of the detailed grid development, bathymetry provided by the multitude of poling data, and the assignment of sediment characteristics to geomorphic units that reflect depositional environments, the spatial distribution of relative deposition and erosion is likely acceptable for the larger sediment trap areas. The sedimentation rates should be used in a relative comparison sense only, and cannot be expected to match actual rates. Data gathered from the sedimentation samplers installed in the spring 2012 in four of the traps should be used to help verify sedimentation rates over the range of flows experienced during their deployment. Because of the multiple remaining questions with the sediment transport model in general and the lack of data to verify sedimentation rates, the April 2012 model is not adequately documented or ready to conclude that it meets objective 3 of the CWP, which is to simulate a variety of scenarios for containment, collection, and recovery of submerged oil.

Sensitivity Analysis

Review comments for sensitivity analysis are included in the above section on data inputs included in "Grid Selection and Model Development".

Base Model Limitations

The model report considers several limitations to the April 2012 model:

- The model is 2D and cannot characterize 3D flows – The subsurface intakes at Morrow Lake Dam and the reversal of water surface elevations in the delta and lake as the powerhouse intakes are opened and closed are two reasons why a 3D model is needed to adequately model sediment transport in Morrow Lake delta and lake over scenarios of various flow inputs, flow outputs, and wind conditions.
- The model does not account for groundwater contributions – The Kalamazoo River system has numerous springs, especially in the lower reaches downstream of Battle Creek. Currently these contributions are equally distributed among tributary inputs.
- The model does not directly simulate submerged oil transport – It is recommended that the sediment input component of the sediment transport model be updated with an additional particle that is representative of submerged oil glob size and density, as an additional simulation.

- The models do not consider submerged oil biodegradation – This aspect could be addressed by a simplification of the particle input as perhaps smaller and heavier.

Summary Comments Specific to the Model Report and Addendum

The following contains the main comments made by the USGS and Weston/START on behalf of the U.S. EPA arranged according to the table of contents of the calibration report. More detailed page by page comments are attached.

Report Objectives

The April 2012 model report was prepared to document the development, calibration, and validation of the riverine and floodplain models that were used to simulate hydrodynamics and sediment transport in the oil-affected 40-mile length of the Kalamazoo River. The report also describes the application of the models in terms of scenarios to help describe sediment transport associated with a range of flow conditions along the entire length as well as the performance of sedimentation-enhancing structures in specific locales along the Kalamazoo River with submerged oil deposition. The report was a step toward meeting the fourth objective of the modeling component of the CWP by documenting the findings of the model for assistance in planning, design, implementation, monitoring, and evaluation of future management methods. The April 2012 model outputs for the spatial distribution of depositional patterns and velocities have been used as supporting information to guide submerged oil recovery, monitoring, permitting, and containment, even though this version of the model has not been fully calibrated and validated. A similar report, with results from an updated model, needs to be written to document the findings of the model.

Report Terminology

Some common terms need definition for clarity in the context of numerical modeling:

1. "Variable" and "parameter". A model contains one or more governing equations; for example, the equation $y = ax^2 + bx + c$ is a model for tracking changes in *y* (a physical quantity) resulting from values given to *x* in a given system. Then the *x* and *y* are the independent and dependent "variables", respectively, in the system; and *a*, *b*, and *c* are "parameters" for the system. "Variables" represent the quantities, such as velocity, flow discharge, water surface elevation, sediment or pollutant concentration, particle size classes and distributions in the suspended sediment and in the bed and bank materials, or time, etc. The answers or solutions for *y* can have a range of spatial and/or temporal variations. On the other hand, "parameters" *a*, *b*, and *c* adjust the actions of the model to fit the (local) system. Their values could be from empirically determined (default) datasets or fitted through the calibration procedures. A parameter can take on one or several values throughout the system. It is through fitting of coefficients that the model becomes calibrated to match with local observed conditions. The parameters may include, e.g., roughness coefficients, critical shear stress, turbulence coefficients, erodible bed thickness, etc.
2. The terms "programs", "models", "grids", and "modules" generally don't cause confusion in their context but are used inconsistently in the calibration report. We suggest using "grids" specifically in the context of setting up computational cells, and using "models" for describing the modeling of hydrodynamic and sediment transport phenomena. The "module" to be used

when indicating components or collections of methods in a specific function, i.e., *hydrodynamic* *module* or *sediment transport* *module*; use "code" specifically for the *EFDC* *code* ; and "program" when citing the *HEC-RAS or another computer* *programs*.

Introduction

Lack of reference of calibration report to the objectives in the CWP -- We recommend the "Purpose and Scope" of the hydrodynamic modeling, described on pages 25 and 26 of the CWP, be brought in here with an introduction how the modeling team met the four main objectives. Adding a "Background" subsection to introduce the study reach, the mile post (MP) system, list of natural and man-made features of the Kalamazoo River, and how to interpret for the transport and deposition of submerged oil/oiled sand can help a better understanding of the modeling work and the transition to the following sections.

Model Code Selection

Lack of reference of calibration report to the objectives in the CWP -- The statements given in each subsection are generic applicable to any EFDC document, there is no connection between the EFDC and the application to the Kalamazoo River setting. We suggest the selection of EFDC be justified by discussing how the EFDC's capabilities can be used advantageously to address the mechanisms acting on the transport and dispersion of sediment at various environmental settings along the Kalamazoo River, and what results from EFDC can be interpreted to fulfill the objectives of the CWP. Clearly modeling the 40 miles of natural river presents great challenges for detailed field application. During the model development, the time required for model execution time became lengthy and a concern, the Enbridge team was able to modify the code to enable EFDC runs in parallel-processing mode, thus reduced the run time appreciably. This enhanced model capability can be considered as a justification for the EFDC selection. On the other hand, "Model Limitations" or "Assumption" should be included at this section. The EFDC is not designed for modeling geomorphologic processes like bank erosion, channel widening, meandering, etc. How to simulate sedimentation for long-term, like one year or more; how to incorporate groundwater inflow; and what mechanism are not suitable for EFDC applications (e.g., limitation in hydrostatic pressure assumption) are some examples worth mentioning at this stage of the report.

QA/QC Documentation

The quality of the data input for either configuring the models or as boundary conditions, and the correctness of the basic setup of the model need be supported with more documentation of quality assurance data. The CWP (p 26) stated that "Early products of the modeling study shall include metadata and maps of the digital elevation model comprising bathymetric and terrain models of the respective sectors of the model domain (e.g., see Figure 4.3.2); graphs showing the goodness-of-fit between measured and simulated values of the calibration targets; and graphs illustrating the sensitivity of simulation results to incremental changes in the calibration parameters." In the current coverage, the QA/QC documents for the LiDAR and the derived DEM, for the ADCP and ADV measurement, and for the HEC-RAS geometry and calibration results; descriptions for the crest stage gage setup and reading accuracy, for the poling depth and their location coordinates, for the thalweg survey, for the high-oil marks collection and analysis, were not given in the report. The text also did not contain technical details for evaluating interpreted information, such as the reasonableness of the tributary inflows and dam rating curves, the treatment of structures like bridges and culverts, or the dissimilarity in channel geometry between the riverine and floodplain grids. These QA/QC issues need to be documented in the report.

Model Development

Data available for setting up the grids, mapping the channel bathymetry and floodplain topographic features, describing the channel bed and bank materials, man-made structures along the study reaches, for setting the boundary conditions, and for scenario analysis should be described here. The data needs to be explained as described in the QA/QC paragraph above. Special features of the channel, like the armored reaches, dams on the tributaries that may affect the discharge/sediment inflows, should be described.

Accompanying the report are a large volume of figures generated for presenting various simulated and derived results from the modeling work for both riverine and floodplain models and for all events and scenarios discussed. The results shown by the figures need to be described in the text. For example, what is the characteristic time used to present the velocity results of a day? How were the simulated results (interval in seconds) processed to compare with daily observations? The definition used in presenting the erosion and sedimentation rates? Etc.

Tabulations for the calibration and verification events are needed and should list their qualifications (i.e, exceedance probabilities, bankfull flows, etc), as well as the available field data, e.g., discharge, water surface elevation, velocity, etc., for validating the results. For the targeted variables in the hydrodynamic and sediment transport modules, describe parameters that will be calibrated (e.g., roughness coefficient), field data (e.g., bulk density, erodibility, etc.) and those that were represented with well-established values (e.g., parameters in turbulence closure terms).

The accuracy and consistency of the grid design needs to be included in the report. At present, an aspect ratio was reported but no explanation was given for how it was chosen. The capability of correctly modeling the lateral velocity distribution across deep, shallow, and expansion into the depositional areas is the purpose of using a 2-D model, hence how the accuracy and consistency were accomplished needs be documented.

In reviewing the grid designs, For example, there did not seem to have a consistent way to assigns grids to model the tributary inflows. The coverage for the Battle Creek, the largest tributary in the study reach, did not include the entire width and the extent to the bridge as shown in the floodplain model, and the Cresco dam in the floodplain model was not described similarly to that in the riverine model. Similar observations can be given to channel border depositional areas and documentation should be given to describe the lateral exchange between the main channel and depositional areas.

Calibration

Documentation -- A calibration document needs to include information about: What variables were targeted for calibration and what data are available for the evaluation? What parameters were adjusted and in what fashion in the calibration? How the calibration results were evaluated? And what were the final, calibrated parameter values? Such information was not given in the report.

The narrative in the text does not lend itself to a clear understanding of what field data are available for the calibration and verification events. For the purpose of setting up the information for calibration and verification, the documentation needs to describe what variables are of primary important for the hydrodynamics and sediment transport, and what variables can be calibrated with available data, and what parameters will be calibrated (e.g., roughness coefficient), what will be taken from field data (e.g., bulk density, erodibility, etc.) and what will use the well-established values (e.g., parameters for turbulence closure terms). The model development also needs to show its plan to address the accuracy concerns even we are still waiting for further data to be collected in 2012 for the final calibration. The grid resolutions are very detailed for the longitudinal transport, but there is a need to demonstrate the accuracy of such coverage for describing the lateral movement of flows in the main channel and lateral exchange with depositional areas with a case study.

The report stated that the models are calibrated but had not provided evidences to support the statement (see model review comments above). The report didn't explain what variables were targeted for calibration? What parameters were adjusted and in what fashion? How the calibration results were evaluated? And what were the final, calibrated parameter values? Several parameters or statements that could be improved with currently available data but were not done are listed in the following bullets.

Estimation of tributary flows -- The Enbridge team described that the area ratio method was applied first to estimate the tributary inflows and the results were further adjusted to balance the flows; that is, the sum of incoming upstream inflow (using the Marshall gage) and tributary inflows from Talmadge, Bear, Minges Brook, and Battle Creeks were balanced at the Kalamazoo River near Battle Creek stream gage, and the downstream flows from Kalamazoo River near Battle Creek plus those from Wabascon, Seven Miles, Augusta, and Gull Creeks were balanced at the Kalamazoo River at Comstock stream gage. Only the area ratio method was discussed, but results were not presented. It is necessary to document the re-balancing work for future reference, especially if there are future efforts undertaken for estimating tributary inflows in the field. The Kalamazoo River is a groundwater-fed river and receives significant groundwater contributions at low flow conditions. Hence, the differences between the estimated and observed flows may have implications for estimating incoming groundwater. It is also necessary to understand the rebalancing method and results when there are concerns about the rating curves developed for the dams in the study reach (see next paragraph). Last but not least, rebalancing the flows should be discussed in model set-up subsections, and not be presented as part of the calibration process.

Dam rating curves – See above.

Demonstrate and support the 2-D modeling efforts -- Understanding the effects of storage areas in the channel and along the channel margins, as well as on the floodplain, on the fate and transport of oiled sediment was one of the reasons for conducting the modeling in 2-D. The report should discuss mechanisms affecting storage versus transport at various locations and describe modeling considerations given that field data may not be available at present. On the other hand, the calibration and verification document needs to provide evidence of the need for 2-D modeling and demonstrate the capability of simulating 2-D flow patterns at these locations. At present the report presented comparisons of cross-sectional geometry between the HEC-RAS, riverine grids, floodplain grids, and LiDAR cutlines at 10 locations. The results showed differences in channel depth and width with the HEC-RAS cross sectional geometry. For transects, the simulated velocity tends to under-estimate and mismatch the location of the highest velocity, and also underestimates velocity magnitudes in the cross-sectional direction. No explanation about the discrepancies was provided. The calibration process and results need to be better documented, and further adjustment of important parameters is necessary.

Validation

With the validation results presented in the similar way as those for the calibration results and with the doubt if the model is calibrated (Section 4), we prefer to hold our comments on the text for this section until the model is rerun.

Model Scenarios (Response to Historical Events)

Reference of calibration report to the objectives in the CWP -- Contents in Section 6 fit the purpose # 2 of the hydrodynamic modeling study (CWP, p 25). "Remobilization Analysis" can be a better heading for the section. The discussion on remobilization potential (Figure 10, Section 10) can be incorporated into the discussion here for different flow conditions.

In the discussion, we recommend emphasize on the resulting deposition / erosion patterns and rates, and texture changes in sand, silt, and clay, for locations in channels and/or on floodplains and under the specified flow regimes. The three depositional areas (Ceresco Lake, Mills pond, and Morrow fans and delta) along the main channel and selected depositional areas in channel margins or the zonal areas that used in the "Sensitivity Analysis" (Section 8) are the areas of concern. The maximum local velocity, shear stress, is useful supplemental information. A tabulation of these results is a systematic approach will provide clear understanding of the sediment transport issues. If there are inconsistencies to the observed oil sediment remobilization patterns or with field judgment, they can be information leading to a more focused Sensitivity Analysis.

Sediment Traps

Reference of calibration report to the objectives in the CWP -- Sediment trap simulation meets part of the objectives for the hydrodynamic modeling study (CWP, p 25). For sediment trap discussion, document the siting criteria and targeted variables first to help discussion about the results. Other management scenarios not discussed include:

1. Risk of sediment transport over Morrow Lake Dam – Due March 23, 2012
2. Risk of sediment remobilization by E4.5 double-chevron removal – Due March 23, 2012
3. Effects of different agitation/recovery methods – Due March 23, 2012

Sensitivity Analysis

The text states that the purpose for conducting the sensitivity analysis is “to evaluate the changes in selected model input parameter values or boundary condition(s) on simulation results.” For this purpose, the Enbridge team varied “roughness coefficient”, “critical shear stress for deposition”, “sediment settling velocity”, and “boundary sediment concentration” parameters by ±50% of the current value, and presented the changes in “velocity”, “shear stress”, “sediment particle size distribution”, “sedimentation rate”, “change in sediment mass”, “water surface elevation”, and “sediment loading” at selected reaches or locations. The purpose of the sensitivity analysis as specified on P 35 of the CWP is: *Once a final calibrated model is obtained, Enbridge shall conduct sensitivity testing to evaluate the uncertainty of simulation results related to uncertainty in model-calibration parameters and other input parameters*. The CWP (same page) also stated that: *Adjusted parameter* *settings shall be increased and decreased from their final settings in the following relative increments: 2, 5, 10, 15, 20, and 25 percent of the final setting used for the calibrated model. For each incrementally adjusted setting, a simulation run shall be used to determine the resultant effect on model sensitivity targets: water levels, velocities, discharge, suspended-sediment concentrations and loads, scour volume, and depositional volume. Effect on each target shall be expressed as a percentage departure from its value in the final, calibrated model.*

It appears there is a difference in the recognition of targeted variables and selected parameters in the two documents. The discharge and suspended concentration sediment are not parameters; their spatial and temporal changes in the model system are the targets of the modeling (they are variables). This error in the April 20 report should be corrected. Because the calibration parameters were not adequately identifies and explained in Section 4, it remains unclear if the most sensitive parameters were included in the test. How to incrementally vary each parameter value in the sensitivity test also should depend on the selected parameters.

With a straight tabulation of results from the incremental change test and a narrative description about the resulting changes in the text, the Sensitivity Analysis section did not result in any information for better assess the reliability of the EFDC Kalamazoo River model. We have proposed to establish the convergence criteria for selected variables and provided initial percentages. A comment to the Enbridge May 8, 2012 Addendum is attached. A feasible way to identify the critical parameter is to tabulate the results as follows. From the tabulation, one can narrow down the parameters and determine the effects with respect to the departure from their original values.

Variable	***roughness***	***Critical shear stress***	***Other parameters***
Velocity – magnitude	High, medium, low, etc	High, medium, low, etc	High, medium, low, etc
Velocity – direction	- - -	- - -	- - -
Discharge	- - -	- - -	- - -
Water depth	- - -	- - -	- - -
Sediment loads	- - -	- - -	- - -
Sediment texture	- - -	- - -	- - -
Erodibility	- - -	- - -	- - -

Base Model Limitations

Depending on the information summarized for this section it could be a worthwhile communication effort about what has been done, what can be done next with improved data, and what cannot be done with the modeling (and whether they are important or not). In its present state the contents of this section covers both general and site-specific information. Some of the general information may be summarized in the “Background” section mentioned above. For the site-specific information, the discussion on topics likes “areas of potential sediment remobilization” using various simulation events is useful and a good subject. Other topics suitable can include: “the amount of oiled sediment deposited in sediment traps”, “the role of depositional areas, like oxbows, in retaining the oiled sediment”, “what induced oiled sand movement”, etc. Further comments on the remobilization analysis presented in this section will be provided pending completion and submittal of model reruns.

Addendum

A request for additional information in May 2011 covered four areas: (1) calibration targets, (2) more interpretation/description of calibration results, (3) more graphical output of and tabulations of sensitivity analysis, and (4) a timeline for additional model refinements.

Calibration targets – The response contained more results, but did not outline the targets as requested.
Interpretation – The response did not include interpretation, only more data outputs.
Sensitivity analysis results – This response was incomplete because the questions for calibration targets and interpretation were incomplete.
Timeline – A schedule for model refinements was proposed by Enbridge. The data collected following the fall 2011 reassessment can be used to refine the model. Calibration targets and more details on sensitivity analysis, especially for the sediment transport model, need to be clarified before additional model runs.

Detailed Comments Related to the April 20, 2012 Report

ITEM NO.	REFERENCE	COMMENT
1	Entire document	Consider use an "Executive Summary" to give an overview of the report. Adding a "Background" section to discuss the oil spill, the Kalamazoo River, what has been resolved and what are remaining challenges, the domain of the problem, and the need for hydrodynamic modeling. Some information described in Section 9.1 is suitable here. A "Background" section makes the transition to the following discussion better.
3	Entire document	The name of USGS streamflow gauging station 04105000 is Battle Creek at Battle Creek. In the report "Battle Creek" was used to represent both station 0410500 and 04105500. The latter should be named correctly as "Kalamazoo River near Battle Creek".
4	P xxii	"List of Acronyms" table contains both acronyms and units. Suggest list the units used in the report in a new table with a title like "Unit Conversion" to cover the both metric and English units used.
7	P 1, in the middle of 2nd paragraph	The report states that USGS gages were used as calibration targets for "…discharge, water surface elevation, and velocity.." Velocity data was not available at these gages so velocity should be removed from this list. Correctly document what data were collected by which agency.
8	Fig 1.	Add MP 0.0 and Talmadge Creek. Remove the model extent image above the confluence of Kalamazoo & Talmadge to be consistent with figures presented in the latter discussion.
10	P 3	Explain where the results are located and how the EFDC results for the Kalamazoo River were processed for comparison with observed data. That is, in EFDC, the finite difference and finite volume spatial discretization, and staggered location of discrete variables (e.g., velocity components are located on the faces of the primary control volume, depth and concentration of transported constituents located at centroid, etc.).
11	Section 3	Banklines that defined the boundaries of the riverine grid were traced from the April 20, 2011 leaf-off aerial orthophotograph. Since there are leakages from the riverine model during the simulation, why were the banklines not evaluated with contour lines to verify the banklines?

12	Section 3	With the time interval differences between the input data (e.g., observations made daily, such as staff gage readings or discharge data retrieved as daily values) and computational intervals (e.g., 1? second for floodplain model and 1? second for riverine model), it is necessary to explain how the simulated data were processed to generate comparable quantities for the comparison. What is the correct name for the "Kalamazoo" dam? Is it Monroe Street Dam?
13	Section 3	For riverine grids, islands at MP 6.25, MP 6.75 were not modeled; islands at MP 9.75, MP 10.75 were not covered in full; side channel between MP 26.0 and MP 26.5 were not covered [Note: the TT may have updated these misses already]

14	Sections 3.1 and 3.2, and part of 3.3	• Page 5. Define which fly-over aerial was used for tracing bank lines. • Section 3.1.1, Page 6. The term "aspect ratios" came out suddenly. The text indicated that this is an index for the model accuracy. Explain why there are different aspect ratios shown in figure 3-4 for the floodplain grids if the grid size is fixed at 15m x 15 m? • Figure 3-3. The 100-year floodplain boundary looped near MP 7.25. • Explain how tributaries were modeled in the floodplain model? • Page 7. During previous meetings / discussions only daily discharge data were used. Clarify if the unit value flow data (15 minute) were used in the model calibration / verification. • Include a table listing the locations of dams, tributaries, gages etc. in terms of MPs. • Figure 3-5. The symbol for Kalamazoo River near Battle Creek was not shown, i.e., it was masked by the label of "Dickman Road". • Section 3.2.3, p 8. List the dams in the u/s - d/s sequence. Document the weir elevations, how they were obtained and what datum system (NGVD or NAVD) was used. • Figure 3-6. Tributary names arranged in u/s to d/s sequence. • Figure 3-7. Use consistent units in presenting the rating curves. Currently the flow is in "cfs" but the head over dam is in "meters". Need to insert a diagram to illustrate the dam crest shapes and elevations. • Page 8. Why the broad crest weir equation was not used? Also, correct the weir equation, i.e., (2g)^0.5, not 2g^0.5. • Document the coefficient values for the rating curves. The discharge constant needs to be calibrated or explained how the value was determined. • Page 9. Remove R^2 in figure 8 since nonlinear regress was used; modify the legend text for data and regression line. • Give reference to the 120 mg/L discussion, i.e., SOSG discussion or personal communication, date.
14.2	Page 7 HDM report: Tributary flow distribution in the model.	It appears that a representative flow yield was determined (discharge/drainage area) for a gauged watershed and then applied to the ungauged tributaries to the model. The tributary flows should be normalized to the flow at the downstream boundary condition. For example, if the difference in flow between the Kalamazoo R. at Battle Creek gage and Kalamazoo R. at Comstock gage is 300 cfs, then that residual should be spread among the several tributaries along that reach of the river. There is potential for discrepancies in total flow in the model using the approach described in the report. Also there are a number of tributaries not listed in the report that are contributing flow to the Kalamazoo river. Please describe rationale for which tributaries were included and which were not.

14.3	Page 7 HDM report: Tributary flow distribution in the model.	It appears that a representative flow yield was determined (discharge/drainage area) for a gauged watershed and then applied to the ungauged tributaries to the model. The tributary flows should be normalized to the flow at the downstream boundary condition. For example, if the difference in flow between the Kalamazoo R. at Battle Creek gage and Kalamazoo R. at Comstock gage is 300 cfs, then that residual should be spread among the several tributaries along that reach of the river. There is potential for discrepancies in total flow in the model using the approach described in the report. Also there are a number of tributaries not listed in the report that are contributing flow to the Kalamazoo river. Please describe rationale for which tributaries were included and which were not.
14.5	Sections 3.1 and 3.2, and part of 3.3 (concluded)	• Use the title "Riverine Bathymetry" for Section 3.3.1.1, and "Floodplain Topography" for Section 3.3.1.2. This can help avoid the confusion about the 9m x 9m resolution discussed in Section 3.3.1.2 from the previous 15m x 15m grids. • Page 13. Include the year when citing a reference. This comment applies to all references cited. • Page 13. Use "roughness factors" or other appropriate terminology for sub-component of the Cowen's approach. Also document the so derived manning's n values are compatible with published data. That is, with n=0.081, does it comply with published report of n values for grass / forbs? • Rename "Sediment Class Size" (currently Section 3.4.2) to "Bed Sediment • Classes (or Characterization"), and focus on bed sediment only.
14.7	Section 3.4 Data Gaps	Page 17. Distinguish the data gap for those needed for "Model Development" and those for "Parameter Estimation". Suggest include 2012 plans for collecting new / additional data to improve the situation.
15	Section 4.1	Modify the opening statement "refine model structure". Generally the model structure is used in the context for describing the complexity of the model (i.e., what equations were solved and how they were solved) especially in the context of discussing model accuracy and sensitivity of parameters. The ungauged tributary inflows, meteorological data, temperature, data and calibration / verification events should have been established earlier in the report. With tributary inflows adjusted, the comparison of magnitudes and time of peak of discharge hydrographs at selected gauging stations tells us if the grid sizes, grid connectivity, and the n-values are appropriate. Therefore it is useful to illustrate a full hydrograph in the comparison. With the stage data from operator of the Morrow Dam, such a comparison will be very beneficial. The modelers can also use such estimations to discuss how the groundwater inflows were considered in the present situation. The report mentioned that comparison on discharge at ADCP transects would be made (P 20) but not results were presented.

16	Section 4.1	Explain why shows the discharge hydrograph at 04105500 in figure 1 only? Was the intent to include those from Marshall and Comstock to discuss the transport characteristics in the stream-wise direction. Clarify if daily flow or the 15-minute flow data were used in the analysis. And was flow duration curve regenerated by the modeling team here? If yes, then documentation is needed. Use "water-surface elevation" instead of "surface water elevation". Larger errors in estimated water surface elevation occurred in reaches upstream and in the vicinity of MP 10.0 and around MP 16.75. During weekly discussions it has been suggested to use thalweg data to modify the riverine and floodplain bathymetry, especially in the vicinity of MP 10.0. Document what have been done and why still there are larger discrepancies in water surface elevation at and above MP 16.75, including MPs 10, 5.25 etc. Since we cannot assume that the EFDC would have the same bed elevation as the thalweg, what information the modeler can give to explain the discrepancy? The operator at Morrow Dam keeps records of water surface elevation upstream of Morrow Dam and that record should be used in the HDM calibration /verification.
17	Section 4.1	Calibration for velocity needs receive equivalent or more attention in the calibration / verification stages because it affects the constituent transport. Both magnitudes and direction of the velocity vectors need to be calibrated. Assuming the transect number in figure 4-4 is the MP index, then we are observing that: • The simulated velocity has little or much less lateral variations than those presented in measured data in a transect. • The location of max velocity sometimes is at opposite side than those measured. • Overall the simulation underestimate velocities measured in the field and the degree of underestimation is more obviously at higher magnitudes. • The simulated velocities near the upstream face of Marrow Dam decreased to approximately zero. But measured velocities were not near zero. Perhaps a longitudinal profile of discharge plot is needed for verifying this simulation. • Were the velocity magnitudes presented with the same arrow scale in the velocity plots in all figures?
18	Section 4.1.2.2	The content of figure 4-7 stated on P 23 the first sentence needs to be checked and corrected. What events were used for calibrating variables of floodplain grids should be explained clearly first.

19	Section 4.2	The sediment inflow discussions need to give considerations that the Marshall and Battle Creek have dams but other tributaries don't. How will this setup affect the sediment inflow estimation? The reaches that are dominated by noncohesive or cohesive sediment and armoring should be described in the model. Such information is useful for reviewing the appropriateness of sediment outputs in relation to the assumptions made, e.g., uniform sediment properties for all sediment layers and through-out the river reach. Document d_{50} in each sediment class used in the bed materials and the sources. If the sediment transport outputs were evaluated qualitatively using field experience that gained through site assessment stage, then state this approach in the opening statement (Section 4.2). Present the sediment flux / load in the longitudinal direction from up- to down- stream so the variations in erosion / deposition can be reviewed. It is difficult to view the results in time series plotted for different locations. Check the sediment loads at Morrow Lake Dam location (Figure 4-10). If the sand, silt, and clay loads were nearly zero, then how can the total load so different?
20	Section 4.3	Check header numbering, i.e., S4.3 and S4.4. The discussion uses some terms not discussed before, like backwater eddying. Need have better documentation in the report.
21	Section 5 Entire Section	Use similar presentation as Section 4 discussed above to address the results and show comparisons between the estimated magnitudes using the calibrated models from selected field events. Difficult to track what data were missing when only plots were shown, e.g., the field data presented in figure 5-2.

22	Section 6 Entire Section	See comment #1 for the suggested focus for Section 6. The information on remobilization potential (Figure 10) needs to be incorporated into the discussion under different flow conditions and addressed here. Targets, such as simulated sedimentation (erosion or deposition) rate and associated texture changes (used as surrogate for oiled sediment) and sediment loads at selected locations (for generate understanding of how much sediment and texture changes moved through natural trap areas) need to be documented. Additional information, such as maximum velocity and bed shear stress can be included as supplementary information of the result. Note that the zonal areas listed in Section 8 should belong here, I believe. A tabulation of these results is a systematic approach and will be helpful. Pay attention to some technical terms used. For example, the Log Pearson Type III analysis leads to the peak magnitude of the flood, not hydrograph. How the 100-year hydrograph, for example, was derived needs to be documented.
23	Section 7 Entire Section	This is a good time to incorporate the current discussion into the Management Scenarios described in CWP. For sediment trap discussion, document the siting criteria and targeted variables first to help discussion about the results.
24	Section 8 Entire Section	The purpose of the sensitivity analysis as specified on P 35 of the CWP is: *Once a final calibrated model is obtained, Enbridge shall conduct sensitivity testing to evaluate the uncertainty of simulation results related to uncertainty in model-calibration parameters and other input parameters*. The targeted variables are: *water levels, velocities, discharge, suspended-sediment concentration and load, scour volume, and depositional volume.* Similar to the comments made for Section 6, systematically present and discuss the results for selected locations will be helpful to both writers and readers. As discussed, the convergence criteria are under development and need be incorporated once ready. The outcome of this section need include a tabulation of “High”, “Medium”, and “Low” evaluation on the effects of selected input and model parameters on the targeted variables. The discussion for floodplain grids should separate the portion in the main channel and on the floodplain. How much sediment would be diverted to the floodplain and where are the information needed. At this point, perhaps adequate information has been generated and the group can agree on more focused location for viewing the sensitivity testing results. Figures prepared for this section include the water-surface elevation only at present. Other targeted variables need be added in the future update.

25	Section 9 Entire Section	As suggested above, some discussions presented here are appropriate for the "Background" section. Difficult to follow the discussions when no further data were given here in this section or discussed in previous sections.

ITEM NO.	REFERENCE	COMMENT
26	Page 8 HDM report dam rating curves	Design plans should be available for each of the dams in the river. These should be referenced to ensure that the rough rating curve approximation using aerial photograph and GIS analysis can be confirmed. Also in figure 3-7 or in the text state the discharge coefficient, and weir width that was used for each rating. Also gravitational constant should be units of m/s^2. In addition, was the dam between Fountain Rd and Dickman Rd bridges included in figure 3-7 as Kalamazoo dam?
27	Page 12 HDM roughness coefficient discussion	The report states a constant roughness of 0.02 was used throughout the model in the channel. There is no description of how this number was arrived at other than modeling experience. I think a more thorough description of the process you used to determine that one number was appropriate needs to be added. Include why you could not do a similar analysis of what was done for the floodplain, for the channel.
28	Page 13 HDM Roughness Coefficient	The value (0.045) used for n_3 or the obstruction component of the Manning's n is outside the range of the adjustment values (0 to 0.030) for the floodplain roughness. Explain why this was necessary, did obstructions make up more than 50% of the floodplain?
29	Page 14 HDM Meteorological Conditions	While these may be minor components there needs to be some table of the volumetric water budget in the model that to illustrate the relative contribution of the various components of the model. The reader needs to be able to decide whether they are significant or not.
30	Page 20 HDM ADCP discharge	The report states that "Model simulated flows were also compared to field measured flows from Acoustic Doppler Current Profiler (ADCP) transects." However, there is no comparison of simulated flows to measured ADCP flows in the figures or tables. Please explain or remove from the text.
31	Page 21 HDM	It states that roughness coefficient values were adjusted to allow simulated velocities to better match

	hydrodynamic calibration	measured velocity and water surface elevation values. If you are using a single bottom roughness coefficient for the entire modeled channel as stated earlier in the report does that mean that adjusting that one roughness value improved the simulated velocity and water surface elevations throughout the model?
32	Page 22-23 HDM ADCP velocity comparison	Why are the simulated velocities in the model being compared to the average ADCP velocity – the standard deviation? A more thorough description of what was compared needs to be put in this section. Was the ADCP data averaged for the entire model cell or just at the cell center? How long was the ADCP data recorded for each point measurement made?
33	Page 22 & fig 4-5 & 4-7HDM Velocity comparison	It appears that the model consistently under predicts the measured velocity in both the floodplain and riverine grids. An attempt should be made to get the total population of residuals evenly distributed around zero by adjusting various parameters in the model. If velocities are under predicted then the model will tend to under predict other processes associated with velocity including sediment transport.
34	Page 23 and fig 4-8 HDM WSE comparison	There are some large residuals (9.51 ft at TR469) in the simulated and measured water surface elevations for the July 25 floodplain simulation. This suggests that some adjustments need to be made to the model to better match those water surface elevations. In addition the pattern is such that between TR418 and TR765 the model predicts WSE too high and then below TR765 the model primarily predicts WSE too low. So these areas can be targeted for model parameter adjustments to better match those water surface elevations.
35	Page 24 HDM Sediment transport results	The report states, "Generally the simulated mass flux at all locations is greatest in the early days of the time series and diminishes over time." Please explain why you feel that this actual behavior and not a numeric artifact of the model equilibrating to the transient effect being simulated. If this is an artifact of the transient model equilibrating, then a series of simulation run-up times should be tested to determine when the results reflect actual sediment contribution to the system.

Detailed Comments Related to the May 8, 2012 Addendum

ITEM NO.	REFERENCE	COMMENT
1	Comment # 1: Attachment 1, Proposed Model Calibration	Documentations provided in Attachment 1 are not the "acceptance criteria" but statistics summarized from current model runs. Please use the table provided by Faith Fitzpatrick as the basis for developing convergence criteria. The table was sent on 04/18/2012 through email (subject: Re: invitation: Hydrodynamic Assessment net Meeting (Apr 19 14:30 CDT in Live Meeting).

	Acceptance Criteria	Cannot understand what expressed in the table 1. • List observed values and use the same variable from simulations; e.g., water depth, not water surface elevation. • Explain why there are multiple data points to compare to one observation? • List the formulas used, and use them for all variables; i.e., mean absolute error, normalized mean absolute error, root mean square error, and normalized root mean square error. Index of agreement was not given for water depth, and several statistics were not given for oil marks. • Naming convention for locations for gages in flow table is unclear
2	Comment # 2: A narrative interpretation of the HDM calibration results. The interpretation shall also include recommendations for additional data collection and/or revisions to the calibrated HDM.	Evidence from the field was expected for such interpretation. Was the un-mentioned Attachment #2 for this purpose? The statements provided were mostly description of model outputs only. The statements do not match with what were required. With acceptance criteria not established in Attachment #1, the response did not document if the simulation at individual stations met the calibration criteria. Recommendation for additional data collection and/or revisions to the calibrated HDM was not mentioned. Overlaying the Spring 2011 submerged oil delineation areas with simulation results is a valid approach. However, the floodplain grid outputs should compare to the overbank oil delineation area also. Interpretation from such overlay should be the basis of this response.
3	Comment # 3: Please provide additional compilations and graphical presentation of data from the sensitivity analysis model to support more detailed evaluation of the HDM response to variations in specific	As discussed in the comments for April 20 HDM report, the sensitivity analysis should be performed after the final calibration is completed. The refinement of the HDM and report need to follow that sequence. When performing the sensitivity analysis, we request the targeted variables, sensitivity evaluation criteria, areas for evaluating the results and targeted contributing parameters be clearly specified at the beginning of the sensitivity analysis. Outcomes of the sensitivity analysis should prepared in the summary form and meet the purpose specified in the CWP. In its present scope, many questions remain about the parameters selected. For example, • Settling velocity that tested was for sand, silt, or clay classes? Was the value of settling velocity changed directly? Or through other parameter, e.g., kinematic viscosity? • By changing silt composition, how composition in other sediment classes was modified relatively to this change? • Similarly, the critical shear stress that tested was for which sediment class? A follow-up question was why critical shear stress for erosion not tested?

	parameter values.	
4	Comment #4: Provide a schedule for performing additional model refinement and additional model scenarios to be evaluated using the calibrated HDM.	The USGS and Weston/START team suggest that additional technical information be provided with the proposed schedule. Information such as: the objectives, scope, background, approaches, supporting data, and deliverables. The USGS and Weston/START team also consider it is necessary to have the completed the model calibration report, developed acceptance / convergence criteria, completed dataset for calibration / verification, and outlined model limitations before the additional work starts.