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Enbridge Line 6B MP 608

Marshall, MI Pipeline Release

Case No.: 15-1411-CE

Large Woody Debris Replacement Work Plan

Prepared for Michigan Department of Environmental Quality

Enbridge Energy, Limited Partnership

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FIGURES

TABLES

ATTACHMENTS

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LIST OF ACRONYMS

BAJ	Bar Apex Jams
Enbridge	Enbridge Energy, Limited Partnership
Line 6B	The pipeline owned by Enbridge Energy, Limited Partnership that runs just south of Marshall, Michigan
LWD	large woody debris
LWD Plan	LWD Installation Plan
LWD Work Plan	*Work Plan for Assessing Large Woody Debris*, submitted to the MDEQ on August 21, 2013.
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MP	Mile Post
Supplemental LWD Work Plan	*Large Woody Debris Supplemental Assessment Work Plan*, submitted to the MDEQ on August 6, 2015.

1.0 INTRODUCTION

1.1 Introduction

This Large Woody Debris (LWD) Replacement Work Plan (Work Plan) summarizes the data, analysis, and conclusions obtained from activities conducted in accordance with the approved *Large Woody Debris Supplemental Assessment Work Plan*, submitted to the Michigan Department of Environmental Quality (MDEQ) on August 6, 2015 (Supplemental LWD Work Plan) (Enbridge, 2015), and addresses LWD removed as a result of response activities. Additionally this Work Plan includes LWD replacement design concepts (number, type, orientation, size, and anchoring) based on the collaborative global concept of targeting areas significantly lacking habitat. This Work Plan also includes a proposed schedule to implement the work.

1.2 Project Background

Response actions completed within the Kalamazoo River to address the July 2010 Enbridge Energy, Limited Partnership (Enbridge) Line 6B crude oil release required the removal of a considerable amount of LWD from the Kalamazoo River. During response removal activities, the locations of removed LWD pieces were recorded using a global positioning system unit. Additionally, attribute data was also collected at most of the removal locations indicating the number, type, and size categories of LWD pieces. In many instances, removed material (that was not impacted with oil) was stockpiled on the adjacent river banks.

Following response activities related to LWD removal, natural recruitment of trees, logs and other various materials occurred throughout the river system, some areas exhibiting higher volumes of LWD recruitment. During the summer of 2013, Enbridge performed an initial assessment at locations where LWD was removed to quantify the number and characteristics of LWD currently present. The assessment was performed in accordance with the procedures outlined in the approved *Work Plan for Assessing Large Woody Debris*, submitted to the MDEQ on August 21, 2013 (LWD Work Plan) (Enbridge, 2013).

The results of the initial assessment indicated that the areas of greatest LWD removal (2,437 pieces or 68.7%) occurred downstream of the 35th Street Bridge (Mile Post (MP) 36.50). The remainder of the LWD removed (1,111 pieces or 31.3%) came from various locations upstream, particularly slower moving and impounded areas with nearby heavily wooded floodplains.

The initial field assessment was completed prior to completion of all spill response activities, and did not produce a complete data set. The Supplemental LWD Work Plan reported the results of the initial field assessment and incorporated LWD removal data through 2014 to provide one data set to identify Target Areas as identified in *Section 1.4*. The supplemental field assessment was performed to further define the presence and characteristics of LWD in Target Areas, and to determine potential LWD replacement locations to optimally restore the overall ecological habitat.

1.3 Overview of LWD

LWD are large pieces of wood that occur within the fluvial environment of streams and rivers. LWD provides habitat for fish, wildlife, and macroinvertebrates while also providing river bank stabilization and protection from erosive forces. LWD for the purposes of this project is considered to be greater than 6 inches diameter and 8 feet long. Large wood can be placed in channels to promote or augment the physical and ecological diversity in rivers and streams that are deficient in a natural loading of LWD. The design of replacement LWD is variable and depends on the objective, the hydrology and hydraulic relationships, available material, impacts to navigable waters, flood impacts, and many other site and regulatory variables. For the purposes of this LWD replacement project, the efforts highlight application techniques that focus on the use of “key members” that will remain stable under high flows and promote improved habitat conditions. Additionally, the intent of the LWD replacement project is to strategically place LWD in areas requiring greater ecological need.

1.4 Target Areas

Based on LWD removal data and the results of the 2013 LWD Assessment, Enbridge identified an optimal list of suggested Target Areas to further assess. A meeting was conducted at Enbridge’s Marshall Office on February 12, 2015 including Enbridge, the MDEQ and Michigan Department of Natural Resources (MDNR) staff to review the proposed Target Areas to be evaluated for possible LWD installation. The discussion and review process generally consisted of reviewing areas where high concentrations of wood pieces were removed as part of response activities, and/or areas where restorative efforts may be needed to replace removed habitat. Additionally, access conditions, municipal infrastructure locations, and public use recreational areas were considered during the review process. This discussion resulted in a jointly agreed-upon final list of 18 Target Areas as shown below. The net difference between the removed LWD data and the initial assessed 2013 LWD removal data is included in parenthetical text below:

1. MP 5.75 to MP 6.75 (Net Difference of -39 LWD Pieces)
2. MP 7.375 to MP 8.25 (Net Difference of +44 LWD Pieces)
3. MP 10.50 to MP 11.00 (Net Difference of +10 LWD Pieces)
4. MP 11.75 (Net Difference of -14 LWD Pieces)
5. MP 12.50 (Net Difference of -3 LWD Pieces)
6. MP 14.75 Sediment Trap Area (Net Difference of +75 LWD Pieces)
7. MP 19.25 to MP 20.25 (Net Difference of -4 LWD Pieces)
8. MP 21.25 to MP 22.75 (Net Difference of +60 LWD Pieces)
9. MP 24.375 (Net Difference of -3 LWD Pieces)
10. MP 25.625 to MP 27.625 (Net Difference of -3 LWD Pieces)
11. MP 28.00 to MP 29.25 (Net Difference of -3 LWD Pieces)
12. MP 29.625 to MP 30.50 (Net Difference of +14 LWD Pieces)
13. MP 31.75 to MP 32.00 (Net Difference of +22 LWD Pieces)
14. MP 32.25 to MP 32.75 (Net Difference of +9 LWD Pieces)
15. MP 33.125 to MP 34.00 (Net Difference of -24 LWD Pieces)
16. MP 34.25 to MP 34.75 (Net Difference of -7 LWD Pieces)
17. MP 35.125 to MP 36.25 (Net Difference of -122 LWD Pieces)
18. MP 36.50 to MP 37.25 (Net Difference of -1,137 LWD Pieces)

For example, at the Target Area within MP 10.50 to MP 11.00, 16 pieces were removed during response activities and 26 pieces were identified during the 2013 assessment resulting in a positive net difference of 10 pieces. For specific LWD Removal Data, the results of the 2013 assessment, and the net difference between both data sets, refer to *Table 1* through *Table 3,* respectively. Additionally, *Figure 1* depicts LWD removal locations and the existing LWD pieces identified during the 2013 survey.

The criteria for selecting proposed work sites, or focus areas, was not exclusively limited to the 18 Target Areas. If areas requiring significant restoration and/or habitat needs were identified during the field assessment, those areas could be considered as focus areas.

2.0 FIELD ASSESSMENT METHODS

To provide information as the basis of LWD replacement, a Field Assessment was conducted on October 7 through and including October 9, 2015. The primary purposes of the field assessment were:

- To assess the nature and extent of existing LWD present within each Target Area,
- To assess the potential for LWD replacement within each Target Area, and
- To provide existing information regarding the type, stability, orientation, and function of LWD which would guide the LWD replacement design.

As discussed in *Section 1.4*, the Target Areas were jointly selected by Enbridge, the MDEQ, and the MDNR based on areas that may require LWD installation. It should be noted however, that through discussions with the MDEQ during and following the Field Assessment, it was suggested by the MDEQ that the actual LWD replacement locations did not necessarily have to focus only within the target areas, therefore the MDEQ specifically mentioned the upper Mill Ponds region and the Ceresco Restoration reaches as two additional candidates. Both areas were not originally included in the list of Target Areas established in the Work Plan.

Present at the Field Assessment were staff and LWD experts representing the MDEQ, the MDNR, and Enbridge. This included the following personnel:

- Michelle DeLong, MDEQ,
- Susan Jones, MDEQ,
- Joe Rathbun, MDEQ (On October 7 and October 8, 2015 only),
- Jay Wesley, MDNR (On October 7, 2015 only),
- Brian Gunderman, MDNR (On October 8 and October 9, 2015 only),
- Brad Parlato, LBG/Enbridge,
- Bryan Dick, Lotic/Enbridge, and
- Ian Jewell, Lotic/Enbridge.

The assessment was conducted by boat in each of the Target Areas. Two members of the assessment team, one representing Enbridge and one representing the MDEQ, counted and recorded LWD. The other team members - representing Enbridge, the MDEQ, and the MDNR observed and documented the existing conditions, erosion sites, existing infrastructure, geomorphology, and general presence or lack of LWD along each Target Area to determine potential LWD placement locations. The general results and observations were documented in the notes section of *Figure 2*. The methods used in both counting and inventorying the LWD and in assessing LWD replacement potential are described in the following sections.

2.1 LWD Inventory

Counting and recording the nature and extent of LWD was accomplished using the field forms included in the Supplemental LWD Work Plan. On this field form, LWD is counted based on LWD “units”. A unit of LWD can consist of a single log, root wad or can be a “complex pile”, which consists of two or more pieces. Use of the field form involved observing a LWD unit, and then recording the presence or absence, through a series of checkboxes, of particular attributes of that LWD unit. The attributes and sub-attributes observed for LWD are shown in *Table 4.*

After observing the first Target Area during the Field Assessment, it was agreed by all parties to add an additional attribute recording the percent submergence of the LWD, as it was thought that this would be a useful attribute to consider in the design stage. This submergence attribute was broken into four categories based on the approximate percent submergence of each LWD unit: 0-10% submerged considered “Very Low”, 10-30% submerged considered “Low”, 30-80% submerged considered “Moderate” and greater than 80% considered “High”.

Based on repeated observations that the observed LWD possessed amphibian and fish habitat, and very few were attributed to pool formation or bank protection, the field team agreed to collectively classify the observed LWD provided fish and amphibian reptile habitat and lacked pool and bank protection, unless otherwise noted.

A detailed explanation of the basis for choosing these particular attributes of LWD can be found in the Supplemental LWD Work Plan.

A copy of the raw observation data and LWD Data Summary Forms are included in *Attachment A*.

2.2 LWD Concept and Target Area Assessment

While the LWD Field Assessment was being conducted, several of the team members recorded general observations of geomorphology, areas of erosion, general areas of abundance and scarcity of LWD, and potential constraints to LWD placement such as infrastructure (i.e. bridges, utilities, shoreline development). After floating through each Target Area, a discussion was had amongst the team members as to their observations and the potential for LWD placement in that Target Area. The results of this discussion and the combined observations were recorded both on the LWD Data Summary Form (see *Attachment A*) and on a set of field maps (see *Figure 2*). The observations recorded on these field maps were used to guide the LWD replacement design described more fully below in *Section 4.0*.

3.0 INVESTIGATION RESULTS

3.1 LWD Assessment Summary

3.1.1 LWD Type

During the LWD Field Assessment, 1,512 units of LWD were observed in the Target Areas. A summary of the type of LWD that were observed in each Target Area is included in *Table 5*. Notably, of these, approximately 778 units, or 52% are complex piles. As previously noted, complex piles are composed of two or more individual pieces of LWD. Moreover, approximately 50% of the complex piles were recorded as “Large” which consisted of six or more pieces. Thus, although obtaining an exact count was impractical for the purposes of this assessment, the actual number of LWD pieces present in the Target Areas is likely significantly larger than the number of LWD “units” recorded.

3.1.2 LWD Stability

Another key attribute which was assessed as reference information was how the LWD is currently anchored into the channel. LWD guidance documents and literature recommend some degree of anchoring to avoid loss of LWD and potential downstream damage. *Table 6* presents a summary of LWD Stability by Target Area. As shown in the table, the vast majority of LWD in the target areas was observed to be “Immobile” or “Semi-Immobile”. It is important to note that the “Semi-Immobile” attribute was recorded for most complex piles as typically some members of the complex pile were anchored into the bank or bed, but other members were suspended or blocked by the anchored members. This fits the “Key piece” concept of LWD design as described in literature and discussed in *Section 4.0*, namely that much LWD is composed of key, anchored pieces that tend to recruit additional smaller pieces of LWD. The results of the assessment suggest that key pieces are abundant along the Kalamazoo River and responsible for much of the LWD complex piles found in the Target Areas.

3.1.3 LWD Orientation

Table 7 summarizes the orientation of LWD by Target Area. As shown in the table, the majority of LWD in each Target Area is oriented either perpendicular or parallel to flow. The percent of LWD oriented at an angle (either pointing upstream or downstream) ranged from 7% to 33% of target areas.

3.1.4 Percent Submergence

As discussed above, percent submergence was an attribute added on the first day of the field assessment by consensus of the team members. While this aspect of LWD will vary based on the flow levels of the Kalamazoo River, it was thought useful to have an indication of the submergence of LWD pieces during a perceived normal baseflow of the river. United States Geological Survey Gage Station records for the Kalamazoo River at Marshall, Michigan and Battle Creek, Michigan indicate that the flows of the river during the time of the assessment were within the range of normal baseflow levels for October, based on historic data.

As shown in *Table 8,* the majority of LWD in each target area has a percent submergence (based on flow levels at the time of the assessment) primarily of “Very Low” (0% to 10%) and “Low” (10% to 30%). Very little LWD was recorded as completely submerged.

3.2 Application of LWD Assessment to LWD Design

The LWD Field Assessment results are useful in guiding the prescription of LWD placement on the Kalamazoo River, particularly in respect to the type, number, and location of LWD that should be replaced on the river. From the assessment results, the following general observations are made about the nature and extent of LWD in the Target Areas:

- Complex piles comprise the majority of LWD types in the Target Areas, while logs and trees comprise a smaller percentage, and stumps are nearly absent,

- The majority of LWD is anchored into the bank and immobile, with complex piles having at least one or more pieces anchored into the bank while other pieces may be mobile and “trapped” by the anchored pieces,
- The majority of LWD is either parallel or perpendicular to flow, and
- During normal October baseflow conditions, LWD was primarily 0% to 30% submerged.

An important result of the assessment was the finding that complex piles, and particularly large complex piles, comprise a majority of the LWD type on the river. This fits within the findings of numerous journal articles that have indicated that the LWD is comprised of “Key pieces” which further recruit additional smaller pieces of LWD (see *Section 4.0*).

4.0 LWD DESIGN AND APPLICATION

4.1 LWD Placement General Concepts

The application of LWD in and along channels is an evolving and changing science, with a relatively high degree of uncertainty related to accurately quantifying the physics involved. This information, coupled with the appropriate education and practical experience of LWD installation projects, has all been considered when deriving an applicable approach to LWD placement on the Kalamazoo River. The overall intent of the LWD replacement project is to not necessarily replace the individual number of pieces removed from the exact locations of removal, but to instead focus on restorative efforts to replace function and habitat values that were lost when LWD was removed during response activities. With that in mind, a particular focus has been placed on the restoration of functional herptile habitat.

The primary goals of LWD installations on the Kalamazoo River include:

- Focus the efforts to place LWD within the areas collaboratively acknowledged during the 2015 Field Assessment as having the highest ecological benefit. These areas, identified by the combined Enbridge and MDEQ/MDNR team, are listed below:
  - Mill Ponds – MP 14.25 to approximately MP 15.00,
  - MP 19.25 to Fort Custer Bridge,
  - Approximately MP 32.00 to 35th Street Bridge – utilizing piles of LWD on banks,

- o Delta Powerline Region, and
- o Ceresco Restoration Reach.

- Within the areas specified above, design and place LWD structures with habitat improvement as the primary focus. LWD structures should be applicable to the location and desired benefit (e.g.: pool formation, aquatic and terrestrial habitat improvement).

Design objectives that guide the proposed LWD structure types and locations include:

- The proposed applications are focused on balancing ecological benefit with a desire to provide stable immobile large wood in and along the river without creating a hazard to public safety. Consideration of the public's safety, both during installation and throughout the structures' service life is critical at each proposed installation location.
- Mimic the natural type, size, frequency, and geomorphic location of observed wood on the Kalamazoo River to the extent practical. This approach is well supported by guidance documents and serves the purpose of emulating current conditions.
- Incorporate anchoring systems that, to the extent practical, use natural components, while acknowledging that mechanical anchoring may be required in some instances due to the inherent uncertainty in placing moderately buoyant and high drag objects in flood flows.
- Utilize available wood that was previously removed and stockpiled within the floodplain during response activities, when applicable. There are several locations where the majority of the removed wood is still present and will be replaced back into the Kalamazoo River.

4.2 Design Concepts

The general LWD concepts that guided the overall design are provided in the following discussion.

4.2.1 Key Members, Racked Members, and Pinning

Naturally occurring large wood in and along channels is initiated by the deposition of "key member" logs that alter the local hydraulics and provide a stable base or platform on which shorter, less complex "racked" members are trapped. Racked members are smaller pieces of wood that interlock with the key member and add to the diversity of habitat and hydraulics in a complex pile. Key members tend to be relatively large, usually representing the largest tree boles (trunk or stem) found along the riparian corridor and often initially become lodged by utilizing an intact root wad, large branch structure, or other complex shape that "catches" on the bank or bed of the river. Key members embedded by a single event with heavy sediment loads may remain intact for decades or longer.

4.2.2 Type and Complexity

The current knowledge on large wood in channels supports the concept that features with multiple key members or intact complex branch structures provide the highest habitat quality. Case studies generally agree that a single key log structure, especially those not having an intact root wad within the flow, provides less overall functional uplift. The diversity of microhabitat features (velocity, depth, local substrate, protective cover, interstitial spaces between logs) is far greater than the same number of logs individually in the channel. In addition, it is recommended to match the material type, complexity, geometry, and geomorphic location of naturally occurring LWD in the proposed Target Area to the extent practical.

The Field Assessment of large wood on the Kalamazoo River reveals that approximately 50% of the wood observed was in the form of complex piles, many of which were tree bole-branch matrix piles. Further, approximately 50% of the complex piles observed are "large complex piles", which will be emulated by the Type 2 structure discussed below. Effective habitat improvements will derive from mimicking the observations of the types of wood observed during the field assessment. The design approach proposes to utilize complex piles, in locations that are appropriate hydraulically, geomorphically, and from a habitat perspective.

4.2.3 Stability of the LWD Structure

With respect to bank protection and, perhaps more importantly, the protection of public safety and local infrastructure, the movement of placed wood is undesirable, even in reaches where natural wood may be mobilized. Therefore, correctly sizing the key member logs is critical for structure stability. Successful projects have used many types of anchoring solutions and the design team proposes to use naturally-occurring materials to the extent possible, but recognizes that a minimal amount of artificial material (chain, steel lag screws) may be required at times. A combination of design and anchoring techniques will be employed for both simple and complex LWD piles placed in the Kalamazoo River.

4.2.4 Geomorphic Position

In addition to the primary focus of habitat improvement, the selection of types of LWD to be placed in the Kalamazoo River is based in large part on geomorphic position, not only from a perspective of what naturally occurs but also from the perspectives of energy, velocity, erosion, or depositional location. The placement of the right type of structure for a given location is a key component of achieving the project goals. The typical location for each structure type, as related to these considerations, is discussed in the description for each proposed structure type.

4.2.5 Angle of Departure/ Key Log Angle

The degree of departure from the bank is a primary design metric for many design variations of LWD. The literature from engineered log jam studies in the Pacific Northwest tends to be contradictory to the literature that is focused on log or stone in-channel structures that are focused on flow hydraulics. An example of this would be the Natural Resources Conservation Service, United States Army Corps of Engineers, and many other stream restoration guidance manuals that show log structures (log vanes, log combo vanes, cross vanes, V-weirs) with the logs angled into the current so that the log is buried below the bed or anchored upstream of the tie-in location with the bank. Angling a log upstream directs the flow path or velocity vectors away from the bank. Since logs that are angled downstream would re-direct flows towards the bank, it should only be done with logs at very slight angles of departure from the bank (max 15 degree angle).

4.2.6 Target Loading Rate

The target wood loading rate generally refers to the density of large woody debris that is needed to reach the project goals. The target loading rate on prior projects has been highly variable. However, both the United States Department of Agriculture (USDA, 2007) and Washington Department of Forestry (WDF, 2012) guidance documents indicate that the loading rates in natural systems are highly variable and that practical approaches should mimic the occurrence rate found from reference sites in the vicinity of the project. Several Target Areas observed within the overall project site contained substantial and stable LWD occurrences. Proposed loading rates generally mimic the occurrence of wood in these areas. Another factor is the collaborative observations and recommendations shared by all parties during the Field Assessment noting areas requiring greater ecological need. This is perhaps the biggest factor in selecting the frequency and spacing of LWD that is to be added to the river system. Areas without strong recruitment potential/evidence received preference during the field assessment.

4.2.7 Bioengineering in LWD context

While many of the LWD replacement structures that will be proposed on the Kalamazoo River will be located without the need for prescribed plantings, areas with higher erosion rates and a concern for bank stability may incorporate live stakes to further increase the structural integrity of the structure. Live stakes will be obtained from locally available trees present within the Kalamazoo River Watershed. By placing live stakes within and around a LWD structure, the design can promote bank stability with deep rooted anchoring of soils and the living plant will augment the designed anchoring of the structure.

4.3 Proposed LWD Structure Types

The design concepts discussed herein are variable, and do not prescribe the exact use of which design method will be used in a particular location. The design of LWD structures is site specific and needs to account for habitat, long term stability, risks of mobility, bank protection (or at least not creating erosion), and multiple other factors previously discussed. The specific LWD design types that are presented in this report are “typical engineering details” that have been prepared utilizing the design concepts discussed and based on the known field data. The designs contain variations based on number of key log members and the energy/typical location where it is applicable. The successful installation of the proposed LWD structures will be highly dependent on the experience of the installer and corresponding field engineering judgement provided for each location.

Additional project detail will be provided under separate cover in a “LWD Installation Plan” (LWD Plan) and submitted to the MDEQ for approval. The LWD Plan will provide logistical and site-specific detail for each work location consisting of the following information:

- Overall figures showing proposed structure types and installation locations, equipment access routes, equipment and wood staging areas, identified available wood pile locations where wood will be removed from the banks, and boat access locations. There will be six figures provided at the following river segments: Ceresco

Restoration Reach, Mill Ponds (MP 14.25 - MP 15.00), MP 19.00 – MP 20.10, MP 25.40 L1, and MP 32.00 to Delta Powerline.

- Engineering Details showing the plan view and cross-section views of the proposed LWD structure types. The details will reference the structure location/position to the approximate Ordinary High Water/Bankfull Elevation and will include typical depth placements, anchor and fastening criteria, overall structure dimensions, and angle orientation related to the river bank. Additionally, the details will report proposed cut/fill volumes and embedment dimensions where log burial and bank excavation is performed. The details included in *Attachment B* of this Work Plan are considered general details showing the overall composition and extent of each structure.
- Means and Methods describing the retrieval of stockpiled wood material, including proposed restoration details addressing disturbed ground surfaces/erosion, as required.

This LWD Plan will be jointly prepared between Enbridge and the selected LWD Contractor.

Four proposed LWD structure types have been developed based on a range of observations of habitat needs, the distribution of energy in the river, the dominant erosional processes, and a weak occurrence of micro-pool habitat within the Target Areas. The structure types are organized from least to highest number of key logs, with progressively higher energy resistance somewhat generally related. Single log structures have an array of potential configurations that vary greatly in the ability to withstand and dissipate higher shear stresses (log vane versus habitat toe log for example). Below are descriptions and representative images (see *Attachment B*) for each structure type.

4.3.1 Type 1 – Single Log Structures

The proposed Type 1 structure will be comprised of 1 or 2 key members in varying configurations. This structure is relevant to a wide range of flows, depending on the manner in which it is implemented. For higher energy locations such as some portion of riffle banks and the typical outer meander banks, the structure may be configured as a single or double log vane, ("Type 1A"), angled upstream at approximately 15 degree to 20 degree angle and buried into the bed material. The area between the vane arm and the bank is normally backfilled with bed material/soil underlain by a geotextile fabric, however the proposed structure will utilize a matrix of racking members and bed material as backfill (see *Attachment C, Exhibit 1*). The Type 1A structures are used sparingly in the proposed locations, as Type 1B provides much more substantial herptile habitat and functional improvement.

At locations in lower and moderate energy areas “Type 1B” structures will be used to function more as habitat logs and would primarily be composed of one or two key members, placed parallel or slightly angled (0 degree to 10 degree angle) away from the bank, pointing downstream. Type 1B structures are a good use of whole trees, or just logs as toe-of-bank habitat in areas of low to moderate energy (see *Attachment C, Exhibit 2*). The 1B structure closely mimics a repeated pattern of LWD distribution on the Kalamazoo River and was considered a primary structure to restore the ecological function in the areas of highest need.

4.3.2 Type 2 – Wooden Wing Deflector

These structures will utilize several key log members in conjunction with racking (angled across key members) and pinning members (vertically angled) to make a small wooden deflector structure. This structure is similar to many of the complex piles that are observed on the river. Properly anchored and configured, these structures will promote a pool formation off the apex of the roughly triangular shaped structure (in planform), with racking members and ballasting members (heavier member to add mass) placed to overhang a few feet into base flow to create cover refuge habitat. Alternatively, the interior of the wing deflector can be backfilled with a matrix of racking members, branches, small wood and bed material to assist with ballasting the logs, in a manner similar to toe-wood. Wing deflectors utilizing both wood and stone are useful in promoting pool formation and the narrowing of low flow channels without a loss of flood capacity and they have been used extensively with mixed degrees of success in high energy areas and with greater success in moderate to low energy areas. With proper anchoring or pinning, this structure type will function well on a range of locations with moderate to low energy, as it is a dynamic structure that functions well for a variety of settings and desired outcomes. Type 2 structures have primarily been proposed on those areas where the river channel appears overly-wide. This structure will provide substantial habitat enhancement and promote deposition to help promote a gradual narrowing in overly-wide reaches while providing moderate bank protection. Key logs would be anchored in to the bed and bank versus what is shown in *Attachment C, Exhibit 3* through *Exhibit 6*.

4.3.3 Type 3 – Bar Apex Jam

Bar Apex Jams (BAJ) are a stable, in-channel structures that mimic the natural occurrence of a single key log structure with a root wad present in the Kalamazoo River. Research and application of BAJs have shown them to be stable due to the geometry of the key log member, anchored in deposits and the associated hydraulics of the downstream oriented key log. They are typically characterized by three primary, structural components; a key member parallel to flow, normal members orthogonal to flow and oblique members at 10 degree to 30 degree angle to flow. These structures are naturally found in lower energy environments where deposition has begun and they further promote deposition of bars immediately upstream and adjacent to the rootwad. BAJs promote three important geomorphological features that are important to the quality of terrestrial and aquatic habitat: bars, pools, and potentially terrestrial island formation. These structures will be targeted to low energy, depositional environments such as backwaters and inside bends just downstream of the point bar. Anchoring or ballast will be required to stabilize the structures in place. A buried “dead man” anchor or log below the key member is likely required, along with a chain tether. The application of the design in the field will vary based on specific geomorphic location, applicable anchoring mechanism and the number or racking members. In some cases, the structure will be installed with minimal or no racking members to allow for natural recruitment of mobile wood that would move through the reach without LWD to trap it. An example schematic and natural example of the BAJ structure is shown in *Attachment C, Exhibit 7* and *Exhibit 8*.

4.3.4 Type 4 – Alternate Structure

Type 4 is a proposed alternate structure for the Type 1B habitat logs. It involves the use of a felled riverbank tree (i.e., felled tree refers to live trees that are pushed over with the root mass intact) kept in place along the riverbank to serve as anchoring wood. There are several ecological advantages to this approach. The tree can be felled and left alive, if desirable, promoting long term stability and emulating the occurrence of many of the trees that have fallen into and remained alive with root contact on the erosional banks of the Kalamazoo. These living, horizontal trees are persistent for years or even decades, and are very effective at trapping and holding mobile wood (see *Attachment C, Exhibit 9* through *Exhibit 13*). There is very little information about the biological importance of green wood in river systems, but the presence of living trees overhanging and laying in rivers is frequent on most sites. Prominent guidance documents (WDF, 2012; USDA, 2007) promote the use of the most local wood for mimicking the natural occurrence of species along the river and avoiding disease and pest introduction to the site.

Although this method is intended to be used sparingly, situations where this method may be utilized consist of banks that show evidence of a tendency for wind-thrown trees or a presence of diseased trees. These processes are the dominant mechanism by which LWD enters a river, with erosional processes having been shown as the primary mechanism for large wood recruitment. The felled tree Type 1B structure would not be used on erosional banks, or locations with high frequency of green ash, as these locations are likely to recruit the same wood in the near future and no substantial ecological benefit is obtained.

In literature, the focus has been on dead wood, but as with other ecological processes, emulating the occurrence observed in the reference condition is one of the soundest principles for ecological restoration. The method does not limit future recruitment as the forest gap now allows forest secession and saplings may become canopy trees in 35 years, promoting the cycle of potential tree recruitment in the future at a point in time where erosion, wind throw, or disease may cause recruitment processes to occur.

4.4 Description of Proposed LWD Replacement by Target Area

Potential LWD replacement locations were identified within each of the original 18 Target Areas. The collaborative observations/recommendations provided from the Enbridge/MDEQ/MDNR LWD Field Assessment identified “global” locations within the 18 Target Areas that would most benefit ecologically from replacement of LWD, as well as the greater Mill Pond Area, Ceresco Restoration Reach, and the erosion site located at MP 25.40 L1 which was previously acknowledged during Kalamazoo River Bank Erosion Assessment (KRBEAS), all of which were not considered Target Areas. The LWD Replacement locations present herein, were not selected on the basis of replacing LWD at every potential site observed, but instead to focus on areas that were determined to be optimal for LWD restoration. These sites consist of eight original Target Areas and three additional areas (Ceresco Restoration Reach, MP 25.40 L1, and Mill Ponds) and are discussed below in *Section 4.4.1* through and including *Section 4.4.6*. The LWD observed within the areas selected generally did not appear to provide significant habitat. The installation of LWD would improve the habitat conditions and also likely improve the texture of in-channel features. The site located at MP 25.40 L1 will be targeted for LWD placement to address erosion issues. Of the original 18, those Target Areas not selected generally appeared stable, highly sinuous, and contained pool/riffle presence. Field maps from the Field Assessment are provided in *Figure 2*, showing relative occurrence of LWD, bank stability (i.e., low-moderate-high), and the general consensus of the group.

The following is a narrative description of the LWD design approach for each location selected for LWD replacement. The type of structures proposed are based on the observations from the Field Assessment noting highest ecological need, geomorphic position, and the intended benefits as discussed for each structure type in *Section 4.2*. The overall proposed structure locations are shown in *Figure 3*.

4.4.1 Mill Ponds – MP 14.25 to MP 15.00

The river channel within this Target Area is predominantly overly-wide resulting in a “fining up” of the bed material and the occurrence of intermittent submerged mid-channel sand bar formations. The assessment team noted that this reach has very little natural recruitment potential as compared to most of the other Target Areas that were assessed. The field team agreed that this was a high priority candidate for LWD replacement because LWD would benefit the aquatic habitat improvement and would also promote a gradual narrowing of the channel by promoting deposition of sediment along the banks. Additionally, MDNR field personnel informed the team that this area contained the highest concentration of turtles within the release area. The historic high turtle presence serves as evidence that turtle habitat could be potentially restored if LWD were replaced in this area.

The proposed LWD placement in this reach starts with primarily using the Type 2 structure near MP 14.25, alternating structures on both banks spaced at about 200 feet apart. Type 2 structures will work well in this relatively low sinuosity environment, promoting channel narrowing and affecting the interior sinuosity of flow. At approximately MP 14.60, this approach is altered to the use of Type 1, vane and/or toe log structures, to protect moderately erosional banks and redirect the flows away from the banks. The channel is no longer overly wide due to the mid-channel island and thus the Type 1 structure will work well in this physical setting. At MP 14.75, the island ends and channel regains the overly wide setting, where Type 2 structure become the proposed solutions, as with upstream of the island.

4.4.2 MP 19.00 to MP 20.10

This Target Area has low sinuosity and is relatively wide when compared to sections with greater sinuosity and deeper pools and runs. The bed material is primarily sands and fine gravels. The left bank at MP 19.25 is moderately erosional and could benefit from placement of wood to protect the bank from further erosion. The rest of the banks through the Target Area are predominantly stable. The consensus of the team was that there were occasional areas, primarily on the right bank, where wood should be placed. Since it was later determined that the focus should be on providing substantial and quality habitat on the areas with the greatest need, the proposed LWD is placed in locations that are mapped with a low occurrence of LWD but is not limited to the few locations that were initially mapped for work in this area.

Type 1B structures will predominantly be used in this reach and at locations where it is low in energy (likely to be toe-log/habitat logs). Type 2 structures are interspersed at areas of moderate energy where very little wood was mapped and where the design team believes there is benefit from promoted deposition and pool formation off the apex of the wing deflector. At the time of installation, Type 3 structures may be substituted for Type 1 based on field conditions and applicability.

4.4.3 MP 32.00 to 35th Street Bridge

This reach is initially fairly sinuous down to MP 33.00 and was observed to have substantial wood occurrence intermittently throughout the reach to the 35th Street Bridge. However, there is also moderate to low LWD occurrence throughout locations where LWD was removed and this correlates well with the locations that would benefit the most from wood placement. The consensus was the left bank was generally low on LWD occurrence and LWD replacement locations were mapped (see *Figure 2*). The reach is predominantly stable throughout but does have an erosional bank at MP 32.75 in the outside of a higher stress meander bend. There are stockpiles of removed wood at several locations through this reach. An overarching theme in this reach will be to utilize the stockpiled material for placement back into the river at key locations for functional habitat uplift.

As with the other reaches, the proposed work goes beyond the few locations that were initially mapped by the Field Assessment Team and attempts to restore a contiguous wood occurrence along both banks, connecting areas of weak LWD occurrence to banks with higher LWD occurrence (*Figure 2*). Following the logic of placement that was discussed in

Section 4.2, Type 1A structures (log vanes) are generally located at high energy areas where flow redirection is desired and for lower energy areas Type 1B structures(toe logs) are used. Type 2 structures are targeted again at overly wide locations or locations with moderate energy and a complex pile is thought to be substantially beneficial to habitat. Generally, Type 2 structures are thought to be a beneficial use of the stock piled logs in this reach and will serve to restore similar structure to what was removed. Type 3 structures are located in areas that were noted as already having bar formation, emulating the natural occurrence of Type 3 structures on the river.

4.4.4 Delta Powerline

This portion of the headwaters of Morrow Lake runs along the powerline as a deeper borrow channel. The banks are stable in this location but it is generally lacking in large wood and represents some of the only channel habitat found at the head of the lake. The consensus of the LWD assessment team was that this location would be a good area to place LWD where it will be beneficial to aquatic species and where it can be installed to remain in place. The proposed installation of wood along the powerline is a series of habitat logs consisting of Type 1B structures, spaced evenly along the reach (*Figure 3*). While a lot of the wood came out of the main channel area, the design team has avoided replacing wood in that exact location for two reasons:

1. The poorly consolidated sediments are very likely to have a low shear capacity and a buoyant piece of large wood has a high risk of becoming dislodged and mobilized, potentially creating a hazard to the public and
2. This reach has a high potential for natural recruitment once the river receives a moderate to high flood.

Deltas are natural sediment and debris traps and this region will continue to recruit wood in each high flow in future years, whereas the powerline area will be less likely to receive mobile wood that can be trapped and retained.

4.4.5 Ceresco Restoration Reach

The Ceresco Restoration Reach was not one of the original Target Areas, nor was it assessed during the Field Assessment. However, based on the “global concept” of concentrating efforts within areas that required significant habitat improvement, the Ceresco Reach was selected as a potential work site. The Ceresco Restoration Reach consists of over 2 miles of restored river channel extending upstream of the previous Ceresco Dam, and has been monitored annually by Enbridge. Based on the annual monitoring results, the river channel is relatively stable and functioning as intended. However, the overall reach lacks complexity, texture, and cover within the riffle and glide locations. Because the Ceresco Restoration Reach consists of a drawn-down impoundment, the existing flood plain is essentially void of mature trees and natural recruitment is not anticipated. Therefore habitat logs will be installed within the constructed riffle/glide locations where their presence does not affect the overall stability of the channel. The addition of habitat logs will create refuge for fish, protecting them from overhead predators within the relatively open and expansive restoration area. Additionally, the habitat logs can provide basking locations for reptiles and attachment locations for stray debris floating from wooded areas upstream. Refer to *Figure 3* for the proposed LWD installation locations selected by the Ceresco Restoration Design Engineer.

4.4.6 MP 25.40 L1

This site was previously restored during KRBEAS Monitoring Trip No. 1 and Trip No. 2 using brush wattles and LWD installation. However, due to natural occurrences, the installed structures were washed away or removed otherwise which may increase the risk of bank erosion. The KRBEAS team determined that the potential risk of erosion should be treated through the installation of LWD at this site.

The proposed design concept consists of installing a conventional toe wood structure along the eroded bank. The toe wood will be backfilled with soil and slash fill and restored with coir netting, straw bales, and live stakes. More specific design information such as proposed excavation depths, structure elevations relating to bankfull and baseflow, and restoration details will be provided in the subsequent LWD Plan.

4.4.7 Alternate Locations

In the event that areas within the LWD Replacement locations are not usable due to landowner access constraints or safety-related issues, the following approximate locations are considered “alternate locations” that could be substituted:

- MP 10.00 to MP 11.25,
- Upstream of MP 19.00 continuing within the Linear Park vicinity,
- MP 21.00 to MP 22.00,

- MP 24.00 to MP 24.50, and
- Upstream of the Ceresco Restoration vicinity.

It should be noted that the locations listed above did contain possible work locations; however these overall Target Areas appeared relatively stable and did not contain the lack of habitat as evidenced by the selected LWD replacement locations. Provided alternate locations are required due to access issues, revised figures included in an amended work plan will be prepared to show the type and locations of LWD replacement structures within the proposed alternate locations.

5.0 PROPOSED SCHEDULE

The following approximate schedule is proposed to complete the work.

Large Woody Debris Replacement Work Plan:	Due March 1, 2016
Large Wood Debris Installation Plan:	Submit by June 16, 2016
Access Process/Contractor Procurement:	February to July 2016
Project Execution:	July to October, 2016 (Potentially 2017 as contingency due to weather, access delays)

6.0 REFERENCES

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