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Technical Memorandum

TO: Ralph Dollhopf, United States Environmental Protection Agency

FROM: Andrew Tuthill, Weston Solutions, Inc.

DATE: 7 November 2012

SUBJECT: Enbridge Line 6B Oil Spill in Marshall – Preliminary Winter Conditions Trip Report

At the request of the USEPA, WESTON-START has prepared the following technical memorandum to report the observations and preliminary findings performed by Andrew Tuthill. The purpose of the visit was to advise on ice issues associated with proposed submerged oil containment measures within three impounded submerged oil target areas.

Introduction and Background

Andrew Tuthill, a retired US Army Corps of Engineers-Cold Regions Research Engineering Laboratory ice expert traveled to the Kalamazoo River on Nov. 6-9, 2012 to advise on ice issues associated with oil containment measures proposed for winter of 2012-13 and beyond.

The objective of the trip was to learn about the ice regime of this section of the Kalamazoo River in order to understand ice interaction with submerged oil containment structures proposed for three impoundments within the project area: the Ceresco Dam, the Mill Ponds, and the Morrow Lake Delta (MLD) where the river transitions into Morrow Lake. Because the sediments within these impoundments are known to contain submerged oil, a project objective and command emphasis is to limit downstream migration of this sediment and submerged oil under normal flow conditions as well as high flow events which can occur during the winter months.

In addition to inspections by helicopter and boat of three impoundment areas on Nov. 7, 2012, these preliminary findings are based on an earlier field visit of Dec. 20-21, 2010, following a freeze-up ice accumulation that formed upstream of the Mill Pond on Dec. 12-14, 2010. This event caused field flooding and interrupted cleanup operations in the vicinity of MP 12.75. Other supporting information includes the detailed photo logs of river conditions by WESTON as well as conversations with WESTON personnel and Enbridge contractors working along the river during the past two years. Supporting documents include the WESTON Tech Memo of Oct. 22, 2012 which describes winter containment alternatives, the USEPA Proposed Order to Enbridge dated Oct. 3, 2012 requiring winter containment, and Nov. 2 Enbridge Response to the Order with attachments that specifically address the feasibility of proposed in-stream containment structures.

Ice Formation Processes in the Project Area

The primary ice type in free flowing rivers is frazil ice which forms as small particles in open water sections that drift downstream to form an ice cover. This process is known as dynamic ice cover formation as opposed to in-situ thermal ice growth as occurs on a pond or lake. Thermal ice is typically clear and smooth surfaced, forming at water velocities of less than about 1 ft/s. Photos taken on Dec. 9, 2010 show clear thermal ice in the MLD in the vicinity of the proposed containment structures.

Frazil ice cover type depends on hydraulic conditions at the time of formation (flow velocity, water surface slope, depth, etc.) and channel geometry (bends, islands, obstructions, sediment deposits, etc.). For low gradient areas with relatively low surface water velocities (≤ about 2 ft/s), drifting frazil slush or floes typically accumulate edge-to-edge to form a single-layer ice cover of relatively uniform thickness in a process known as "juxtaposition". By this formation mode, the initial thickness of the upstream progressing ice cover will be similar to that of the arriving floes. Based on the Dec. 2010 photo record, and discussions with field observers, the ice covers in the backwaters of Ceresco Dam and the Mill Pond formed by a combination of thermal ice growth and juxtaposition of frazil floes on the order or 6 inches in thickness. The photo in Attachment 2 of the Enbridge Response also shows a single-layer ice cover composed of juxtaposed frazil floes accumulating at the E4.0 boom that was located downstream of the 35th St. Bridge. Since this type of surface boom was not designed to withstand ice forces, it is not surprising that it broke free from its anchors.

In steeper sections of river with channel velocities in the 2-4 ft/s range, hydraulic forces are sufficient to stack up arriving frazil slush or floes in an ice cover formation process known as "shoving". The ice accumulation that progressed up past MP 12.75 on Dec. 12-14, 2010 attained thicknesses up to 2 ft as a result of this shoving process.

In addition to juxtaposition and shoving, under certain conditions, drifting frazil ice may be entrained beneath an existing ice cover to increase its total thickness. It is not clear to what extent under-ice deposition occurs in the three impoundment areas but, based on existing evidence, it does not appear to be an important factor in the vicinity of the proposed structures.

Finally, in periods of extreme cold (≤10ºF or so), frazil may adhere to the bed of a turbulent reach of river in the form of anchor ice. Once the air temperatures moderate, the anchor ice typically erodes or melts without releasing dynamically. The preliminary review of the photo record found no evidence of anchor ice formation in the project area.

Ice Breakup Processes on in the Project Area

Based on the 2010-11 and 2011-12 winters and limited field observations, ice-out in the project area is relatively benign with much of the ice cover melting in place rather than breaking up and transporting en-mass downstream. Supporting the benign ice-out assumption is the absence of tree scars along the river banks. Review of historic discharges and temperature data will improve understanding of the nature of ice-out in the project area and the probability of dynamic breakup.

Dynamic ice breakups, if they occur, would likely consist of the steeper reaches releasing their ice which would run and jam against the stronger thicker ice on the downstream impoundment areas. The greatest concern would be a dynamic breakup ice run progressing far enough into the impoundment to impact the containment structures.

Preliminary Findings

In the three impoundment areas in the vicinity of the proposed containment structures, a relatively smooth ice cover of uniform thickness ice covers can be expected. Review of historic temperature data and accumulated freezing degree day analysis will provide maximum ice thickness estimates for the impoundment areas. Assuming a maximum ice thickness of about 1 ft, the proposed containment structures, with all components submerged at least 2 ft, will likely avoid damage during the ice formation period.

The HEC-RAS model contains a routine that calculates the thickness of an equilibrium ice cover. HEC-RAS modeling of ice cover thickness for the freezeup and breakup flow ranges will improve confidence in the above assertions of ice cover type and ice thickness in the project area particularly in the locations of the proposed containment structures.

The greatest concern in terms of potential ice damage to the proposed structures relates to ice breakup processes. Two years of ice observations and a lack of field evidence to the contrary (no tree scars) suggest that ice-out in this section of river is relatively benign. The above mentioned analysis of historic discharge and temperature data will improve knowledge on the nature of breakup and allow us to estimate of the probability of dynamic breakups and potential the proposed structures.