ATTACHMENT 78 – *ENBRIDGE LINE 6B INCIDENT CONCEPTUAL SITE MODEL, JULY 8, 2011*

Approved

Enbridge Energy, Limited Partnership
Line 6B Incident, Marshall, Michigan

Conceptual Site Model

Prepared: May 10, 2011

Approved: July 8, 2011

Approved

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LIST OF ACRONYMS

ac-ft	acre-feet
amsl	above mean sea level
AOC	Area of Concern
API	American Petroleum Institute
ATSDR	Agency for Toxic Substances and Disease Registry
cfs	cubic feet per second
CL	Cold Lake Blend
Company	Enbridge Energy, Limited Partnership
CSM	Conceptual Site Model
ft	foot or feet
ft/mi	feet per mile
GIS	geographic information system
KRWC	Kalamazoo River Watershed Council
Line 6B	The pipeline owned by Company that runs just south of Marshall, Michigan
LNAPL	light non-aqueous phase liquid
MDEQ	Michigan Department of Environmental Quality
MDEQ Order	Administrative MDEQ Order And Partial Settlement Agreement entered In the Matter of Enbridge Energy Partners, L.P., and Enbridge Energy, Limited Partnership, proceedings under the Michigan Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, MCL 324.101 et seq. signed November 1, 2010
MDNR	Michigan Department of Natural Resources
mg/kg	milligrams per kilogram (parts per million)
mg/l	milligrams per liter (parts per million)
MP	Mile Post
NAPL	non-aqueous phase liquid
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRDA	natural resource damage assessment
OPA	Oil Pollution Act
PAH	polycyclic aromatic hydrocarbons
Part 201	Part 201 of Michigan's Act 451 of 1994 as amended
redox	reduction oxidation
SCAT	Shoreline Cleanup and Assessment Technique
SOTF	Submerged Oil Task Force
TES	threatened, endangered and sensitive
TPH	Total Petroleum Hydrocarbons
U.S. EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey

VOC	Volatile Organic Compound
WCS	Western Canadian Select
WMU	Western Michigan University

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1.0 Introduction

On July 26, 2010, Enbridge Energy, Limited Partnership ("Company" of Enbridge) discovered a release of crude oil from Line 6B, in the vicinity of its pump station located in Marshall, Michigan. The crude oil was released below grade level via a break in Line 6B, emerged onto the ground surface, flowed over land following the natural topography downhill and into Talmadge Creek, and proceeded to flow downstream into the Kalamazoo River and continue down the river. Crude oil was transported down the Kalamazoo River as far as the delta at Morrow Lake near Kalamazoo, Michigan. The Company shut down the pipeline and immediately initiated response activities to remove free oil as a first action to protect human health and the environment. Initial response activities to remove free crude oil from the surface waters, to protect human health, and to restore the natural systems were performed under orders from the United States Environmental Protection Agency (U.S. EPA).

On November 1, 2010, the Company and the State signed the Administrative Michigan Department of Environmental Quality (MDEQ) Order and Partial Settlement Agreement entered *In the Matter of Enbridge Energy Partners, L.P., and Enbridge Energy, Limited Partnership*, proceedings under the Michigan Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, MCL 324.101 et seq. (MDEQ Order) in which the Company agrees to perform response and restoration activities at and near the location of the release of crude oil in Marshall, Michigan. This report presents the current *Conceptual Site Model* (CSM) that will be refined and updated with acquisition of additional data to support decision- making processes for the Company's continued evaluation of the Spill Area as required in Section 7.2 of the MDEQ Order. A CSM presents an understanding of site known and suspected sources of contamination, the media potentially affected by source impacts, known and potential routes of migration and known or potential human and environmental receptors. The CSM includes the following components identified in the MDEQ Order:

- description of nature and extent of contamination and resource impacts from released crude oil and response activities,
- description of contaminant fate and transport, potential receptors, all human and ecological exposure pathways, uncertainties, and restoration and risk reduction strategies, and
- a schedule for regular submittals of CSM updates.

The CSM provides the foundation for site-related decision making which utilizes available historical and current information to do the following:

- Identify and describe the conditions before the spill occurred, including geomorphologic system, hydrological characteristics, the human and built environment, and the ecological communities present in the system to allow identification of potential receptors and exposure pathways and description of current site (or baseline) conditions,
- Describe the crude oil spill event, and the fate and transport of the spilled crude oil in order to estimate where residual contamination is (or might be) located, including spatial patterns and discontinuities, and what is happening to crude oil-related residuals in terms of fate and migration within the system,
- Describe the response actions undertaken to remove crude oil, mitigate impacts, and restore affected habitats,
- Describe the existing conditions of the system, as initial response activities are nearing completion, and
- Identify uncertainties, important study questions, and data gaps for follow-up evaluation.

Further definition of these items will be incorporated into the work products generated for this project.

The CSM was prepared by AECOM on behalf of the Company with contributions from TetraTech and JFNew. Updates to the CSM will be provided following the schedule in *Section 8*. The Company anticipates working collaboratively with MDEQ on future updates via working group meetings.

Sections 2 through 9 present the input and components of the CSM. The principal study questions for further investigation are included at the end of *Sections 3, 4, 5, 6, and 7*. Principal study questions that are applicable to all areas of the Study Area include the following:

I. Has the nature and extent of crude oil contamination been adequately defined to evaluate all impacts and future risk?
    a. Do non-oiled areas need to be further studied?
    b. Does groundwater contain soluble hazardous constituents that were in the crude oil above residential groundwater criteria under Part 201 of Michigan's Act 451 of 1994, as amended (Part 201)?

c. Does soil contain hazardous constituents that were in the crude oil above residential soil criteria under Part 201?
d. Does surface water contain hazardous constituents that were in the crude oil above Rule 57 non-drinking water criteria?
e. Does sediment contain hazardous constituents that were in the crude oil above risk based sediment criteria under Part 201?

II. Are there sufficient crude oil-related constituents remaining to act as a migration pathway?
III. What is the ultimate fate of the crude oil in the system?
IV. Is the implemented interim habitat restoration appropriate for final restoration?
V. Have site conditions been adequately described to understand pre-spill conditions?
VI. Have human and ecological exposure pathways and receptors been sufficiently identified?
VII. Based on analytical results and the location of observed impacts, are there predicted human health and ecological potential adverse risk that warrant further evaluation?

2.0 Overview of System Information

The crude oil released from Line 6B flowed through a forested scrub/shrub wetland, down Talmadge Creek for approximately 2.2 linear miles to the confluence with the Kalamazoo River (just past Mile Post (MP) 2.00) and flowed down the Kalamazoo River, with crude oil-related residuals reaching as far down the Kalamazoo River as Morrow Lake (MP 37.75) near Kalamazoo, Michigan. This area is defined as the Study Area for this CSM, as shown in *Figure 2-1*. To provide sufficient detail, this CSM will describe separately three main areas associated with the spill: (1) the Source Area (i.e., the upland area where the pipeline break occurred and where the crude oil flowed toward Talmadge Creek), (2) Talmadge Creek, and (3) the Kalamazoo River (including impoundments along the river as well as Morrow Lake). Under each of these sections, information is presented on the following:

- conditions present before the pipeline spill and release,
- conditions resulting from the crude oil release,
- response to the spill event, and
- current conditions within each area including description of human health and ecological receptors.

The outcome of the current CSM as described by the current conditions and receptors will be utilized for guiding the upcoming remedial investigation and remedial alternative evaluation.

Prior to discussing each area, this section provides an overview of information that applies to the entire system, including the following:

- a description of the release,
- a summary of the spill response and interim restoration activities that have taken place to date,
- an overview of the fate and transport of spilled crude oil in this natural system, and
- a description of the regional geographic setting.

Figure 2-2 provides a summary of the system characteristics including morphological and geographic features, fate and transport and receptor identification and the affect or presence of oil in the system.

2.1 Description of the Spill Event

On July 26, 2010, the Company notified the National Response Center that a pipeline release of crude oil had occurred near Marshall, Michigan from Line 6B. The spill occurred from a 30-inch diameter oil pipeline, just west of pipeline milepost 608 in the vicinity of its pump station located in Marshall, Calhoun County, Michigan (N1/2, Section 2, T3S, R6W, Latitude: 42.2395273 Longitude: -84.9662018). The Line 6B release point is located in an undeveloped rural area, south of Marshall, Michigan. The Company estimated that 20,082 barrels (at 25 degrees Celsius and 1 atmosphere) of crude oil was released. The crude oil was released below grade level via a break in Line 6B, emerged onto the ground surface, flowed over land following the natural topography downhill and into Talmadge Creek, and proceeded to flow downstream into the Kalamazoo River and continue down the river. Crude oil was transported down the Kalamazoo River as far as the delta at Morrow Lake near Kalamazoo, Michigan. The Company shut down the pipeline and immediately initiated response activities to remove free oil as a first action to protect human health and the environment.

> ***Crude Oil Classification System according to measured API Gravity***
> ***light crude*** *– API gravity higher than 31.1º API*
> ***medium crude*** *– API gravity between 22.3 and 31.1º API*
> ***heavy crude*** *– API gravity below 22.3 ºAPI*
> ***extra heavy crude*** *– API gravity below 10 ºAPI*
> *The released crude oil had an API gravity of 11*
> If the API gravity is greater than 10, the material is lighter and floats on water; if less than 10, it is heavier and sinks.

Based upon information obtained subsequent to the release and after the pipeline was restarted, it appears that the release may have occurred at or about the time that the latter end of a batch of Western Canadian Select (WCS) crude oil was passing through Marshall, Michigan and a batch of Cold Lake Blend (CL) crude oil had begun. The composition of the crude oil released was approximately 77.5 % CL and 22.5 % WCS. CL is a heavy crude of bitumen and blended with diluents, produced by a number of oil companies and originating from the production field at Cold Lake, Alberta, Canada, which is located approximately 185 miles northeast of Edmonton, Alberta, Canada. WCS is a blend of existing Canadian heavy conventional and bitumen crude oils blended with diluents, produced by various oil companies in Western Canada. The American Petroleum Institute (API) gravity of a sample of the crude oil that was released from pipeline was 11º API. The released crude oil was therefore slightly less dense than water and would be classified as a "heavy crude."

2.1.1 Mile Post Reference System

To provide a consistent reference for activities related to the spill of the crude oil, a reference system was established by the Company for the surface waters. Mile Posts (MP) were established every 0.25 mile of the impacted reaches of Talmadge Creek and the Kalamazoo River starting with MP 0.00 at the point of product entry into Talmadge Creek. The impacted area of Talmadge Creek then extends from MP 0.00 to just past MP 2.00 at the confluence with the Kalamazoo River. The MP system continues downstream in the Kalamazoo River from MP 2.00 on to MP 37.75. Additional MP were established downstream of the Morrow dam but were not impacted and, therefore, are not discussed or referenced in this CSM. MP references are included throughout the text and are shown on most maps of the system for spatial reference purposes.

2.1.2 Rain Event Prior to the Spill Event

Weather conditions prior to and immediately after the spill influenced how the spilled crude oil was transported in the environment. Just prior to the spill event, a significant rain event occurred in Marshall, Michigan and through much of the watershed for the Kalamazoo River basin upstream from the Ceresco Dam. Over the four days from July 22 to July 25, the town of Ceresco reportedly received 5.70 inches of rain (about 5 miles west of the spill) and the town of Albion received 5.65 inches of rain (about 10 miles east of the spill). In other areas of the Kalamazoo River watershed, rainfall was lower than the area where the spill occurred (United States Geological Survey (USGS), 2010 and Michigan State University, 2010). The subsequent increase in water volume within the Kalamazoo River sub-basin from this significant rainfall event (see *Figure 2-3*) influenced how the crude oil behaved within the riverine environment and is discussed further in *Sections 3 to 5*.

2.2 Spill Response and Interim Restoration Actions

During and after the spill, the Company performed response and interim restoration activities to address the impacts from the release. These activities included a rapid mobilization of people and equipment to immediately initiate removal of the crude oil from the environment. Response and interim restoration activities in the Source Area, Talmadge Creek and the Kalamazoo River are discussed in the individual sections of the report on these areas. Response activities performed by the Company are presented in the *Final Report to U.S. EPA* (Enbridge, 2010c) and included, but are not limited to the following:

- Shut-down of pipeline and closures of pipeline isolation valves,
- Installation and operation of flumes (underflow weirs) down gradient of the spill area,
- Installation and operation of oil and water containment and recovery systems,
- Development and implementation of plans for remediation of Source Area [*Source Area Response Plan*] and downstream impacts [*Response Plan for Downstream Impacted Area*],

- Development of a *Sampling and Analysis Plan and Quality Assurance Project Plan* for work under the U.S. EPA Order,
- Sediment and surface water monitoring from the Source Area all of the way down the Kalamazoo River to Lake Michigan,
- Operations and Maintenance of oil control structures,
- Source Area response activities that included the excavation of impacted Source Area soils as documented in the Source Area Response Completion Report, excavation of soils along Talmadge Creek, and development of a qualitative ecological characterization of the Kalamazoo River and Talmadge Creek,
- Downstream excavation of impacted soil,
- Air monitoring and sampling,
- Sampling and analysis of private and public drinking water wells,
- Use of Shoreline Cleanup and Assessment Technique (SCAT) to identify oiled shoreline and floodplain areas and recommend appropriate cleanup treatment methods,
- Characterization and response activities to address submerged oil: identification of submerged oil priority areas and Submerged Oil Task Force (SOTF) actions including dredging at Ceresco Dam and aeration and hydraulic recovery of submerged oil in priority areas,
- Stabilizing and/or restoring Kalamazoo River bank erosion sites where bank erosion is associated with response activities,
- Soil erosion and sedimentation controls along Talmadge Creek,
- Interim restoration of wetlands and upland areas within the floodplain of Talmadge Creek and the Kalamazoo River,
- Seeding and stabilizing restored areas,
- Monitoring soil erosion controls and areas along the creek where interim restoration activities occurred,
- Investigations of groundwater along the Kalamazoo River and of surface soils along the banks of public parks, and
- Investigations of the Source Area under the direction of the MDEQ.

2.3 Summary of Wildlife Recovery Efforts

The Company mobilized Focus Wildlife International, on the day of the release, to the site in order to assist the US Fish and Wildlife Service (USFWS) and MDEQ with recovery of oiled wildlife. Shortly thereafter, the USFWS retained Herpetological Research Management to lead recovery of reptiles and amphibians. On July 30, 2010, the Company also mobilized staff from Stantec to assist with recovery efforts. The Company also retained specialized assistance for specific species such as beaver and mobilized staff from Superior Environmental to set up wildlife deterrents in high quality habitats along the river corridor.

Following initiation of wildlife recovery efforts, the Company requested completion of a Threatened, Endangered, and Sensitive (TES) Species assessment in order to guide recovery of such species if necessary and to assist in mitigating any effects to sensitive species during cleanup activities. Wildlife Recovery staff evaluated the potential for TES species within the spill area and 13 turtles were recovered from three different species:

Collection Date	Intake Number	Species Name	Collection Point	
08/25/10	R0454	Turtle, Blanding's (*Emydoidea blandingii*)	42.31188	-85.36913
09/10/10	R1004	Turtle, Blanding's (*Emydoidea blandingii*)	42.29324	-85.12404
09/12/10	R1140	Turtle, Blanding's (*Emydoidea blandingii*)	42.30197	-85.38124
09/12/10	R1142	Turtle, Blanding's (*Emydoidea blandingii*)	42.31413	-85.36926
09/13/10	R1180	Turtle, Blanding's (*Emydoidea blandingii*)	42.30213	-85.37962
09/13/10	R1205	Turtle, Blanding's (*Emydoidea blandingii*)	42.30885	-85.37109
09/14/10	R1236	Turtle, Blanding's (*Emydoidea blandingii*)	42.30453	-85.37631
09/19/10	R1435	Turtle, Blanding's (*Emydoidea blandingii*)	42.31014	-85.37067
09/30/10	R1972	Turtle, Blanding's (*Emydoidea blandingii*)	42.35167	-85.28110
08/30/10	R0603	Turtle, Eastern Box (*Terrapene carolina caroline*)	42.25714	-84.99578
09/01/10	R0689	Turtle, Eastern Box (*Terrapene carolina caroline*)	42.29900	-85.15800
09/17/10	R1344	Turtle, Eastern Box (*Terrapene carolina caroline*)	42.33060	-85.34467
08/17/10	R0260	Turtle, Spotted (*Clemmys guttata*)	42.25100	-84.98400

Active animal recovery efforts ran from July 29 through October 29, 2010 when the last turtle recovery effort was made. Recovery efforts ceased thereafter due to declining water temperatures and the lack of substantial animal activity. Two turtles disturbed by dredging were subsequently collected in early November, 2010 and 36 turtles have been collected thus far during 2011. Over the course of the wildlife recovery effort, 3160 animals were collected as summarized below in *Table 2-1*.

Table 2-1 Wildlife Recovery Summary Data (as of May 2011)

	Reptiles	Crustaceans	Amphibians	Birds	Mammals	Fish	Total
Animals Collected Un-Oiled	239						239
Oiled Animals Rescued	2546	4	53	171	38		2812
Oiled Animals Found Dead	15	3		25	25	42	109
Rescued Animals Released	2119	2	50	144	23		2338
Rescued Animals Live in Care	371		1 –toad				372
Turtle hatchlings in Care							42

Survival Percentage Rate – 93.3% (109 found dead and 102 died in care)
(Total released (2338) + Animals live in care (372) + Un-oiled released (239) / Total animals collected (3160)

2.4 Natural Resource Damage Assessment Efforts

The Oil Pollution Act of 1990 (OPA), 33 United States Code 2701 et seq., establishes a broad approach for oil spill prevention, preparedness, response, and liability, including the restoration of natural resources and services that may be injured by the discharge of oil or significant threat of a discharge. A major goal of OPA is to make the environment and public “whole” for injury to or loss of natural resources and services resulting from an oil spill. This goal is accomplished by returning injured natural resources and services to the condition that would have existed had the incident not occurred (known as “baseline”) and compensating for the interim loss of natural resources and services from the time of the injury until recovery to baseline condition is complete.

The process used to accomplish these goals is known as a natural resource damage assessment (NRDA). Designated state and federal agencies and recognized Indian tribes known as “trustees” are authorized to seek restoration or recover damages from responsible parties to fund restoration of injured natural resources on behalf of the public. The NRDA process provides a framework to help guide determinations about the amount and types of restoration that are needed based on quantification of any adverse effects to natural resources and services from the discharge, as well as the benefits that will be provided through restoration. OPA encourages trustees and responsible parties to work together cooperatively to reduce transaction costs and avoid litigation; however, the trustees retain final decision-making authority in all matters.

Restoration under OPA is any action or combination of actions used to restore, rehabilitate, replace, or acquire the equivalent of injured natural resources and services. Within the context of NRDA, restoration may take one of two forms: primary restoration or compensatory restoration. Primary restoration is any action that is taken to restore injured natural resources and services to baseline condition at the location of the injury. Primary restoration may include human intervention to accelerate natural recovery or remove conditions that would otherwise impair or delay recovery, or it may consist of natural recovery without human intervention. Removal and replacement of oiled substrate from a recreational area or replanting vegetation killed by oil or removed during cleanup are examples of primary restoration involving human intervention. Compensatory restoration is any action that is taken to compensate the public and the environment for the interim loss of natural resources and services that occurs from the time of the initial injury until recovery of the injured resources and services to baseline condition. Compensation for interim lost services is achieved by providing additional resources and services of the same general type and quality as those that were injured in order to replace or offset the services that were lost or reduced for some period of time.

Immediately following the release, the Company began working cooperatively with federal and state trustees to collect the information and data needed to conduct a NRDA. The trustees for this incident include the MDEQ, Michigan Department of Natural Resources (MDNR), Michigan Attorney General, USFWS, National Oceanic and Atmospheric Administration (NOAA), and the Nottawaseppi Huron Band and Match-E-Be-Nash-She-Wish Band of the Potawatomi Tribe.

A variety of NRDA data collection efforts and field studies have been conducted cooperatively by Enbridge and the Trustees, including the following activities:

- surface water, sediment and tissue sampling,
- shoreline and floodplain oiling assessment,
- macroinvertebrate and fish population surveys,
- vegetation and tree surveys,
- recreational use surveys,
- riverbank erosion surveys, and
- mussel shell assessment.

Some of these data collection efforts have been completed, while others are ongoing and may be repeated in the future to provide information about the recovery of injured natural resources through time. Information and data gained from these studies will be used to guide primary restoration, as well as to quantify interim lost ecological and human use services as a basis for scaling the amount of compensatory restoration needed to offset these losses. In the future, the Company and the Trustees will begin identifying a range of potential restoration alternatives. These options will then be characterized and screened in order to select a preferred restoration alternative, which may consist of a single project or a suite of projects designed to address multiple types of natural resource injuries.

Once identified, the preferred alternative as well as the injury quantification and scaling leading to its selection, will be presented for public comment in a Draft Restoration Plan. After considering comments received from the public, the trustees will publish a Final Restoration Plan, which will form the basis for their claim for natural resource damages. The Company will then have the opportunity to implement the restoration themselves and/or fund the cost of the trustees performing the restoration.

The CSM and NRDA processes are separate and distinct, yet share some commonalities particularly during the injury quantification phase. Moreover, decisions make within each regulatory framework have the potential to positively or negatively influence outcomes of the other. For example, post-cleanup restoration performed as part of response efforts constitutes primary restoration and potentially accelerates the recovery of injured natural resources to baseline condition. Conversely, invasive remediation may lead to collateral impacts to natural resources that exceed probable service reductions associated with the presence of residual contamination alone.

Data collected for NRDA purposes may be relevant to certain aspects of the CSM development process. Where applicable, NRDA data will be incorporated into the CSM to provide information on current conditions and help answer principal study questions. Additionally, the Company will ensure that considerations potentially relevant to NRDA are identified and evaluated from the proper perspectives during development of the CSM and promote and facilitate coordination and data sharing among entities involved in NRDA and response actions.

2.5 Fate and Transport of the Crude Oil

2.5.1 Transport of Crude Oil

The released crude oil was initially transported via flow overland from the break towards Talmadge Creek, the nearby topographic low point; and along the surface water in Talmadge Creek and the Kalamazoo River. The pipeline break occurred beneath a scrub-shrub wetland. The crude oil was forced from the pipeline under pressure into the surrounding soils and emerged onto the ground surface. The released crude oil was slightly less dense than water and flowed over land through the forested scrub shrub wetland area, following the natural topography downhill and into Talmadge Creek. Talmadge Creek was flowing with higher than normal flow due to the recent heavy rains. The crude oil flowed down Talmadge Creek towards the confluence with the Kalamazoo River, and on into the Kalamazoo River. Due to the elevated water level, the crude oil slick affected floodplain areas on both sides of the creek. The crude oil continued downstream along the Kalamazoo River. The river level was high, near its maximum, at the time of the release event and therefore had overflowed its banks in many areas (see *Figure 2-3*). Oil slicks were observed in floodplain areas including the shoreline, banks, and low-lying floodplains. As water levels in the river receded, some crude oil became stranded in hydrologically isolated topographic depressions within the flooded areas.

As discussed in the following section, the crude oil gradually became denser than water, and there may have been emulsified oil driven into the water column at turbulent flows over dam spillways. This material settled in quiescent portions of river channel, becoming submerged oil. Submerged oil was observed as far down river as Morrow Lake (MP 37.75).

Enbridge Experience with Crude Oil Resource Impacts in Bemidji Minnesota

A similar oil release occurred near Bemidji, Minnesota in 1979, spilling approximately 445,000 gallons of crude oil onto glacial outwash deposits. In contrast to the Marshall Line 6B spill, the oil at Bemidji collected in a wetland and topographic depressions where crude oil infiltrated through the unsaturated zone to a lower water table. After cleanup efforts were completed in 1979 to 1980, about 105,000 gallons of crude oil remained in the subsurface. At the Bemidji site, the trapped oil has been extensively studied to evaluate provided information on processes at work.

Subsequent studies of the crude oil source at Bemidji have shown that the oil phase is slowly evolving with time as hydrocarbon components are lost through mass transfer to water and soil gas, and biodegradation. The oil-phase loss of relatively soluble components (e.g., toluene and xylenes) is sensitive to factors controlling dissolution, such as water concentrations and flow rates. Relatively volatile components can be rapidly lost through volatilization. Other constituents are also removed from the crude oil by methanogenic degradation which may be influenced by hydrologic conditions at a site.

Although the geochemical processes have changed over time, the plume has not migrated as far as predicted considering the groundwater flow velocities and sorption constants for the crude oil compounds. Research at this site has demonstrated that biodegradation in anaerobic environments can remove substantial amounts of hydrocarbons from groundwater. Solute-transport modeling indicated that 40 percent of total dissolved organic carbon was degraded through aerobic degradation and 60 percent was degraded through anaerobic degradation.

2.5.2 Weathering of the Crude Oil through Volatilization and Dissolution

Volatile and semivolatile hazardous substances that have been identified through analysis by the MDEQ in the crude oil are presented in *Table 2-2* along with select chemical properties. Most of these compounds have low, but appreciable solubility in water. While the solubilities are low enough for these compounds to be present as a separate oil phase, some of the compounds will partition into water at a level that can be important in this site where the crude oil spread out over the surface water and traveled miles downstream. For example, the solubility of benzene is over 1,000 milligrams per liter (mg/l) (0.1%); the solubility of toluene, ethylbenzene and xylene all exceed 100 mg/l, and the solubility of trimethylbenzenes, cyclohexane, isopropylbenzene, naphthalene, and 2-methyl naphthalene are all over 10 mg/l.

It is predicted that as the crude oil interacted with water and air in the environment, the composition of the crude oil changed. A major change in the crude oil was the preferential removal of compounds that were more soluble in water and volatilization of more volatile constituents. These constituents were transferred to water or air. The ultimate fate of the lighter fractions that dissolved in the surface waters is volatilization from the surface water, which is often followed by natural degradation in the atmosphere. As an example, the primary route for the removal of cyclohexane from the aquatic environment is volatilization (half-life in a model river, 2 hours) [U.S. EPA, 1994]. Once in the atmosphere, cyclohexane degrades by reaction with photochemically produced hydroxyl radicals with an estimated half-life for this type of reaction of 52 hours (U.S. EPA, 1994).

Similarly, the high volatility of benzene is the controlling physical property for environmental transport and partitioning. Benzene released to waterways is subject to volatilization, photo-oxidation, and biodegradation. Benzene reactions with hydroxyl radicals in the atmosphere “limit the atmospheric residence time of benzene to only a few days, and possibly to only a few hours” (Agency for Toxic Substances and Disease Registry [ATSDR], 2007).

Volatilization is also expected to be an important fate for the loss of naphthalene and 2-methylnaphthalene from water. The half-life of naphthalene dissolved in the Rhine River has been measured as 2.3 days (ATSDR, 2005). The vapor pressures, water solubility and Henry's law constants for 2-methylnaphthalene are similar to naphthalene, and it is likely that loss of 2-methylnaphthalene from surface water also occurs by volatilization (ATSDR, 2005).

The organic compounds in *Table 2-2* are also degraded naturally in surface waters and sediments through photolysis and biological processes. The half-life for photolysis of naphthalene in surface water is estimated to be about 71 hours, with a longer half-life in deeper water (5 m) of 550 days. The half-life for photolysis of 2-methylnaphthalene in surface water has been estimated at 54 hours (ATSDR, 2005). Furthermore, naphthalene biodegradation rates are about 8 to 20 times higher in sediment than in the water column above the sediment. The half-life of naphthalene in oil-contaminated sediment is 4.9 hours and over 88 days in uncontaminated sediment, respectively (Herbes & Schwall, 1978 as reported in ATSDR, 2005). 2-Methylnaphthalene biodegrades more slowly, with half-life in sediments reported from 14 to 50 weeks (ATSDR, 2005). Degradation is influenced by factors such as temperature and oxidation-reduction state.

As the volatile organic components preferentially volatilize or dissolve into the surface water, the lighter fraction of the crude oil was removed leaving the crude oil heavier, and more viscous. Some of the crude oil achieved the same density as water or even a slightly greater density than water and sank in the surface water to the top of the sediment. While loss of volatile organic compounds (VOCs) through volatilization and dissolution occurred, some volatiles will remain in the submerged material in the sediments. Structures in Talmadge Creek and the Kalamazoo River, such as dams and flow constrictions, enhanced higher energy turbulent mixing within the surface water column increasing preferential solubilization and volatilization of some components of the crude oil. Further characterization of the constituents that remain in the crude oil after weathering and with distance from the source needs to be considered.

Additionally, cold water temperatures will slow the spread of oil on the surface. At cold temperatures just above freezing, the rate of biodegradation starts to decrease; however, natural attenuation may continue to proceed at low temperatures due to evaporation, depending on factors such as slope, solar radiation, surface wetness, and landform properties (Ferguson et al., 2003; Revill et al., 2007).

2.5.3 Fate and Transport of Crude Oil in Soil and Groundwater

Potential factors influencing the fate and transport of residual crude oil compounds in soil and groundwater broadly depend on the physical, geochemical, and biological properties of the soil and groundwater, and each compound weathers at different rates as discussed in the previous section. The physical properties of the soil that influence the mobility of residual crude oil include the position within the subsurface (i.e., within the unsaturated zone or saturated zone) and soil porosity, including primary porosity, secondary porosity and soil heterogeneities. The geochemistry (mineral composition) of soil provides electron receptors and donors and sorption sites via organic carbon, clay minerals, or electrostatic forces of fine particle sizes and soil pH influences mobility and uptake by vegetation. The microbial populations and their distribution in soil also influence degradation.

Residual oil compounds will be transported primarily by diffusion in the unsaturated zone as soil vapor (volatilization) and by advection and dispersion in the saturated zone as a groundwater plume (dissolution). Coarse-grained soils characteristic throughout the Kalamazoo River basin (Bent, 1971) have high porosity, permitting a greater degree of moisture saturation and mobility compared to fine-grained soils, which inhibit mobility due to lower permeabilities. Volatilization and dissolution of soluble hydrocarbons are anticipated to occur more quickly in coarse-grained soil units because of increased potential for air and water contact and the composition of residual oil is anticipated to be more highly weathered than in fine-grained soil units.

The more soluble, volatile constituents such as benzene, toluene, ethyl benzene and xylenes are degradable through natural biological process in aquifers. The mobility of the lighter organic compounds in the crude are expected to be limited in groundwater through biological degradation.

Exposure to air and water in pore spaces is unlikely to affect the mobility and degradation of larger-ringed hydrocarbons such as polycyclic aromatic hydrocarbons (PAHs) (Garcia Frutos et al., 2007) because of their affinity to adsorb to soil organic matter. Bound PAHs may undergo less sorptive retardation, may be bound to particles too large to pass through pore spaces, and may have lower biodegradation by microorganisms than unbound PAHs (Sorlie et al., 1994). The larger PAHs also have lower solubilities and are preferentially sorbed onto organic matter and exchange sites in the aquifer matrix.

Secondary porosity features caused by burrowing animals and vegetation (e.g., tree roots) provide a pathway for residual oil to enter the soil, though mobility may be limited to the extent of the burrowing. Crude oil in secondary porosity features has greater contact with water and air than oil in the smaller primary porosity features, potentially enhancing residual oil degradation rates in the secondary porosity.

Heterogeneities of primary porosity features in the unsaturated zone such as changes in moisture content and grain size influences residual oil mobility and degradation by affecting the soil's permeability and oxidation-reduction potential (redox). Coarse grained soils with otherwise high permeability may retain crude oil and restrict mobility in the unsaturated zone via low capillary pressure heads. Highly organic soils are common in the vicinity of the source area (NRCS, 2011) and processes operating in these soils are anticipated to be more highly dependent on soil and groundwater geochemistry (organic carbon and redox) than porosity.

The fate and transport of metals contained in the crude oil are expected to be a function of how the metals are bound into the organic molecules in the crude oil and on the geochemical conditions in the soils. The metals are expected to be tightly bound to organic molecules in the crude oil. Once the metals are released to the soil environment, the mobility will be influenced by geochemical conditions in the soil that include pH, oxidation-reduction conditions, the amount of organic matter in the soil, and the cation exchange capacity of the soil. Studies conducted by Iwebeque and others (Iwegbue et al., 2007) on metals speciation from a crude oil spill in Nigeria found that nickel was associated with residuals and iron and manganese oxides. Cadmium, lead, zinc and nickel were the most mobile metals in that system (Iwegbue et al., 2007). Coarser sandy soils in the Study Area typically have low cation exchange capacities whereas highly organic soils such as those adjacent to Talmadge Creek and in many of the wetland areas along the Kalamazoo River have very high cation exchange capacities (NRCS, 2011). The higher cation exchange capacity of the highly organic soils means those soils will tend to adsorb metals and render them immobile. Nickel, if it becomes mobile, is expected to precipitate out or sorb to mineral surfaces such as carbonates and anions will be mobilized at pH values above neutral (Evanko and Dzombak, 1997).

Metals in the soil and groundwater can also be influenced by changes in the oxidation conditions in the aquifer that are brought about through the natural degradation of oil constituents. These processes can reduce the oxidation potential in the aquifer and mobilize metals such as iron.

Other saturated zone factors that influence fate and transport include: position within the groundwater flow system, rates and locations of recharge, physical and chemical mixing, oxidation-reduction potential, microorganism populations, and groundwater quality.

Dissolved oxygen concentrations in groundwater in the Study Area are variable, ranging from 0.13 mg/l (anaerobic) to 10.47 mg/l (aerobic). Redox conditions are typically reducing (SCRIBE database, 2011). The type of anaerobic reduction (i.e., nitrate reducing, manganese reducing, iron reducing, sulfate reducing, or carbon-dioxide reducing) has not yet been evaluated but can be evaluated by assessing oxidized and reduced inorganic compounds or by measuring H2 (see Christensen et al., 2000 and Chappelle et al., 1997 for example). The microbial populations in the saturated zone are also unknown. While the potential for natural attenuation has not been fully accessed, attenuation is expected to occur in the soil and groundwater.

2.6 Regional Geological and Hydrogeological Setting

Talmadge Creek and the Kalamazoo River flow through glacial deposits in Michigan that overlie bedrock at varying depths. The primary bedrock units are Mississippian and include Marshall Sandstone throughout the Kalamazoo River basin in Calhoun County, and Coldwater Shale in portions of Kalamazoo County (Dorr and Eschman, 1970; Western Michigan University (WMU), 1981). Depth to bedrock varies within the Study Area from ground surface to approximately 200 feet below ground surface (approximately 700 to 900 feet above mean sea level [amsl]). Within the Kalamazoo River basin, the bedrock topography ranges from approximately 1,100 feet amsl near the headwaters to 400 feet amsl near Lake Michigan (WMU, 1981). Erosional terraces of

Table 2-2. Properties of Constituents in the Curde Oil

	MDNRE Sample 1	MDNRE Sample 2	Chemical Abstract Service Number (CAS#)	Log Octanol-Water Partition Coefficient (Log Kow)	Boiling Point	Vapor pressure	Henry's Law Constant at 25°C (HLC)	Water Solubility (S)	Soil Organic Carbon-Water Partition Coefficients (Koc)	Molecular Weight (MW)
units	mg/kg	mg/kg		unitless	oF	mmHG	atm-m^3/mol	ug/L	L/Kg	g/mol
Volatile Organic Compounds (VOCs)										
Benzene	910	1100	71-43-2 b	2.13 a	176 b	75 b	0.00555 a	1,750,000 a	58 a	78 a
Ethylbenzene	220	260	100-41-4 b	3.14 a	277 b	7 b	0.00788 a	169,000 a	367 a	106 a
Xylenes (total)	1410	1650	mixture	3.11 a	281 - 292 b	7 to 9 b	0.00604 a	186,000 a	348 a	106 a
Toluene	1700	2000	108-88-3 b	2.75 a	232	21	0.00664 a	526,000 a	180 a	92 a
1,2,3-Trimethylbenzene	44	58	526-73-8 b		349 b	1 @ 62°F b				120 b
1,2,4-Trimethylbenzene	340	410	95-63-6 b	3.67 a	337 b	1 @56°F b	0.00587 a	55,890 a	965 a	120 a
1,3,5-Trimethylbenzene	170	190	108-67-8 b	3.5 a	328 b	2 b	0.00738 a	61,150 a	708 a	120 a
Cyclohexane	1900	2200	110-82-7 b	3.44 e	177 b	78 b	0.195 eC	55,000 eC	482 eC	84 b
Isopropylbenzene	51	57	98-82-8 b	3.6 a	306 b	8 b	0.015 a	56,000 a	3,460 a	122 a
n-Propylbenzene	91	100	103-65-1 a	3.69 a			NA a	NA a	4,240 a	120 a
p-Isopropyl toluene	35	40	99-87-6							
Sec-Butylbenzene	33	35	135-98-8 a	4.57 a			NA a	NA a	31,100 a	134 a
Semivolatile Organics (SVOCs)										
2-Methylnaphthlane	130	150	91-57-6 c	3.9 a	241 c	0.068 c	0.000499 a	24,600 a	6,820 a	142 a
Naphthalene	63	72	91-20-3 c	3.36 a	218 c	0.087 c	0.000483 a	31,000 a	2,010 a	128 a
Phenanthrene	82	86	85-01-8 d	4.6 a	340 d	0.00068 d	0.000023 a	1,000 a	33,300 a	178 a

Table 2-2. Properties of Constituents in the Curde Oil

	MDNRE Sample 1	MDNRE Sample 2	Chemical Abstract Service Number (CAS#)	Log Octanol-Water Partition Coefficient (Log Kow)	Boiling Point	Vapor pressure	Henry's Law Constant at 25^{0}C (HLC)	Water Solubility (S)	Soil Organic Carbon-Water Partition Coefficients (Koc)	Molecular Weight (MW)
units	mg/kg	mg/kg		unitless	oF	mmHG	atm-m^3/mol	ug/L	L/Kg	g/mol
Metals										
Beryllium	0.4	0.8	Form of metal not specified							9 a
Iron	30	7.7	Form of metal not specified							56 a
Mercury	0.0003	0.0003	Form of metal not specified							201 a
Molybdenum	ND	9.3	Form of metal not specified							96 a
Nickel	59	67	Form of metal not specified							59 a
Titanium	2.8	3.2	Form of metal not specified							48
Vanadium	130	140	Form of metal not specified							51 a

a MDEQ, 2006a.
b NIOSH, 2005.
c ATSDR, 2005.
d ATSDR, 1995.
e US EPA, 1994. eC = calculated

NA Data are not available for this parameter
NR Parameter or property is not relevant for this compound

Marshall Sandstone outcrop at various locations along the Kalamazoo River, including at Ceresco Dam. The bedrock units have a slight dip to the northeast (Vanlier, 1966).

> *On November 8, 2010, Calhoun County Department of Public Health removed a three-month drinking water well water advisory for those living within 300 feet of the river. The advisory was issued July 29, 2010.*
>
> *"We're just satisfied that to date, the groundwater supplies haven't been impacted as a result of the oil spill," said Health Officer Jim Rutherford. "We're satisfied that currently all the wells are free of any contaminants."*
>
> *The decision affected about 200 households within the 300 feet of the river, Rutherford said.*

Overlying the bedrock are an assortment of glacial outwash sands, coarse end-moraine deposits (sands and gravel), fine end-moraine deposits, ice contact material (sorted sands and gravel), clayey till, lake plain deposits, and post-glacial and modern alluvium. The Kalamazoo River basin is dominated by well-drained outwash, coarse end-moraine deposits and ice contact deposits, which have higher groundwater yields compared to basins with less permeable deposits (Bent, 1971). In these well-drained soils, a large amount of precipitation and snow-melt percolates to the groundwater and the groundwater flows to the Kalamazoo River, associated tributaries such as Talmadge Creek and sub-basin wetlands (Wesley, 2005). Slug test data collected during the Hydrogeological Assessment measured hydraulic conductivities ranging from approximately 12 feet/day in the finer silt and sand intervals to over 300 feet/day in the fractured sandstone bedrock. These values are within the range of published values for the encountered soils and bedrock (AECOM, 2010).

Groundwater is used as a source of drinking water in the rural areas along Talmadge Creek and the Kalamazoo River. The groundwater is generally of good quality, though naturally occurring metals are locally present and may in some instances exceed aesthetic and health-based drinking water criteria (e.g., iron and arsenic) (AECOM, 2010). In addition, known and unknown sites of environmental impact were present prior to the spill along the Kalamazoo River, which may have locally impacted groundwater with hazardous constituents such as chlorinated solvents and also gasoline and oil-related constituents (AECOM, 2010).

The Kalamazoo River is the major drainage for this area and groundwater is expected to discharge into the river during most periods. Two expected exceptions are localized groundwater flow at dams and tight bends in the river (AECOM, 2010). At dams in the river where there is a significant and rapid drop in the elevation of the surface water body, groundwater locally flows out of the river at the higher surface water elevation above the dam, parallels the river, and then flows back into the river at the lower surface water elevation below the dam. This observation has been confirmed at Ceresco Dam during six rounds of groundwater elevation measurements (AECOM, 2010). Based on groundwater elevation data collected during the Hydrogeological Evaluation and Overbank Remedial Investigations, at tight bends in the river, shallow groundwater parallels the general flow of the river, flowing across the tight bend, and then flowing back into the river downstream of the bend. On straighter reaches of the river, groundwater flows sub-parallel to the river before discharging into the river.

The longitudinal profiles of Talmadge Creek and the Kalamazoo River were constructed to assess the erosional and depositional potential along the lengths of the water bodies. The profiles were constructed using ground surface contour (LiDar) data in Calhoun County and USGS 10-meter resolution digital elevation models in Kalamazoo County, stream lengths measured in geographic information system (GIS), and manual poling of water depths and surface water elevation surveys conducted by Tetra-Tech EC, Inc. in the channel thalweg. Poling data were collected at approximate 150-foot (ft) intervals. Water depths in Morrow Lake were sufficient for bathymetric survey data to be collected instead of by manual poling. Longitudinal profiles were constructed for the both left and right banks of Talmadge Creek because the bank stations were not well aligned. The profiles are included in *Appendix A-1*. Talmadge Creek flows through culverts under several roads between the Source Area and the confluence with the Kalamazoo River. The longest culvert, which is beneath 16 Mile Road and U.S. Interstate 69, is over 300 feet long, which is coincident to a transition from an upgradient depositional regime to a downgradient erosional regime (see *Appendix A-1*). Stream gradients range from 14.2 to 15.1 feet per mile (ft/mi) upstream of the culvert to 21.2 to 26.1 ft/mi downstream of the culvert.

2.7 Residual Oil

It is expected that there will be limited areas of remaining residual oil contamination following site response activities approved by U.S. EPA to remove free oil on the ground surface. For residual crude oil, human health impacts will be evaluated and potential ecological impacts that may include adverse aesthetic impacts. Residual crude oil will weather with time. The weathering process and rate will depend upon the location of the residual oil. Residual oils exposed to the atmosphere, such as tree rings and tarred stains, will have lost most of the soluble components early after the spill and will continue to oxidize if exposed to sunlight. Residual crude oil in sediments or saturated conditions will also weather with soluble and more biologically degradable constituents preferentially weathering out of the residual.

The potential for residual oil in creek bank soil and sediment to cause sheen on surface water has been routinely monitored and documented during U.S. EPA response activities. The documentation process for sheen and submerged oil observations is summarized in *Insert 2-1*.

The main components of the assessment and documentation process are environmental inspections, fly-over observations, and observations made during containment operations/maintenance and routine monitoring.

Approved

Insert 2-1 Initial Response Activities Documentation of Sheen and Submerged Oil

Enbridge

Operations and Planning

Operations-Environmental Inspections

- ❑EI inspectors document presence/absence of oil/sheen at O&M sites on inspection forms. EPA representatives accompany EI inspector. All parties meet and discuss findings at least daily.
- ❑Other field notes (e.g. site visited, sheen not observed) also noted. Photo-documentation varies by site.
- ❑Inspection form notes rolled up into Daily O&M Tracking Table. Current observations tracked in bold red text.
- ❑Sites investigated minimum once per week. Inspections continue for minimum of 3 consecutive weeks without sheen.
- ❑After 3 weeks w/o sheen, site recommended for closure and sign-off process initiates. Sites since October remain on tracking table until after spring thaw inspections confirm absence of sheen.
- ❑Daily tracking table documentation stored on site. This is a formal EPA close out/sign off process. "Closure Reports" remove the O&M Site from the list of EPA sites.

Operations - Containment

- ❑Containment operations notes observations of sheen/oil at control points, depositional areas, the Morrow Lake delta, downstream of Morrow Lake dam, and at in-channel sediment snares.
- ❑Depositional areas are assessed for the potential of reimpact by observing spontaneous sheen and sheen generated by poling/agitation. Delta is observed (upon lake access) every 2-3 days. Booms at control points are observed during weekly maintenance.
- ❑Notes and documentation includes:
  - Waste quantities.
  - Degree of impact, or lack of, on sediment snares
  - Estimated percent sheen/submerged oil (spontaneously and upon agitation).
  - Stream stage.

Operations-Fly-overs

- ❑Geospatially referenced photographs are taken from the source area to Morrow Lake three times per week or as needed. Frequency may increase to daily during runoff events (e.g. spring thaw).
- ❑Photographs are date-time stamped and stored electronically on-site.
- ❑Select photographs are presented in the daily 0900 Command & General Staff Meeting and the weekly MAC meeting.
- ❑Observations of sheen are noted and the O&M/Operations team is alerted for inspection/assessment.

Environment-Monitoring

Routine Surface Water and Sediment Monitoring

- ❑Surface water quality is monitored at twenty-one locations (access permitting) weekly and sediment quality is monitored at nine locations biweekly.
- ❑Presence/absence of sheen in sample matrix is recorded in field notebook.
- ❑Analytical results are reported to the USEPA SCRIBE database and compared to Part 31 criteria.

Routine Groundwater Monitoring

- ❑To be initiated.

Agencies

US EPA Fly-overs

- ❑Photographs are routinely taken sequentially from the source area to Morrow Lake.
- ❑Photographs are date-time stamped.
- ❑Select photographs are shared on US EPA's website.

US EPA Start Contractor Environmental Inspections

- ❑Photographs are routinely taken at O&M sites during inspections.
- ❑Land-based photographs are taken by reoccupying same spot at inspection sites.
- ❑Photographs are organized, cataloged, and captioned.

NOTE: Not all activities are ongoing.

2.8 Environmental Stressors Not Associated with Crude Oil Related Chemicals

"Stressors" are physical, chemical or biological entities that can induce an adverse response (U.S. EPA, 1997). Non-chemical stressors are environmental stressors present throughout the Study Area of the crude oil release that are relevant to the ecological evaluation and response activities but not associated with crude oil related chemical constituents. Remediation and interim restoration must consider the integrated manner in which stressors interact and their potential to degrade the quality of the habitat and limit recovery or restoration. Some non-chemical stressors are directly related to remediation and restoration efforts while others are indirectly related or not related to these efforts. Non-chemical stressors may be physical or biological. An example of a spill related stressor is a limited fish kill downstream of the Study Area due to a lowering of Lake Allegan water levels as an emergency response measure (MDNR, 2010).

Physical stressors that may influence the remediation and restoration may include the following:

- Substrate (e.g., grain size distribution, organic content, etc.) limitations strongly influence the species, numbers and diversity of benthic macro-invertebrates that can colonize and persist in river and creek sediments (particularly around urban areas and in impounded water behind dams).
- Hydrologic alterations such as buildings and transportation facilities can increase impervious surfaces and alter the drainage and therefore the natural flow of a river. (For example, increased run-off in urban areas such as Battle Creek and also channelized from with stabilized banks [such as from MP 15.8 to MP 16.5 and from MP 16.5 to MP 18] can lead to hydrologic modification).
- Pre-existing and new structures, such as culverts, will alter the hydrology of the creek and river.
- Culverts, dams, and flumes can affect movement of fish and other aquatic organisms. (The Study Area includes three dams: Ceresco Dam near MP 5.8; Mill Pond Dam near MP 15.7; and the Morrow Lake Dam near MP 39.8).
- Mat roads and heavy equipment may result in trampling of vegetation and soil compaction, affecting habitat recovery;
- Raking, vegetation cutting, dredging and excavation of river and adjacent areas potentially remove plants and destabilize shorelines;

- Removal of oiled woody debris may affect habitat availability and result in modified hydrodynamics;
- Soil erosion and sedimentation resulting from response activities (including activities that use boats and airboats) may adversely affect banks by increasing erosion, and may in-stream water and benthic habitat quality through increased suspended solids transport.
- Sediment aeration and dredging may temporarily affect sediment and habitat quality for benthic organisms.

Biological stressors that may influence remediation and restoration may include:

- Invasive species may affect wetland restoration and restoration of other disturbed areas (e.g., laydown areas). Notable invasive species in the Study Area are reed canary grass, purple loosestrife, *Phragmites* and glossy buckthorn. Imported soils may also contain seeds, roots or rhizomes of invasive species. Invasive species may preferentially colonize areas cleared of vegetation by cutting or excavation.
- Aquatic invasive species, which could have been transported into the area during emergency response activities (i.e., via the boats and equipment mobilized from other parts of the country), may affect restoration.
- Diseases and disease vectors may affect wetland restoration and re-vegetation efforts (e.g., disease carried by the emerald ash borer is stressing and killing ash trees in the area);
- National Pollutant Discharge Elimination System (NPDES) permitted discharges which may add chemical and thermal loads to the river;
- Non-point source pollutants consisting of sediments, nutrients, bacteria, organic chemicals, or metals may be introduced from sources such as agricultural fields, surface runoff from construction sites, parking lots, urban streets, uncontrolled septic seepage, groundwater contamination and industrial sites (Wesley, 2005).
- Re-vegetation, if not conducted properly (i.e., correct soil preparation, species mix, and fertilization procedures) may adversely affect the ability of natural plant communities to reemerge in impacted areas; however, if properly conducted it may have beneficial effects.
- Grazing and browsing by deer and rabbits may delay or prevent the growth and establishment of new shrubs and trees.

Other sources of environmental stressors to the river system, which are not associated with the crude oil release, include releases and impacts resulting from sites regulated under Part 201 (AECOM, 2010) in the watershed and from NPDES permitted discharges that can affect human health and the environment. The impacts on the river system from other sources include the following:

- chemical impacts (i.e., hazardous substances in releases, including PAHs, volatile organic compounds, and potentially limited metals),
- biological impacts (e.g., increased oxygen demand, eutrophication, and pathogens [viral and/or bacterial] from discharges), and
- physical impacts (e.g., temperature extremes in cooling water).

2.9 Principal Study Questions

I. Has the nature and extent of crude oil contamination been adequately defined to evaluate all impacts and future risk?
   a. Do non-oiled areas need to be further studied?
   b. Is it reasonable to focus investigation in areas where (past and/or current) presence of crude oil was/ is present per the MDEQ Order?
   c. Does groundwater contain soluble hazardous constituents that were in the crude oil above residential groundwater criteria under Part 201?
   d. Does soil contain hazardous constituents that were in the crude oil above residential soil criteria under Part 201?
   e. Does surface water contain hazardous constituents that were in the crude oil above Rule 57 non-drinking water criteria?
   f. Does sediment contain hazardous constituents that were in the crude oil above risk based sediment criteria under Part 201?

II. Are there sufficient crude oil-related constituents remaining to act as a migration pathway?
   a. What site-specific analytical data may be needed to support assumptions on fate and transport of crude oil?

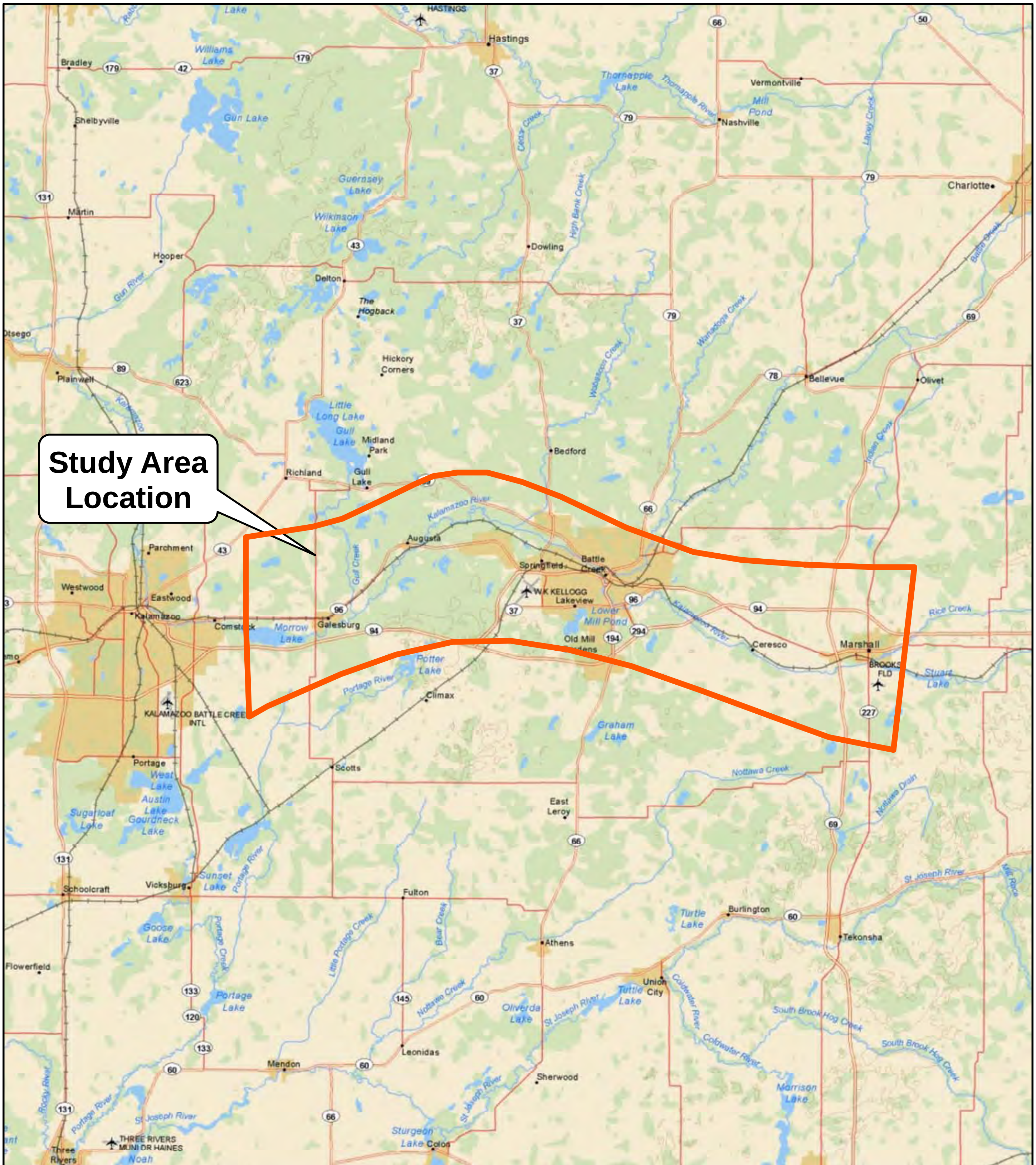
III. What is the ultimate fate of the crude oil in the system?
   a. How has weathering of the crude oil changed the composition of the chemicals detected, and how will weathering continue to change the composition of the residual crude oil?

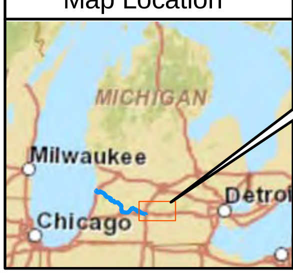
   b. What does analytical testing of the product indicate for the chemical constituents (toxicity), the mobility of constituents in the product (fate and transport) and its ability to act as a source to other media?

IV. Is the implemented interim habitat restoration appropriate for final restoration?

V. Have site conditions been adequately described to understand pre-spill conditions?

   a. How environmental stressors are best monitored or evaluated; how are response-related stressors best controlled?
   b. Did increased boat traffic cause riverbank erosion?
   c. Is there evidence of exotic species or pathogens such as biological or viral stressors that could have been introduced via equipment and boats brought in from other regions?
   d. Evaluate how the crude oil release and response efforts may have exacerbated pre-existing environmental stressors within the Spill Area.
   e. Are oil rings and stains a permanent or temporary issue and/or an aesthetic issue?





Map Location

0 2 4 8
Miles

N

KALAMAZOO RIVER
CONCEPTUAL SITE MODEL
STUDY AREA LOCATION MAP

ENBRIDGE LINE 6B M608
PIPELINE RELEASE
MARSHALL, MI

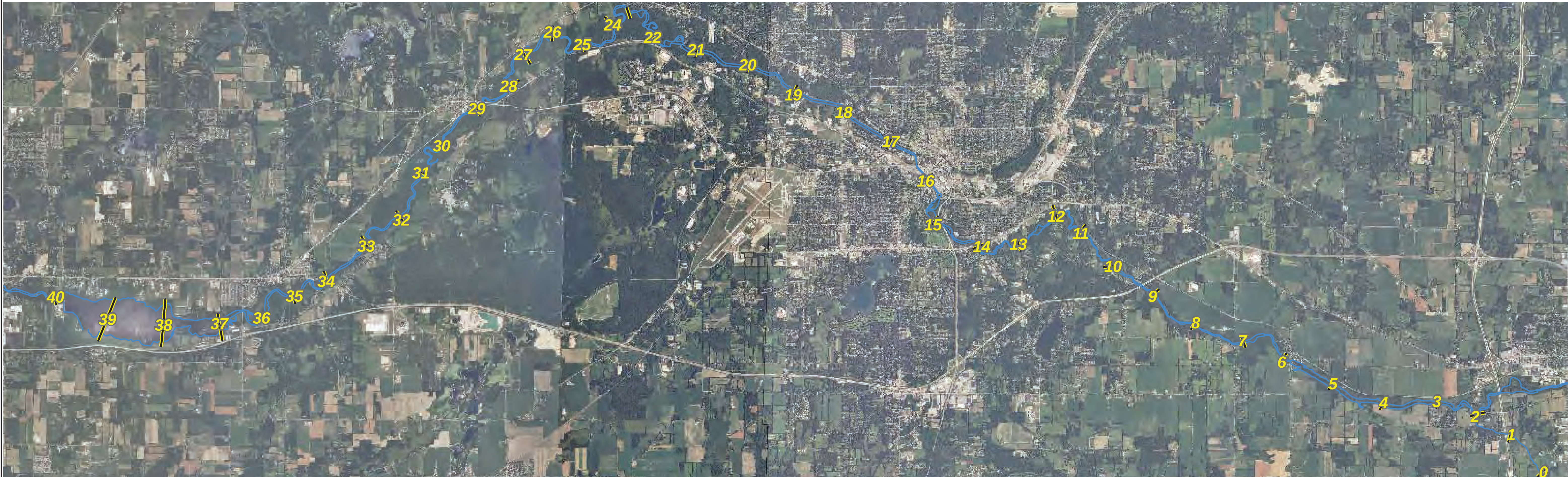
ENBRIDGE

AECOM

Map Name:
CSM_SiteMap.mxd

November 2010

Figure 2-1



Mile Post	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Morphological and Geographic Features																																									
Geographic Unit		Morrow Lake			Mill Creek Dam to Morrow Lake																				CD to Mill Creek Dam										CD pool		TC to Ceresco Imp.			TC	
Functional Unit	Impounded				High sinuosity																	Anth./low sin.		Cha.	Imp.	low sin.	High sinuosity					Low sinuosity			Imp.		Low sinuosity			Creek	
MDNRE Valley Segment	1072				347																			3043	3042	3041									3040		3039			1092	
Slope	Flat				Low																Medium-low				Flat	Medium-low									Flat		Medium-low				
Stream bed		Silt			Silt, sand, some clay. Silty backwaters.																Sand,gravel			(1)	Silt	Silt, sand, gravel						Sand to cobble			Silt		Sand to cobble			Silt/Gr.	
Sinuosity	N.A.				High																Low			None	N.A.	Medium to high						Low			N.A.		Low			Medium	
Bank material					Alluvial silt with clay and sand. Limited gravel and cobble.																Armored					Alluvial silt over cobble/gravel														Silt	
Overbank Flow					Low (riverstage during event not as high)																None					Medium to high						Low to medium					Low to medium			High	
Fate and Transport																																									
Sediment sinks				Heavy	Yes. Backwaters and eddies.																Few or none			None	Heavy	Yes. Some backwaters.						Few			Heavy		Few			Few	
Aeration/evaporation at dams																									Yes										yes						
Original Floating Oil		Limited oil slicks on surface - overbank flow stranding low or absent																							Oil slicks		Extensive oil slicks on surface - discontinuous overbank stranding in flooded areas														
Submerged Oil	Submerged oil (sinking of heavier fractions, emulsification at dams) transport and deposition in quiescent areas/backwaters																																								
Receptors																																									
Human Health																																									
Shoreline land use		Ag/P/Ud		S/R		A/P		S/R		Ag/P/Ud			Ub	Ag/P/Ud			S/R	Ub(R+C/I)			Ub(C/I)		Ub (R + C/I)				Ag/P/U					S/R	A/P	S/R	Ub	Ag/P		S/R			
Water wells within 200 feet of river																																									
Fishing		Fishing and fish consumption may occur throughout Kalamazoo River																																						No	
Recreation		River recreation likely																			Minimal in-water recreation					River recreation likely														Minimal	
Ecological Impacts																																									
Main stream community		Lake-like			River-like: sinuous conditions with numerous backwaters																Limited			None	LL	River-like: sinuous conditions						River-like			Lake-like		River-like			Creek	
Overbank riparian/wetland community		Little or none			Very infrequent affected areas																No affected areas					Frequent affected areas						Infrequent affected areas								Frequent	
Impacted wetlands or fens		No	Yes (delta)		Less extensive flooding: impacts limited to backwater fringing wetlands																No					Yes						Few areas present								Yes	

ENBRIDGE

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Land Use

Ag: agricultural
P: parkland
R: residential
CD: Ceresco Dam
TC: Talmadge Creek
Imp.: Impoundment
C/I: commercial / industrial
Ud: undeveloped
S: suburban
Ub: urban

Other Modifiers

(1): Channelized in concrete ditch
Anth: Anthropogenic
Sin.: Sinuosity
Cha.: Channelized
Gr.: Gravel
N.A.: Not Available
LL - Lake-like

Summary of System Characteristics

ENBRIDGE LINE 6B RELEASE

N

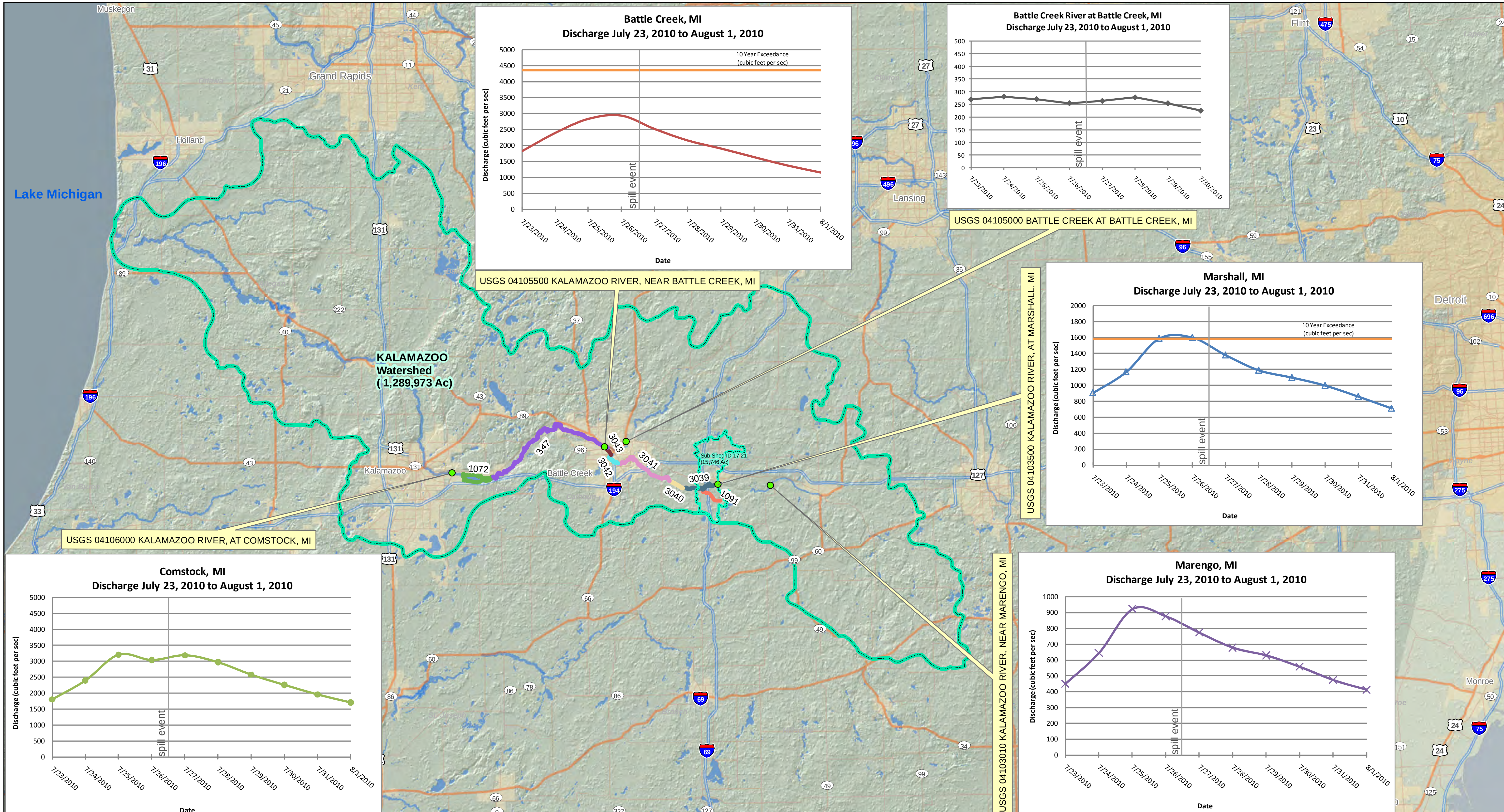
0 0.5 1 2 3 4

Miles

Figure 2-2

Date: Nov. 30, 2010
Revised: March 2011

Bjorn Bjorkman
Colin Plank



AECOM

This information is for reference only. Data Source: Michigan CGI Library, Valley Segment data published in 2004-03-20, by Michigan Department of Natural Resources. USDA NAIP aerial image acquired 2010.

Legend

Valley Segment

347, 1072, 1091, 3039, 3040, 3041, 3042, 3043

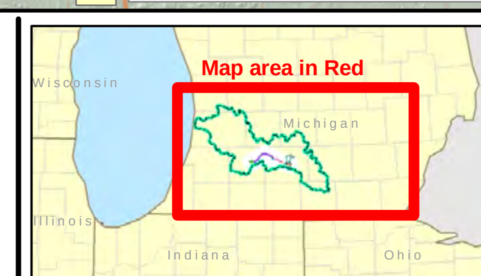
USGS Gauge

Watershed

Lakes

Kalamazoo River Watershed and Rain Event Hydrographs

ENBRIDGE LINE 6B RELEASE



0 5 10 Miles

1 inch equals 10 miles

Figure 2-3

Date: Nov 29, 2010

Approved: Staci Goetz

Drawn: ATV

3.0 Source Area

3.1 Pre-Spill Condition in the Source Area

The release from Line 6B occurred in an undeveloped rural area, south of Marshall, Michigan which is adjacent to developed properties used for private residences and light industry. The habitat in the Source Area where the crude oil came to the surface and flowed to Talmadge Creek was a mixture of scrub-shrub and forested wetland. Adjacent areas were mostly deciduous forested upland. The area was not frequently visited by local residents or recreational users, and no residences are present within 300 feet of the source area.

3.2 Release Event

During the release, crude oil impacted the surface and subsurface soils near the pipeline and then flowed overland for about 600 feet to Talmadge Creek. These soils were saturated with water as a result of the recent rains, so the crude oil generally stayed near the top of the soil column between the point of the release and Talmadge Creek and did not penetrate deeply into the ground. The crude oil followed a preferential path defined by local micro-topography overland through the wetland, and did not affect the upland woodlands. Acute ecological exposure may have occurred for vegetation and biota in the affected wetland areas, and any wildlife that may have come into contact with the crude oil. Residual exposure may exist from any residual crude oil related constituents still present in the subsurface of the wet meadows.

3.3 Response Actions in the Source Area

Upon discovery of the release, the Company shut the pipeline off and immediately initiated the removal of crude oil from the Source Area. The objectives of response actions in the Source Area were to remove crude oil and impacted soils and vegetation that could potentially threaten navigable waterways and wildlife (see Stream and Floodplain Restoration Plans – JFNew, 2010a, b, and c). Response actions in the Source Area near Talmadge Creek include the following:

- Shut down of pumping in Line 6B and isolation of the leak,
- Repair of Line 6B,
- Evacuation of Local residents,
- Installation of a sheet pile trench box around the release site to allow pipeline repairs,
- Installation of temporary collection trenches and berms for recovery and containment of crude oil to prevent the flow of crude oil to Talmadge Creek,

- Installation and placement of mat roads for access to Talmadge Creek for workers and heavy equipment,
- Recovery of crude oil,
- Site clearing and grubbing of trees and vegetation to allow completion of free-phase crude oil removal,
- Performance of air monitoring,
- Generation of laydown areas for equipment and wastes, and eventual restoration of these laydown areas (see *Section 6*),
- Removal of soil impacted by crude oil, staging and bulking for disposal,
- Backfill of excavated area with organic rich soils to support interim wetland restoration (see *Insert 3-1*),
- Placement of berms after backfill as a precautionary measure to inhibit the flow of any sheen; later removal of the berms when no sheen was being captured,
- Removal and interim restoration of mat roads and operational areas,
- Seeding of entire area with a mixture of native emergent and scrub-shrub wetland plant species and oats and annual rye, and
- Storm water management and erosion control.

Insert 3-1 Source Area after re-grading with clean organic soils

Looking west down the pipeline. Note presence of berm extending across Source Area grading in center of picture. Source: U.S. EPA Website. http://www.epa.gov/enbridgespill/photos.html

3.4 Current Conditions in the Source Area

Soils were replaced in the excavated areas in the Source Area following the removal of crude oil impact. Groundwater has saturated the soils in the footprint of the wetland area, and water or moist soils are present at the ground surface in the low areas with some shallow water present at the ground surface in areas. Oil sheens are not observed in source area soils, on the surface of the ground, or on the shallow water present on the ground surface.

Groundwater flow near Talmadge Creek is expected to be toward the creek with a regional flow toward the Kalamazoo River.

An investigation was completed in the Source Area to document the presence or absence of any crude oil related constituents in the soils extending below the water table (in native and backfilled areas). Field screening techniques were used to identify crude oil in the field during the investigation.

Visible oil and visually impacted soil were removed during initial response activities. Groundwater monitoring wells and soil borings were installed and sampled in the Source Area under the supervision of the MDEQ to document the direction of groundwater flow and the groundwater quality. Concentrations of all volatile and semi-volatile analytes in groundwater samples from these wells were less than detection limits in the initial samples collected on October 28, 2010. However, it is possible there are residual crude oil-related constituents in the Source Area that may exceed the applicable Part 201 criteria in the future. Light non-aqueous phase liquid (LNAPL) has not been identified in any of the shallow monitoring wells. Continued monitoring will take place to ensure identification of LNAPL in the future.

The wet meadow wetlands at the Source Area were re-built and seeded after the excavations. A final restoration plan for this area will be developed to direct and monitor additional restoration as appropriate. These plans will facilitate re-vegetation by preferred native species and will limit the colonization by invasive species.

3.5 Principal Study Questions

Uncertainties about the current conditions define the principal study questions associated with the source area. Addressing these will provide the information necessary to evaluate the nature and extent of hazardous constituents and free crude oil that may be present in the Source Area and allow for an evaluation of potential exposure and estimation of risk in this area.

I. Has the nature and extent of crude oil contamination been adequately defined to evaluate all impacts and future risk?
    a. Do non-oiled areas need to be further studied?
    b. Does groundwater contain soluble hazardous constituents that were in the crude oil above residential groundwater criteria under Part 201?
        i. In the area of the pipeline break is groundwater contamination present?
    c. Does soil contain hazardous constituents that were in the crude oil above residential soil criteria under Part 201?

II. Are there sufficient crude oil-related constituents remaining to act as a migration pathway?
    a. Leach hazardous constituents from the crude oil into the groundwater and other media at concentrations above residential groundwater criteria under Part 201,

b. Create methane during natural degradation of any remaining crude oil (noting that wetlands naturally produce methane as a result of bacterial degradation of organic carbon), or

c. Flow into a monitoring well screened across the water table?

d. Increase the mobility of inorganic compounds?

III. What is the ultimate fate of the crude oil in the system?

IV. Is the implemented interim habitat restoration appropriate for final restoration?

a. Did dewatering activities and installation of sheet piling at the location of the pipeline break result in deeper groundwater contamination?

V. Have site conditions been adequately described to understand pre-spill conditions?

a. Have crude oil release and response efforts exacerbated pre-existing environmental stressors within the Spill Area?

4.0 Talmadge Creek

4.1 Pre-Spill Conditions in Talmadge Creek

The hydrology of Talmadge Creek is influenced by surface water discharges, groundwater discharge and precipitation within its sub-basin. Talmadge Creek receives most of its water from numerous groundwater springs and wetlands present near its banks along most of its length (see *Insert 4-1*). The creek is bordered by riverine wetlands before it discharges into the Kalamazoo River just west of Marshall. In addition to the wetlands, there are also ponds adjacent to the creek. The adjacent and nearby wetlands and ponds are at slightly higher elevations than the creek, supporting that the creek is gaining water through this reach. Groundwater elevation data in the Source Area further supports that Talmadge Creek is a gaining stream.

Insert 4-1 Spring-fed wetlands adjacent to Talmadge Creek.

Spring fed wetlands are common along the length of the creek. Talmadge Creek is located on left side and behind photographer. Source: photo by B.Bjorkman, 18-Nov-2010; looking north near MP 0.50.

Based on information provided by the MDEQ Water Resources Division, Talmadge Creek above Division Avenue consists of a 1.9 square mile drainage system that flows at an annual median rate of 1.4 cubic feet per second (cfs).

Natural (e.g., iron bacteria) sources of sheening have been commonly observed along Talmadge Creek resulting from natural organic materials, particularly near groundwater seeps. These natural sheens are visible in wetlands and seeps along the creek in areas that were not impacted by the pipeline release and have been observed upgradient of the Source Area. The natural sheens are developed in areas where organic materials in the environment are degraded independent of the spilled oil. Any potential relationship, if any, between the spill and the natural sheens is not known.

Some of the dominant plant species in several areas of the creek were invasive non-native species, which is of importance when considering restoration options (see box below with JFNew observations). However, as noted in the box below, areas of native vegetation also occur along

TALMADGE CREEK – VEGETATION AND OBSERVATIONS

JFNew surveyed a portion of Talmadge Creek and its associated floodplain prior to completion of the excavation activities along the creek corridor. JFNew staff first viewed the creek and its associated floodplains, consisting of both upland and wetland, on August 25, 2010. At that time there were still areas of undisturbed vegetation between the temporary mat roads and the banks of the creek.

Vegetation that was still visible in the upper reaches (east of I-69) included a mixture of native and non-native species commonly associated with wet meadow, scrub shrub wetlands. Along the edges of the stream still containing vegetation, the areas were dominated by such plant species as reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), blue joint grass (*Calamagrostis canadensis*), lakebank sedge (*Carex lacustris*), tussock sedge (*Carex stricta*), joe-pye-weed (*Eupatorium maculatum*) and boneset (*E. perfoliatum*). Intermixed with these herbaceous grasses and forb species were scattered shrubs and tree species. Sandbar willow (*Salix exigua*), pussy willow (*S. discolor*), silky dogwood (*Cornus amomum*), and poison sumac (*Rhus vernix*) were the apparent dominant shrub species. Only a few tree species were identified and included bur oak (*Quercus macrocarpa*) and pin oak (*Q. palustris*). Soils identified in these upper reaches consisted primarily of muck and mucky mineral soils over sands and/or marl encrusted gravel substrates at deeper depths.

Vegetation that was still visible in the lower reaches (west of I-69) included a mixture of native and non-native species commonly associated with emergent, scrub shrub, and forested wetlands. Along the edges of the creek there was a greater diversity of wetland and upland types within the floodplain of the creek. There were emergent and wet meadow wetlands near the creek with scrub-shrub wetland on the outer edges. Forested wetlands were observed in areas that appeared unimpacted by the release. Dominant plant species were very similar to those identified in the upper reaches (east of I-69), consisting of reed canary grass, purple loosestrife, lakebank and tussock sedge, blue joint grass, and joe-pye-weed. In the furthest downstream reaches of the creek, there was a change in topography and soils. In these lower reaches there were fewer wet meadow wetland species and a greater number of forested wetland species along the creek banks. Soils identified in these lower reaches consisted of a mixture of muck, mucky mineral and various loamy soils (e.g., silt, clay and sandy loams).

The vegetation along the final ±100-foot reach of Talmadge Creek, from A Drive to the Kalamazoo River, appeared to have been primarily maintained lawn comprised primarily of grass species (i.e., *Festuca* spp. and *Poa* spp.). In these areas soils were comprised of a mixture of soils, including mostly silty clay loams and historically placed fill.

the creek, including a rare fen wetland community. The otherwise unstable, muck soils were often bound by a fine network of live and dead roots. Coupled with the apparent dense mats of vegetation these soils appear to have been fairly stable despite an apparent high water table and seeps moving over and through these soils enroute to the creek.

Approved

4.2 Release Event

The crude oil reached Talmadge Creek by overland flow and flowed down the creek and into the Kalamazoo River. The water level in the creek was elevated at the time of the release from recent rains, with the adjoining wetlands were already inundated prior to the release. The crude oil migrated down the main path of the creek, coating the banks and vegetation with crude oil (*Insert 4-2)*. In the floodplain, most of the vegetation was not completely submerged at the time of the release, and the undersides of vegetation were coated with crude oil. The crude oil mixed with water and was exposed to air as it spread out on the surface of the creek and flowed through the vegetation.

Insert 4-2 Talmadge Creek west of I-96, with visible sheen on July 28, 2010.

This photo shows impacted overbank areas where vegetation was coated below the tops of the plants. Source: U.S. EPA Website. http://www.epa.gov/ enbridgespill/photos.html

Constrictions in the flow path of Talmadge Creek (such as the culverts at Division Street, 16 Mile Road and I-69, 15 ½ Mile Road, and A Drive) caused water with floating crude oil to back up on the water surface upstream of the constriction and increased mixing as the water and crude oil flowed out of the culverts at a higher velocity.

The released crude oil was slightly less dense than water and was classified as “heavy crude.” The crude floated on the water in the creek and spread out beyond the banks of the creeks on the high water. As the crude oil interacted with the water and atmosphere, volatile and soluble fractions were gradually removed from the crude oil or some suspended solids were entrained in the crude oil. Some of the crude oil is expected to have exceeded the density of water and sank in the creek. In addition crude oil entrained with sediment or solids could also become heaver than water and sink.

As the water levels receded, crude oil was trapped in floodplain areas and became stranded. The crude oil resulted in acute impacts to aquatic biota including vegetation, benthic invertebrates, and fish.

4.3 Response Actions in Talmadge Creek

The Company immediately initiated response actions to remove crude oil and eliminate the discharge of crude oil onto surface waters. These activities included actions to block or control the flow of crude oil and activities to capture and remove crude oil. Following these response activities, interim restoration activities have been initiated throughout the areas impacted by the spill and the response actions *(Insert 4-3)*.

Control structures were used in Talmadge Creek to reduce the migration of crude oil further downstream and into the Kalamazoo River. These control structures included absorbent booms and underflow dams to reduce downstream migration of floating crude oil. In addition, a sediment trap was created near the confluence with the Kalamazoo River to capture sediments mobilized as a result of Talmadge Creek response and interim restoration actions.

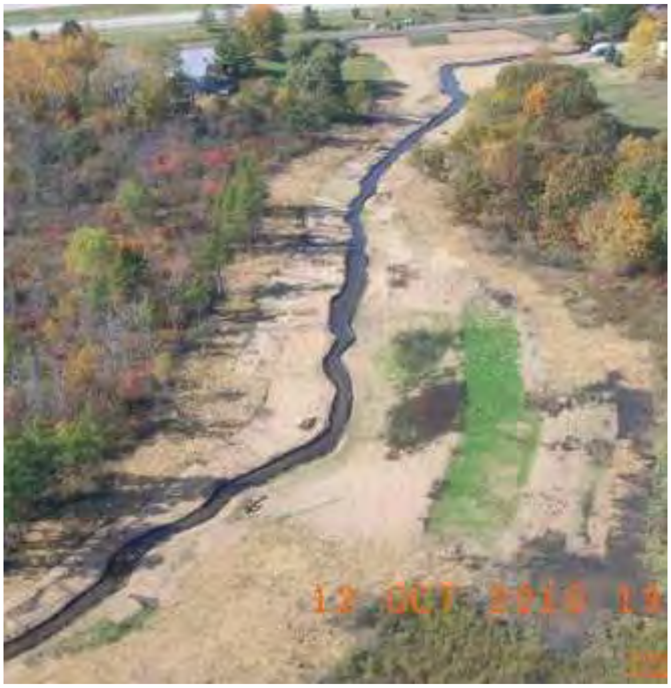
Insert 4-3 Oiled soils during initial response actions.

Note the abundance of Purple Loosestrife on both banks.
Source: U.S. EPA Website.
http://www.epa.gov/enbridgespill/photos.html

The floodplain areas that contained observable free crude oil were excavated. Under supervision by the U.S. EPA, excavations were classified as: surface excavation where free crude oil was only present at the ground surface (Method A), deeper excavations that extended to the water table, which was typically within a few feet of grade (Method B), or excavations that extended below the water table (Method C). Excavated soils were removed, staged, bulked, and disposed of off-site. The floodplain area was divided into a series of clearance areas, and the U.S. EPA signed off documenting the removal of free crude oil in each clearance area prior to interim restoration (Enbridge, 2010a). During the clearance of the excavation areas, soil samples were collected in coordination with the MDEQ.

During excavations of the creek floodplain, the creek channel was left in place through much of the length of the creek, and excavated in some areas at the direction of the U.S. EPA. After the soil excavations, portions of the creek bottom were raked and locally aerated to remove crude oil from the bottom of the creek, with concurrent collection and recovery of the crude oil that was released by these processes. Raking and aerating the subsurface sediments caused free crude oil to float to the surface and also provided further mixing with water.

Mat roads were constructed along the entire length of Talmadge Creek to support the excavation activities from the spill area (MP 0.00) down to the confluence with the Kalamazoo River just after MP 2.00. The mat roads were removed at the completion of backfill operations. As the mat roads were being removed, soils that were exposed under the mats were inspected and oiled soils were removed.



Insert 4-4 Talmadge Creek shortly after mat roads were removed near MP 1.00.

Source: U.S. EPA Website. http://www.epa.gov/enbridgespill/photos.html

In general, interim restoration consisted of replacing excavated soil with clean organic soil, placing 12-inch coir logs along both banks of the stream as necessary, seeding disturbed areas with native wetland seed mixes and placing biodegradable erosion control blankets over the seeded areas (*Insert 4-4*). In a few isolated areas field stone was used to stabilize affected and/or erosion prone banks. As of mid-December 2010, all of the underflow dams in the creek have been removed.

Planting of native shrubs and trees is planned for the spring of 2011. The length of the creek is monitored weekly both for restoration and soil erosion.

The specific response actions and locations in Talmadge Creek are identified in ten *Pipeline Release Source Contamination Removal and Verification Summary Reports* (Enbridge, 2010a). Sediment raking is detailed in the *Submerged Oil Recovery Summary Report* (Enbridge, 2010b) and the process used to identify areas of submerged oil is described below. Interim restoration of Talmadge Creek is documented in three interim restoration plans (JFNew, 2010a, b and c). Additional response activities included wildlife recovery and erosion monitoring.

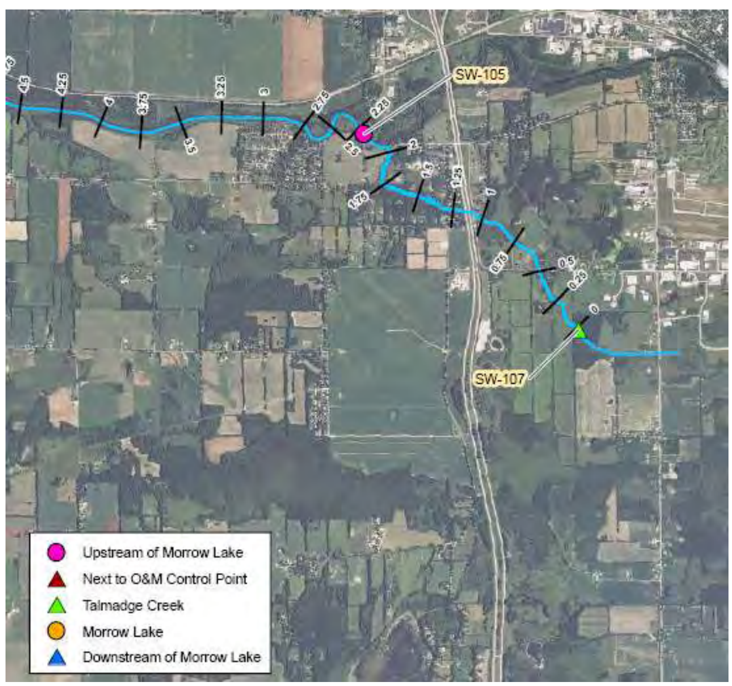
Approved

4.4 Current Conditions in Talmadge Creek

4.4.1 Residual Impacts

Visible crude oil was removed from Talmadge Creek and the adjacent floodplain areas during interim restoration activities. Soil confirmation samples were collected in the interim restoration areas to document the conditions of the remaining soils. Of 465 soil samples 19 exceed Part 201 criteria and/or the internal MDEQ Total Petroleum Hydrocarbons (TPH) screening levels for the crude oil constituents (VOCs, PAHs, and TPH). Residual contaminants may be present in places along the creek banks and concentrations of some chemicals in soil, sediment, surface water, and groundwater may exceed applicable Part 201 criteria and/or Rule 57 Water Quality Standards. *Figure 4-1* presents the CSM for Talmadge Creek showing conditions at the time of the release and in the fall of 2010.

Residual crude oil is present in some soils and creek sediments, for examples in some of the places where the creek channel and the bank material along Talmadge Creek were left in place. The floodplain soils are typically clean fill or clean native soils farther from the creek, but there are limited areas where some crude oil can be visually identified along the bank of the creek.



Insert 4-5 Monitoring location SW-107 at MP 01 was sampled twice a week from August 26 through October 24, 2010.

Groundwater along the creek flows toward the creek. Seeps can be observed draining groundwater into the creek. The hydraulic gradient toward the creek was strong enough that soil backfilling procedure was modified to adjust to situations where the groundwater gradient toward the creek created bank instability. With the gradient toward the creek, there is very limited potential for residual oil in the creek banks to impact groundwater. However, there is ongoing monitoring of potable wells near Talmadge Creek, current and future residential use of groundwater will continue to be a primary focus of the CSM. Additionally, private irrigation wells or surface water irrigation wells were identified and sampled (with permission from the landowner) when identified.

4.4.2 Response Monitoring

Confirmation soil samples were collected following the closure of the clearance areas by U.S. EPA in the Response Action. Furthermore, routine surface water and sediment monitoring was conducted at one location in Talmadge Creek near the source area, at SW-107 *(see Insert 4-5).* Samples were collected twice a week during the period of August 26, 2010 through October 24, 2010 under the U.S. EPA approved August 17, 2010 Sampling and Analysis Plan. Because there were limited detections of crude oil related contaminants in surface water limited to the month of August and that were below Michigan Rule 57 Surface Water values, U.S. EPA approved a modified monitoring program that dropped the location from the monitoring program in October. Further monitoring of surface water and sediment is ongoing.

Similarly, there were limited detections of crude oil related contaminants in sediment below the U.S. EPA “consensus” probable effect levels for benthic biota (MDEQ, 2006b) (at SW-107). Volatile organic compounds such as benzene, ethylbenzene, toluene, and xylenes were not detected. Polycyclic aromatic hydrocarbons were frequently detected with total PAH concentrations below a 22.8 milligrams per kilogram (mg/kg), a commonly applied U.S. EPA “consensus” probable effect level for benthic biota (MDEQ, 2006b).

Metals such as nickel, vanadium, and mercury were frequently detected, as were other naturally-occurring metals commonly found in regional soil (e.g., arsenic, iron, and magnesium) and at concentrations below the U.S. EPA “consensus” probable effect levels for benthic biota (MDEQ, 2006b) for metals having screening levels.

Impacts (primarily aesthetic, but may also include ecological impacts) may exist due to small oil sheens in stranded floodplain water or staining on tree trunks and structures that abut Talmadge Creek.

4.4.2.1 Submerged Oil Assessments

In addition to the routine monitoring of surface water and sediment, surface sheen and submerged oil were characterized for presence or absence, qualitatively described and quantitatively characterized for both Talmadge Creek and Kalamazoo River August 29, 2010 through October 29, 2010. The objectives for the qualitative analysis prior to recovery efforts were to quickly identify depositional areas with submerged oil and to prioritize sites for recovery actions ("priority areas"). This process allowed for the development of a targeted sampling design and, in conjunction with U.S. EPA, development of a recovery plan that ranked priority areas for treatment. The objectives for the analysis after recovery efforts were conducted were to qualitatively assess the effectiveness of removal efforts and to supplement the geomorphological understanding of the fluvial system (e.g., in channel deposition and erosion areas, sediment bed material, etc.). The procedures for the qualitative analysis are presented in the Revised Supplement to Response Plan for Downstream Impacted Areas (Enbridge, 2010e) and the results of the sheen/submerged oil characterization, identification of submerged oil deposits and treatment areas were presented in the Submerged Oil Recovery Report (Enbridge, 2010b) and included here in *Appendix A-2.*

Sediment cores were collected, logged, and sampled to quantitatively characterize the nature and extent of submerged oil. Sediment cores were logged following the standard operating procedures described in the September 14, 2010 Supplement to the Quality Assurance Project Plan (Enbridge, 2010f). These data were used to detail the sediment profile and the depths at which submerged oil occurred. This information was also used in conjunction with water depths for selection by the SOTF team of the appropriate submerged oil recovery method. Sediment texture that was characterized using the Unified Soil Classification System and laboratory analytical results were reported to the project's SCRIBE database (2010); sediment core logs and laboratory analytical results were included in the Report to U.S. EPA (Enbridge, 2010c).

4.4.2.2 Ongoing Activities

Impacts (primarily aesthetic, but may also include ecological impacts) that may exist due to small oil sheens in stranded floodplain water or staining on tree trunks and structures that abut Talmadge Creek Sheen/oil observations are documented following the process described in *Insert 2-1*. Actions taken subsequent to observation are developed and implemented by the Company in concurrence with U.S. EPA. For example, sheen/oil was observed on and behind bank stabilization structures (e.g., coir logs) in February and an assessment and response were initiated.

The overbank area of Talmadge Creek was re-built after the excavations of visible crude oil. A final restoration plan for this area will be developed to direct and monitor the restoration as appropriate. These plans will facilitate re-vegetation by preferred native species and will limit the colonization by invasive species. In addition, interim restoration activities, already begun, will ensure that appropriate habitat is present for wildlife along Talmadge Creek.

4.5 Principal Study Questions

I. Has the nature and extent of crude oil contamination been adequately defined to evaluate all impacts and future risk?
   a. Do non-oiled areas need to be further studied?
   b. Does groundwater contain soluble hazardous constituents that were in the crude oil above residential groundwater criteria under Part 201?
      i. Are private irrigation wells or surface water irrigation wells impacted with crude oil constituents that affect human health or the environment?

   c. Does soil contain hazardous constituents that were in the crude oil above residential soil criteria under Part 201?
   d. Does surface water contain hazardous constituents that were in the crude oil above Rule 57 non-drinking water criteria?
   e. Does sediment contain hazardous constituents that were in the crude oil above risk based sediment criteria under Part 201?

II. Are there sufficient crude oil-related constituents remaining to act as a migration pathway?
   a. Leach hazardous constituents from the crude oil to groundwater that would migrate into the sediment and surface water or a residential well at concentrations above generic criteria under Part 201,
   b. Flow into a monitoring well screened across the water table, or
   c. Create sheen on the creek?
   d. Cause longer-term mobilization of crude oil/ non-aqueous phase liquid (NAPL) in sediments from ice scour, bioturbation, etc.?

III. What is the ultimate fate of the crude oil in the system?
   a. Is there sufficient oil present to release sheen to the river?
   b. Is there sufficient oil present to impact sediment or surface water quality above standards?

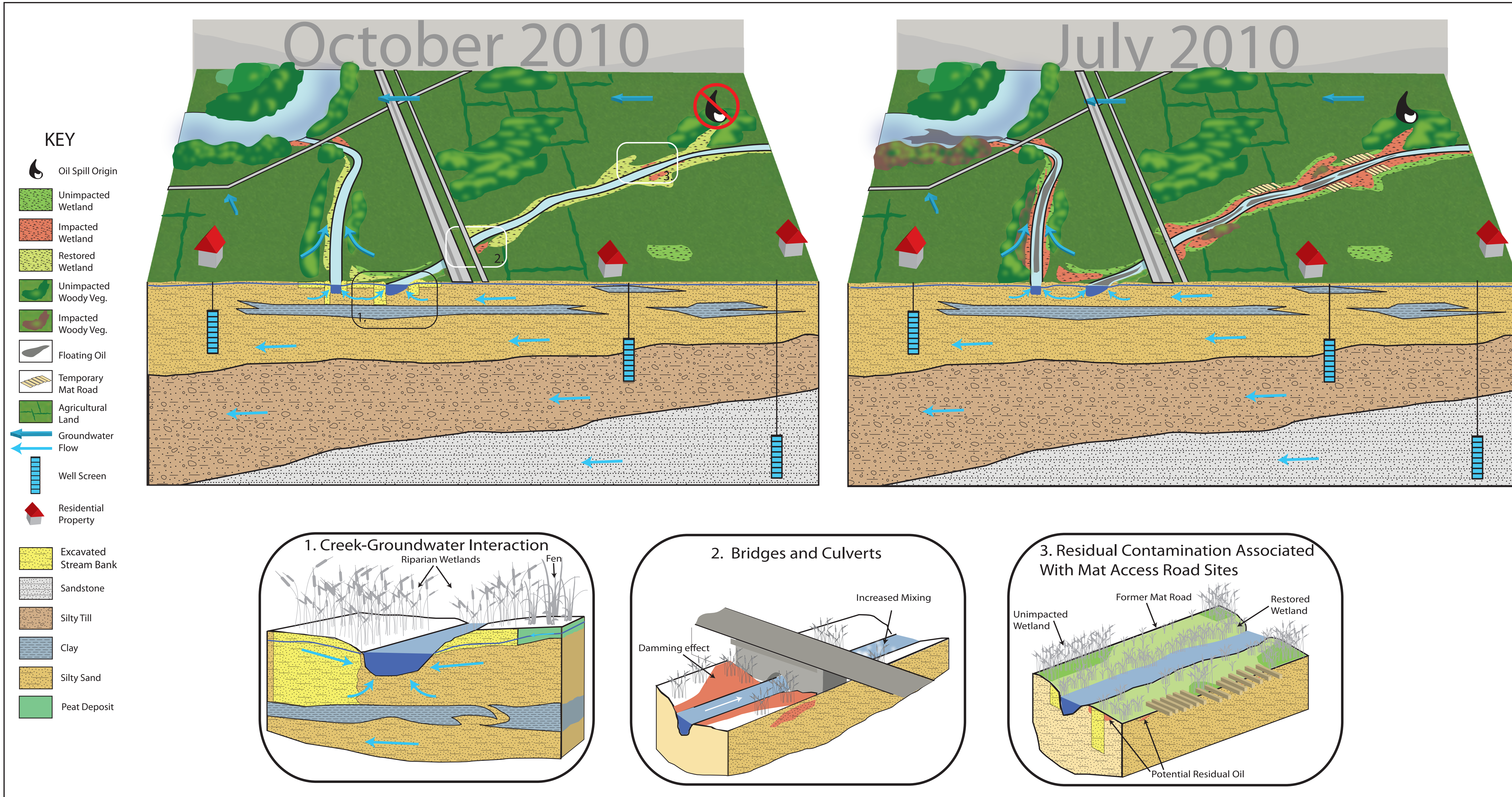
IV. Is the implemented interim habitat restoration appropriate for final restoration?
   a. Is the recovery of vegetation, soil biota, and wetland biota following the exposure to crude oil acceptable for site decision making?
   b. Will natural channel design enhancements be necessary to stabilize and restore the creek subsequent to further Remedial Activities?

V. Have site conditions been adequately described to understand pre-spill conditions?

   a. Have crude oil release and response efforts exacerbated pre-existing environmental stressors within the Spill Area?

Figure 4-1: CSM-Talmadge Creek

Fate and Transport



Map