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Local Watershed Analysis for Hubbell and Lake Linden, Michigan

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LOCAL WATERSHED ANALYSIS FOR HUBBELL AND LAKE LINDEN, MICHIGAN

By

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A REPORT

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This report has been approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE in Civil Engineering.

Department of Civil, Environmental, and Geospatial Engineering

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Thank you to my river guide family for instilling wonder about the river and to my friends for forcing me to take breaks.

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Abstract

This report analyzes flood frequency risk, examines drainage, and delineates local level watershed characteristics for the Site located in western HUC 12-040201 030304 Torch Lake Subwatershed. Specifically, unnamed catchments in need of HUC-14 or HUC-16 local level delineation are evaluated to determine the effects of excess runoff on the cities of Hubbell and Lake Linden, Michigan. Further, this report aims to identify the location of known or suspected historical and current drainage infrastructure, and to prioritize locations for low-impact sustainable designs that reduce excess runoff and provide flood protection for these lakeshore communities.

1 Introduction

1.1 Background

A one in one-thousand year rainstorm event (5.86 inches in 24 hours) resulted in severe flooding across Houghton County Michigan on June 17, 2018, known locally as the Father's Day Flood. Of particular interest in this report is the area along the western shore of Torch Lake between Hubbell and Lake Linden, Michigan (here on out referred to as the Site), where excess runoff resulted in wide-spread stormwater infrastructure failure along the MDNR UP3 Trail (Rail Grade) and in urban floodplain areas.

The Houghton County Hazard Mitigation Plan (HMP) [1] recurrently identifies that:

1. "The communities of Houghton, Hancock, Lake Linden, Hubbell, Ripley, Dollar Bay, and Painesdale regularly experience high runoff related to steep topography and should continue upgrades that assist in management of those conditions."
2. "Houghton County municipalities have several severely deteriorated storm drainages within their built-up communities. These drainage systems enclose seasonal and permanent waterways and have been built haphazardly, many by residents who have filled in ditches with scrap material and undersized pipe materials over the past 100 years. These drainages need upgrading that alleviates ongoing maintenance and flooding problems. Some of the most severe problems are in Chassell, Dollar Bay, Mason, Ripley, Houghton, Hubbell, and Lake Linden."
3. "Inspection and maintenance of the existing drainage system to assess plugged culverts and upgrading of culverts is needed to complete flood analysis of M-26 corridor between Hubbell and Lake Linden."
4. "Houghton County Road Commission maintains a future project list and continues to identify and upgrade inadequate culverts and problem roadways as needed."

In addition, drainage basins across the Site are shared between Osceola, Torch Lake, and Schoolcraft Townships, stormwater infrastructure from mining era is not well documented, two faults create steep topography, geology includes highly erodible Jacobsonville Sandstone formation, highly developed impervious floodplains that increase excess runoff in urban lowland, and former copper mining land use has left contaminated sediments across the floodplain that erode and transport during flood size rainfall events.

1.2 Research Objective

This report analyzes flood risk, examines drainage, and delineates local level watershed characteristics for the Site located in western HUC 12-040201 030304 Torch Lake

Subwatershed. Specifically, unnamed catchments in need of HUC-14 or HUC-16 local level delineation are evaluated to determine the effects of excess runoff on the cities of Hubbell and Lake Linden, Michigan. Further, this report aims to identify the location of known or suspected historical and current drainage infrastructure, and to prioritize locations for low-impact sustainable designs to reduce excess runoff and provide flood protection for these lakeshore communities.

2 Site Selection and Characteristics

2.1 Site Location & Elevation

The project site (the Site) is located in the western region of Torch Lake Subwatershed, United States Geologic Survey (USGS) HUC 12-040201 030304, in northern Houghton County, Michigan. Specifically, the Site is located within the USGS Laurium Quadrangle and covers territory within Osceola, Torch Lake, Schoolcraft, and Calumet Townships. The Site includes specific catchments at HUC-14 local level that outlet into Torch Lake along the western shoreline communities of Hubbell and Lake Linden. Refer to Figure 2.1: Site Location Map and Figure 2.2: Torch Lake Subwatershed Boundary provided by the National Map [2].

The Site elevation ranges from 602 feet to 1223 feet above mean sea level (MSL). Refer to Figure 2.3: Site Elevation.

2.2 HUC-12 Torch Lake Subwatershed Boundary

In the far north western region, between Calumet and the Houghton County Memorial Airport (CMX), the USGS HUC-12 subwatershed boundary (WBD) conflicts with 10-meter digital elevation model (DEM) derived drainage boundary assessed using ArcGIS Pro. Interconnected wet uplands cover this region encompassing the headwaters of Gooseneck, Dover, and Hammel Creeks. USGS HUC-12 WBD, delineated at 1:24,000-scale, suggests this region is to drain to Dover Creek. Flow accumulation modeling, using 10-m DEM, shows this region is to drain to Gooseneck Creek. Additionally, drainage from this region can be observed in aerial imagery to outlet into Hammel Creek. Flow pathways have been altered over time by historical mining rail grades, industry, and development. Field investigation is needed to clarify the Torch Lake Subwatershed boundary in this region as flow pathways have been altered by historical mining land use, industry, and development. Based on the USGS WBD, 10-m DEM derived boundary, and aerial imagery, it is assumed that the wet upland region between Calumet and CMX is hydraulically connected to Gooseneck, Dover, and Hammel Creeks. Therefore, design values for Dover Creek local watershed are suggested to include this catchment. Refer to Figure 2.2 and to Figure 2.3.

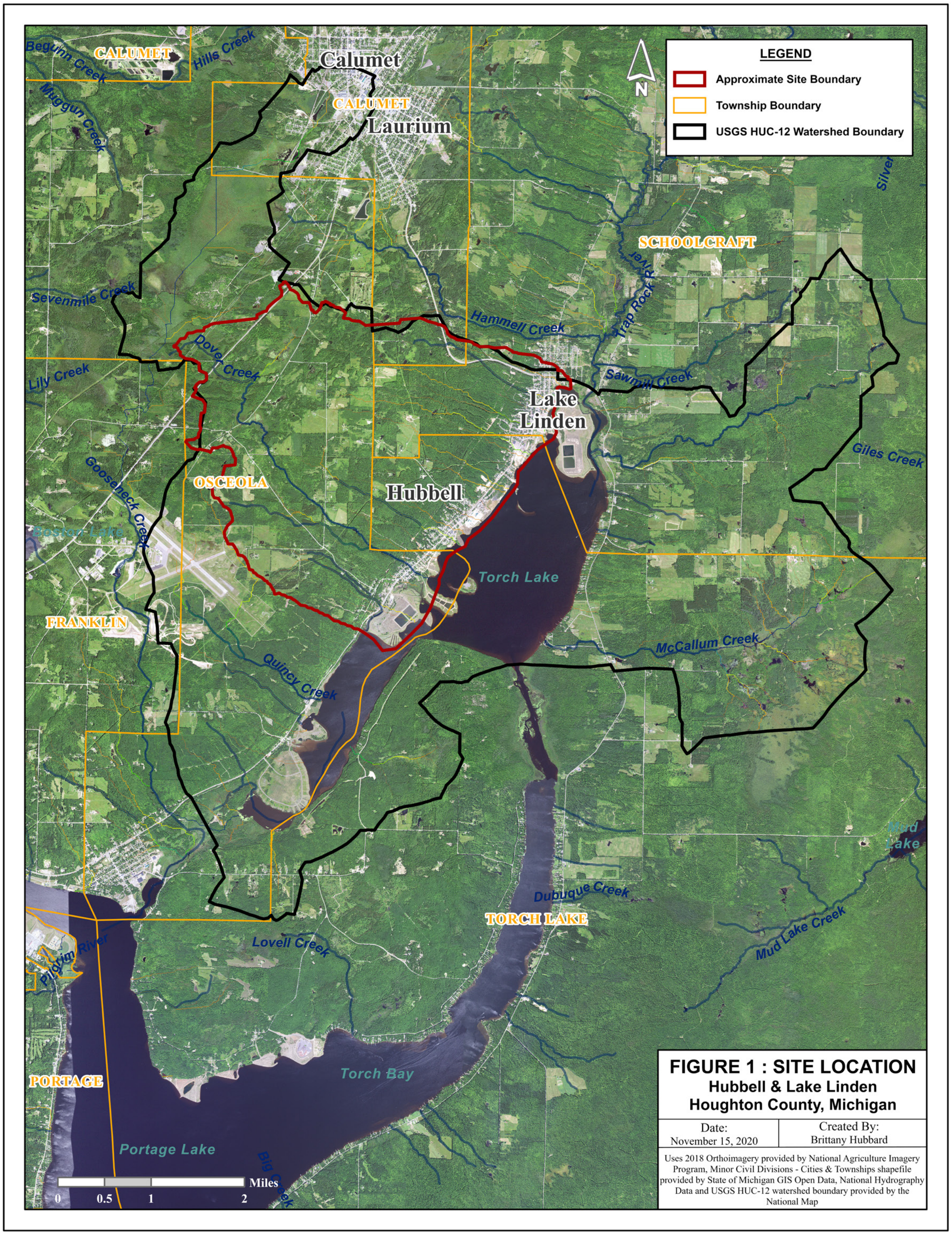

Figure 2.1. Site Location Map.

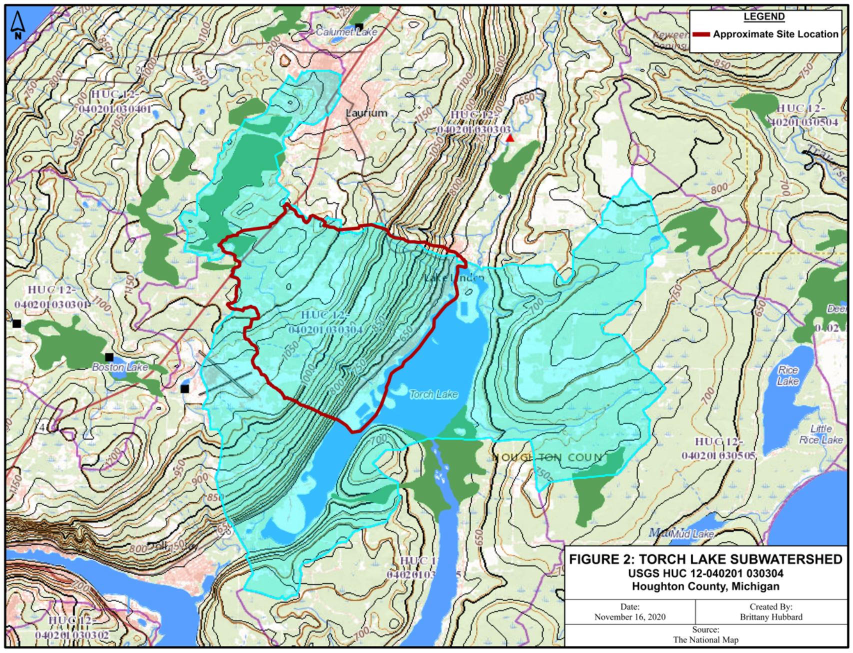

Figure 2.2. Torch Lake Subwatershed Boundary.

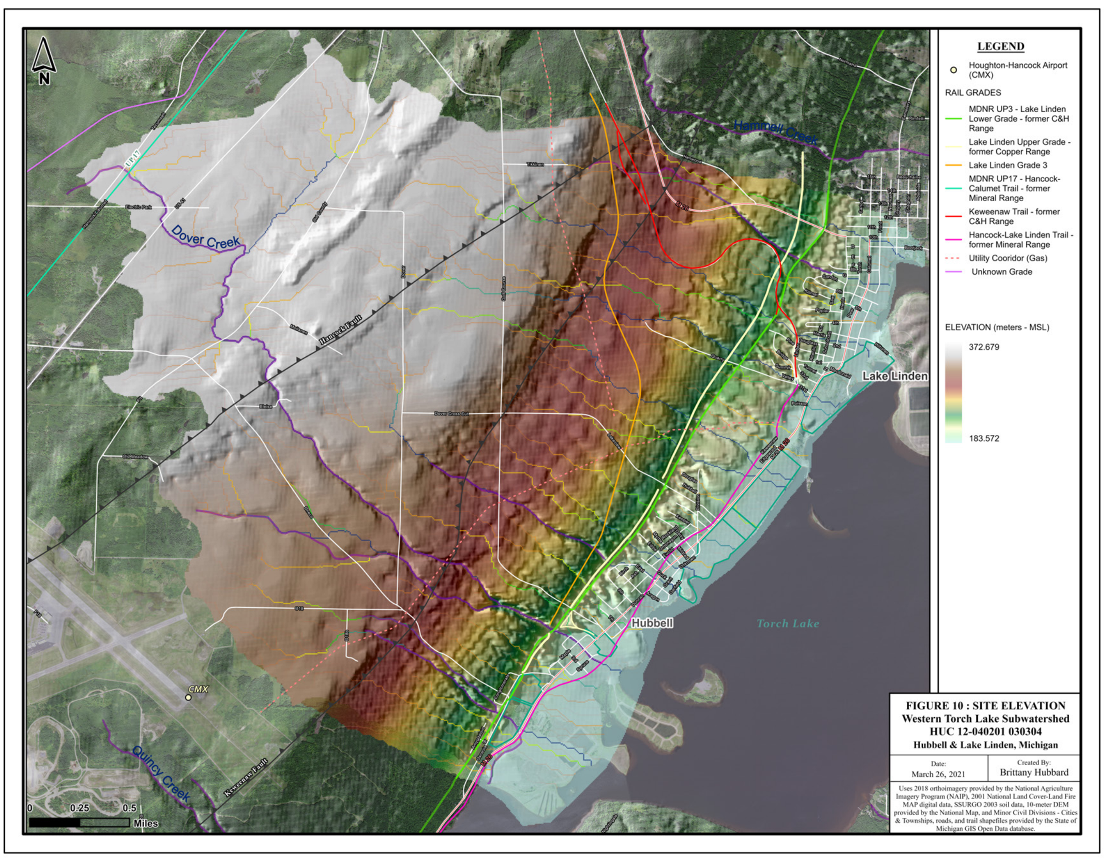

Figure 2.3. Site Elevation.

2.3 Precipitation Frequency Analysis

Gumbel, Log-Pearson III (LP3), and Generalized Extreme Value (GEV) distribution models were used to predict the recurrence frequency for the Father's Day storm event. Annual maximum precipitation data for the Hancock Houghton County Airport (CMX or Houghton AP) is provided by the National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) [3] and the Western Regional Climate Center (WRCC) [4]. Specifically, precipitation data was obtained using stations COOP 201213, 203908, 201215 (Calumet 1887-1937), and GHCND-USW0014858. Figures 2.4, 2.5, and 2.6 show quantile-quantile plots for GEV, Gumbel, and LP3 distributions. A linear trendline and R-squared analysis is used to assess each probability model. R-squared values of 0.95, 0.93, and 0.86 were computed for GEV, Gumbel, and LP3 models, respectively. Results indicate the GEV distribution using L-moment parameters best modeled annual maximum rainfall events observed at CMX over the past 133 years. This model can be used to estimate the recurrence frequency for an X-year rainfall event within USGS HUC-12 Torch Lake Watershed, and thus, local level watersheds at the Site as well. For the 50, 100, 500, and 1000-year rainfall event, the GEV distribution model estimates approximately 3.6, 4.1, 5.3, and 5.86 inches of precipitation, respectively. On June 17, 2018, Keweenaw Research Center (KRC) weather station recorded 6.72 inches of rainfall in 24-hours [5] and NOAA CMX weather station recorded 5.86 inches of rainfall in 24-hours [3]. NOAA precipitation frequency tables currently designate 6.79 inches of rainfall for the 1000-year 24-hour rainfall event [6]. Refer to Appendix B: Calculations.

Low impact development is suggested across the Site upstream from stormwater drain inlets existing up-grade from developed lowland to increase flood water storage capacity as frequency and intensity of rainfall events increase. Possible options for low impact development are discussed further in Chapter 4 of this report.

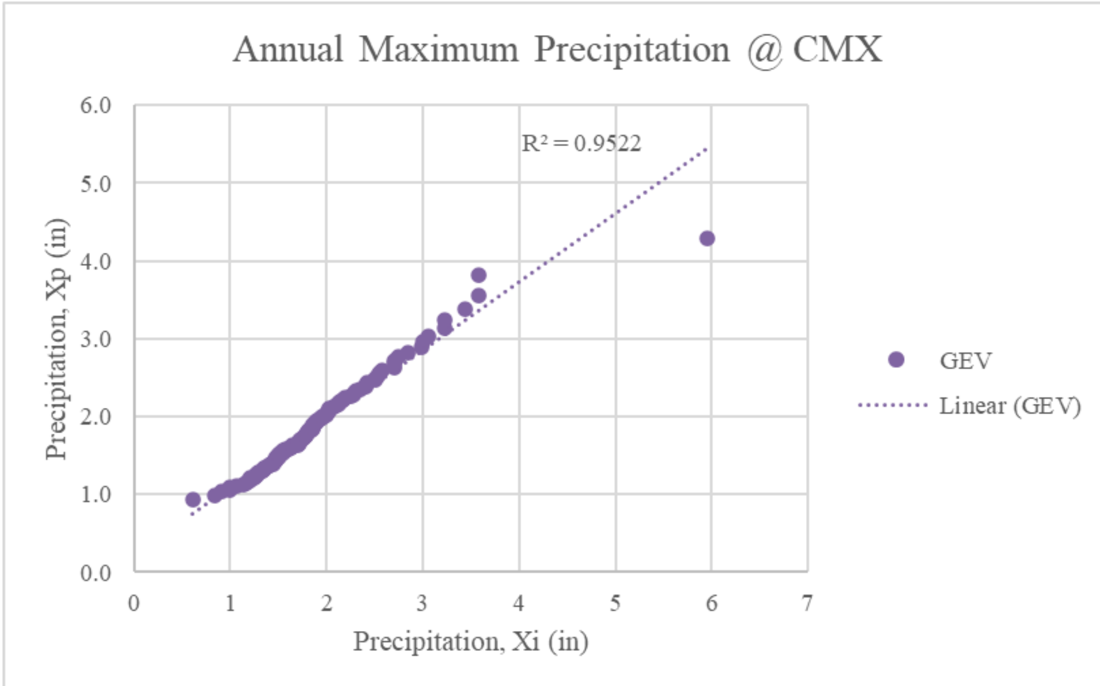

Figure 2.4. Generalized Extreme Value Plot.

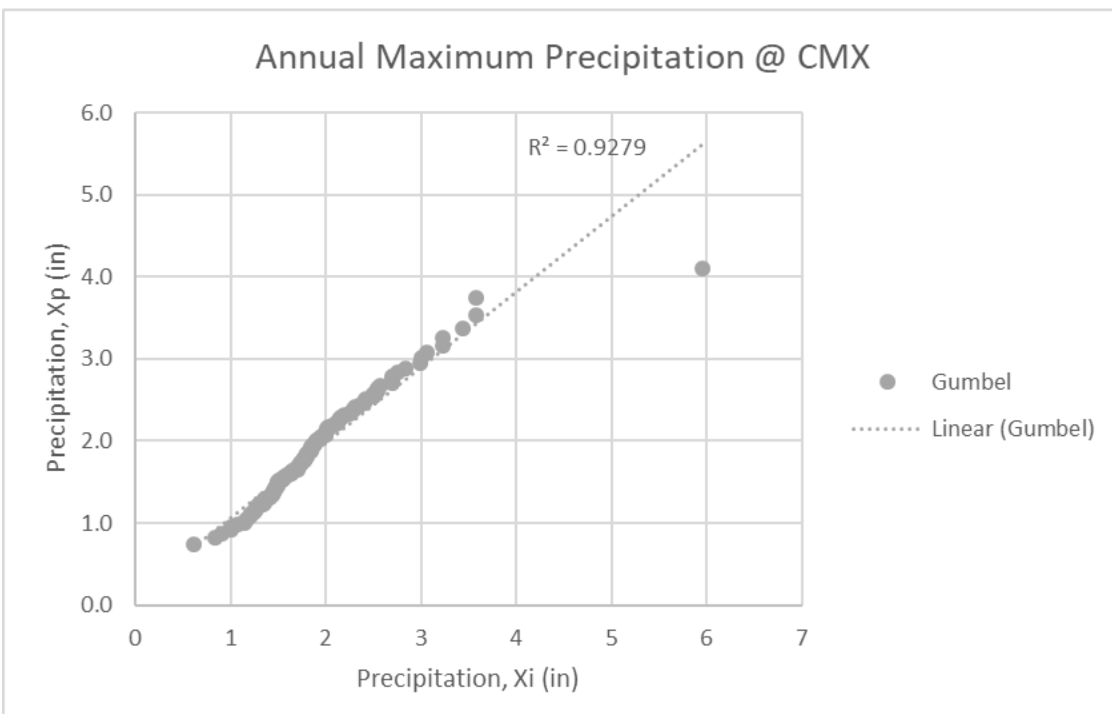

Figure 2.5. Gumbel Plot.

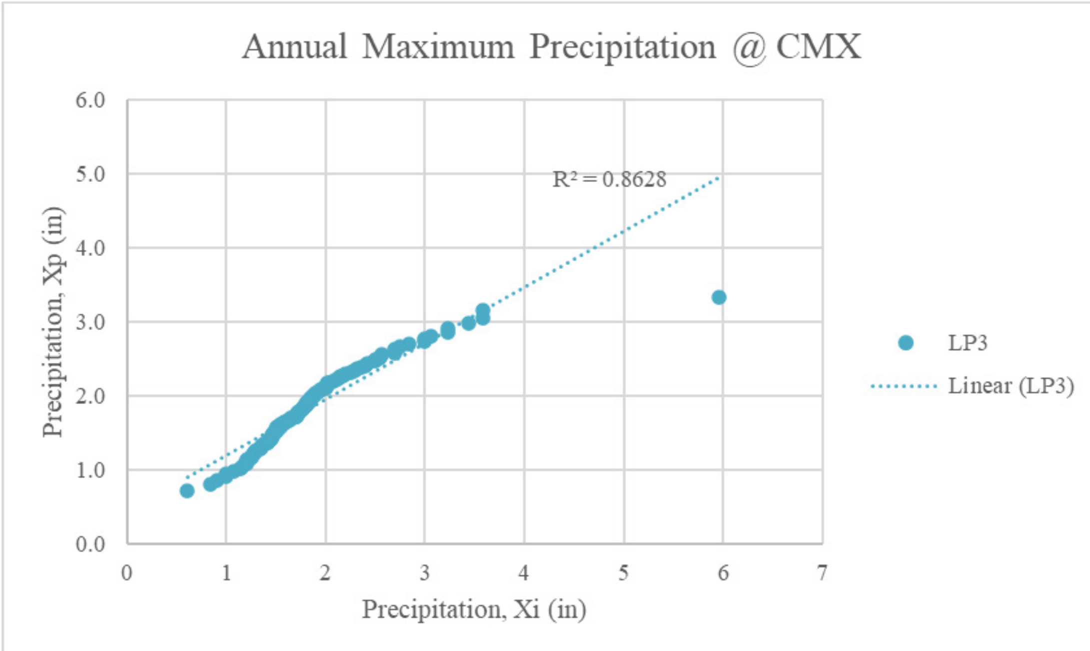

Figure 2.6. LP3 Plot.

2.4 Historical Activity

2.4.1 Mining

Copper mining activities occurring from the 1840's until 1968 [7] left the Copper Country area littered with industrial infrastructure and contamination. Several mining era properties exist at the Site including the former Osceola, Tamarack, Ahmeek, and Calumet and Hecla (C&H) Stamp Mills and facilities, as well as the former C&H smelting and refining operations, mineral building, and former coal docks property.

2.4.2 Restoration of Former Mining Land

Much work has been undertaken by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Environmental Protection Agency (EPA), Michigan Department of Health and Human Services (MDHHS), Western Upper Peninsula Health Department (WUPHD), Michigan Technological University (MTU), Keweenaw Land Trust (KLT), and others to remediate Torch Lake and surrounding areas of concern. Existing contamination concerns are in stamp sand sediments found along the shoreline floodplain region stretching between Hubbell and Lake Linden and is known to include asbestos, heavy metals, and PCBs. Several shoreline locations have installed vegetative caps covering the stamp sands to prevent erosion and increase water-holding capacity. However, "vegetation has not been able to grow uniformly over the stamp sands and there are numerous bare patches where there is no plant growth at all. Native vegetation could not grow properly because of Cu toxicity, and the nutrient-poor quality of stamp

sands, which texturally lack water-holding capacity" [8]. Flood events threaten destruction of restorative efforts designed to protect the water quality of Torch Lake.

2.4.3 Flooding of Former Mining Land

During the 2018 Father's Day flood event, ten of fifteen main stream channels across the Site exceeded bank full stage or capacity of the stormwater and sewer system, reshaping the urbanized floodplain, and spilling across industrial mining properties that obstruct the outlet into Torch Lake. Significant flooding occurred at Torch Lake Backwater Area, Lake Linden Recreation Area, Lake Linden Processing Area, Hubbell Processing Area, Hubbell Beach and Slag Dump, Ahmeek Processing Area, and the Tamarack Sands and Processing Area [9].

2.4.4 Rail Grades and Recreation Trails

Several mining era railroad grades exist across the Site. Nearly parallel to M-26, a twin rail road grade exists on the hillside above Hubbell and Lake Linden, Michigan. This rail road grade was known historically as the Copper Range and Calumet & Hecla Range (C&H). It is currently managed by Michigan Department of Natural Resources (MDNR) and is now known as the Lake Linden Trail or MDNR UP3 snowmobile trail (Rail Grade), and is further designated into upper (LLUG) and lower (LLLG) grades. Scars from an unnamed rail road grade can be observed from aerial imagery up-grade from the MDNR UP3 trail and is designated as the Lake Linden 3rd grade (LL3G) by the MDNR. Additionally, the C&H range had a connecting rail grade from Calumet to approximately Louie's Market, Lake Linden. This section of trail may be a good place for future work, although it is unclear who owns/manages it presently, if anybody, and it is not on any current trail maps (hiking, ATV, snowmobile, biking). Oher existing historical rail road grades across the Site include the Mineral Range (known currently as the Hancock-Lake Linden trail) along the shoreline of Torch Lake. A section of the Mineral Range (MR) transects the wet upland regions west of M-41 between Calumet and CMX and is also a managed MDNR snowmobile trail (UP17). Refer to Figure 2.7: Historic Mining Properties & Railroad grades.

The MDNR UP3 snowmobile trail has mining era hydraulic infrastructure existing throughout upper and lower grades. Excess runoff pooling upgrade threatens landslides in Hubbell, Tamarack City, and Lake Linden. Post 2018, major flood event damages along the Rail Grade were investigated by MDNR, EGLE, and the Federal Emergency Management Agency (FEMA) to identify failed hydraulic structures and provide emergency restoration to repair stream channels. Wash-out size varied, some culverts were restored, and many stream channels were naturalized by stabilizing banks with varying sized cobble and boulders. With respect to naturalization, however, material is sparse and may be an area to assess before the next flood. Similar infrastructure is likely present within the Lake Linden Grade 3 (LL3G), MR, and C&H range rail grades and

may risk similar fate. For information on washouts and current status of repairs, refer to MDNR Houghton County Incident Report [10].

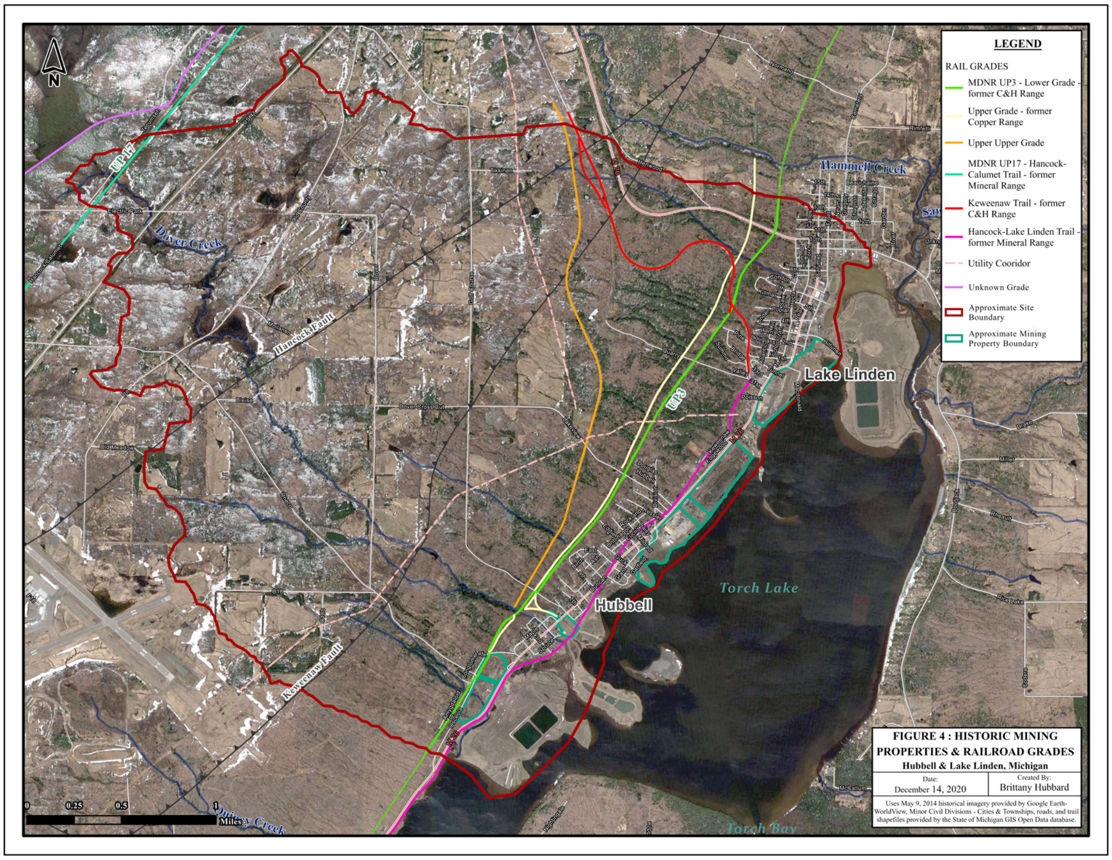

Figure 2.7. Historic Mining Properties and Railroad Grades.

2.5 Geology

2.5.1 Soils

Houghton County soil data (2003) from the Web Soil Survey Geographic database (SSURGO) [11], provided by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), was used to analyze hydrologic group soil types for the Site. Upper, middle, hillside, and lower regions of the Site refer to the upland area located above the Hancock Fault, between the Hancock and Keweenaw Faults, steep hillside area between the Keweenaw Fault and developed floodplains, and low land urbanized area located between the base of the hill and Torch Lake, respectively. Upper regions are the most diverse consisting of hydrologic group A, A/D, B, B/D, C, and D soil types. Somewhat poorly drained high runoff coarse-loamy type C soils dominate this region. Middle and hillside regions are dominated by somewhat poorly to moderately well-drained, high to very high runoff, coarse-loamy hydrologic group B soils. The middle region, nearest the

Houghton-Hancock Airport (CMX), also contains a portion of somewhat poorly-drained high runoff coarse-loamy type C soils. Lower regions of the Site are heavily developed and historically industrialized. Soils in this region consist of very poorly-drained loamy, somewhat poorly-drained sandy, moderately well-drained sandy, well-drained coarse loamy and sandy hydrologic group A, A/D, and A/SS soils. In addition, stamp sands (SS), unknown excavated earth and fill material, and impermeable surfaces associated with high to very high runoff cover the shoreline region. Refer to Figure 2.8: Hydrologic Soil Group.

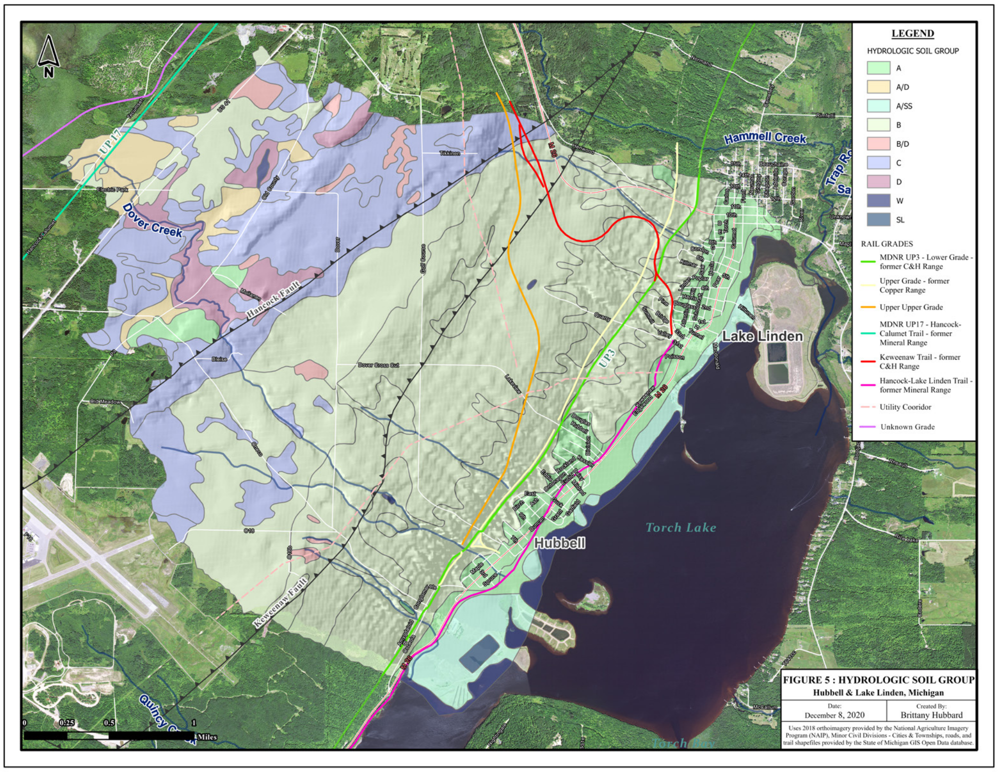

Figure 2.8. Hydrologic Soil Group.

2.5.2 Bedrock and Quaternary Geology

Michigan bedrock and quaternary geology is provided by State of Michigan GIS Open Database [12]. Bedrock geology consists of Portage Lake Volcanics and Jacobsville Sandstone above and below the Keweenaw Fault, respectively. Quaternary geology consists of thin to discontinuous glacial till over bedrock and coarse-textured glacial till above and below the Hancock Fault, respectively. Refer to Figure 2.9: Bedrock Geology, and Figure 2.10: Quaternary Geology.

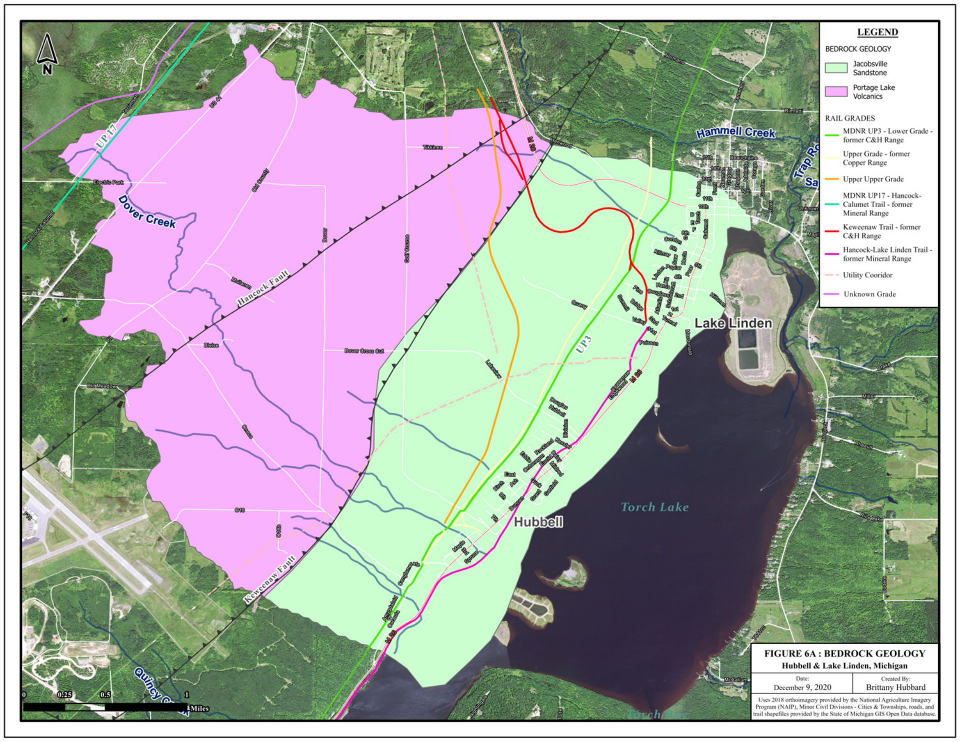

Figure 2.9. Bedrock Geology.

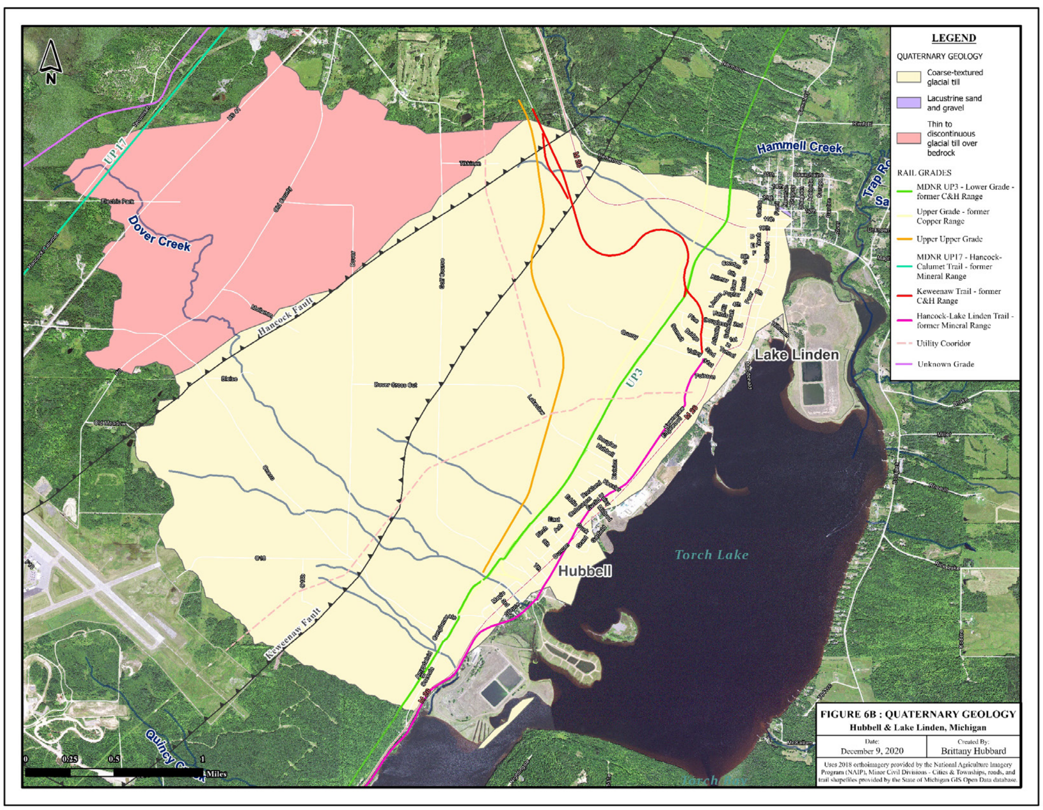

Figure 2.10. Quaternary Geology.

2.6 Land Use

Average types of land use at the Site were determined using IFMAP/GAP Upper Peninsula Land Cover - Land Use digital data (NLCD 2001) [13]. Specifically, ArcGIS Pro was used to delineate average land uses for the Site and for each local level watershed, refer to Chapter 3 and Figure 3.1 for local watershed details. The primary land cover type for the Site is forest consisting of 29.5%, 13.7%, and 13.5% of northern hardwood, coniferous, and Aspen/White Birch forests, respectively. Other land uses include herbaceous openland, shopping center/mall, emergent wetland, residential, barren, shrub, water, pine, shrub/scrub wetland, and non-forested wetland at 9.1%, 6.6%, 6.0%, 4.4%, 4.4%, 3.2%, 2.1%, 1.3%, 1.3%, and 1.2%, respectively. Land uses covering less than 1% of the Site include wooded wetlands, lowland conifers, central hardwoods, strip commercial, flats wetland, cropland, Christmas tree plantation, and forested wetland. Refer to Figure 2.11: Land Use.

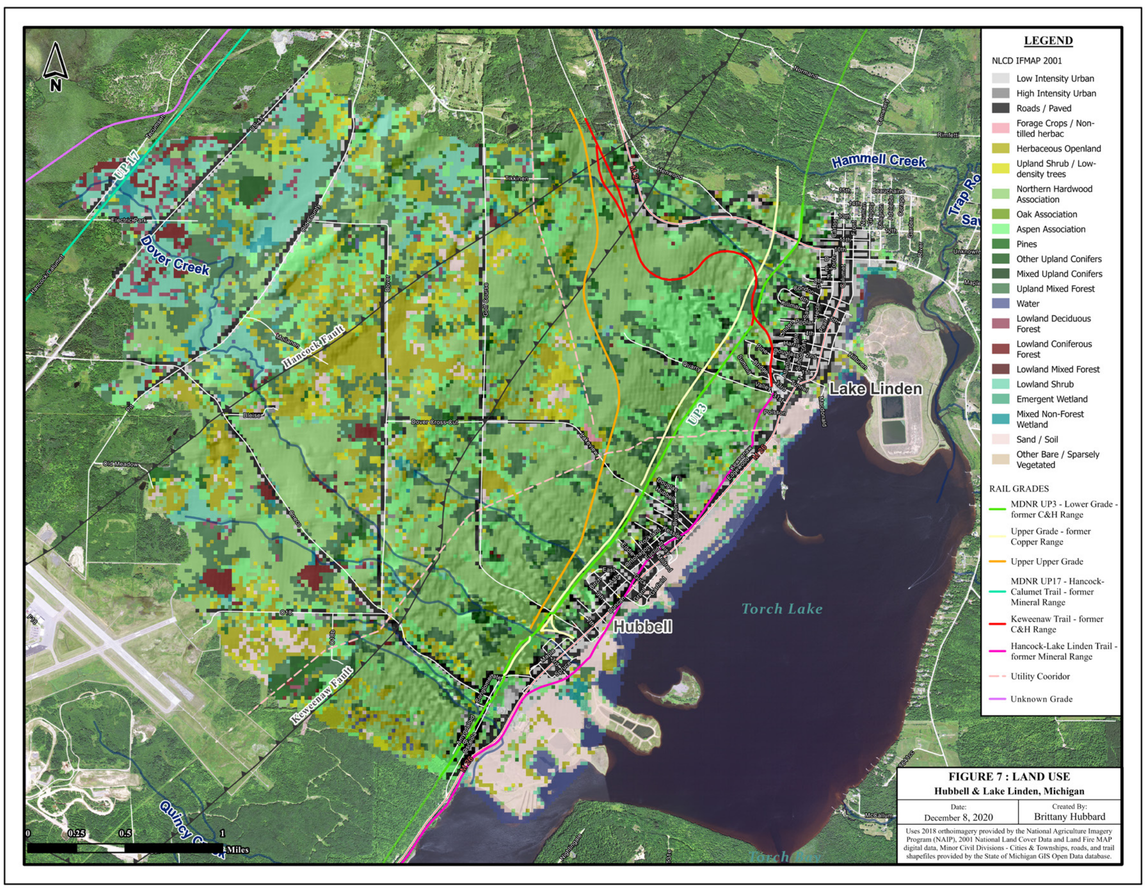

Figure 2.11. Land Use.

2.7 Runoff Curve Number

The NLCD 2001 land cover-land use data for Houghton County was combined with SSURGO soil data to compute the SCS Runoff Curve Number (RCN) for the Site. Specifically, an average RCN for the Site and an average RCN for each local level watershed was computed. Unique curve numbers (CN) correspond to each soil/land use combination. Combined land use and soil type resulted in a null RCN value for hydrologic group A soil types associated with dumps and stamps sands (A/SS). USDA NRSC Technical Release 55 (TR-55) [14], Exhibit A, suggest using hydrologic soil group B for dumps and tailings. Therefore, RCN values for stamp sand land use polygons were adjusted to reflect increased RCN values associated with hydrologic group B soil types suggested for dumps and stamps sands. Using a semi-distributed watershed model, an area-weighted RCN value is computed for each polygon and totaled to compute the composite RCN for the Site and for each local level watershed. The average RCN for the Site is 69. Each sub-watershed was further analyzed using a semi-distributed model to better assess the natural heterogeneities observed across the Site. Recall, the Site is further divided into upper, middle, hillside, and lower regions referring to the upland area located above the Hancock Fault, between the Hancock and Keweenaw Faults, steep hillside area between the Keweenaw Fault and MDNR UP3 Rail Grade, and low land urbanized area located down-grade the rail trail extending to Torch Lake, respectively. Refer to Appendix A: Tables and Table A.1: Local Watershed Characteristics Summary. Refer below to Figure 2.12: Runoff Curve Number.

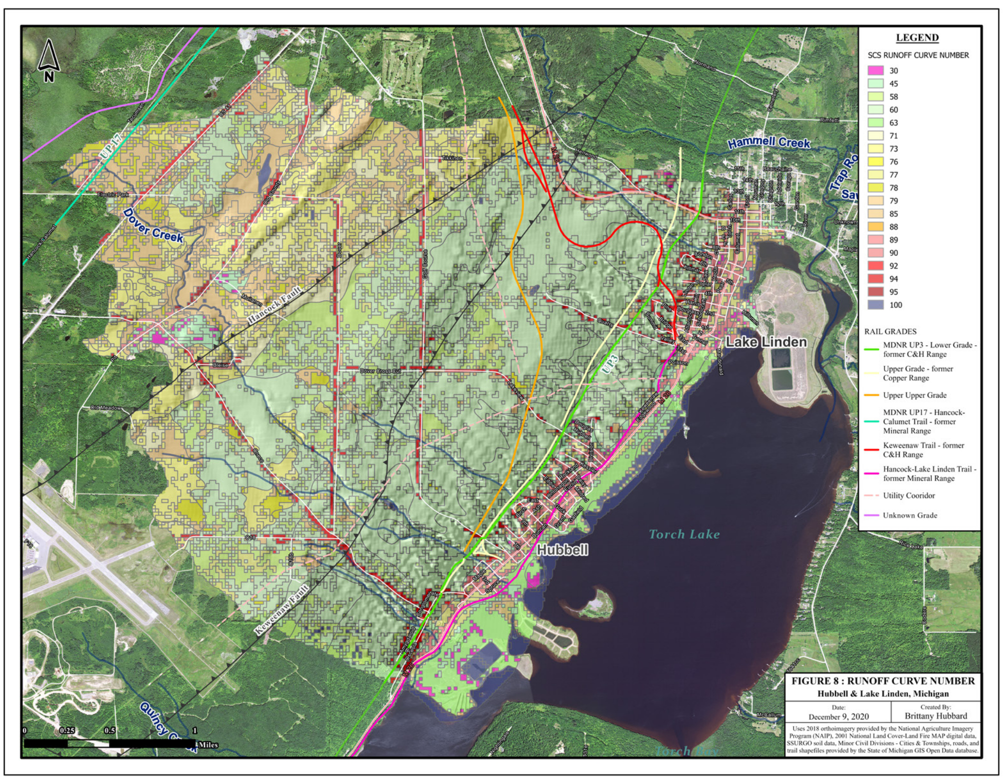

Figure 2.12. Runoff Curve Number.

3 Local Watershed Delineation & Characteristics

This section aims to delineate local level drainage basins across the Site. ArcGIS Pro 2.5.2 and ArcGIS Pro Intelligence was used to delineate HUC-14 local catchment boundaries and characteristics for the Site. Results identified fifteen local drainage areas. Each catchment was delineated to identify watershed characteristics, stream channels, surface water bodies, and any known hydraulic, stormwater, or sewer structures. Refer to Figure 3.1. Local Watershed Boundary.

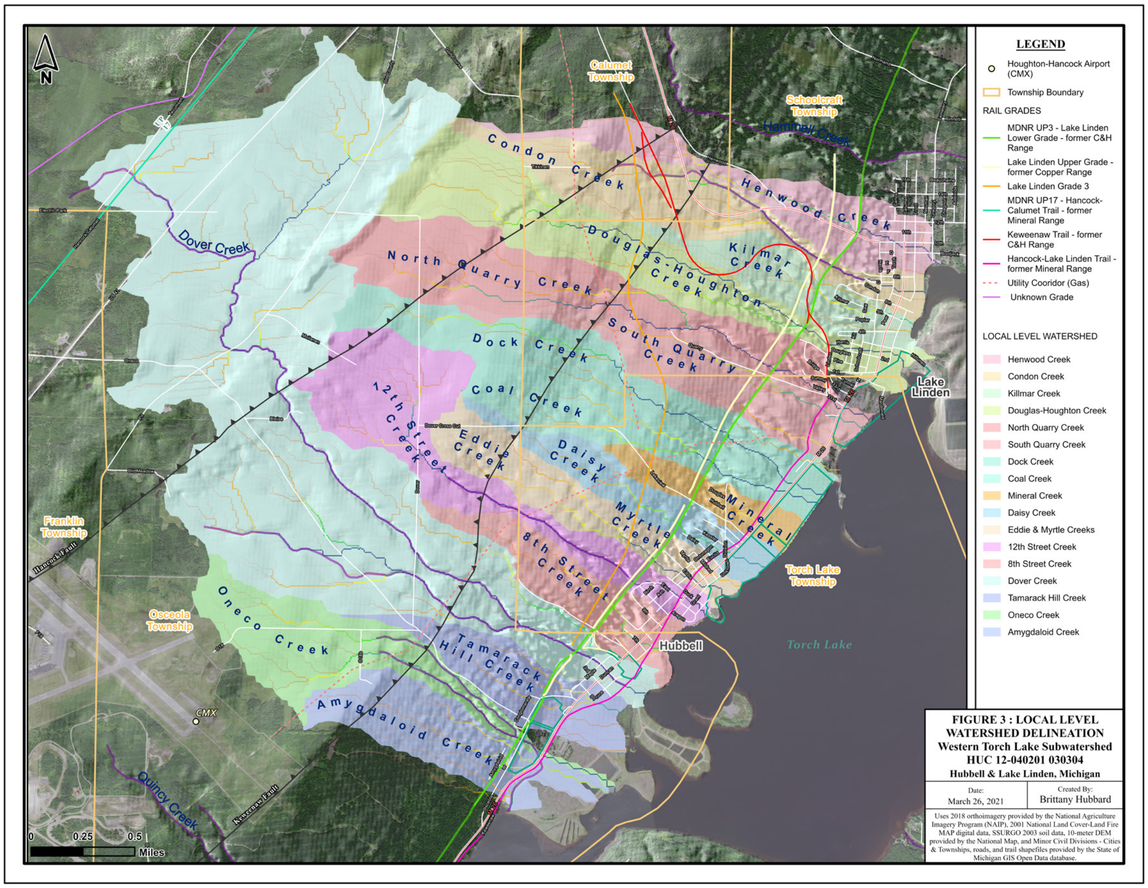

Figure 3.1. Local Watershed Boundary.

3.1 Procedure

The procedure within ArcGIS Pro to delineate the watershed was as follows: fill sinks to create depressionless DEM, create flow direction raster from filled DEM, use flow direction to create flow accumulation raster, create pour point (outlet shapefile), define and snap pour point, use flow direction and pour point to process the watershed, convert watershed raster to polygon shapefile, and finally calculate watershed parameters as described below.

The procedure for finding selected watershed characteristics of watershed slope, main channel slope, and main channel length were as follows: clip hydrography layers to watershed polygon, Extract by Mask the filled DEM by the watershed polygon, run Slope tool on the clipped DEM, select the main channel and export data (attribute table of this layer and Field Calculator is used to find main channel length), Extract by Mask the slope layer and main channel shapefile, convert this raster using INT tool, apply weighted values and calculate main channel slope using Field Calculator, convert slope raster layer using INT tool, and apply weighted values and calculate total watershed slope using Field Calculator. To estimate the hydraulic length of the watershed: a polyline was created extending from the farthest upstream point of the main channel to a point the maximum distance away on the watershed boundary, length was measured using calculate geometry, and added to the length of the main river channel.

The NRCS Curve Number (CN) method, and data from the National Land Cover Data (NLCD 2001) for Houghton County combined with soil data from the Soil Survey Geographic database (SSURGO), was used to determine a composite runoff curve number (RCN). RCN values for each watershed use a composite CN based on weighted CN values totaled for each soil / land use type. The procedure within ArcGIS Pro was as follows: project soil data to correct coordinate system, clip soil data to watershed, use Join to add necessary metadata to attribute table, project land cover data to correct coordinate system, clip land cover data to watershed, convert land use from raster file to polygon shapefile, intersect soil and land use data, join metadata to attribute table, compute area, percent total area, and partial RCN values using Calculate Geometry and Field Calculator.

A semi-distributed watershed model is used to further subdivide the local watershed into sub-basins to better approximate total watershed characteristics. Upper, middle, hillside, and lower regions roughly indicate how each local watershed would be subdivided into sub-basins using this method. Sub-basin 1 represents the wet upland region above the Hancock Fault. Sub-basin 2 represents shallow concentrated flows of the middle region approximately between the Hancock and Keweenaw Faults. Sub-basin 3 experiences channel flow in the steep hillside region between the Keweenaw Fault and developed floodplain below. Sub-basin 4 includes the urbanized lower region between the base of the hill and outlet at Torch Lake. Analyzing the watershed this way, in addition to soil and land use types, can provide better approximation of characteristics affecting composite RCN value and result in better estimates of potential runoff volumes.

3.2 Local Watershed Delineation

Numerous small tributaries drain the wet upland and have cut deep meandering gullies through the landscape. Four of fifteen local watersheds at the Site have a main stream identified by the National Hydrography data set [2]. This includes Dover creek and three unnamed perennial streams subsequently referred to as Oneco, 12th St., and Condon Creek. ArcGIS Pro flow accumulation analysis using a 10-meter DEM compared with Google Earth-WorldView high resolution aerial imagery from May 9, 2014 [15], pre-leaf out, during spring melt conditions and helicopter transect video of the June 17, 2018 Father's Day flood event, provided by the Michigan State Police and Michigan Emergency Management & Homeland Security Division (EMHS) [9], was used to identify fourteen additional main tributaries to Torch Lake (subsequently referred to as Amygdaloid, Tamarack Hill, 8th St., Eddie & Myrtle, Daisy, Mineral, Coal & Dock, Quarry (north & south), Douglas-Houghton, Kilmar and Henwood Creeks after the nearby infrastructure commonly damaged during flood events). Further investigation is needed to determine which of the small creeks are perennial or temporary and further classify as intermittent or ephemeral streams. Local watersheds are subsequently referred to by their main stream channels referenced above. The following section provides watershed characteristics specific to each local watershed. This information is summarized in Table A.1. Local Watershed Characteristics Summary contained in Appendix A.

Digital data sources utilized are as follows:

- 2013 National Elevation Dataset (NED) 10-meter digital elevation map (DEM), and National Hydrography Dataset (NHD) provided by the National Map [2],
- 2011 high resolution Orthoimagery and 2018 National Agriculture Initiative Program (NAIP) imagery provided by EarthExplorer [17],
- Shapefiles including: roads, village, census designated place, quaternary geology, and bedrock geology provided by the State of Michigan GIS Open Data [12],
- Aerial flood imagery of the 2018 Father's Day flood event provided by the Michigan State Police and State of Michigan Emergency Homeland Management Services [9],
- 2003 soils information for Houghton County from SSURGO database provided by the Web Soil Survey [11], and
- Flood incident locations along the upper and lower rail grade from the June 17, 2018, flood event, and hydraulic structure imagery provided by the Michigan Department of Natural Resources (MDNR) [10].

3.2.1 Amygdaloid Creek Watershed

Amygdaloid Creek Watershed resides entirely within Osceola Township encompassing 0.37 square miles east of Houghton-Hancock Airport (CMX) and west/southwest of Hubbell. The catchment is short in length and narrow in the hillside region between the Keweenaw fault and outlet at Torch Lake.

Drainage includes two main stream channels with several smaller flow paths. Multiple hydraulic structures, restored with a culvert post June 17, 2018, convey flow beneath the Rail Grade. Flow is channelized along Junction Rd. (Osceola Rd.) to route around the former Osceola and Lake Stamp Mill mining property. Stream channels converge downgrade of Junction Road then enter a road-side swale to await passage under M-26 via a culvert to outlet into a weir controlled retention pond and into Torch Lake. Two surface bodies exist in the upper reaches of the watershed.

The weighted average main stream channel slope for the hillside and lower regions, and local watershed are 8.8, 11.0, and 9.2 percent rise, respectively. The approximate length of the main stream channel is 0.70 miles. The approximate hydraulic length of the catchment area is 1.10 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 4.0, 8.8, 4.7 and 6.9 percent rise, respectively.

Amygdaloid Creek local watershed ranges from 602 feet to 1045 feet mean surface elevation (MSL). The primary hydrologic soil type is B in the middle and hillside region. Stamp sands (A/SS) dominate the lower region. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use is primarily coniferous and northern hardwood in the middle and hillside regions, but the lower region is predominantly residential, barren, and impervious surfaces. The weighted average RCN for the local watershed is 66. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 61, 62, and 79, respectively.

Refer to Figure 3.2: Amygdaloid Creek Local Watershed Characteristics, Figure 3.1: Local Watershed Boundary, Figure 2.3: Site Elevation, Figure 4.1: Amygdaloid Creek Drainage and LID, and Table A.1: Local Watershed Characteristics for details.

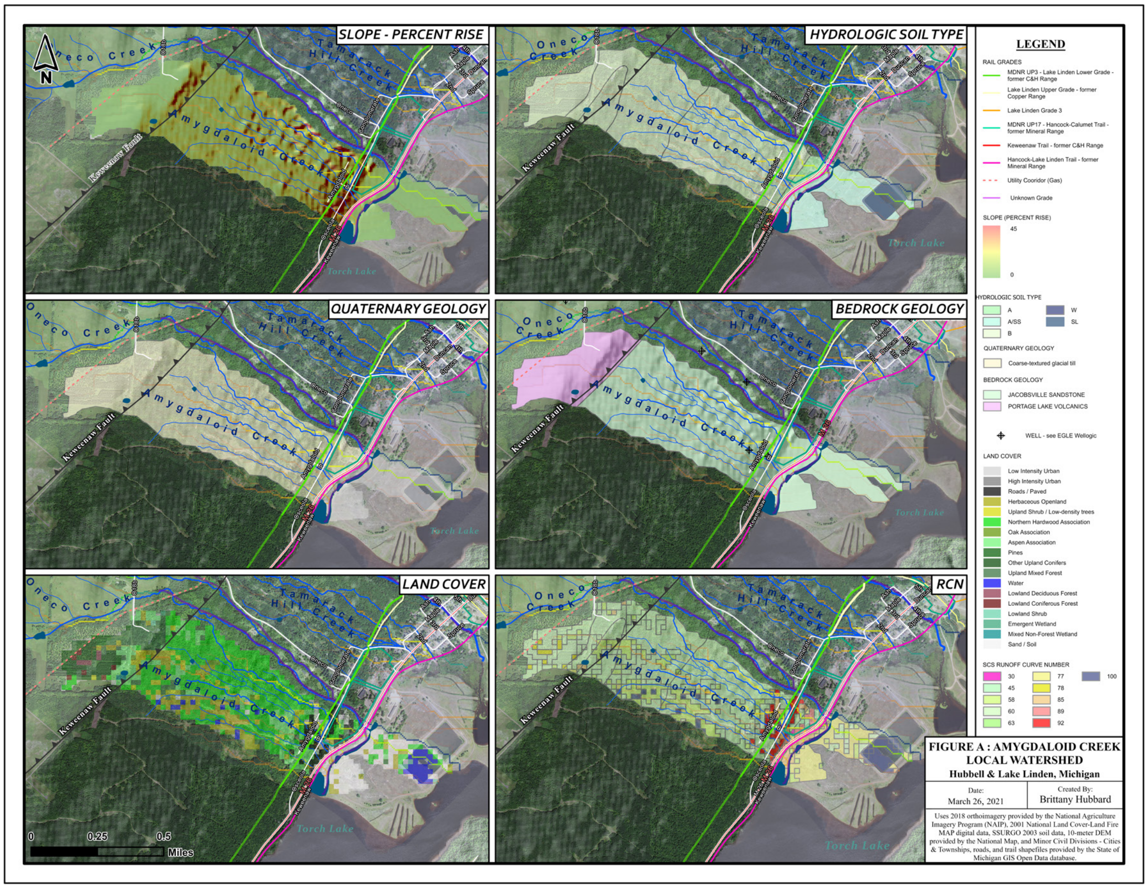

Figure 3.2. Amygdaloid Creek Local Watershed Characteristics.

3.2.2 Oneco Creek Watershed

Oneco Creek Watershed resides entirely within Osceola Township encompassing an area 0.5 square miles east of Houghton-Hancock Airport (CMX) and west/southwest of Hubbell. The catchment is wide in the middle region above the Keweenaw fault and narrow in the hillside region between the Keweenaw fault and Rail Grade below.

Drainage in the middle region is heavily channelized for agriculture and the nearby airport. Oneco Creek catchment includes two main stream channels that parallel Oneco Road. Flow descends the steep hillside, elevation change of approximately 150 feet, to confluence upstream from the Rail Grade. Restored post June 17, 2018, flood event, a culvert conveys flow beneath the Rail Grade and Junction Rd (Osceola Rd.). Downstream from Junction Rd. the outlet has been significantly altered from the natural hydrology due to historical copper mining era operations. The stream uses a man-made open-channel to pass through the former Osceola and Lake Stamp Mill mining property, a culvert to bypass M-26, and a series of three retention ponds before reaching the outlet at Torch Lake. Two surface water bodies exist in the middle region that appear to be storage ponds for agriculture and may contribute to flow control (culvert controlled).

The weighted average main stream channel slope for the middle, hillside, lower regions, and local watershed are 7.3, 15.9, 10.8, and 13.7 percent rise, respectively. The approximate length of the main stream channel is 1.00 mile. The approximate hydraulic length of the catchment area is 2.32 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 1.8, 17.4, 5.0, and 4.4 percent rise, respectively.

Oneco Creek local watershed ranges from 602 feet to 1084 feet MSL. The primary hydrologic soil type is B with an area of soil type C found in the northwestern portion of the watershed boundary. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use is primarily herbaceous, deciduous forest, and barren in the middle, hillside, and lower watershed regions, respectively. The weighted average RCN for the local watershed is 67. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 67, 62, and 80, respectively.

Refer to Figure 3.3: Oneco Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.6: Oneco Creek Drainage & LID, and Table A.1 for details.

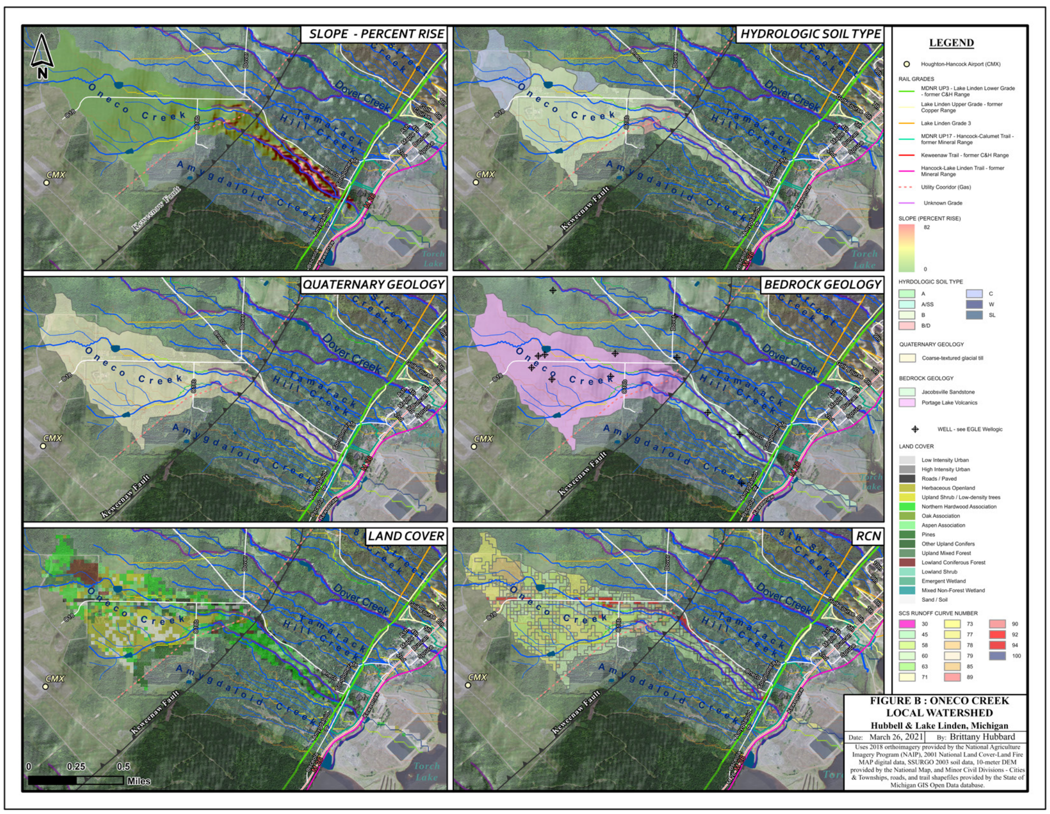

Figure 3.3. Oneco Creek Local Watershed Characteristics.

3.2.3 Tamarack Hill Creek Watershed

Tamarack Hill Creek Watershed resides entirely within Osceola Township encompassing 0.48 square miles east of Houghton-Hancock Airport (CMX) and west/southwest of Hubbell. The catchment is short in length and narrow in the hillside region between the Keweenaw fault and outlet at Torch Lake.

Drainage in Tamarack Creek catchment includes several smaller stream channels that converge upstream from a culvert at the intersection of Tamarack Hill Rd. with Maple Road. Several hydraulic structures, restored or naturalized post June 17, 2018, flood event, convey flow beneath the Rail Grade. Impeded by Tamarack Hill Rd, drainage is routed around the former Tamarack Stamp Mill property and through an open channel with a series of four culverts to bypass Maple Rd., M-26, Spruce St., and the Hancock-Lake Linden Trail grade to outlet into Torch Lake. One surface water body exist in the hillside region.

The weighted average main stream channel slope for the middle, hillside, lower region, and local watershed are 6.4, 9.7, 6.5, and 8.5 percent rise, respectively. The approximate length of the main stream channel is 0.92 miles. The approximate hydraulic length of the catchment area is 1.37 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 4.0, 10.2, 5.2 and 7.6 percent rise, respectively.

Tamarack Hill Creek local watershed ranges from 602 feet to 1041 feet MSL. The primary hydrologic soil type is B. Soil Type A and stamp sands (A/SS) dominate the lower region. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use is primarily Northern Hardwood in the middle and hillside regions, and barren or residential in the lower watershed regions. The weighted average RCN for the local watershed is 69. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 71, 64, and 65, respectively.

Refer to Figure 3.4: Tamarack Hill Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.7: Tamarack Hill Creek Drainage and LID, and Table A.1 for details.

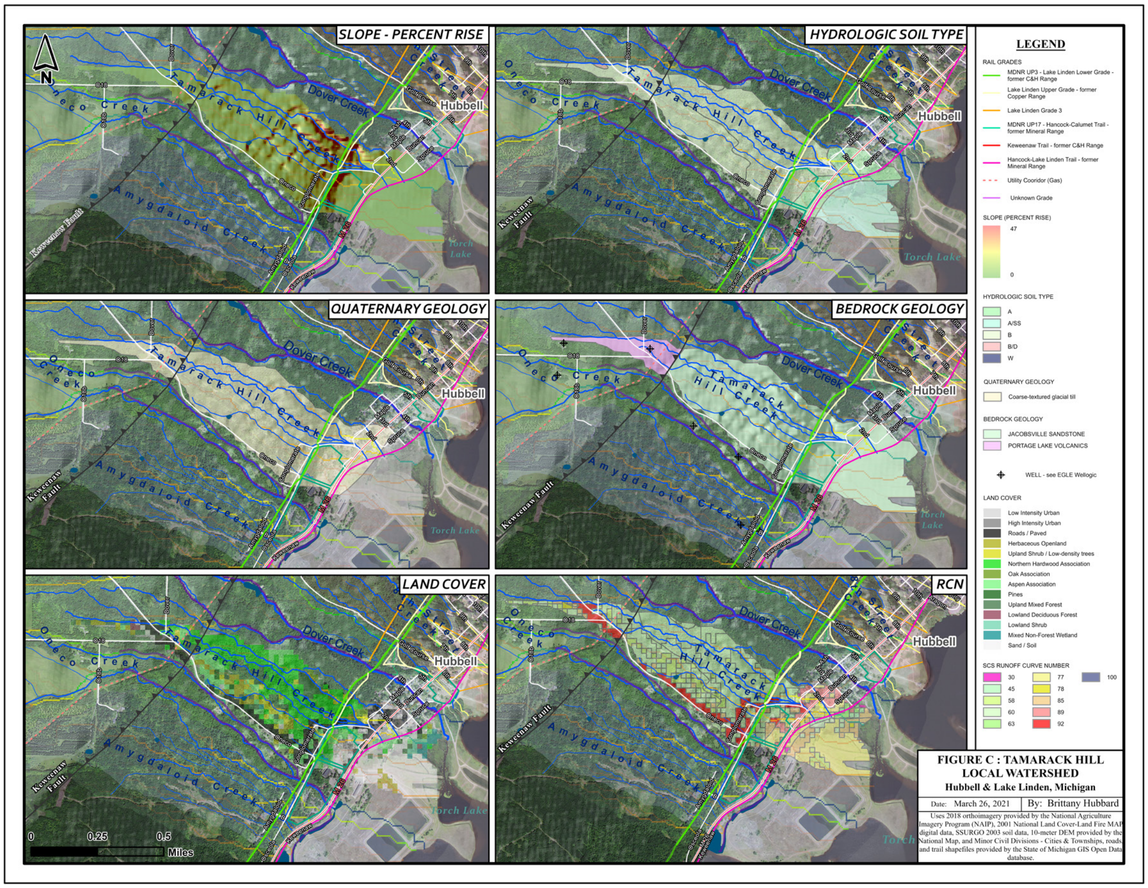

Figure 3.4. Tamarack Hill Creek Local Watershed Characteristics.

3.2.4 Dover Creek Watershed

Dover Creek Watershed is primarily within Osceola Township but enters into Torch Lake Township along Golf Course Road near the Keweenaw Land Trust's (KLT) Hungarian Falls Nature Area. Encompassing 3 square miles, this is the Site's largest and most diverse watershed. Dover Creek watershed is boomerang in shape - wide in the upper and middle regions of the watershed to constrict sharply in hillside and lower regions. Elevation ranges from 602 feet to 1222.70 feet MSL.

Significant alterations to the hydrology of this area have occurred historically due to mining era infrastructure and currently due to surface water, agricultural and stormwater management infrastructure. The National Map HUC-12 watershed boundary, refer to Figure 2, suggest this watershed includes Swedetown and a portion of Calumet and Laurium. Surface and stormwater from Swedetown and vicinity are retained in a series of surface water bodies before draining into an expansive wetland system in the upland between the headwaters of Gooseneck, Dover, and Hammel Creeks. Flow accumulation analysis in ArcGIS Pro suggests this wetland system drains south into the neighboring watershed to join Gooseneck Creek. Visual analysis using USGS high resolution aerial

imagery suggests portions of this wetland system are connected to Hammel Creek. Therefore, upper portions of this watershed need further delineation to determine an accurate boundary which reflect current surface hydrologic conditions. For this flood analysis, the ArcGIS Pro delineated boundary is used to assess Dover Creek watershed conditions and it is assumed the majority of drainage from the wetland system does outlet via Gooseneck and Hammel Creeks as suggested by flow accumulation and aerial imagery analysis.

Drainage in Dover Creek catchment includes a main stream channel and a major tributary that confluence near the middle/lower Hungarian Falls, and a minor tributary that has been altered historically from mining activities to enter the storm water drainage system between Fifth and Sixth streets in Hubbell. Upper portions of the watershed, above the Hancock Fault, may include much of the connected wetland system outside the delineated boundary. Stream flow must traverse two fault lines, the Hancock and Keweenaw Faults, dropping 190 feet before reaching the channelized outlet at Torch Lake. Flowing from northwest to southeast, the creek descends Hungarian Falls, including the upper falls, a reservoir (constructed by the Ahmeek Mining Company off Golf Course Road [18]), a check dam providing flow control, the middle falls, and the lower falls, dropping approximately one-hundred feet collectively. This popular hiking area, known as Hungarian Falls Nature Area, is managed by the KLT and MDNR. Several hydraulic structures, restored or naturalized post June 17, 2018, flood event, convey flow beneath the Rail Grade. Dover Creek uses a rectangular open-channel made of brick/concrete and series of four culverts to bypass Maple Rd., M-26, Spruce St., and the Hancock-Lake Linden Trail grade to outlet into Torch Lake.

The weighted average main stream channel slope for the upper, middle, hillside, and lower regions and the local watershed are 1.0, 6.1, 19.6, 3.8, and 5.5 percent rise, respectively. The approximate length of the main stream channel is 4.54 miles. The approximate hydraulic length of the catchment area is 4.54 miles. The weighted average land slope for the upper, middle, hillside, lower regions, and for the local watershed are 1.6, 3.5, 17.0, 7.0, and 3.4 percent rise, respectively.

Upper regions of the watershed, above the Hancock Fault, primarily contain soils that are not well draining including hydrologic groups C, B, A/D, D, and wetland areas with ponded surface water. Middle regions also primarily contain B, C, and B/D soils. Hillside portions of the watershed, where the greatest elevation changes occur, are primarily B type soils. Lower regions consist mostly of well-drained type A soils with areas of stamp sand existing along the shoreline of Torch Lake. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use in the upper, middle and hillside regions of the watershed consist primarily of emergent wetlands, Northern Hardwood, and Coniferous or Aspen/White Birch, respectively. Land use is primarily barren, residential, or impervious in the highly developed lower region. The weighted average RCN for the local watershed is 69.

Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 71, 64, and 65, respectively.

Refer to Figure 3.5. Dover Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.11. Dover Creek Drainage and LID, and Table A.1 for details.

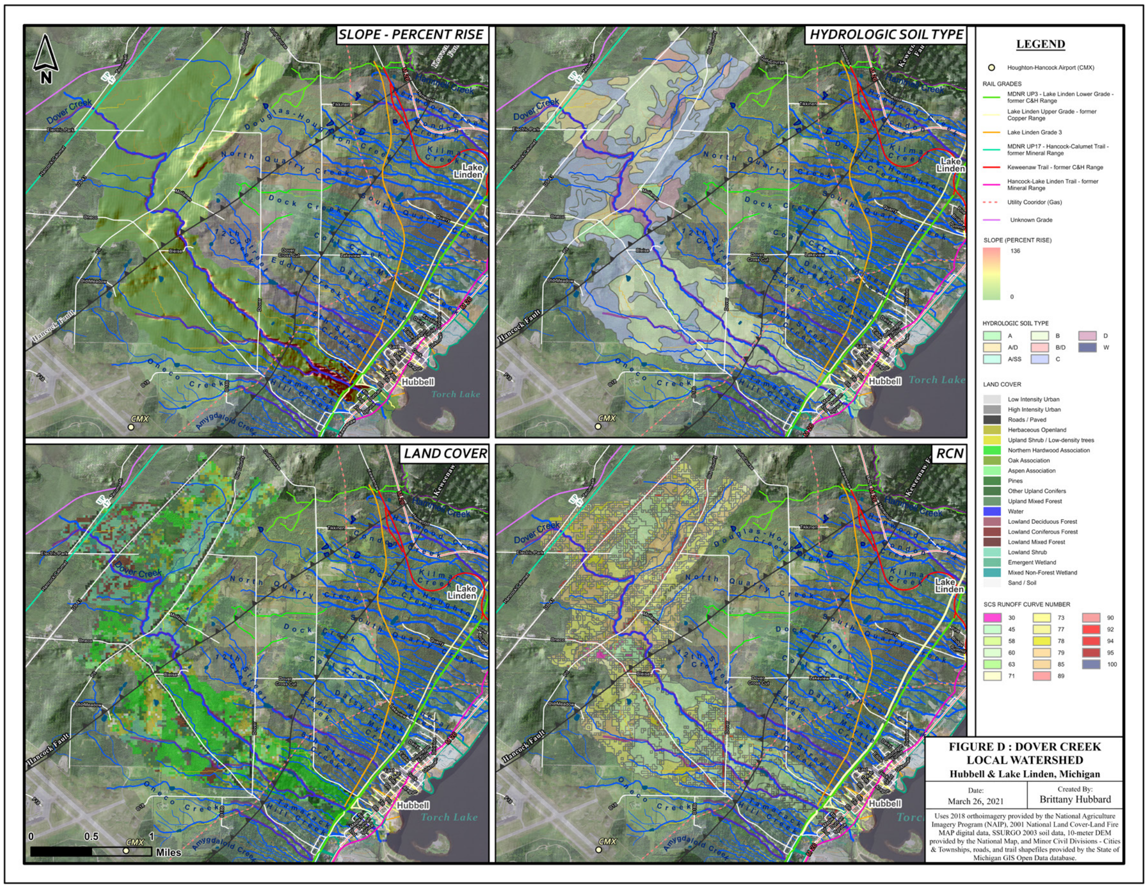

Figure 3.5. Dover Creek Local Watershed Characteristics.

3.2.5 8th St. Creek Watershed

8th Street Creek Watershed resides mostly within Torch Lake Township but shares territory with Osceola Township in its middle and lower reaches. The catchment is long and narrow encompassing an area 0.30 square miles east/northeast of Houghton-Hancock Airport (CMX) and west/northwest of Hubbell. Historically, the Ahmeek Stamp Mill operated nearby and within the floodplain.

The steep ravined landscape fractures this watershed into small flow accumulation zones that can produce significant flow during large rainstorm events. A potentially overlooked creek, 8th Street creek, passes through the upper and lower Rail Grade before entering a

stormwater drain at the NW end of W. 8th Street. The stream is buried beneath 8th Street all the way to the outlet at Torch Lake. This watershed had nine historical mining era culverts naturalized along upper and lower Rail Grade trails by the June 17, 2018, flood event. No surface water bodies are present within this catchment.

The weighted average main stream channel slope is 10.0 percent rise. The approximate length of the main stream channel is 1.15 miles. The approximate hydraulic length of the catchment area is 1.44 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 4.0, 9.6, 10.1, and 9.3 percent rise, respectively.

8th Street Creek local watershed ranges from 602 feet to 1056 feet MSL. The primary hydrologic soil type is B covering the middle and hillside regions. Soil Type A, B, and stamp sands dominate the lower region. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use is primarily northern hardwood in the middle and hillside regions, but the predominant land use in the lower region is residential, northern hardwood, and barren. Twenty-eight percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 65. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 60, 61, and 74, respectively.

Refer to Figure 3.6. 8th St. Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.16. 8th St. Creek Drainage and LID, and Table A.1 for details.

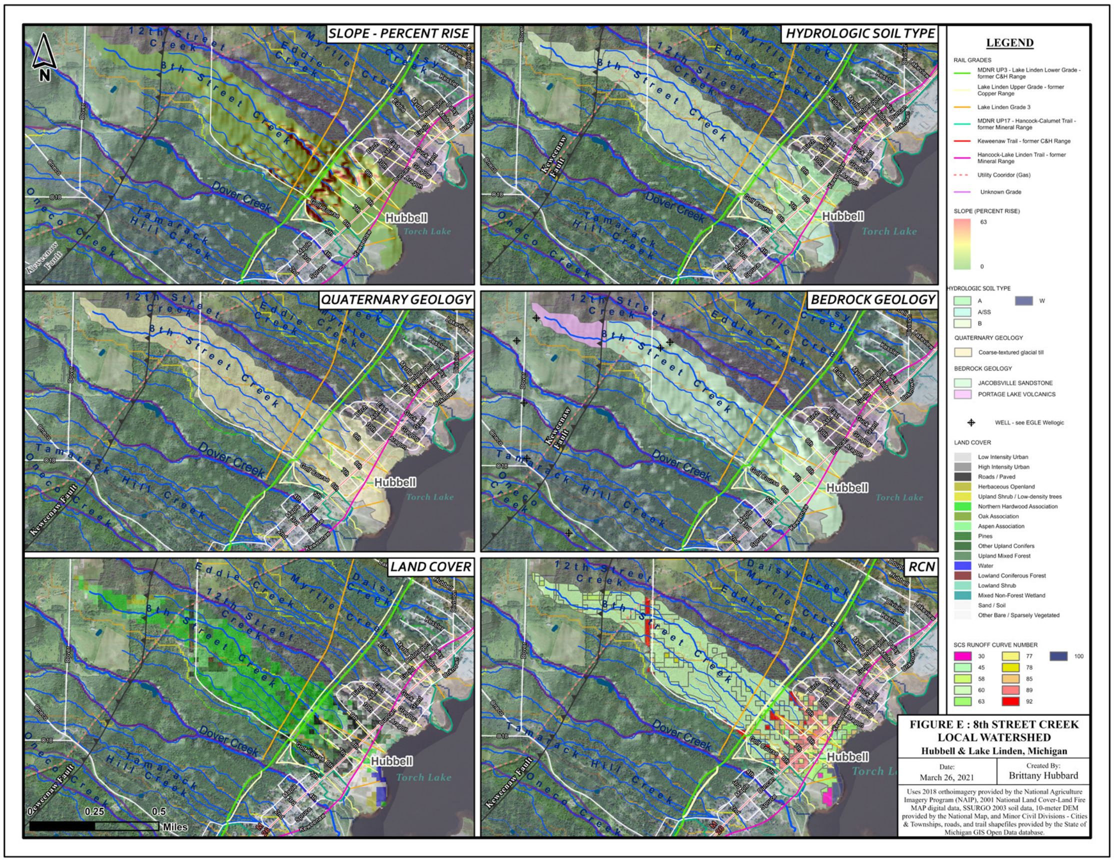

Figure 3.6. 8th St. Creek Local Watershed Characteristics.

3.2.6 12th St. Creek Watershed

12th St. Creek Watershed encompasses 0.58 square miles between Osceola and Torch Lake Townships. The catchment is wide near the Hancock Fault narrowing sharply across the Keweenaw Fault down the hillside, parallel to 12th street, to outlet at Torch Lake.

Drainage in the upper region has been altered to accommodate agriculture. Flow from the upper watershed accumulates in a reservoir located at the top of the hill above the Keweenaw Fault. The stream flows from the reservoir down the hillside through the Rail Grade disappearing above W.12th street (G Ave.) into a drain where it remains buried beneath the roadways in the stormwater system until reaching the outlet into Torch Lake near the Hubbell Park boat launch. During the Father's Day Flood, six mining era culverts failed along the Rail Grade in this watershed. Three surface water bodies exist; the reservoir located at the top of the hill just above the Keweenaw Fault and two ponds in upper reaches of the watershed.

The weighted average main stream channel slope for the middle and hillside regions, and local watershed are 6.7, 12.2, and 11.2 percent rise, respectively. The approximate length

of the main stream channel is 1.51 miles. The approximate hydraulic length of the catchment area is 3.54 miles. The weighted average land slope for the upper, middle, hillside, and lower regions, and for the local watershed are 3.4, 3.0, 13.3, 8.0, and 5.5 percent rise, respectively.

12th Street Creek local watershed ranges from 602 feet to 1200 feet MSL. Upper and middle regions primarily have poorly drained to somewhat well drained hydrologic type D, C and B soils. Hillside and lower regions consist of well drained type B, A and A/SS soils, respectively. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use is mostly herbaceous and mixed deciduous forest with highly developed urban areas in the lower region. Fifty-two percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 65. Subdivided into upper, middle, hillside, and lower regions, the weighted average RCN becomes 77, 64, 61, and 79, respectively.

Refer to Figure 3.7. 12th St. Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.24. 12th St. Creek Drainage and LID, and Table A.1 for details.

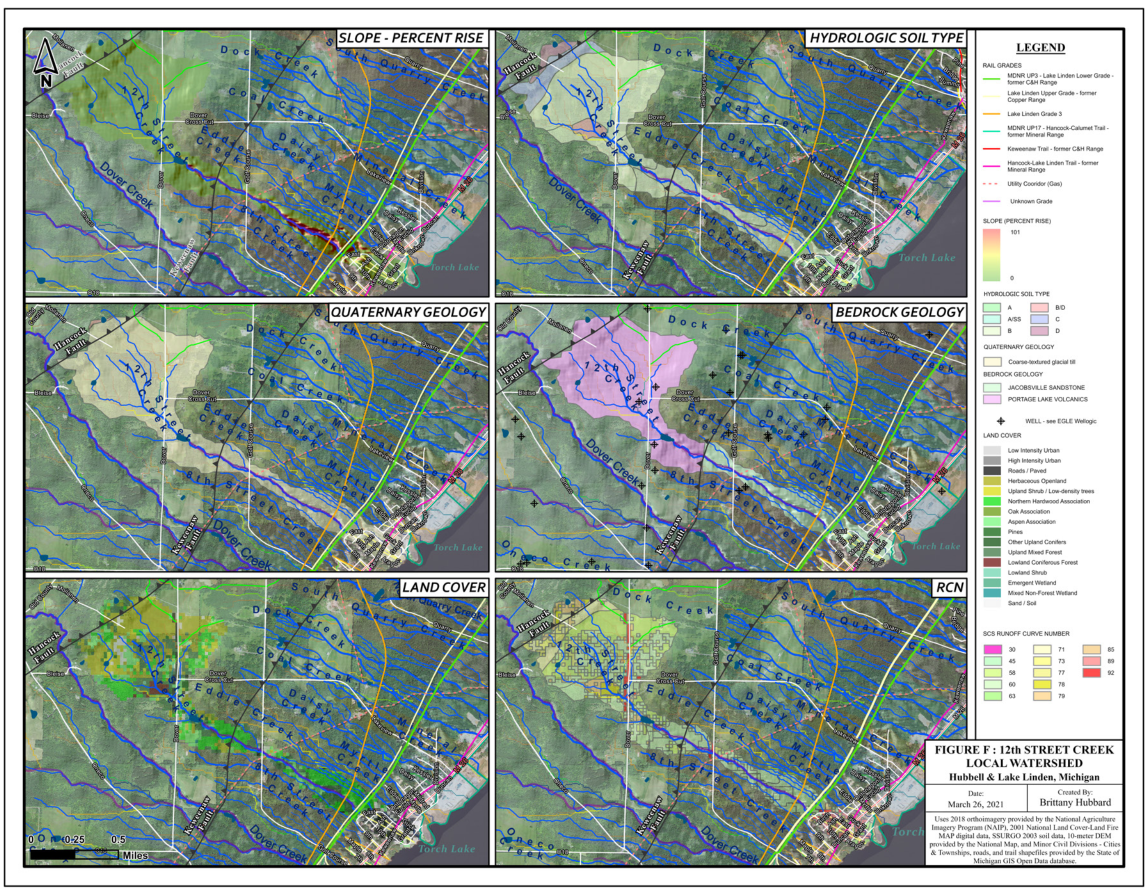

Figure 3.7. 12th St. Creek Local Watershed Characteristics.

3.2.7 Eddie & Myrtle Creek Watershed

Eddie & Myrtle Creeks Watershed covers 0.58 square miles between Torch Lake Township and Osceola Township northeast of Houghton-Hancock Airport (CMX) and north/northwest of Hubbell. The catchment is long and narrow ranging in elevation from 602 feet to 1121 feet MSL.

Drainage from Eddie Creek, the main stream channel, extends from the middle region near Dover Cross Cut (Lakeview Rd.) above the Keweenaw Fault, down the steep hillside, through the Rail Grade, and enters a drain into the stormwater system upstream of Ontonagon Ave. between Guck St. and Eddie Street. Drainage from Myrtle Creek, the secondary main stream channel, extends from the middle of the hillside region near the gas utility corridor, down the steep hillside, through the Rail Grade, and enters a drain into the stormwater system upstream of Ontonagon Ave. between Eddie and Myrtle streets. Both stream channels share a common floodplain but remain buried beneath the roadways until reaching the outlet at Torch Lake near the southwest end of 15^{th} Street. Six mining era culverts existed in the MDNR UP3 Trail (Rail Grade) in this watershed. Five structures have been naturalized and one restored with a culvert post June 17, 2018, flood event. No surface water bodies are present within this catchment.

The weighted average main stream channel slope for the middle, hillside, lower regions, and local watershed are 5.0, 7.5, 9.5, and 7.5 percent rise, respectively. The approximate length of the main stream channel is 1.25 miles. The approximate hydraulic length of the catchment area is 1.80 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 5.8, 6.6, 8.7, and 6.8 percent rise, respectively.

Hydrologic group B soils dominate the middle and hillside regions of the watershed whereas high runoff urban areas present at the bottom of the hill near the outlet mainly consist of A, B, and stamp sand soil types. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Dominant land use is northern hardwood, Aspen/White Birch, and coniferous in middle and hillside regions. The highly developed lower region is mostly barren, residential, or forested. Forty percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 64. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 60, 61, and 77, respectively.

Refer below to Figure 3.8. Eddie & Myrtle Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.27. Eddie & Myrtle Creek Drainage and LID, and Table A.1 for details.

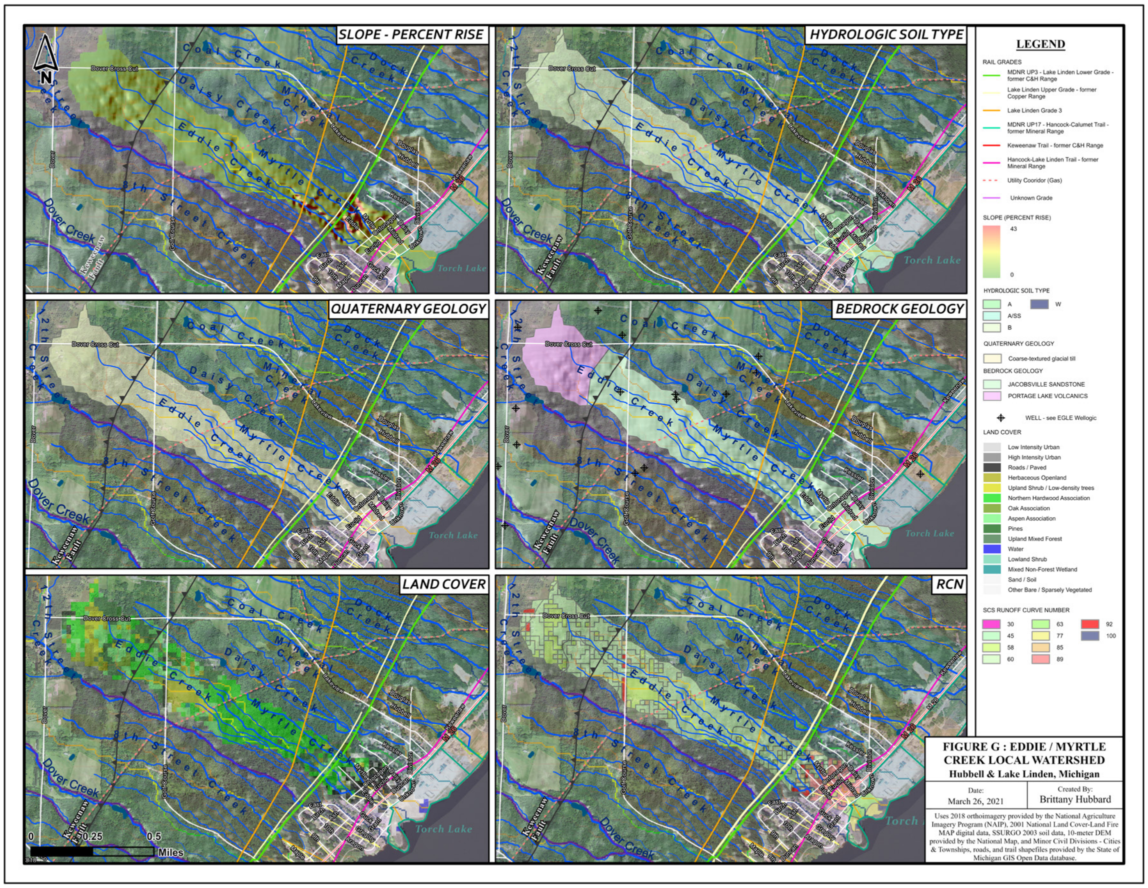

Figure 3.8. Eddie & Myrtle Creek Local Watershed Characteristics.

3.2.8 Daisy Creek Watershed

Daisy Creek Watershed is primarily in Torch Lake Township with a small area above the Keweenaw Fault in Osceola Township. The shape is long and narrow covering an area of 0.46 square miles south from Lakeview Road.

Drainage in Daisy Creek catchment is heavily dissected by a gas utility corridor, Lake Linden Grade 3, and the upper and lower Rail Grades. Several smaller stream channels converge at the gas utility corridor indicating a need for drainage assessment at this intersection. Aerial imagery shows ponding upstream from Lake Linden Grade 3. Six mining era hydraulic structures in the Rail Grade have been naturalized post June 17, 2018, flood event. Tributaries converge with the main stream channel downstream from the Rail Grade in a small retention pond before entering the stormwater system up-grade from the intersection of W 19th St. with Division Ave. (L Ave.) between Kessler (W. 18th) and W. 20th streets. Downstream from M26 the outlet has been significantly altered from the natural hydrology by historical copper mining era operations. The former

Calumet and Hecla (C&H) Smelting and Refining industrial property occupies the floodplain impeding the outlet to Torch Lake. The stream remains buried in the stormwater system, routed south around the former mining site, to outlet at the southeast end of W. 15th St where Eddie and Myrtle creeks also outlet. A reservoir exists below the Keweenaw Fault up-grade from the gas utility corridor at the top of the hillside.

The weighted average main stream channel slope for the hillside and lower regions, and for the local watershed are 6.1, 7.4, and 6.3 percent rise, respectively. The approximate length of the main stream channel is 1.15 miles. The approximate hydraulic length of the catchment area is 1.45 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 6.6, 6.8, 7.8, and 7.1 percent rise, respectively.

Daisy Creek local watershed ranges from 602 feet to 1019 feet MSL. The predominant hydrologic soil group is type B in the middle and hillside regions. Developed urban areas in the lower region consist of soil type A, stamp sands, and excavated earthen fill material mostly from the mining era. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. The main land use in the middle and hillside region is northern hardwood, Aspen/White Birch, and coniferous mixed forest. The developed land of the lower region, including the former C&H industrial property, is primarily barren or residential. Thirty-two percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 66. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 64, 61, and 74, respectively.

Refer to Figure 3.9. Daisy Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.29. Daisy Creek Drainage and LID, and Table A.1 for details.

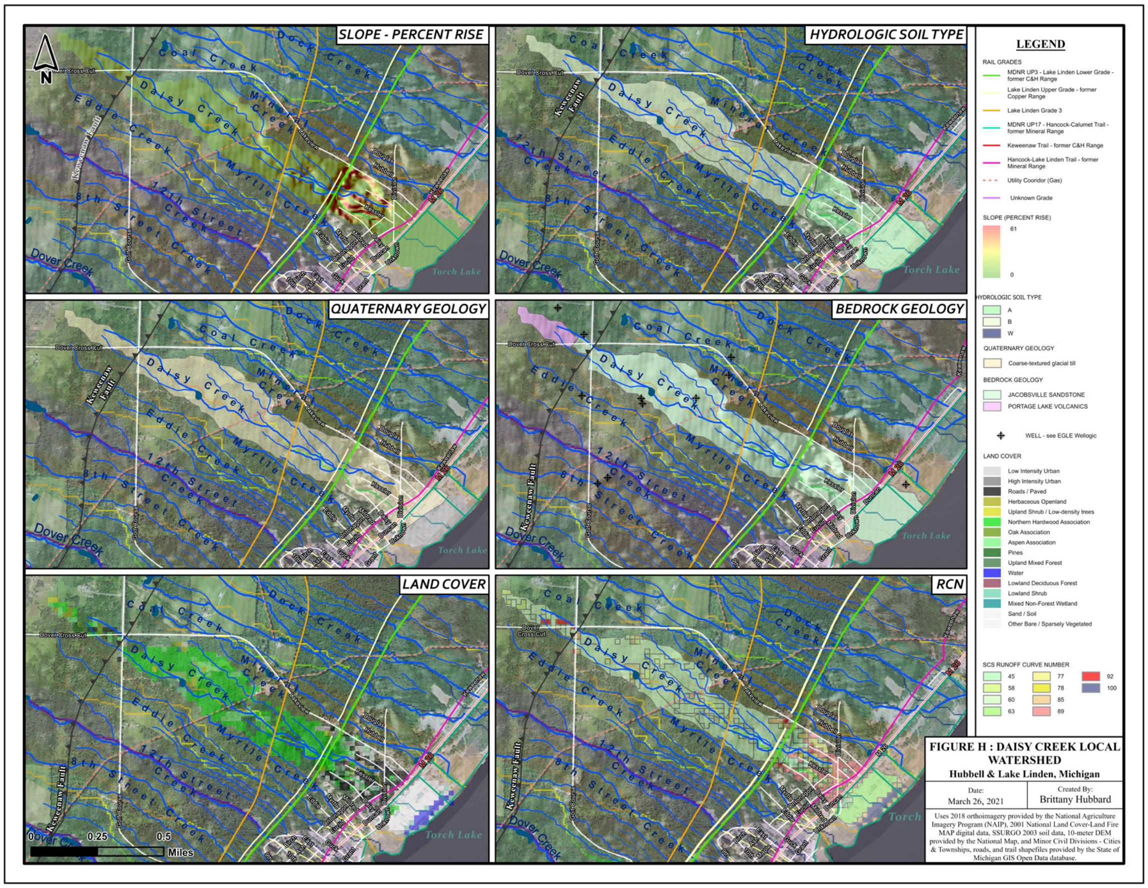

Figure 3.9. Daisy Creek Local Watershed Characteristics.

3.2.9 Mineral Creek Watershed

Mineral Creek Watershed in Torch Lake Township is long and narrow covering an area of 0.15 square miles north of Lakeview Rd. in Hubbell. Mineral Creek has two main stream channels that descend the steep hillside to confluence downstream from Division Avenue. A small surface water body provides some ponding storage upstream from M-26. A culvert coneys flow beneath M-26 and into an open channel drainage ditch on the former C& H industrial property, immediately northeast of the Mineral Building, to discharge at Torch Lake. Two hydraulic structures failed at the Rail Grade; one culvert was restored post June 17, 2018, flood event. Two surface water bodies exist above Lake Linden Grade 3, one north and one south of Lakeview Rd. In addition, a portion of the drainage area from north neighboring Coal Creek Watershed is heavily channelized for agriculture and is routed into Mineral Creek Watershed. This includes a storage pond that may contribute to flow control.

The weighted average main stream channel slope for the hillside and lower regions, and local watershed are 11.9, 4.1, and 6.2 percent rise, respectively. The approximate length of the main stream channel is 1.30 miles. The approximate hydraulic length of the catchment area is 1.05 miles. The weighted average land slope for the hillside and lower regions, and for the local watershed are 9.4, 7.1, and 8.0 percent rise, respectively.

Mineral Creek local watershed ranges from 602 feet to 942 feet MSL. The main hydrologic soil group is type B in the hillside region. Developed urban areas in the lower region consist of soil type A and stamp sands. Bedrock geology is Jacobsville Sandstone and quaternary geology is primarily coarse-textured glacial till. Land use is primarily northern hardwood, barren, and residential. Twenty-one percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 68. Subdivided into hillside and lower regions, the weighted average RCN becomes 64 and 70, respectively.

Refer to Figure 3.10. Mineral Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.30. Mineral Creek Drainage and LID, and Table A.1 for details.

Figure 3.10. Mineral Creek Local Watershed Characteristics.

3.2.10 Coal Creek Watershed

Coal Creek Watershed resides in Torch Lake, Osceola, and Schoolcraft Townships encompassing an area of 0.32 square miles northeast of Houghton-Hancock Airport (CMX), north of Hubbell, and south of Lake Linden. The catchment is long and narrow extending from the middle region above the Keweenaw fault to Torch Lake below.

Drainage in the middle and upper hillside regions is heavily channelized for agriculture. Two main stream channels descend the steep hillside to confluence near the Rail Grade. Downstream flow is channelized between Ziemnick Excavating Inc. and a warehouse on the south and north, respectively. A culvert conveys flow beneath M-26 and into an open channel drainage ditch, through the former C&H Coal Docks industrial property, routing the stream around contaminated mining sediments that impede the outlet to the lake shore. Four hydraulic structures failed at the Rail Grade, three were restored with a culvert and one was naturalized post 2018 flooding. Three surface water bodies exist: one reservoir in the middle region above the Keweenaw Fault, one reservoir in the hillside region assumed to provide flow control downstream (north of Lakeview Rd. upstream from the Lake Linden Grade 3), and one storage pond or agricultural reservoir that appears to route drainage into south neighboring Mineral Creek Watershed. In addition, a portion of the drainage area from north neighboring Dock Creek Watershed is heavily channelized for agriculture and drainage appears to be connected to Coal Creek watershed.

The weighted average main stream channel slope for the middle, hillside, lower regions, and for the local watershed are 7.1, 7.1, 5.5 and 6.5 percent rise, respectively. The approximate length of the main stream channel is 1.60 miles. The approximate hydraulic length of the catchment area is 1.90 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 6.2, 6.5, 8.8, and 6.8 percent rise, respectively.

Coal Creek local watershed ranges from 602 feet to 1123 feet MSL. The primary hydrologic soil type is B in the middle and hillside regions, with hydrologic group A soils and stamp sands found in the lowland and shoreline floodplain regions. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use is predominantly northern hardwood, Aspen/White Birch, and coniferous mixed forest. The lower outlet region is developed including residential, barren land, and was used historically as the Hubbell Processing Area and Coal Docks for C & H mining operations (now recovering forest with some exposed stamp sands). The weighted average RCN for the local watershed is 64. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 64, 63, 86, respectively.

Refer to Figure 3.11. Coal Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.40. Coal & Dock Creek Drainage and LID, and Table A.1 for details.

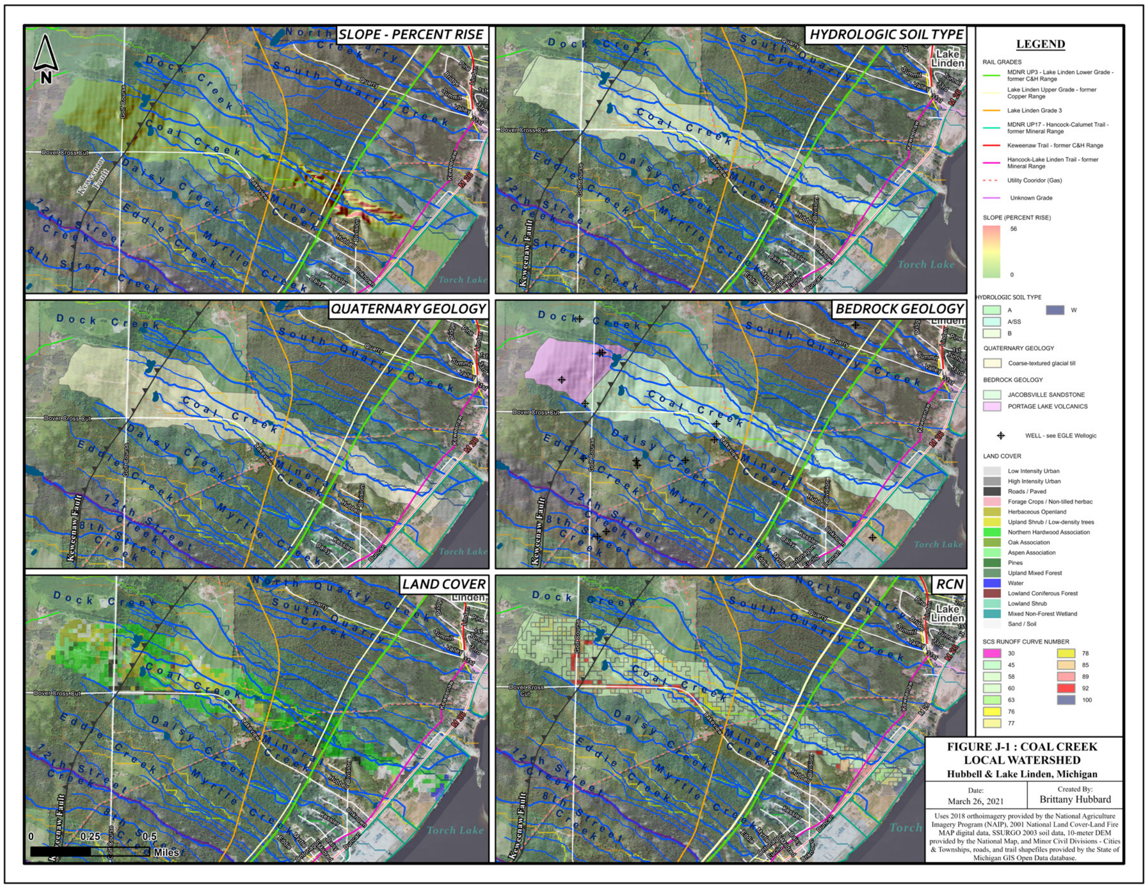

Figure 3.11. Coal Creek Local Watershed Characteristics.

3.2.11 Dock Creek Watershed

Dock Creek Watershed encompasses an area of 0.92 square miles between Torch Lake, Osceola, and Schoolcraft Townships. Long and narrow in shape, this catchment extends from above the Hancock Fault, east across the Keweenaw Fault, narrowing down the hill past the rail grade, and contracting further at urban areas to outlet into Torch Lake.

Land channelized for agriculture, just downgrade from the Hancock and Keweenaw Faults, creates several smaller diverging braided stream channels at the outlet of the property where a tributary, main channel, and gas utility corridor intersect. Most of the flow paths converge to the main channel downstream from Lake Linden Grade 3, but several flow paths have established less energy intensive routes down the hillside and remain disconnected from the main channel. These formed channels contribute to wash outs along the Rail Grade below, and potentially, ponding and erosion of the barren land up-grade from the warehouse north from Ziemnick Excavating. The main stream channel intersects with the Rail Grade in close proximity to the gas utility corridor. The Rail

Grade has an impoundment and six failed mining hydraulic structures of which two were restored and the others naturalized. A stormwater inlet (SWInletLakeLMAve [10]), located northeast from the warehouse and up-grade from M-26, delivers discharge to the open channel drainage ditch that conveys flow to the outlet at Torch Lake through the former C&H Coal Docks industrial property to bypass contaminated soils. In 2016, "drainage ditch clean-out was conducted on the former Coal Dock property in the Hubbell Processing Area in order to allow for rain and snow-melt to flow along the original drainage ditch paths across the property and to avoid erosion of the PCB-containing wastes and contaminated soil into Torch Lake"... "In 2017 IR actions were undertaken at the Hubbell Coal Dock property, including:

- Capping of approximately 7-acres of PCB-contaminated soils to stop water and wind erosion and inhibit direct contact with;
- Replacement of approximately 170 feet of failing culverts;
- Improvement and armoring of 750 feet of drainage ditch
- Removal and disposal of 320 pounds of ACBM and one drum of PCB-contaminated RPM; and,
- Removal and disposal of 118 tons of hazardous waste soil contaminated with PCBs and lead." [16].

The weighted average main stream channel slope for the upper, middle, hillside, lower regions, and for the local watershed are 1.9, 3.1, 7.0, 4.6, and 4.9, respectively. The approximate length of the main stream channel is 1.25 miles. The approximate hydraulic length of the catchment area is 2.67 miles. The weighted average land slope for the upper, middle, hillside, and lower regions, and for the local watershed are 2.0, 3.6, 6.8, 6.2, and 5.0 percent rise, respectively.

Dock Creek local watershed ranges from 602 feet to 1084 feet MSL. One surface water body is visible within the forested area east of Golf Course Rd above the Keweenaw Fault. Primary hydrologic soil group is C, B, B and A, A/SS in the upper, middle, hillside, and lower regions, respectively. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till below with areas of thin to discontinuous glacial till over bedrock above the Hancock Fault. Deciduous and evergreen forest cover the steep hillside. The mostly forested lower region includes the former Coal Dock property, a large barren land surface, and residential developed areas. The weighted average RCN for the local watershed is 64. Subdivided into upper, middle, hillside, and lower regions, the weighted average RCN becomes 75, 63, 60, and 64, respectively.

Refer to Figure 3.12. Dock Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.40. Coal & Dock Creek Drainage and LID, and Table A.1 for details.

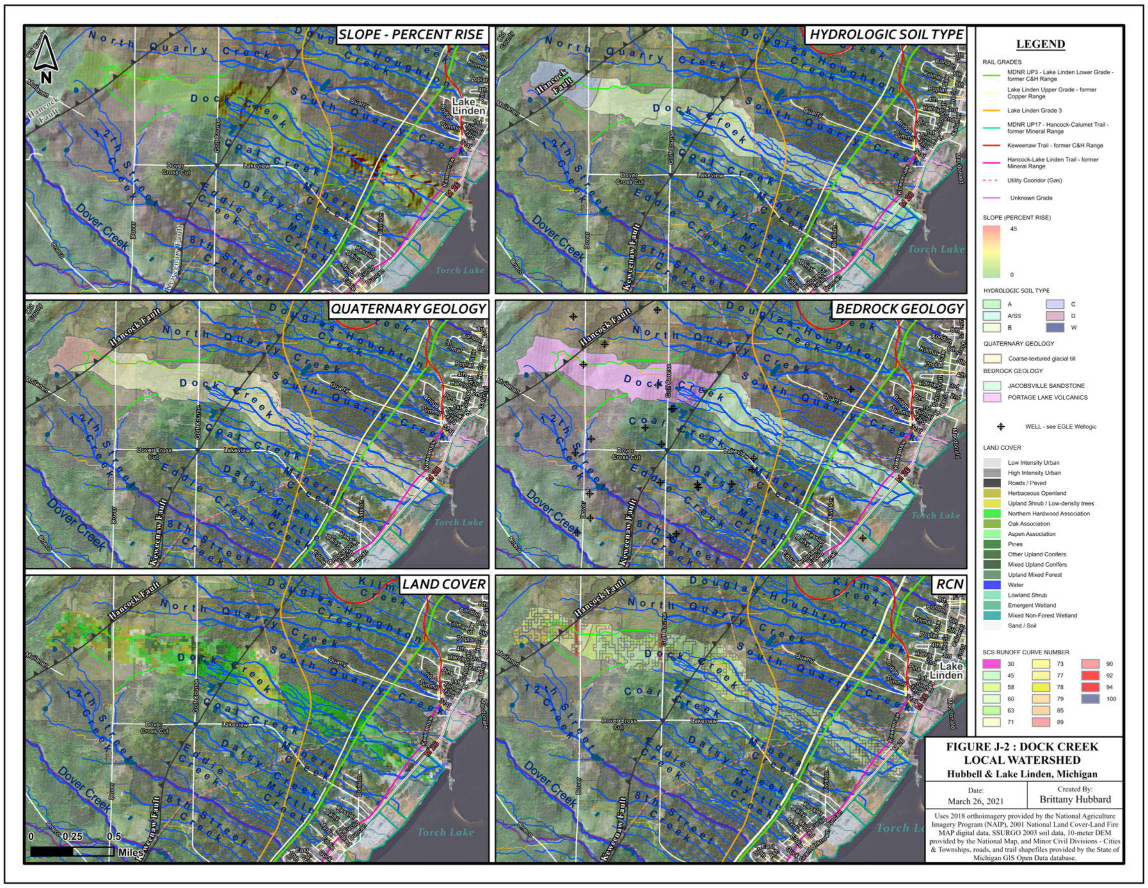

Figure 3.12. Dock Creek Local Watershed Characteristics.

3.2.12 South Quarry Creek Watershed

Quarry Creek Watershed (South) encompasses a long, narrow, 0.54 square mile stretch of area south of Quarry Rd, Lake Linden in Schoolcraft, Torch Lake, and Osceola Townships.

Drainage extends from the middle region above the Keweenaw Fault, down the steep hillside south of Quarry Rd, to confluence downstream from the Rail Grade. The outlet has been significantly changed and natural flood plain removed due to historical mining activities. Near the intersection of M-26 and Quarry Road, stream flow enters the storm water system and is routed south around the former C&H stamp mills property. A small catchment area, subsequently referred to as Edgewood Creek, joins the rerouted South Quarry Creek outlet to empty into Torch Lake via a drainage ditch (SWOUTLET #7 [10]) across M-26 from Edgewood Ave (W. 27th St.). Eight failed hydraulic structures in the Rail Grade have been naturalized post 2018 flood events. Additionally, aerial

imagery suggests surface water may be ponding upstream of Lake Linden Grade 3 connecting flow paths to the nearby reservoir and North Quarry Creek.

The weighted average main stream channel slope for the hillside, lower regions, and local watershed are 5.6, 5.9, and 5.7 percent rise, respectively. The approximate length of the main stream channel is 1.24 miles. The approximate hydraulic length of the catchment area is 1.75 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 5.1, 6.3, 7.0, and 6.5 percent rise, respectively.

South Quarry Creek local watershed ranges from 602 feet to 1125 feet MSL. Hydrologic group A and some stamp sands exist in the lower region between the base of the hill and Torch Lake, but B type soils dominate the catchment. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Northern hardwood, Aspen/White Birch, and coniferous forest cover most of the watershed. A former mining building exists in the hillside region south Quarry Rd. The floodplain region, east of M-26, includes the former C&H stamp mills, regrinding and leaching plants, and other mining facilities now managed by The Houghton County Historical Society (HCHS). The weighted average RCN for the local watershed is 62. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 60, 61, and 62, respectively.

Refer to Figure 3.13. South Quarry Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.50. North & South Quarry Creek Drainage and LID, and Table A.1 for details.

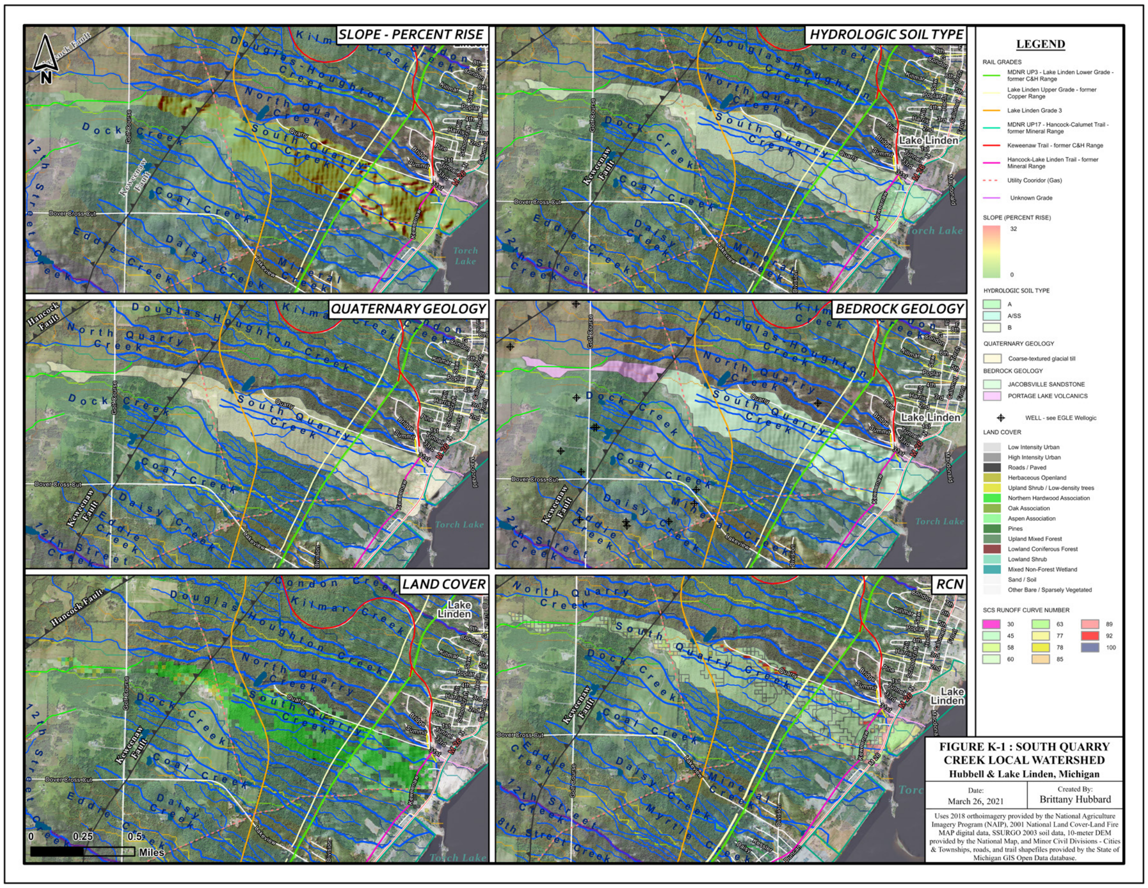

Figure 3.13. South Quarry Creek Local Watershed Characteristics.

3.2.13 North Quarry Creek Watershed

Quarry Creek Watershed (North) encompasses a 0.63 square mile long narrow stretch of land north of Quarry Rd located in Schoolcraft, Osceola, and Torch Lake Townships. The watershed extends from west of Dover Rd. above the Hancock Fault, east across the Keweenaw Fault, down the hillside paralleling north of Quarry Rd., narrowing sharply at Bridge St. near Louie's Market, Lake Linden.

Drainage in the middle and upper regions are heavily channelized for agriculture. The natural stream channel and floodplain have been significantly altered by historical mining activities. One main stream and one main tributary (Bridge St. creek) convey discharge down the hillside to two stormwater inlets below Pine St. grade and near the intersection of Bridge St. with Quarry Road. EHMS flood aerial imagery suggests that during heavy rainfall events significant stream flow is reached in both the main channel of N. Quarry Creek and Bridge St. Creek tributary which confluence in the stormwater system just above Louie's market. High intensity development blocks the outlet of this watershed

including Louie's market, HCHS, residential homes, and the former C&H stamp mills and facilities. The outlet is routed south via a drainage ditch around the C&H historical site shared with S. Quarry Creek Watershed and Edgewood Creek. Five hydraulic structures failed at the Rail Grade; one culvert was restored, and Bridge Creek was naturalized post June 17, 2018, flood event. A reservoir exists at the top of the hill at the northwest end of Quarry Road.

The weighted average main stream channel slope for the upper, middle, hillside, lower regions and for the local watershed are 1.7, 3.1, 7.3, 15.5, and 6.4 percent rise, respectively. The approximate length of the main stream channel is 2.24 miles. The approximate hydraulic length of the catchment area is 2.75 miles. The weighted average land slope for the upper, middle, hillside, and lower regions, and for the local watershed are 2.3, 3.6, 7.6, 13.1, and 5.0 percent rise, respectively.

Quarry Creek local watershed ranges from 602 feet to 1210 feet MSL. Primarily hydrologic group B soil types exist except for in urban areas at the narrow outlet and upper reaches above the Hancock Fault where soil types A, stamp sands, and C dominant, respectively. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till with areas of thin to discontinuous glacial till over bedrock above the Hancock Fault. Land use is predominantly mixed forest. Thirty-one percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 67. Subdivided into upper, middle, hillside, and lower regions, the weighted average RCN becomes 75, 63, 62, and 72, respectively.

Refer to Figure 3.14. North Quarry Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.51. N/S Quarry Creek Outlet Drainage and LID, and Table A.1 for details.

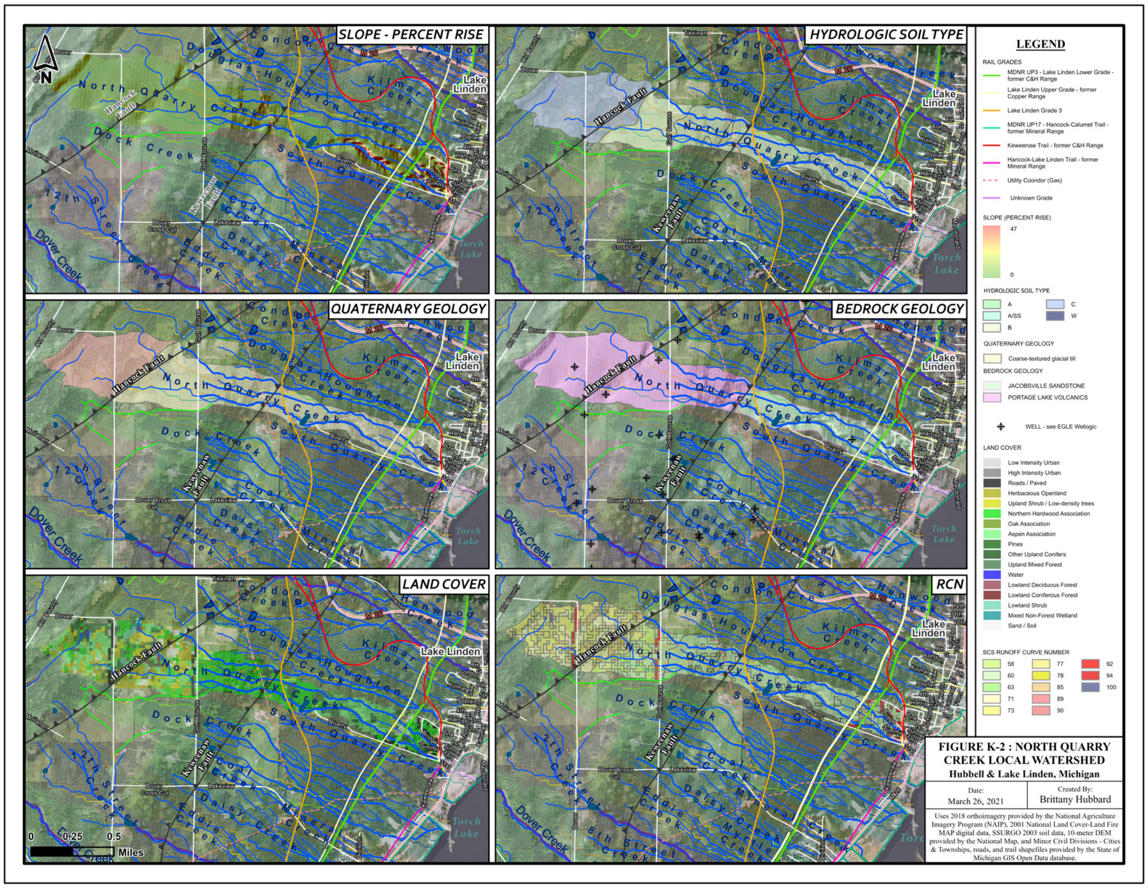

Figure 3.14. North Quarry Creek Local Watershed Characteristics.

3.2.14 Douglas-Houghton Creek Watershed

Douglas-Houghton Creek Watershed covers 1.29 square miles between Schoolcraft, Osceola, and Calumet Townships. The catchment is wide where it begins just east of Old County Rd and narrows in shape down the hillside to outlet near Lake Linden Campground Beach.

The main stream channel, Douglas-Houghton Creek, descends the Hancock and Keweenaw Faults, crossing the gas utility corridor and four rail grades (Lake Linden Grade 3, Upper/Lower Grades, and the Keweenaw Trail formerly the C&H Range). A tributary joins the main stream between the upper and lower Rail Grade. Flow enters a stormwater inlet between Douglas St. and Harris St. just above the Keweenaw Trail Grade. The outlet culvert (SW Inlet #9 [10]) appears just south of the baseball field near the intersection of 2nd St. and Front Street. The floodplain to this watershed, at Lake Linden Park and Beach, has been restored with a vegetative cap, to provide protection and erosion control of stamp sands and contamination left by mining era activities.

Erosion from flooding during large rainstorm events in this area are a concern to water quality. Two hydraulic structures failed in the Rail Grade during the 2018 flooding events. Four surface water bodies exist in this boundary: one in the headwater region west of Golf Course Rd., two are located east of Golf Course Rd. above the Hancock Fault, and the fourth surface water body exists below the Hancock Fault in the middle region. Additionally, aerial imagery suggest ponding is occurring upstream from Lake Linden Grade 3 and upstream from Quarry Rd. at the Atlantic Mine incline dam.

The weighted average main stream channel slope for the upper, middle, hillside, lower regions, and for the local watershed are 1.2, 4.2, 7.7, 7.3, and 5.1 percent rise, respectively. The approximate length of the main stream channel is 2.64 miles. The approximate hydraulic length of the catchment area is 2.75 miles. The weighted average land slope for the upper, middle, hillside, and lower regions, and for the local watershed are 2.5, 4.5, 7.0, 6.8, and 4.6 percent rise, respectively.

Douglas Houghton Creek local watershed ranges from 602 feet to 1221 feet MSL. Soil type is primarily hydrologic group B except for some C and B/D in the upper watershed wetland areas and A/stamp sands in the lower region. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till with areas of thin to discontinuous glacial till over bedrock above the Hancock Fault. Land use in the upper portions of the watershed (above Hancock Fault) are primarily emergent wetlands with deciduous and mixed forest. Middle and hillside regions are heavily wooded including northern hardwood, Aspen/White Birch, and coniferous forest. Agriculture land use exists in the vicinity of Golf Course Road. Highly developed urban areas cover the lower floodplain region of the watershed. Fifty percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 70. Subdivided into upper, middle, hillside, and lower regions, the weighted average RCN becomes 77, 62, 60, and 78, respectively.

Refer to Figure 3.15. Douglas Houghton Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.60. Douglas Houghton Creek Drainage and LID, and Table A.1 for details.

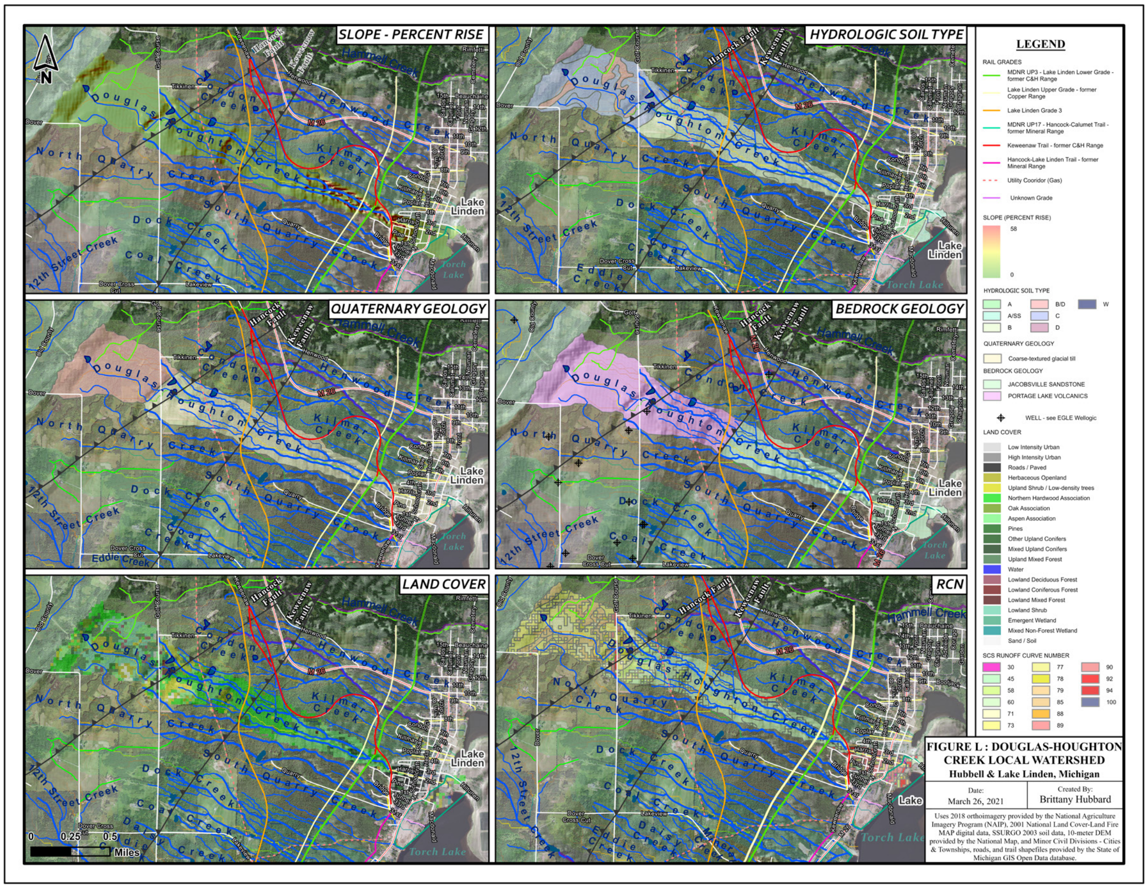

Figure 3.15. Douglas-Houghton Creek Local Watershed Characteristics.

3.2.15 Kilmar Creek Watershed

Kilmar Creek Watershed encompasses approximately 0.26 square miles within Schoolcraft Township in Lake Linden. The catchment is short and narrow, covering a small area down-grade from the Keweenaw fault that includes the majority of the S-turn of the Keweenaw Trail rail grade.

Headwaters begin to the Northwest of Lake Linden above the Keweenaw Fault near the boundary with Calumet Township. Drainage is heavily disconnected due to the intersection of the Keweenaw Trail rail grade with the Lake Linden Grade 3, upper and lower Rail Grades, and the S-turn of the Keweenaw Trail that crosses the width of the watershed at three locations. Kilmar Creek catchment includes three small stream channels that are routed into the stormwater system (SW Inlet LakeLPoplar&4th [10]) up-grade from Saw St. and residential areas between 4th and 6th Streets. Flow is buried beneath the urban area until it reaches the outlet (SW Outlet #10 [10]) into Torch Lake at the east end of 4th Street. Flooding in 2018 caused wash outs at six locations along the

Rail Grade in this watershed. One culvert has since been restored and the other points remain naturalized. No surface water bodies exist though aerial imagery suggests ponding is occurring up-grade from the Keweenaw Trail rail grade S-turn.

The weighted average main stream channel slope for the hillside, lower regions, and for the local watershed are 6.0, 9.4, and 7.0 percent rise, respectively. The approximate length of the main stream channel is 1.11 miles. The approximate hydraulic length of the catchment area is 1.48 miles. The weighted average land slope for the middle, hillside, and lower regions, and for the local watershed are 4.0, 6.7, 7.9, and 7.1 percent rise, respectively.

Kilmar Creek local watershed ranges from 602 feet to 1038 feet MSL. Soil type is primarily hydrologic group B. Urban areas closer to the watershed outlet also consist of soil type A and stamp sands. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till. Land use is mostly deciduous and mixed forest. The highly developed low land floodplain area between the hillside and Torch Lake includes residential and mixed forest. Thirty-eight percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 67. Subdivided into middle, hillside, and lower regions, the weighted average RCN becomes 60, 60, 76, respectively.

Refer to Figure 3.16. Kilmar Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.65. Kilmar Creek Drainage and LID, and Table A.1 for details.

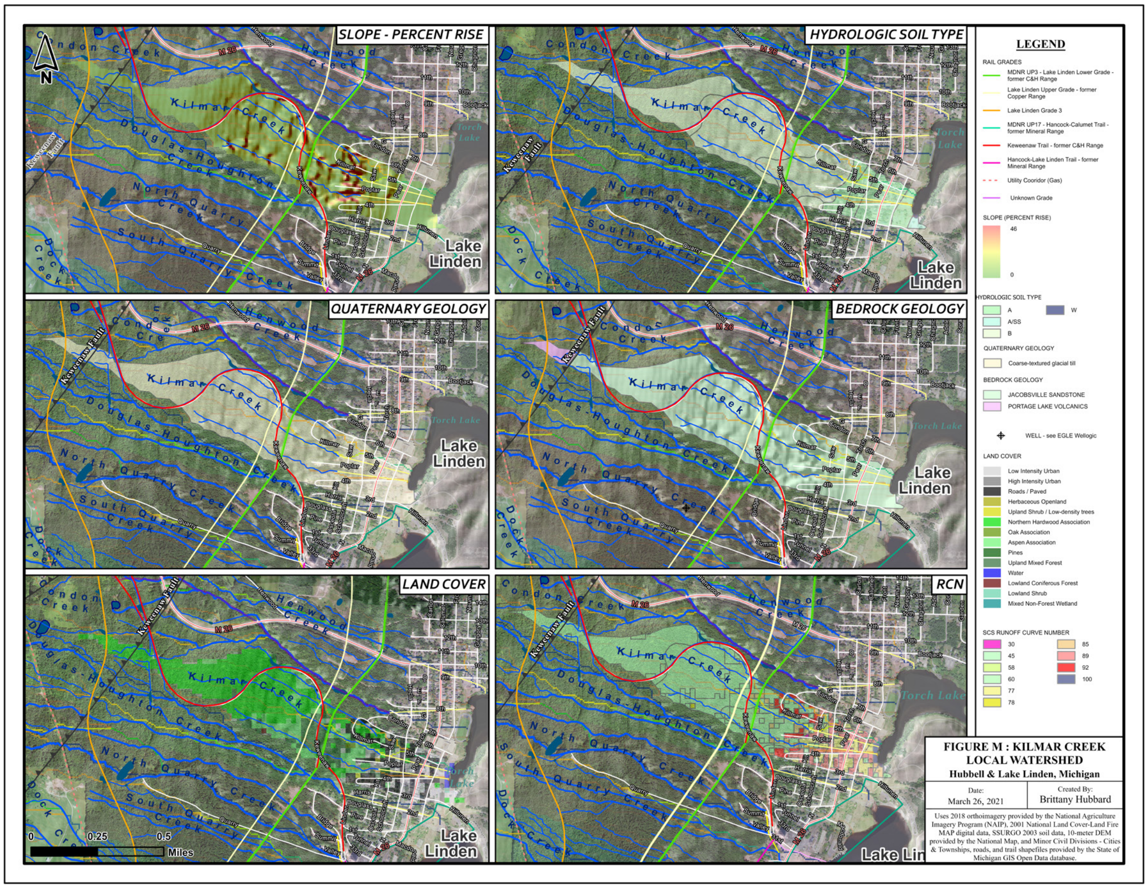

Figure 3.16. Kilmar Creek Local Watershed Characteristics.

3.2.16 Condon Creek Watershed

Condon Creek Watershed includes the jurisdictions of Calumet, Schoolcraft, and Osceola Townships covering approximately 0.85 square miles northwest of Lake Linden. Headwaters begin above the Hancock Fault near the intersection of Golf Course and Tikkinen roads. Drainage is heavily disconnected in the upper watershed due to the convergence of several rail grades and M-26 highway. The catchment is wide atop the hill then contracts dramatically into a single channel to descend the grade. Two failed hydraulic structures have been naturalized in the upper and lower Rail Grades post 2018 flood events. Downstream of the Rail Grade, flow enters a stormwater inlet between Condon and G St. The stream is buried beneath urban infrastructure until reaching the outlet at Torch Lake (assumed to be SWOUTLET #11 [10], culvert data not available on EGLE MiWaters) located at the east end of 8th Street in Lake Linden. The floodplain delta expands toward Torch Lake covering the approximate area between 5th and F Streets. Two surface water bodies are present: one in the upper region and one in the middle region of the watershed.

The weighted average main stream channel slope for the middle, hillside, lower regions, and for the local watershed are 5.1, 13.5, 15.1, and 11.1 percent rise, respectively. The approximate length of the main stream channel is 1.70 miles. The approximate hydraulic length of the catchment area is 2.46 miles. The weighted average land slope for the upper, middle, hillside, and lower regions, and for the local watershed are 4.1, 5.5, 11.4, 8.5, and 7.3 percent rise, respectively.

Condon Creek local watershed ranges from 602 feet to 1223 feet MSL. The primary hydrologic soil type is B, although soil Type C and A are predominant in the upper and lower regions. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till with areas of thin to discontinuous glacial till over bedrock above the Hancock Fault. Land use is primarily northern hardwood. Emergent wetlands, Aspen/White Birch, and conifers also inhabit upper, middle, and hillside regions. High intensity urban and residential land use cover a majority of the lowland floodplain including the Lake Linden High School and public library. Forty-four percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 68. Subdivided into upper, middle, hillside, and lower regions, the weighted average RCN becomes 75, 62, 64, and 77, respectively.

Refer to Figure 3.17. Condon Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.67. Condon Creek Drainage and LID, and Table A.1 for details.

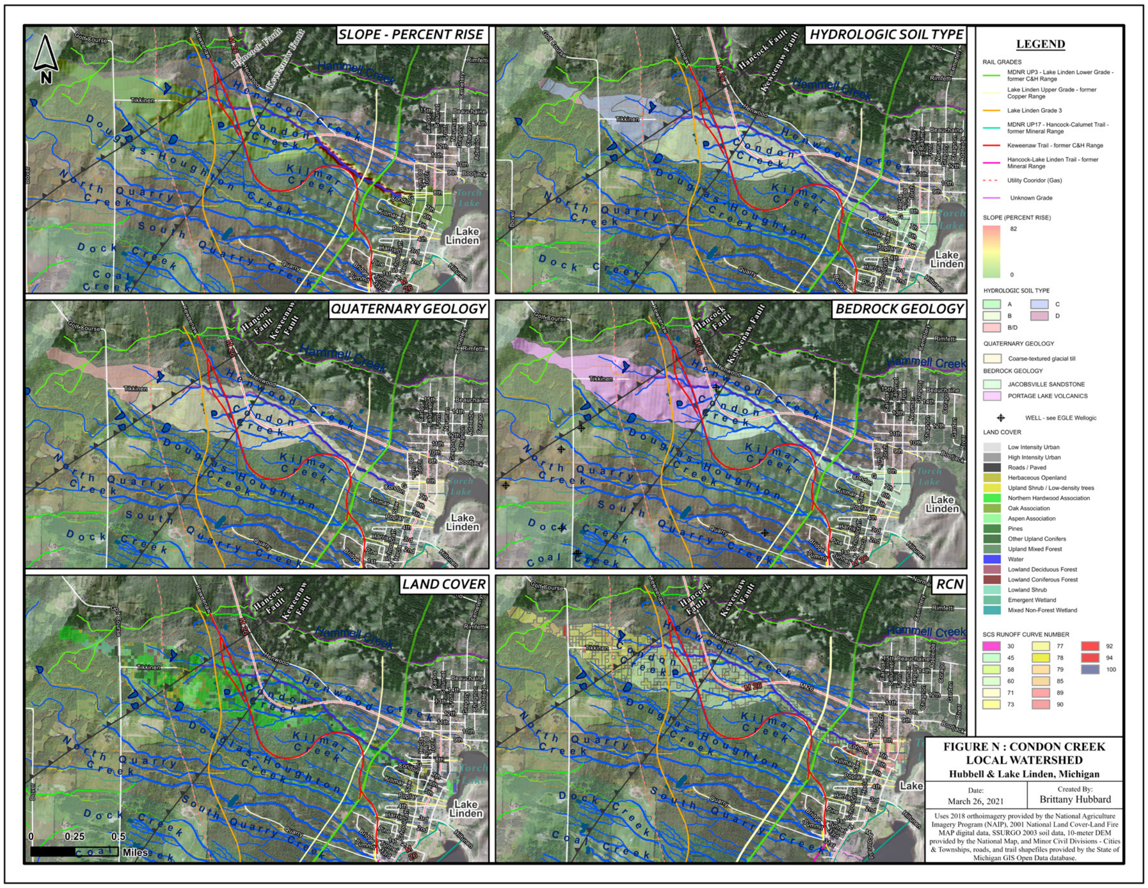

Figure 3.17. Condon Creek Local Watershed Characteristics.

3.2.17 Henwood Creek Watershed

Henwood Creek Watershed encompasses territory in Calumet, Schoolcraft, and Osceola Townships. Covering approximately 0.36 square miles north/northwest of Lake Linden, the catchment is long and narrow in shape in the upper watershed where the boundary extends across the Hancock and Keweenaw Faults and is wide down-grade from Henwood road to the outlet at Torch Lake. The immediately adjacent catchment to the north is Hammel Creek Local watershed.

Drainage in the upper watershed is heavily disconnected west of M-26 where several rail grades come together. Henwood Creek main channel crosses M-26, parallels the north side of an unknown rail grade, crosses Henwood Rd., parallels the north side of M-26, and enters a stormwater inlet north of the intersection of M-26, 10th, and Hecla streets in Lake Linden. The stream remains buried in the stormwater system until reaching the outlet at Torch Lake (assumed to be SWOUTLET #12 [10]) located near the intersection of Bootjack (9th) and Gregory Roads, south of the Torch Lake Sewage office/treatment

facility. Two hydraulic structures failed at the Rail Grade; both have been naturalized post June 17, 2018, flood event. One surface water body exists in the hillside region of the watershed.

The weighted average main stream channel slope for the middle, hillside, lower regions, and for the local watershed are 4.9, 8.1, 12.0, and 7.8 percent rise, respectively. The approximate length of the main stream channel is 1.50 miles. The approximate hydraulic length of the catchment area is 2.26 miles. The weighted average land slope for the upper, middle, hillside, and lower regions, and for the local watershed are 5.1, 6.3, 8.1, 7.8, and 7.3 percent rise, respectively.

Henwood Creek local watershed ranges from 602 feet to 1194 feet MSL. Mostly hydrologic group B soils cover this watershed; however, upper regions and urban lower regions are primarily C and A soil types. Bedrock geology is split above and below the Keweenaw Fault between the Portage Lake Volcanics and Jacobsville Sandstone, respectively. Quaternary geology is primarily coarse-textured glacial till with areas of thin to discontinuous glacial till over bedrock above the Hancock Fault. Land use is primarily mixed and deciduous forest except for developed lower regions that contain residences and local businesses. Thirty-two percent of the land use in the lower region is occupied by impervious surfaces. The weighted average RCN for the local watershed is 71. Subdivided into upper, middle, hillside, and lower regions, the weighted average RCN becomes 74, 70, 66, and 74, respectively.

Refer to Figure 3.18. Henwood Creek Local Watershed Characteristics, Figure 3.1, Figure 2.3, Figure 4.69. Henwood Creek Drainage and LID, and Table A.1 for details.

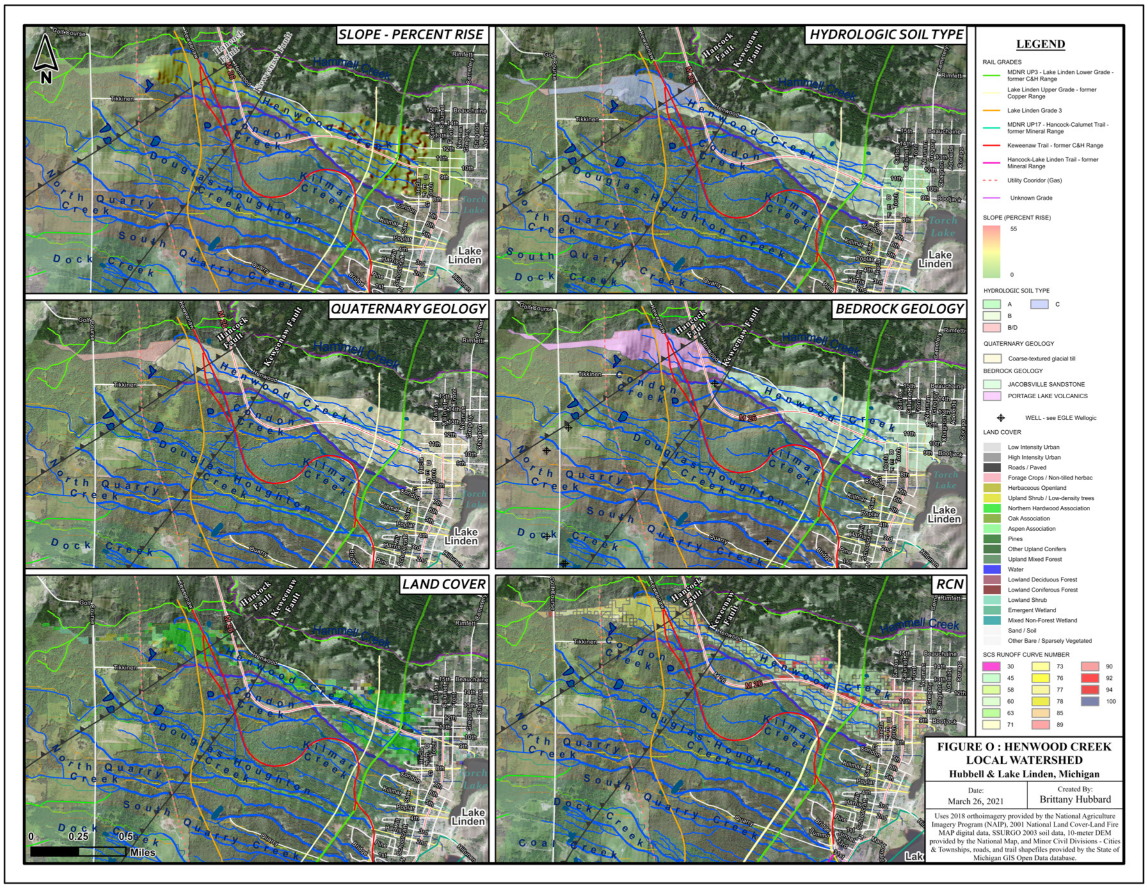

Figure 3.18. Henwood Creek Local Watershed Characteristics.

4 Stormwater, Stream Restoration, and Suggestions for Low Impact Development

4.1 Challenges

Numerous areas across the Site have been affected by historical activities and will continue to be affected by future development. Riverine flooding, channel bank overflows, and inundation of the floodplain are natural. Enabling watersheds to function in a natural way provides water quality and flood protection by reducing excess runoff, nutrient load, pollutants, and sediment concentration as well as improving infiltration, floodwater storage, and groundwater recharge.

Many challenges exist to this area. Flow paths are disconnected by railroad grades, agricultural drainage ditches, roads, driveways, ATV trails, and a gas utility corridor. Steep topography created by multiple fault lines promote the formation of new stream path rivulets. Flow velocity and slope can quickly form an accumulation channel and can vary over time making it difficult to predict where hydraulic structures within the Rail Grade will be most effective. Roadways that parallel the hillside are steep. Most of the main stream channels inlet directly into the stormwater infrastructure upon reaching the base of the hillside. The outlet for many of these stream channels coincides with historical mining land use. Stream flow is conveyed around these properties to protect restorative vegetative capping efforts that prevent environmental contaminates and human health hazards present in the sediment from eroding into Torch Lake. In addition, a highly developed floodplain make the Site particularly susceptible to riverine and urban flooding.

4.2 Local Watershed Urban Stormwater & Suggested LID

This section provides review of drainage pathways for each local level watershed at the Site. Specifically, this report seeks to locate current or most recent potential or known hydraulic structures and identify high risk areas of the Rail Grade and urban stormwater sewer system that may benefit from low-impact green design (LID) solutions. LID options, as a means to improve existing stormwater and sewer infrastructure, optimize the natural hydrologic performance to provide increased flood protection and reduce frequency of hydraulic structure damage. Locations of hydraulic structures were identified using hydraulic structure documents available through MiWaters – Water Resource Information database provided by EGLE [18], MDNR Houghton County Incident Report [10], Michigan State Police helicopter transect video of the June 17, 2018 Father's Day flood event provided by the Michigan Emergency Management & Homeland Security Division (EMHS) [9], Google Earth high resolution WorldView historical aerial imagery from May 9, 2014 [15], 2008 High Resolution Orthoimagery [17], and 2018 NAIP high resolution imagery [17].

4.2.1 Amygdaloid Creek Stream Restoration & LID

Upstream areas drain land historically used for mining. Waste piles and cleared barren land exists in historical aerial imagery. Low impact development (LID) such as a sediment trap or sediment basin is suggested where stream flow outlets this former mine property to reduce sediment and pollutants entering streams.

Due to development, several smaller stream channels confluence near the intersection of Osceola Rd (Junction Rd.) and Osceola Hill Rd. (B St.). Drainage is channelized to avoid the historical site of the former Osceola Stamp Mill. An in-stream wetland near the confluence can be utilized to reduce excess runoff volume and provide water storage until safely able to discharge through culverts.

A series of culverts are used to bypass the Rail Grade and three roads: Amygdaloid St., Junction Rd., and M-26. The culvert at M-26 (31-M-26 at tributary to Torch Lake) is the main route under the highway for the discharge of the Amygdaloid Creek Watershed to outlet into Torch Lake. Severe flooding along Amygdaloid St., B St., Junction Rd., and M-26 occurred during the Father's Day flood event. Ponding occurred upstream of Amygdaloid St., MDNR Rail Grade, and at M-26. Stream channel improvements and potentially an in-stream wetland is suggested upstream of residential development to reduce stream velocity and provide floodwater storage should culverts become blocked. Vegetated swales in the drainage ditch used to route flow parallel to M-26 (for approximately 200 feet to the north or south) to reach a culvert inlet to Torch Lake, are recommended to increase available excess runoff storage capacity.

Refer below to Figure 4.1. Amygdaloid Creek Drainage & Suggested Locations for LID, Figure 4.2. MDOT M-26 Hubbell Drainage from Station 2385+00 to Station 2400+00 (75464-PlanHalf), and Figures 4.3, 4.4, and 4.5. MDOT-Fishbeck Amygdaloid Creek at M-26 culvert figures detailing the main outlet hydraulic structure (31-M26 at tributary to Torch Lake) provided by EGLE MiWaters [18].

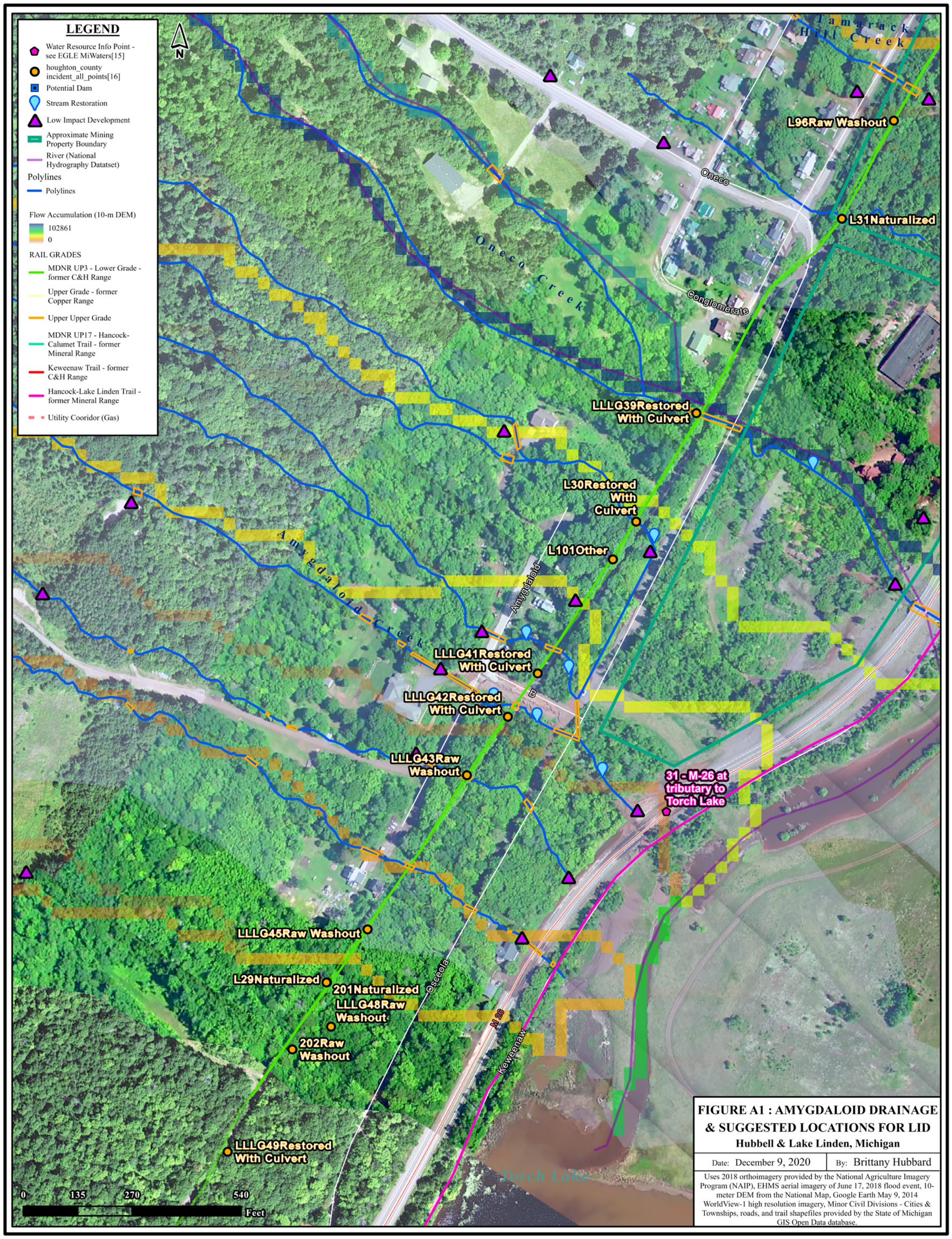

Figure 4.1. Amygdaloid Creek Drainage & Suggested Locations for LID.

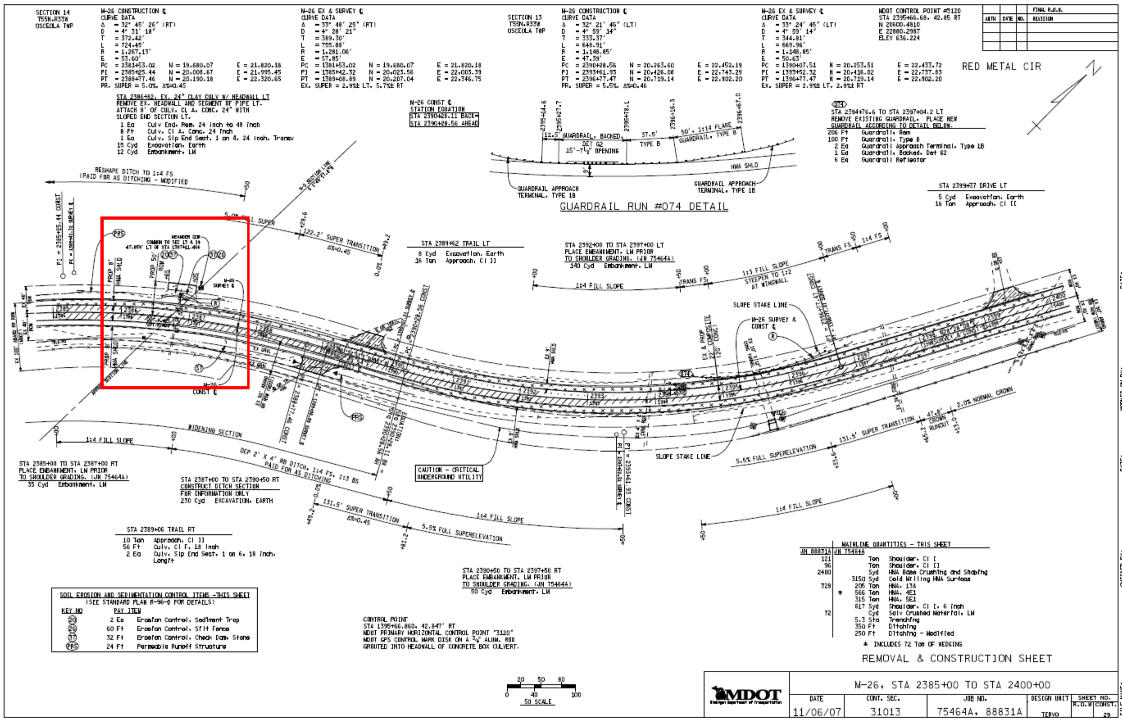

Figure 4.2. MDOT M-26 Hubbell Drainage [18]. Modified by author.

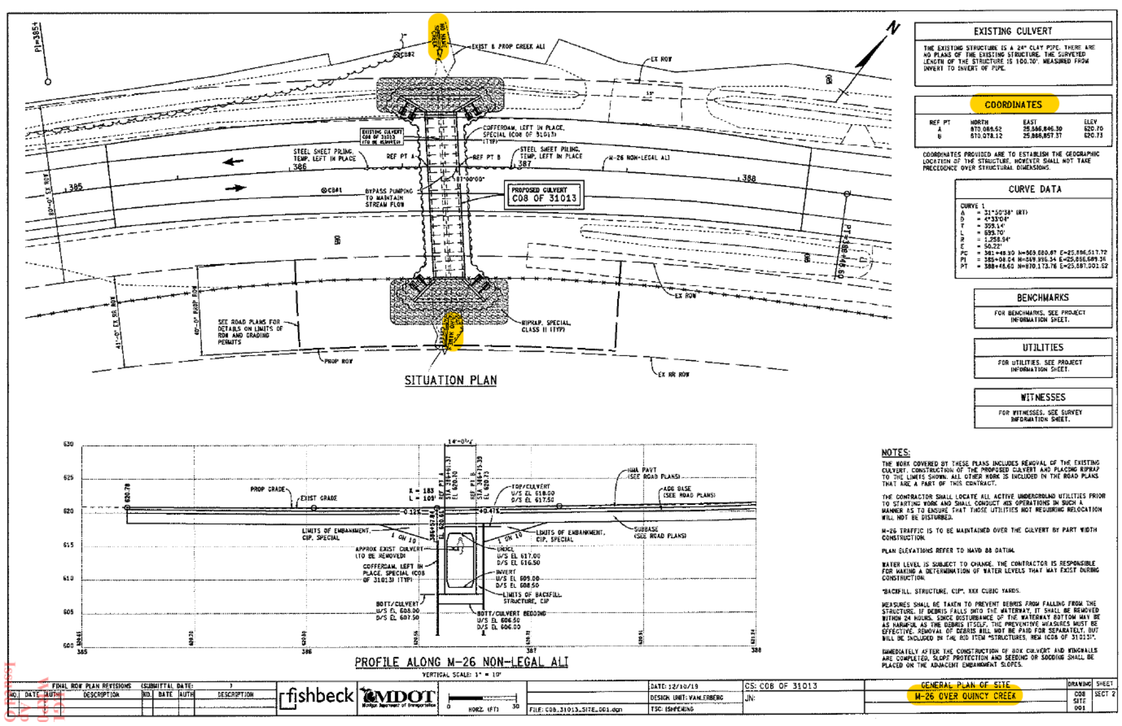

Figure 4.3. MDOT Fishbeck Amygdaloid Creek Culvert Plan at M-26 [18]. Modified by author.

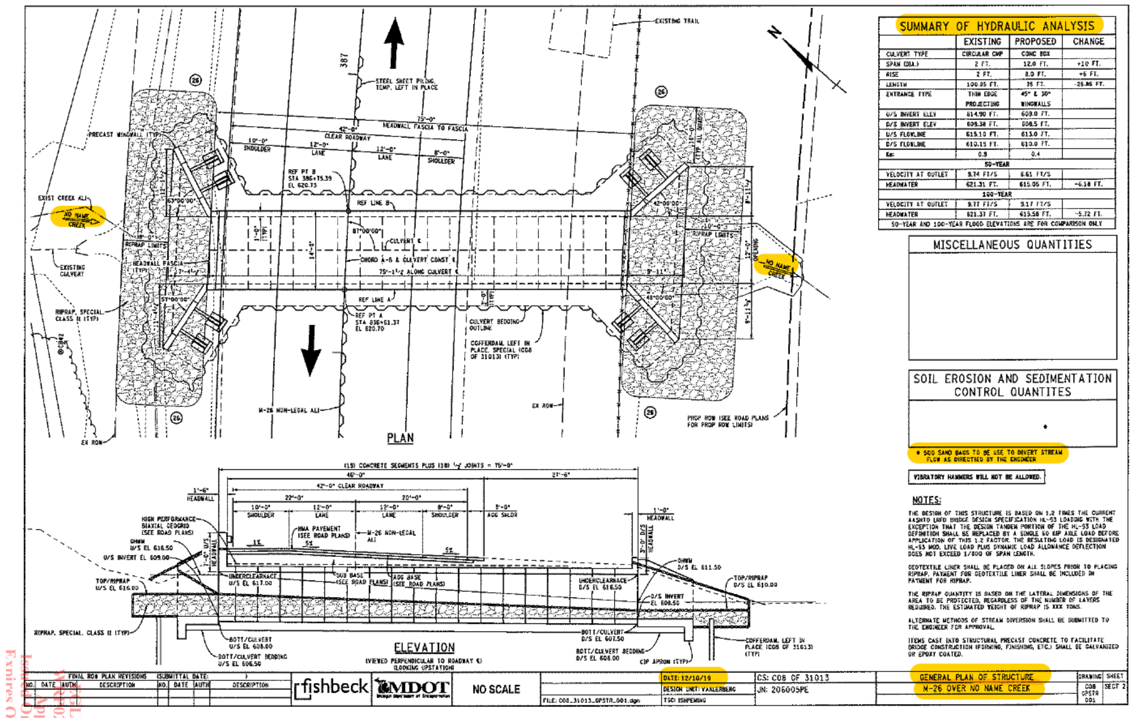

Figure 4.4. MDOT Fishbeck Amygdaloid Creek Culvert Profile at M-26 [18]. Modified by author.

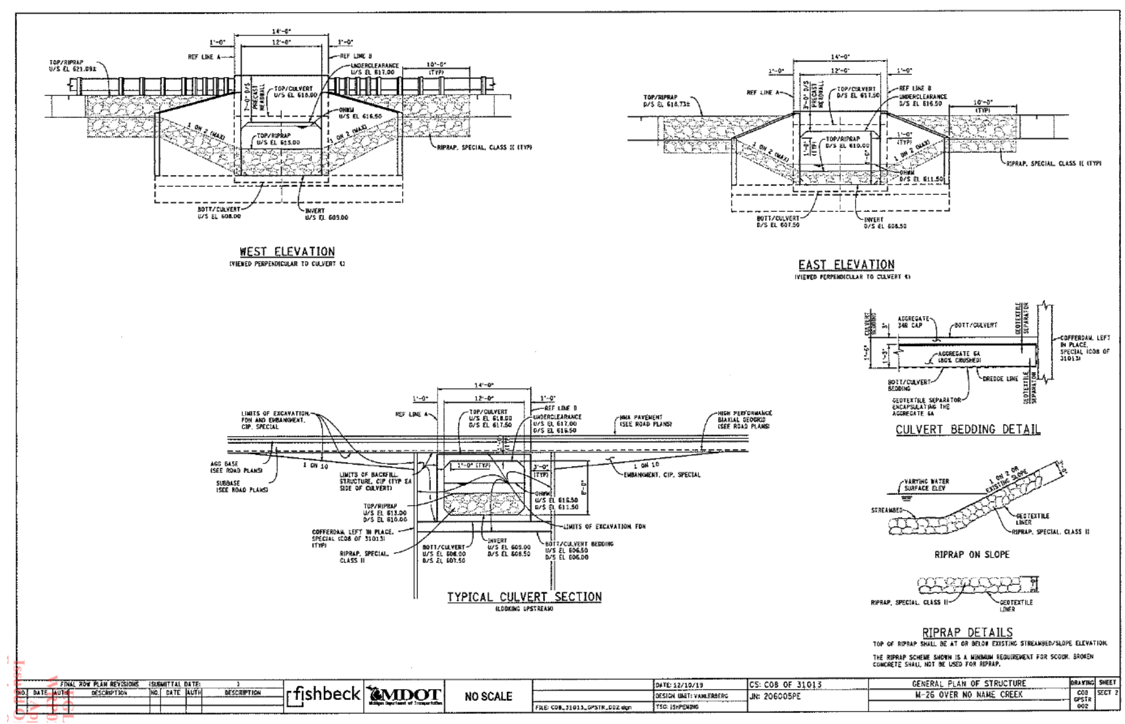

Figure 4.5. MDOT - Fishbeck Amygdaloid Creek Culvert Detail at M-26 [18].

4.2.2 Oneco Creek Stream Restoration & LID

Low impact development is suggested in upper portions of the watershed where drainage paths have been connected to accommodate the Houghton-Hancock Airport (CMX) and agriculture. If land use or drainage channels can no longer be reconnected, then future hydraulic structures need to assume the land area to be drained is larger than delineated and includes the area east of CMX.

Stream restoration is suggested where Oneco Creek intersects with the gas utility corridor above the Keweenaw Fault. Upstream of Seeburg Dr (O18b) exists a large agricultural property. Low impact development such as a wetland, retention pond, or rock check dams is suggested where flow path intersects with Seeburg Drive to remove excess nutrients, increase ponding storage, and provide additional flow control. A retention pond with check dam exists further upstream on the agricultural property.

Flow modeling and assessment for stream restoration is needed where the flow path intersects the MDNR Rail Grade at LLLG39-Restored with culvert.

Stream channel improvements and LID is suggested where Oneco Creek flow is channelized through the former Osceola Stamp Mill site. This site is acting as a floodplain when stream discharge exceeds the channel banks during flooding. Low impact development such as a sediment trap or infiltration basin can be used to reduce sediment and pollutants from transporting downstream into the retention pond system and Torch Lake.

Downstream of M-26 three retentions ponds use weirs to control flow to the outlet at Torch Lake. Oneco creek enters the retention pond system at the upstream pond. Regular maintenance, including removal and proper disposal of sediments, can provide protection during flood size rainfall events. Currently, a 10-foot by 12-foot concrete tunnel carries the stream beneath M-26 and provides flow control to the downstream retention ponds. The retention system outlet is shared with Amygdaloid watershed. See above Figure 4.2. MDOT drainage for M-26, Station 2385+00 to Station 2400+00 provided by EGLE MiWaters Database (75464-PlanHalf) [18].

Refer below to Figure 4.6. Oneco Creek Drainage & Suggested Locations for LID.

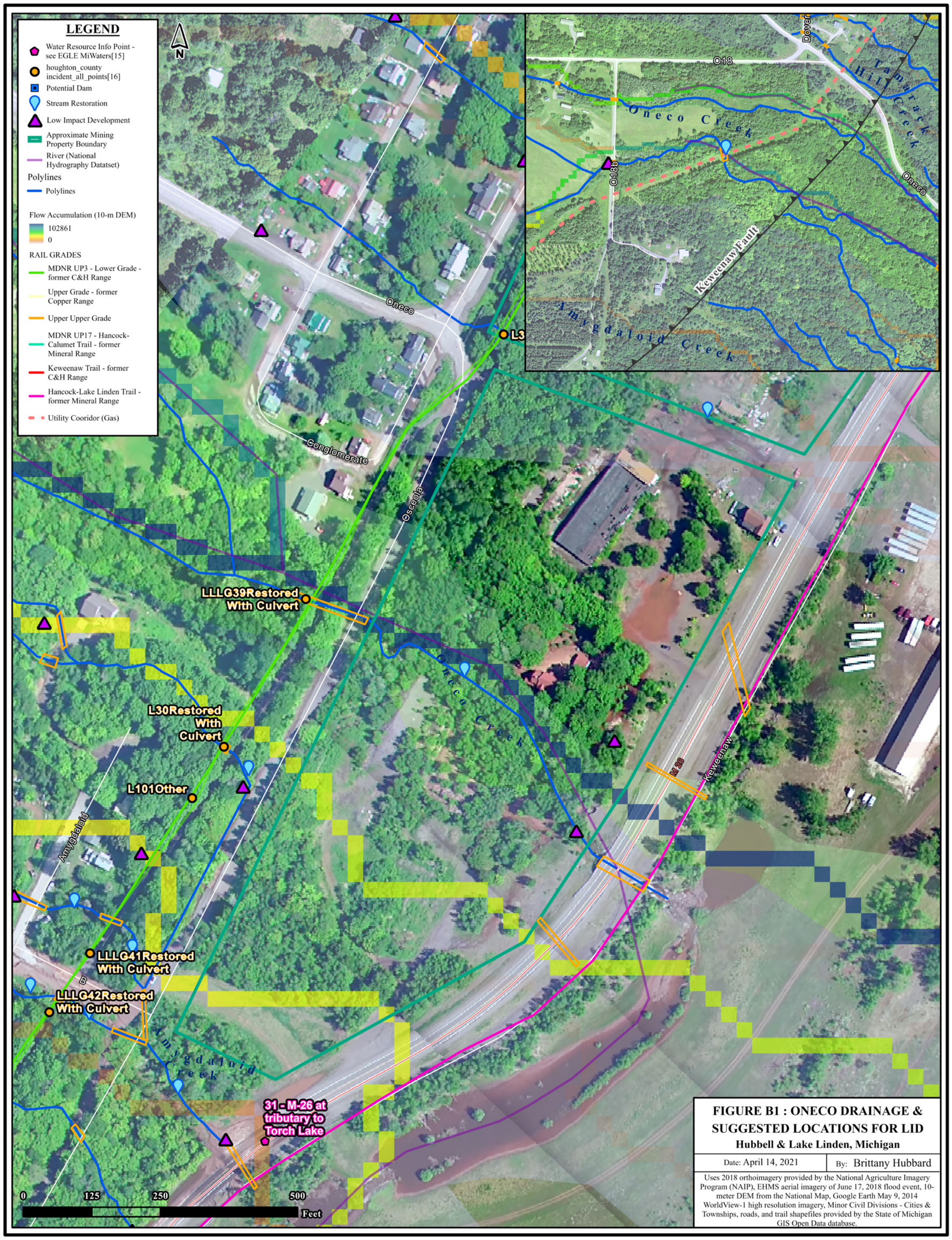

Figure 4.6. Oneco Creek Drainage & Suggested Locations for LID.

4.2.3 Tamarack Hill Creek Stream Restoration & LID

Rock check dams in series and stream restoration is suggested upstream of Conglomerate and Amygdaloid streets to reduce flow velocity, and along the north side of Tamarack Hill Rd. to protect the road and right-of-way from erosion.

Hydraulic structures along the Rail Grade failed at each flow path. Two flow paths (L31 Naturalized and L96 Raw Washout) through the historical mining sites of the Osceola and Tamarack Stamp Mills. During major flooding of 2018, accumulated flow inclined to drain south across the former stamp mill land into Oneco Creek outlet at M-26 to Torch Lake. Stream restoration is suggested where flow outlets onto the former Tamarack Stamp Mill property in order to limit the land surface area exposed to erosion. Vegetate barren zones within the floodplain and implement a sediment control system such as a sediment basin or infiltration trench to contain suspended sediment particles on-site.

Four stream paths confluence between the Rail Grade and the bottom of the hill converging to an existing 30-inch concrete culvert where Tamarack Hill Rd. (Oneco) intersects Maple Street. Stream flow uses a drainage ditch and series of culverts at: M-26 (36-inch inlet/outlet), Spruce St. (36-inch culvert), and the Hancock-Lake Linden Trail (36-inch culvert - 3/4 plugged) [18]. Water enters a retention pond before reaching the outlet at Torch Lake. Additional stormwater plumbing exists beneath nearby 2nd street and uses a 24-inch outlet, south from the corner where 2nd St. meets Spruce St., and an 18-inch clay culvert in the Hancock-Lake Linden Trail to outlet into Torch Lake [18]. Stream restoration and LID such as a wetland or bioretention system is suggested at the confluence of these creeks to increase available ponding storage before flow enters the stormwater drainage system.

Drainage paths in upper areas of this sub-watershed have been channelized to connect with some portions of neighboring Dover Creek sub-watershed.

Refer to Figure 4.7. Tamarack Hill Drainage & Suggested Locations for LID, Figure 4.8. MDOT Drainage and Vicinity, and Figure 4.9 MDOT 2nd St. Storm Sewer provided by EGLE MiWaters [18].

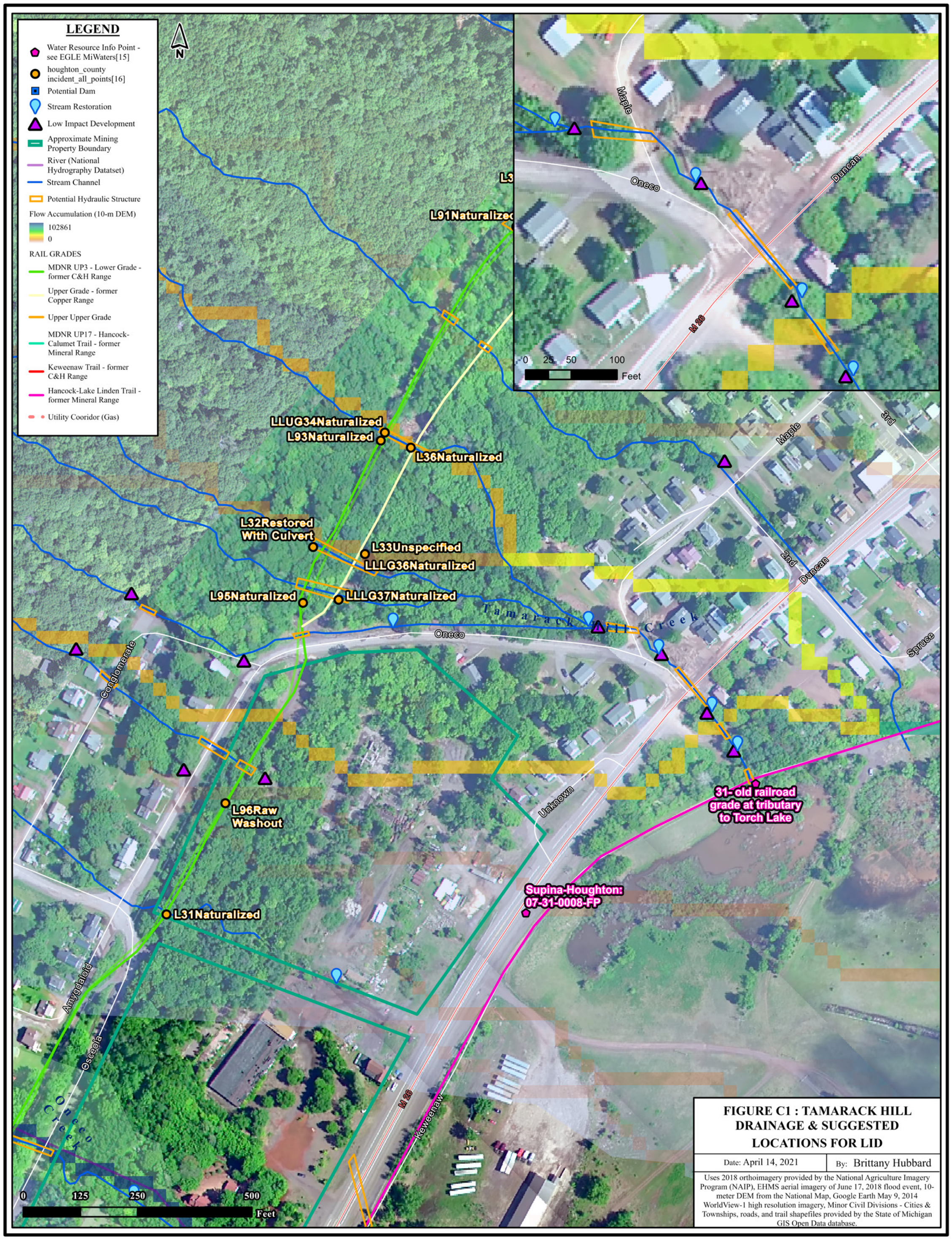

Figure 4.7. Tamarack Hill Creek Drainage & Suggested Locations for LID.

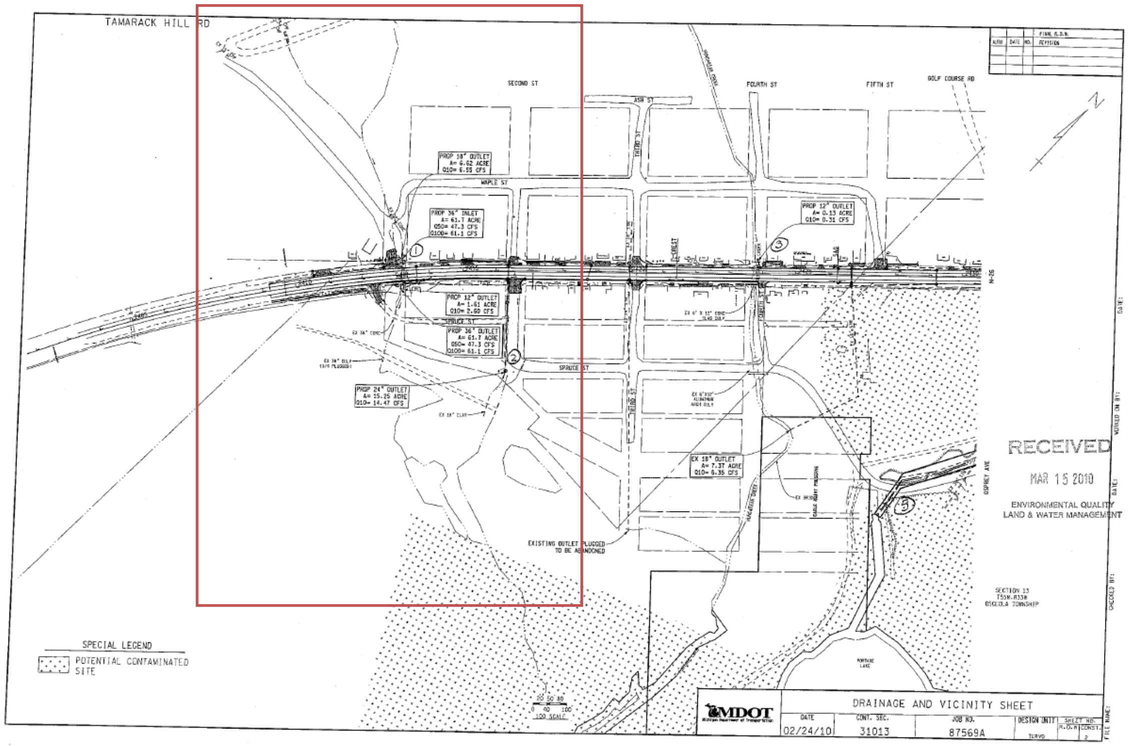

Figure 4.8. MDOT Drainage and Vicinity [18]. Modified by author.

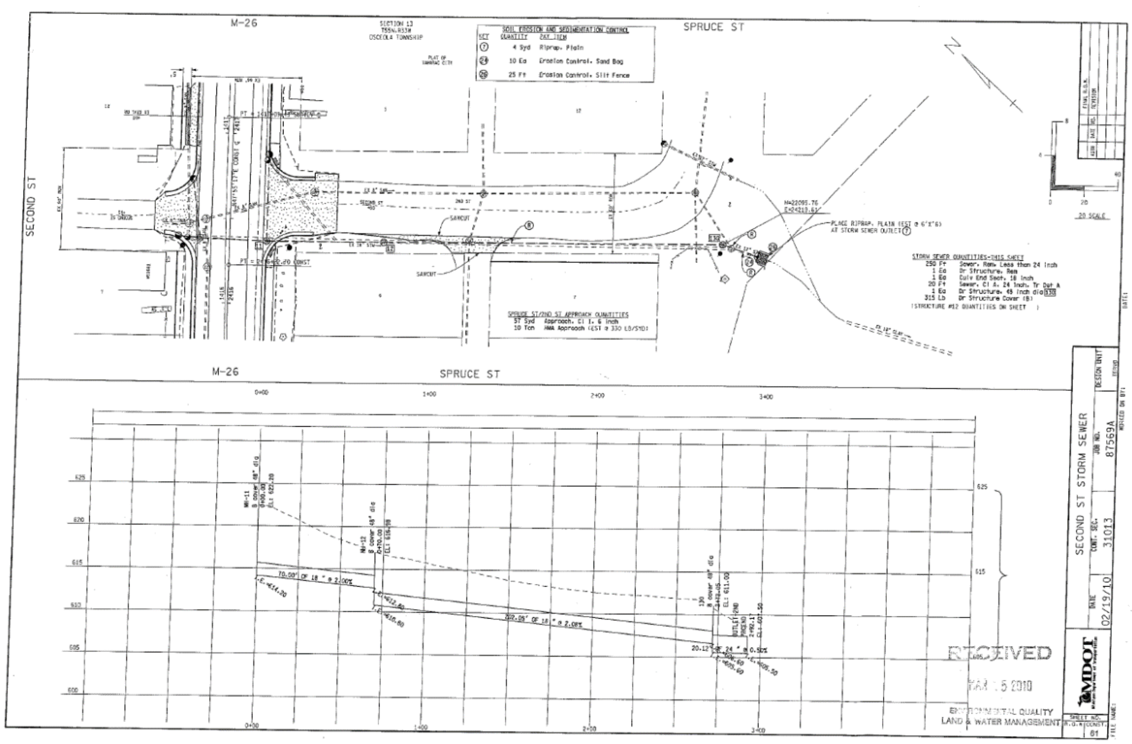

Figure 4.9. MDOT 2nd St. Storm Sewer [18].

4.2.4 Dover Creek Stream Restoration & LID

Dover Creek, also known as Hungarian Creek, narrows into a straight open channel through residential developed land parallel to 4th Street. Stream flow encounters Maple St., M-26, Spruce St., and the Keweenaw Trail. The reach between Ash St. and Spruce St., has been channelized using concrete, rip-rap, and cobble to contain flow within the limited land space between residences and 4th Street. A concrete box culvert and aluminum box culvert convey flow beneath M-26 and Spruce St., respectively [18]. Severe flooding occurred downstream of the hydraulic structure bypassing M-26 during the June 2018 extreme rainfall event. Improvements to the stream channel and riparian zones between Ash and Spruce streets are suggested to improve water storage capacity and increase infiltration. An in-stream wetland upstream of Ash St. could provide water storage until able to safely drain through the channel during flood size discharges. 2-D flow analysis for this channelized reach is recommended. It may be relatively cost effective to complete a bathymetric survey of the channel, needed for flow modeling, as improvements to drone and available lidar sensor technology continue to increase.

Stream restoration is suggested down grade of the rail grade to reconnect a tributary stream (south of and parallel to Golf Course Rd.) to its natural drainage path to Dover Creek. The drainage path has been altered by historical mining activities, specifically the rail grade extending up-grade from the former Ahmeek Stamp Mill operation. Drainage is assumed to enter a stormwater drain north from the intersection of 5th St. with M-26 to outlet at Dover Creek upstream of the Hancock-Lake Linden Trail via an existing 18-inch stormwater culvert, see MDOT Drainage and Vicinity Figure [18]. During flood events, excess runoff tends to flow over M-26 and accumulate on the former Stamp Mill property. A drainage outlet exists on the south east boundary of this property that channels stormwater into a culvert beneath Spruce St. to a drainage canal extending to Torch Lake. Vegetated swales are suggested in the drainage ditches on-site the former stamp mill property. A sediment basin is suggested upstream from the Spruce St. culvert to prevent scoured soils depositing into Torch Lake.

Refer to Figure 4.11. Dover Creek Drainage & Suggested Locations for LID, Figure 4.10. 2010 MDOT Drainage and Vicinity figure between Tamarack Hill Rd. and Fifth St. in Hubbell, MI, and Figures 4.12 to 4.15. Houghton County Road Commission (HCRC) Dover Creek at Spruce St. and Dover Rd. culvert figures provided by EGLE MiWaters [18].

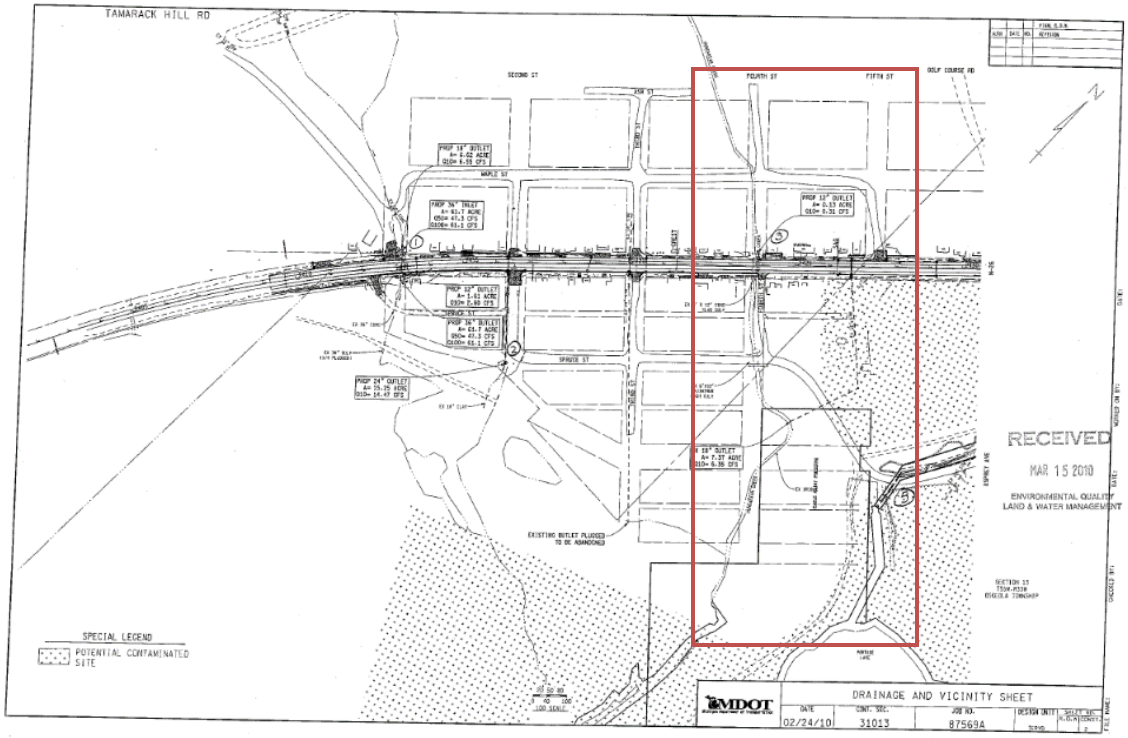

Figure 4.10. MDOT Drainage and Vicinity Sheet [18]. Modified by author.

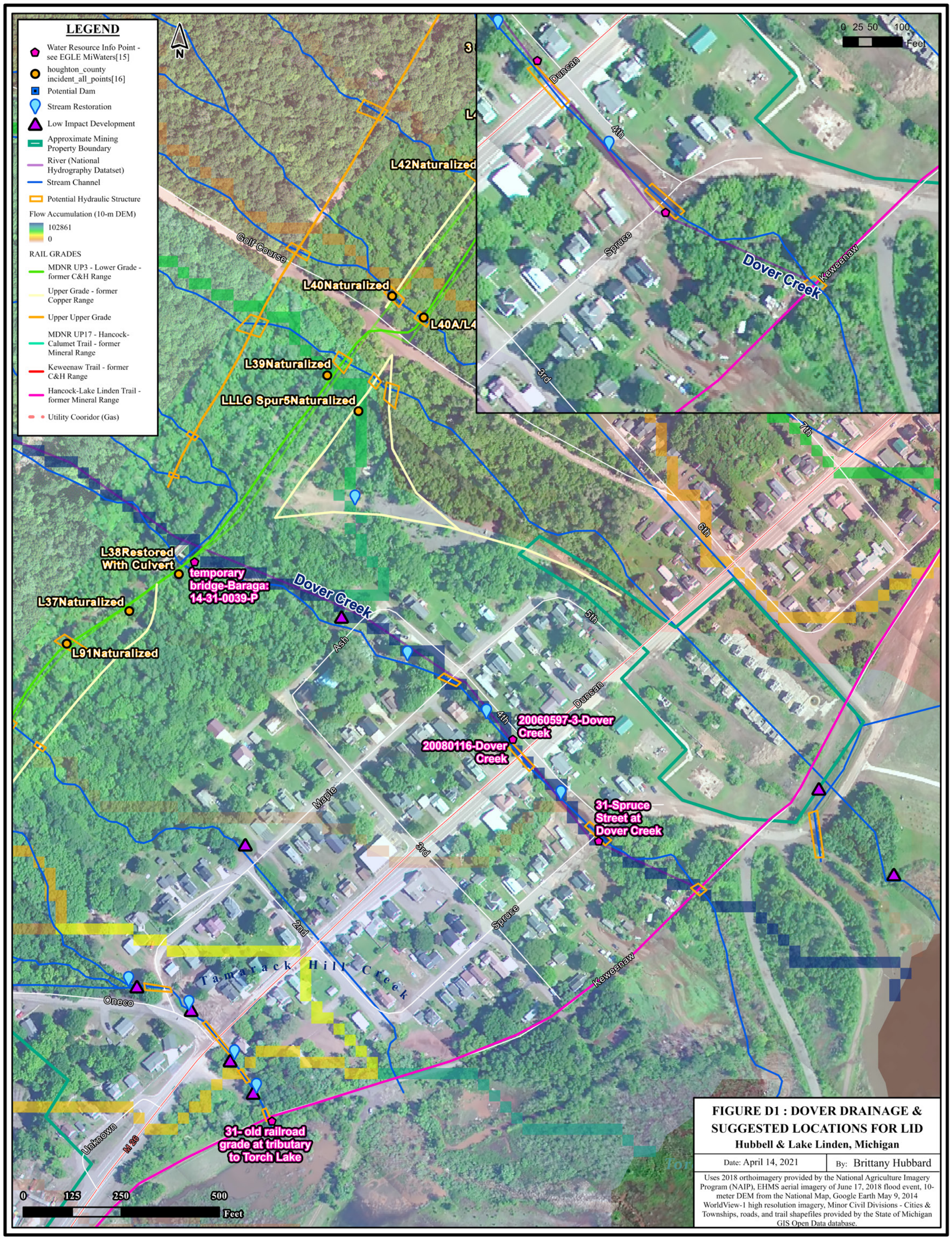

Figure 4.11. Dover Creek Drainage & Suggested Locations for LID.

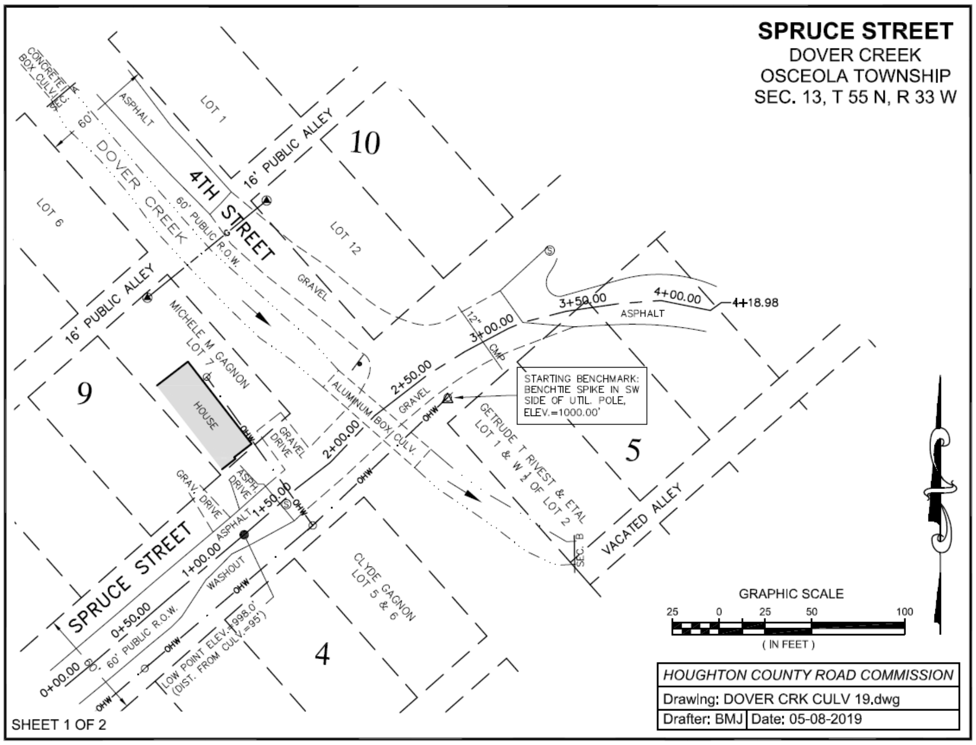

Figure 4.12. HCRC Dover Creek at Spruce St. Culvert Plan [18].

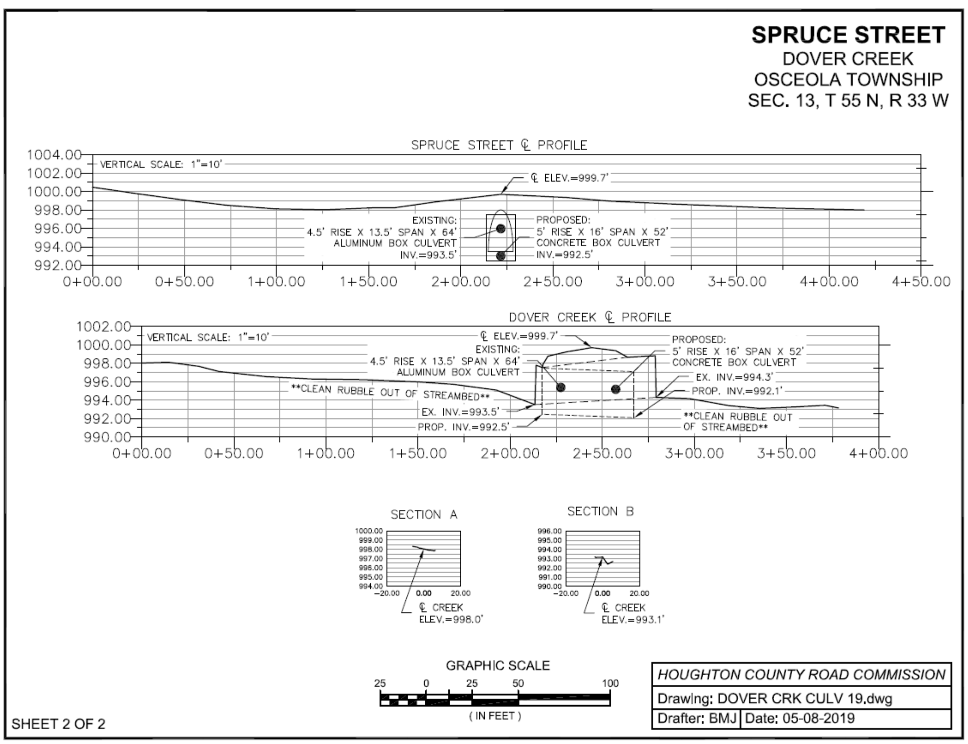

Figure 4.13. HCRC Dover Creek at Spruce St. Culvert Profile [18].

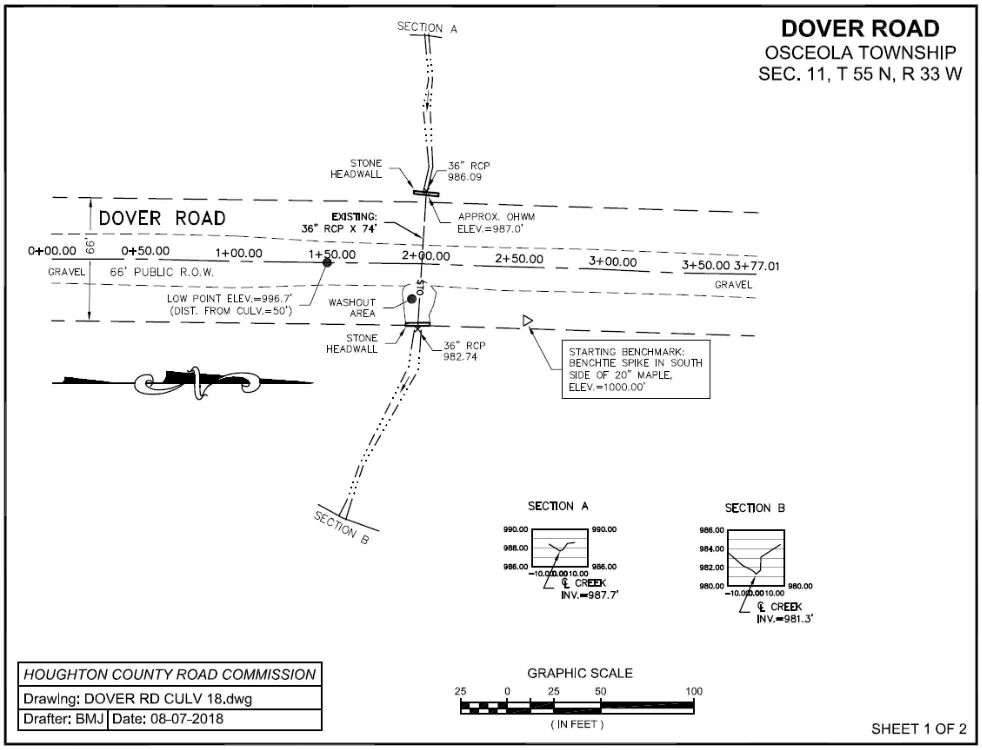

Figure 4.14. HCRC Dover Creek at Dover Rd. Culvert Plan [18].

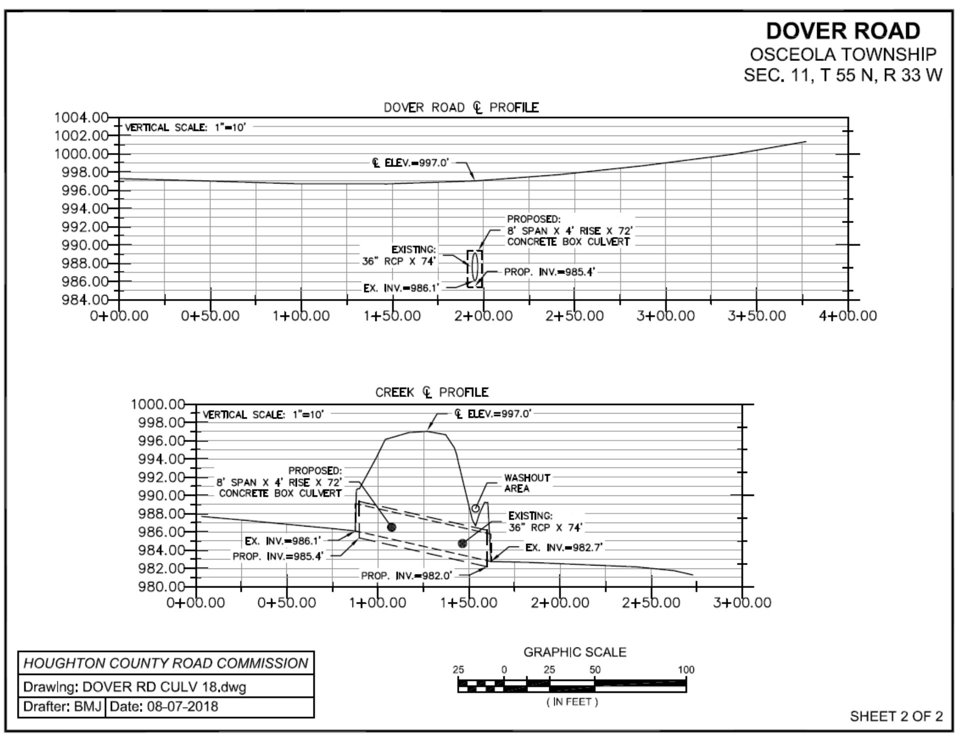

Figure 4.15. HCRC Dover Creek at Dover Rd. Culvert Profile [18].

4.2.5 8th St. Creek Stream Restoration & LID

Several small stream channels drain 8th Street Creek catchment. These streams have been naturalized where flow intersects the Rail Grade post 2018 flood events. The floodplain encompasses the approximate area between 6th St. and 10th St. in Hubbell.

A stream parallels the north side of Golf Course Rd. and inlets the stormwater system at a drain upstream of the northwest end of Sixth Street. Flow remains beneath 6th St. to beyond Spruce St. resurfacing at the eastern corner of the former Ahmeek Stamp Mill property near the intersection of 6th St. with Osprey Drive. An open channel drainage ditch and culvert convey drainage to Torch Lake. An in-stream wetland or detention pond is suggested upstream from residences on 6th St. to provide water storage for when the drain inlet becomes overwhelmed or clogged during flood events. Additional LID is suggested to the drainage ditch on the historical Ahmeek Stamp Mill property to trap contaminated sediment from leaving the Site. See MDOT Sixth Street Storm Sewer and Sixth Street Storm Sewer Outlet figures below.

The steep grade of 8th Street and deeply carved stream channel valley suggest high stream discharge velocity. The main stream channel inlets the stormwater drain up-grade from the northwest end of 8th Street. Rock check dams up-grade of the northwest end of 8th Street could be used to decrease approaching stream velocity. Historical frequency of flooding and severity of flooding along 8th Street that occurred on June 17, 2018, suggests rehabilitation of the stream outlet is a priority. Open-channel stream restoration to repair the natural stream path to the outlet at Torch Lake may be necessary to protect residential areas from flooding, but no clear path for an open channel stream exists between homes.

Additional sites recommended for LID exist at the north west end of 7th and 9th streets, a wetland or detention system to improve storage capacity where the creek inlets into the stormwater system and east of Golf Course Rd stream restoration is suggested to reduce scour occurring downstream of the Golf Course Rd. hydraulic structure.

Refer to Figure 4.16. 8th Street Creek Drainage & Suggested Locations for LID, Figure 4.17. 2010 MDOT Drainage and Vicinity for Hubbell, MI, and Figures 4.18, 4.19, and 4.20. MDOT 6th Street Storm Sewer, 6th St. Storm Sewer Outlet, and 8th St. Storm Sewer Outlet, respectively, Figure 4.21. MDNR Rail Grade Plan – Hubbell, and Figure 4.22. OHM - MDNR Rail Grade Plan – LLUG-29 provided by EGLE MiWaters [18].

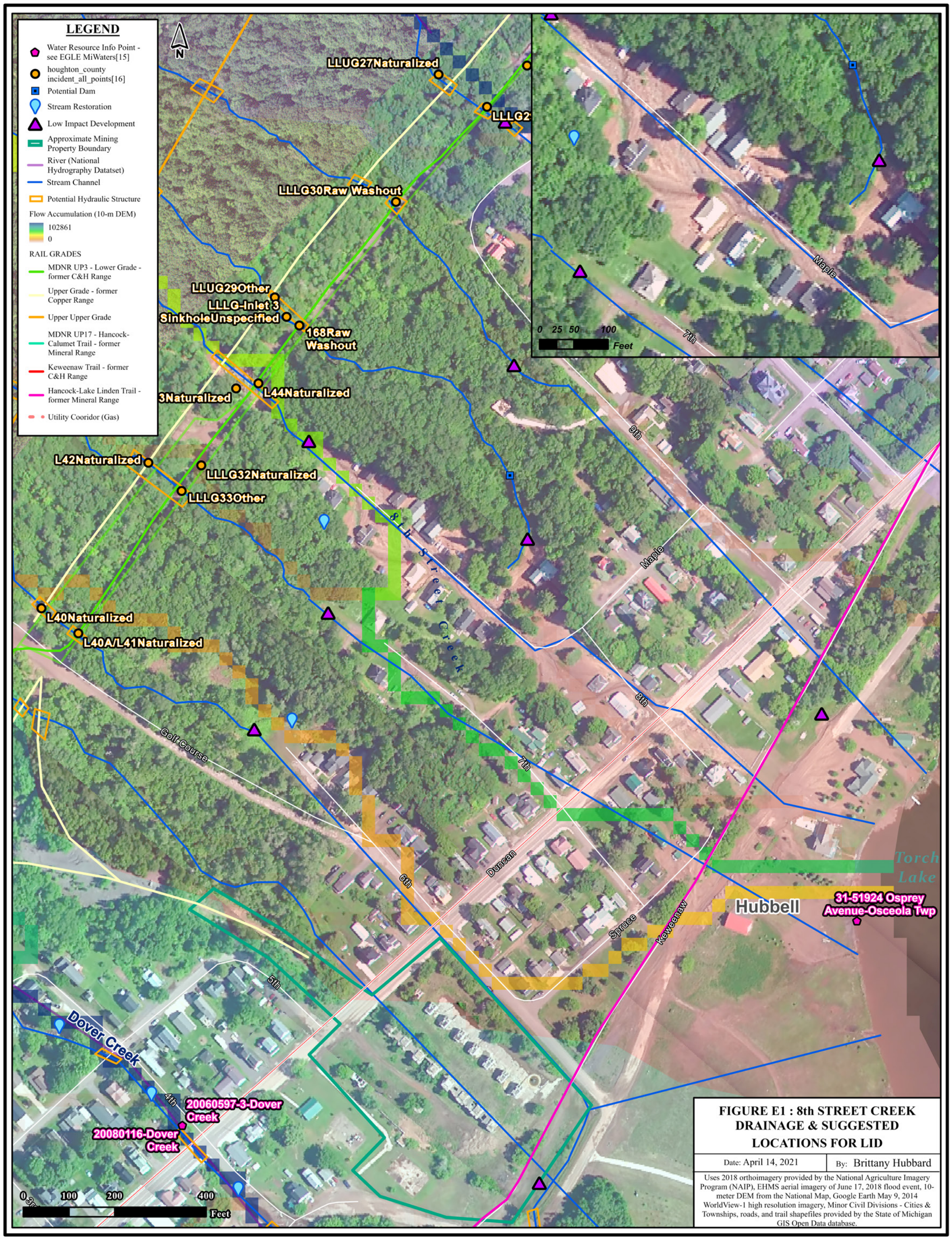

Figure 4.16. 8th St. Creek Drainage & Suggested Locations for LID.

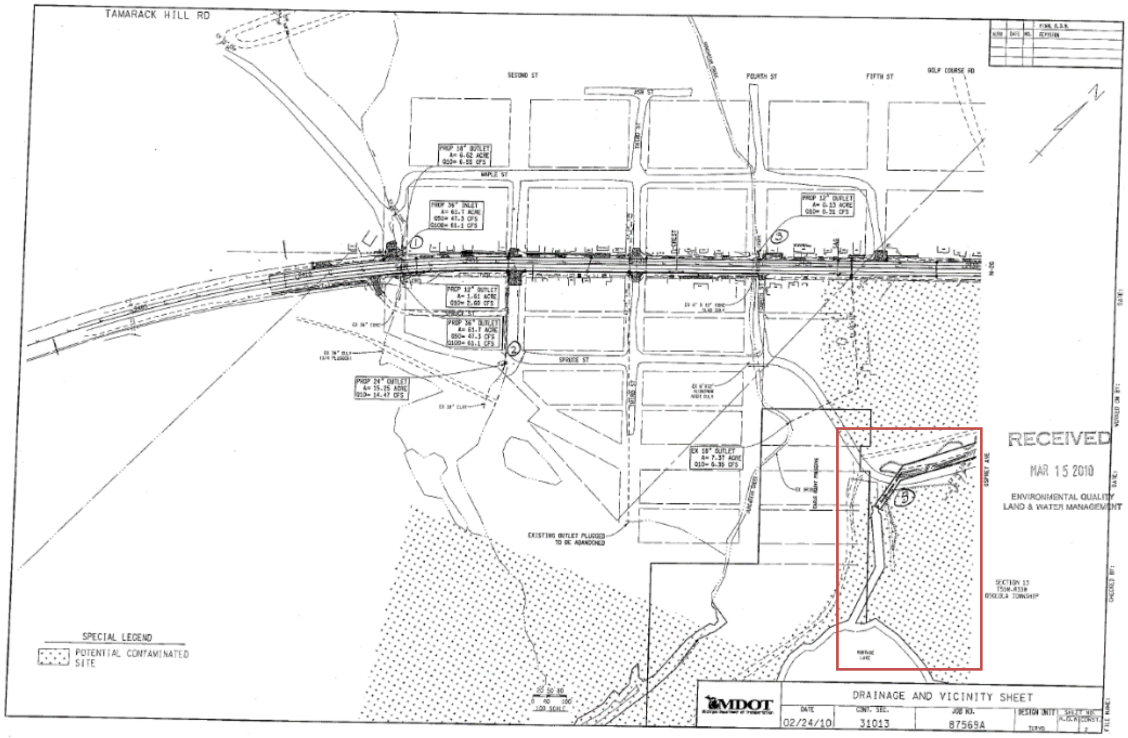

Figure 4.17. MDOT Drainage and Vicinity Sheet [18]. Modified by author.

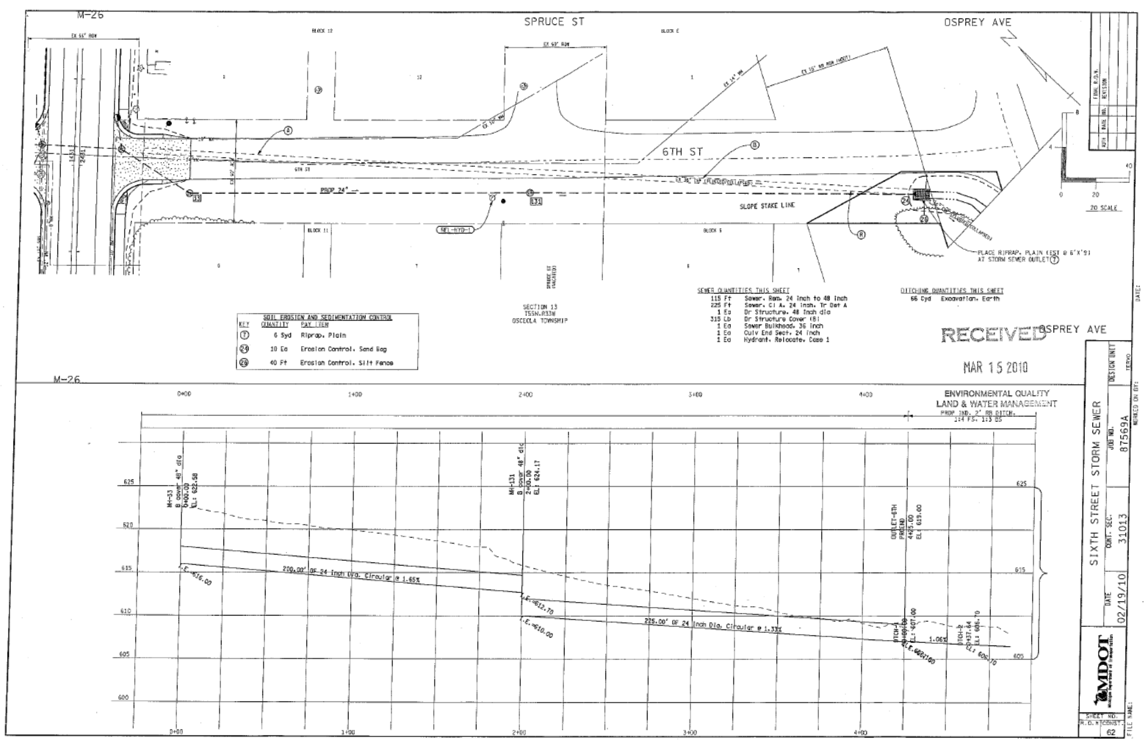

Figure 4.18. MDOT 6th St. Storm Sewer [18].

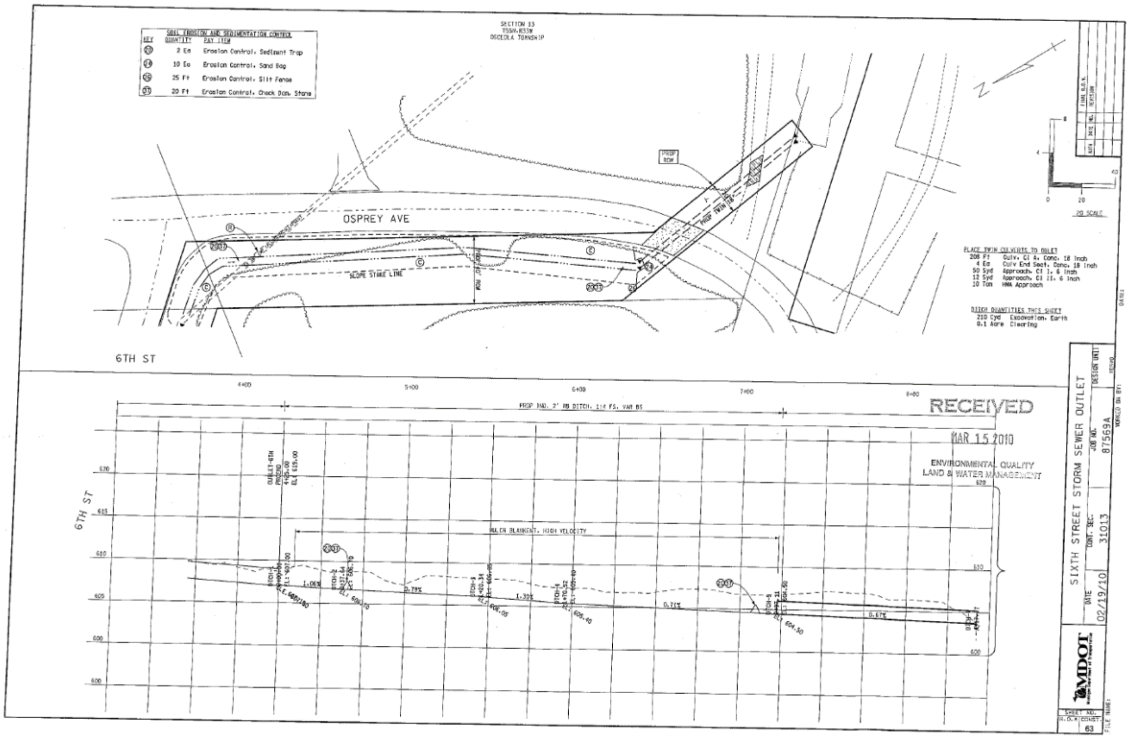

Figure 4.19. MDOT 6th St. Storm Sewer Outlet [18].

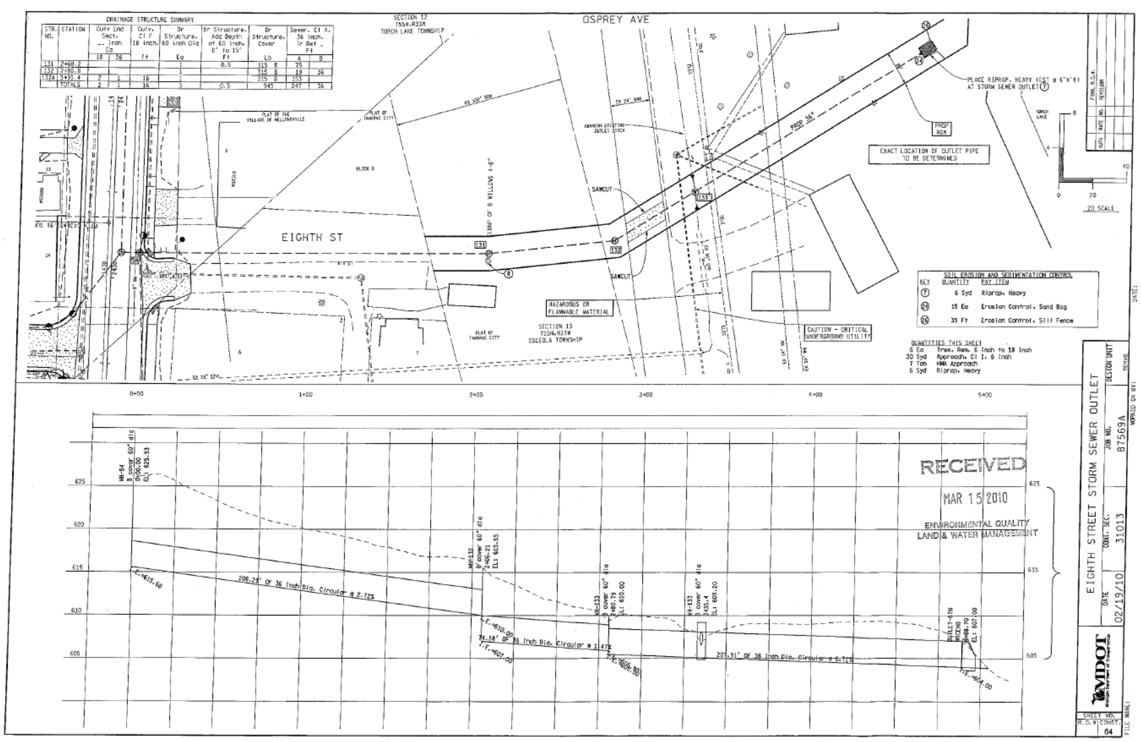

Figure 4.20. MDOT 8th St. Storm Sewer Outlet [18].

Figure 4.21. MDNR Rail Grade Plan – Hubbell [18].

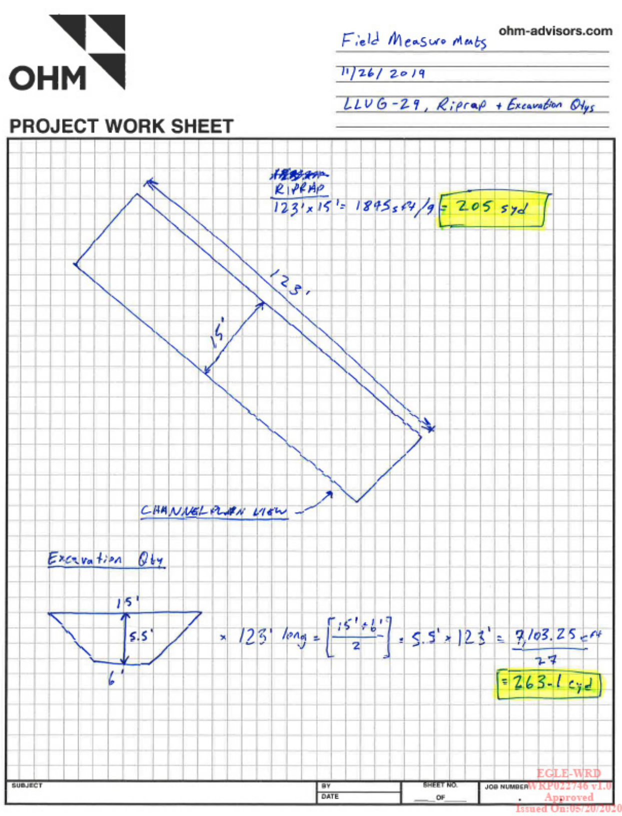

Figure 4.22. OHM - MDNR Rail Grade Plan – LLUG-29 [18].

4.2.6 12th Creek Stream Restoration & LID

12th Street Creek enters a drain up-grade from the intersection of W. 10th St. and G Avenue. An in-steam wetland is suggested upstream from the drain inlet to increase water storage capacity. Major stream restoration would be required to repair open channel flow reaching to outlet at Torch Lake. 12th Street Creek remains buried in stormwater sewer system until reaching the outlet into Torch lake at the southeast end of Argon St. (11th St.).

Several tributary creeks exist. Southwest from the main stream channel, one tributary is assumed to enter the stormwater system upstream from a residential driveway on the southwest side of 9th Street. Northeast from the main stream channel, two creeks converge downhill from the Rail Grade and inlet a drain up-grade of the intersection of 12th St. (G Ave.) and F Ave (Birch). An in-stream wetland is suggested downstream from the confluence and upstream from the drain inlet. The stream has been naturalized where flow intersects the Rail Grade for all tributaries and 12th St Creek main stream channel.

Refer to Figure 4.24. 12th Street Creek Drainage & Suggested Locations for LID, Figure 4.23. 2010 MDOT 11th Street Storm Sewer Outlet figure, and Figure 4.25. HCRC 12th St Creek at Golf Course Rd. Culvert provided by EGLE MiWaters [18].

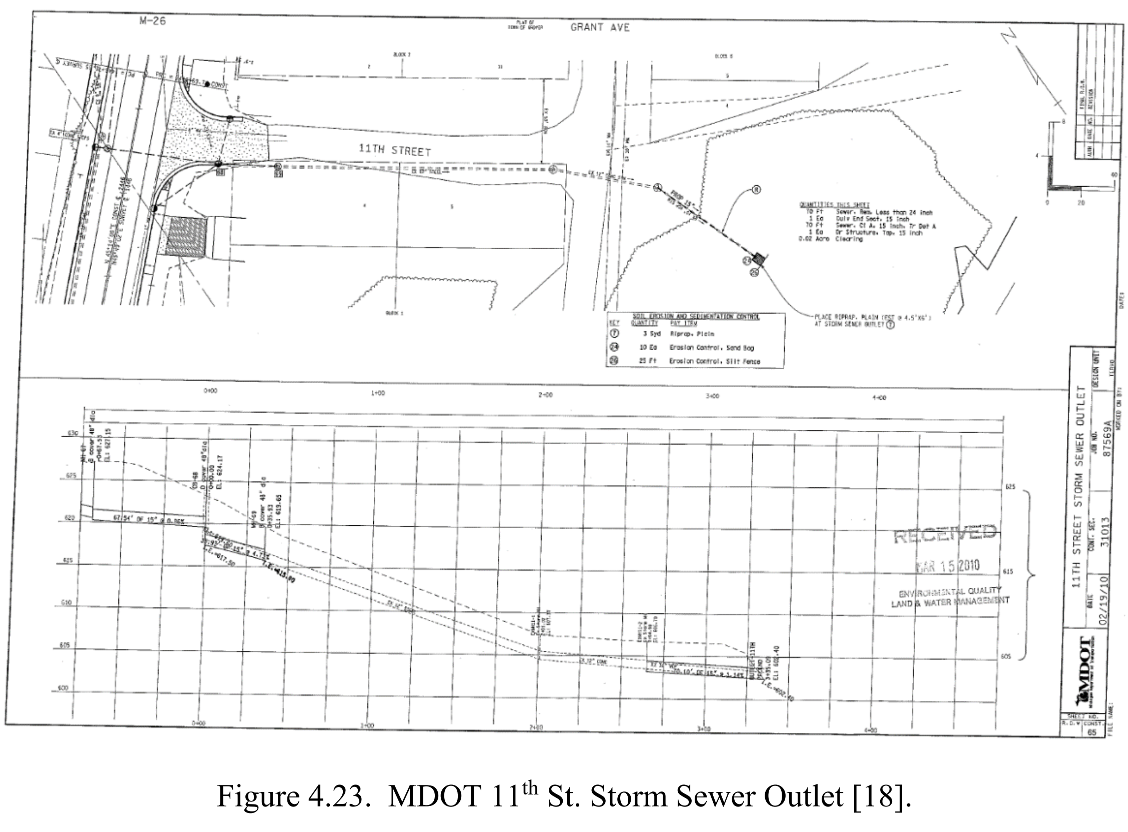

Figure 4.23. MDOT 11th St. Storm Sewer Outlet [18].

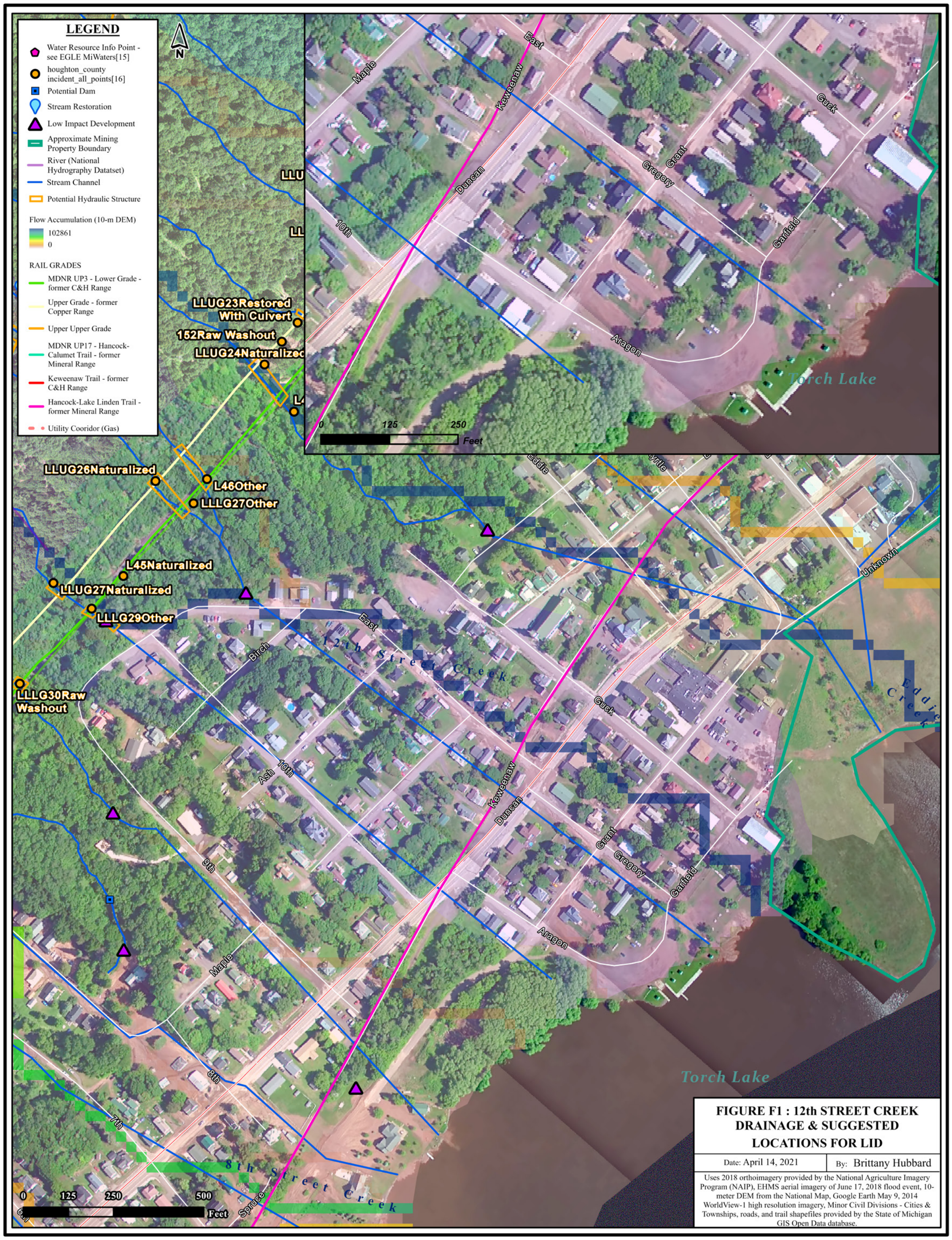

Figure 4.24. 12th St. Creek Drainage & Suggested Locations for LID.

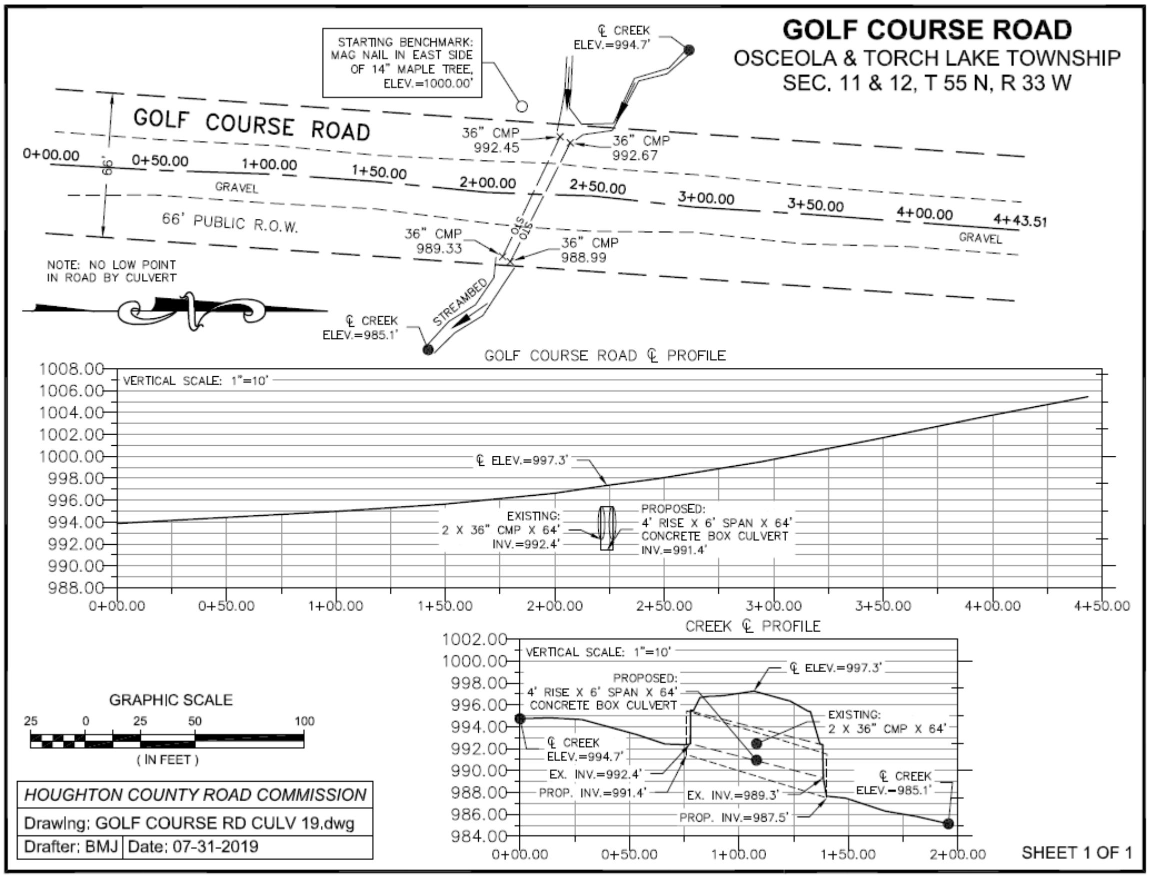

Figure 4.25. HCRC 12th St Creek at Golf Course Rd. Culvert [18].

4.2.7 Eddie & Myrtle Creek Stream Restoration & LID

Several small stream channels drain Eddie & Myrtle Creek catchment. The June 2018 flood event naturalized the intersection with the Rail Grade at every stream. Three culverts have been restored within the upper-grade [10]. The floodplain encompasses the approximate area between Guck St. to Daisy St. in Hubbell, Michigan.

Drainage from Eddie and Myrtle main stream channel inlets the stormwater system northwest of Ontonagon St. at two locations: between Guck St. and Eddie St. (Eddie Creek), and between Eddie and Myrtle streets (Myrtle Creek). A bioretention system is suggested upstream from both drain inlets as a means to reduce excess runoff during rainfall events. The stream outlet into Torch Lake exists at the southeast end of 15th St. See MDOT 15th Street Storm Sewer Outlet figure below.

Approximately 200 feet north from Myrtle creek, along the Rail Grade, a rivulet has formed resulting in overland flow, ponding water, and erosion on the Rail Grade. The

stream has been naturalized (L50) where flow intersects the lower Rail Grade and a culvert (LLUG20) has been restored in the upper grade. Downstream topography from the Rail Grade suggests flow accumulation outlets toward and, over time, will converge with Myrtle creek. This area needs further assessment to determine if stream restoration or LID is needed to protect nearby residences

Refer to Figure 4.27. Eddie & Myrtle Creek Drainage & Suggested Locations for LID and Figure 4.26. 2010 MDOT 15th Street Storm Sewer Outlet figure provided by EGLE MiWaters [18].

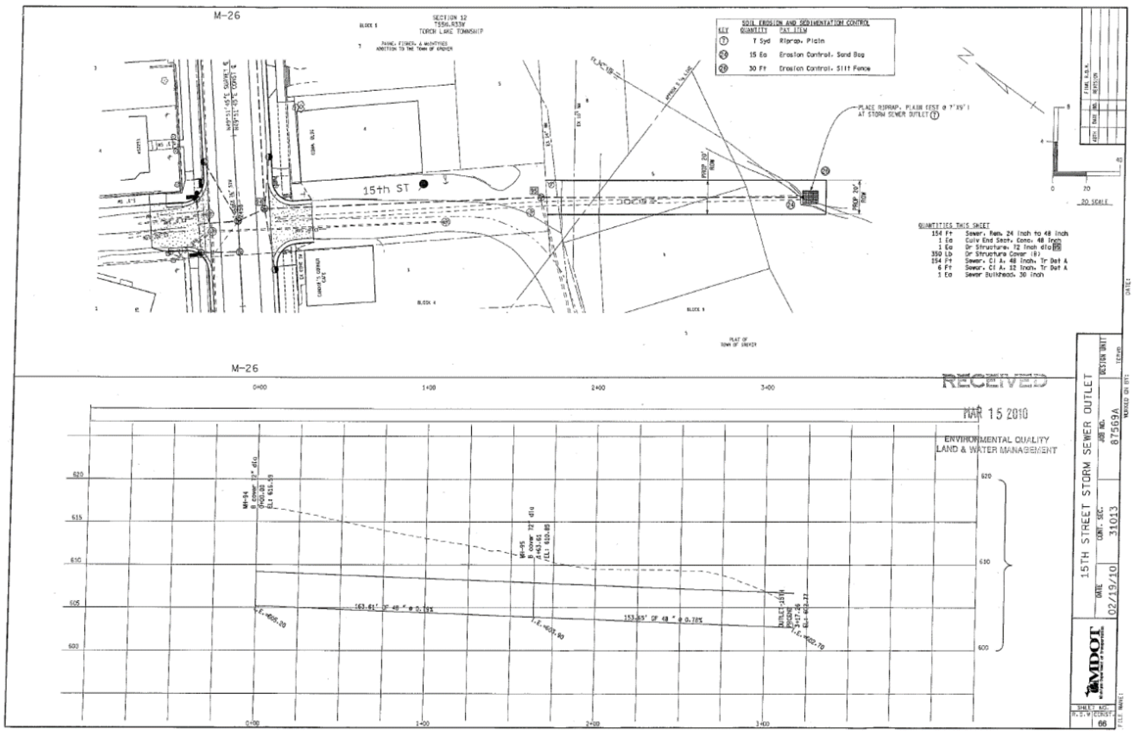

Figure 4.26. MDOT 15th St. Storm Sewer Outlet [18].

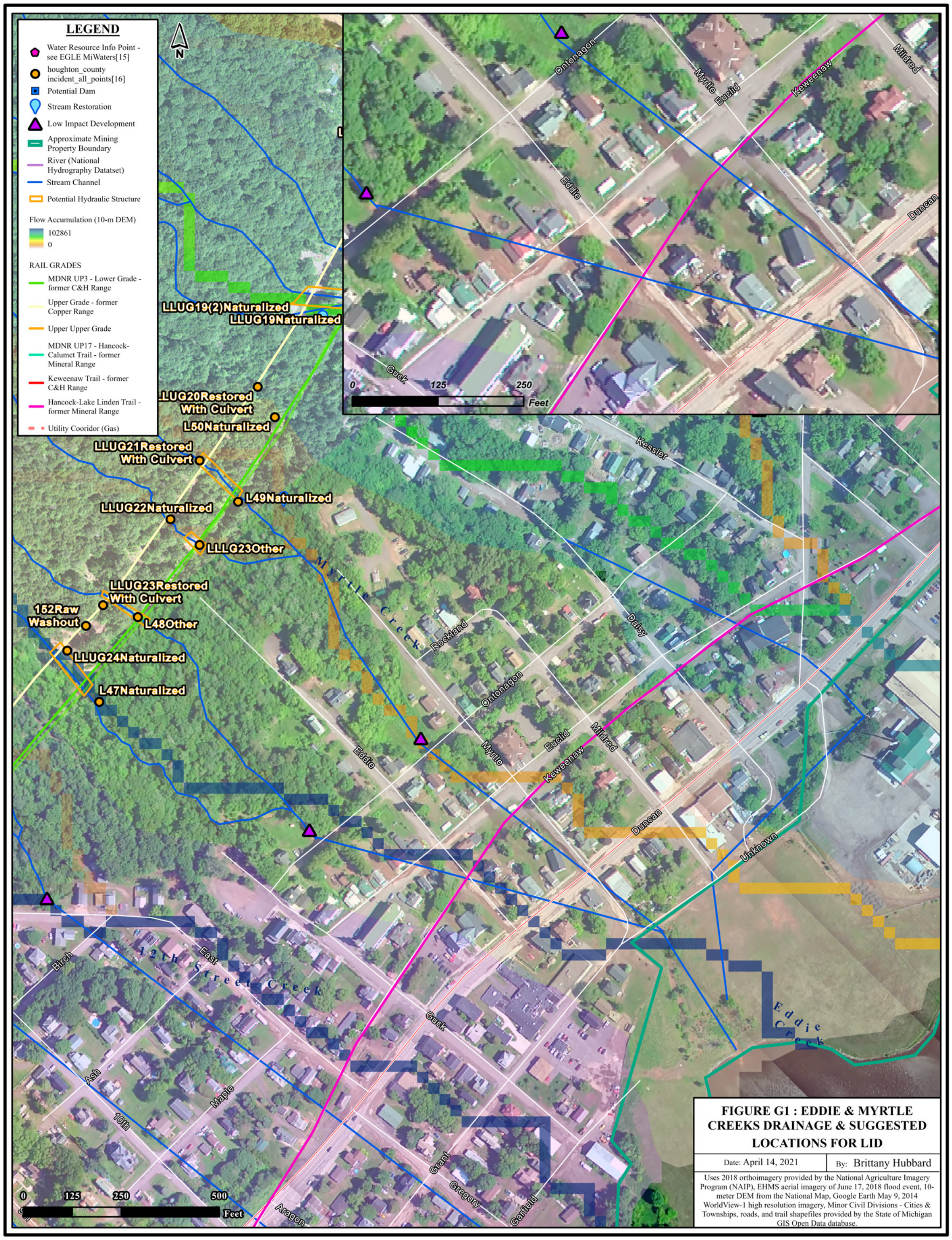

Figure 4.27. Eddie & Myrtle Creek Drainage & Suggested Locations for LID.

4.2.8 Daisy Creek Stream Restoration & LID

Assessment for future stream restoration is suggested at the intersection of the main stream channel with the gas utility line, Lake Linden Grade 3, and upper rail grades. Historical imagery suggest surface water is ponding at these locations.

Approximately 200-250 feet south from Lakeview St. (W 21st St.) along the Rail Grade, a rivulet has formed resulting in overland flow, ponding water, and erosion on the Rail Grade. Post 2018 flooding events, the stream has been naturalized (LLUG18 & L53 [10]) where flow intersects the Rail Grade.

Downstream from the Rail Grade, several tributary creeks converge and are channelized north of Kessler St. (W. 18th St.) into the stormwater sewer. Aerial imagery suggests surface water is ponding at this convergence with the main stream channel. Further investigation is needed to confirm whether observed ponding is a designed retention system or if a natural surface water body has formed where flow paths converge. Daisy Creek enters a drain near the intersection of Division St (W. 20th St.) and Division Ave. (L Ave.). Excess runoff tends to use Daisy St. as a flow path and floods the area between Daisy St. and Kessler Street. Rock check dams in series are suggested upgrade from Daisy St. and the stormwater drain inlet between W. 20th St. and Division Ave. to reduced stream velocity and capture sediment. Major stream restoration may be required to reconnect flow to natural topographical open channel to increase water storage capacity, infiltration, and reduce excess runoff during extreme rainfall events. Additionally, Daisy and Kessler Streets could incorporate permeable roads and bioretention systems in drainage ditches to further reduce excess runoff.

Refer to Figure 4.29. Daisy Creek Drainage & Suggested Locations for LID and Figure 4.28. MDOT Drainage and Vicinity Sheet B provided by EGLE MiWaters [18].

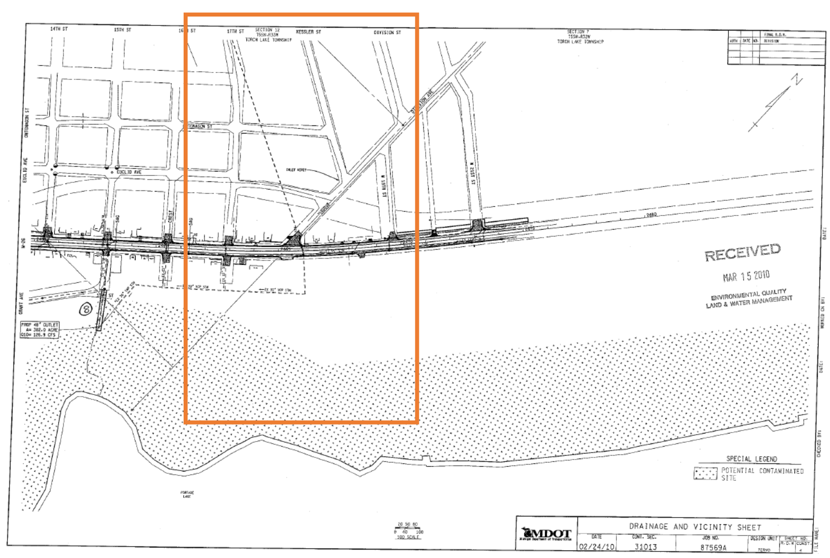

Figure 4.28. MDOT Drainage and Vicinity Sheet B [18]. Modified by author.

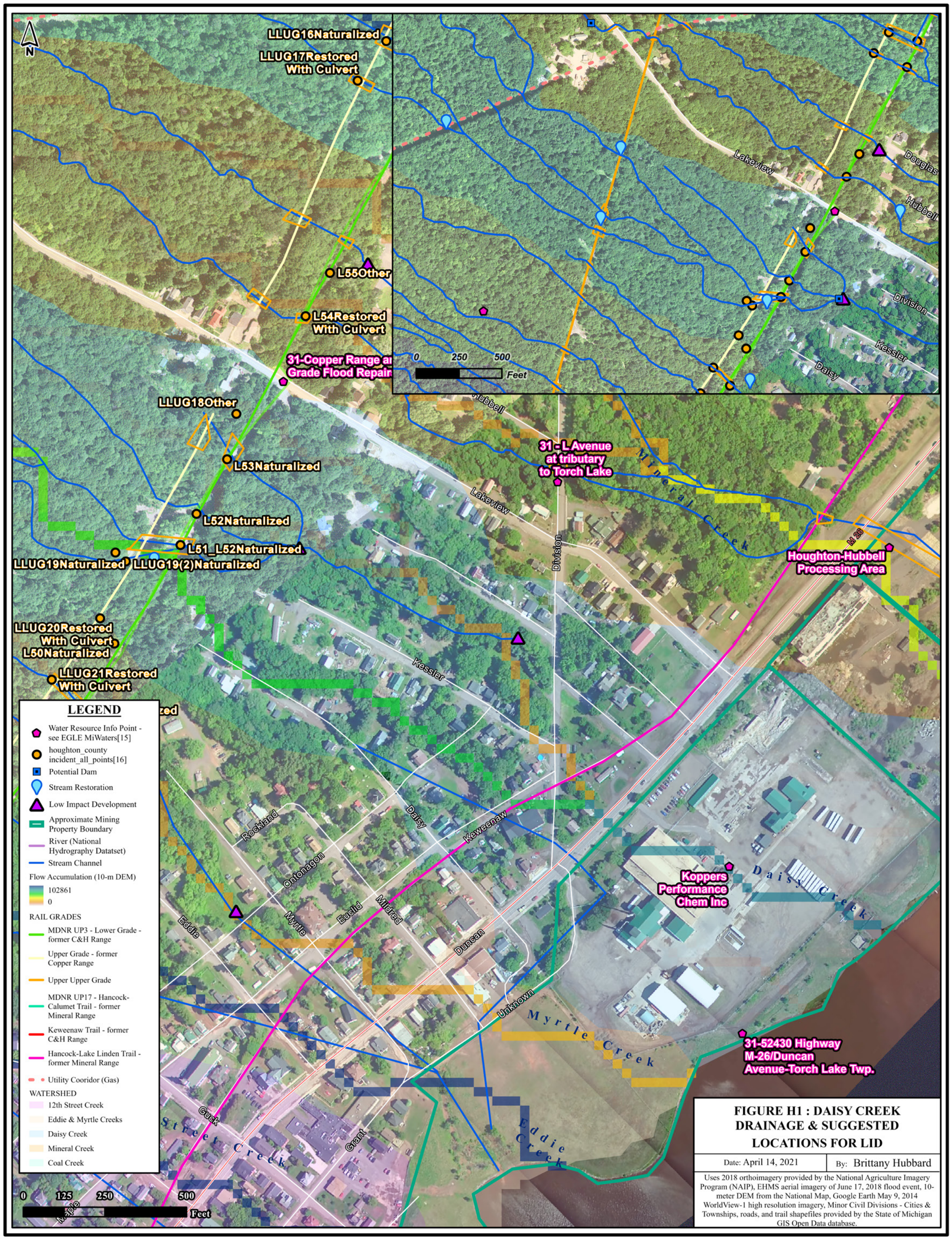

Figure 4.29. Daisy Creek Drainage & Suggested Locations for LID.

4.2.9 Mineral Creek Stream Restoration & LID

Mineral Creek is relatively unimpeded in the developed lowland region, but the upper and middle regions have been altered for agricultural use. Ditches connect drainage from the adjacent Coal Creek watershed to outlet via Mineral Creek watershed. Designs should account for the extra drainage area as a result of connected agricultural developed drainage routes.

Two main stream channels drain Mineral Creek catchment. Upstream from the Lake Linden Grade 3, two existing surface water bodies may provide flow control.

Stream channel improvements are suggested downstream from the Rail Grades between Lakeview St (W 21st St.) and Hubbell St. west of Division Ave. The stream path may have become disconnected due to land use changes around residences and excess runoff appears to pond and extend down a driveway.

A culvert conveys stream flow beneath Division Ave. See L Avenue culvert figures below. Site photo at this location, available through EGLE MiWaters, shows invasive Japanese Knotweed taking over the stream crossing. Refer below to Figure 4.33. Restoration and treatment to remove this invasive plant species is recommended to prevent further spread downstream and into Torch Lake and the greater Lake Superior watershed.

At the north west end of Douglas St., an existing stormwater inlet is assumed to convey stream flow beneath Douglas St. to an outlet east of Division Avenue. Downstream from Division Ave., the stream channel is open. An in-stream wetland or bioretention system is suggested upstream from the stormwater inlet at the west end of Douglas St.

A small surface water body provides water storage capacity just up-grade from M-26. A vegetated swale along the right-of-way corridor of M-26 in this region could be used to increase the effective floodplain area and trap transporting sediment before it enters the downstream drainage ditch. This area includes hard to vegetate, easy to erode, stamp sand soils.

Downstream from M-26 stream flow is routed through an open channel drainage ditch, immediately north-northeast of the mineral building, through the Hubbell Processing Area land formerly used by Calumet and Hecla mining operations. Drain reconstruction and maintenance had been performed prior to the 2018 Father's Day flood [18]. Regularly scheduled maintenance to remove accumulating sediments and debris will be needed to ensure channel remains functional. A sediment basin could be utilized to improve water quality by capturing transporting particles and pollutants on-site prior to their outlet into Torch Lake.

Refer to Figure 4.30. Mineral Creek Drainage & Suggested Locations for LID, Figures 4.31 and 4.32. 2018 L Avenue culvert plan and profile by the Houghton County Road Commission, Figure 4.39. 2016 Mannik Smith Group Hubbell Coal Dock Drainage Ditch

Clean Out, and Figures 4.34 through 4.38. 2017 Hubbell Processing Area Plan Set A by the Mannik Smith Group provided by EGLE MiWaters [18].

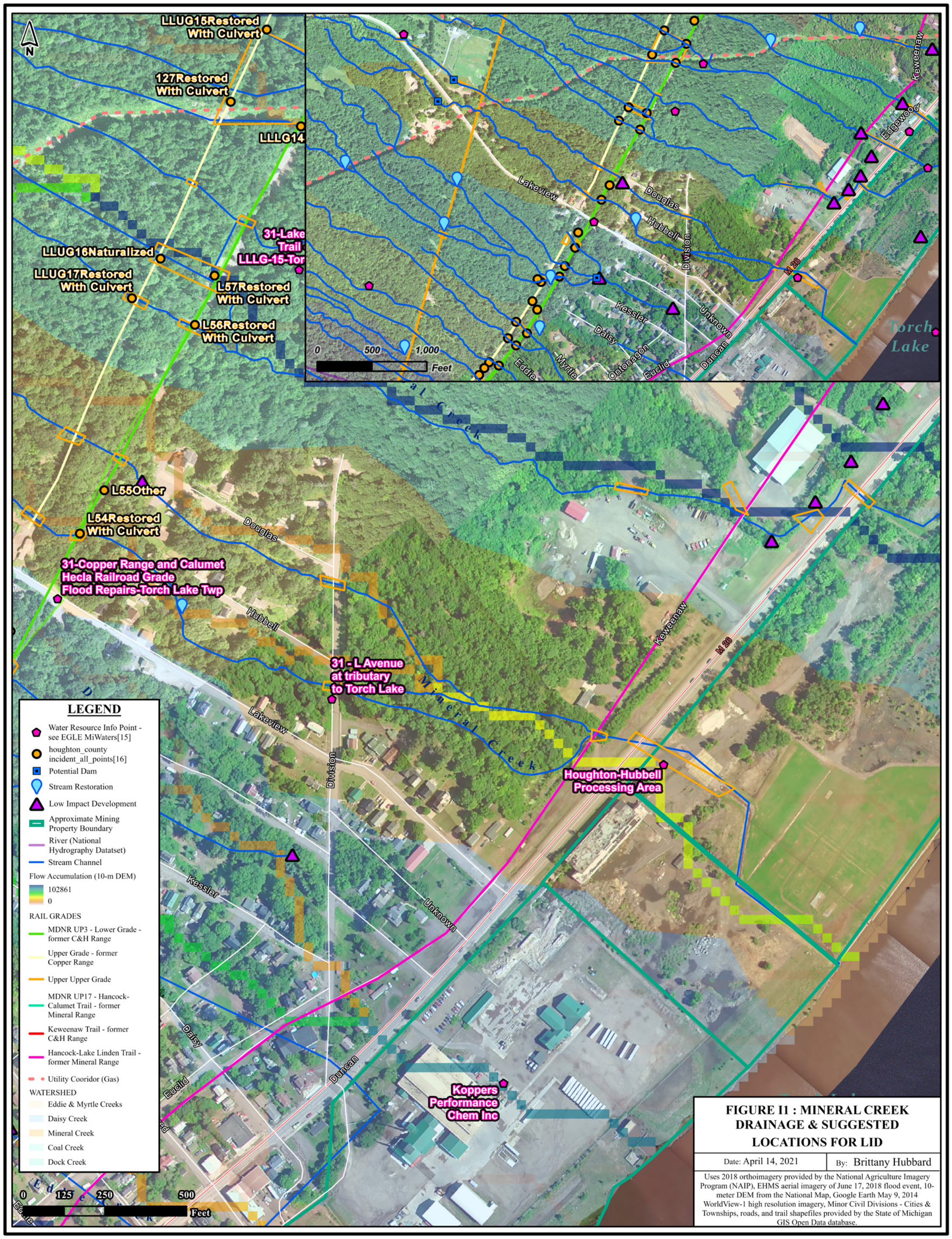

Figure 4.30. Mineral Creek Drainage & Suggested Locations for LID.

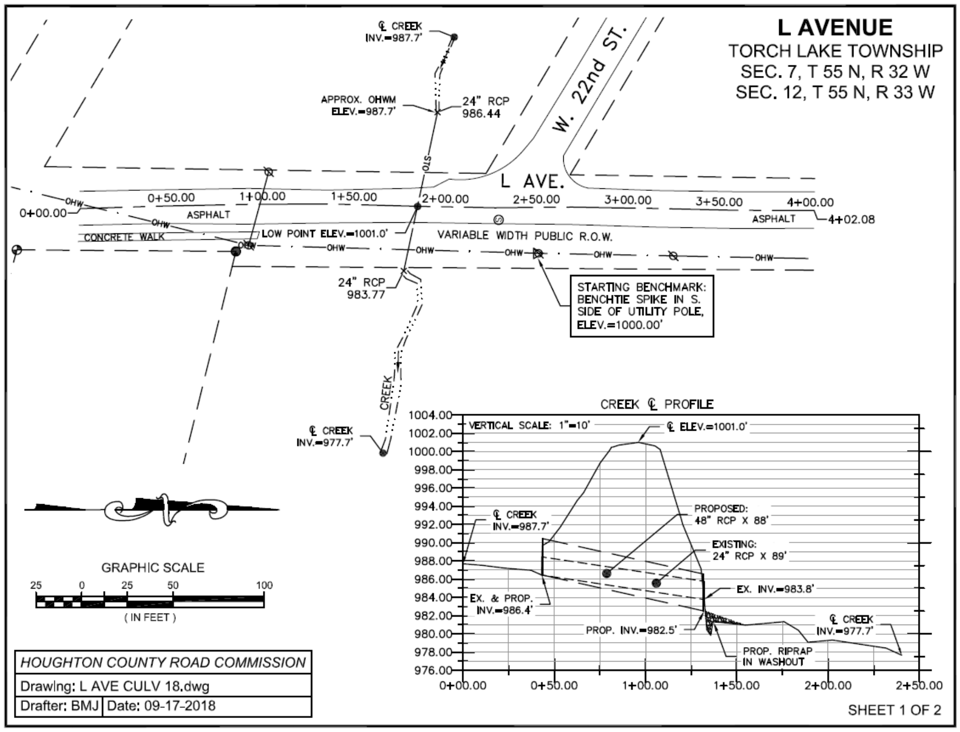

Figure 4.31. HCRC L Ave. Culvert Plan [18].

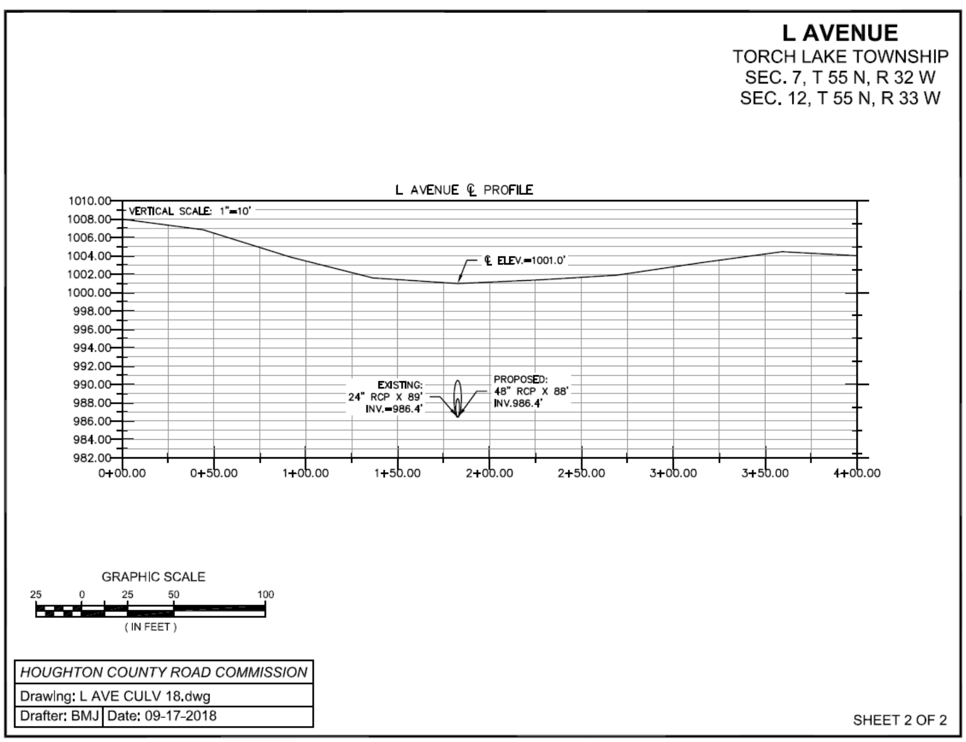

Figure 4.32. HCRC L Ave. Culvert Profile [18].

Photographs taken by: John G.

Date photographs taken: 9/5/18

Crossing location

Figure 4.33. Invasive Japanese Knotweed in Waterway [18].

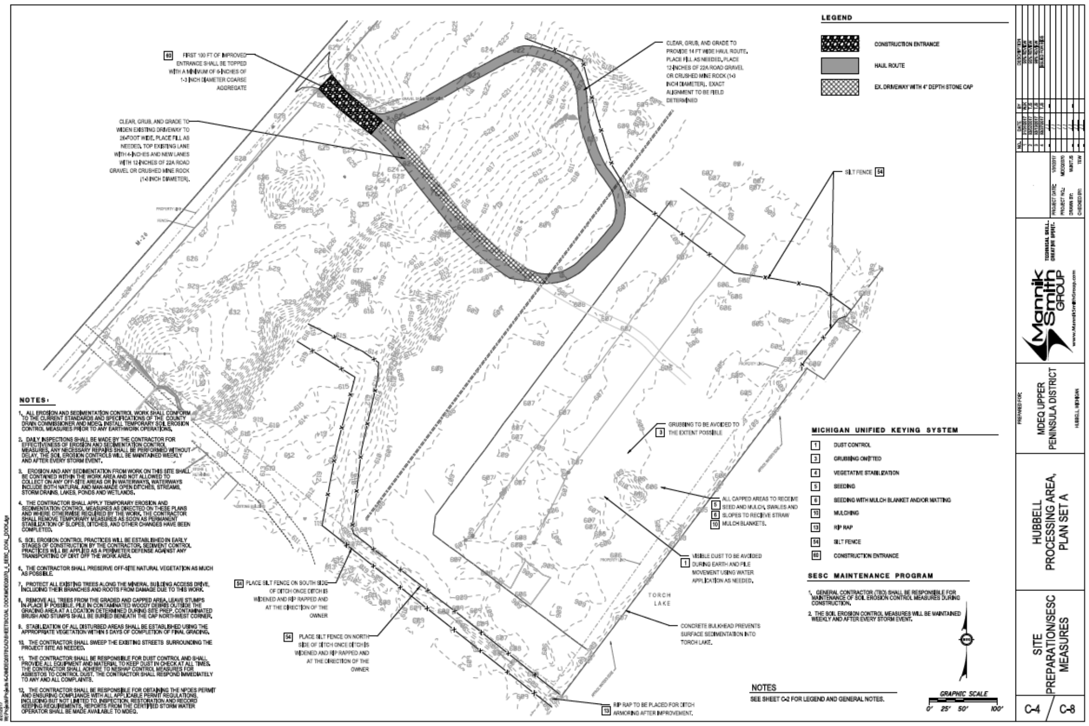

Figure 4.34. MSG Hubbell Processing Area Drainage Ditch [18].

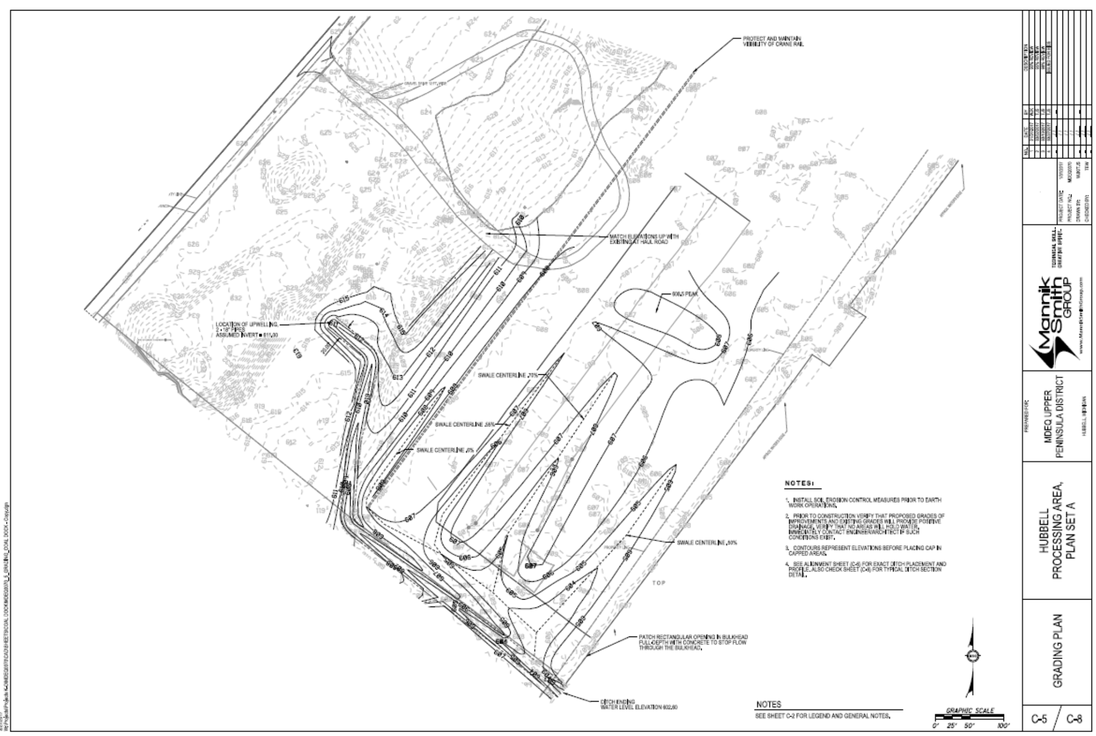

Figure 4.35. MSG Hubbell Processing Area Drainage Ditch Grading Plan [18].

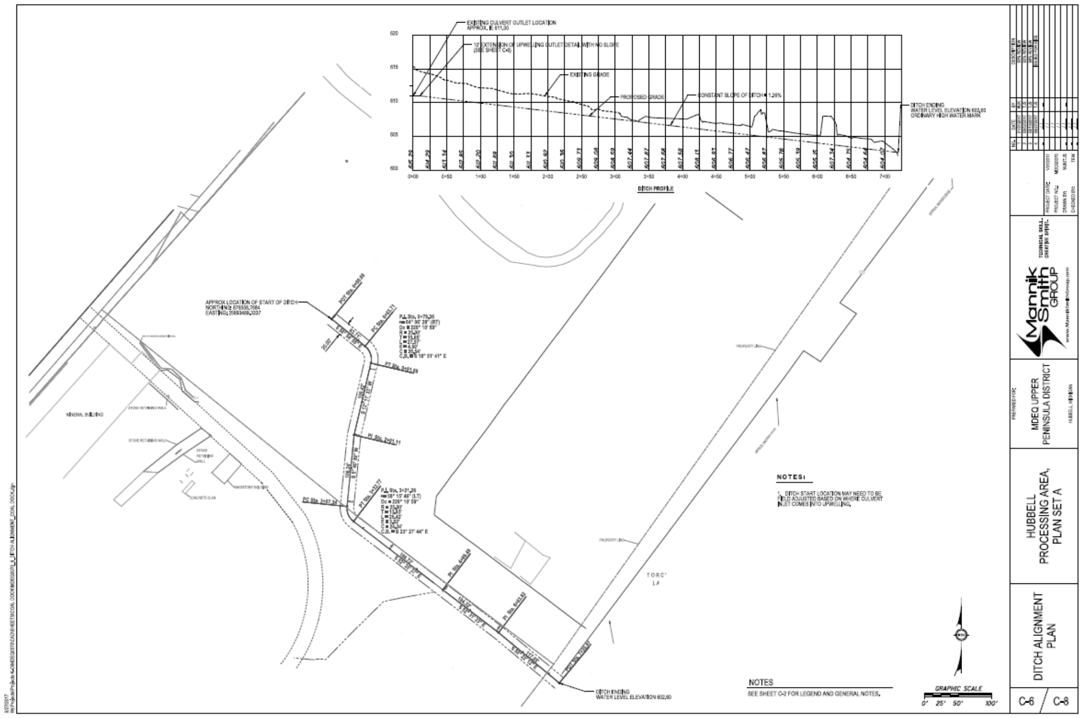

Figure 4.36. MSG Hubbell Processing Area Drainage Ditch Alignment Plan [18].

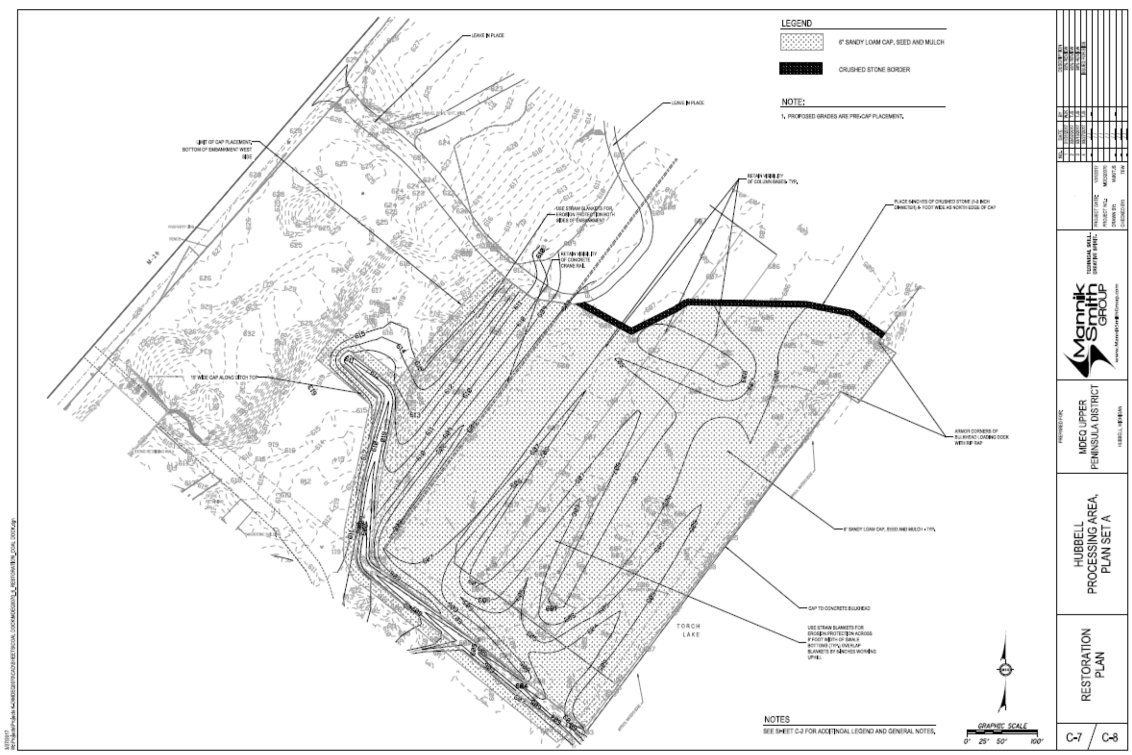

Figure 4.37. MSG Hubbell Processing Area Drainage Ditch Restoration Plan [18].

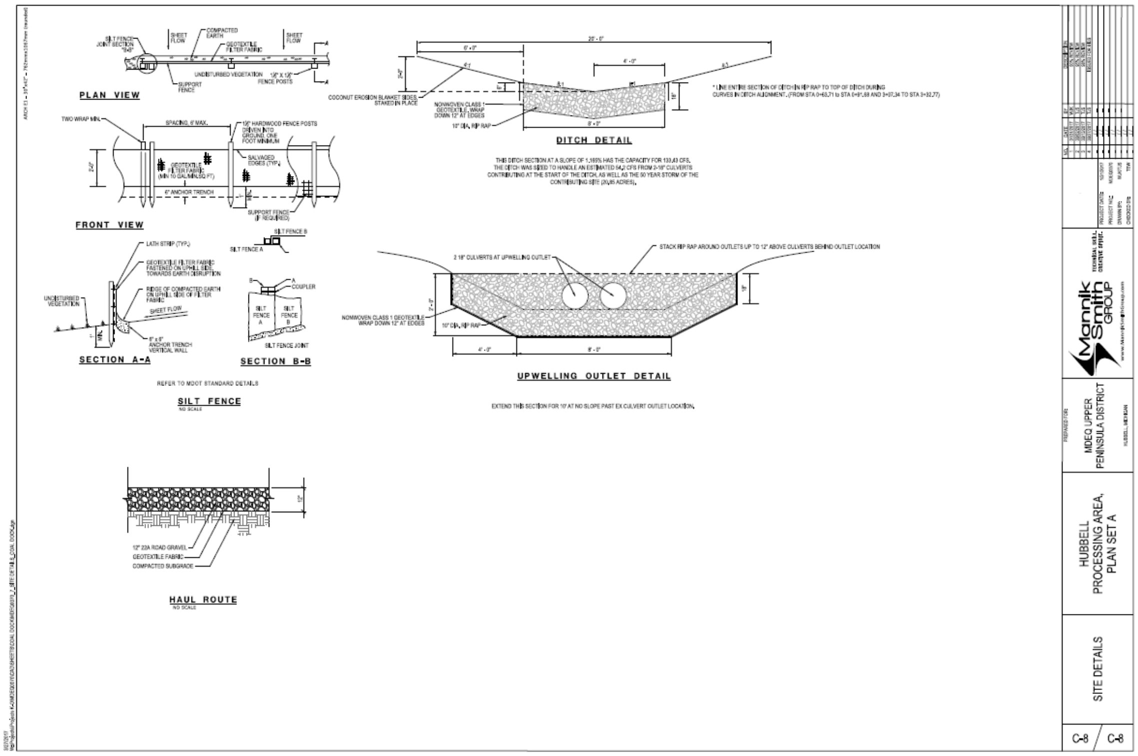

Figure 4.38. MSG Hubbell Processing Area Drainage Ditch Site Details [18].

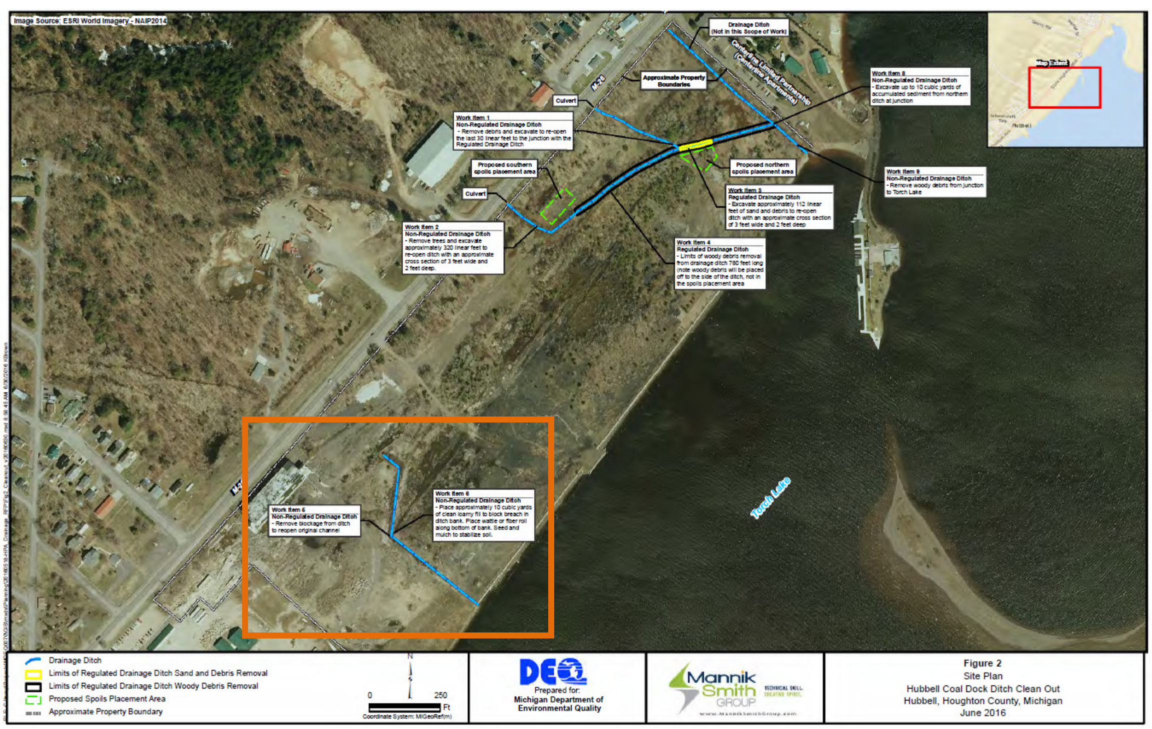

Figure 4.39. MSG Coal Dock Ditch Clean Out Site Plan [18]. Modified by author.

4.2.10 Coal Dock Creek Stream Restoration & LID

4.2.10.1 Coal Creek

Several upstream surface water bodies and a large agricultural property exist east of Golf Course Rd. and north of Lakeview St. connecting drainage from adjacent Dover Creek catchment. Stream channel improvements and a sediment basin is suggested downstream from the agricultural property to repair the disconnected flow path to main stream channel. The stream has been naturalized (LLUG16) or restored with a culvert (LLUG17) where flow intersects with the upper rail grade and two culverts (L57, L56) have been restored in the lower rail grade [10].

Coal Creek is channelized through developed lowland currently used by Ziemnick Excavating Inc. and former mining era coal docks property of the Calumet and Hecla Lake Linden Operations Area (CHLL) – Hubbell Processing Area. Three hydraulic structures are used, two driveway culverts and a structure at M26, to bypass roadways. The stream exceeded the channel banks between Ziemnick Excavating and the northern warehouse property during June 2018 flooding. Flow traversed the dirt roadway on site ponding in a swale up-grade of M-26. Stream channel improvements are suggested to repair the riparian zones through Ziemnick Excavating property and a vegetated swale up-grade from M26 to increase infiltration, provide additional ponding storage for excess runoff, and trap sediment prior to its transport downstream.

Downstream from M-26, a drainage ditch, identified as being cleaned out by the EGLE abandoned mining waste project as recently as 2017 [18], exists to convey stream flow through the former coal docks property to the outlet at Torch Lake. Excess runoff exceeding drainage ditch banks uses the historical coal docks mining property as a floodplain. The partially vegetated property contains contaminated stamp sands and is prone to erosion. Drainage ditches are recommended to be inspected and maintained often as sediment accumulation may be more likely due to commercially used barren land upstream and historical stamp sands on site. Prior to the stream outlet into Torch Lake, a sedimentation basin or infiltration trench is suggested on the coal docks property to contain transporting sediments and pollutants on-site.

Additionally, upgrade from Ziemnick Excavating Inc. and nearby sand/gravel pit, a flow path has developed which may be contributing to ponding observed on barren soils. Further investigation is required at this location to assess the need for stream restoration or LID.

Refer to Figure 4.40. Coal & Dock Creek Drainage & Suggested Locations for LID, Figures 4.45 and 4.46. Mannik Smith Group 2016 Hubbell Coal Dock Drainage Ditch Clean Out plans, and Figures 4.41 through 4.44 detailing Rail Grade site LLLG-15 drainage reconstruction plans approved by EGLE water resources department (WRD) and provided by EGLE MiWaters [18].

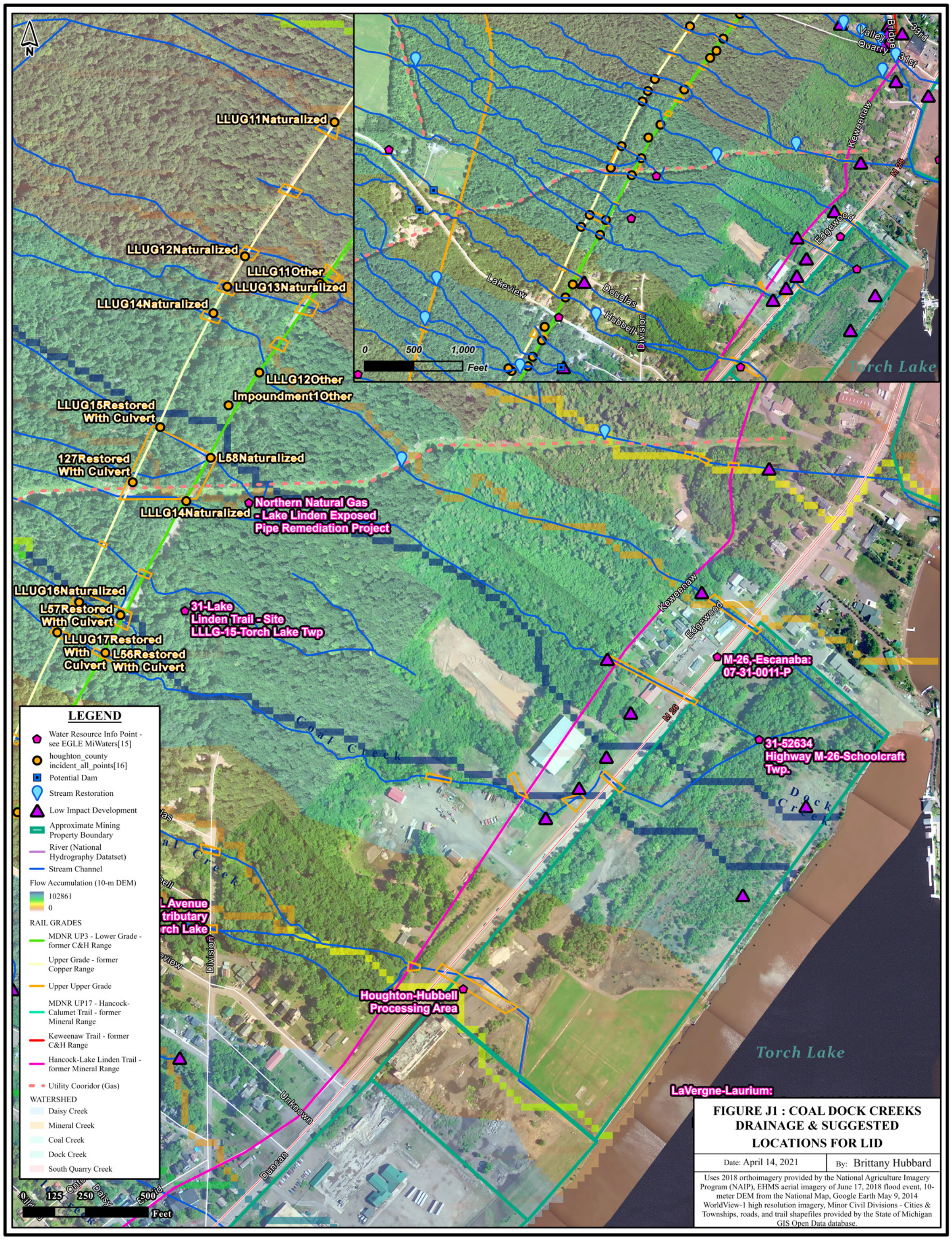

Figure 4.40. Coal & Dock Creek Drainage & Suggested Locations for LID.

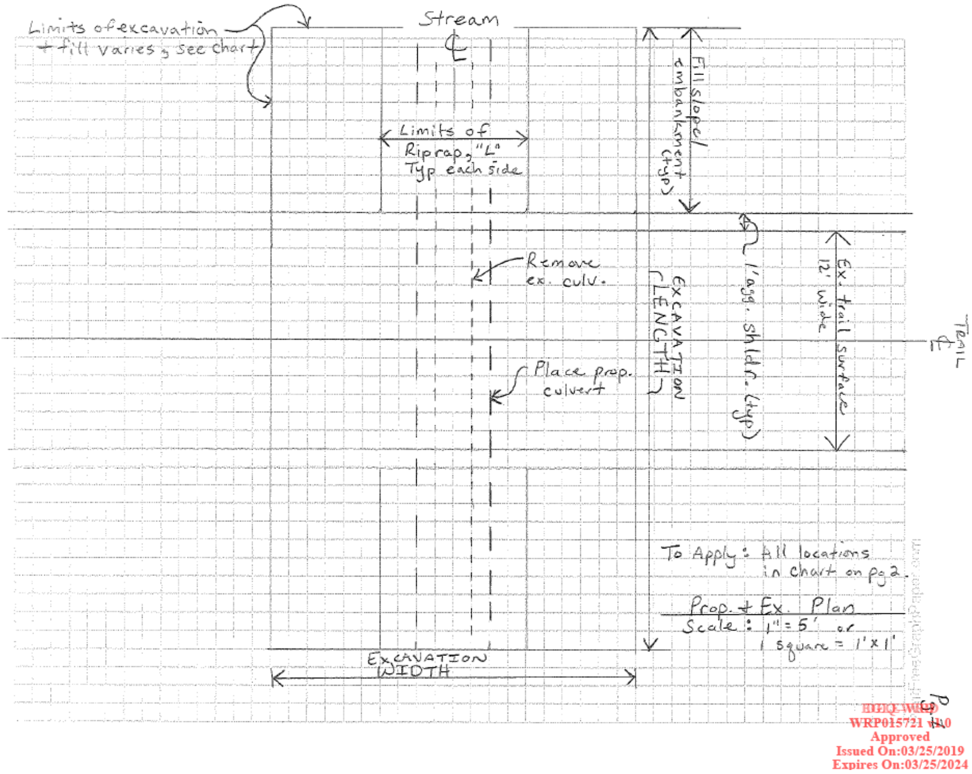

Figure 4.41. LLLG-15 Culvert Replacement Plan [18].

LOCATION	EXCAVATION (L)	EXCAVATION (W)	FILL (L)	FILL (W)	RIPRAP (L)	EX. CULV. (L)	EX. CULV. (Dia.)	PROP. CULV (L)	PROP. CULV (Dia.)	NOTES
B19	36'	14'	36'	14'	21'	42'	12"	44'	60"	
LLLG-15	98'	20'	120'	20'	20'	98'	30"	120'	48"	
L4	24'	10'	24'	10'	15'	24'	12"	24'	30"	w/ inlet end sect.

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Figure 4.42. LLLG-15 Culvert Details [18].

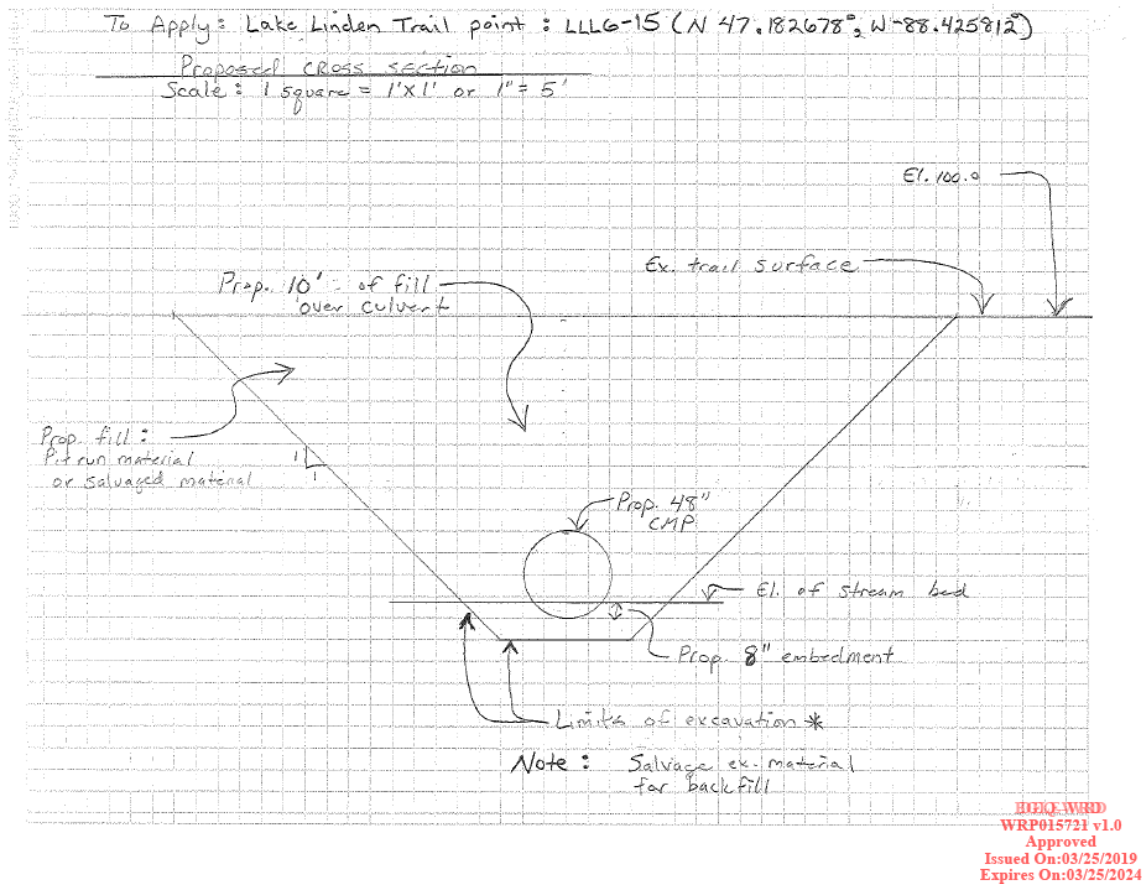

Figure 4.43. LLLG-15 Culvert Replacement Cross Section [18].

U.S. Army Corps of Engineers www.lre.usace.army.mil Michigan Department of Environmental Quality www.mi.gov/jointpermit

14 **Bridges and Culverts** Including Foot and Cart Bridges. (See EZ Guides and Sample Drawings 5, 14A, 14B, 14C, 14D.)

- Complete other applicable Sections, including 10A-C.
- A hydraulic analysis or hydrologic analysis may be required to fully assess impacts. ➡Attach hydraulic calculations.
- High Water Elevation - describe reference point and highest known water level above or below reference point and date of observation.

➡Attach additional sheets for multiple bridges and/or culverts.

➡Provide detailed site-specific drawings of existing and proposed Plan and Elevation View at a scale adequate for detailed review.

➡Provide all information in the boxes below; do not write in a reference to plan sheets. Show reference datum used on plans.

Stream Information

The site has a high water elevation (ft) *10* ☐ above or ☒ below the Reference Point of *El. 100* Date observed *10-1-19*

Reference datum used ☐ NGVD 29 ☐ NAVD 88 ☐ IGLD 85 (Great Lakes coastal areas) ☒ other *Field Survey*

Average stream width (ft) at the ordinary high water mark (OHWM) outside the influence of any ponding or scour holes around the structure	Upstream	*3.5*
	Downstream	*3.5*

Cross-sectional area of primary channel (sq ft) *7* (See Sample Drawing 14C for more information)

The width of the stream where the water begins to overflow its banks. Bankfull width (ft) *3.5*

The invert of the stream 100-feet from structure (ft)	Upstream	*88.66*
	Downstream	*80.66*

Is the existing culvert perched? ☒ No ☐ Yes If Yes, provide a profile of the channel bottom at the high and low points for a distance of 200 feet upstream and downstream of the culvert.

Section	Complete this form for each bridge / culvert location.		Existing	Proposed
Bridge	Number of bridge spans			
	Bridge type (concrete box beam, concrete I-beam, timber, etc.)			
	Bridge span (length perpendicular to stream) (ft)			
	Bridge width (parallel to stream) (ft)			
	Bottom of bridge beam (ft)	Upstream		
		Downstream		
	Stream invert elevation at bridge (ft)	Upstream		
		Downstream		
	Bridge rise from bottom of beam to streambed (ft)			
Culvert	Number of culverts		*1*	*1*
	Culvert type (arch, bottomless, box, circular, elliptical, etc.)		*Circular*	*Circular*
	Culvert material (concrete, corrugated metal, plastic, etc.)		*CMP*	*CMP*
	Culvert length (ft)		*98*	*120*
	Culvert ☐ width ☒ diameter (ft)		*2.5*	*4*
	Culvert height prior to any burying (ft)		*90*	*90*
	Depth culvert will be buried (ft)		*10*	*16*
	Elevation of culvert crown (ft)	Upstream	*90*	*90*
		Downstream	*84*	*84*
	Higher elevation of ☐ culvert invert OR ☒ streambed within culvert (ft)	Upstream	*86.67*	*86.67*
		Downstream	*80.67*	*80.67*
Complete for both Bridges and Culverts	Entrance design (mitered, projecting, wingwalls, etc.)		*Inlet structure*	*Projecting*
	Total structure waterway opening above streambed (sq ft)		*5.58*	*10.50*
	Total structure waterway area below the 100-year elevation (sq ft) (if known)			
	Elevation of road grade at structure (ft)		*110*	*100*
	Elevation of low point in road (ft)		*110*	*100*
	Distance from low point of road to mid-point of bridge crossing (ft)		*0*	*0*
	Length of approach fill from edge of bridge/culvert to existing grade (ft)		*12*	*12*

A Licensed Professional Engineer may certify that your project will not cause a harmful interference for a range of flood discharges up to and including the 100-year flood discharge. The "Required Certification Language" is found under "forms" on the "maps, forms and documents" link from the www.mi.gov/jointpermit page or a copy may be requested by phone, email, or mail. A hydraulic report supporting this certification may also be required.
Is Certification Language attached? ☒ No ☐ Yes

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Figure 4.44. LLLG-15 Culvert Replacement Summary [18].

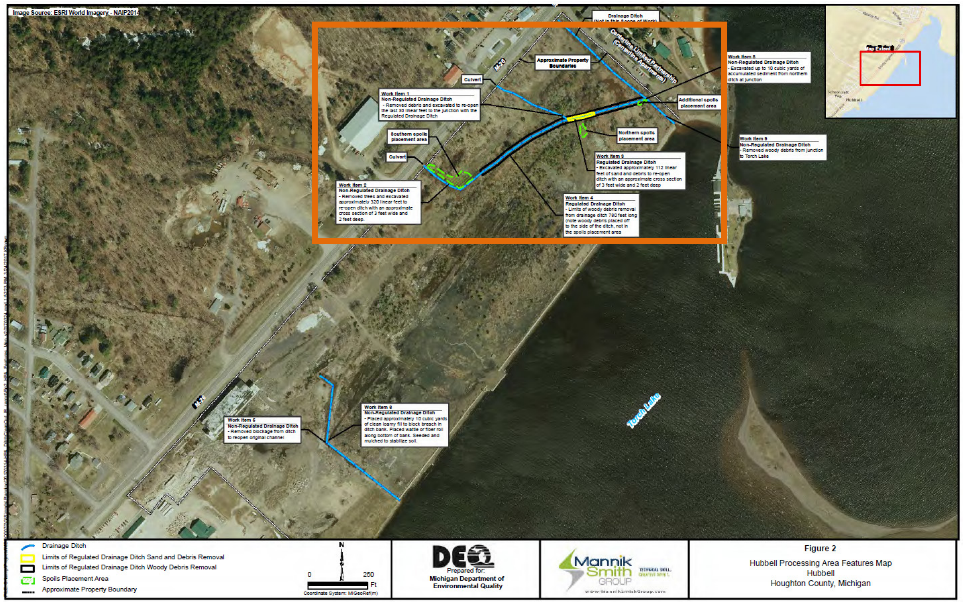


Figure 4.45. MSG Coal Dock Ditch Clean Out Site Plan [18]. Modified by author.

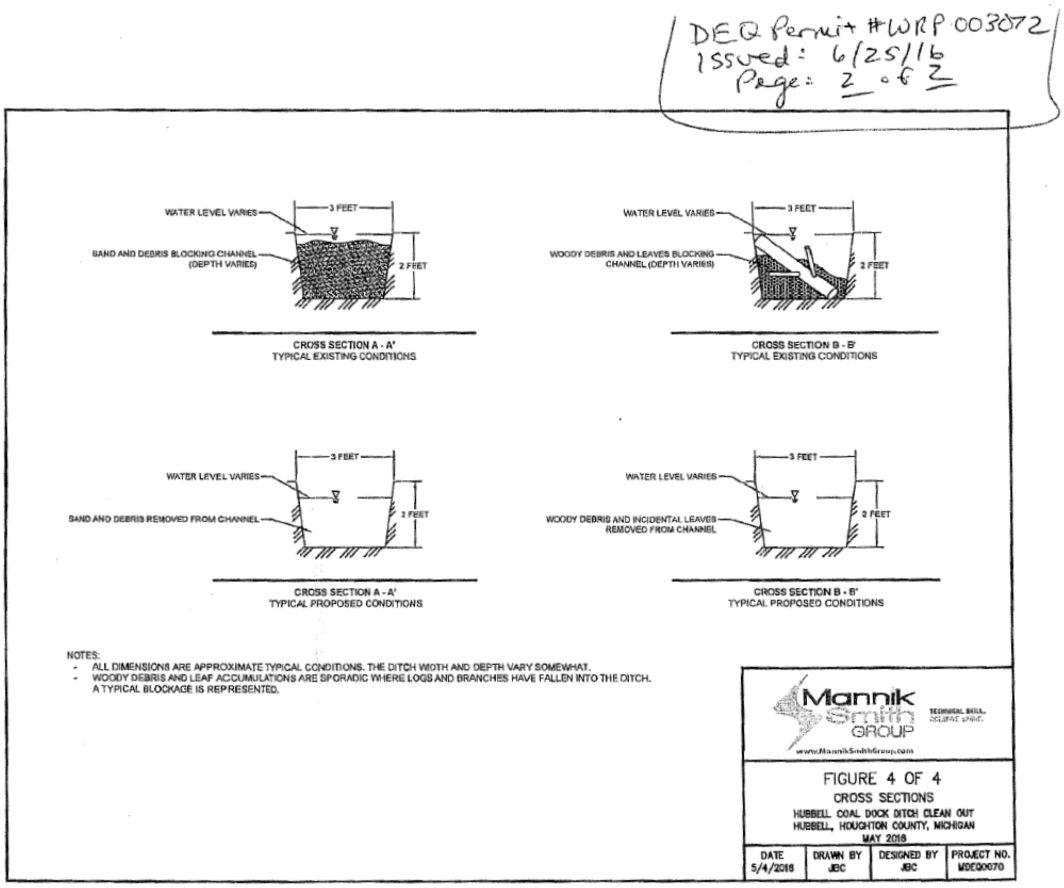


Figure 4.46. MSG Coal Dock Ditch Clean Out Cross Section [18].

4.2.10.2 Dock Creek

Heavy agricultural land use in the middle and upper regions of Dock Creek Watershed have altered drainage ways connecting drainage ditches to adjacent North Quarry Creek watershed upstream from the reservoir at the northwest end of Quarry Road. Stream restoration to reconnect tributaries will reduce total discharge accumulated in Coal Creek and Quarry Creek watersheds but will increase total discharge to Dock Creek watershed. While all three outlet regions suffered inundation post June 2018 Father's Day rainfall event, reduction of excess runoff in Quarry Creek watershed may be more priority due to catastrophic flood damage experienced at the developed outlet near Louie's Market. Both Coal and Dock Creek outlets could spatially accommodate excess runoff using LID if care were taken to address potential increase in sediment load due to sand pit operation and protection from erosion of contaminated stamp sands on historical coal docks property.

Dock Creek intersects the upper and lower rail grades in close proximity to the intersection of the gas utility corridor with the upper and lower grades. In addition, a tributary confluence with Dock Creek exists near this intersection. Dock Creek and tributary have been naturalized where flow intersects the lower rail grade (LLLG14 and L58) and a culvert has been restored in the upper rail grade (127 and LLUG15). Flooding in June 2018 exposed the gas pipeline where the utility corridor intersects Dock Creek. Remediation approved by EGLE-WRD includes installation of 833 cubic yards of riprap fill to 150 linear feet of stream bed [18]. See below Figure 4.46. Dock Creek Stream Reconstruction at Gas Utility Pipeline by Northern Natural Gas [18].

Dock Creek enters a drain upgrade from residential area near the south end of Edgewood Dr. (identified by MDNR as SWInletLakesLMAve [10]; see Figure 4.45 below) and outlets downstream of M-26 into the drainage ditch on the former coal docks mining property. A blocked inlet resulted in excess runoff spilling south to southeast over land and ponding in a swale up-grade from M-26. Stream restoration may be needed, but further assessment is required to confirm the flow path has not rerouted into a nearby sand pit. Low impact development is suggested to vegetate swales upstream from M26. Drainage ditches are recommended to be inspected and maintained often as sediment accumulation may be more likely due to commercially used barren land upstream and historical stamp sands on outlet floodplain. Prior to the stream outlet into Torch Lake, a sedimentation basin or infiltration trench is suggested on the coal docks property to contain transporting sediments and pollutants on-site.

Additionally, a tributary, north from Dock Creek, has been naturalized where flow intersects the Rail Grades (LLUG14, Site 5/LLLG12) and an impoundment exists immediately upgrade from the lower rail grade [10]. Further investigation is required downhill where the tributary intersects the utility corridor to assess if stream restoration is needed post June 2018 flooding. A wetland or bioretention system is suggested upgrade from homes near the creek intersection with the Keweenaw Trail, Edgewood Dr., and

M26. A third drainage ditch channel downstream of M26 (along E. 27th St.) carries flow out to Torch Lake across the former Coal Docks property.

Refer above to Figure 4.40. Coal & Dock Creek Drainage & Suggested Locations for LID, Figure 4.45. MSG Coal Dock Ditch Clean Out Site Plan, and below to Figure 4.47. MDNR Rail Grade Plan – North Hubbell, Coal Docks, & South Lake Linden, and Figure 4.48. Dock Creek Stream Restoration at Northern Natural Gas Utility Pipeline provided by EGLE MiWaters [18].

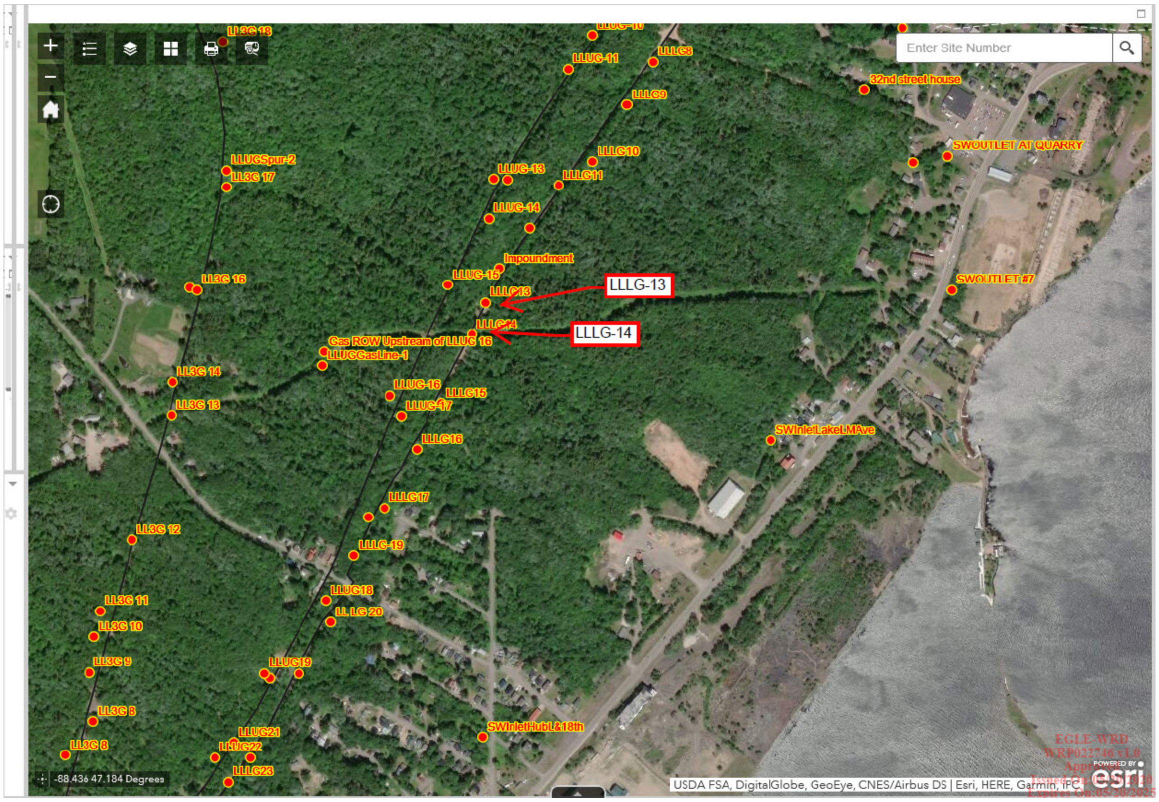
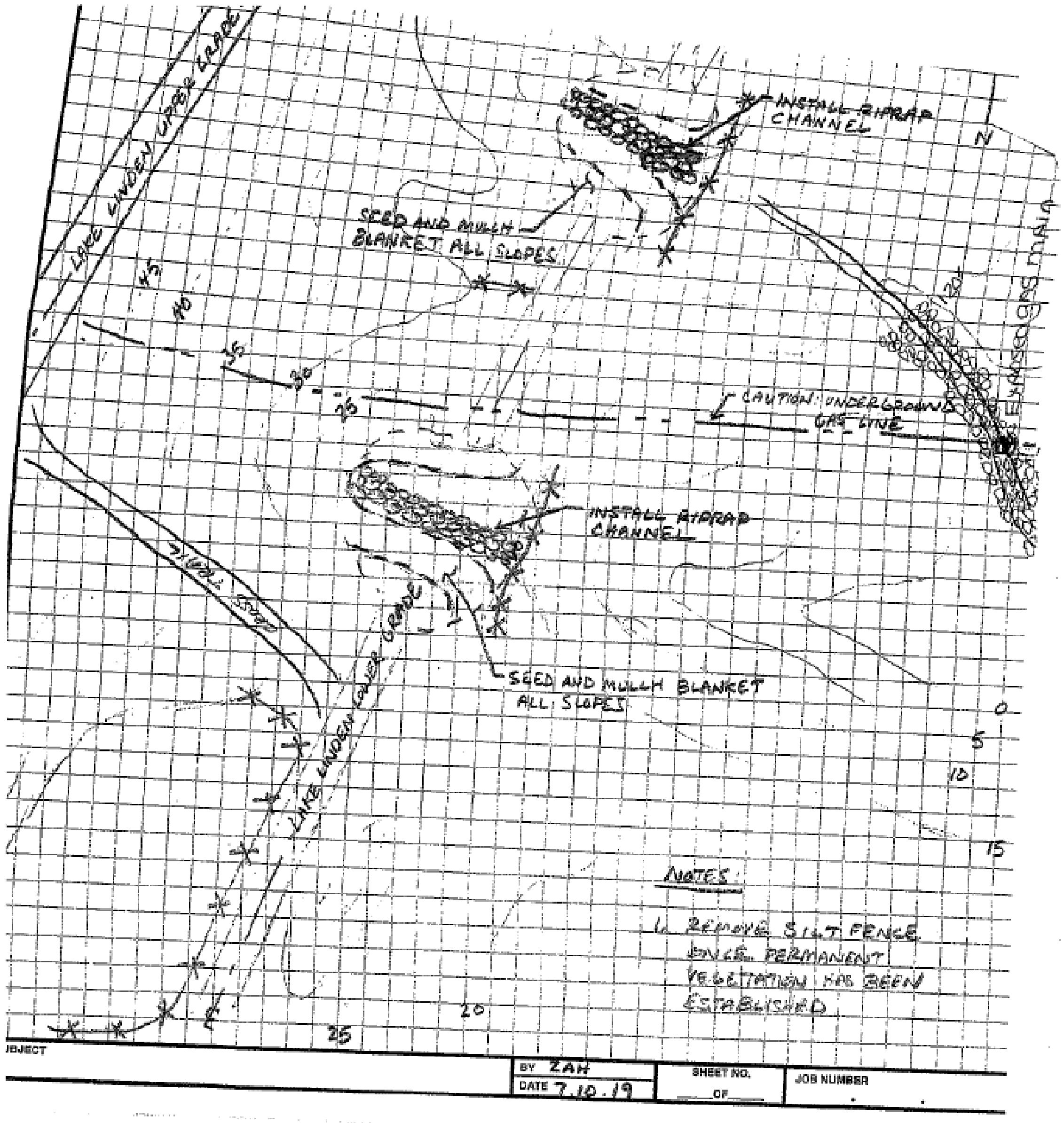


Figure 4.47. MDNR Rail Grade Plan – North Hubbell, Coal Docks, & South Lake Linden [18].



NORTHERN NATURAL GAS
PROPOSED WORK TO ESTABLISH PROPER COVER OVER PIPE

150 LF of Stream Reconstruction. Geotextile fabric & riprap approximately 4' wide stream bed. 4' high slopes of riprap. Minimum 3' cover over gas main.

120' upstream from exposed gas main & about 30' downstream. Seed & mulch blanket on exposed or disturbed soil.

If approved or questions contact Mike Delene 201-0617

Figure 4.48. Dock Creek Stream Reconstruction at Gas Utility Pipeline [18].

4.2.11 Quarry Creek Stream Restoration & LID

4.2.11.1 South Quarry Creek

A small catchment shares a similar outlet floodplain with north and south Quarry Creeks. Specifically, the floodplain site includes the former C&H Stamp Mill, assay laboratory, power plant, still and boiler house located south of the Houghton County historical society. Upstream the main channel has been naturalized where flow intersects the rail grade (Site LLUG-13/LLUG13, Site LLUG-12/LLUG12, Site 4/LLLG11 [10]). A bioretention or detention basin is suggested between the Keweenaw Trail and homes down-grade to provide increased water storage capacity during heavy or intense rainfall events and reduce stream velocity prior to the stormwater drain inlet.

Several creeks confluence down-grade from the Rail Grade into the main stream channel for South Quarry Creek watershed. The stream has been naturalized where flow intersects the Rail Grade (L59, Site 2/L60, Site LLUG-11/LLUG11, 112 and Site 1/LLLG8 [10]). Stream channel improvements and an in-stream wetland is suggested immediately upstream from developed lowland. Specifically, between residential parcel 27563 W 30th St. and 27561 W 31st St., Lake Linden, MI 49945. Stream flow at this location is constricted into an open channel routed through several culverts beneath M-26 and around the west and south side of the former C&H operations property.

Refer below to Figure 4.50. North & South Quarry Creek Drainage & Suggested Locations for LID and Figure 4.49. Quarry Creek Outlet Channel Easement showing drainage channel easement on residential property provided by EGLE MiWaters database [18].

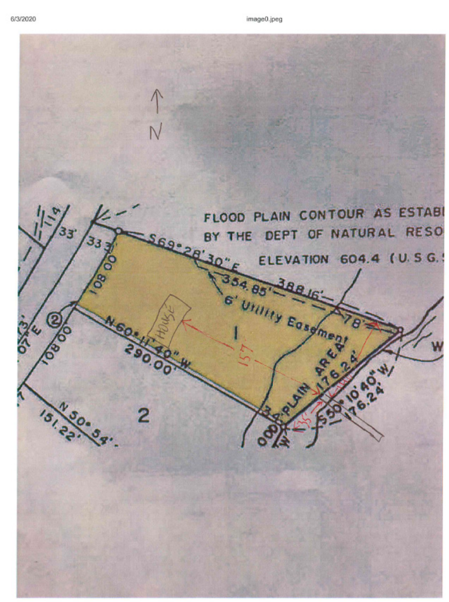


Figure 4.49. Quarry Creek Outlet Channel Easement [18].

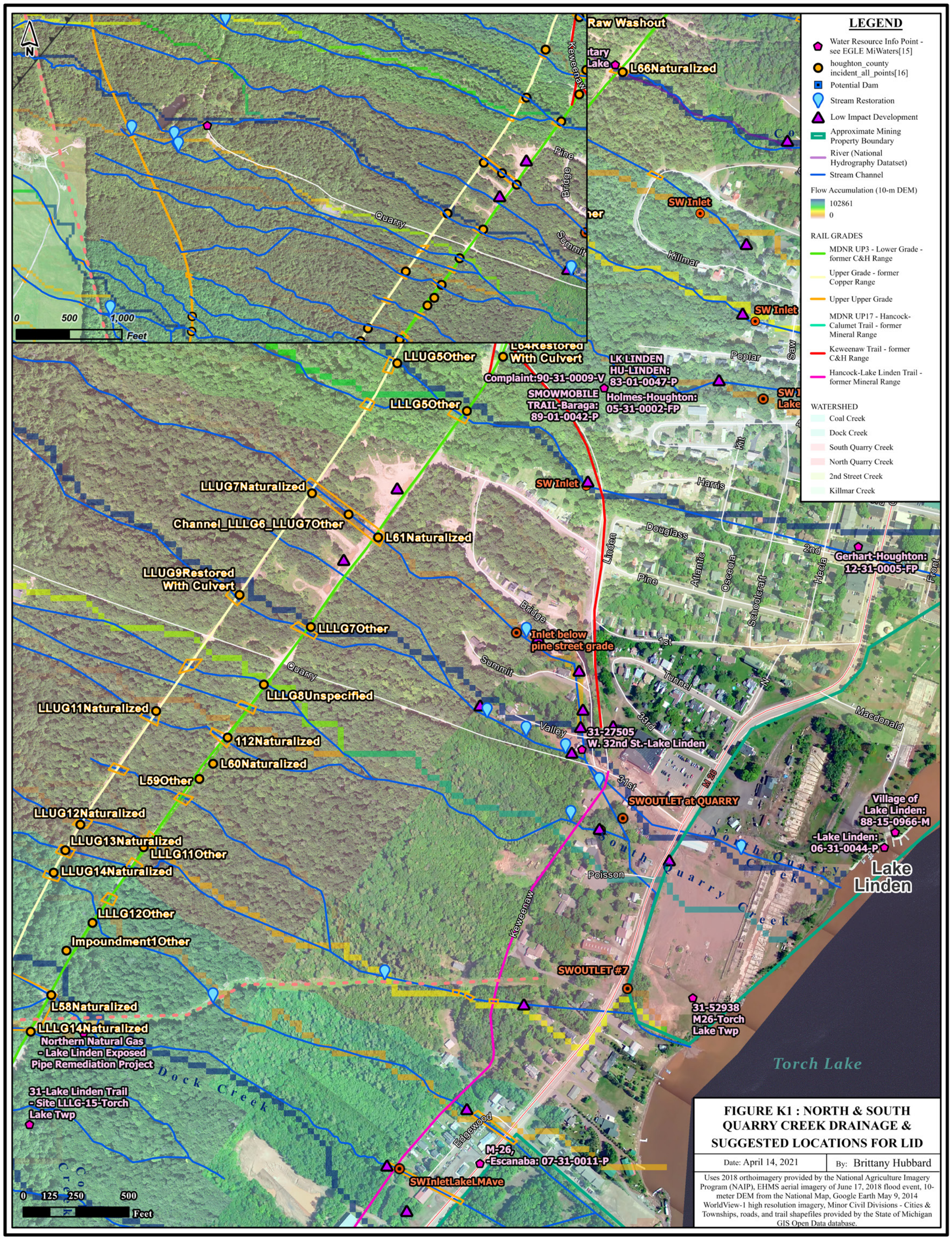


Figure 4.50. North & South Quarry Creek Drainage & Suggested Locations for LID.

4.2.11.2 North Quarry Creek

Drainage ditches from upper agricultural regions of south adjacent Dock Creek watershed connect to Quarry Creek watershed upstream from the Quarry Rd. reservoir. The Quarry Rd. reservoir (west of Quarry Rd. bend) provides flow control downstream. More research is needed downstream from the reservoir to verify stream paths are stabilized (not breaching or rerouting) and have not become disconnected due to frequent large rainfall events. Designs need to consider excess drainage from adjacent Dock Creek watershed due to connected agricultural drainage in upper regions.

Flow is constricted and channelized at developed urban area upgrade from Valley Street. North Quarry creek main channel parallels the roadway in between Quarry Rd. and Valley St. (W 32nd St.) entering a stormwater drain near the intersection of Quarry Rd. and Bridge St. immediately upgrade from Louie's Market in Lake Linden. Rock check dams in series and stream channel improvements are suggested immediately upgrade from homes on Valley St., drain inlet (SWOUTLET at QUARRY [10]), and incorporated into right-of-way vegetated drainage swales along Valley and Bridge streets to provide reduction in flow velocity, increase storage, improve infiltration, and reduce flow accumulating on roadways, respectively.

Excess runoff exceeding drain capacity tends to use 31st St. (Quarry Rd.) as a flow path and the former C&H mining stamp mill property and facilities as a floodplain. Alternatively, stream restoration is suggested to repair the outlet region and floodplain for this river. Specifically, between Valley St. and Quarry Rd., along 31st St. (Quarry Rd.) and through the former C&H property, to restore open channel flow to the outlet at Torch Lake, repair the riparian zone, and integrate a sediment basin or infiltration trench into the floodplain to protect against erosion of stamp sands.

A tributary intersects the Rail Grade (at LLUG7 and LLLG6 /L61 [10]) and navigates south of Bridge St. to enter a stormwater drain inlet up-grade from development (Inlet below pine street grade [10]). To the east of Bridge St., the Keweenaw Trail acts as a berm routing flow south to confluence with Quarry Creek near the intersection of Quarry Rd. and Bridge Street. Excess runoff exceeding drain capacity occurs immediately upgrade from Louie's Market. Major infrastructure damage occurred during June 2018 flooding and an expansive floodplain delta can be observed downstream of this location from EHMS aerial imagery. Further investigation is needed to confirm stability of channel banks in the stream reach in proximity to the Rail Grade and Bridge Street. LID is suggested to vegetate barren soils existing between upper and lower rail grades, improve the stream channel and riparian zone through the developed reach, and implement a sediment basin, rock check dam in series, or bioretention system in vegetated swales to reduce sediment transport and erosion during heavy rainfall events, and increase water storage capacity upstream from the stormwater inlet and in the right-of-way drainage ditches along Bridge Street.

North Quarry Creek outlet region is currently connected and shared with South Quarry Creek (SWOUTLET at QUARRY and SWOUTLET #7 [10]) to reach Torch Lake around the former C&H mine property. Major flooding occurred at this drainage outlet.

Refer below to Figure 4.51. N/S Quarry Creek Outlet Drainage & Suggested Locations for LID and Figures 4.52 through 4.56. Quarry Creek at Quarry Road Culvert Replacement figures designed by Upper Peninsula Engineers & Architects (UPEA) provided by EGLE MiWaters database [18].

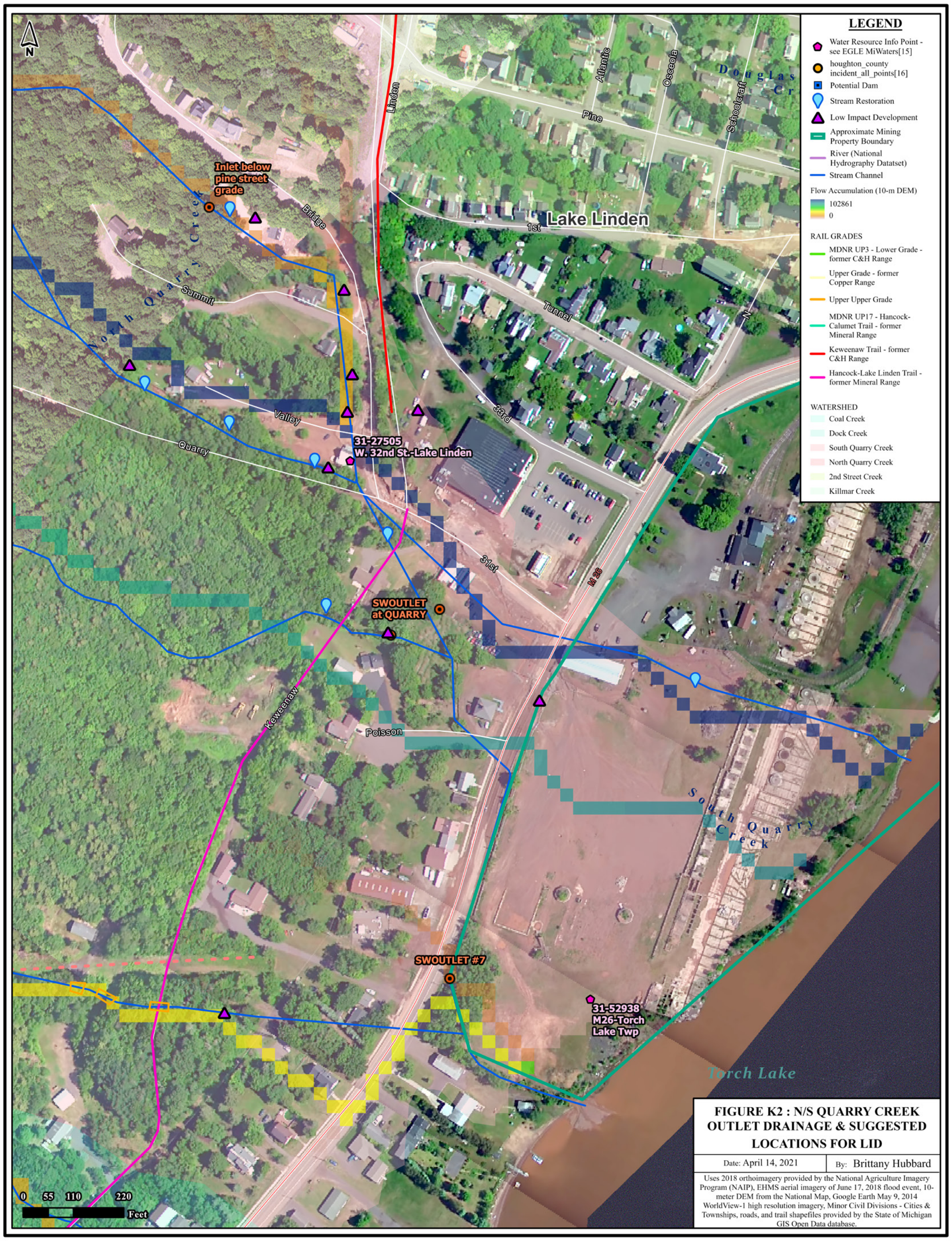


Figure 4.51. N/S Quarry Creek Outlet Drainage & Suggested Locations for LID.

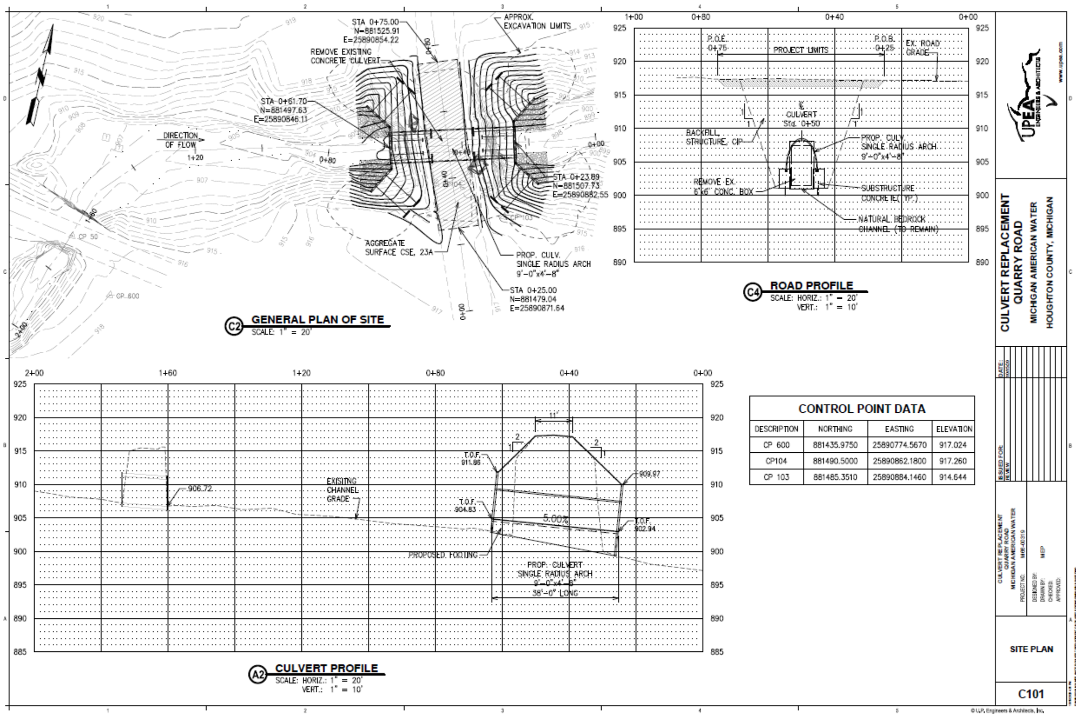


Figure 4.52. UPEA Quarry Creek at Quarry Rd Culvert Site Plan [18].

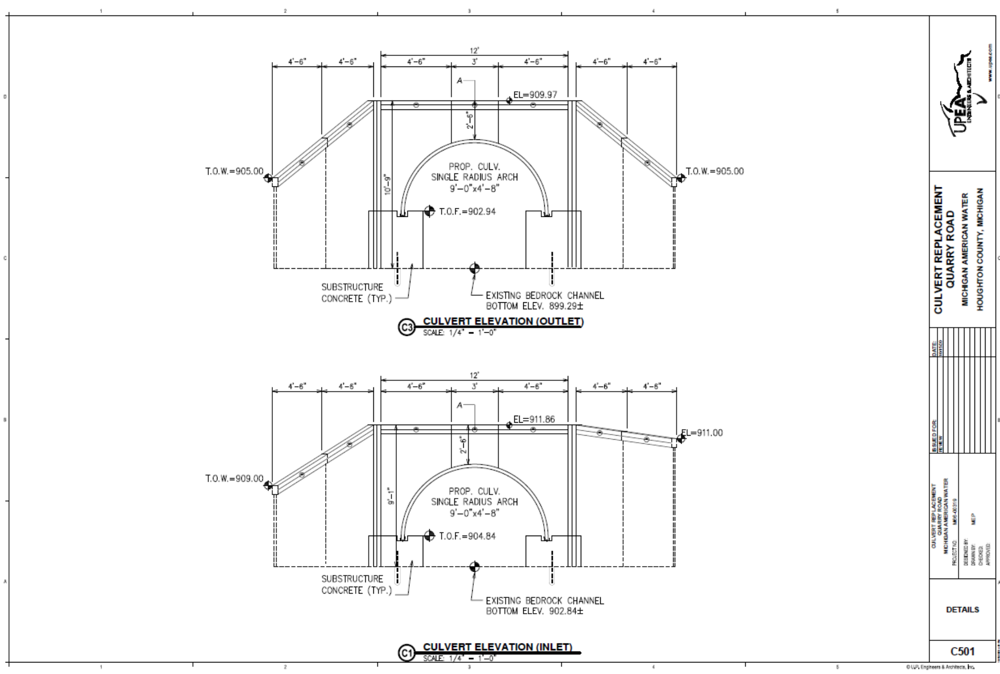


Figure 4.53. UPEA Quarry Creek at Quarry Rd Culvert Inlet-Outlet Plan [18].

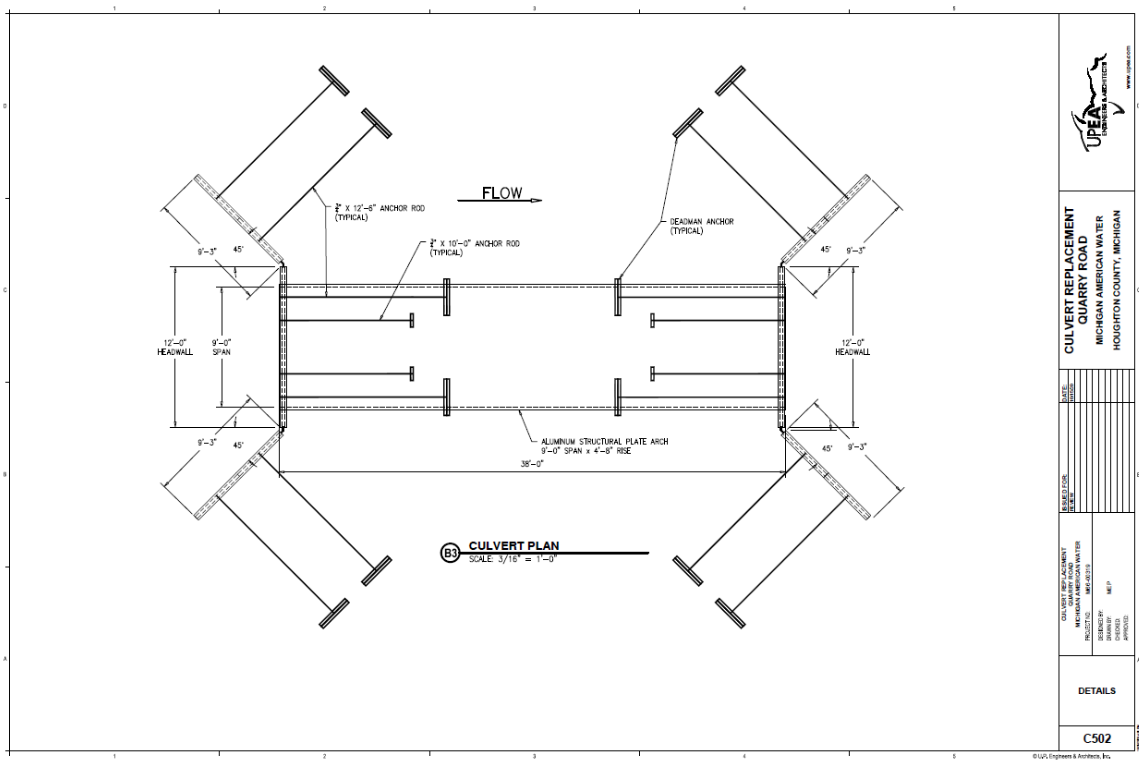


Figure 4.54. UPEA Quarry Creek at Quarry Rd Culvert Plan [18].

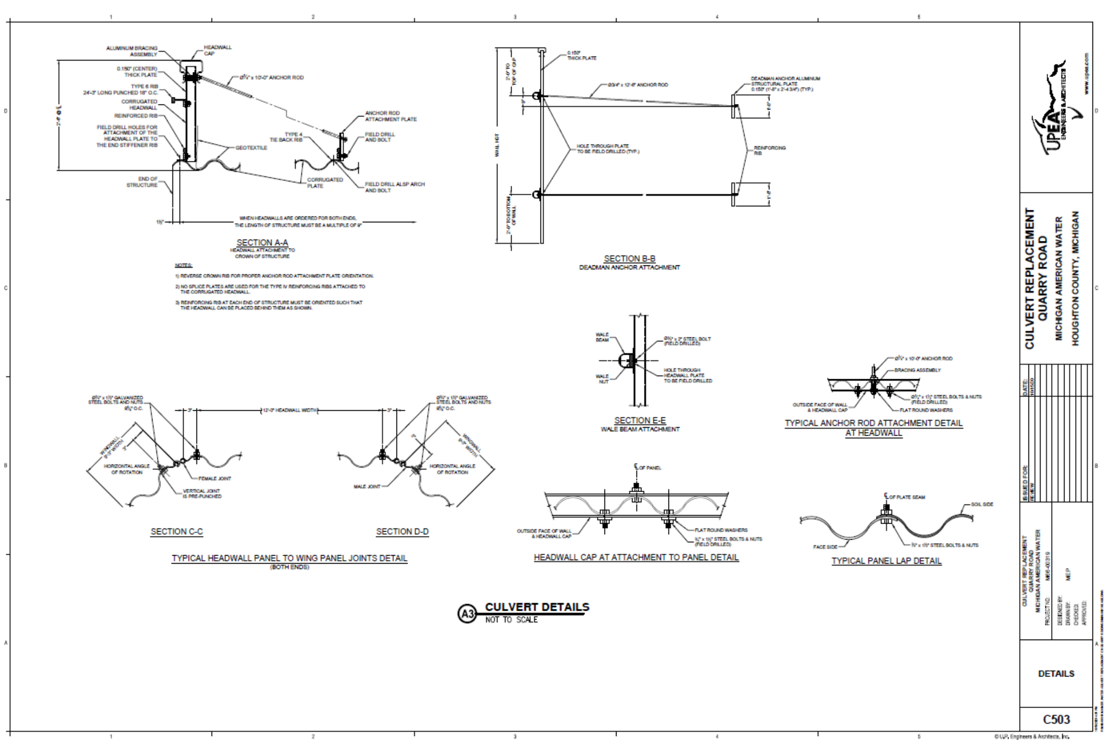


Figure 4.55. UPEA Quarry Creek at Quarry Rd Culvert Detail [18].

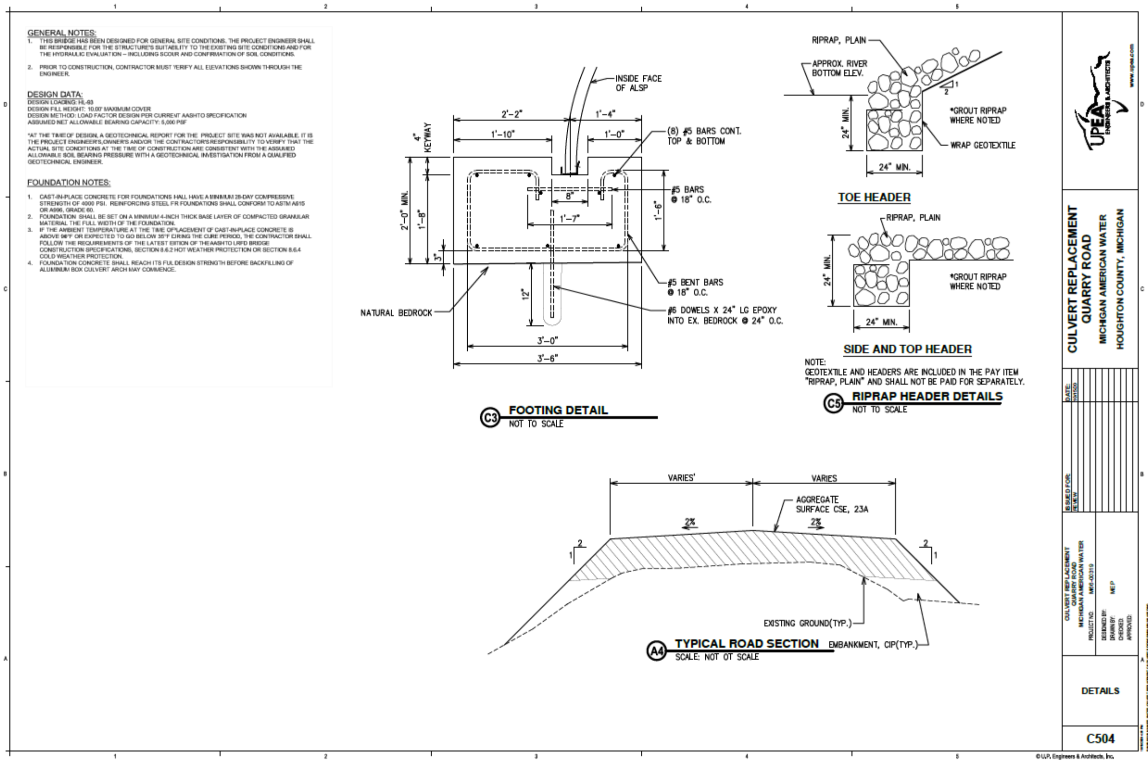


Figure 4.56. UPEA Quarry Creek at Quarry Rd Culvert Footing Detail [18].

4.2.12 Douglas-Houghton Creek Stream Restoration & LID

Stream restoration is suggested where stream channels intersect the Lake Linden Grade 3 and Quarry Road. Specifically, ponding upstream of Lake Linden Grade 3 and Quarry Rd. needs to be confirmed and assessed. Aerial imagery [15] suggests ponding upstream of Quarry Rd has created an alternative flow path for the main stream at the location of the incline dam, replaced in 2015, see Douglas-Houghton Creek at Quarry Road culvert figures below [18].

A tributary converges with the main stream channel between the upper and lower rail grades. Hydraulic structures impacted by flooding at this confluence with the upper and lower rail grade include LLUG-5/LLUG5 and Site 4/LLLG5 [10].

Low impact development such as a wetland or bioretention facility is suggested upstream from the stormwater drain (SW Inlet) located immediately upgrade from the Keweenaw Trail northwest from the intersection of Douglass St. and Linden Street. The main river enters the urban stormwater/sewer system at this location and is assumed to be buried beneath 2nd Street to the outlet at Torch Lake (SW Inlet #9 [10]). Impacted areas along the sewer system during the 2018 flood event occurred along 1st St. between Schoolcraft

St. and N Ave. as well as east of M-26 along 2nd St in Lake Linden where flow is observed to have exceeded the capacity of the stormwater system resulting in destruction of the roadway. Residences can implement rain gardens in their landscaping to mitigate excess runoff, improve infiltration, and provide temporary ponding storage capacity.

Refer below to Figure 4.58. Douglas Houghton Creek Outlet Drainage & Suggested Locations for LID and Figure 4.57. Douglas-Houghton Creek at Quarry Rd Culvert Summary, Figure 4.59. AFM Douglas-Houghton Creek at Quarry Rd Culvert Location Map, and Figures 4.60 and 4.61. Douglas-Houghton Creek at Quarry Rd Proposed & Existing Culvert plans provided by EGLE MiWaters database [18].

U.S. Army Corps of Engineers www.lre.usace.army.mil Michigan Department of Environmental Quality www.mi.gov/jointpermit DEQ

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JUL 1 4 2015
MDEQ UP DISTRICT OFFICE

14 Bridges and Culverts Including Foot and Cart Bridges. (See EZ Guides and Sample Drawings 5, 14A, 14B, 14C, 14D.)

- Complete other applicable Sections, including 10A-C.
- A hydraulic analysis or hydrologic analysis may be required to fully assess impacts. ➡ Attach hydraulic calculations.
- High Water Elevation - describe reference point and highest known water level above or below reference point and date of observation.
  - ➡ Attach additional sheets for multiple bridges and/or culverts.
  - ➡ Provide detailed site-specific drawings of existing and proposed Plan and Elevation View at a scale adequate for detailed review.
  - ➡ Provide all information in the boxes below; do not write in a reference to plan sheets. Show reference datum used on plans.

Stream Information

The site has a high water elevation (ft) *1* ☐ above or ☐ below the Reference Point of — Date observed *6/15/15*

Reference datum used ☐ NGVD 29 ☐ NAVD 88 ☐ IGLD 85 (Great Lakes coastal areas) ☐ other

Average stream width (ft) at the ordinary high water mark (OHWM) outside the influence of any ponding or scour holes around the structure — Upstream *4*; Downstream *5*

Cross-sectional area of primary channel (sq ft) *5* (See Sample Drawing 14C for more information)

The width of the stream where the water begins to overflow its banks. Bankfull width (ft) *5*

The invert of the stream 100-feet from structure (ft) — Upstream *+4*; Downstream *-12*

Is the existing culvert perched? ☒ No ☐ Yes If Yes, provide a profile of the channel bottom at the high and low points for a distance of 200 feet upstream and downstream of the culvert.

Section	Complete this form for each bridge / culvert location.		Existing	Proposed
Bridge	Number of bridge spans			
	Bridge type (concrete box beam, concrete I-beam, timber, etc.)			
	Bridge span (length perpendicular to stream) (ft)			
	Bridge width (parallel to stream) (ft)			
	Bottom of bridge beam (ft)	Upstream		
		Downstream		
	Stream invert elevation at bridge (ft)	Upstream		
		Downstream		
	Bridge rise from bottom of beam to streambed (ft)			
Culvert	Number of culverts		*1*	*1*
	Culvert type (arch, bottomless, box, circular, elliptical, etc.)		*circular*	*circular*
	Culvert material (concrete, corrugated metal, plastic, etc.)		*clay tile*	*plastic*
	Culvert length (ft)		*15*	*30*
	Culvert ☐ width ☒ diameter (ft)		*2*	*2.5*
	Culvert height prior to any burying (ft)		*2*	*2*
	Depth culvert will be buried (ft)			*.5*
	Elevation of culvert crown (ft)	Upstream	*3*	*3*
		Downstream	*1*	*1*
	Higher elevation of ☐ culvert invert OR ☒ streambed within culvert (ft)	Upstream		*.5*
		Downstream		*.5*
Complete for both Bridges and Culverts	Entrance design (mitered, projecting, wingwalls, etc.)			
	Total structure waterway opening above streambed (sq ft)		*12*	*15*
	Total structure waterway area below the 100-year elevation (sq ft) (if known)			
	Elevation of road grade at structure (ft)		*5*	*5*
	Elevation of low point in road (ft)		*4*	*4*
	Distance from low point of road to mid-point of bridge crossing (ft)		*160*	*160*
	Length of approach fill from edge of bridge/culvert to existing grade (ft)		*0*	*0*

A Licensed Professional Engineer may certify that your project will not cause a harmful interference for a range of flood discharges up to and including the 100-year flood discharge. The "Required Certification Language" is found under "forms" on the "maps, forms and documents" link from the www.mi.gov/jointpermit page or a copy may be requested by phone, email, or mail. A hydraulic report supporting this certification may also be required.
Is Certification Language attached? ☐ No ☐ Yes

Figure 4.57. Douglas-Houghton Creek at Quarry Rd Culvert Summary [18].

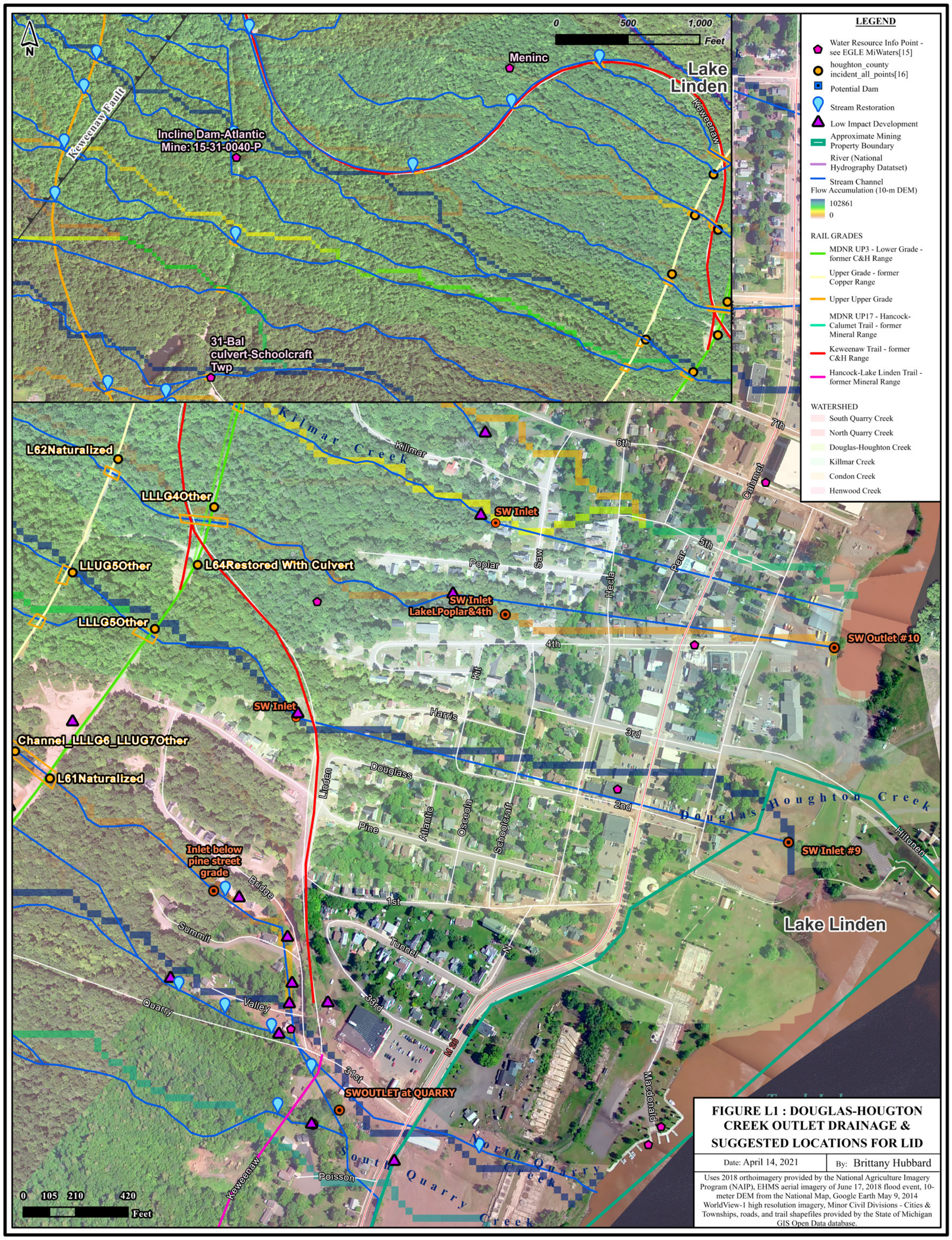

Figure 4.58. Douglas-Houghton Creek Drainage & Suggested Locations for LID.

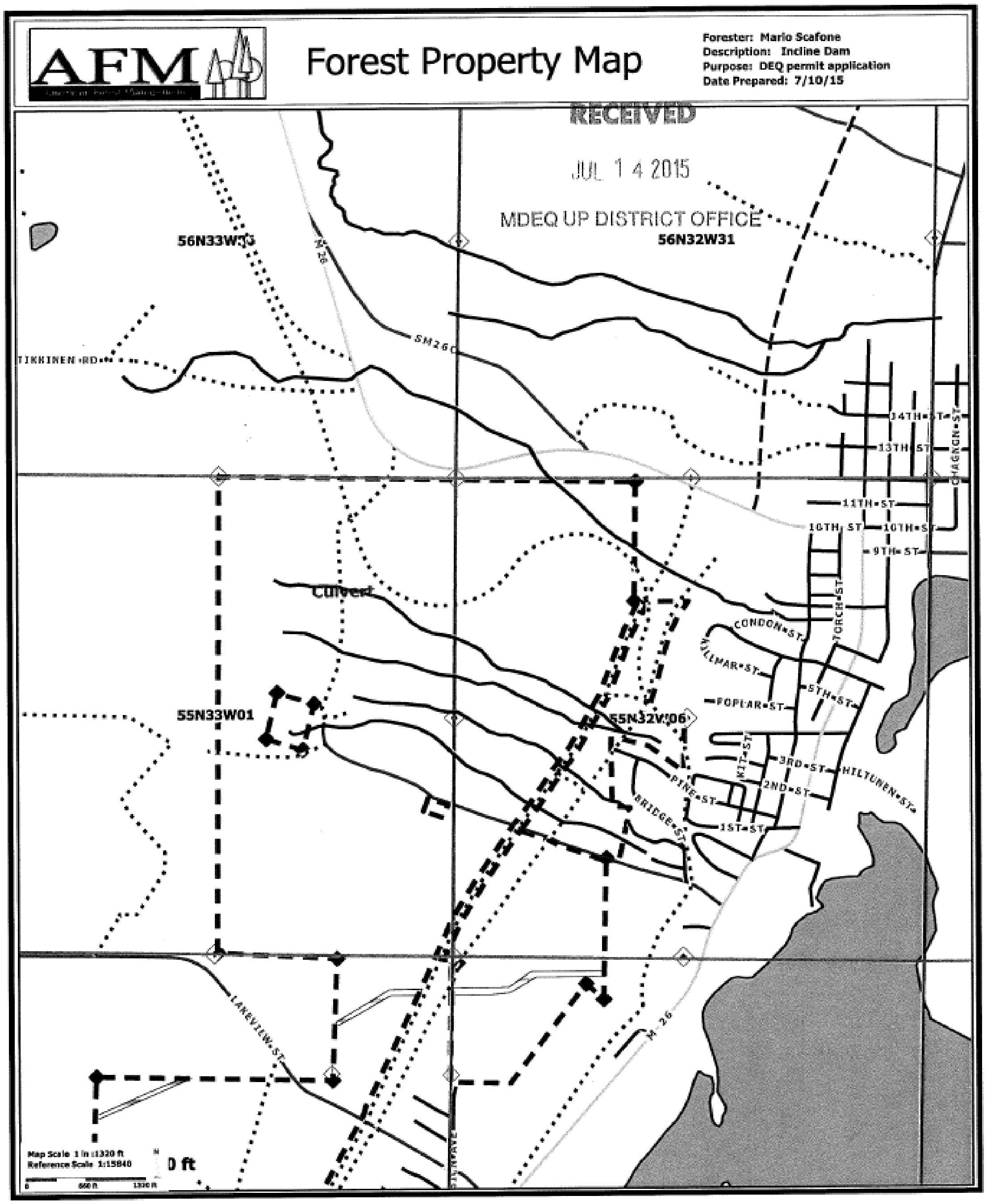

Figure 4.59. AFM Douglas-Houghton Creek at Quarry Rd Culvert Location Map [18].

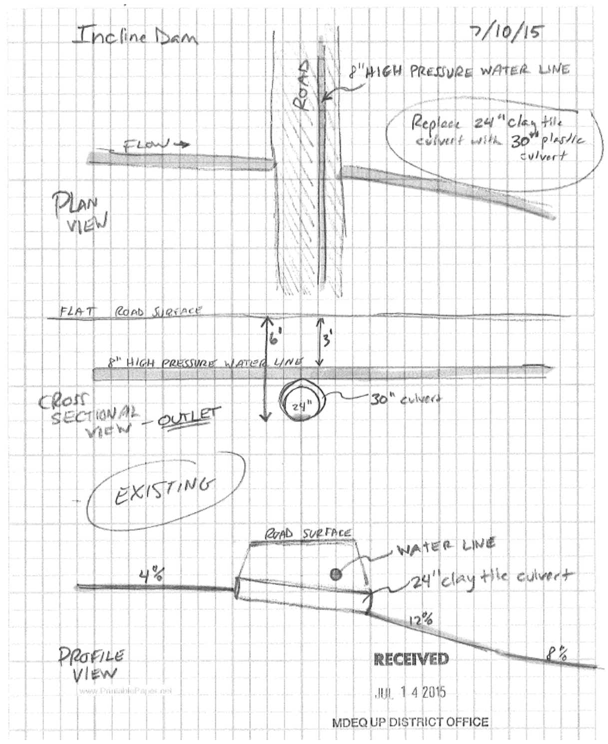

Figure 4.60. Douglas-Houghton Creek at Quarry Rd Existing Culvert [18].

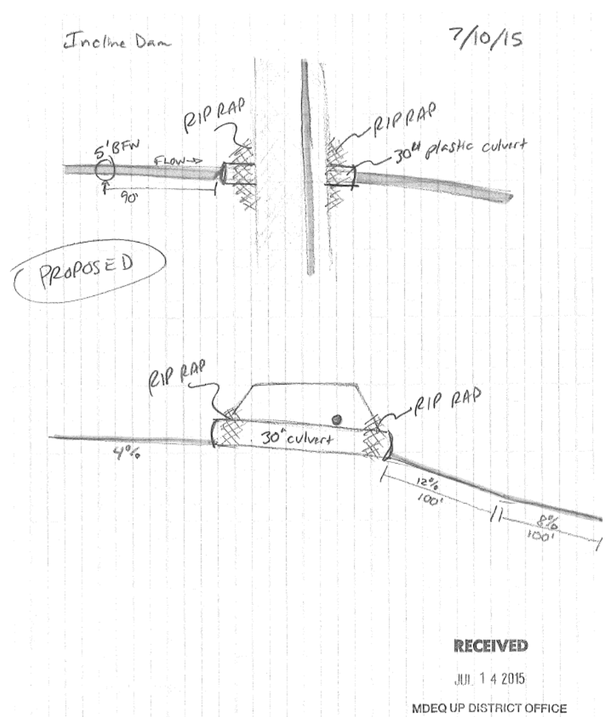

Figure 4.61. Douglas-Houghton Creek at Quarry Rd Proposed Culvert [18].

4.2.13 Kilmar Creek Stream Restoration & LID

Three small streams drain Kilmar Creek catchment. The main S-turn of the Keweenaw Trail rail grade dissects the watershed. Stream restoration to mitigate scour and erosion of the channel is suggested up-grade from the stream intersection with the Keweenaw Trail where ponding above the rail grade can be observed. Streams have been naturalized where flow intersects the upper rail grade (L62, L63, and L455 [10]). A stormwater drain inlet (SW Inlet LakeLPoplar&4th [10]) exists west of Hecla St. between 4th St and Poplar Street. Two additional stormwater drains are assumed to exist, located west of Saw St. between Poplar and Kilmar streets and between Kilmar and 6th streets in Lake Linden. Low impact development such as a wetland or bioretention area is suggested upstream from all three stormwater drain inlets to increase flood water storage capacity as frequency and intensity of rainfall events increase.

Refer below to Figure 4.63. Kilmar Creek Outlet Drainage & Suggested Locations for LID and Figure 4.62 MDNR Rail Grade Plan – Lake Linden.

Figure 4.62. MDNR Rail Grade Plan - Lake Linden [18].

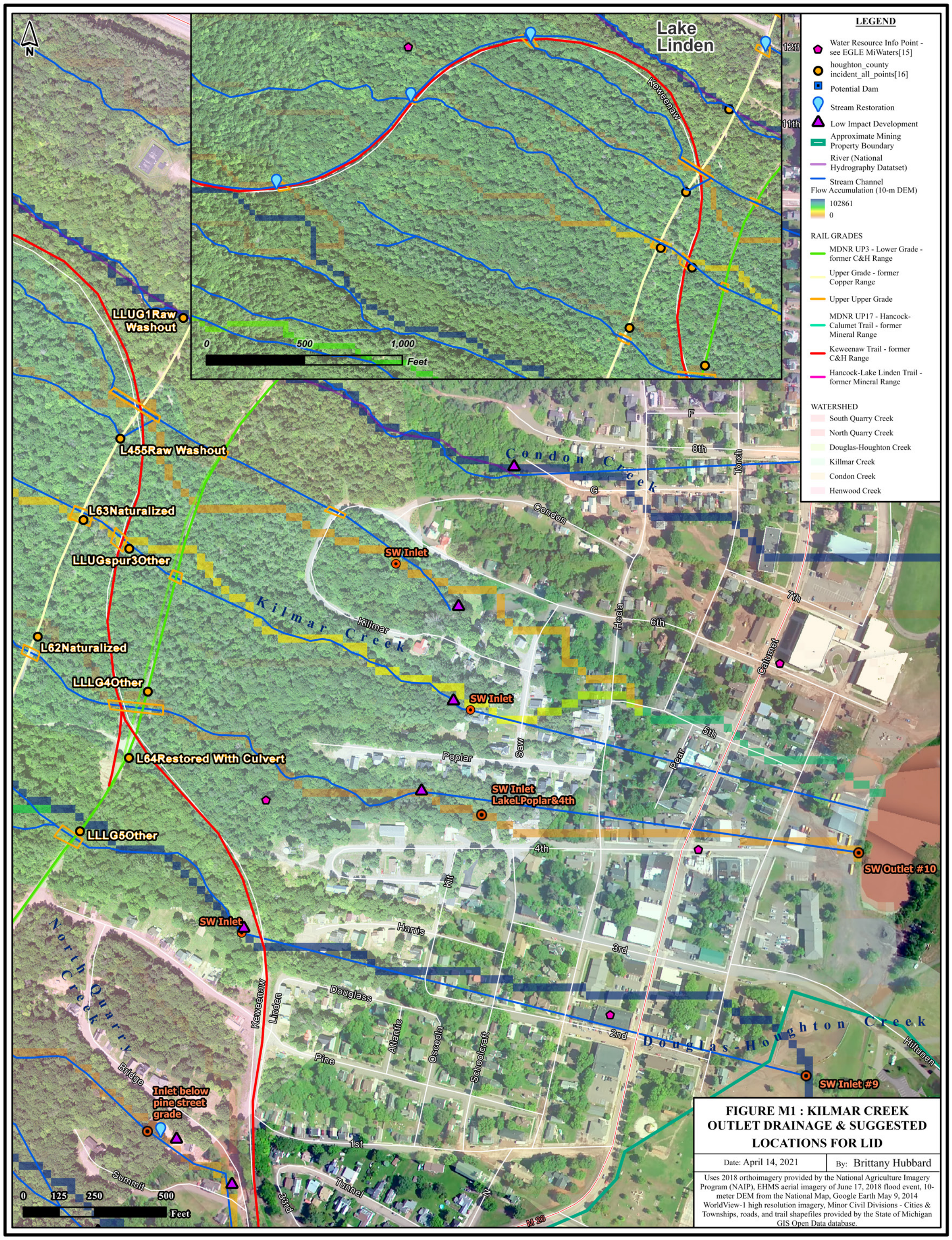

Figure 4.63. Kilmar Creek Drainage & Suggested Locations for LID.

4.2.14 Condon Creek Stream Restoration & LID

A tributary converges with Condon Creek downstream from M26 above the Rail Grade. Stream channel improvements are suggested where the tributary and Condon Creek intersect the Lake Linden Grade 3, Keweenaw Trail rail grade, and a bypass rail grade in between the two. Disconnected stream channels and ponding upstream of the rail grades at these crossings can be observed in historical aerial imagery. The main stream channel has been naturalized where flow intersects the Rail Grade (LLUG1 and LLLG1/L66 [10].

Condon Creek enters a stormwater sewer drain at the northwest end of G St. north of Condon Street. A wetland or bioretention system upstream from the drain inlet is suggested to provide increased flood water storage. Excess runoff exceeding the capacity of the stormwater system tends to flow southeast to east over developed lowland to reach Torch Lake. The floodplain delta expanded the approximate area between 6th St. and 8th St. in Lake Linden as the result of the one in a thousand year rainfall event that occurred in June 2018. This floodplain area includes Lake Linden-Hubbell High School and grounds. Condon Creek is expected to outlet (SWOUTLET #11[10]) from the stormwater sewer system into Torch Lake north of the high school track and field facility. Additionally, rain gardens and vegetated swales in urban landscaping as well as permeable pavement for large parking lots which exist for school facilities in the floodplain can further reduce excess runoff and provide protection from future flood events.

Refer above to Figure 4.62. MDNR Rail Grade Plan – Lake Linden, and below to Figure 4.64. MDNR Rail Grade Plan – LLLG-1 provided by EGLE MiWaters [18], and Figure 4.65. Condon Creek Drainage & Suggested Locations for LID.

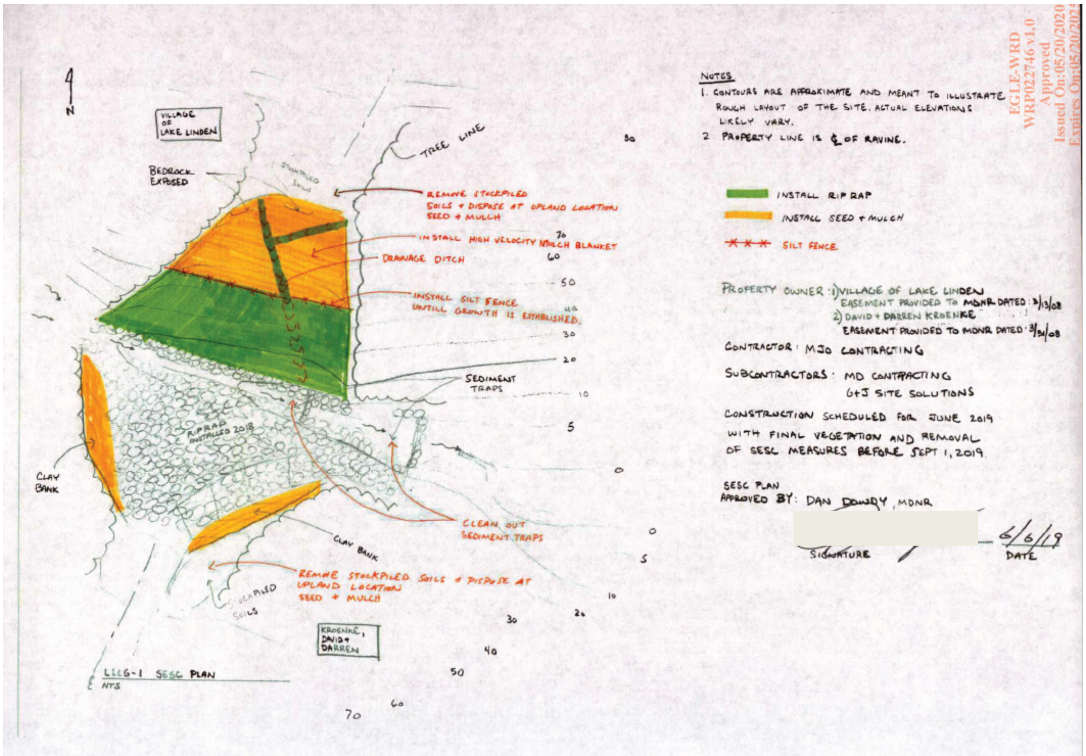

Figure 4.64. MDNR Rail Grade Plan – LLLG-1 [18].

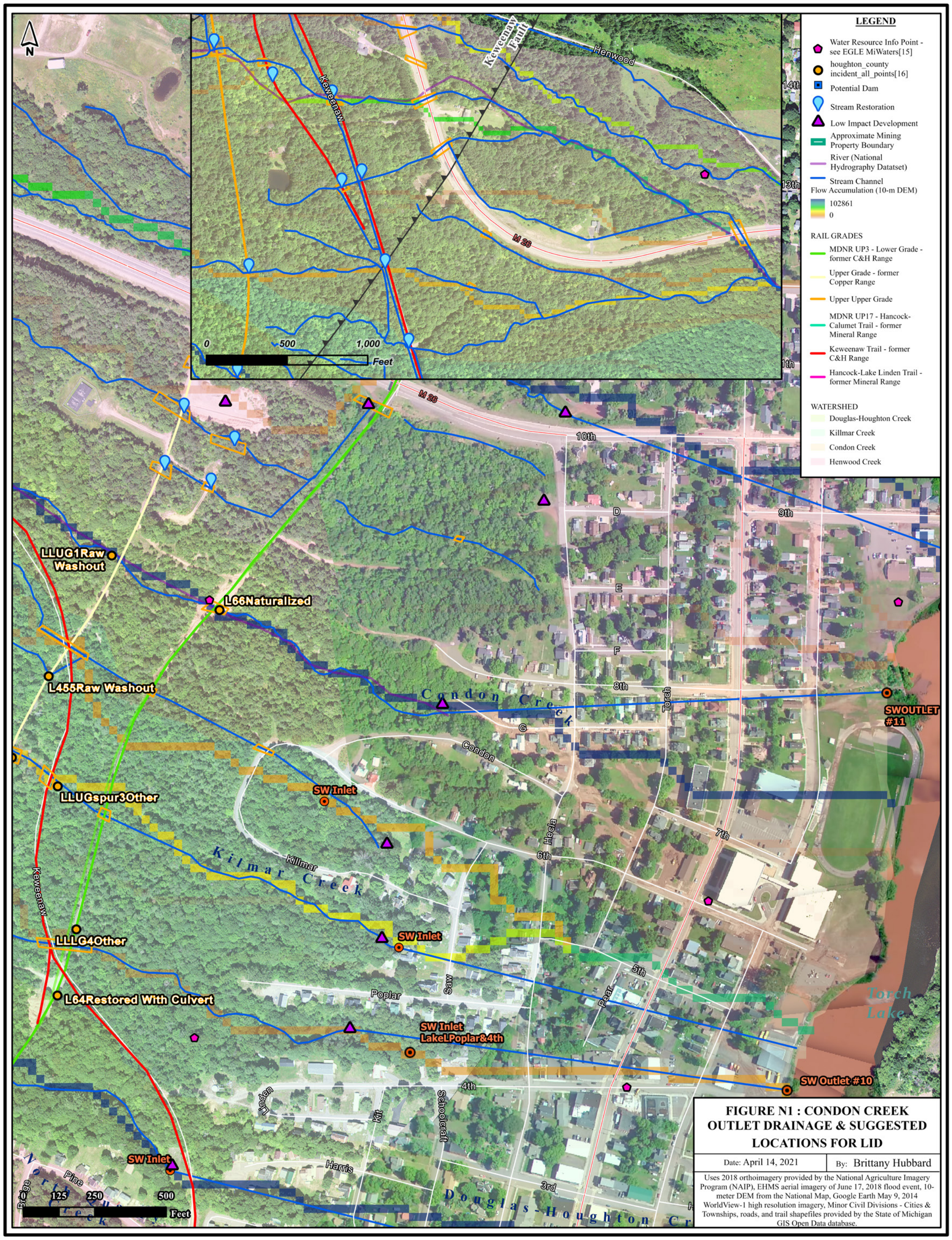

Figure 4.65. Condon Creek Drainage & Suggested Locations for LID.

4.2.15 Henwood Creek Stream Restoration & LID

Drainage in the upper region of Henwood Creek catchment is impeded by the Lake Linden Grade 3, Keweenaw Trail, and bypass rail grades. Aerial imagery suggests ponding upstream of these rail grades has resulted in connected upper drainage regions to adjacent Condon Creek and Hammell Creek watersheds. Stream restoration is suggested where the main channel intersects the Lake Linden Grade 3 and the Keweenaw Trail rail grade. The stream has been naturalized where flow intersects the Rail Grade (L90/LLCC21).

Henwood creek enters a drain north of the intersection of M26 and Hecla Street. A wetland or bioretention area is suggested above the drain inlet. The stream is assumed to remain buried in the stormwater sewer system until reaching the outlet (SWOUTLET #12 [10]) to Torch Lake near the Torch Lake Waste Water Treatment Facility.

Additionally, low impact development may be needed up-grade from the west end of 12th St. in Lake Linden. More research is needed to assess if a drain exists at this creek outlet or if this flow path is a result of impeded tributary flow at the upper rail grade in north adjacent Hammell Creek watershed.

Refer below to Figure 4.67. Henwood Creek Outlet Drainage & Suggested Locations for LID, Figure 4.66. MDNR Rail Grade Plan – North Lake Linden, and Figure 4.68. OHM – MDNR Rail Grade Plan – LLCC21 [18].

Figure 4.66. MDNR Rail Grade Plan – North Lake Linden [18].

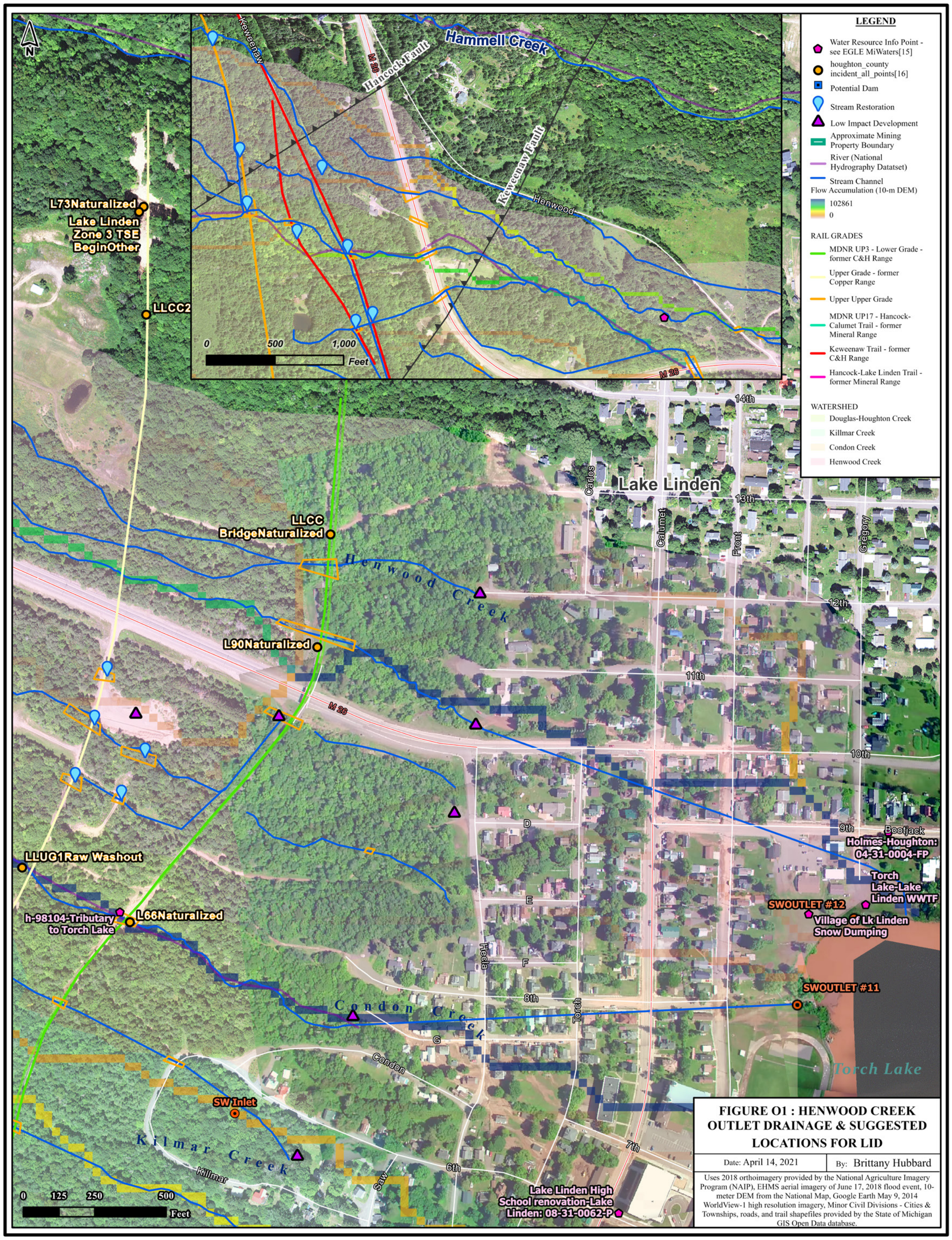

Figure 4.67. Henwood Creek Drainage & Suggested Locations for LID.

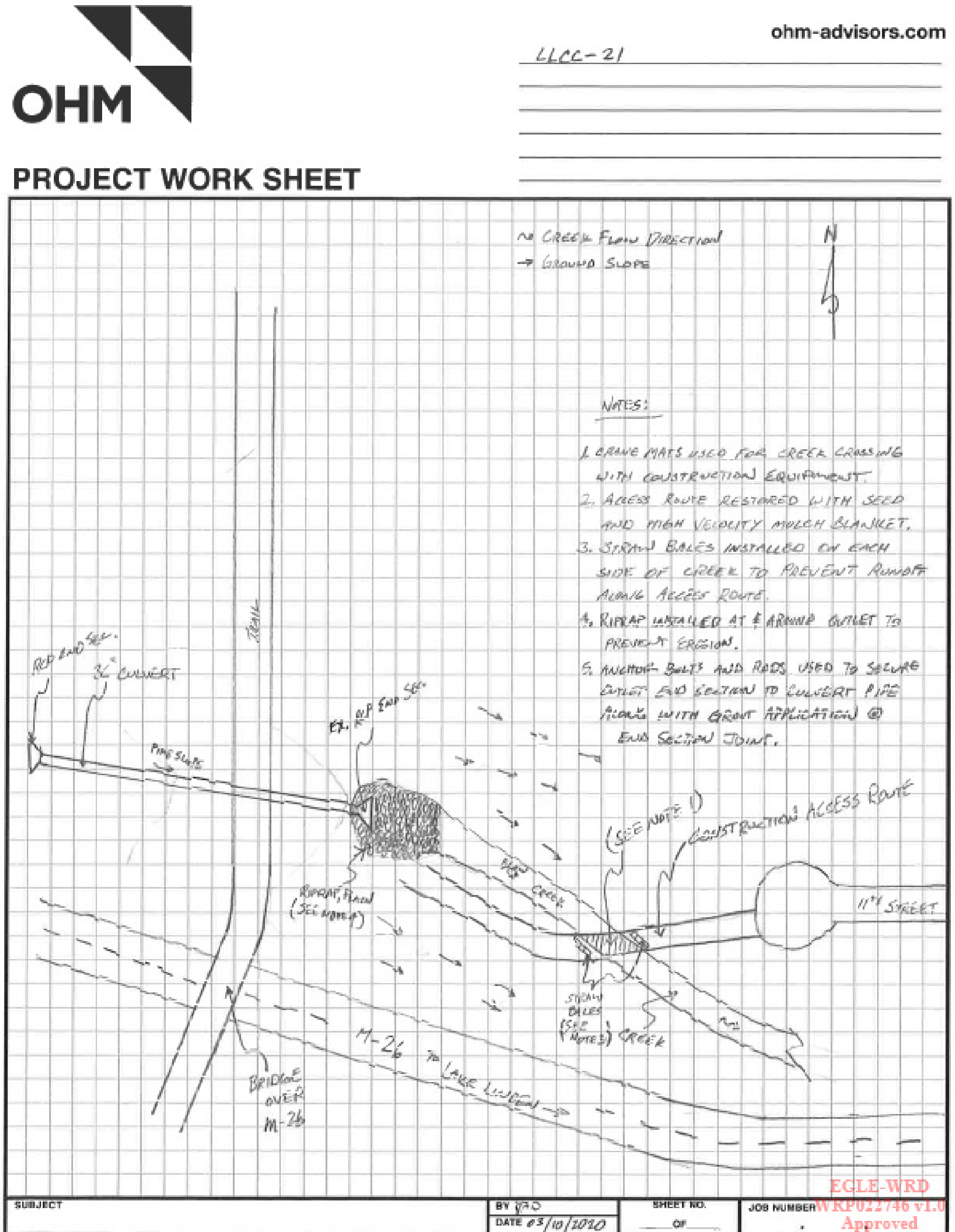

Figure 4.68. OHM – MDNR Rail Grade Plan – LLCC21 [18].

5 Conclusion

5.1 Summary of Results

Results of stochastic hydrologic comparison indicate the GEV distribution using L-moment parameters best modeled annual maximum rainfall events observed at CMX over the past 133 years. This model can be used to estimate the recurrence frequency for an X-year rainfall event within USGS HUC-12 Torch Lake Watershed and thus local level watersheds at the Site as well. For the 50, 100, 500, and 1000-year rainfall event, the GEV distribution model estimates approximately 3.6, 4.1, 5.3, and 5.86 inches of precipitation, respectively.

General local watershed characteristics are summarized as follows:

- Area ranged from 0.15 to 3.00 square miles for each local watershed with an average area of 0.68 square miles.
- Average land slope ranged from 3.3 to 9.3 percent rise for each local watershed. Compared to land slope analyzed regionally that ranged from 4.7 to 13.1, 6.3 to 17.4, 1.8 to 6.6, and 1.6 to 5.1 percent rise for lower, hillside, middle, and upper regions and average 7.6, 9.4, 4.5, and 3.0 percent rise, respectively.
- Main channel length ranged from 0.7 to 4.5 miles.
- Average main stream channel slope range from 4.8 to 13.70 percent rise for each local watershed. Compared to main stream channel slope analyzed regionally that ranged from 7.6 to 15.5, 9.4 to 19.6, 4.5 to 7.3, and 1.0 to 1.9 percent rise for lower, hillside, middle, and upper regions and average 8.6, 9.6, 5.4, and 1.4 percent rise, respectively.
- Hydraulic length ranged from 1.0 to 4.5 miles for each local watershed
- The primary land use is Northern Hardwood and ranged from 22% to 48% in each local watershed. Barren and impervious land use ranged from 1% to 11.5 % and 3% to 16 %, respectively. in each local watershed.
- Soils in upper regions are the most diverse consisting of hydrologic group A, A/D, B, B/D, C, and D soil types but poorly drained high runoff coarse-loamy type C soils dominate this region. Middle and hillside regions are primarily somewhat poorly to moderately well-drained, high to very high runoff, coarse-loamy type B soils. Lower regions of the Site are heavily developed and historically industrialized. Soils in this region consist of very poorly-drained loamy, somewhat poorly-drained sandy, moderately well-drained sandy, well-drained coarse loamy and sandy type A, A/D, and A/SS soils. In addition, stamp sands (SS), unknown excavated earth and fill material, and impermeable surfaces associated with high to very high runoff cover the shoreline region.
- Bedrock geology consists of Portage Lake Volcanics and Jacobsville Sandstone above and below the Keweenaw Fault, respectively.
- Quaternary geology consists of thin to discontinuous glacial till over bedrock and course-textured glacial till above and below the Hancock Fault, respectively.

- Runoff Curve Number ranged from 62 to 71 for each local watershed. Compared to RCN analyzed regionally that ranged from 62 to 80, 60 to 64, 60 to 71, and 74 to 77 for lower, hillside, middle, and upper regions, respectively.

Most of the main stream channels inlet directly into urban stormwater infrastructure upon reaching the base of the hillside. The highly developed floodplain makes the Site particularly susceptible to riverine and urban flooding. The outlet for many of these stream channels coincides with historical mining land use.

Stream restoration is suggested downstream from agricultural property to repair disconnected flow paths to the main stream channel. Designs should account for the extra drainage area as a result of connected agricultural developed drainage routes to adjacent watersheds.

LID and stream restoration is suggested upstream of residential development to reduce stream velocity prior to stormwater drain inlet.

- Stream restoration and LID such as a wetland is suggested where several small streams confluence to increase available ponding storage before flow enters the stormwater drainage system.
- Low impact development is suggested upstream from residences on the west end of 6^{th}, 7^{th}, and 9^{th} Streets in Hubbell, where the creek inlets into the stormwater system.
- LID is recommended up-grade of the northwest end of 8^{th} Street. Historical frequency of flooding and severity of flooding along 8^{th} Street that occurred on June 17, 2018, suggests rehabilitation of the stream outlet is a priority
- Low impact development is suggested upstream from 12^{th} Street Creek, Eddie & Myrtle Creeks, and Daisy Creek stormwater drain inlets, and upstream from the stormwater inlet at the west end of Douglas St.
- Low impact design is suggested upgrade from homes near the intersection of Dock Creek with the Keweenaw Trail, Edgewood Dr., and M26.
- Low impact development is suggested upstream from Douglas Houghton Creek stormwater drain located immediately upgrade from the Keweenaw Trail northwest from the intersection of Douglass St. and Linden Street.
- Low impact design is suggested immediately upstream of homes on Valley St., stormwater drain inlet, and incorporated into right-of-way drainage swales along Valley and Bridge streets to provide reduction in flow velocity, increase storage, infiltration, and reduce flow accumulating on roadways, respectively.
- Stream restoration and LID is suggested between the Rail Grade and Bridge Street, to confirm stability of channel banks in the stream reach, mitigate barren soils existing between upper and lower rail grades, and increase water storage capacity upstream from the stormwater drain inlet and in the right-of-way drainage ditches along Bridge Street.

Vegetated swales in the drainage ditch are recommended to increase infiltration, reduce flow velocity, and trap sediment.

- Low impact development is suggested in the right-of-way up-grade from M26 to provide additional ponding storage for excess runoff and trap sediment prior to its transport downstream.
- Stream restoration is suggested along Dover Creek to improve water storage capacity by increasing infiltration potential of riparian zones between Ash and Spruce streets. Low impact design upstream of Ash St. could provide water storage capacity prior to stream constriction at development until able to safely drain through the channel during flood size discharges.
- Stream restoration is suggested on 8th St. Creek east of Golf Course Rd to reduce scour occurring downstream of the hydraulic structure
- Stream restoration of Mineral Creek is suggested downstream from the Rail Grades between Lakeview St (W 21st St.) and Hubbell St west of Division Ave.
- Stream restoration and LID is suggested immediately upstream from developed lowland. Specifically, between residential parcel 27563 W 30th St. and 27561 W 31st St Lake Linden, MI 49945.

Low impact development (LID) is suggested where stream flow outlets former mine properties to reduce sediment and pollutants entering streams.

- Stream restoration and LID is suggested where Oneco Creek flow is channelized through the former Osceola Stamp Mill site
- Stream restoration is suggested where Tamarack Hill Creek passes through the former Tamarack Stamp Mill property in order to limit the barren land surface area exposed to erosion during flood events. LID techniques are suggested to reduce barren zones within the floodplain and implement a sediment control system to contain suspended sediment particles on-site.
- LID is suggested to the drainage ditch on the historical Ahmeek Stamp Mill property to trap contaminated sediment from leaving the Site.
- Drainage ditches through former coal docks mining site are recommended to be inspected and maintained often as sediment accumulation may be more likely due to commercially used barren land upstream and historical stamp sands on site.

Further stream restoration is recommended at locations along rail grades.

- Stream restoration is suggested up-grade from the Kilmar Creek intersection with the Keweenaw Trail where ponding above the rail grade can be observed.
- Stream restoration is suggested where the main tributary and Condon Creek intersect Lake Linden Grade 3, Keweenaw Trail rail grade, and a bypass rail grade in between the two.

- Stream restoration is suggested where the Henwood Creek intersects the Lake Linden Grade 3 rail grade and the Keweenaw Trail rail grade.

On-going cleaning and maintenance of current stormwater systems and structures is suggested to mitigate flood related damages. A drainage ditch located on the mineral building property was cleaned and maintained just prior to the Father's Day Flood Event and avoided outlet inundation unlike most other watersheds between Hubbell and Lake Linden, MI.

5.2 Future Research

Future research is suggested at the following locations across the Site:

- Field investigation is needed to clarify the Torch Lake Subwatershed boundary in the northwestern region near Swedetown. Flow pathways have been altered by historical mining land use, industry, and development.
- Assessment for future stream restoration is suggested at the intersection of Daisy Creek main stream channel with the gas utility line, Lake Linden Grade 3, and upper rail grades.
- Further investigation is needed to confirm the outlet channel for Daisy Creek and if observed ponding is a designed retention pond or if LID may be needed
- Up-grade from Ziemnick Excavating Inc. and nearby sand/gravel pit, a flow path may have developed contributing to ponding observed on barren soils. Further investigation is required at this location to assess the need for stream restoration or LID.
- In the hillside region of Dock Creek Watershed, a tributary intersects the utility corridor before converging with Dock Creek main stream channel. Stream restoration may be needed but further assessment is required to confirm flow path has not rerouted into nearby sand pit.
- More research is needed downstream from the reservoir off Quarry Rd. to verify stream channels are stabilized (not breaching or rerouting) and have not become disconnected due to frequent large rainfall events.
- Specifically, ponding upstream of Lake Linden Grade 3 and Quarry Rd. in Douglas Houghton Creek Watershed needs to be confirmed and assessed.
- Two additional stormwater drains are assumed to exist located west of Saw St. between Poplar and Kilmar streets and between Kilmar and 6^{th} streets in Kilmar Creek Watershed in Lake Linden. More research is needed to assess if a drain exist or if this flow path is a result of impeded tributary flow at the Rail Grade.

Additionally, 2-D flow analysis is recommended for the Site. It may be relatively cost effective to complete a bathymetric survey of the channel, needed for flow modeling, as improvements to drone and available lidar sensor technology continue to increase. As of

June 2021, LIDAR digital elevation data became available through the USGS data delivery website. LIDAR provides 1-meter resolution elevation data versus the 2013 DEM data, prior to the flood event, providing 10-meter resolution. LIDAR’s increased resolution is needed for modeling to clearly understand the natural hydraulics of the steam channel, size structures, and better define extent of rehabilitation, restoration, and improvements needed in the watershed.

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A Tables

Table A. 1. Local Watershed Characteristics

Table 1.1. LOCAL WATERSHED CHARACTERISTICS

Local Watershed Name		Township	Shape	Approx. Area (mi^2)	Approx. Area w/Floodplain (mi^2)	Avg. Land Slope (%)	Approx. Main Stream Channel Length (mi)	Avg. Main Stream Channel Slope (%)	Approx. Hydraulic Length (mi)	RCN	Land Use	Region[1]	Avg. Regional Land Slope (%)	Avg. Regional Main Stream Channel Slope (%)	Approx. Regional Hydraulic Length (mi)	RCN	Surface Water Bodies	Hydro-logic Soil Group[2]	Regional Land Use
Amygdaloid	Creek	Osceola	short, narrow	0.37	0.37	6.9	0.70	9.2	1.10	66	Northern Hardwood (37%), Aspen/White Birch (11.5%), Herbaceous (10.5%), Barren (8%), Coniferous (7.5%), Residential (4.5%), ***Impervious (4.4%),*** Lowland Conifers (4%), Shrub (3%), Pine (1%)	upper:	-	-	-	-	-	-	-
												middle:	4.0	-	0.45	61	-	B	Coniferous (29%), Lowland Conifer (22%), Aspen/White Birch (17%), *Impervious (0%)*
												hillside:	8.8	8.8	0.67	62	2 ponds	B	Northern Hardwood (59%), Herbaceous (14%), Aspen/White Birch (12%), *Impervious (1.7%)*
												lower:	4.7	11.0	0.13	79	retention ponds at outlet	A/SS[4]	Barren (32%), Residential (15%), ***Impervious (14%)***
Oneco	Creek	Osceola	long, narrow	0.47	0.62	4.4	1.00	13.7	2.32	67	Northern Hardwood (21.5%), Herbaceous (19%), Coniferous (14%), Aspen/White Birch (13%), Barren (8.5%), Shrub (5%), Shrub/Shrub Wetland (4%), ***Impervious (4%),*** Lowland Conifer (3%), Residential (3%), Pine (2%), Emergent Wetland (1%)	upper:	-	-	-	-	-	-	-
												middle:	1.8	7.3	1.21	67	2 ponds	B, C	Herbaceous (22%), Northern Hardwood (18%), Coniferous (16%), *Impervious (2.9%)*
												hillside:	17.4	15.9	0.62	62	-	B	Northern Hardwood (62%), Aspen/White Birch (15%), Coniferous (11%), *Impervious (3.7%)*
												lower:	5.0	10.8	0.47	80	retention ponds at outlet, sewage lagoon	B, A/SS	Barren (35%), Northern Hardwood (14%), ***Impervious (12%)***
Tamarack Hill	Creek	Osceola	long, wide to narrow	0.48	0.29	7.6	0.92	8.5	1.37	69	Northern Hardwood (28%), ***Impervious (15%),*** Aspen/White Birch (12%), Barren (11.5%), Residential (10.5%), Coniferous (9%), Herbaceous (5%), Shrub (3%), Central Hardwood (2%), Nonforested Wetland (2%), Emergent Wetland (1%)	upper:	-	-	-	-	-	-	-
												middle:	4.0	6.4	0.50	71	-	B	Northern Hardwood (23%), Coniferous (13%), Herbaceous (12%), ***Impervious (26%)***
												hillside:	10.2	9.7	0.60	64	1 pond	B	Northern Hardwood (44%), Aspen/White Birch (15%), Coniferous (13%), ***Impervious (11%)***
												lower:	5.2	6.5	0.27	75	floodplain / wetland retention pond	A, A/SS, B	Barren (30%), Residential (22%), ***Impervious (18%)***
Dover	Creek	Torch Lake, Osceola	boomerang	3.00	3.06	3.4	4.54	5.5	4.54	71	Northern Hardwood (27%), Coniferous (17%), Emergent Wetland (14%), Aspen/White Birch (11%), Herbaceous (8%), ***Impervious (5.3%),*** Scrub/Shrub Wetland (3%), Residential (3%), Shrub (2.5%), Nonforested Wetland (2.5%), Wooded Wetland (2.5%), Barren (1%)	upper:	1.6	1.0	2.13	76	large interconnected wetlands	C, B, A/D, D, A, B/D	Emergent Wetland (23%), Coniferous (20%), Northern Hardwood (13%), Aspen/White Birch (10%), *Impervious (5.5%)*
												middle:	3.5	6.1	1.36	67	4 ponds	B, C, B/D	Northern Hardwood (43%), Coniferous (14%), Aspen/White Birch (12%), Herbaceous (12%), *Impervious (4%)*
												hillside:	17.0	19.6	0.65	61	1 reservoir,	B	Northern Hardwood (70%), Aspen/White Birch (13%), Coniferous (8%), *Impervious (1.5%)*
												lower:	7.0	3.8	0.41	68	floodplain / wetland	A, B, A/SS	Barren (21%), Northern Hardwood (15%), Coniferous (14%), Residential (11%), ***Impervious (23%)***
8th Street	Creek	Torch Lake, Osceola	long, narrow	0.30	0.22	9.3	1.15	10.0	1.44	65	Northern Hardwood (42%), Coniferous (14%), Aspen/White Birch (13%), ***Impervious (11%),*** Residential (7%), Barren (3%), Herbaceous (2%) , Shrub (1%), Lowland Conifer (1%), Emergent Wetland (1%)	upper:	-	-	-	-	-	-	-
												middle:	4.0		0.30	60	-	B	Northern Hardwood (37%), Aspen/White Birch (36%), Coniferous (11%), *Impervious (0%)*
												hillside:	9.6	10.0	0.79	61	-	B	Northern Hardwood (60%), Coniferous (20%), Aspen/White Birch (12%), *Impervious (3%)*
												lower:	10.1		0.35	74	-	A, B, A/SS	Residential (19%), Northern Hardwood (15%), Barren (10%), ***Impervious (28%)***
12th Street	Creek	Torch Lake, Osceola	wide upper, long, narrow	0.58	0.60	5.5	1.51	11.2	3.54	65	Herbaceous (25%), Northern Hardwood (22%), Coniferous (16%), Aspen/White Birch (12.5%), ***Impervious (7.7%),*** Shrub (4%), Residential (3.3%), Barren (3%), Shrub/Shrub Wetland (1.5%), Pines (1%), Central Hardwood (1%)	upper:	3.4	-	0.20	77	1 pond	D, C	Herbaceous (37%), Coniferous (29%), Aspen/White Birch (12%), *Impervious (0%)*
												middle:	3.0	6.7	1.04	64	1 pond, 1 reservoir	B, C, B/D	Herbaceous (36%), Northern Hardwood (18%), Coniferous (14%), *Impervious (3%)*
												hillside:	13.3	12.2	0.84	61	-	B	Northern Hardwood (46%), Coniferous (20%), Aspen/White Birch (17%), *Impervious (2%)*
												lower:	8.0	-	0.40	79	-	A	Residential (17%), Barren (13%), Northern Hardwood (9%), ***Impervious (52%)***

Table A.1. Local Watershed Characteristics (2 of 3)

Table 1.1. LOCAL WATERSHED CHARACTERISTICS

Local Watershed Name		Township	Shape	Approx. Area (mi^2)	Approx. Area w/Floodplain (mi^2)	Avg. Land Slope (%)	Approx. Main Stream Channel Length (mi)	Avg. Main Stream Channel Slope (%)	Approx. Hydraulic Length (mi)	RCN	Land Use	Region[1]	Avg. Regional Land Slope (%)	Avg. Regional Main Stream Channel Slope (%)	Approx. Regional Hydraulic Length (mi)	RCN	Surface Water Bodies	Hydrologic Soil Group[2]	Regional Land Use
Eddie & Myrtle	Creek	Torch Lake, Osceola	long, narrow	0.58	0.33	6.8	1..25	7.5	1.80	64	Northern Hardwood (38%), Aspen/White Birch (15%), Coniferous (13%), ***Impervious (9.5%),*** Herbaceous (7.5%), Shrub (4%), Barren (4%) Residential (3%), Central Hardwood (2%), Pines (1.5%)	upper:	-	-	-	-	-	-	-
												middle:	5.8	5.0	0.45	60	-	B	Aspen/White Birch (23%), Northern Hardwood (23%), Coniferous (23%), Herbaceous (11%), Shrub (11%), *Impervious (2%)*
												hillside:	6.6	7.5	0.95	61	-	B	Northern Hardwood (55%), Aspen/White Birch (16%), Coniferous (12%), *Impervious (2%)*
												lower:	8.7	9.5	0.40	77	-	A, B, A/SS	Barren (19%), Northern Hardwood (15%), Residential (14%), ***Impervious (40%)***
Daisy	Creek	Torch Lake, Osceola	long, narrow	0.46	0.25	7.1	1.15	6.3	1.45	66	Northern Hardwood (43%), Coniferous (12%), ***Impervious (12.5%),*** Barren (9%), Residential (6%), Emergent Wetland (2%), Central Hardwood (1.5%), Herbaceous (1%), Pines (1%)	upper:	-	-	-	-	-	-	-
												middle:	6.6	-	0.30	64	-	B	Coniferous (24%), Aspen/White Birch (22%), Northern Hardwood (18%), ***Impervious (12%)***
												hillside:	6.8	6.1	0.90	61	reservoir	B	Northern Hardwood (67%), Coniferous (16%), Aspen/White Birch (10%), *Impervious (1%)*
												lower:	7.8	7.4	0.25	74	-	A, A/SS	Barren (25%), Residential (13%), Northern Hardwood (9%), ***Impervious (32%)***
Mineral	Creek	Torch Lake	long, narrow	0.15	0.15	8.0	1.30	6.2	1.05	68	Northern Hardwood (44%), ***Impervious (15%),*** Residential (9%), Barren (9%), Aspen/White Birch (7%), Coniferous (6%), Emergent Wetland (2%), Herbaceous (1%)	upper:	-	-	-	-	-	-	-
												middle:	-	-	-	-	-	-	-
												hillside:	9.4	11.9	0.50	64	2 ponds	B	Northern Hardwood (79%), Residential (7%), *Impervious (7%)*
												lower:	7.1	4.1	0.55	70	1 pond	A, A/SS, B	Northern Hardwood (19%), Barren (15%), Residential (11%), ***Impervious (21%)***
Coal	Creek	Torch Lake, Osceola, Schoolcraft	long, narrow	0.32	0.32	6.8	1.60	6.5	1.90	64	Northern Hardwood (38%), Aspen/White Birch (14%), Coniferous (12%), Herbaceous (11%), Shrub (7%), ***Impervious (6%),*** Residential (5%), Barren (4%), Cropland (1%)	upper:	-	-	-	-	-	-	-
												middle:	6.2	7.1	0.35	64	1 pond	B	Northern Hardwood (30%), Aspen/White Birch (23%), Herbaceous (17%), *Impervious (7%)*
												hillside:	6.5	7.1	0.90	63	2 ponds	B	Northern Hardwood (40%), Coniferous (15%), Aspen/White Birch (11%), *Impervious (5.3%)*
												lower:	8.8	5.5	0.65	66	-	B, A, A/SS	Northern Hardwood (44%), Coniferous (16%), Residential (10%), Barren (8%), ***Impervious (9%)***
Dock	Creek	Torch Lake, Osceola, Schoolcraft	long, narrow	0.92	0.51	5.0	1.25	4.9	2.67	64	Northern Hardwood (31%), Aspen/White Birch (21%), Herbaceous (17%), Coniferous (12%), Shrub (6%), Barren (4%), ***Impervious (3%),*** Residential (2.5%), Central Hardwoods (1%), Pines (1%)	upper:	2.0	1.9	0.30	75	-	C, D	Herbaceous (33%), Northern Hardwood (20%), Coniferous (15%), Aspen/White Birch (15%), *Impervious (0.5%)*
												middle:	3.6	3.1	0.90	63	1 pond	B, C	Northern Hardwood (29%), Herbaceous (26%), Aspen/White Birch (18%), Coniferous (11%), *Impervious (4%)*
												hillside:	6.8	7.0	0.89	60	-	B	Northern Hardwood (46%), Aspen/White Birch (17%), Coniferous (11%), Herbaceous (11%), *Impervious (0%)*
												lower:	6.2	4.6	0.58	64	-	B, A, A/SS	Aspen/White Birch (37%), Northern Hardwood (17%), Coniferous (14%), Residental (8%), Barren (8%), ***Impervious (6.4%)***

Table A.1. Local Watershed Characteristics (3 of 3)

Table 1.1. LOCAL WATERSHED CHARACTERISTICS

Local Watershed Name		Township	Shape	Approx. Area (mi^2)	Approx. Area w/Floodplain (mi^2)	Avg. Land Slope (%)	Approx. Main Stream Channel Length (mi)	Avg. Main Stream Channel Slope (%)	Approx. Hydraulic Length (mi)	RCN	Land Use	Region[1]	Avg. Regional Land Slope (%)	Avg. Regional Main Stream Channel Slope (%)	Approx. Regional Hydraulic Length (mi)	RCN	Surface Water Bodies	Hydro-logic Soil Group[2]	Regional Land Use
Quarry (south)	Creek	Torch Lake, Osceola, Schoolcraft	long, narrow	0.54	0.34	6.5	1.24	5.7	1.75	62	Northern Hardwood (44%), Aspen/White Birch (22%), Coniferous (15%), Barren (5.5%), ***Impervious (5%),*** Residential (2.3%), Pines (2%), Shrub (1.5%), Herbaceous (1%)	upper:	-	-	-	-	-	-	-
												middle:	5.1	-	0.25	60	-	B	Northern Hardwood (37%), Aspen/White Birch (21%), Coniferous (17%), Herbaceous (11%), *Impervious (1%)*
												hillside:	6.3	5.6	0.90	61	-	B	Northern Hardwood (59%), Coniferous (18%), Aspen/White Birch (15%), *Impervious (4%)*
												lower:	7.0	5.9	0.60	62	-	B,A,A/SS	Aspen/White Birch (31%), Northern Hardwood (27%), Barren (14%), Coniferous (11%), ***Impervious (8%)***
Quarry (north)	Creek	Torch Lake, Osceola, Schoolcraft	long, narrow	0.63	0.63	5.0	2.24	6.4	2.75	67	Northern Hardwood (30%), Aspen/White Birch (22%), Coniferous (13%), Herbaceous (13%), Shrub (6%), ***Impervious (5%),*** Barren (3%), Residential (2.5%), Emergent Wetland (2%), Pines (1%)	upper:	2.3	1.7	0.47	75	wetlands	C, D	Aspen/White Birch (23%), Herbaceous (22%), Coniferous (15%), Northern Hardwood (14%), Shrub (9%), *Impervious (3 %)*
												middle:	3.6	3.1	0.88	63	-	B, C	Northern Hardwood (45%), Herbaceous (17%), Aspen/White Birch (10%), *Impervious (2%)*
												hillside:	7.6	7.3	0.89	62	1 reservoir	B	Aspen/White Birch (41%), Northern Hardwood (29%), Coniferous (20%), *Impervious (2%)*
												lower:	13.1	15.5	0.59	72	-	A, A/SS	Northern Hardwood (37%), Aspen/White Birch (11%), Residential (9%), ***Impervious (31%)***
Douglas-Houghton	Creek	Osceola, Schoolcraft, Calumet	long, narrow	1.29	0.67	4.6	2.64	5.1	2.75	70	Northern Hardwood (28%), Aspen/White Birch (20%), Coniferous (13%), Emergent Wetland (8.5%), Herbaceous (7%), ***Impervious (7%),*** Residential (4%), Shrub (3%), Pines (2%), Central Harwood (1%), Wooded Wetland (1%)	upper:	2.5	1.2	0.69	77	3 ponds	C, B/D, D	Emergent Wetland (21%), Coniferous (21%), Northern Hardwood (15%), Aspen/White Birch (14%), Herbaceous (11%), *Impervious (2%)*
												middle:	4.5	4.2	0.58	62	1 pond	B, C	Northern Hardwood (49%), Aspen/White Birch (15%), Herbaceous (10%), Shrub (10%), *Impervious (1%)*
												hillside:	7.0	7.7	0.85	60	-	B	Aspen/White Birch (43%), Northern Hardwood (40%), Coniferous (12%), *Impervious (0%)*
												lower:	6.8	7.3	0.52	78	-	A, A/SS, B	Residential (22%), Northern Hardwood (13%), Aspen/White Birch (4%), ***Impervious (50%)***
Kilmar	Creek	Schoolcraft	long, narrow	0.26	0.26	7.1	1.11	7.0	1.48	67	Northern Hardwood (48%), ***Impervious (15%),*** Aspen/White Birch (13%), Coniferous (12%), Residential (10%), Central Hardwood (4%), Emergent Wetland (3%), Shrub (3%), Pines (3%), Shrub/Shrub Wetland (1%)	upper:	-	-	-	-	-	-	-
												middle:	4.0	-	0.14	60	-	B	Northern Hardwood (97%), Aspen/White Birch (2%), *Impervious (0%)*
												hillside:	6.7	6.0	0.83	60	-	B	Northern Hardwood (71%), Aspen/White Birch (14%), Coniferous (14%), *Impervious (0%)*
												lower:	7.9	9.4	0.51	76	-	B, A, A/SS	Residential (24%), Aspen/White Birch (12%), Coniferous (11%), Northern Hardwood (11%), ***Impervious (38%)***
Condon	Creek	Osceola, Schoolcraft, Calumet	long, narrow	0.85	0.45	7.3	1.70	11.1	2.46	68	Norther Hardwood (32%), Coniferous (18%), Aspen/White Birch (15%), ***Impervious (10%),*** Residential (7%), Pines (5%), Herbaceous (4%), Emergent Wetland (3%), Shrub (2%), Lowland Conifer (2%), Central Hardwood (1%)	upper:	4.1	-	0.74	75	1 pond	C, B/D, D	Northern Hardwood (28%), Coniferous (22%), Aspen/White Birch (12%), Emergent Wetland (12%), Pine (10%), *Impervious (2%)*
												middle:	5.5	5.1	0.47	62	1 pond	B, C	Northern Hardwood (46%), Aspen/White Birch (19%), Coniferous (13%), *Impervious (3%)*
												hillside:	11.4	13.5	0.78	64	-	B	Northern Hardwood (33%), Coniferous (24%), Aspen/White Birch (19%), Residential (7%), *Impervious (5%)*
												lower:	8.5	15.1	0.47	77	-	A, B	Residential (24%), Coniferous (10%), Northern Hardwood (8%), ***Impervious (44%)***
Henwood	Creek	Osceola, Schoolcraft, Calumet	long, narrow	0.36	0.36	7.3	1.50	7.8	2.26	71	Northern Hardwood (27%), Coniferous (20%), ***Impervious (16%),*** Residential (13%), Aspen/White Birch (12%), Herbaceous (3%), Lowland Conifer (3%), Emerent Wetland (2%), Pines (1%)	upper:	5.1	-	0.71	74	-	C, B/D	Northern Hardwood (46%), Coniferous (15%), Aspen/White Birch (11%), *Impervious (1%)*
												middle:	6.3	4.9	0.33	70	-	B, C	Coniferous (31%), Northern Hardwood (22%), Lowland Conifer (13%), Aspen/White Birch (10%), ***Impervious (10%)***
												hillside:	8.1	8.1	0.81	66	1 pond	B, A	Coniferous (29%), Northern Hardwood (28%), Aspen/White Birch (13%), ***Impervious (13%)***
												lower:	7.8	12.0	0.41	74	1 pond	A, B	Residential (27%), Northern Hardwood (15%), Aspen/White Birch (12%), ***Imprevious (32%)***

B Calculations

Normal Distribution Parameters

mean = $\mu = \frac{1}{n}\sum_{i=1}^{n} x_i$

standard deviation = $\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n} x_i$

skew = $\gamma = \frac{n}{(n-1)(n-2)}\sum_{i=1}^{n} \frac{(x_i-\mu)^3}{\sigma}$

GEV Distribution Parameters using L-Moments

$$x_p = b + \left(\frac{a}{k}\right)\{1 - [-\ln(p)]^k\}$$

$$\beta_r = (r+1)^{-1}\left\{b + \frac{a}{k}\left[1 - \frac{\Gamma(1+k)}{(r+1)^k}\right]\right\} \text{ for r = 0,1,2,3}$$

Calculations of an unbiased PWM estimator was used to determine L-moments, for r = [0,3], are below.

$$\beta_r = \frac{1}{n}\sum_{i=1+r}^{n} \frac{\binom{i-1}{r}x_i}{\binom{n-1}{r}} = \frac{1}{n}\sum_{i=1+r}^{n} \frac{\left[\frac{(i-1)!}{(i-1-r)!}\right]x_i}{\left[\frac{(n-1)!}{(n-1-r)!}\right]}$$

$$\beta_0 = \frac{1}{133}\sum_{i=1+0}^{133} \frac{\left[\frac{(i-1)!}{(i-1-0)!}\right]x_i}{\left[\frac{(133-1)!}{(133-1-0)!}\right]} = \frac{1}{133}\sum_{i=1}^{133} \frac{\left[\frac{(i-1)!}{(i-1)!}\right]x_i}{\left[\frac{(132)!}{(132)!}\right]} = \frac{1}{133}\sum_{i=1}^{133} \frac{[1]}{[1]} x_i = \frac{1}{133}\sum_{i=1}^{133} x_i =$$

$$\beta_0 = 1.8674 \text{ inches}$$

$$\beta_1 = \frac{1}{133}\sum_{i=1+1}^{133} \frac{\left[\frac{(i-1)!}{(i-1-1)!}\right]x_i}{\left[\frac{(133-1)!}{(133-1-1)!}\right]} = \frac{1}{133}\sum_{i=2}^{133} \frac{\left[\frac{(i-1)!}{(i-2)!}\right]x_i}{\left[\frac{(132)!}{(131)!}\right]} = \frac{1}{133}\sum_{i=2}^{133} \left[\frac{(i-1)}{132}\right]x_i =$$

$$\beta_1 = 1.0994\ inches$$

$$\beta_2 = \frac{1}{133}\sum_{i=1+2}^{133} \frac{\left[\frac{(i-1)!}{(i-1-2)!}\right]x_i}{\left[\frac{(133-1)!}{(133-1-2)!}\right]} = \frac{1}{133}\sum_{i=3}^{133} \frac{\left[\frac{(i-1)!}{(i-3)!}\right]x_i}{\left[\frac{(132)!}{(130)!}\right]} = \frac{1}{133}\sum_{i=3}^{133} \frac{[(i-1)(i-2)]x_i}{[(132)(131)]} = \frac{1}{133}\sum_{i=1}^{133} \frac{[(i-1)(i-2)]x_i}{(17292)}$$

$$\beta_2 = 0.8011\ inches$$

$$\beta_3 =$$

$$\frac{1}{133}\sum_{i=1+3}^{133}\frac{\left[\frac{(i-1)!}{3!(i-1-3)!}\right]x_i}{\left[\frac{(133-1)!}{3!(133-1-3)!}\right]} = \frac{1}{133}\sum_{i=4}^{133}\frac{\left[\frac{(i-1)!}{3!(i-4)!}\right]x_i}{\left[\frac{(132)!}{3!(129)!}\right]} = \frac{1}{133}\sum_{i=4}^{133}\frac{[(i-1)(i-2)(i-3)]x_i}{[(132)(131)(130)]} = \frac{1}{133}\sum_{i=1}^{133}\frac{[(i-1)(i-2)(i-4)]x_i}{(2247960)} =$$

$$\beta_3 = 0.6384\ inches$$

L -moments are calculated in terms of PWMs using the following relationships.

$$\lambda_1 = \beta_0$$

$$\lambda_2 = 2\beta_1 - \beta_0$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0$$

$$\lambda_1 = \beta_0 = \text{ 1.8674 inches}$$

$$\lambda_2 = 2\beta_1 - \beta_0 = 2(1.0994) - 1.8674 = 0.3313\ inches$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0 = 6(0.8011) - 6(1.0994) + 1.8674 = 0.0779\ inches$$

GEV parameters are calculated in terms of L -moments using the following relationships.

$$c = \left[\frac{2\lambda_2}{\lambda_3+3\lambda_2}\right] - \frac{\ln(2)}{\ln(3)}$$

$$k = 7.8590\ c + 2.9554\ c^2$$

$$a = \frac{k\lambda_2}{[(1-2^{-k})\Gamma(1+k)]}$$

$$b = \lambda_1 + \frac{a[\Gamma(1+k)-1]}{k}$$

$$c = \left[\frac{2\lambda_2}{\lambda_3+3\lambda_2}\right] - \frac{\ln(2)}{\ln(3)} = \left[\frac{2(0.3313)}{0.0779+3(0.3313)}\right] - \frac{\ln(2)}{\ln(3)} = -0.0127$$

$$k = 7.8590\ c + 2.9554\ c^2 = 7.8590(-0.0127) + 2.9554\ (-0.127)^2 = -0.0993$$

$$a = \frac{k\lambda_2}{[(1-2^{-k})\Gamma(1+k)]} = \frac{(-0.0993)(0.3313)}{[(1-2^{-(-0.0993)})\Gamma(1+(-0.0993))]} = 0.4323\ inches$$

$$b = \lambda_1 + \frac{a[\Gamma(1+k)-1]}{k} = 1.8674 + \frac{a[\Gamma(1+(-0.0993))-1]}{-0.0993} = 1.5711\ inches$$

GEV Distribution is calculated using the determined parameters above and the following relationship.

$$x_p = b + \left(\frac{a}{k}\right)\{1 - [-\ln(p)]^k\}$$

where p is the cumulative probability of interest and x_p is the estimated event size (annual maximum precipitation in inches).

C Figures

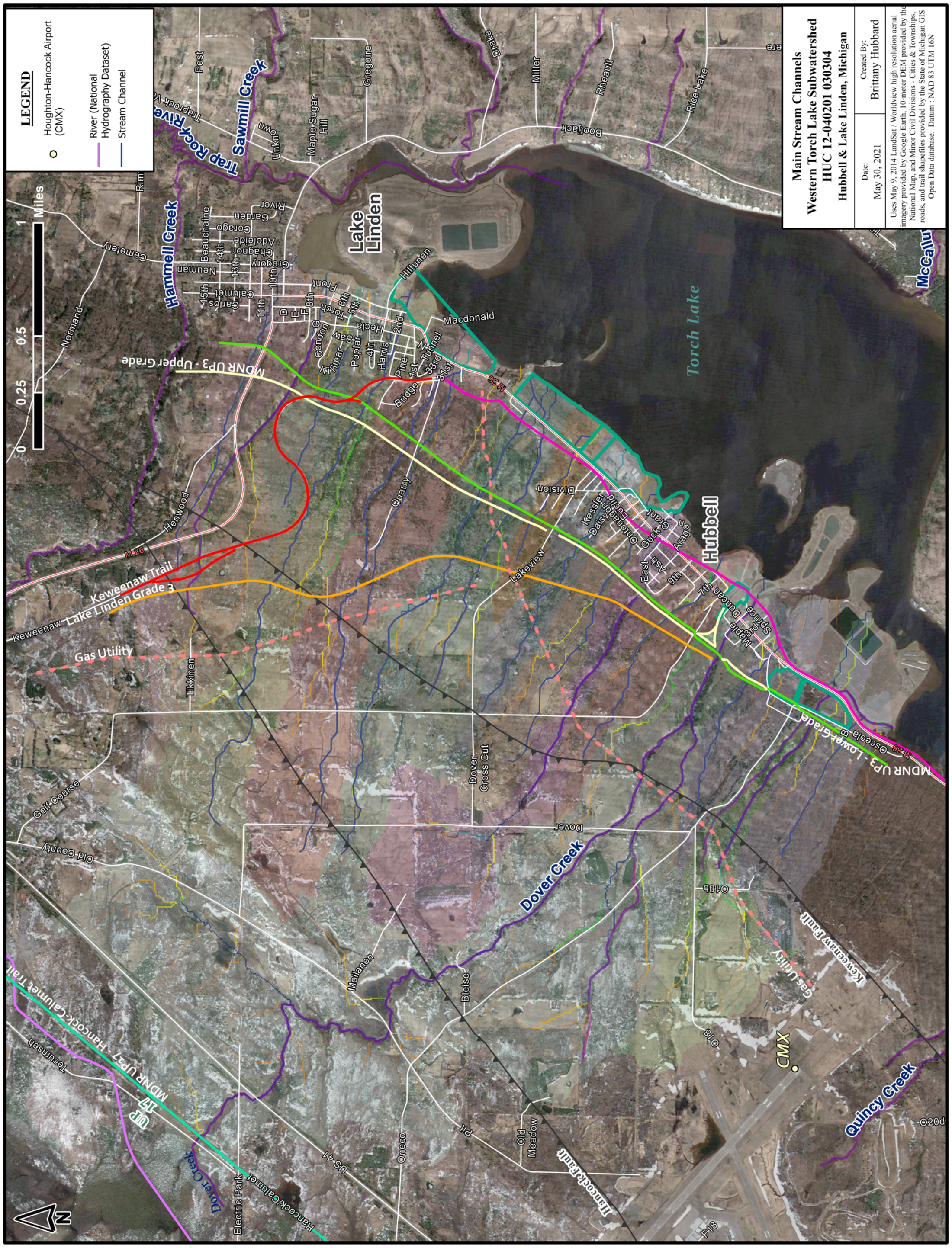

Figure C. 1. Main Stream Channels.