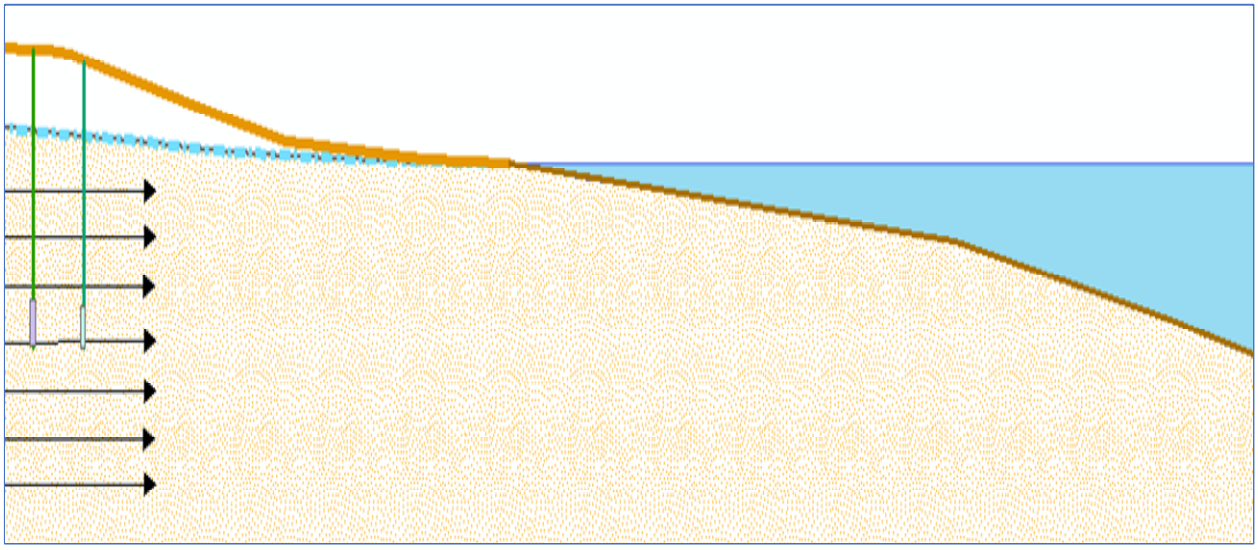
Groundwater-Surface Water Interface (GSI), Evaluation of Perfluorooctanesulfonic Acid (PFOS) at Van Etten Creek and the Au Sable River

Former Wurtsmith Air Force Base, Oscoda, Michigan

By the Michigan Department of Environment, Great Lakes, and Energy, Remediation and Redevelopment Division (EGLE), Superfund Section, Geology and Defense Site Management Unit



EGLE

September 2019

Groundwater-Surface Water Interface (GSI), Evaluation of Perfluorooctanesulfonic Acid (PFOS) at Van Etten Creek and the Au Sable River

Former Wurtsmith Air Force Base, Oscoda, Michigan

Executive Summary

A GSI evaluation of perfluorooctanesulfonic Acid (PFOS) was performed along the southern boundary of the former Wurtsmith Air Force Base, Iosco County, Michigan. The surface water areas evaluated for GSI were Van Etten Creek and Au Sable River and wetlands. Horizontal groundwater flow and groundwater concentrations of PFOS and PFOA were reviewed with respect to the GSI pathway and are the primary data sets used in the evaluation. Supplemental data used in the evaluation consisted of surface water temperature profiling and thermal imaging data to select porewater and surface water sampling locations, pore-water sampling data, and surface water sampling data EGLE identified four areas were identified for the evaluation: Mission Street, Three Pipes Drain, FT02 (Fire Training Area 2), and the Wastewater Treatment Plant. The data sets support the conclusion PFOS concentration in groundwater is greater than the GSI criteria established by the State of Michigan and the GSI pathway is complete. Remedial investigation recommendations include developing a long-term GSI monitoring well network, collecting additional data from permanent monitoring wells, and vertical aquifer sampling to characterize the vertical and horizontal extent of PFOS.

Purpose

Summarize and interpret horizontal groundwater flow data and concentration of PFOS in groundwater samples (greater than the GSI Criteria of 12 parts per trillion [ppt] PFOS) collected at selected monitoring locations along southern and eastern boundary of the former air force base. The interpretation of the data is to determine if groundwater, above the GSI criteria, is venting to Van Etten Creek and Au Sable River and adjacent wetlands. As defined by the State of Michigan, wetlands are waters of the State of Michigan (see Definitions section under GSI Evaluation Elements). Additional supplemental data (surface water temperature profiling and thermal imaging, pore water sampling, and surface water sampling) were evaluated.

GSI Evaluation Elements

GSI Relevance Statement

"The GSI pathway is relevant when a remedial investigation or application of best professional judgment leads to the conclusion that a hazardous substance in groundwater can be reasonably expected to vent to surface waters of the state (see definition of waters of the state) in concentrations that exceed the generic GSI criteria (Section 20120e(3) of the National Resources and Environmental Protection Act, 1994 PA451, as amended [NREPA]) currently or in the future. The GSI pathway may be relevant for all land uses if there is a hydraulic connection between the groundwater and surface water."

Key elements in determining pathway relevancy include the following:

- There must be a hydraulic connection between the contaminated groundwater and surface water to have a GSI. This includes an intermittent stream or water body that has flow until the groundwater table drops below the stream bottom. Intermittent streams are protected for acute and chronic risks. An ephemeral stream or water body only has flow during periods of surface runoff (rain or snowmelt). An ephemeral stream would not have a GSI.

- The hydraulic connection must transport contaminated groundwater to the surface water; a 'losing' surface water body would have a hydraulic connection with groundwater but would not transport contaminated groundwater to the surface water body.

- The designation of groundwater "not in an aquifer" does not eliminate the need to evaluate the GSI pathway. Groundwater "not in an aquifer" may be hydraulically connected to a surface water body and may vent or be reasonably expected to vent in concentrations that exceed generic GSI risk-based screening levels (RBSLs)/criteria (see definition of generic GSI risk-based screening levels/criteria).

- The applicable generic GSI RBSLs/criteria for all appropriate hazardous substances released or otherwise affected (reactions, breakdown byproducts, etc.) and appropriate Water Quality Standards (WQS) for physical characteristics are or could be exceeded in representative samples at GSI monitoring points.

- Contaminated groundwater is discharging into a separate storm sewer that discharges to a surface water body.

EGLE has promulgated rules that establish WQS for hazardous substances pursuant to Part 31, Water Resources Protection (Part 31), of NREPA. The WQS are the generic GSI

RBSLs/criteria. The surface WQS establish water quality requirements applicable to the surface waters of the state that protect the public health and welfare, enhance and maintain the quality of water, and protect the state's natural resources. All surface waters of the state are designated and protected for the following uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, and fish consumption (R 323. 1100 Designated uses).

WQS includes chronic chemical-specific values that represent the most restrictive of the water quality values protective for aquatic life, human health, or wildlife; acute chemical-specific values protective of aquatic life; acute and chronic toxic units protective of aquatic life; standards for water quality characteristics such as hydrogen ionization potential (pH), nutrients, or dissolved oxygen; and include physical characteristics such as, color, foam or sheens, taste, and odor (See WQS Part 31, Part 4 Rules). The current chronic chemical-specific GSI criteria are listed in the RBSLs/criteria tables and the associated footnotes. Acute chemical-specific GSI RBSLs/criteria protective of aquatic life are included in the Part 31, Part 4 Rule 57, Water Quality Values spreadsheet available from the EGLE web page. Note that Rule 57 values are updated periodically, and the most current values are applicable criteria. In addition to the chemical-specific WQS, a discharge may not exceed 1.0 acute toxic units at the GSI, and venting groundwater may not cause or contribute to an exceedance of 1.0 chronic toxic units in the surface waters outside of any EGLE allocated mixing zone (R 323. 1219(1) Whole effluent toxicity).

Definitions

GSI (Section 20120e(23)(c) of NREPA): Groundwater Surface Water Interface that is the location at which groundwater enters a surface water body.

GSI Monitoring Well (Section 20120e(23)(d) of NREPA): A vertical well installed in the saturated zone as close as practical to surface water with a screened interval or intervals that are representative of the groundwater venting to the surface water.

Generic GSI RBSLs/Criteria (Section 20120a(1)(a), Section 21303(j) and Section 21304a(5)(b) of NREPA): The water quality standards for surface waters developed by the EGLE pursuant to Part 31.

Surface Waters of the State of Michigan (R 323. 1044(u) [Part 31 rule definition]): Includes all the following, but does not include drainage ways and ponds used solely for wastewater conveyance, treatment or control:

- The Great Lakes and their connecting waters.
- All inland lakes.
- Rivers.
- Streams.
- Impoundments.
- Open drains.
- Wetlands.
- Other surface bodies of water within the confines of the state.

GSI Evaluation of Primary Data

Primary Data:

- Horizontal groundwater flow data using the difference in groundwater elevation between selected monitoring wells
- Concentration of PFOS in groundwater samples (GSI Criteria of 12 parts per trillion [ppt]) collected at selected groundwater sampling locations closest to the respective surface water body (includes wetlands). This area is noted on the attachments as the EGLE Estimated PFOS GSI Line. Sample locations located in close proximity to this line were used. Groundwater quality data collected from monitoring wells located within a wetland were not used.

Primary Data Assumptions and Evaluation

Assumptions:

- Horizontal flow component of groundwater is greater than the vertical flow component of groundwater, known as vertical anisotropy. This is typical of fluvial sediments.
- The horizontal flow of groundwater is assumed to exist between selected monitoring wells used during this evaluation.
- Concentrations of PFOS greater than the GSI criteria presented in this evaluation is assumed to flow into Van Etten Creek and Au Sable River (and adjacent wetlands) when the interpreted horizontal flow component of groundwater indicates venting into Van Etten Creek and Au Sable River (and adjacent wetlands).
- The data is reproduceable data and with the exception of FT-02 assumes no temporal variation.

Horizontal Flow Determination and Wetlands Areas

Groundwater flow direction is interpreted from the sitewide November 2017 groundwater level measurement event performed by Air Force Civil Engineer Center (AFCEC) (Attachment 1). Attachment 1 also depicts the National Wetlands Inventory (2005) wetlands areas for Van Etten Creek and the Au Sable River.

Groundwater Quality Data – PFOS Greater Than GSI Criteria

Groundwater data collected from 2011 to 2018 by EGLE designated personnel and AFCEC designated personnel was compared to the GSI criteria of 12 ppt PFOS. Only the groundwater samples equal to or greater than 12 ppt PFOS are presented in each section. Four per- and polyfluoroalkyl substances (PFAS) areas are presented, as designated by EGLE: Mission Street, Three Pipes Drain, FT02, and the Wastewater Treatment Plant (Attachment 2). These areas were designated by EGLE as areas located down gradient from areas of elevated concentrations of PFOS.

Primary Data Conclusions:

Mission Street

The highest concentration of PFOS in groundwater (17 ppt is located at temporary well location VAS01030 from 42 to 46 feet below ground level. A permanent monitoring well, AF-15-MW2 is screened from approximately 40 to 45 feet below ground level and is located immediately down gradient from VAS01030. A map view of this area is presented in Attachment 3

Mission Street, Groundwater Samples Above the GSI Criteria for PFOS in Close Proximity of EGLE Estimated GSI Line Units are ppt; GSI criteria is 12 ppt				
IRP/Site Name	Location/Well ID	Concentration of PFOS	Collection Date	Collected By
AF-15, WP-04	AF-15-MW2	12	10/21/2014	EGLE
AF-15, WP-04	VAS01030 (42-46 feet)	17	6/19/2018	AFCEC
OT24, A2	*OT24-MW4	14.2	9/18/2018	AFCEC
* Monitoring well is located within a wetland.				

Question: Is the source of the PFOS the result of United States Air Force (USAF) activities?
Response: PFOS concentrations in groundwater are consistent with detections of other compounds associated with previously investigated releases from USAF areas of concern up-groundwater gradient from VAS01030, and AF-12-MW2 sample locations.

Question: Is groundwater venting into Van Etten Creek?
Response: Yes. Analysis of groundwater elevation data up gradient from Van Etten Creek indicates a horizontal component of groundwater flow that is venting into Van Etten Creek.

Question: Are the concentrations of groundwater samples collected from within the area above the EGLE GSI PFOS criteria of 12 ppt?
Response: Yes. Groundwater samples collected from temporary locations and permanent locations by the designated AFCEC and EGLE representatives have concentrations above the GSI criteria for PFOS within this area.

Three Pipes Drain

The highest concentration of PFOS was detected at temporary well VAS02012 (35-40 feet) (PFOS=584 ppt) located up gradient from the upper portion of Three Pipes Drain. A map view of this area is provided in Attachment 4.

Three Pipes Drain, Groundwater Samples Above the GSI Criteria for PFOS in Close Proximity of EGLE Estimated GSI Line Units are ppt; GSI criteria is 12 ppt				
IRP/Site Name	Location/Well ID	Concentration of PFOS	Collection Date	Collected By
Three Pipes Drain, OT-24, A2	A2-MW12	43.5	10/2/2018	AFCEC
Three Pipes Drain, OT-24, A2	VAS02012 (25-30 feet)	40.7	10/23/2017	AFCEC
Three Pipes Drain, OT-24, A2	VAS02012 (35-40 feet)	584	10/23/2017	AFCEC
Three Pipes Drain, OT-24, A2	VAS02012 (45-50 feet)	67.5	10/23/2017	AFCEC
Three Pipes Drain, OT-24, A2	H17S	253	9/23/2018	AFCEC
Three Pipes Drain, OT-24, A2	A2-MW8S	310	9/13/2018	AFCEC
Three Pipes Drain, OT-24, A2	A2-MW8D	366	9/13/2018	AFCEC
Three Pipes Drain, OT-24, A2	OT24-PZ1	79.8	9/13/2018	AFCEC
Three Pipes Drain, OT-24, A2	OT24-MW16	44.5	9/12/2018	AFCEC

Recommendations:

- Collect groundwater samples from permanent monitoring wells OT24-MW14, OT24-MW17, OT24-MW18, H113S, H113D, H115S, H115D, H71S, H71D for the analysis of PFOS. These wells lie along the east side of Three Pipes Drain. Groundwater flow

direction inferred from the November 2017 water-level measurement event indicates groundwater flow toward the Three Pipes Drain in these areas.

Question: Is the source of the PFOS the result of USAF activities?
Response: PFOS concentrations in groundwater are consistent with detections of other compounds associated with previously investigated releases from USAF areas of concern.

Question: Is groundwater venting into the Au Sable River via Three Pipes Drain?
Response: Yes. Analysis of groundwater elevation data up gradient from Three Pipes Drain indicates a horizontal component of groundwater flow that is venting into Three Pipes Drain within this area.

Question: Are the concentrations of groundwater samples collected from within the area above the EGLE GSI PFOS criteria of 12 ppt?
Response: Yes. Groundwater samples collected from temporary locations and permanent locations by the designated EGLE representatives have concentrations above the GSI criteria for PFOS within this area.

FT02 (Fire Training Area)

Elevated concentrations of PFOS were detected in groundwater at the permanent monitoring well FT02-MW6D (PFOS=110,000 ppt) in October 2010. The concentration of PFOS in FT02-MW6D in May 2016 was 6,100 ppt. Groundwater samples collected down gradient from FT02 and OT16 from both permanent and temporary well locations up gradient from wetlands adjacent to the Au Sable River detected concentrations of PFOS above the GSI criteria of 12 ppt. A map view of this area is provided in Attachments 5 and 6.

FT02, Groundwater Samples Above the GSI Criteria for PFOS in Close Proximity of EGLE Estimated GSI Line Units are ppt; GSI criteria is 12 ppt				
IRP/Site Name	Location/Well ID	Concentration of PFOS	Collection Date	Collected By
OT16	VAS12006 (22-27 feet)	206	10/24/2017	AFCEC
OT16	VAS12006 (32-37 feet)	37.3	10/25/2017	AFCEC
OT16	VAS12006 (42-47 feet)	13.9	10/25/2017	AFCEC
OT16	VAS12004 (15-20 feet)	18.8	10/11/2017	AFCEC
OT16	VAS12004 (25-30 feet)	180	10/11/2017	AFCEC
OT16	VAS12004 (35-40 feet)	21.3	10/11/2017	AFCEC
OT16	VAS12008 (32-37 feet)	82.7	11/29/2017	AFCEC
OT16	VAS12008 (42-47 feet)	32.8	11/29/2017	AFCEC
OT16	VAS12005 (30-35 feet)	1,030	10/24/2017	AFCEC
OT16	VAS12005 (40-45 feet)	28.8	10/24/2017	AFCEC
OT16	VAS12003 (30-35 feet)	73.4	10/10/2017	AFCEC
OT16	VAS12003 (40-45 feet)	21.3	10/10/2017	AFCEC
OT16	OT16-MW12	12	10/31/2012	EGLE
OT16	MW06 (60-61 feet)	28.5	10/4/2018	EGLE
FT02	MW12 (30-31 feet)	35.8	10/3/2018	EGLE
FT02	MW12 (40-41 feet)	232	10/3/2018	EGLE
FT02	FT15S	8,220	6/4/2015	EGLE
FT02	FT15D	563	6/4/2015	EGLE
FT02	FT16S	8,200	5/17/2016	EGLE
FT02	FT18S	25,000	5/17/2016	EGLE
FT02	FT02-MW10	75,000; 42,000; 30,000	Oct-2010, Oct-2012, May-2016	EGLE
FT02	FT02-MW9	60,000; 63,000; 42,000	Jul-2010, Oct-2010, May-2016	EGLE
FT02	FT02-MW8S	37,000; 76,000; 12,000	Jul-2010, Oct-2010, May 2016	EGLE
FT02	FT02-MW8D	37,000; 39,000	Oct-2010, May-2016	EGLE
FT02	FT02-MW7S	260; 100	Oct-2010, May-2016	EGLE
FT02	FT02-MW4S	1,700; 4,400; 1,200	Jul-2010, Oct-2010, May-2016	EGLE
FT02	FT02-MW4M	27,000; 7,900	Oct-2010, May-2016	EGLE
FT02	FT02-MW4D	2,200; 620	Oct-2010, May-2016	EGLE
FT02	FT02-MW6S	64,000; 8,800	Oct-2010, May-2016	EGLE
FT02	FT02-MW6D	110,000; 42,000; 6,100	Oct-2010, Oct-2012, May-2016	EGLE
FT02	FT02-MW5	90,000; 7,400	Oct-2010, May-2016	EGLE
FT02	FT02-PZ19	920	5/17/2016	EGLE
FT02	FT02-PZ12	3,600	5/17/2016	EGLE
FT02	FT02-MW11	30; 46; 2,000	5/17/2016	EGLE

Question: Is the source of the PFOS the result of USAF activities?
Response: PFOS concentrations in groundwater are consistent with detections of other compounds associated with previously investigated releases from USAF areas of concern.

Question: Is groundwater venting into wetlands adjacent to Au Sable River?
Response: Yes. Analysis of groundwater elevation data up gradient from the wetlands adjacent to the Au Sable River indicate a horizontal component of groundwater flow that is venting into the wetlands adjacent to the Au Sable River.

Question: Are the concentrations of groundwater samples collected from within the area above the EGLE GSI criteria of 12 ppt for PFOS?
Response: Yes. Groundwater samples collected from temporary and permanent locations by the designated AFCEC and EGLE representatives have concentrations above the GSI criteria for PFOS within this area.

Wastewater Treatment Plant

Elevated concentrations of PFOS (2,600 ppt) were detected in permanent monitoring well WWTP-MW7, immediately down gradient from the wastewater treatment plant. Four temporary well locations west of monitoring well WWTP-MW7 had concentrations of PFOS vary from 14.7 to 2,940 ppt. A map view of this area is provided in Attachments 5 and 7.

Wastewater Treatment Plant, Groundwater Samples Above the GSI Criteria for PFOS
Units are ppt; GSI criteria is 12 ppt

IRP/Site Name	Location/Well ID	Concentration of PFOS	Collection Date	Collected By
Between SS-72 and LF-27	VAS12007 (20-25 feet)	194	10/26/2017	AFCEC
Between SS-72 and LF-27	VAS12007 (30-35 feet)	13.1	10/26/2017	AFCEC
Between SS-72 and LF-27	VAS12007 (55-60 feet)	84.5	10/26/2017	AFCEC
WP-32 (Surface Impoundment)	VAS11008 (19-22 feet)	73.8	5/5/2016	EGLE
WP-33 (Wastewater Treatment Plant)	WWTP-MW7	2,600	11/1/2012	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11009 (16-19 feet)	474	5/5/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11009 (26-29 feet)	580	5/5/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11009 (36-39 feet)	613	5/5/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11009 (46-49 feet)	502	5/5/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11010 (4.5-7.5 ft)	1,130	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11010 (14.5-17.5 ft)	1,680	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11010 (24.5-27.5 ft)	1,350	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11010 (34-37 feet)	2,940	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11011 (15-18 feet)	2,380	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11011 (25-28 feet)	1,010	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11011 (35-38 feet)	462	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11011 (45-48 feet)	479	5/10/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11022 (17-20 feet)	546	11/9/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11022 (27-30 feet)	1,840	11/9/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11022 (37-40 feet)	134	11/9/2016	EGLE
WP-33 (Wastewater Treatment Plant)	VAS11022 (47-50 feet)	14.7	11/9/2016	EGLE

Recommendations/Comments:

- At WWTP-MW7 – Perform vertical aquifer sampling northeast of this monitoring well to determine the horizontal extent of PFOS.
- Data collected from both temporary and permanent monitoring wells (VAS11009, VAS11010, VAS11011, VAS11022, WWTP-MW7) down gradient from the wastewater treatment plan indicate an extensive continuous area of groundwater exceeding the PFOS GSI criteria of 12 ppt.

Question: Is groundwater venting into wetlands adjacent to the Au Sable River?
Response: Yes. Analysis of groundwater elevation data up gradient from the wetlands adjacent to the Au Sable River indicate a horizontal component of groundwater flow that is venting into the wetlands adjacent to the Au Sable River.

Question: Are the concentrations of groundwater samples collected from within the area above the EGLE GSI PFOS criteria of 12 ppt?
Response: Yes. Groundwater samples collected from temporary locations and permanent locations by the designated AFCEC and EGLE representatives have concentrations above the GSI criteria for PFOS within this area.

GSI Evaluation of Supplemental Data

Supplemental Data:

- Surface water temperature profiling and thermal imaging data to determine potential groundwater discharge locations and assist in surface water sampling locations.
- Surface water sampling data

Supplemental Data Assumptions and Evaluation

Assumptions:

- Surface water temperature profiling and thermal imaging
    - Assumes a temperature contrast between groundwater and surface water. The greater the temperature difference, the increase in certainty of detecting groundwater discharge.
- Surface water sampling analysis
    - Concentration in the surface water correlates with the corresponding groundwater GSI data, qualitatively. This data will not be compared to GSI criteria.

Surface Water Temperature Profiling Data:

Surface water temperature profiling was performed in July 2017 along the north shore of the Au Sable River (See Figure 5 of Attachment 8 for extent of survey). Surface water temperature profiling data was used to (1) Understand potential groundwater discharge into the Au Sable River; (2) Develop a better understanding of groundwater flow to improve the base-wide Conceptual Site Model (CSM). This data was used to determine where groundwater was venting into the Au Sable River. The results of the profiling indicated a contrast between the temperature of the groundwater and the temperature of the surface water of the Au Sable River in four areas. The full report is presented in Attachment 8.

Surface Water Sampling Data:

Mission Street - Surface water samples collected from Van Etten Creek indicate concentrations of PFOS (SW01011 – PFOS=115 and 129 ppt; Van Etten Creek 1 – PFOS=40 ppt) at a location that correlates with groundwater data (AF15-MW2 and temporary well VAS01030).
Three Pipes Drain – Surface water samples collected from Three Pipes Drain (3 Pipes OWS – PFOS=340 ppt; 3 Pipes Center – PFOS=170 ppt; 3 Pipes Outfall – 180 ppt) have detections of PFOS.

FT02 and Wastewater Treatment Plant – Surface water samples collected from the surface water bodies and wetlands adjacent to the Au Sable River and down gradient from FT02 and the Wastewater Treatment Plant have concentrations of PFOS ranging from non-detect (located

upstream from FT02 and the Wastewater Treatment Plant) to 19,000 ppt from a seep near FT02.

Figures of the PFOS surface water data are presented in Attachment 9.

Supplemental Data Conclusions:

The surface water temperature profiling data, thermal imaging data from the Au Sable River and surface water quality data from Van Etten Creek and the Au Sable River qualitatively support the venting of groundwater containing PFOS above the GSI criteria.

References

Section 324.20120e, Part 201, Environmental Remediation, Natural Resources and Environmental Protection Act (NREPA), PA 451, 1994, as amended. http://legislature.mi.gov/doc.aspx?mcl-324-20120e

Section 324.21304a, Part 213, Environmental Remediation, Natural Resources and Environmental Protection Act (NREPA), PA 451, 1994, as amended. http://legislature.mi.gov/doc.aspx?mcl-324-21304a

2019, Air Force Civil Engineer Center, *SSI Monitoring Well Sampling Results, Fall 2018, Former Wurtsmith AFB*, January 16, 2019 SSI Update Meeting presentation and supplemental materials.

2018, Bay West LLC, *Draft Final 2017 Annual Remedial Action Operation Report for Installation Restoration Program Sites LF-27, OT-16, SS-05, SS-08, SS-51, SS-71, SS-72, ST-68, ST-69, and WP-04, Former Wurtsmith Air Force Base, Oscoda, Michigan*, prepared for U.S. Air Force Civil Engineer Center, Revision 00, November 2018.

2018, Michigan Department of Environmental Quality, Remediation and Redevelopment Division, *Groundwater-Surface Water Interface Pathway Compliance Options, Remediation and Redevelopment Division Resource Materials*, April 2018.

Attachment 1 – November 2017 Groundwater Flow Map (Entire Site) and Wetlands Areas (National Wetlands Inventory [2005])

LEGEND

- Idle Purge Well
- Operating Purge Well
- Monitoring Well Sampled in 2017
- Wells Gauged for Water Elevation in 2017
- Treatment Facility Location
- Staff Gauge Location
- Stream
- Groundwater Flow Direction
- November 2017 Equipotential Contour (feet MSL)
- Approximate IRP Site Location
- Former Installation Boundary
- Engineered Wetland Treatment System

2017 Plumes

- 124-TMB > GSI
- PCE > GSI
- Undifferentiated Fuel Constituents where concentrations inferred to GSI
- Lake

NOTES & SOURCES

1. Map Coordinates: NAD 83, State Plane, Michigan Central, International Feet
2. Equipotential contours based on annual basewide water level gauging November 2017
3. Equipotential contours reflect idle or operating pumping purge wells as indicated
4. Where well couplets are present, only gauging data from shallow well used to develop equipotential contours
5. Equipotential contours in feet above mean sea level (ft MSL)
6. Only Contaminants of Concern exceeding one or more Generic GSI Criteria shown
7. Plumes that are defined using wells that are sampled biennially are depicted using the most recent sampling data.
8. Concentrations in µg/L
9. PCE = tetrachloroethene, TCE = trichloroethene, 1,2,4-TMB = 1,2,4-trimethylbenzene
10. GSI Criteria are the Generic Groundwater Surface Water Interface Cleanup Criteria, from MDEQ Part 201

TITLE

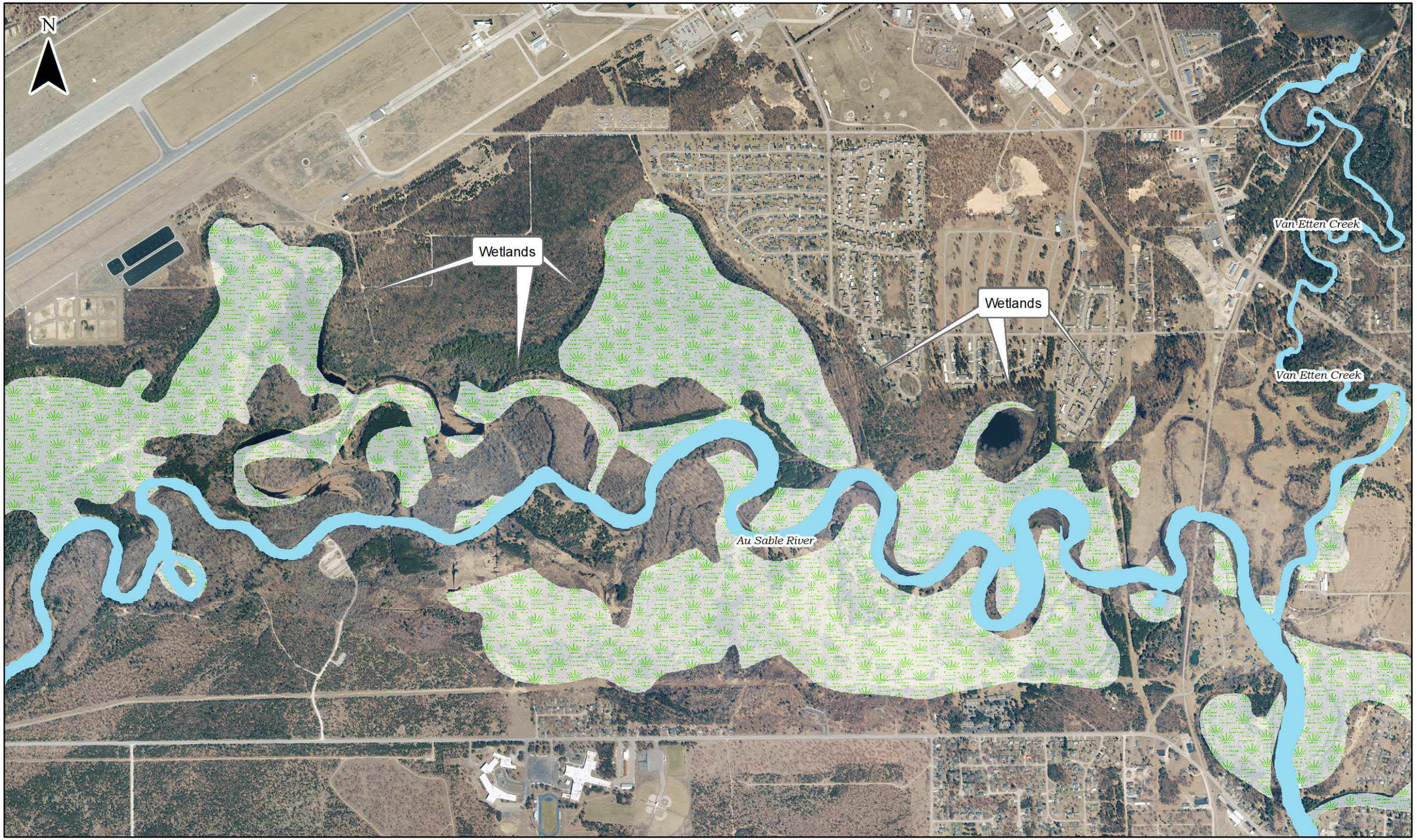
Appendix B
Contaminants of Concern Generic GSI Criteria Exceedences, 2017
Wurtsmith Air Force Base

0 1,000 2,000 Feet

FIGURE
C

Bay West
Customer-Focused Environmental & Industrial Solutions

Document Path: Y:\Clients\US_AIR_FORCE_CIVIL_ENGINEER_CENTER\Wurtsmith\MapDocs\150973\Basewide\tl14_LTM_2017\150973_Wurtsmith_002_App_B_Fig_C_GSI_2017.mxd



EGLE

Michigan Department of Environment, Great Lakes, and Energy

www.michigan.gov/degle

Outlines of Van Etten Creek and Au Sable River National Wetlands Inventory (2005)

Former Wurtsmith Air Force Base

Oscoda, Michigan

Drawn By: MAB

Date Drawn: 26 August 2019

Datum: NAD 83

Projection: Michigan GeoRef

Scale: AS SHOWN

Imagery Date: 2018, 1 ft resolution

Site EPA ID: MI5570024278

EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU

Notes:
(1) Wetlands layer downloaded 9/3/2019 from EGLE Wetlands Map Viewer. https://www.mcgi.state.mi.us/wetlands/
(2) Van Etten Creek and Au Sable layers hand digitized by EGLE-RRD-Superfund-GDSMU staff from 2018 imagery.

Legend

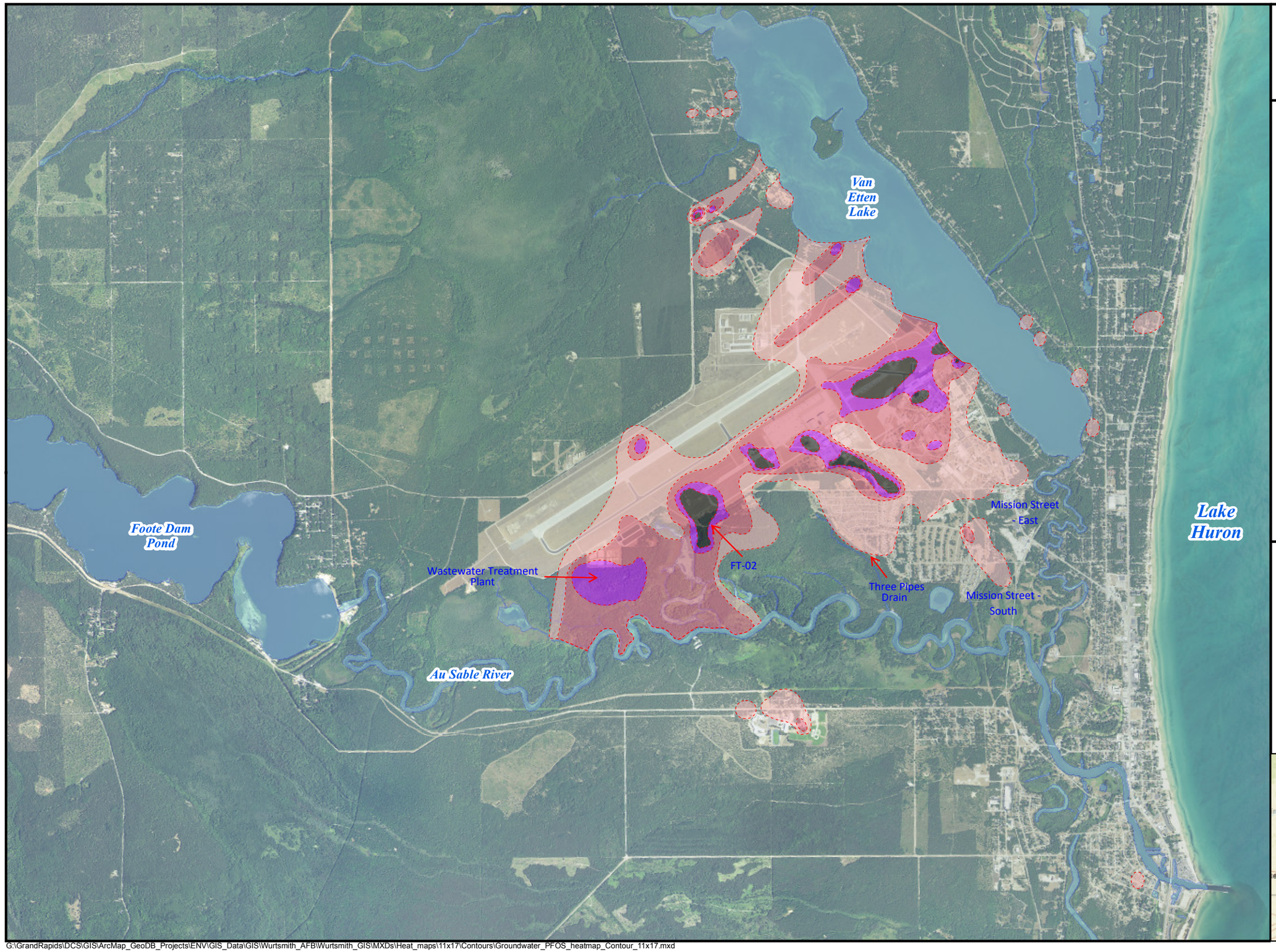
- Van Etten Creek
- Au Sable River
- National Wetlands Inventory 2005

750 375 0 750 1,500 2,250 3,000 Feet

Van Etten Creek and Au Sable River - Groundwater-Surface Water (GSI) Interface, Evaluation of Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

Attachment 2 – EGLE Designated PFAS Areas



EGLE

6/20/2019

Legend

PFOS Plume

Concentration (ppt)

- 12
- 70
- 1,000
- 5,000

GROUNDWATER AND RESIDENTIAL SAMPLING RESULTS PFOS CONTOURS

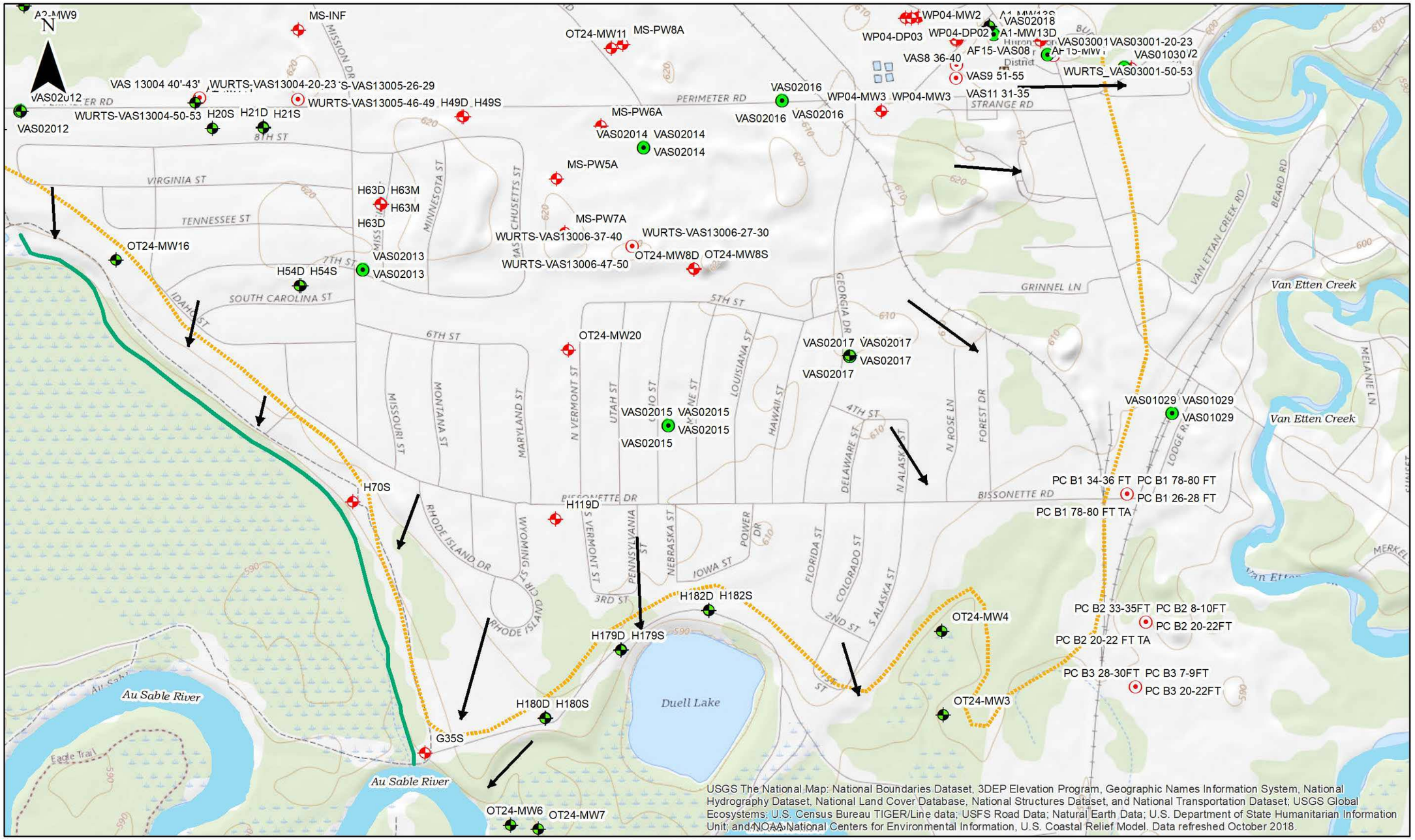
FORMER WURTSMITH AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 3,400 6,800
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Heat_maps\11x17\Contours\Groundwater_PFOS_heatmap_Contour_11x17.mxd

Attachment 3 – Mission Street
PFOS Concentration in Groundwater



USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed October 2018.

EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

250 125 0 250 500 750 1,000 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- MPART PFAS Sampling Location, Temporary (2017 to 2018)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

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EGLE and AFCEC Groundwater Sampling Locations
Mission Street
Former Wurtsmith Air Force Base
Oscoda, Michigan

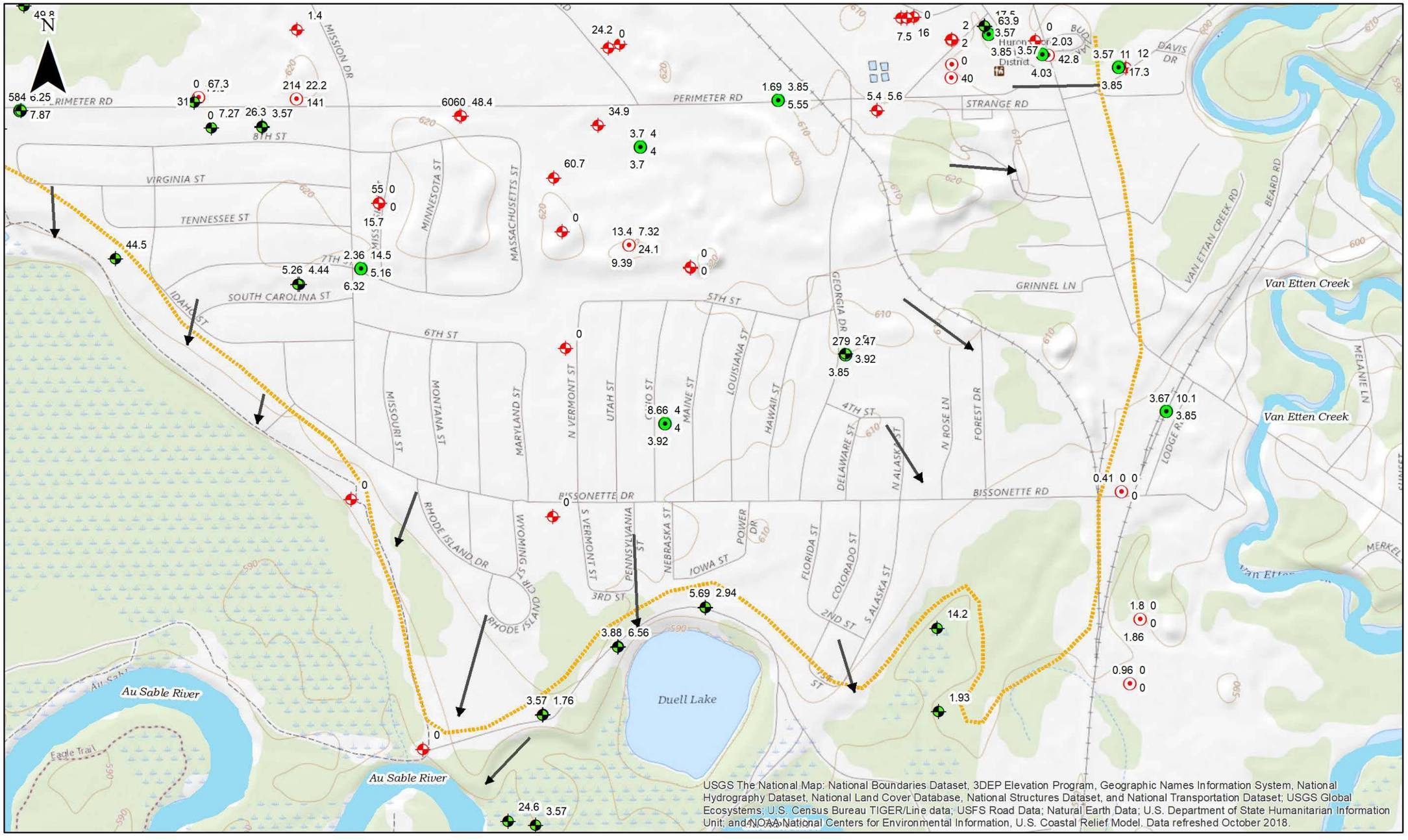
Drawn By: MAB
Date Drawn: 9/5/2019

Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU



USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed October 2018.

EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

250 125 0 250 500 750 1,000 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

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Mission Street - EGLE and AFCEC Groundwater Data - PFOS Concentration (ppt)

Former Wurtsmith Air Force Base

Oscoda, Michigan

Drawn By: MAB
Date Drawn: 9/5/2019

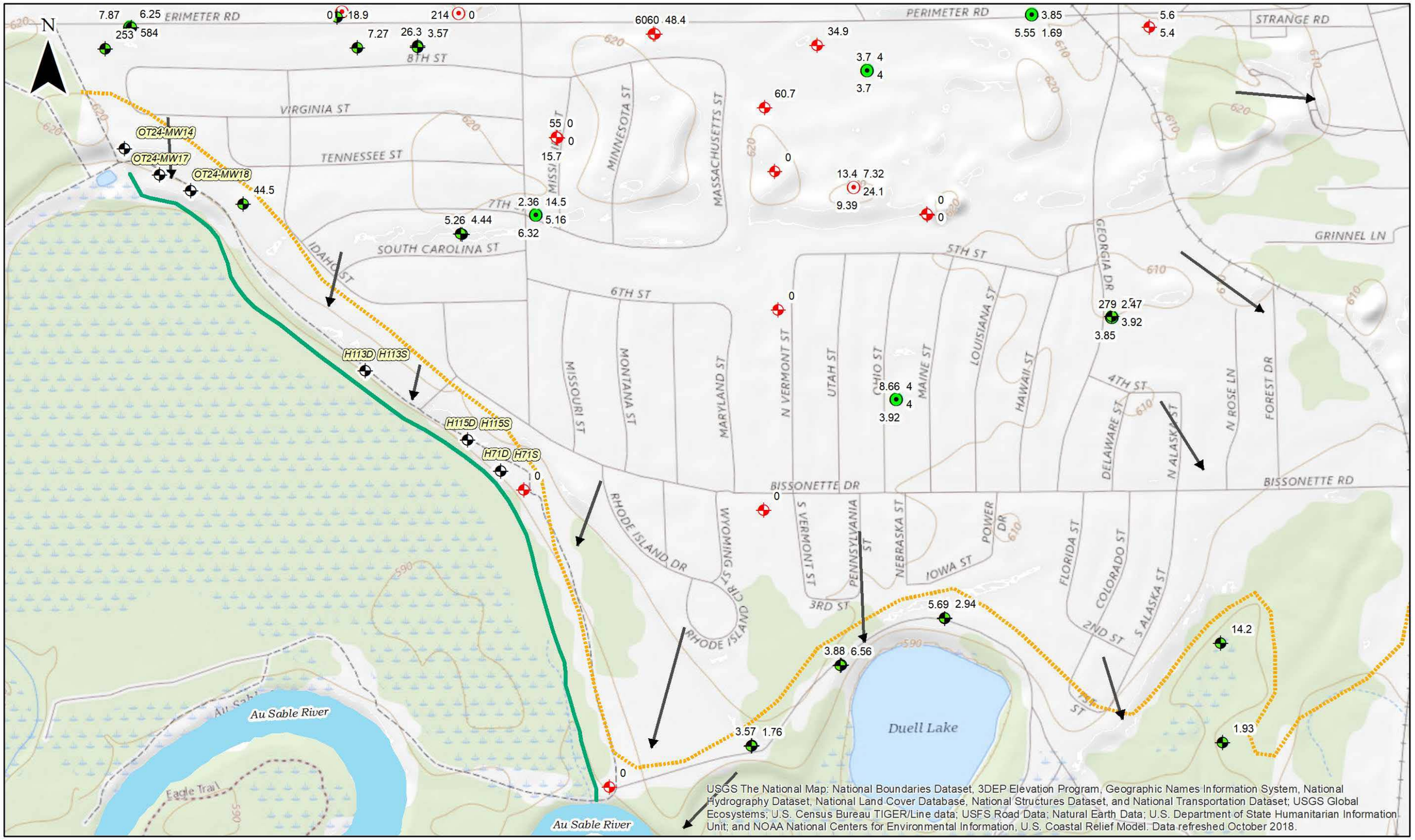
Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU

Attachment 4 – Three Pipes Drain
PFOS Concentration in Groundwater



USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed October 2018.

EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

250 125 0 250 500 750 1,000 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- Three Pipes Drain EGLE Recommended PFOS MWs
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

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Three Pipes Drain - EGLE and AFCEC Groundwater Data - PFOS Concentration (ppt)

Former Wurtsmith Air Force Base

Oscoda, Michigan

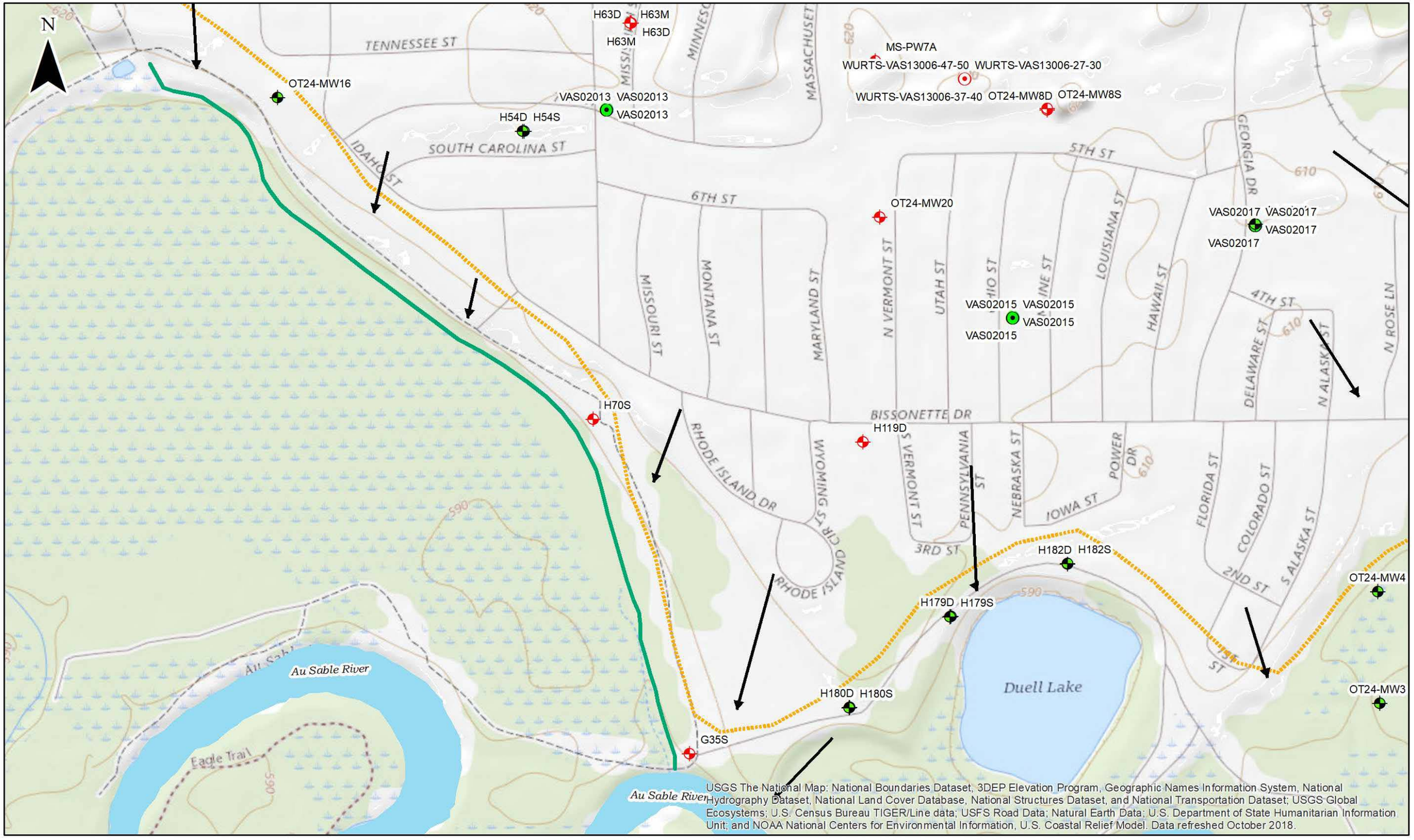
Drawn By: MAB
Date Drawn: 9/5/2019

Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU



USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed October 2018.

EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

250 125 0 250 500 750 1,000 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- MPART PFAS Sampling Location, Temporary (2017 to 2018)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

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EGLE and AFCEC Groundwater Sampling Locations Three Pipes Drain

Former Wurtsmith Air Force Base

Oscoda, Michigan

Drawn By: MAB
Date Drawn: 9/5/2019

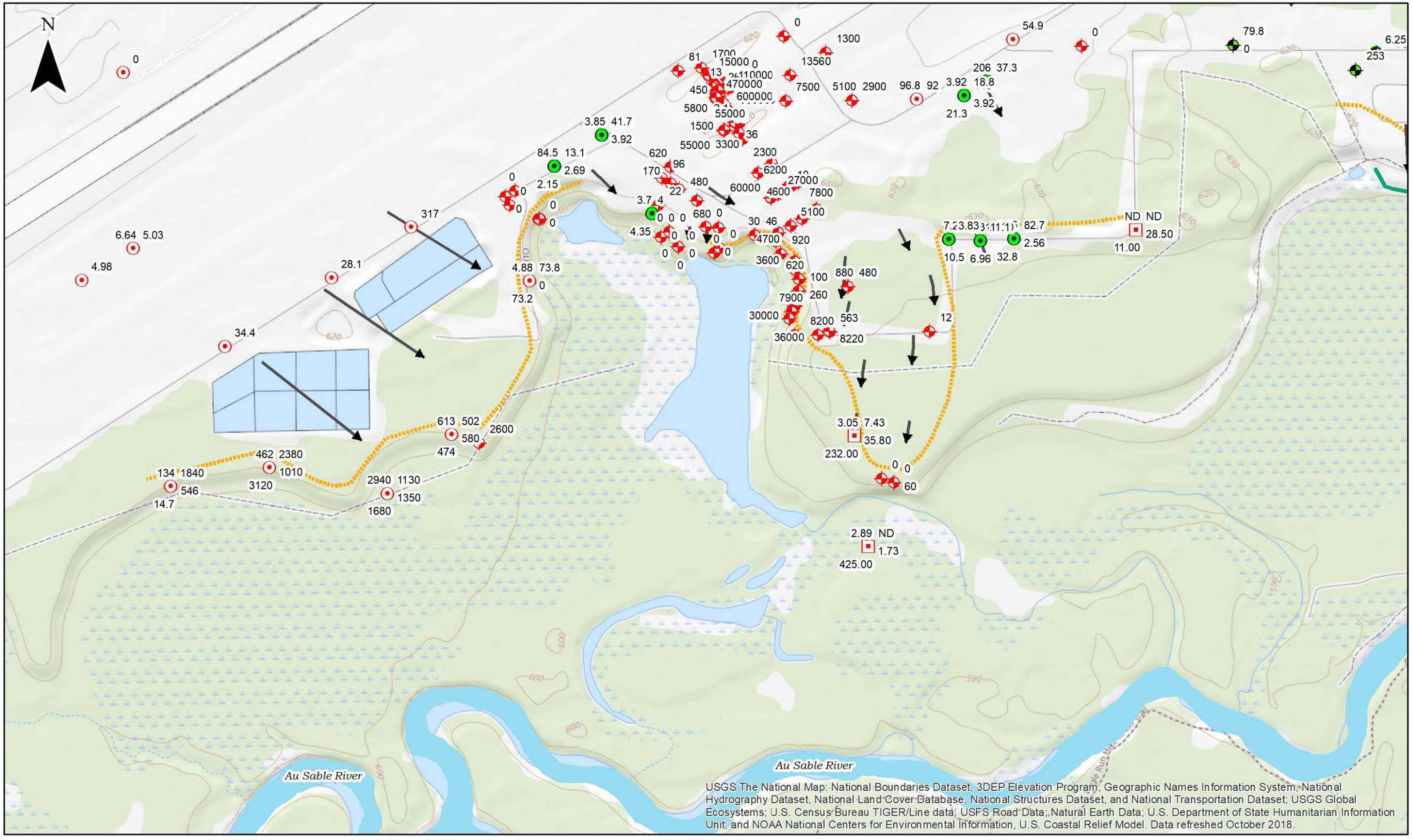
Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU

Attachment 5 – FT-02, Former Fire Training Area and Wastewater Treatment Plant, PFOS Concentration in Groundwater



EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

250 125 0 250 500 750 1,000 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- MPART PFAS Sampling Location, Temporary (2017 to 2018)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

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FT02 and Wastewater Treatment Plant - EGLE and AFCEC Groundwater Data - PFOS Concentration (ppt)

Former Wurtsmith Air Force Base

Oscoda, Michigan

Drawn By: MAB

Date Drawn: 9/6/2019

Datum: See note

Projection: See note

Scale: As shown

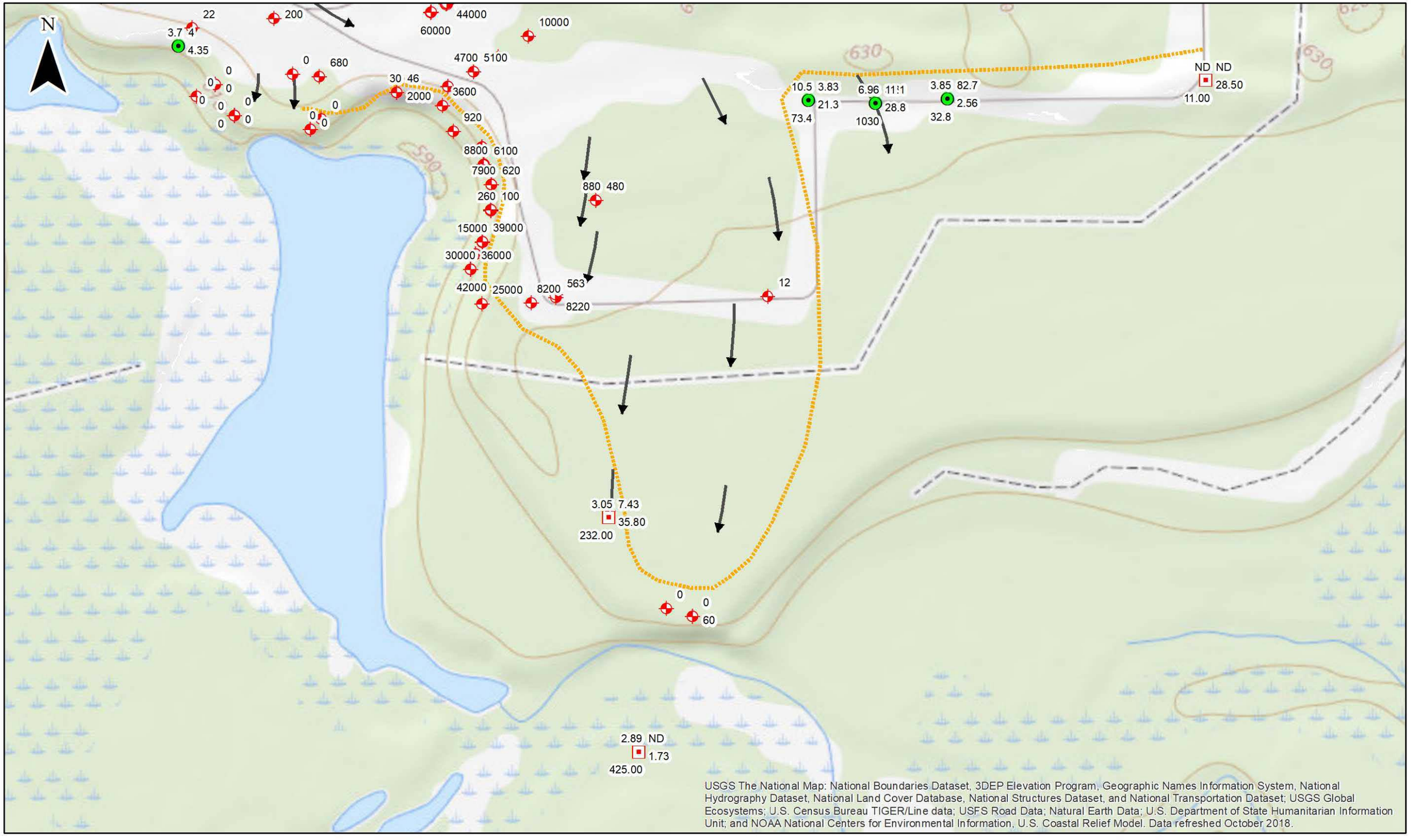
Imagery Date: See note

Site EPA ID: MI5570024278

EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU

Attachment 6 – FT-02, Former Fire Training Area, PFOS Concentration in Groundwater



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Former Fire Training Area FT02 - EGLE and AFCEC Groundwater Data - PFOS Concentration (ppt)

Former Wurtsmith Air Force Base

Oscoda, Michigan

EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

125 62.5 0 125 250 375 500 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- MPART PFAS Sampling Location, Temporary (2017 to 2018)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

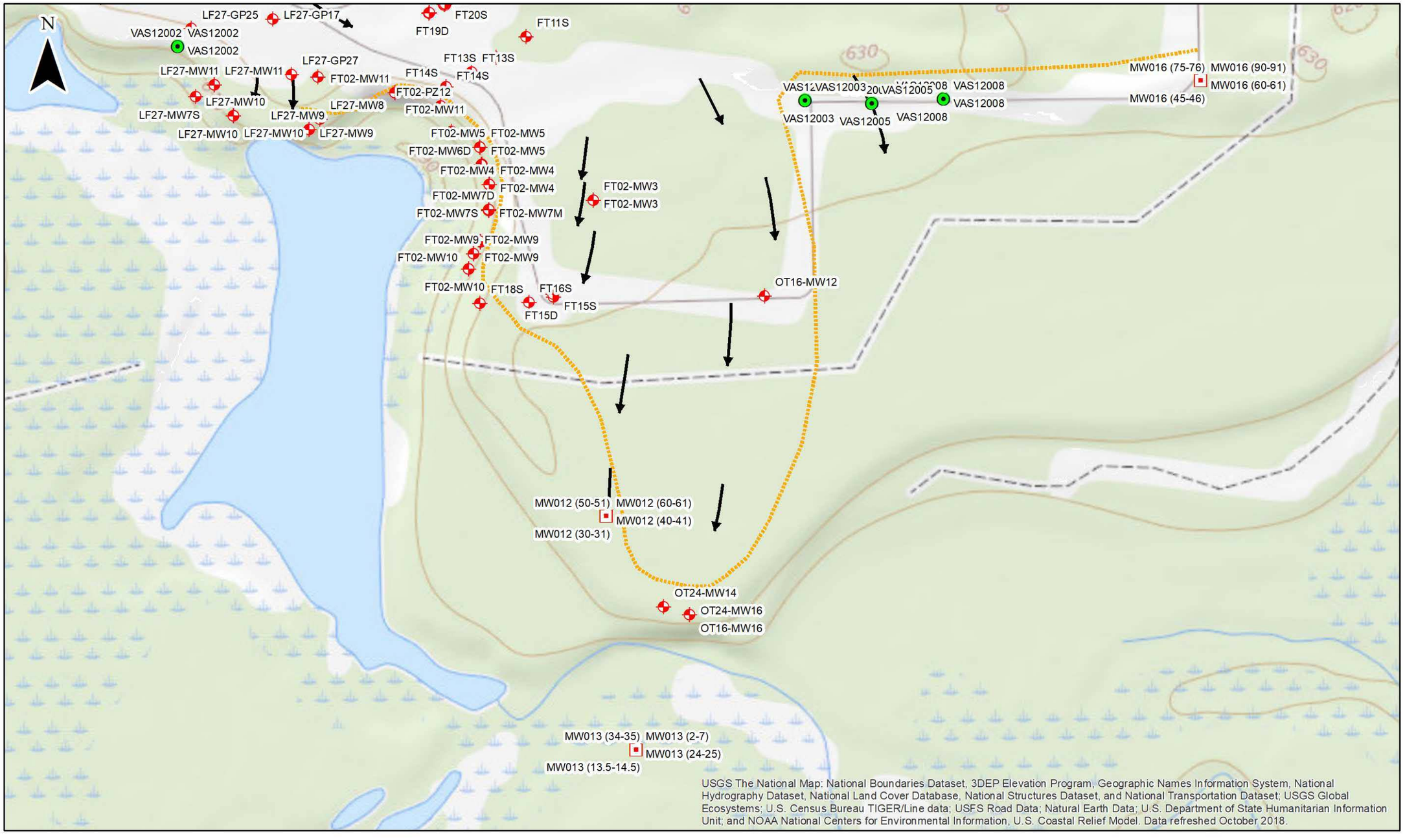
Drawn By: MAB
Date Drawn: 9/6/2019

Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU



EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

125 62.5 0 125 250 375 500 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- MPART PFAS Sampling Location, Temporary (2017 to 2018)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

EGLE

Michigan Department of Environment, Great Lakes, and Energy

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EGLE and AFCEC Groundwater Sampling Locations
Former Fire Training Area FT02
Former Wurtsmith Air Force Base
Oscoda, Michigan

Drawn By: MAB
Date Drawn: 9/5/2019

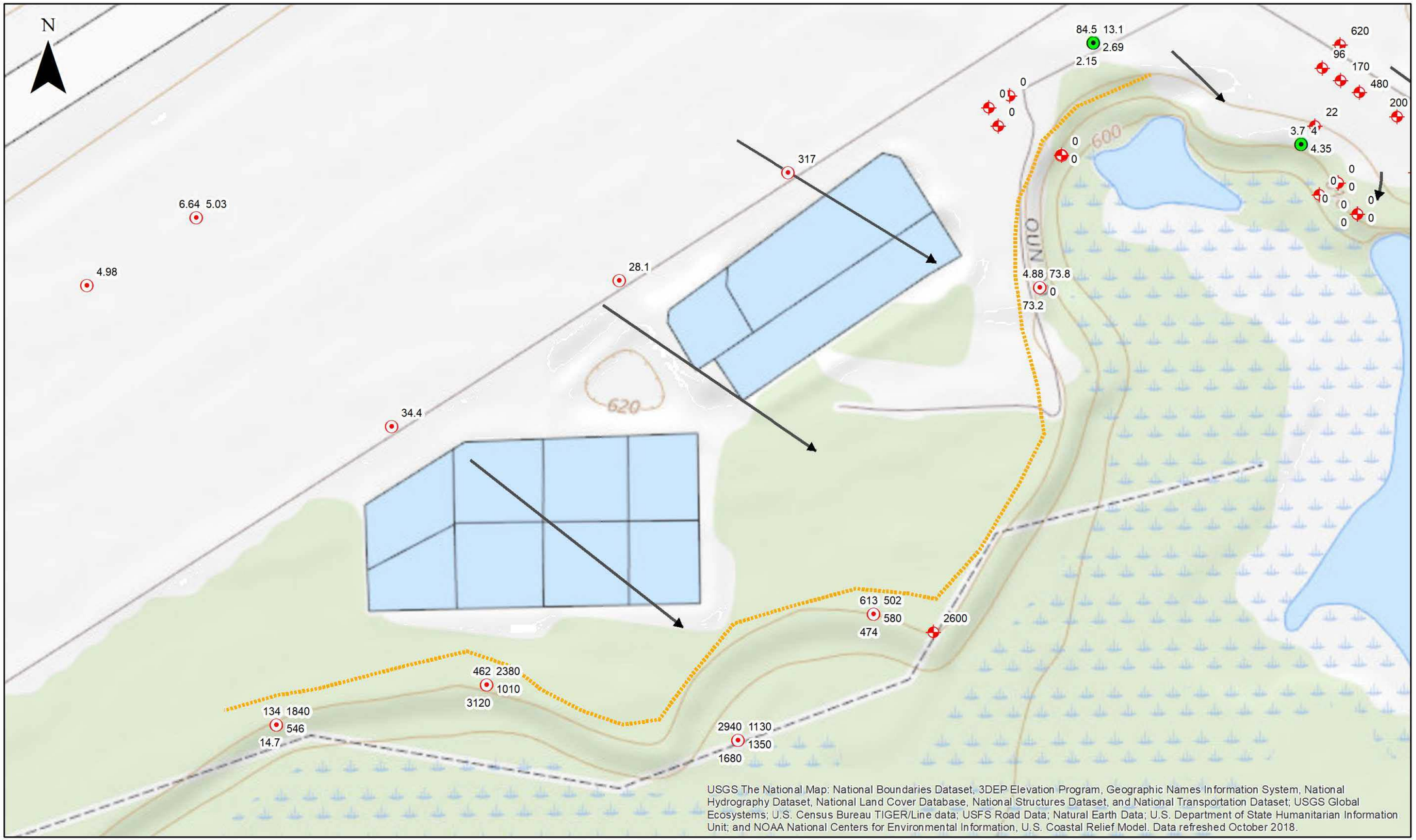
Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU

Attachment 7 – Wastewater Treatment Plant, PFOS Concentration in Groundwater



EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

125 62.5 0 125 250 375 500 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

EGLE

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Wastewater Treatment Plant - EGLE and AFCEC Groundwater Data - PFOS Concentration (ppt)

Former Wurtsmith Air Force Base

Oscoda, Michigan

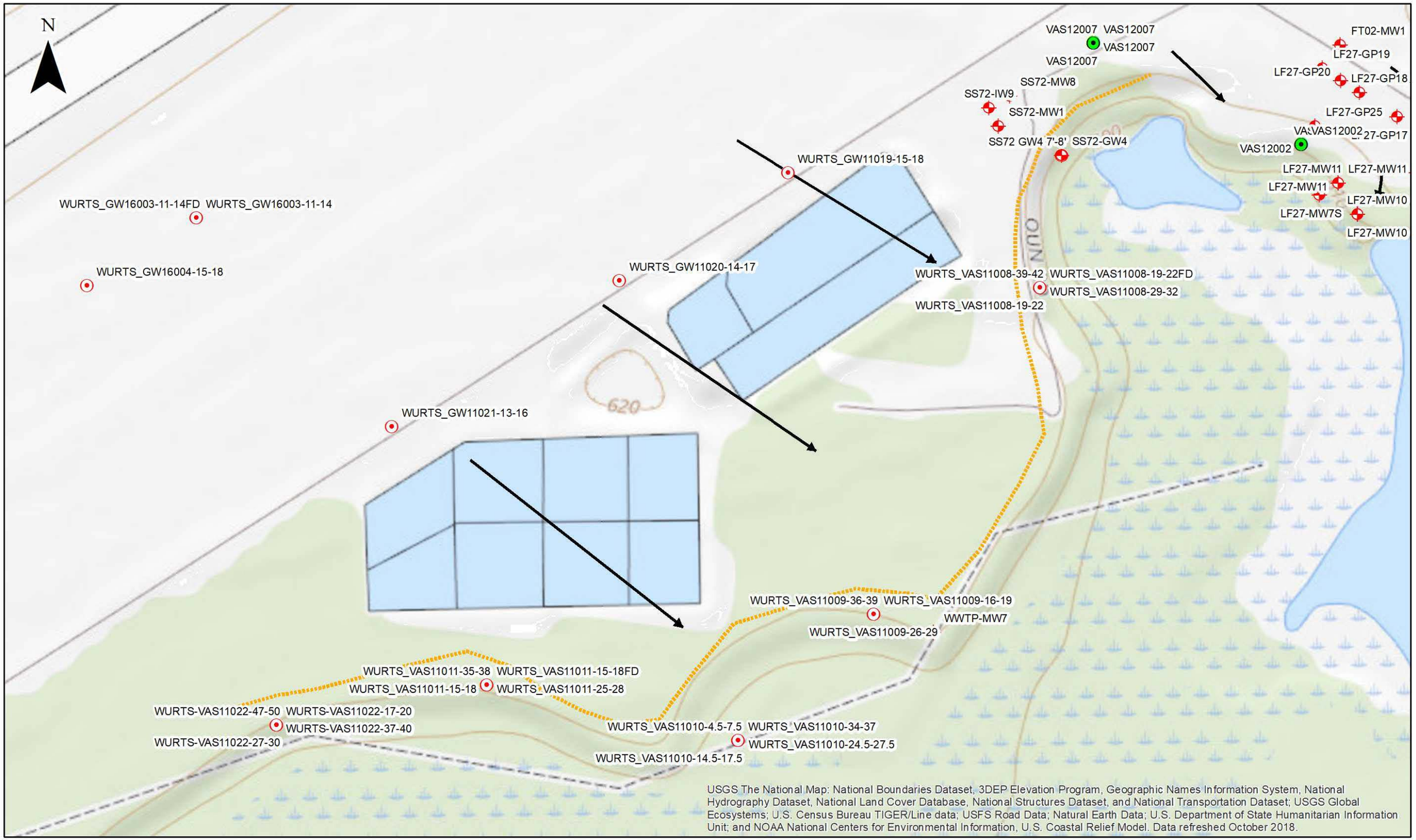
Drawn By: MAB
Date Drawn: 9/6/2019

Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU



EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

125 62.5 0 125 250 375 500 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- MPART PFAS Sampling Location, Temporary (2017 to 2018)
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

EGLE

Michigan Department of Environment, Great Lakes, and Energy

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EGLE and AFCEC Groundwater Sampling Locations Wastewater Treatment Plant

Former Wurtsmith Air Force Base

Oscoda, Michigan

Drawn By: MAB
Date Drawn: 9/5/2019

Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU

Attachment 8 – 2018 Temperature Mapping of the Au Sable River and Van Etten Lake by AECOM on behalf of EGLE (formerly known as MDEQ)

AECOM Imagine it. Delivered.

Temperature Mapping of the Au Sable River and Van Etten Lake

Wurtsmith Air Force Base

Project number: 60518528

January 31, 2018

Prepared for:

Robert Delany, Jr.
Michigan Department of Environmental Quality
Remediation and Redevelopment Division
Constitution Hall, 5th Floor, South Tower
525 West Allegan Street
Lansing, Michigan 48933

Prepared by:

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MI, 49546
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Table of Contents

Figures

1. Introduction

This technical memorandum summarizes and reports the findings of the temperature study of Van Etten Lake and the Au Sable River performed between July 25 and 27, 2017. Van Etten Lake and the Au Sable River are located in Oscoda, MI adjacent to the former Wurtsmith Air Force Base (WAFB) (**Figure 1**). The objectives of the temperature study are to:

1. Understand potential groundwater discharge into the Au Sable River and Van Etten Lake;
2. Identify potential pathways for perfluoroalkyl and polyfluoroalkyl substances (PFAS) to discharge into surface water; and
3. Develop a better understanding of groundwater flow to improve the base-wide Conceptual Site Model (CSM).

2. Background

The geology at WAFB is generally characterized as lacustrine and eolian sands overlying lacustrine clay, till, and ultimately bedrock consisting of the Marshall Sandstone and Coldwater Shale. The lacustrine sands and gravels are a series of large deltaic deposits created by the Glacial Au Sable River where it entered an evolving series of late Wisconsinan pro-glacial lakes (**Figure 2**) (Burgis, 1977). As illustrated on **Figure 2**, WAFB is located on the northern limb of a large delta, designated as part of the Algonquin Delta with several nearby paleo shorelines.

Site stratigraphy consists of progradational deltaic sediments, which are expected to dip to the east/north-east. **Figure 3** is a general depositional model at the time of deposition (Larson and Schaetzl, 2001; Reineck and Singh, 1975). Upper layers of the delta deposits are expected to be sandy with only minor and spatially limited fine-grained (silt and clay) facies present in this system with a high sediment load modified by wave action. Delta mouth bar deposits of coarse sand, upward-fining (gravel to fine sand) distributary channel fills, and minor medium to fine-grained beach ridge/shore face sands will also be present until the transition to delta slope (foreset) beds. The focus of the investigation is on the distributary channels (i.e. paleo-channels) within the delta filled with coarse grained deposits that could provide preferential pathways for contaminant transport.

The sand and gravel aquifer is mostly under water-table conditions, with the depth to water ranging from less than 10 ft on the western side of the base to approximately 25 ft on the east. There is a northwest-southeast trending groundwater divide that extends across the base which directs the groundwater flow to the east towards Van Etten Lake and Van Etten Creek and south towards the Au Sable River (**Figure 4**). The subsurface geology influences how the groundwater flows, therefore, understanding WAFB's deltaic stratigraphy is key to the overall understanding potential groundwater discharge locations and the fate and transport of groundwater contaminants, including PFAS.

The approximate extent of PFAS-contaminated groundwater at WAFB using Michigan Department of Environmental Quality (MDEQ) and United States Air Force (USAF) sampling data is shown in **Figure 5**. This figure was developed from PFAS groundwater data collected between 2010 and 2016 by using the highest total PFAS concentration found at any location within the groundwater, regardless of its depth. Recently, PFAS-contaminated groundwater has been identified off the base to the south, north, across Van Etten Lake and Van Etten Creek, and in Van Etten Lake and the Au Sable River. One of the primary objectives of this study is to identify potential pathways for PFAS to discharge into these surface water bodies.

3. Temperature Study Methods

Beginning on July 25, 2017, AECOM, contracted with Affiliated Researchers, LLC, to provide temperature mapping services at the former WAFB along the lower Au Sable River and Van Etten Lake at the areas shown in **Figure 5**. The temperature survey areas were located near shore to observe potential groundwater discharge into the surface water bodies.

Affiliated Researchers integrated the data collection of water temperatures with GPS positions to collect continuous *in situ* temperature-position datasets along the nearshore of Van Etten Lake and the lower Au Sable River. This procedure provided accurate measurement, delineation, documentation, and mapping of surface water temperatures near the shores. The temperature mapping was completed during the end of July through the first part of August when ambient water temperatures are at their highest, offering the greatest differential to the groundwater temperatures.

A *Trimble R8* RTK-GPS survey system was used onboard the survey vessel. Survey data were collected using US State Plane, NAD83, NAVD88 using the units of U.S. Survey Feet. Geospatial accuracies during the water temperature mapping at Van Etten Lake were < 0.1 ft by means of obtaining continuous RTK corrections broadcasted via the NGS network of Continuously Operating Reference Stations (CORS).

Geospatial accuracies during the water temperature mapping at the Au Sable River were sub-meter (< 3 ft) by means of obtaining continuous corrections broadcastfrom the Federal Aviation Administration network of the Wide Area Augmentation System (WAAS).

A *YSI 600R* water temperature sonde was used to collect water temperature data at a resolution of 0.02 degrees Fahrenheit (º F) at a rate of 1 data point per second. *HYPACK* software installed on a hydrographic computer onboard the survey vessel was utilized to collect, combine, and record the temperature and geospatial data.

Transects were run along the shore at water depths of approximately 3 and 7 to 14 ft in Van Etten Lake, and 2 and 6 ft in the Au Sable River. The locations of the transects are shown in **Figure 5**. A manual downrigger, mounted on the gunwale of the survey vessel, was used to deploy the temperature sonde within 1 ft of the bottom while navigating the parallel transects. Since groundwater seepage occurs along the bottom of the surface water body, and the colder groundwater would tend to stratify along the bottom, the temperature sonde was kept close to the bottom where groundwater potentially discharges to the lake.

More than 10,500 temperature-position data points were collected during the temperature mapping of nearshore Van Etten Lake and approximately 6,500 points were collected along the Au Sable River.

A FLIR E8 infra-red (IR) camera was also used to identify potential groundwater seeps along the shorelines. The IR does not penetrate water, therefore the camera is limited to recording surface temperatures. The temperature range of the camera was adjusted to maximize the average groundwater temperature (approximately 55º F). The FLIR indicated seeps along the Au Sable River, but not along the shore of Van Etten Lake.

4. Results

The temperature data from each transect were evaluated by averaging the temperatures for each transect and then identifying measurements that exceeded 1 and 2 standard deviations from the average value as potential temperature anomalies.

4.1 Van Etten Lake

Van Etten Lake temperatures ranged from 73.9 to 77.7º F for the shallow transect (3 ft) and 71.4 to 78.4º F for the deep transect (7 to14 ft). The average temperature for the shallow and deep transects were 76.3 and 73.7º F, respectively. The deeper temperatures are expected to be less than shallow temperatures due to normal summertime thermal stratification in a lake. The standard deviation for the shallow transect was 0.7º F, resulting in 1 and 2 standard deviation lower temperatures of 75.7 and 75.0º F, respectively. The standard deviation for the deep transect was 1.2º F, with 1 and 2 standard deviation lower temperatures of 72.6 and 71.4º F, respectively.

Figure 6, Sheets 2 and 3 show the relationship of the 1 and 2 standard deviation temperature locations for the shallow and deep transects, respectively, and the PFAS plumes. The figures show 9 areas that exceed 2 standard deviations along the shallow transect and only 1 area that exceeds 2 standard deviations along the deep transect. The area that exceeds 2 standard deviations along the deep transect does not correspond to any of the areas observed in the shallow transect.

Soil borings located along the western side of the lake nearest the transects indicate a surficial, fine-grained sand overlying clay at a depth of 42 ft. No groundwater seeps were observed along the shoreline based on the FLIR camera observations. In addition, none of the areas (shallow or deep) that exceed 2 standard deviations correspond to locations where the maximum PFAS plume concentrations would be expected to discharge to the lake based on the groundwater PFAS data.

Figure 6, Sheets 2 and 3 also show the location and results of 10 surface water samples collected along the Van Etten Lake shoreline within the area that exceeds 1 and 2 temperature standard deviations. Total PFAS concentrations range from 14.7 to 184.1 ng/L in the surface water samples. One of the PFAS components, perfluorooctanesulfonic acid (PFOS) ranges from non-detect to 34.3 ng/L. These data suggest that PFAS-impacted groundwater is discharging to Van Etten Lake. The 34.3 ng/L PFOS concentration exceeds the MDEQ Part 201 Groundwater Surface Water Interface (GSI) criterion of 12 ng/L.

4.2 Au Sable River

Au Sable River temperatures ranged from 74.0 to 75.3º F for the shallow transect (2 ft) and 76.2 to 76.4º F for the deeper transect (6 ft). The average temperature for the shallow and deep transects were 74.4 and 76.3º F, respectively. This inverse in temperature may be due to the groundwater seeps observed along the river bank.

The standard deviation along the shallow transect in the Au Sable River was 0.1º F with 1 and 2 standard deviation lower temperatures of 74.3 and 74.2º F, respectively. The standard deviation for the deep transect was calculated as 0.03º F with 1 and 2 standard deviation lower temperatures of 76.26 and 76.23º F, respectively. The very small standard deviation in temperature measurements for the deep transect suggests that the river is well mixed. **Figure 6, Sheets 4 through 7** show the relationship of the 1 and 2 standard deviation temperature locations for the shallow and deep transects with respect to the PFAS plumes in groundwater. Only 1 area had temperatures that exceeded 2 standard deviations along the shallow transect (**Figure 6, Sheet 6**). Three areas had temperatures that exceeded 2 standard deviations along the deep transect (**Figure 6, Sheets 5 and 7**).

The FLIR photographs indicate a number of potential groundwater seeps along the north river bank as shown in **Figure 7**. **Figure 7** incorporates the FLIR camera photographs with the areas that exceed the 1 and 2 standard deviation locations. Each photograph has a temperature scale showing a range of temperatures with blue being the coolest (approximately 55º F) and red to white being the warmest (73º F and above). The temperature displayed in the upper left corner of each photograph corresponds to the temperature within the target at the center of the photograph.

There appears to be some correlation between the potential seeps identified in the FLIR photographs and the shallow transect data where temperatures exceed 1 standard deviation.

The area where surface water temperatures exceed 2 standard deviations (photographs 36 and 48 on **Figure 7, Sheet 6**) is just downstream of the Three Pipes Drain discharge point.

No soil borings are located adjacent to the river; however, up gradient borings indicate the presence of a medium sand grading to a fine sand at a depth of approximately 33 ft which overlies a clay at a depth of approximately 43 ft, similar to what is observed adjacent to the lake.

Figure 6, Sheets 4 through 7 also show the location and results of 28 surface water samples collected along the Au Sable River shoreline within the area that exceeds 1 and 2 temperature standard deviations. Total PFAS concentrations range from 4.2 to 6,354.2 ng/L in the samples. PFOS ranges from non-detect to 4,600 ng/L. These data suggest that PFAS-impacted groundwater is discharging to the Au Sable River. Six of the surface water sample locations have PFOS concentrations that exceed the MDEQ Part 201 GSI criterion of 12 ng/L.

5. Conclusions

The temperature evaluation of Van Etten Lake and the Au Sable River identifies areas where groundwater may be discharging to the surface water bodies.

Surface water temperatures in 10 areas (nine along the shallow transect and one along the deep transect) in Van Etten Lake are 2 standard deviations less than the average lake temperature. These areas are potential pathways for PFAS to discharge into Van Etten Lake. Additional evidence for groundwater discharge is provided by PFAS surface water data that exceed the GSI criterion for PFOS at one location.

Four areas (one along the shallow transect and three along the deep transect) in the Au Sable River had water temperatures 2 standard deviations less than the average river temperature. The shallow transect anomaly is located directly downstream from a major surface discharge source (Three Pipes Drain) and the deep transect anomalies are less than 0.1º F from the average river temperature. Surface water PFAS data also suggests discharge of PFAS-impacted groundwater based on six surface water sample locations that exceed the PFOS Part 201 GSI criterion.

6. References

Burgis, Winifred A., 1977. Late-Wisconsinan History of Northeastern Lower Michigan. PhD Thesis, University of Michigan.

Larson, Grahame and Randall Schaetzl, 2001. Origin and Evolution of the Great Lakes. Journal of Great Lakes Research, 27(4): 518-546.

Reineck, H.E. and I.B. Singh, 1975, Depositional Sedimentary Environments with reference to terrigenous clastics. Springer-Verlag, Berlin.

Figures

Drawn:	NS	12/16/2016
Approved:	DB	12/16/2016
Project #:	60514613	

Legend

Former Wurtsmith AFB Installation Boundary

N

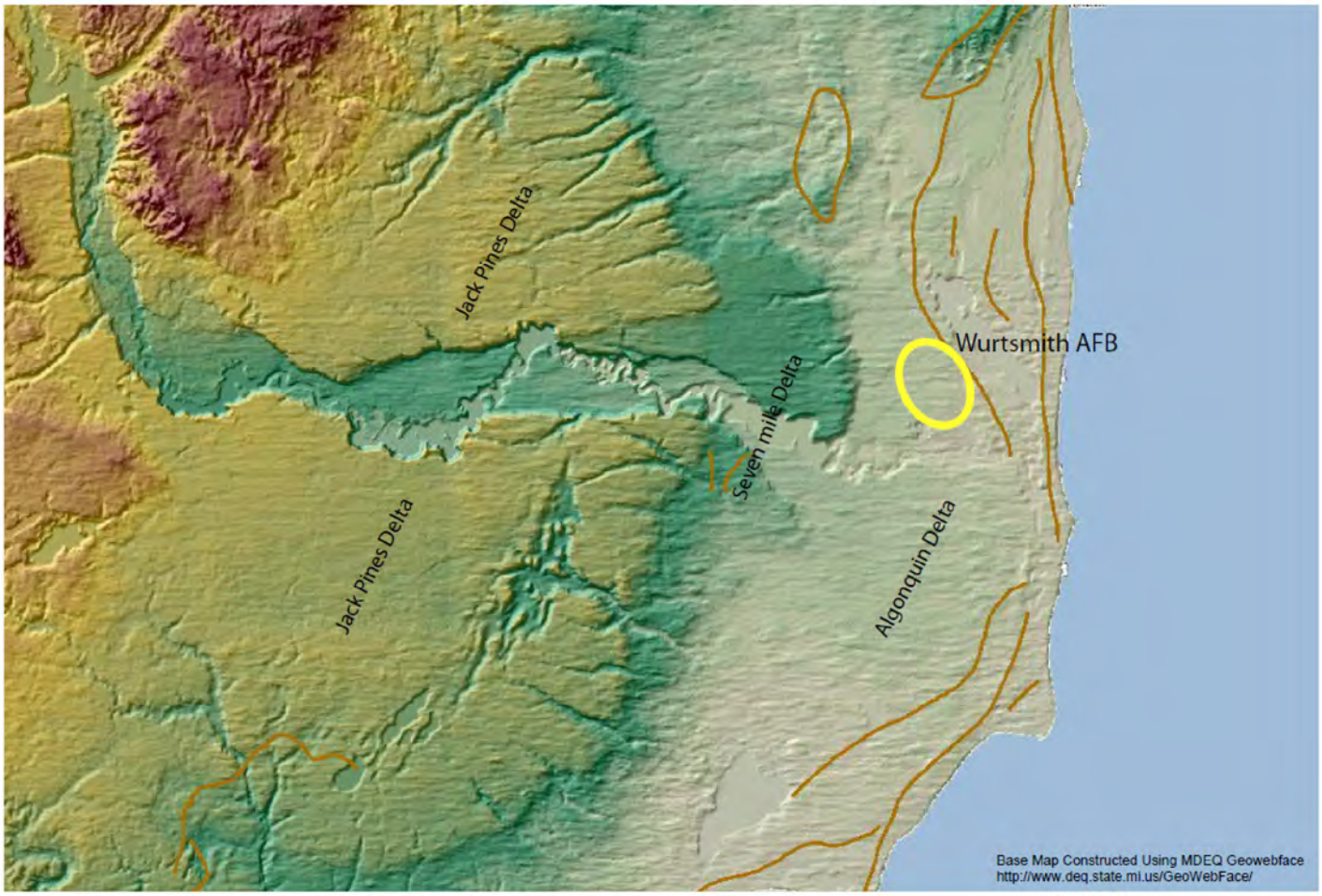
0 2,000 4,000

Feet

FIGURE 1
SITE LAYOUT

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

P:\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Reports\Hydrant_Report\Figure_1_Site_Layout.mxd



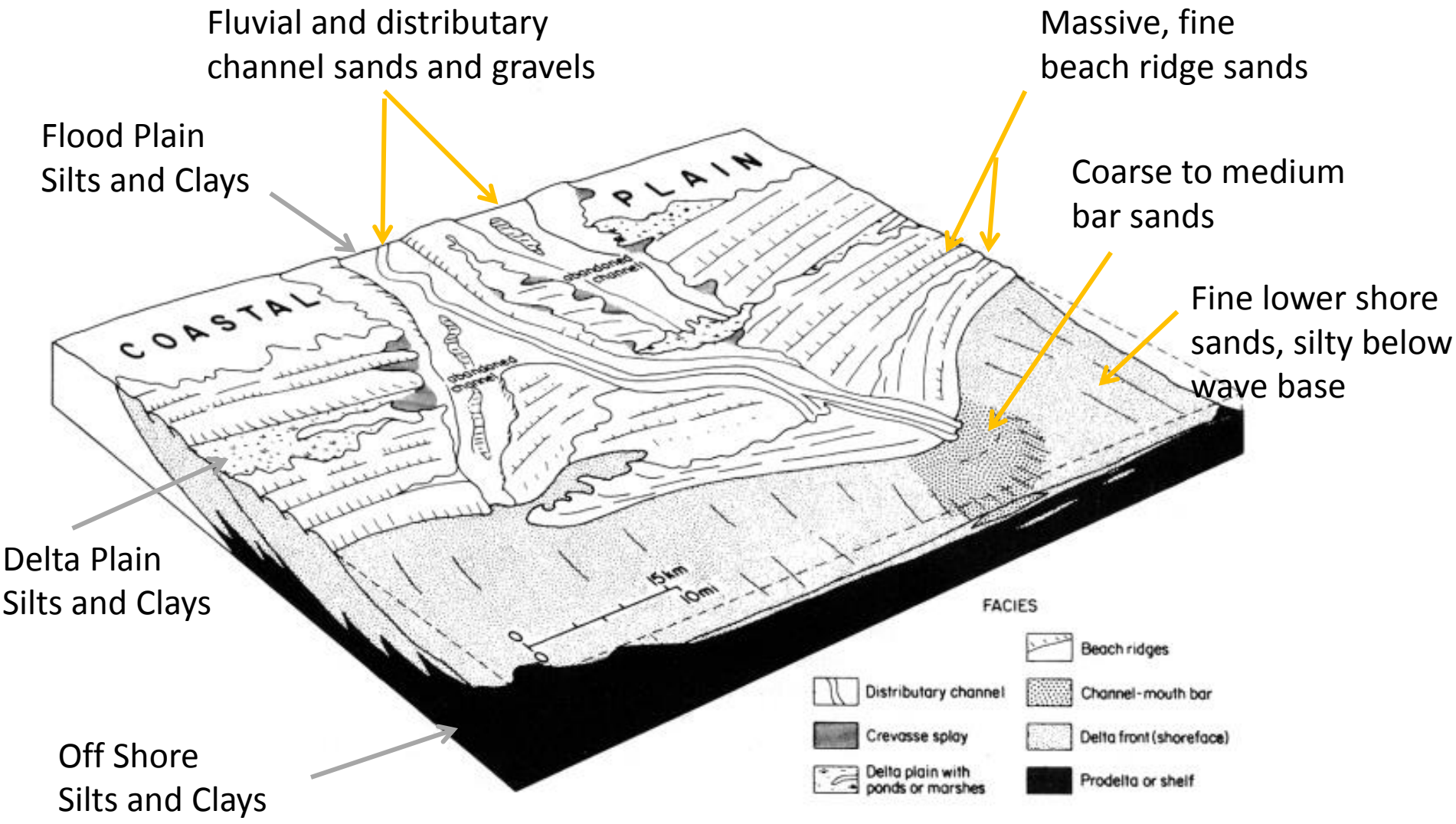
Drawn:	NS	12/15/2016
Approved:	DB	12/15/2016
Project #:	60514613	

FIGURE 2
WAFB RELATIVE TO PALEO
AU SABLE RIVER
DELTA LANDFORMS

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

P:\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Reports\Hydrant_Report\Figure_2_WAFB_Relative_to_Paleo_Au_Sable_River_Delta_Landforms.mxd

Figure 3 -Delta: Facies Components



10/27/2017

Legend

- Approximate Groundwater Divide
- Groundwater Flow Direction
- Groundwater Contour
- Former Wurtsmith AFB Installation Boundary

FIGURE 4

GROUNDWATER FLOW

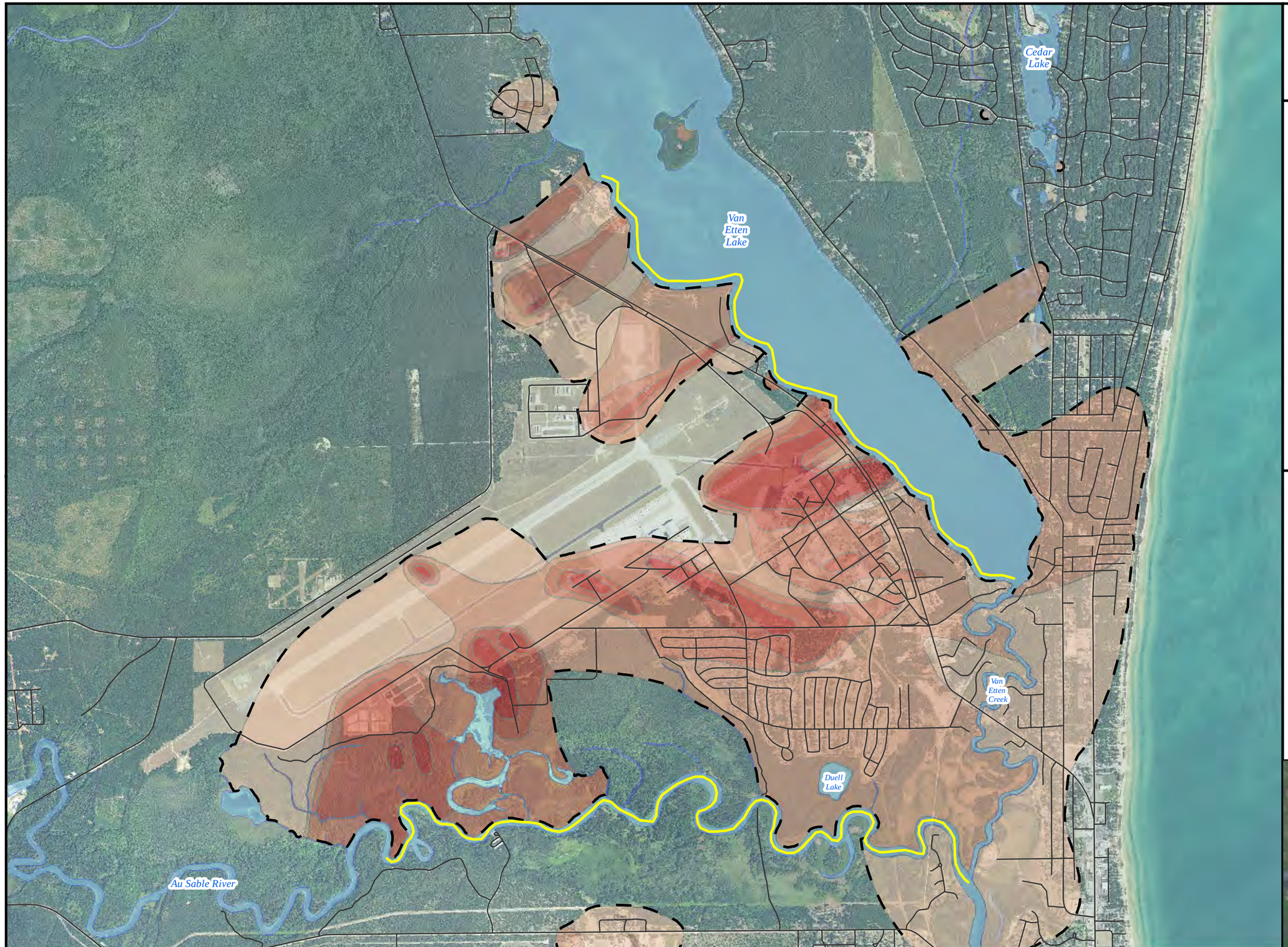
FORMER WURTSMITH AIR FORCE BASE IOSCO COUNTY, MICHIGAN

N

0 1,600 3,200

Feet

Y:\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Reports\temp_study\fig04_Groundwater_elv.mxd



2/16/2018

Legend

- Temperature Survey Extent
- Road

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

FIGURE 5
TEMPERATURE
SURVEY LOCATION

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 2,500 5,000
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Reports\temp_study\Figure_5_location.mxd

2/16/2018

Legend

Surface Water Sample

Groundwater Impact
Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary

Temperature Survey Results

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation

2 & 3

4 & 5

6 & 7

FIGURE 6
TEMPERATURE
SURVEY RESULTS
Sheet 1 of 7

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 2,500 5,000
Feet

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Van Etten 10
10/15/2014
14.7 (1.4 | 1.5)

Van Etten 8
7/31/2014
21.9 (1.9 | 1.6)

Van Etten 7
7/31/2014
23.4 (1.6 | 1.6)

Van Etten - Seep 2
5/14/2012
34.7 (15 | 2.7)

Van Etten - Seep 1
5/14/2012
184.1 (25 | ND)

Van Etten 6
7/31/2014
21.8 (1.8 | 1.8)

Van Etten 5
7/31/2014
28.5 (2.2 | 2)

Stem L4
7/13/2017
18.3 (1.6 | 3.9)

Van Etten 9
11/1/2012
34.3 (ND | 34.3)

Van Etten 4
7/31/2014
31.5 (1.3 | 2.5)

2/16/2018

Legend

Surface Water Sample

Temperature Survey Results

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary

Location
Sample Date
Total PFAS (PFOA | PFOS)

*Measurements in units of PPT
ND = Non-Detect

FIGURE 6
TEMPERATURE SURVEY RESULTS
Sheet 2 of 7

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 600 1,200
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Surface_water\180123_SurfaceWater_Foam_sampling.mxd

Van Etten 10
10/15/2014
14.7 (1.4 | 1.5)

Van Etten 8
7/31/2014
21.9 (1.9 | 1.6)

Van Etten 7
7/31/2014
23.4 (1.6 | 1.6)

Van Etten - Seep 2
5/14/2012
34.7 (15 | 2.7)

Van Etten - Seep 1
5/14/2012
184.1 (25 | ND)

Van Etten 6
7/31/2014
21.8 (1.8 | 1.8)

Van Etten 5
7/31/2014
28.5 (2.2 | 2)

Stem L4
7/13/2017
18.3 (1.6 | 3.9)

Van Etten 9
11/1/2012
34.3 (ND | 34.3)

Van Etten 4
7/31/2014
31.5 (1.3 | 2.5)

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DEQ

2/16/2018

Legend

Surface Water Sample

Temperature Survey Results

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary

Location
Sample Date
Total PFAS (PFOA | PFOS)

*Measurements in units of PPT
ND = Non-Detect

FIGURE 6
TEMPERATURE SURVEY RESULTS
Sheet 3 of 7

FORMER WURTSMITH AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 600 1,200
Feet

DEQ

2/16/2018

Legend

Surface Water Sample

Temperature Survey Results

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary

Location
Sample Date
Total PFAS (PFOA | PFOS)

*Measurements in units of PPT
ND = Non-Detect

Long Marsh Stream 1
10/8/2014
3119.6 (150 | 1800)

Long Marsh Stream 1
7/30/2014
6354.3 (180 | 4600)

WWTP Stream 1 Outlet
7/30/2014
16.8 (1.3 | 3.9)

Au Sable 4
7/30/2014
4.2 (ND | ND)

SW11017
5/12/2016
4.6 (ND | 1.9)

Au Sable 6
7/30/2014
8.7 (0.8 | 1.4)

Au Sable 7
7/30/2014
12.2 (1.1 | 1.7)

Au Sable 8
7/30/2014
26.4 (3.7 | 5.7)

Pond 2 Stream 1
5/22/2012
2625.4 (150 | 1400)

SW11018
5/12/2016
13.9 (ND | 11.3)

Au Sable 9
7/30/2014
52.3 (6.9 | 16)

Pond 3 Stream 1
5/22/2012
3903.9 (480 | 1400)

Au Sable 10
7/30/2014
27.4 (3.4 | 7.4)

Au Sable 11
7/30/2014
23.9 (2.5 | 6.3)

CREEK #2
5/15/2017
90.4 (7.4 | 1.9)

Au Sable 12
7/30/2014
19.8 (2 | 3.9)

FIGURE 6
TEMPERATURE
SURVEY RESULTS
Sheet 4 of 7

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 600 1,200
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Surface_water\180123_SurfaceWater_Foam_sampling.mxd

DEQ

2/16/2018

Legend

Surface Water Sample

Temperature Survey Results

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary

Location
Sample Date
Total PFAS (PFOA | PFOS)

*Measurements in units of PPT
ND = Non-Detect

Long Marsh Stream 1
10/8/2014
3119.6 (150 | 1800)

Long Marsh Stream 1
7/30/2014
6354.3 (180 | 4600)

WWTP Stream 1 Outlet
7/30/2014
16.8 (1.3 | 3.9)

Au Sable 4
7/30/2014
4.2 (ND | ND)

SW11017
5/12/2016
4.6 (ND | 1.9)

Au Sable 6
7/30/2014
8.7 (0.8 | 1.4)

Au Sable 7
7/30/2014
12.2 (1.1 | 1.7)

Au Sable 8
7/30/2014
26.4 (3.7 | 5.7)

Pond 2 Stream 1
5/22/2012
2625.4 (150 | 1400)

SW11018
5/12/2016
13.9 (ND | 11.3)

Au Sable 9
7/30/2014
52.3 (6.9 | 16)

Au Sable 10
7/30/2014
27.4 (3.4 | 7.4)

Pond 3 Stream 1
5/22/2012
3903.9 (480 | 1400)

Au Sable 11
7/30/2014
23.9 (2.5 | 6.3)

CREEK #2
5/15/2017
90.4 (7.4 | 1.9)

Au Sable 12
7/30/2014
19.8 (2 | 3.9)

FIGURE 6
TEMPERATURE SURVEY RESULTS
Sheet 5 of 7

FORMER WURTSMITH AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 600 1,200
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Surface_water\180123_SurfaceWater_Foam_sampling.mxd

2/16/2018

Legend

Surface Water Sample

Temperature Survey Results

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary

Location
Sample Date
Total PFAS (PFOA | PFOS)

*Measurements in units of PPT
ND = Non-Detect

FIGURE 6
TEMPERATURE SURVEY RESULTS
Sheet 6 of 7

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 600 1,200
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Surface_water\180123_SurfaceWater_Foam_sampling.mxd

Au Sable 13
7/30/2014
11.9 (1.4 | 2.3)

Au Sable 14
7/30/2014
16.2 (1.7 | 2.9)

3 Pipes Outfall
4/12/2012
829.6 (55 | 180)

Au Sable 15
7/30/2014
15.3 (1.6 | 2.8)

Au Sable 16
7/30/2014
53.4 (3.7 | 11)

SW14007
5/5/2016
36.4 (1.8 | 27.1)

Consumers Ditch Outlet 1
5/22/2012
2256 (80 | 3)

Au Sable 18
7/30/2014
15.4 (1.7 | 2.9)

Au Sable 20
7/30/2014
15.5 (1.5 | 3)

Au Sable 19
7/30/2014
149.8 (7.1 | 3.6)

Au Sable 17
7/30/2014
15.8 (1.3 | 2.8)

Van Etten Creek 3
10/9/2012
39.9 (5 | 3.5)

DEQ

2/16/2018

Legend

Surface Water Sample

Temperature Survey Results

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary

Location
Sample Date
Total PFAS (PFOA | PFOS)

*Measurements in units of PPT
ND = Non-Detect

FIGURE 6
TEMPERATURE SURVEY RESULTS
Sheet 7 of 7

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 600 1,200
Feet

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2/16/2018

Legend

- Photo Location
- Temperature Survey Extent
- Road

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

Van Etten Lake

Van Etten Creek

Au Sable River

2 3 4 5 6 7 8

FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
SHEET 1 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 2,000 4,000
Feet

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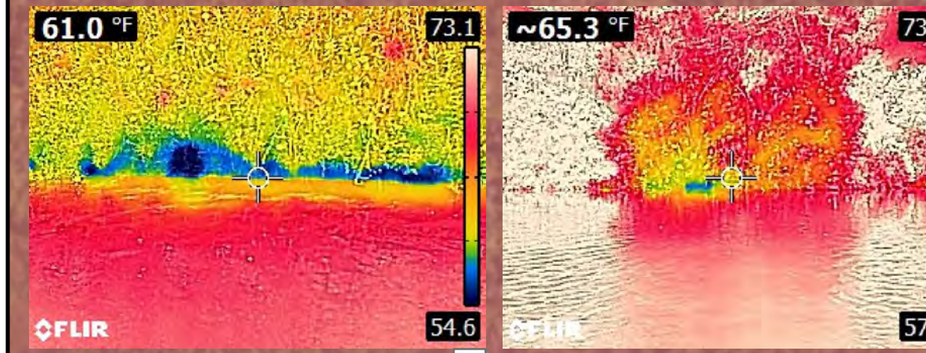

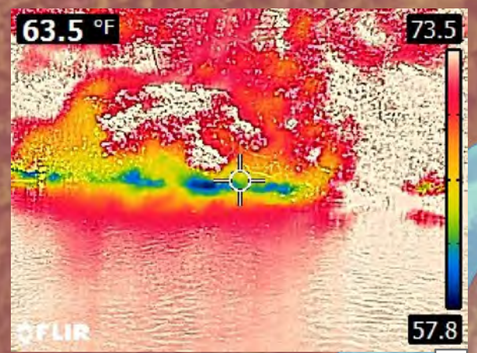

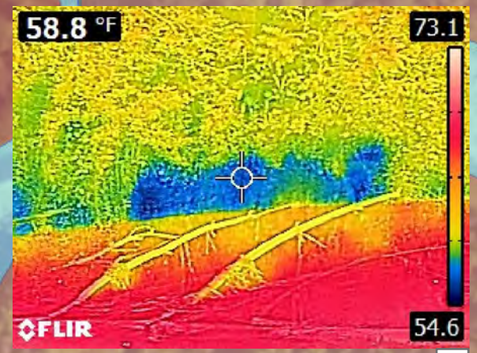

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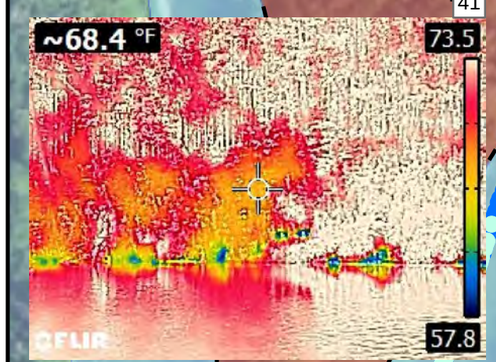

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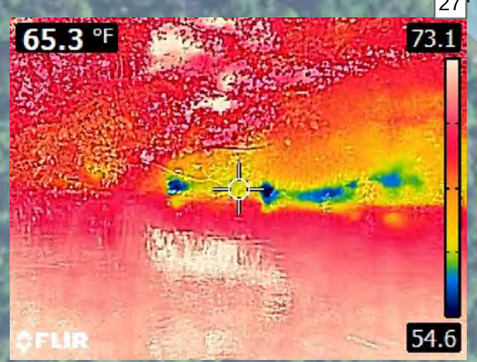

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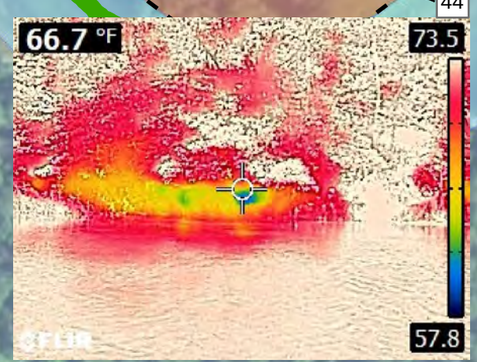

44

DEQ

2/16/2018

Legend

Photo Location

Temperature Survey Results
depth, dev

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation
- Road

Groundwater Impact
Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
Sheet 2 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 210 420
Feet

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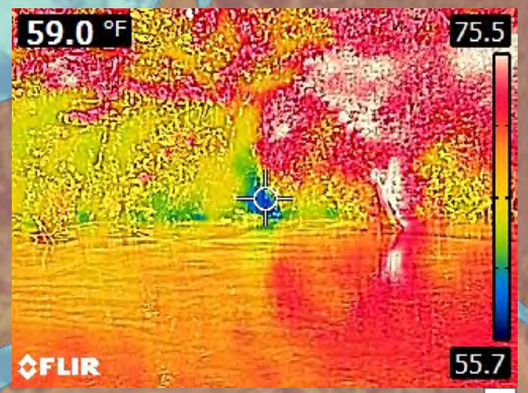

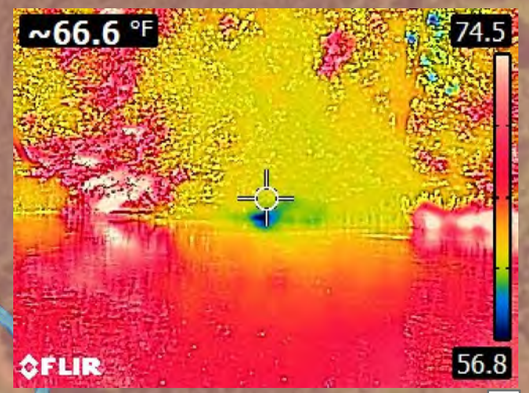

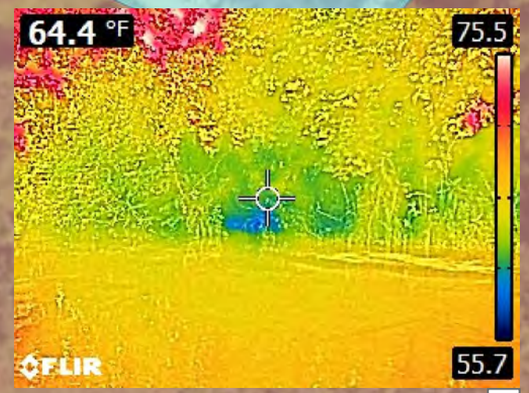

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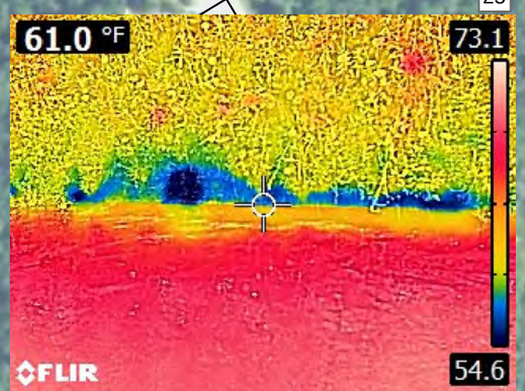

2/16/2018

Legend

Photo Location

Temperature Survey Results

depth, dev

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation
- Road

Groundwater Impact

Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
Sheet 3 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 210 420
Feet

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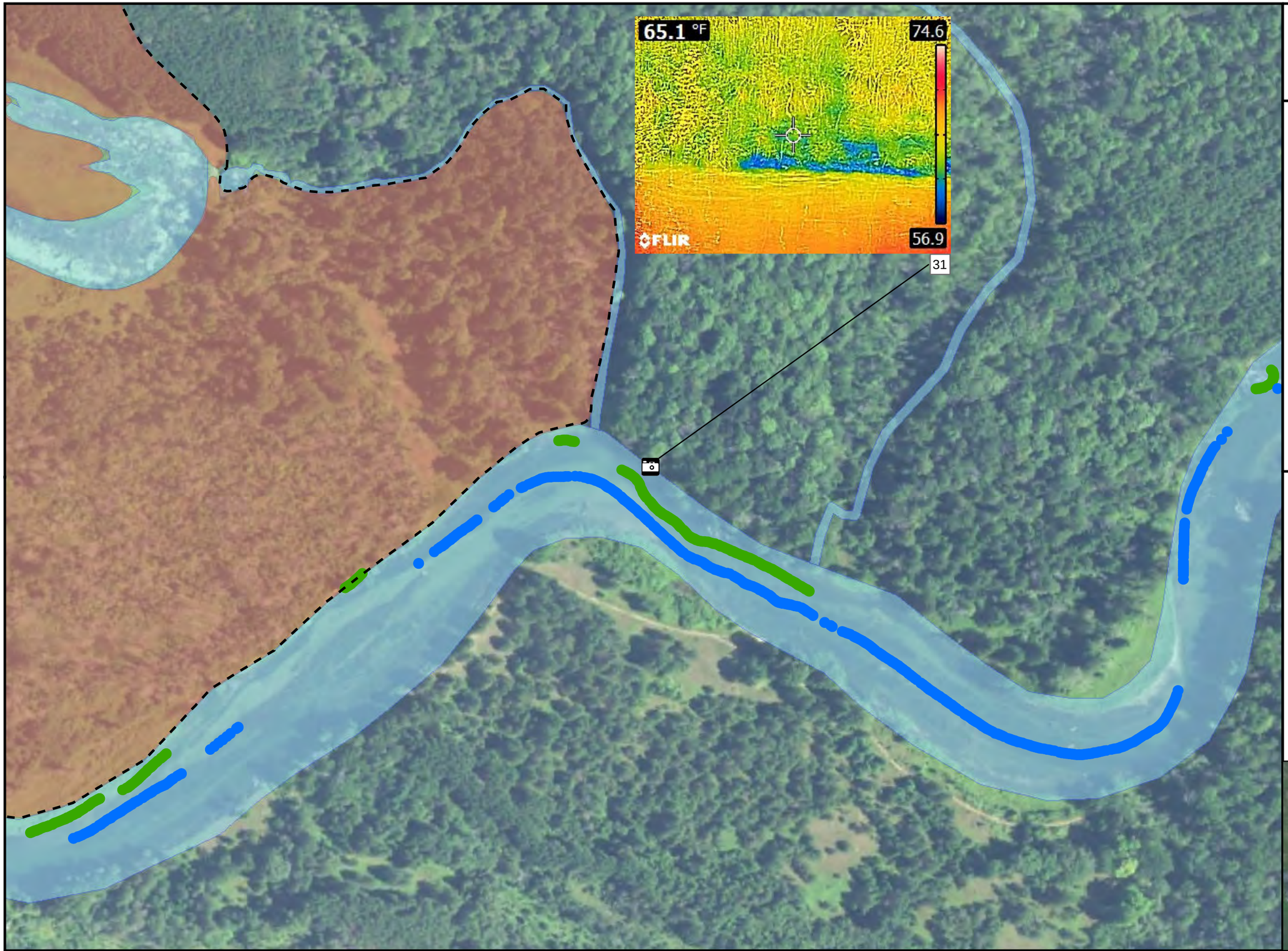


2/16/2018

Legend

Photo Location

Temperature Survey Results
depth, dev

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation
- Road

Groundwater Impact
Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

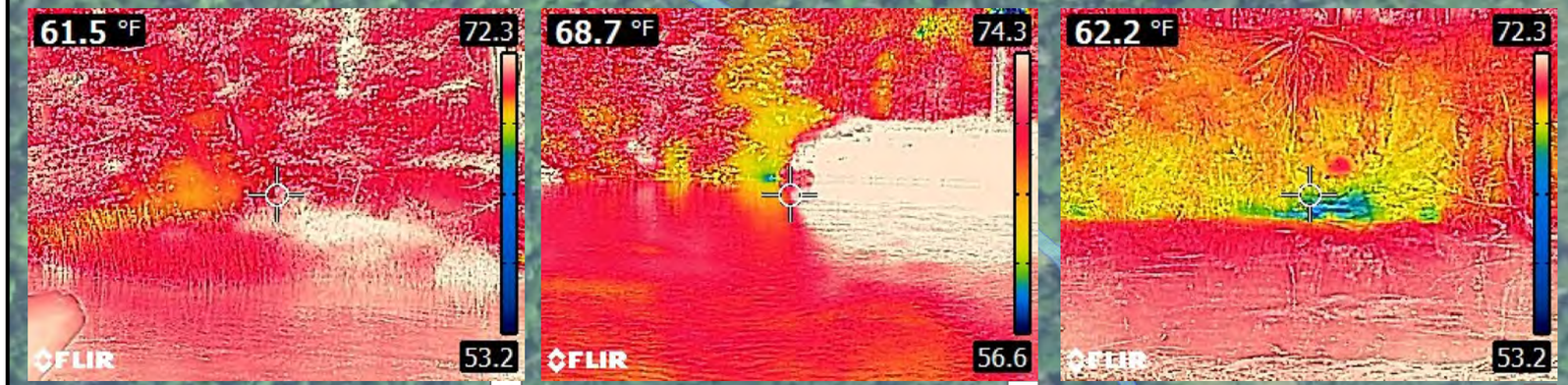
FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
Sheet4 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 210 420
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Reports\temp_study\Figure_7_photo_locations_page4.mxd



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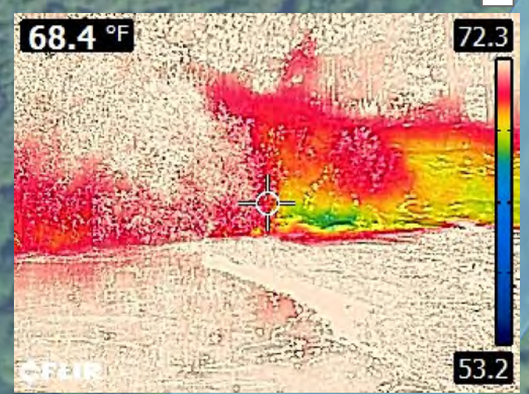

DEQ

2/16/2018

Legend

Photo Location

Temperature Survey Results
depth, dev

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation
- Road

Groundwater Impact
Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
Sheet 5 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 210 420
Feet

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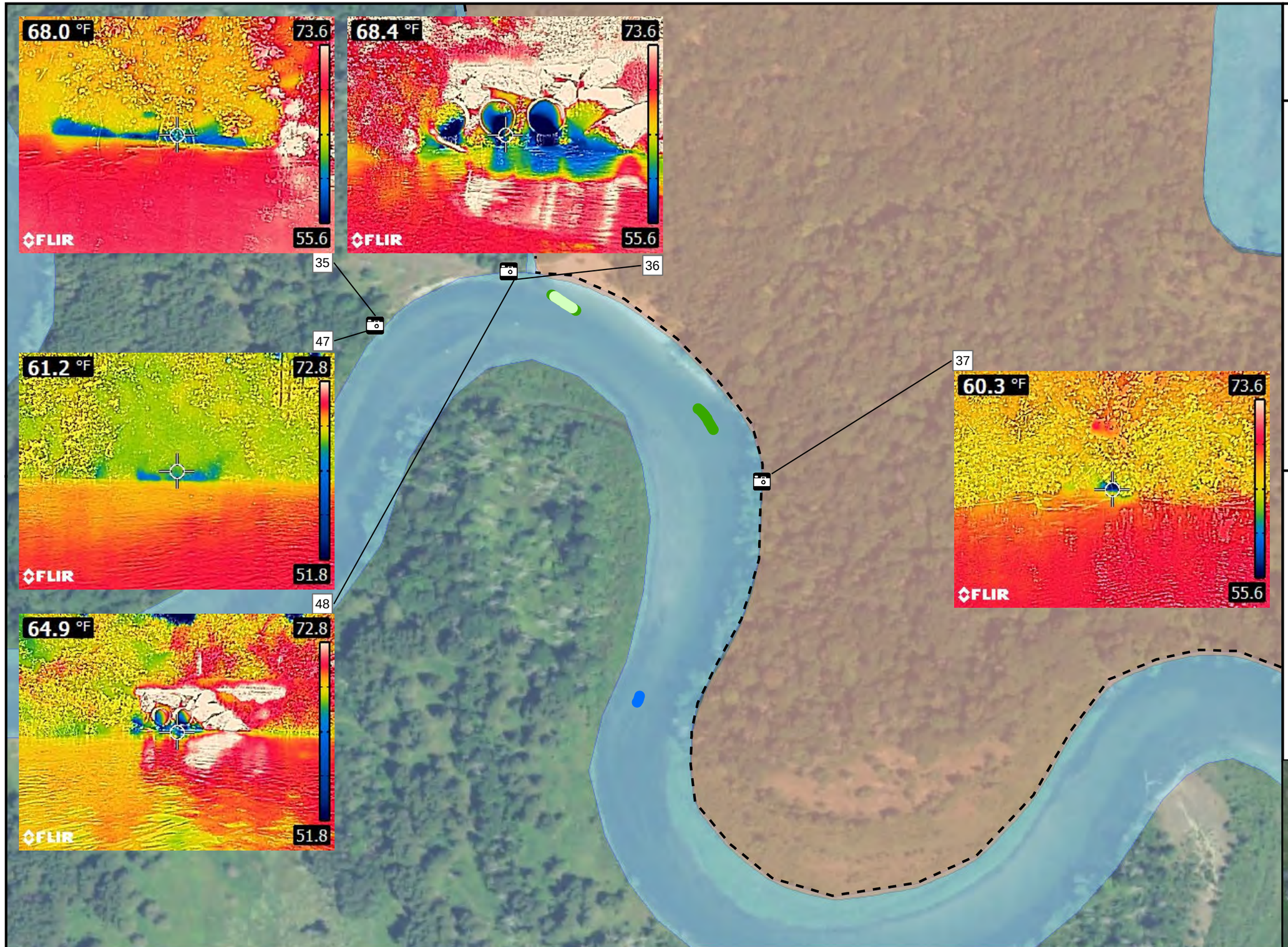


2/16/2018

Legend

Photo Location

Temperature Survey Results
depth, dev

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation
- Road

Groundwater Impact
Total PFAS ppt

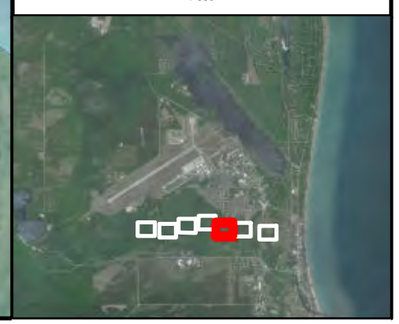
- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
Sheet 6 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 210 420
Feet



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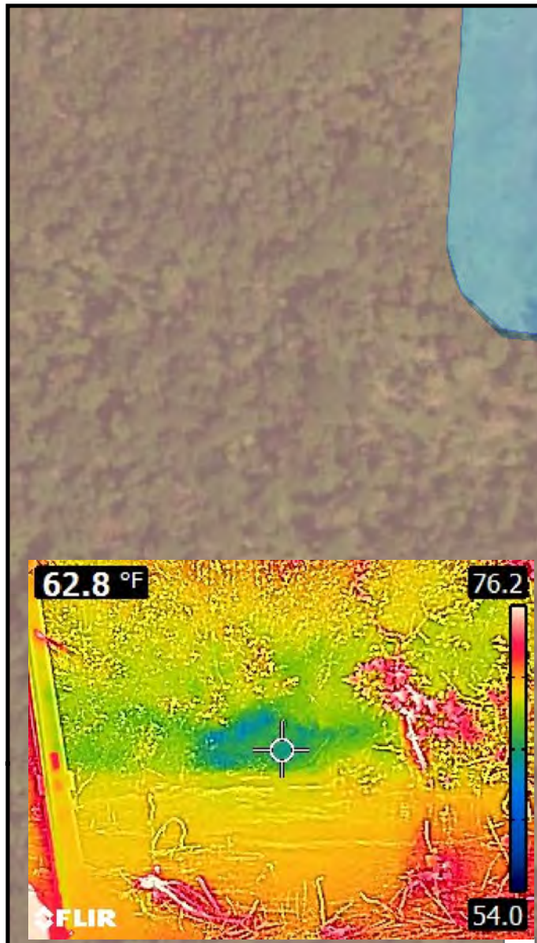
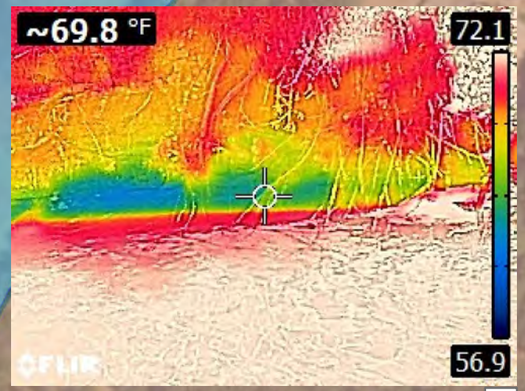




39

38

DEQ

2/16/2018

Legend

Photo Location

Temperature Survey Results
depth, dev

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation
- Road

Groundwater Impact
Total PFAS ppt

- 1 - 50
- 51 - 300
- 301 - 1,000
- 1,000 - 5,000
- > 5,000
- Estimated Boundary
- Surface Water

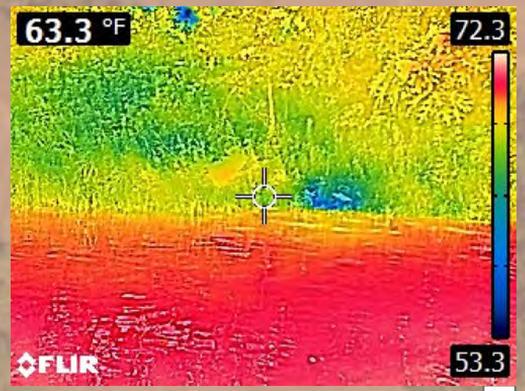
FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
Sheet 7 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

N

0 210 420
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Reports\temp_study\Figure_7_photo_locations_page7.mxd



40

2/16/2018

Legend

Photo Location

Temperature Survey Results
depth, dev

- Deep - 1 Standard Deviation
- Deep - 2 Standard Deviation
- Shallow - 1 Standard Deviation
- Shallow - 2 Standard Deviation
- Road

Groundwater Impact
Total PFAS ppt

- 1 - 50
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- 1,000 - 5,000
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- Estimated Boundary
- Surface Water

FIGURE 7
AU SABLE RIVER
TEMPERATURE
SURVEY RESULTS
Sheet 8 of 8

FORMER WURTSMITH
AIR FORCE BASE
IOSCO COUNTY, MICHIGAN

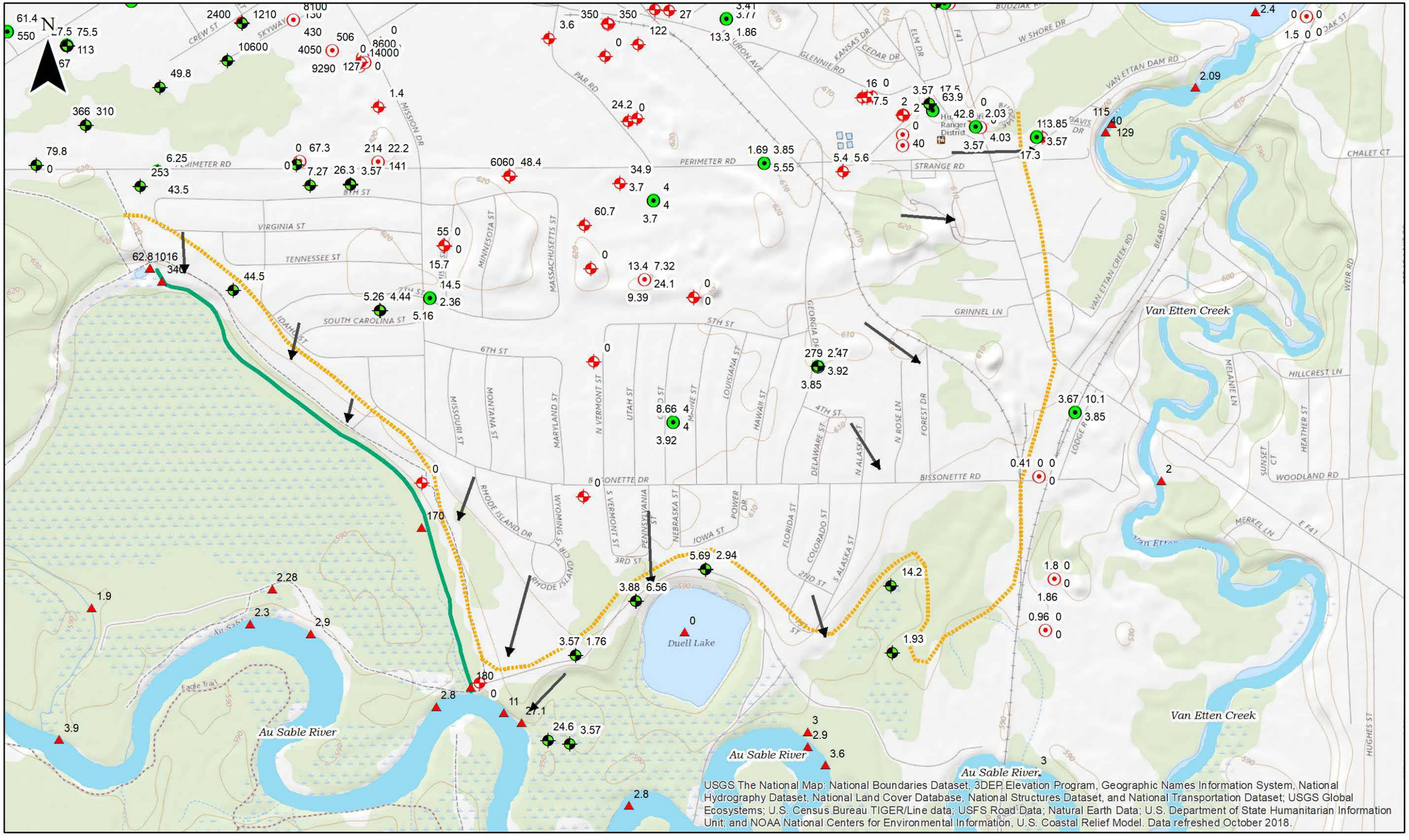
N

0 210 420
Feet

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\Wurtsmith_AFB\Wurtsmith_GIS\MXDs\Reports\temp_study\Figure_7_photo_locations_page8.mxd

3950 Sparks Drive SE
Grand Rapids, Michigan 49546
aecom.com

Attachment 9 – PFOS Concentration in Surface Water



EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

500 250 0 500 1,000 1,500 2,000 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- EGLE Surface Water Sampling Location
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

EGLE

Michigan Department of Environment, Great Lakes, and Energy

www.michigan.gov/degle

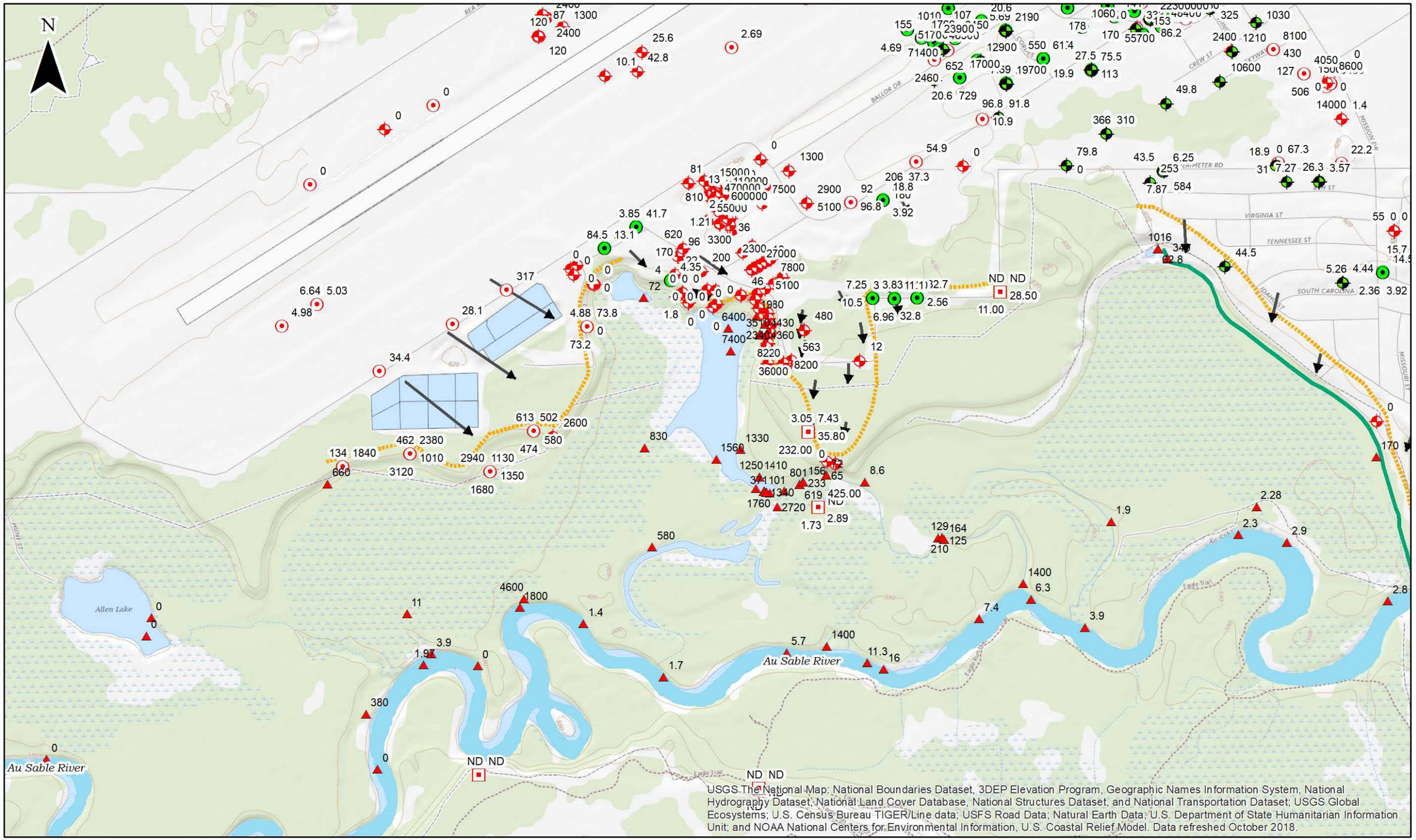
Drawn By: MAB
Date Drawn: 9/6/2019

Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU



EGLE data collected from 2010 to 2017.

Note: Not all temporary well sampling data is shown due to labeling constraints.

500 250 0 500 1,000 1,500 2,000 Feet

Legend

- AFCEC PFAS Sampling Location, Permanent (2018)
- AFCEC PFAS Sampling Location, Temporary (2018)
- EGLE PFAS Sampling Location, Permanent (2010 to 2017)
- EGLE PFAS Sampling Location, Temporary (2010 to 2017)
- MPART PFAS Sampling Location, Temporary (2017 to 2018)
- EGLE Surface Water Sampling Location
- EGLE Interpreted November 2017 Groundwater Flow Direction
- EGLE Estimated PFOS GSI Line
- Three Pipes Drain

Groundwater-Surface Water (GSI) Interface Evaluation of Van Etten Creek and Au Sable River for Perfluorooctane Sulfonate (PFOS)

Site Address: 3950 Arrow Street, Oscoda, MI 48750-2203

EGLE

Michigan Department of Environment, Great Lakes, and Energy

www.michigan.gov/degle

FT02 and Wastewater Treatment Plant - EGLE and AFCEC PFOS Concentration (ppt)

Former Wurtsmith Air Force Base

Oscoda, Michigan

Drawn By: MAB
Date Drawn: 9/6/2019

Datum: See note
Projection: See note

Scale: As shown
Imagery Date: See note

Site EPA ID: MI5570024278
EPA Registry ID: 110006741259

EGLE-RRD-Superfund-GDSMU