AN OVERVIEW OF THE SITE CHARACTERIZATION AND LNAPL MASS REDUCTION

MEMPHIS SHELL LUST SITE

Presented by:

Larry Kinsman

ORIN Technologies, LLC

Client: Environmental Resource Group (ERG)

Wixom, MI

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INTRODUCTION

- Background
- Site
- Risk
- Solution
- Results

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BACKGROUND

- Gasoline Station from 1970s to 2001
- Six USTs totaling approximately 20,000 gallons
- Gasoline, diesel, kerosene, used oil
- Three reported releases in 1998 – 1999
- Multiple investigations and monitoring from 1998 to present

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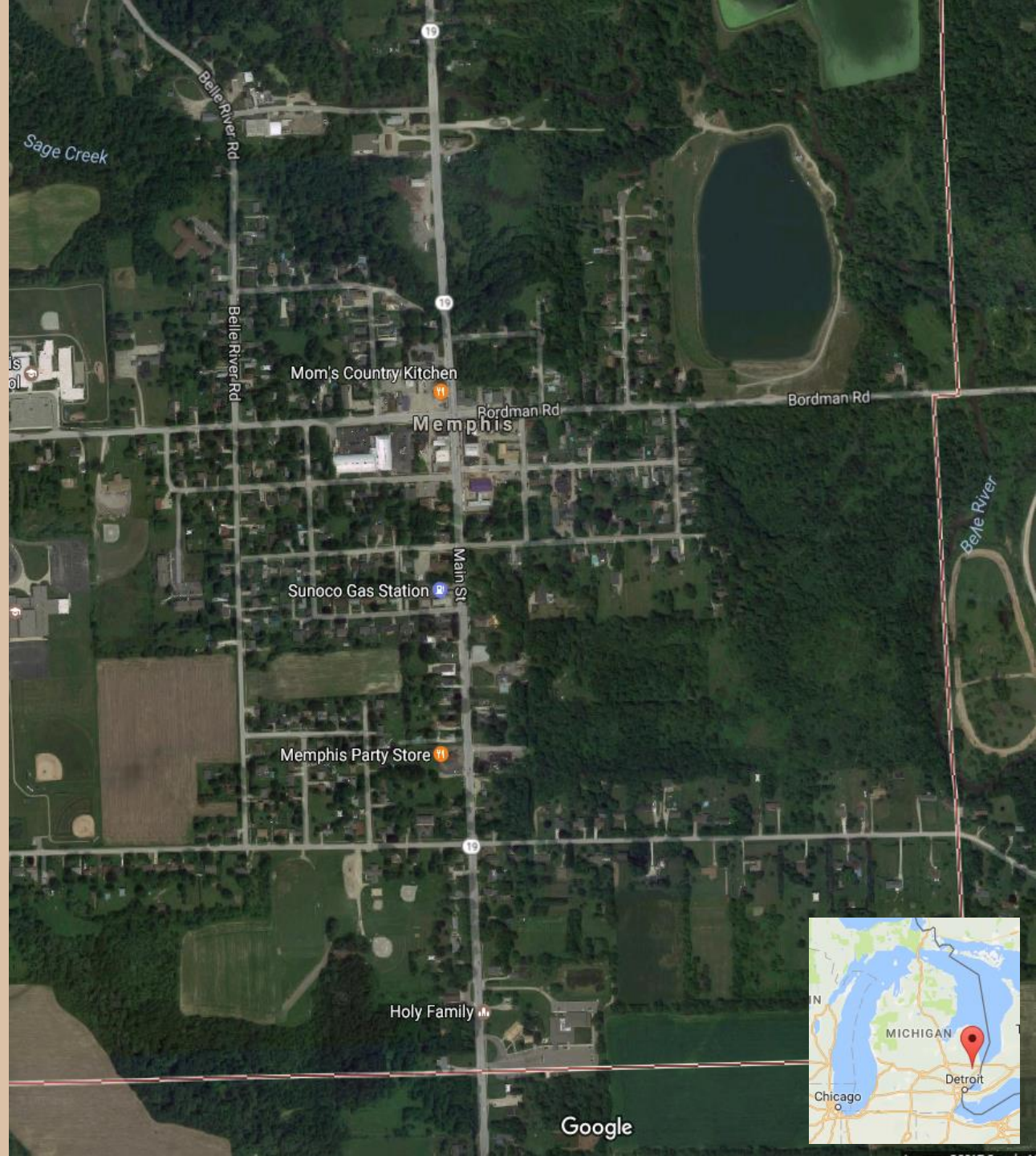
GENERAL SITE SETTING

- Small town in northern Macomb County, MI
- Commercial and residential properties adjacent to Site
- Municipal water supply, but many private wells
- Nearby Belle River (1/2 mile)



ZOOM IN…

- “Site” on west side of M-19 (Main Street)
- Former (and current) UST basin
- Residential dwellings, with basements, on east side of M-19
- Sparse residential and wooded land to east

PRIOR INVESTIGATIONS

- Initial Assessment Report – 1998
  - 15 Monitoring wells (MW-1 thru MW-15 installed on and around Site and on east side of M-19
  - Groundwater at 42 feet bgs, flowing to east
  - Up to 3 feet of LNAPL in 4 of 15 MWs, migrating under M-19
- Additional Investigation – 2000 – 2012
  - Periodic groundwater monitoring
  - LNAPL monitoring (Free Product Reports)

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PRIOR REMEDIAL ACTIONS

- "Enhanced fluid recovery" (a vac truck) 1998 – 2000
  - ~8,000 gallons water/product recovered
- Manual bailing 2000 – 2004
  - Additional ~200 gallons recovered
- No soil remediation
- No groundwater remediation

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REMEDIAL INVESTIGATION

- MDEQ took over in 2013
- Contracted RI/FS
- 10 additional soil boring/monitoring wells (MW-16 thru MW-25) installed on east side of M-19 at residential properties
- LIF for LNAPL Delineation Soil Gas Survey for Vapor Intrusion
- Periodic monitoring

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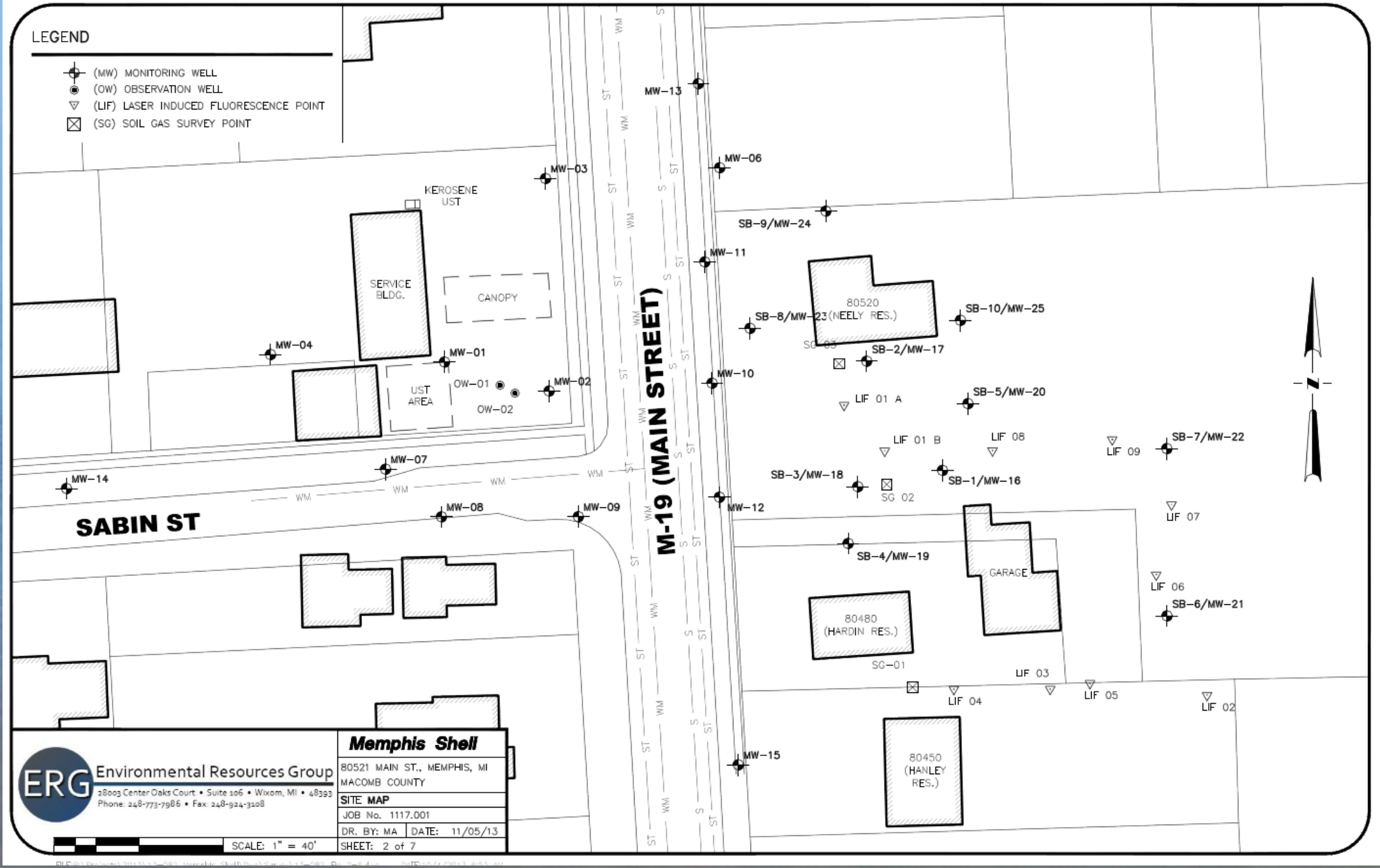
LEGEND
(MW) MONITORING WELL
(OW) OBSERVATION WELL
(LIF) LASER INDUCED FLUORESCENCE POINT
(SG) SOIL GAS SURVEY POINT
MW-13
MW-06
MW-03
KEROSENE UST
SB-9/MW-24
MW-11
SERVICE BLDG.
CANOPY
80520 (NEELY RES.)
SB-8/MW-23
SB-10/MW-25
SG-03
SB-2/MW-17
MW-04
MW-01
MW-10
OW-01
OW-02
UST AREA
MW-02
LIF 01 A
SB-5/MW-20
LIF 01 B
LIF 08
LIF 09
SB-7/MW-22
MW-07
SB-3/MW-18
SB-1/MW-16
MW-14
SG 02
MW-12
LIF 07
SABIN ST
MW-08
MW-09
M-19 (MAIN STREET)
SB-4/MW-19
GARAGE
LIF 06
SB-6/MW-21
80480 (HARDIN RES.)
SG-01
LIF 03
LIF 04
LIF 05
LIF 02
MW-15
80450 (HANLEY RES.)
N
Environmental Resources Group
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Phone: 248-773-7986 • Fax: 248-924-3108
SCALE: 1" = 40'
Memphis Shell
80521 MAIN ST., MEMPHIS, MI
MACOMB COUNTY
SITE MAP
JOB No. 1117.001
DR. BY: MA
DATE: 11/05/13
SHEET: 2 of 7

REMEDIAL INVESTIGATION RESULTS

- Primarily 10 feet of clay overlying fine to medium sand, tight
- Groundwater at 43 to 47 feet bgs
- Flowing to east at ~ 1.7 cm/sec (0.05 ft/day)
- Dissolved petroleum plume extends under and beyond residential properties
- Up to 3 feet of LNAPL in 7 of 25 MWs, including under residential properties
- LIF confirmed extent of LNAPL plume: ~250 feet east to south-east of source
- No vapors detected near residences above screening levels

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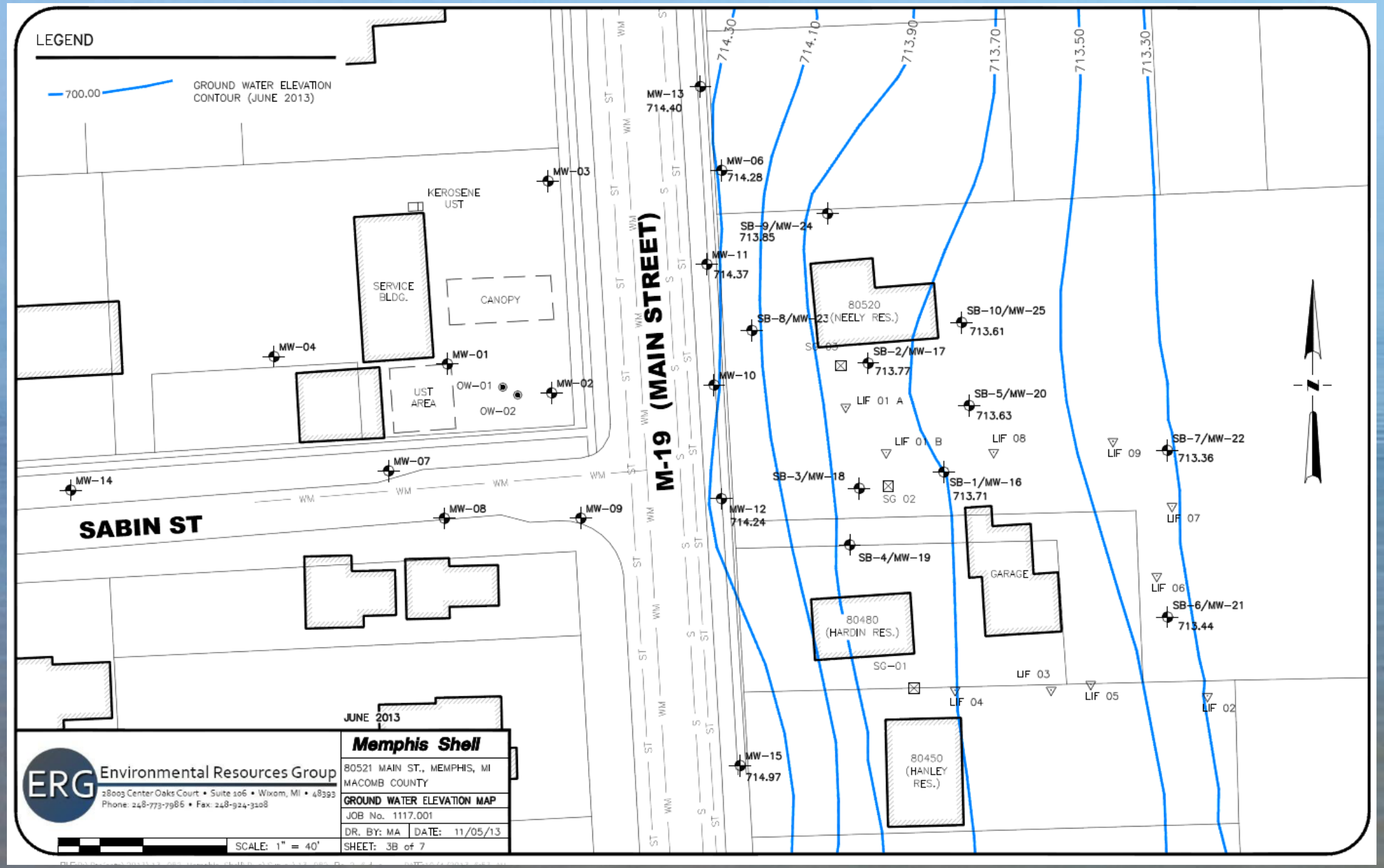
LEGEND
700.00
GROUND WATER ELEVATION CONTOUR (JUNE 2013)
714.30
714.10
713.90
713.70
713.50
713.30
MW-13
714.40
MW-06
714.28
MW-03
KEROSENE UST
SERVICE BLDG.
CANOPY
SB-9/MW-24
713.85
MW-11
714.37
80520 (NEELY RES.)
SB-10/MW-25
713.61
SB-8/MW-23
SG-03
SB-2/MW-17
713.77
MW-04
MW-01
MW-10
UST AREA
OW-01
OW-02
MW-02
LIF 01 A
SB-5/MW-20
713.63
LIF 01 B
LIF 08
LIF 09
SB-7/MW-22
713.36
M-19 (MAIN STREET)
MW-07
MW-14
SB-3/MW-18
SG 02
SB-1/MW-16
713.71
MW-12
714.24
LIF 07
SABIN ST
MW-08
MW-09
SB-4/MW-19
GARAGE
LIF 06
SB-6/MW-21
713.44
80480 (HARDIN RES.)
SG-01
LIF 03
LIF 04
LIF 05
LIF 02
80450 (HANLEY RES.)
MW-15
714.97
N
JUNE 2013
ERG
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GROUND WATER ELEVATION MAP
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DATE: 11/05/13
SHEET: 3B of 7

OCCURRENCE OF LNAPL

- MW’s 01, 02, and OW’s 01, 02 on west side
- MW’s 10, 12, **18,** 19, 23 on east side
- Up to 2.5 feet thick in wells 10 and 18
- Migrating

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CONCEPTUAL SITE MODEL

- CSM as developed in 2013
- Identifies areas of greatest risk to be addressed

- CONTAMINANT SOURCES
  - USTs and associated piping located on the Site
  - Grossly contaminated soils in the area of the USTs
  - LNAPL plume
  - Dissolved plume
- POTENTIAL RECEPTORS
  - On-site subsurface construction workers
  - Three residential properties located east of the site
  - Additional downgradient residences
  - Water supply wells approximately 0.5 mile east of the Site
  - Belle River, located approximately 0.75 mile east of the site.
- POTENTIAL EXPOSURE PATHWAYS
  - Direct Contact of contaminated and potential saturated soils on-site
  - Drinking Water at off-site water supply wells
  - Vapor Intrusion into nearby residential
  - GSI from dissolved and LNAPL plume migrating towards Belle River

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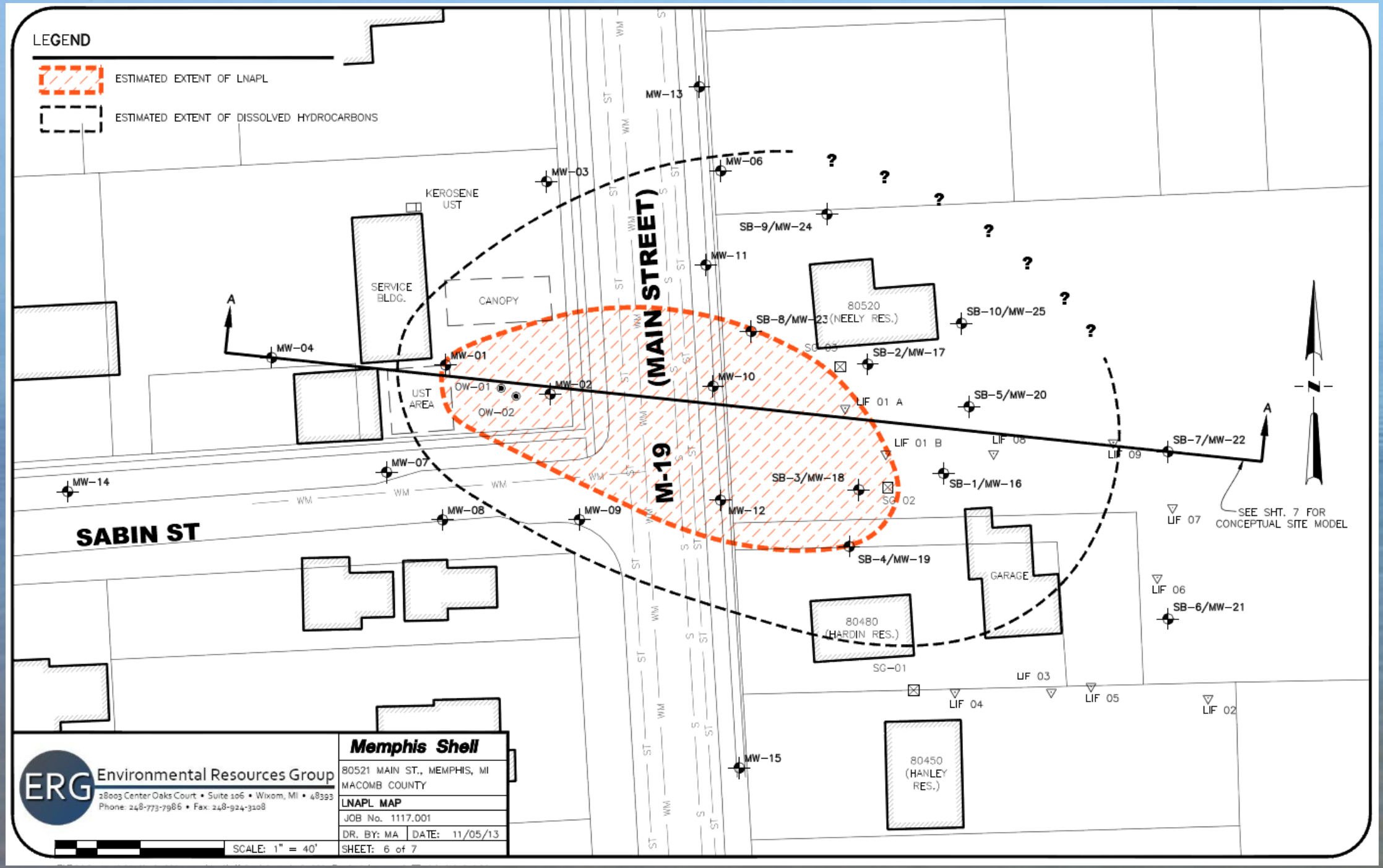

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SCALE: 1" = 40'

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LNAPL MAP

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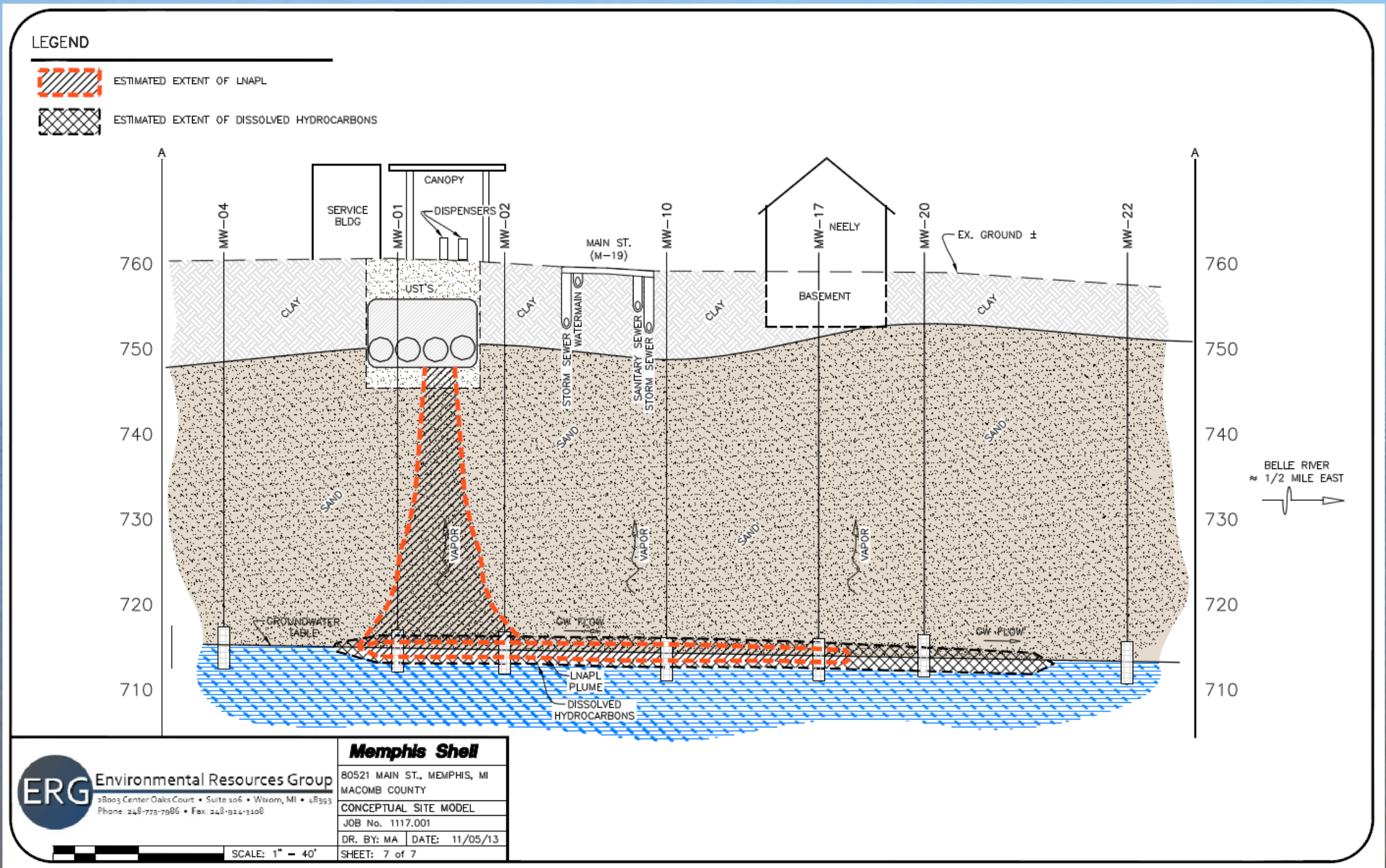
DR. BY: MA | DATE: 11/05/13

SHEET: 6 of 7


LEGEND
ESTIMATED EXTENT OF LNAPL
ESTIMATED EXTENT OF DISSOLVED HYDROCARBONS
A
A
MW-04
SERVICE BLDG
MW-01
CANOPY
DISPENSERS
MW-02
MAIN ST. (M-19)
MW-10
MW-17
NEELY
MW-20
MW-22
EX. GROUND ±
760
750
740
730
720
710
CLAY
UST'S
STORM SEWER
WATERMAIN
SANITARY SEWER
STORM SEWER
BASEMENT
SAND
VAPOR
GROUNDWATER TABLE
GW FLOW
LNAPL PLUME
DISSOLVED HYDROCARBONS
BELLE RIVER
≈ 1/2 MILE EAST
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CONCEPTUAL SITE MODEL
JOB No. 1117.001
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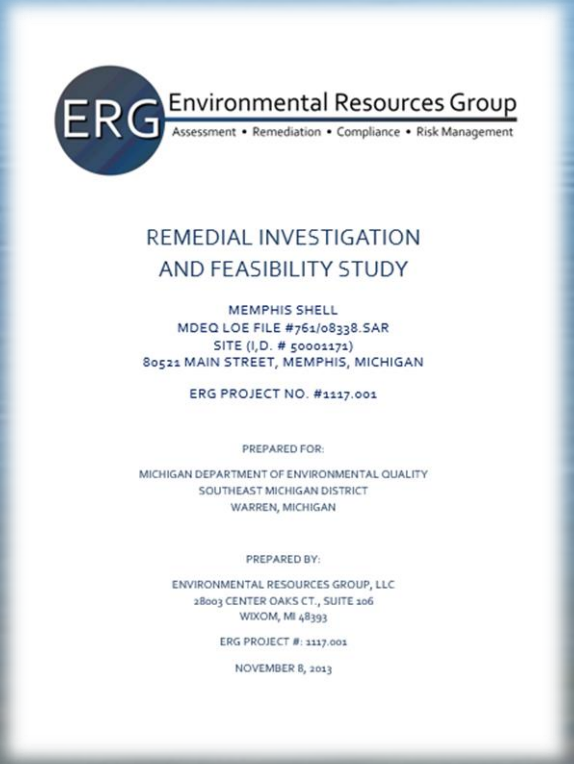
SCALE: 1" = 40'
SHEET: 7 of 7

RISK SUMMARY

- Primary: Exposure risks from migrating LNAPL
- Primary: Exposure risks from existing USTs and grossly contaminated soil
- Secondary: Risks from soil and dissolved contamination

FEASIBILITY STUDY

- Evaluated highest risk alternatives, not Site closure (yet)
- UST removal
- Source soil removal
- LNAPL destruction using In-Situ Chemical Oxidation (ISCO)



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Assessment • Remediation • Compliance • Risk Management

REMEDIAL INVESTIGATION
AND FEASIBILITY STUDY

MEMPHIS SHELL
MDEQ LOE FILE #761/08338.SAR
SITE (I.D. # 50001171)
80521 MAIN STREET, MEMPHIS, MICHIGAN

ERG PROJECT NO. #1117.001

PREPARED FOR:

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
SOUTHEAST MICHIGAN DISTRICT
WARREN, MICHIGAN

PREPARED BY:

ENVIRONMENTAL RESOURCES GROUP, LLC
28003 CENTER OAKS CT., SUITE 106
WIXOM, MI 48393

ERG PROJECT #: 1117.001

NOVEMBER 8, 2013

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UST AND SOIL REMOVAL

- July 2014
- Three fuel and one used oil
- Tanks pitted and holes
- Removal coincided with UST replacement
- 200 tons of soil removed

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ISCO LNAPL DESTRUCTION

- The most expedient and cost effective method for this Site
- Pilot study in 2015
- Two events conducted in March and August 2016

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ISCO TECHNOLOGY

- Injection of Klozur - sodium persulfate catalized with sodium hydroxide
- Capable of oxidizing a broad range of recalcitrant compounds and LNAPL
- Injected using direct push technology (DPT) and/or injection wells, with simultaneous extraction from nearby wells
- “Pulls” chemicals through the formation

$$S_2O_8^{-2} + Fe^{+2} \rightarrow SO_4^{-\bullet} + Fe^{+3} + SO_4^{-2} \qquad E^\circ \cong 2.6v$$

$$2S_2O_8^{-2} + NaOH \rightarrow H^+ + 2SO_4^{-\bullet} + 2SO_4^{-2} + \tfrac{1}{2}O_2 + Na^+$$

$$2S_2O_8^{-2} + CaO_2 + 2H_2O \rightarrow 2SO_4^{-\bullet} + 2SO_4^{-2} + O_2 + Ca(OH)_2 + 2H^+$$

$$2S_2O_8^{-2} + 4H_2O_2 \rightarrow 2H_2SO_4 + 2SO_4^{-\bullet} + 2H_2O + 3O_2$$

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ISCO PILOT STUDY

- August 2015
- Injection at five DPT points, 35 to 48 feet bgs
- Extraction at one well
- Fail: three DPT points with very low volume acceptance, two with refusal
- Permanent well (MW-26) was used as an injection point as a trial
- Success: ~900 gallons into well and 500 ppm persulfate observed at extraction well 40 feet away
- Change in original strategy to using permanent injection points

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ISCO INJECTION #1

- Installation of 20 injection wells (2”), December 2015
- Injection at 6 points on west side, then 14 points on east side
- About 3 days of injection, March 2016
- Total of ~ 9,000 gallons injected
- Strategic extraction at 10 points
- Periodic checks for 2 months showed major reduction in LNAPL
- Substantial LNAPL remained, second round recommended

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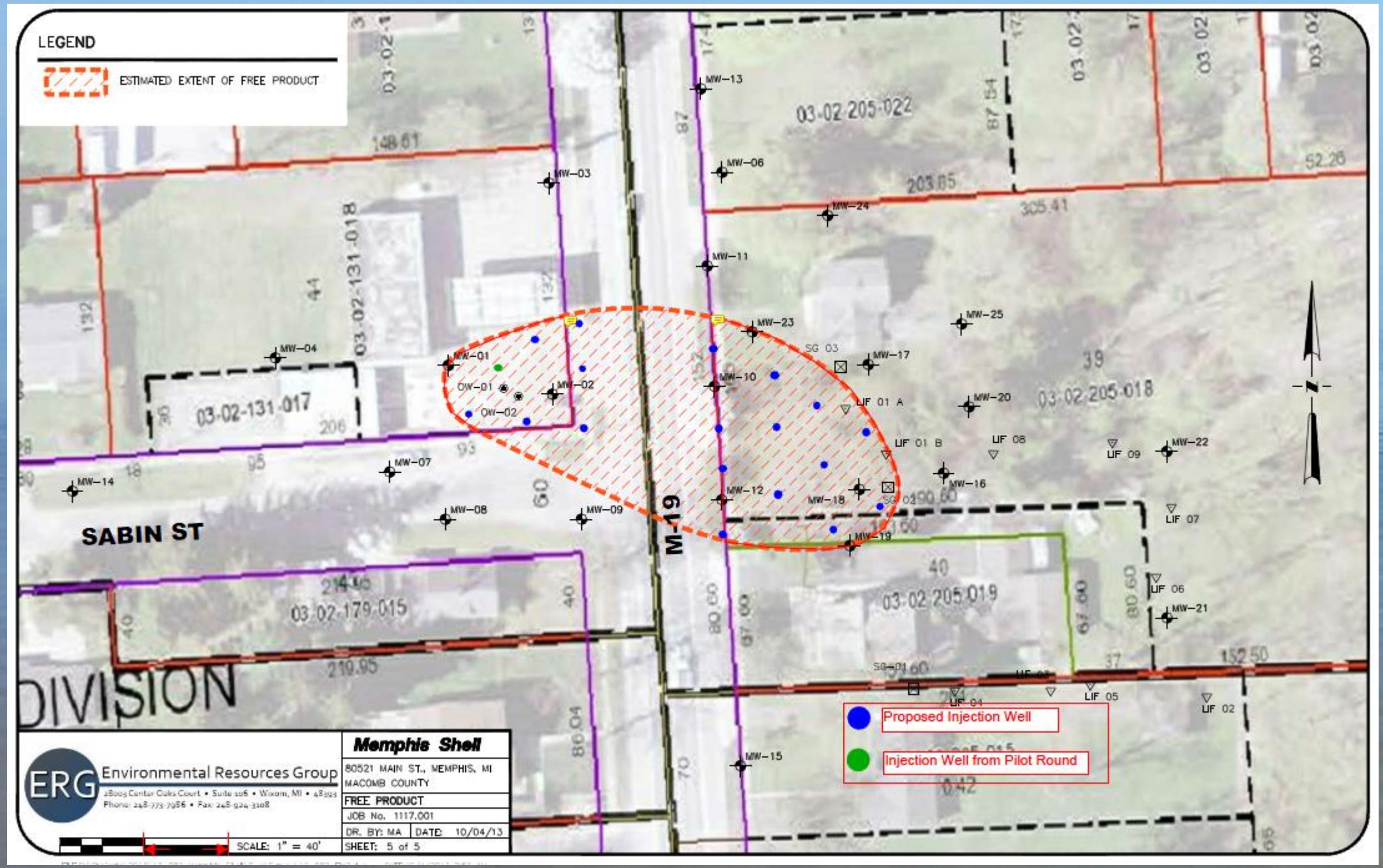
LEGEND
ESTIMATED EXTENT OF FREE PRODUCT
SABIN ST
M-19
DIVISION
03-02-131-017
03-02-131-018
03-02-205-022
03-02-205-018
03-02-205-019
03-02-179-015
MW-01
MW-02
MW-03
MW-04
MW-06
MW-07
MW-08
MW-09
MW-10
MW-11
MW-12
MW-13
MW-14
MW-15
MW-16
MW-17
MW-18
MW-19
MW-20
MW-21
MW-22
MW-23
MW-24
MW-25
OW-01
OW-02
LIF 01 A
LIF 01 B
LIF 02
LIF 04
LIF 05
LIF 06
LIF 07
LIF 08
LIF 09
SG 03
Proposed Injection Well
Injection Well from Pilot Round
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MACOMB COUNTY
FREE PRODUCT
JOB No. 1117.001
DR. BY: MA
DATE: 10/04/13
SCALE: 1" = 40'
SHEET: 5 of 5

ISCO INJECTION #2

- Repeat of previous Injection Event
- About three days of injection, August 2016
- Total of ~ 9,500 gallons injected
- Results very favorable

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CHEMICAL APPLICATION

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TYPICAL INJECTION POINT

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VAC TRUCK EXTRACTION

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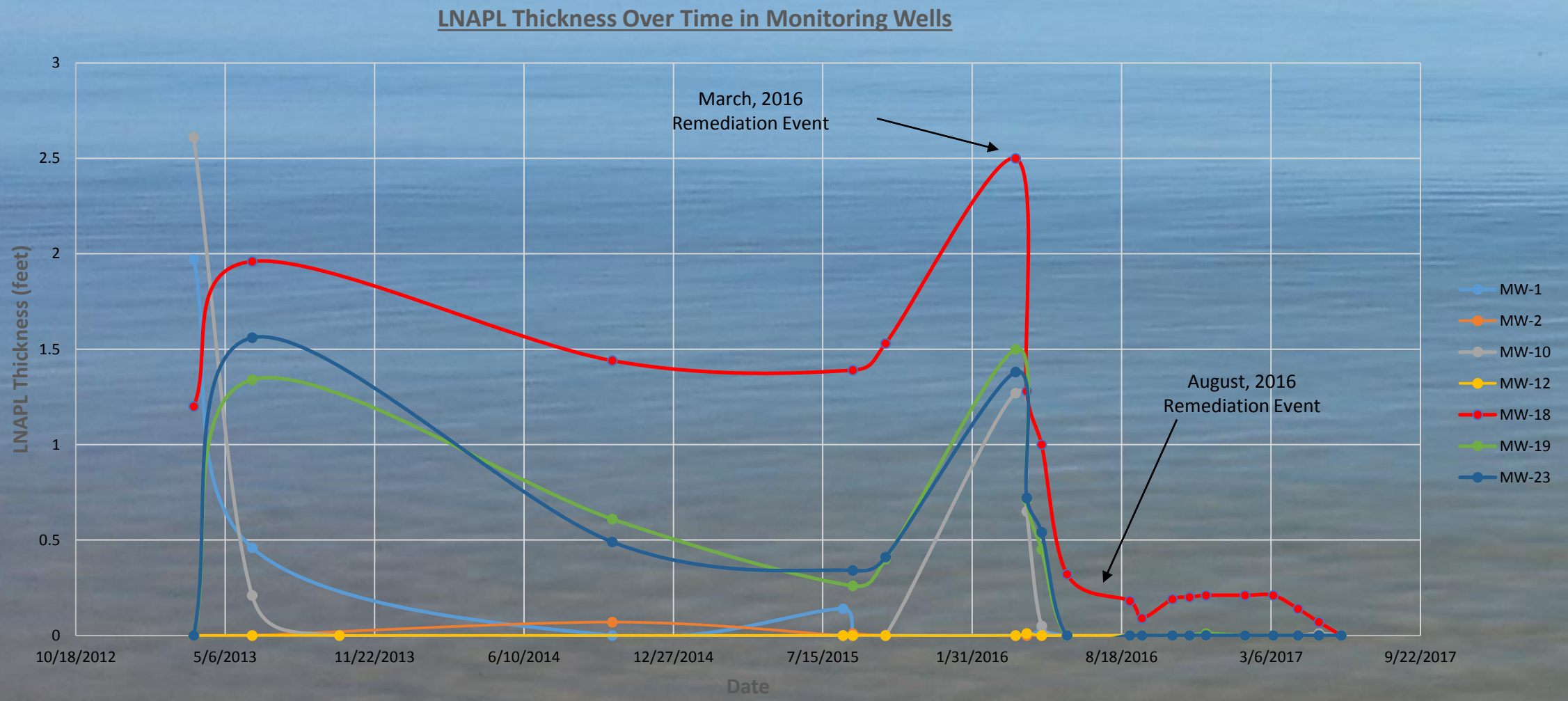
RESULTS 1.5 YEARS AFTER INITIAL EVENT



Well ID	Date	Depth to Water (ft.)	DEPTH TO LNAPL (ft.)	LNAPL THICKNESS (ft.)
MW-01	3/25/2013	--	43.06	1.97
	6/11/2013	43.62	43.16	0.46
	10/7/2015	42.95		
	3/29/2016	44.1	43.40	0.70
	4/13/2016	43.54	--	--
	5/3/2016	43.23	43.21	0.02
	6/6/2016	42.96	--	--
	7/9/2016	42.77	--	--
	8/10/2016	42.69	--	--
	8/29/2016	42.69	--	--
	9/14/2016	42.71	--	--
	10/25/2016	42.84	--	--
	11/17/2016	42.95	--	--
	12/9/2016	43.02	--	--
	1/30/2017	43.10	--	--
	3/9/2017	43.09	--	--
	4/11/2017	42.96	--	--
	5/6/2017	42.47	--	--

Well ID	Date	Depth to Water (ft.)	DEPTH TO LNAPL (ft.)	LNAPL THICKNESS (ft.)
MW-10	3/25/2013	47.1	44.49	2.61
	6/11/2013	45.56	44.35	1.21
	10/6/2014	44.27	--	--
	8/24/2015	44.32	--	--
	10/7/2015	44.35	--	--
	3/29/2016	45.88	44.61	1.27
	4/13/2016	45.17	44.52	0.65
	5/3/2016	44.47	44.42	0.05
	6/6/2016	44.22	--	--
	7/9/2016	44.03	--	--
	8/10/2016	44.01	--	--
	8/29/2016	43.97	--	--
	9/14/2016	44.03	--	--
	10/25/2016	44.25	--	--
	11/17/2016	44.31	--	--
	12/9/2016	44.35	--	--
	1/30/2017	44.38	--	--
	3/9/2017	44.33	--	--
	4/11/2017	44.23	--	--
	5/6/2017	43.69	--	--

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Well ID	Date	Depth to Water (ft.)	DEPTH TO LNAPL (ft.)	LNAPL THICKNESS (ft.)
MW-23	6/11/2013	45.57	44.01	1.56
	10/6/2014	44.43	43.94	0.49
	8/24/2015	44.36	44.02	0.34
	10/7/2015	44.46	44.05	0.41
	3/29/2016	45.70	44.32	1.38
	4/13/2016	44.98	44.26	0.72
	5/3/2016	44.66	44.12	0.54
	6/6/2016	43.99	--	--
	7/9/2016	43.80	--	--
	8/10/2016	43.78	--	--
	8/29/2016	43.79	--	--
	9/14/2016	43.02	--	--
	10/25/2016	46.27	--	--
	11/17/2016	44.09	--	--
	12/9/2016	44.19	--	--
	1/30/2017	44.13	--	--
	3/9/2017	44.11	--	--
	4/11/2017	43.98	--	--
	5/6/2017	43.45	--	--

Well ID	Date	Depth to Water (ft.)	DEPTH TO LNAPL (ft.)	LNAPL THICKNESS (ft.)
MW-19	6/11/2013	46.96	45.62	1.34
	10/6/2014	46.08	45.47	0.61
	8/24/2015	45.83	45.57	0.26
	10/7/2015	46.00	45.60	0.40
	3/29/2016	47.16	bailed	1.50
	4/13/2016	46.63	45.92	0.71
	5/3/2016	46.10	45.65	0.45
	6/6/2016	45.50	--	--
	7/9/2016	48.31	--	--
	8/10/2016	45.35	--	--
	8/29/2016	45.30	--	--
	9/14/2016	45.37	--	--
	10/25/2016	45.56	--	--
	11/17/2016	44.61	--	--
	12/9/2016	45.71	45.7	0.01
	1/30/2017	45.69	--	--
	3/9/2017	45.64	--	--
	4/11/2017	45.52	--	--
	5/6/2017	44.95	--	--

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MW-18 LNAPL REMOVED

Well ID	Date	Depth to Water (ft.)	DEPTH TO LNAPL (ft.)	LNAPL THICKNESS (ft.)
MW-18	3/25/2013	46.57	45.37	1.2
	6/11/2013	46.80	44.84	1.96
	10/6/2014	46.11	44.67	1.44
	8/24/2015	46.11	44.72	1.39
	10/7/2015	46.28	44.75	1.53
	3/29/2016	47.15	bailed	2.50
	4/13/2016	46.31	45.03	1.28
	5/3/2016	45.92	44.92	1.00
	6/6/2016	45.14	44.82	0.32
	7/9/2016	44.82	44.66	0.16
	8/10/2016	44.81	44.65	0.16
	8/29/2016	44.83	44.65	0.18
	9/14/2016	44.81	44.72	0.09
	10/25/2016	45.10	44.91	0.19
	11/17/2016	45.15	44.95	0.20
	12/9/2016	45.26	45.05	0.21
	1/30/2017	45.22	45.01	0.21
	3/9/2017	45.18	44.97	0.21
	4/11/2017	45.02	44.88	0.14
	5/6/2017	44.32	--	--

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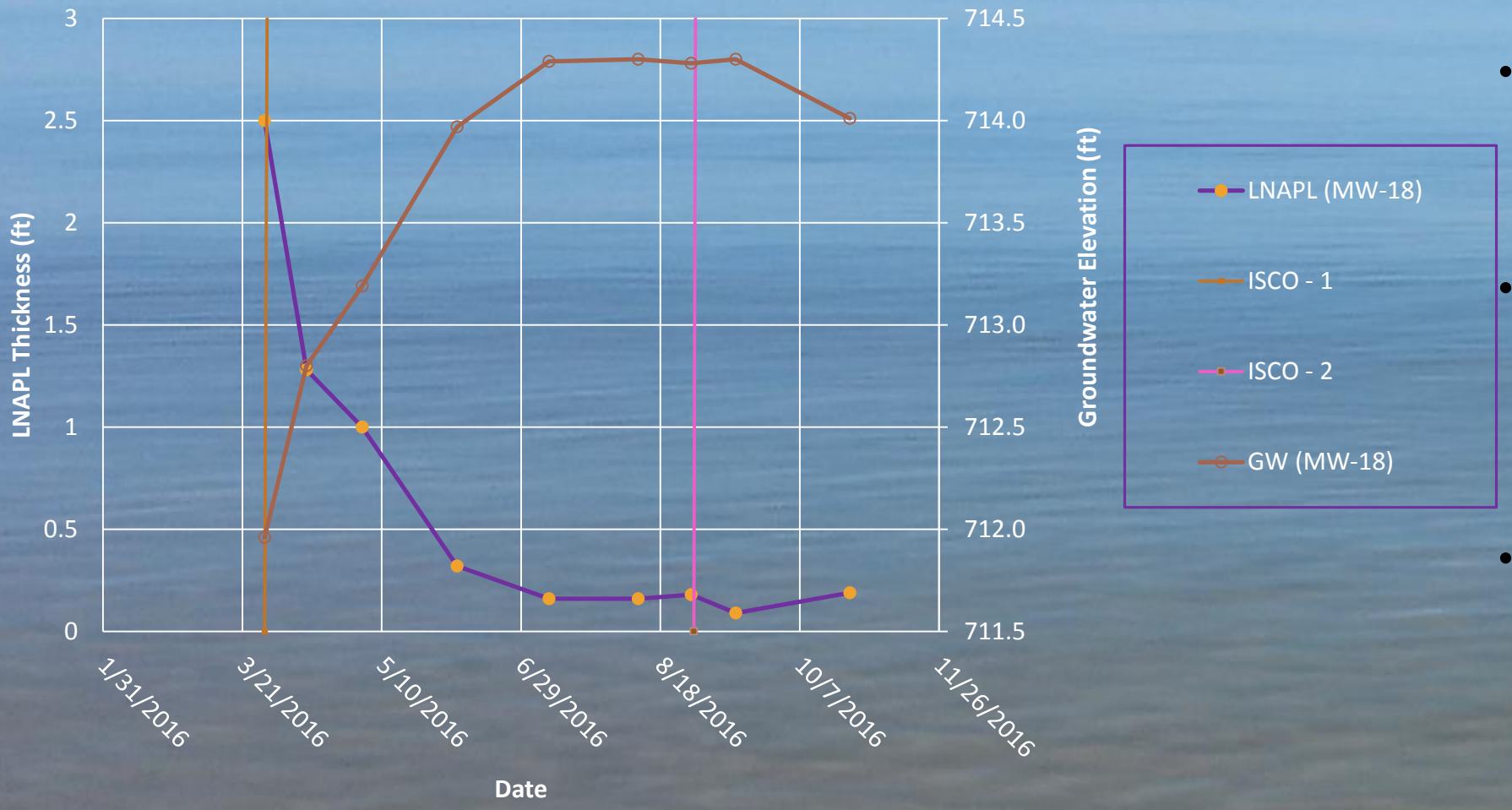
MW-18 POST INJECTION



- Highest thickness of LNAPL was observed in MW-18 in March 2016.
- More than 90% decrease in LNAPL thickness in MW-18 (from 1st ISCO injection to the 2nd injection)
- Indicates an excellent reduction in LNAPL

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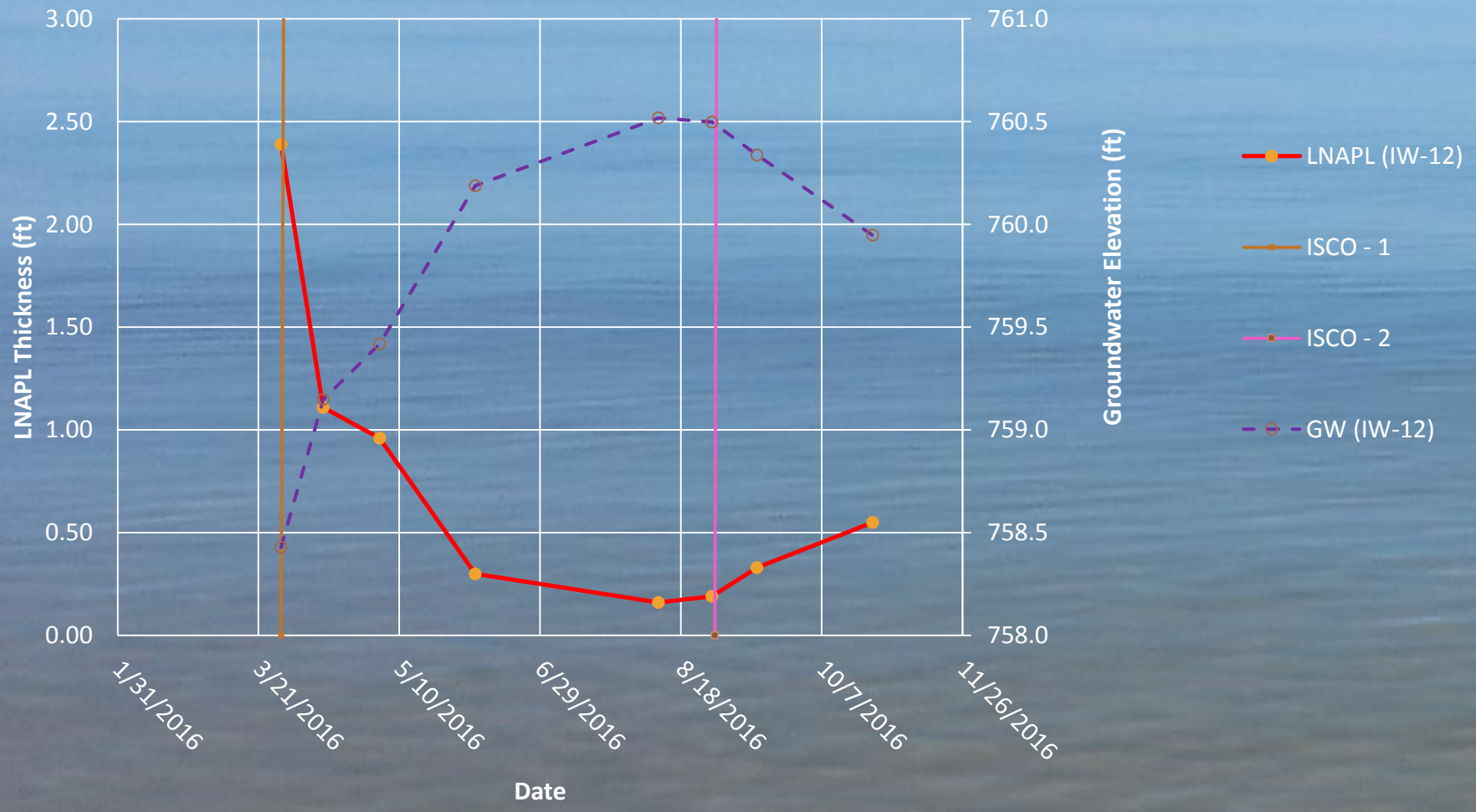
IW-12 POST INJECTION



- IW-12 is located approximately 45 feet NW of MW-18.
- More than 90% decrease in LNAPL thickness in IW-12 (from 1st ISCO injection to the 2nd injection)
- Indicates an excellent reduction in LNAPL throughout the Site

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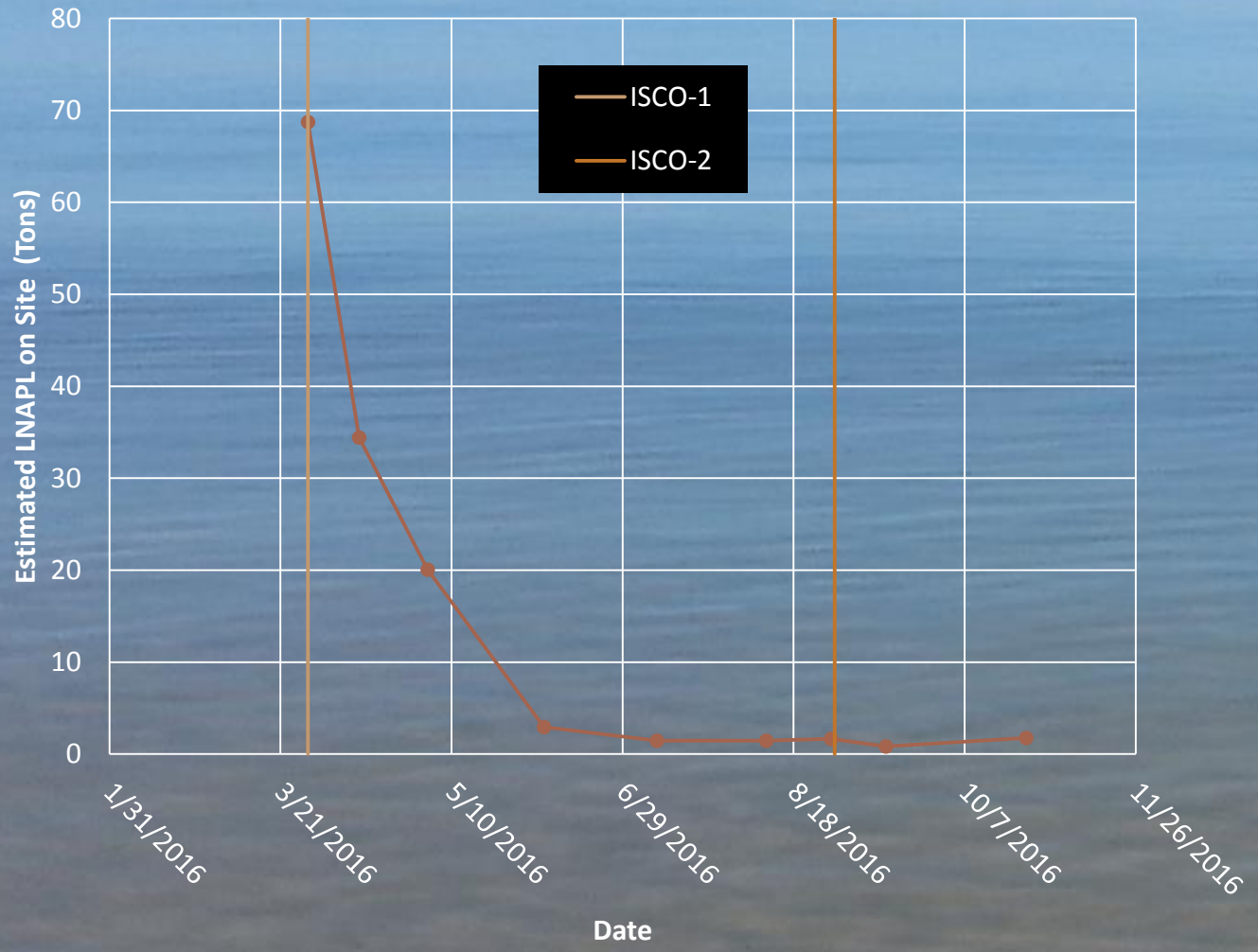
ESTIMATED MASS OF LNAPL ON SITE



- Mass of LNAPL was estimated based on the LNAPL thicknesses measured at monitoring wells.
- More than 90% of LNAPL has been removed from the 1st ISCO injection to the 2nd injection.
- Indicates an excellent reduction in LNAPL throughout the Site.

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MW-18

Good enough to drink!

Maybe not….

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CONCLUSIONS

- Source (UST) removal very important
- ISCO was very effective
- Continued monitoring
- Closer look at dissolved plume
- Possibly some additional delineation

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QUESTIONS?

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