From:	Theodore Pagano
To:	Ferrigan, Jennifer (EGLE)
Cc:	Carey, Kevin (EGLE)
Subject:	MPC 3D Artificial Brine Disposal Permit Modification Request
Date:	Monday, May 20, 2024 6:23:38 PM
Attachments:	2024-05-17 3D EGLE MODIFICATION PERMIT FINAL, vf.pdf

Dear Ms. Ferrigan,

Please find attached, an application to modify the MPC 3D Artificial Brine Disposal Well to include the Reed City Dolomite member of the Dundee Formation. The Reed City Dolomite is an additive, or alternate, disposal formation in the event the Sylvania and Bass Islands do not respond to step rate injection testing as anticipated. Therefore, this modification request, carefully references the prior approved information; but adds information specific to the Reed City Dolomite Member of the Dundee formation.

As you are aware, the Reed City Dolomite is shallower than the prior proposed injection horizons, and therefore, this modification request does not change the wellbore drilling, location, or construction plans. Appendix 1 of the prior application remains valid, as it referenced all wells that penetrated the injection and confining interval (Reed City and Bell Shale), and no new wells have been drilled in the AOR.

Sincerely,

Ted Pagano

Theodore A. Pagano, P.E., P.G.
Michigan Potash Operating
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www.mipotash.com
a quick video link: About Michigan Potash


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MICHIGAN POTASH OPERATING, LLC

Permit Application Modification Request

MPC-3D
PART 625 MINERAL WELL, BRINE INJECTION

OSCEOLA COUNTY, MICHIGAN

THE UNITED STATES POTASH PROJECT

A Submission to

EGLE

PERMIT APPLICATION SUPPLIMENT

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The U.S. Potash Project

Part 625 Mineral Well Update for MPC-3D:

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WELL IDENTIFICATION AND PROJECT DESCRIPTION

1. Describe in detail the purpose of the well and its anticipated life expectancy

NEED FOR PROPOSED ACTION

Potassium is one of the three primary nutrients essential to support carbohydrate production and plant life. It a natural fertilizer to improve productivity, efficiency, and yields of agribusiness.

The major source of potassium is potash (potassium chloride), extracted form sylvinite, a naturally occurring mineral containing both potassium chloride (potash) and sodium chloride (table salt). Since 1965, world consumption of potash grew from 14 million to an approximate 80 million short tons today. In 50 years, potash consumption has increased over 5 fold, and is necessary for global food security. In the last two decades, potash consumption has more than doubled.

The American farmer, the most efficient in the world, consumes about ten million short tons of potash annually. Over 94% of U.S. potash consumption is imported. Domestic potash supply comes principally from the Designated Potash Area in New Mexico; established in 1939 as a strategic resource. Over the past 80 years, the Designated Potash Area has become critically depleted, producing less than 300,000 tons of muriate of potash, or 3% of the US needs.

Despite being required for food growth, potash is the world's tightest controlled commodity. It is utilized throughout the globe, but commercial production occurs in only 12 countries and from 11 companies, creating high concentration risk. Current supply chain disruption has increased potash prices by 300% in two years, resulting in increased food prices, creating a global fertilizer, food, and inflationary security crisis.

The State of Michigan controls *one of three* domestic supplies for potash. Michigan potash was discovered in 1980, making it the youngest global commercial deposit of sylvinite. Potash is a U.S. Department of the Interior designated Strategic and Critical Mineral, and shortage of which poses critical and national harm. Michigan has the only proven and probable, commercial, potash available and ready for development.

Fertilizer is the American farmer's greatest cost of production. A further increase in U.S. imports and tighter control of potash has resulted in a currently distressed supply chain. This has resulted in less staple crop growth, which in turn is quickly leading to global food shortages, price instability, and significantly higher costs and food costs, and food shortages.

Michigan's potash is critically important to the American farmer, who provides our food.

- The State of Michigan, as a contributive part of the U.S. soybean and corn belt, is a large producer of sugar beets and potatoes, and resides within the greatest potash demand region in all of North America.
- There are 53,000 Farms in Michigan. A 91 Billion dollar economic contribution to the State.
- The State of Michigan contains the world's purest and highest grade potash and it resides in the U.S. corn belt, closest to the U.S. farmer.
- Discovered in 1980, and successfully produced between 1989 and 2013, this concentrated area is only *one of three* known potash producing regions in the United States. The other two have been critically depleted. There is only one, marginal potash producer in the United States.
- The known, delineated, deposit in Michigan has the capability to more than triple domestic potash production for over a century.

The proposed action will:

- Create a competitive potassium fertilizer price for the US farmer, which helps the noblest of professions. Helping our farmer, means supporting their choice to 'keep the farm' and grow food for us.
- Potassium levels and crops the most critical component to a farmer's water management, allowing growers to get the most efficient use of what water they have available for a specific crop.
- Reduce over-irrigation, and increase crop water use and efficiency.
- Provide domestic production of a material critical to the US farmer, the nation's agricultural health, and the nation's food security.
- Reduce the need for import and improve the nation's balance of trade.

- Reduce transportation costs to key agricultural areas throughout the US.

- Create a new and sizable opportunity in Rural Western Michigan, providing jobs directly and indirectly to an area with a great need.

ALTERNATIVES TO THE PROPOSED ACTION

There are no commercial alternatives for potash. 50% of the world's supply is controlled by nations, that are, on occasion, antagonistic to our initiatives (Russia, Belarus, China).

THE PROPOSED ACTION

I. Modification Request

Michigan Potash Operating, LLC ("MPO") was recently granted an extension effective June 1st, 2024 for MPC 1D, 2D, and 3D EGLE permits 61328, 61329, 61330, respectively.

The EGLE permit modification request presented herein requests the addition of the Reed City Dolomite within the Dundee Formation. The existing permitted injection horizons are the Sylvania Sandstone, and Bass Islands Dolomite. The Reed City Dolomite was included in the original equivalent EPA application for all three of the above permit numbers, however was removed during the early permitting process because one well within the 2-Mile area of review that did not have adequate cement coverage; the Johnson et al. 1-6.

MPO has since remediated the Johnson et al. 1-6 by adding cement across and above the proposed injection and confining intervals. Therefore, this modification request is submitted to add the Dundee Formation as a permitted injection zone.

This modification request introduces the information necessary to consider the Reed City Dolomite as a disposal horizon. This includes geological and remediation data on the Johnson 1-6 et al.

II. Process to Amend the Permit Application

MPO has included all modified information as necessary to include the Reed City Dolomite interval of the Dundee Formation as a permitted injection zone. This includes information concerning Area of Review ("AOR") support specific to the Dundee Formation and the Bell Shale as a confining interval.

Portions of the prior application remain applicable and unchanged and may be referenced in this modification request.

2. **Notification: At the same time as submitting the permit application, mail via first-class United States mail, a copy of the first page of the permit application and cover letter to the clerk of the township and the surface owner of record of the land on which the well is to be located.**

The surface owner and township clerk of record were notified during the original permit application.

3. Form EQP 7200-1, Application for Permit to Drill, Deepen, Operate, with an original signature from the applicant or the applicant's agent. See instructions on reverse of form.

EQP 7200-1 for permit number 61330 remains valid. The location, drilling, cementing, casing and completion design remains unchanged.

4. Form EQP 7200-2, Survey Record of Well Location signed and sealed by a surveyor licensed in the state of Michigan:

EQP 7200-2 for permit number 61330 remains valid. The location and surveyed features contained in the form remain unchanged.

5. Form EQP 7200-4, Wellhead Blowout Control System.

EQP 7200-4 for permit number 61330 remains valid. The approved sour trim BOP system remains unchanged.

6. Form EQP 7500-3, Environmental Impact Assessment for Mineral Wells and Surface Facilities.

EQP 7500-3 for permit number 61330 remains valid. There are no proposed modifications to this form.

7. Form EQP 7200-18, Soil Erosion and Sedimentation Control Plan

EQP 7200-18 for permit number 61330 remains valid and unchanged.

8. Provide a conformance bond.

Michigan Potash Operating, LLC currently holds a cash blanket bond in the amount of Four Hundred Thousand, Four Hundred Dollars held by the Michigan Department of Environment, Great Lakes and Energy for disposal, storage, or brine production. The bond number is DEPN0114507721.

9. The permit application fee as specified by statute.

MPO will pay all application fees as required.

10. An organization report, form EQP 7200-13, if not on file with the supervisor.

EQP 7200-13 is on file with EGLE.

11. Description of the drilling program, including the drilling fluid and mud program, how the fluids will be handled and ultimate disposition of the drilling fluids. Include a discussion of whether over pressured zones are anticipated and how the mud program will be modified to accommodate such a condition.

The anticipated drilling program, including fluids management and anticipation of pressurized zones for MPC-3D remains unchanged.

A modified Wellbore Diagram for the MPC-3D showing inclusion of the Dundee Formation within the injection zone is provided below.

These diagrams show that the intended well construction for the MPC-3D remains unchanged, with the exception of the proposed Reed City Dolomite perforations.

MPC 3D

Figure 1. Proposed Wellbore Diagram of the MPC-3D

MPC 3D

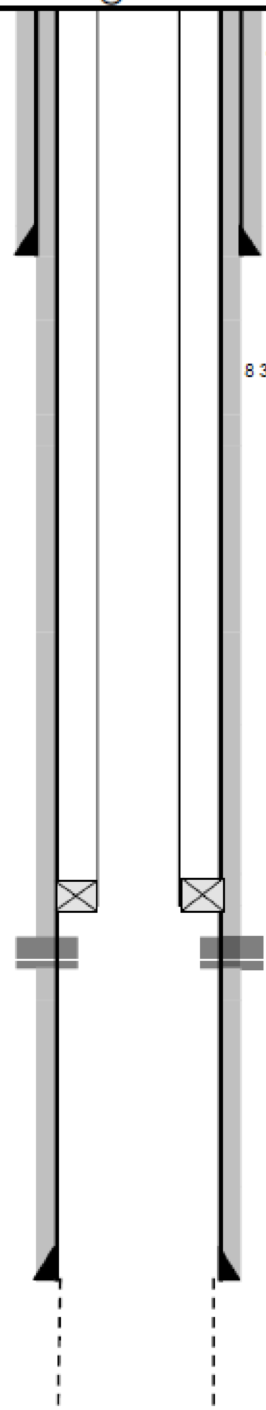
SURFACE: NE/4 SEC 36, T17N R09W, 43.818448, - 85.326073
VERTICAL WELL
OSCEOLA COUNTY, MI

PROPOSED WELLBORE DIAGRAM

GL @ +/-1,190'
KB @ +/- 2003'

UPDATED SEP 2024 by CJS

Geological Zone	TVD	MD
Quaternary H	0	0
Quaternary G	117	117
Quaternary F1	165	165
Quaternary F	196	196
Quaternary E	342	342
Quaternary E/1	410	410
Quaternary D	461	461
Jurrasic Red Beds	712	712
Pennsylvantian	706	706
Michigan	1261	1261
Marshall Sandstone	1719	1719
Coldwater Shale	1893	1893
Antrim Shale	2653	2653
Traverse Formation	3296	3296
Bell Shale	3889	3889
Dundee	3945	3945
Reed City Dolomite	4030	4030
Detroit River Group	4170	4170
Amherstburg	4962	4962
Sylvania Sand Stone	**5143**	**5143**
Bois Blanc	5337	5337
Bass Islands Group	**5390**	**5390**



13 3/8" HOLE

SURFACE CASING
9-5/8" 36# J-55
SET @ 900'
Cement to Surface
350 SX Lite, 1.69 Yield Lead
150 SX A, 1.18 Yield Tail
Lowest USDW at 620', behind surface casing.

8 3/4" HOLE DRILLED TO 5,500' (5,500 TVD)

Production String
4.5# 11.6-15.5 L-80
Arrow Set 10K 7" Packer at +/- 3900' MD
Set in Compression
Annulus fluid is inhibited brine, +/- 1.1-1.2 SG

PRODUCTION CASING
7" 23-38# N-80
SET @ 5,160' MVD, TVD
BASE of AMHURSTBURG
DV Tool @ 3,500'
Cement from Shoe to Surface
Stage 1: 240 SX Class A, 1.18 Yield
Stage 2: 430 SX 14.2 LITE, 1.47 Yield

Reed City Dolomite Perforations
Estimated Gross 3970'-4120' TVD

LINER HANGER AT +/ - 5,100'
SLOTTED LINER BELOW CASING SHOE
TO TD AT +/- 5,550

PBTD = TD
TD @ +/- 5,550'

The proposed injection wells will be drilled and cased according to the following detailed construction procedure.

Construction Procedure:

This modification is a recomplete in a pre-existing cased wellbore, therefore wellbore construction conforms to the original application.

Proposed Mud Program

This modification is a recomplete in a pre-existing cased wellbore, therefore wellbore construction conforms to the original application.

Proposed Directional Plan:

The MPC-3D is a vertical well.

12. Description of the cementing program including the type, properties and compressive strength of cement to be used on each casing string. Indicate if DV tools will be used.

The approved cementing program for permit number 61330 remains valid & unchanged.

13. Description of the proposed wireline logging program.

The approved wireline & logging program for permit number 61330 remains valid & unchanged.

14. Description of the testing program, including pressure tests on casing strings, and any planned drill stem tests.

Proposed Injectivity Step Rate Test:

Following step rate injection testing of the Sylvania Sandstone and Bass Island Dolomite and a determination of inadequate injection pressures and/or rates, the Reed City Dolomite will be perforated.

A step-rate injection test will be performed on the Reed City Dolomite:

1. MIRU service Unit. Give 48 hr notice to regulatory oversight in anticipation of step rate injection testing.
2. MIRU Wireline services, RIH with CCL and tie to CCL on CBL
3. Perforate the Reed City Dolomite from 3,970’ – 4,120’ gross; net TBD following Open Hole logs
4. POOH, RIH with wireline & set plug (2sx cement if necessary, if CIBP)
5. RDMO wireline.
6. PU workstring & RIH. Spot 15% HCl acid across perforated interval. Set pkr and initiate formation treatment as designed.
7. Initiate extended formation step-rate testing.
8. POOH with workstring, RDMO.

Based on step rate test results, the information will be available to determine the maximum injection pressure. After the two tests are performed, the packers will be removed so that injection may take place into the permitted formations.

All other approved testing programs remain valid & unchanged.

15. Description of any planned coring program.

N/A. There are no cores planned for this well.

ADDITIONAL INFORMATION REQUIRED FOR AN APPLICATION FOR A PERMIT TO DRILL AND OPERATE A DISPOSAL WELL

1. Form EQP 7200-14, Injection Well Data.

The approved Form EQP 7200-14 for permit number 61330 remains valid & unchanged for the Sylvania Sandstone and Bass Islands. A complimentary form EQP 7200-14 illustrating the Bell Shale as the confining interval, and including the Reed City Dolomite as an injection zone is surrendered as part of this permit modification request.

1. Notification information: provide name and address of the permittee of each oil, gas, and injection well and permitted location(s) within 1,320 feet of this proposed well, and the name and address of the last surface owner(s) of record within 1,320 feet of this proposed well.

There are no oil, gas, or injection operators, or permitted locations within 1,320 feet of the proposed permit modification.

The MPC 8D is a pending permit located approximately 20' South.

Surface Owner and Mailing Address within 1320 feet of the Proposed Well

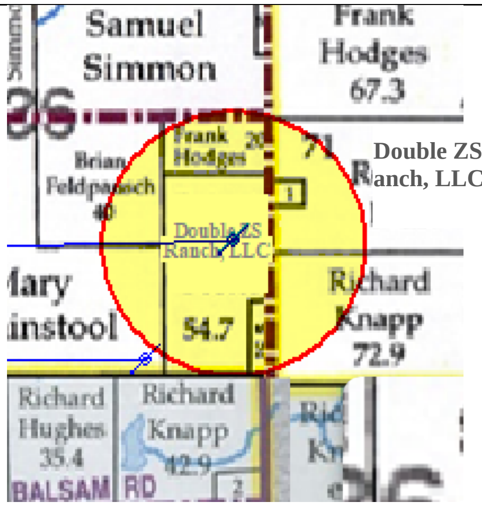
Mary E. Brininstool, P.O. Box 1007 Evert, MI 49631
Double ZS Ranch, 900 Monroe Ave NW Grand Rapids, MI 49503
Brian E. Feldpausch, 11350 W Dexter Trail, Westphalia, MI 48894
Heirs & Divisees of Richard Knapp C/O
Bobbi Ann Knapp, 185 Scotty Drive, Carbondale, IL 62903
Jason & Tracy Storch, 125 120th Ave Hersey, MI 49639

There are no oil, gas, or injection operators, or permitted locations within 1,320 feet of the proposed well (please see Figure 8).

2. File a separate plat: Which identifies the depth and location of this proposed well and all oil, gas, injection, and abandoned well within 1,320 feet. Also identify the permittee of each producing well within 1,320 feet of this proposed well, the surface owner(s) of record of the lands within 1,320 feet of this proposed well, and all freshwater, irrigation, and public water supply wells within 1,320 feet of this proposed well.

The supplemental plat and identified well types within 1,320' has not changed from the original application.

Surface ownership has changed and has been updated as above, and below on the below plat.



3. Enclose a copy of the completion reports: for all wells and the plugging records for all plugged wells shown on the plat. Identify what steps that will be which identifies the depth and location of this proposed well and all oil, gas, injection, and abandoned well within 1,320 feet.

All completion and plug and abandonment reports for all wells that penetrate the confining zone within 1,320' and within the 2-mile Area of Review are on record as part of the original approved permit number 61330.

4. If this is an existing well: to be converted to an injection well, enclose this form with a full permit application package per EQC 7200. Also enclose a copy of the completion report and geologic description and electric logs for this well.

N/A

5. Identify and describe all faults, structural features, karst, mines, and lost circulation zones: within the area of review that can influence fluid migration, well competency, or induced seismicity. Include a plan for mitigating risks of identifiable features.

Please reference this supplemental report herein. There are no faults, structural features, karsts, mines, or lost circulation zones that can influence fluid migration, well competency, or induced seismicity. There are no identifiable features.

6. Attach a proposed plugging and abandonment plan (EQP 7200-6): along with a schematic detailing the depths, volumes, and types of cement and mechanical plugs, and depths where casing will be recovered.

Please see section 15.

7. Provide information demonstrating that construction of the well will prevent the movement of fluid: that causes endangerment to an Underground Source of Drinking Water (USDW).

Please reference sections within this supplemental report in its entirely.

Items 8-16 of Form EQP 7200-14 are summarized below for comparative ease for which was approved prior.

8. Type of Fluid to be Injected

The information provided in the previously approved permit application #61330 remains applicable. There is no change.

9. Maximum Anticipated Daily Injection Rate:

The addition of the Reed City Dolomite may allow an increase in anticipated daily injection rates.

The maximum anticipated injection rate has not changed from previously submitted application. This injection volume maximum equates to 14.3 bpm. We do not anticipate exceeding this maximum with the modification to this permit.

10. Specific Gravity of the Injected Fluid: Show Calculations

There will be no change to the specific gravity of the injection fluid. For this permit modification we are defining the specific gravity of the injection fluid to be 1.20 g/cc with a 0.05 g/cc factor of safety.

11a. Maximum Anticipated Injection Pressure: Show Calculations

Form EQP 7200-14, has been filed with a default 0.8 psi/ft fracture gradient as directed by regulator direction from the US EPA despite substantial offset data available. Upon completion of the wells, step rate injection testing will be performed to obtain site specific data that will match the offsets and expected operating parameters listed in section 12.A of this permit modification.

The maximum anticipated injection pressure is based on the shallower depth of the Bell Shale.

11b. Maximum Injection Pressure: Show Calculations

As above

12. Maximum Bottom Hole Injection Pressure:

The maximum anticipated Bottom Hole Pressure is based on the shallower depth of the Bell Shale.

13. Fracture Pressure of the Confining Interval:

The maximum anticipated fracture pressure is based on the shallower depth of the Bell Shale.

14. Fracture Pressure of the Injection Interval:

Form EQP 7200-14, has been filed with a default 0.8 psi/ft fracture gradient as directed by regulator direction from the US EPA despite substantial offset data available (demonstrating 1.18 psi/ft). Upon completion of the wells, step rate injection testing will be performed to obtain site specific data.

15. Chemical Analysis

No change from the prior application

16. To be Completed in a Potential, Previous or current oil & gas producing formation:

No change from the prior application. No oil and gas reservoirs are established in the Reed City Dolomite. It is currently used for artificial brine disposal in the immediate area.

MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY - OIL, GAS, AND MINERALS DIVISION

INJECTION WELL DATA

Supplemental information for drilling or converting to an injection well
By authority of Part 615 or Part 625 of Act 451 PA 1994, as amended.
Non-submission and/or falsification of this information may result in fines and/or imprisonment.

INSTRUCTIONS: Complete all portions of form which apply to this well.
Attach supplemental documents as needed.

Applicant
Michigan Potash Operating, LLC
C/O Steptoe Johnson
600 17th St. Ste 2300
Denver, CO 80202

Well name and number
MPC 3D

1. Notification information: provide name and address of the permittee of each oil, gas, and injection well and permitted location(s) within 1,320 feet of this proposed well, and the name and address of the last surface owner(s) of record within 1,320 feet of this proposed well.
2. File a separate plat which identifies the depth and location of this proposed well and all oil, gas, injection, and abandoned well within 1,320 feet. Also identify the permittee of each producing well within 1,320 feet of this proposed well, the surface owner(s) of record of the lands within 1,320 feet of this proposed well, and all freshwater, irrigation, and public water supply wells within 1,320 feet of this proposed well.
3. Enclose a copy of the completion reports for all wells and the plugging records for all plugged wells shown on the plat. Identify what steps will be necessary to prevent injected fluids from migrating up or into inadequately plugged or completed wells.
4. If this is an existing well to be converted to an injection well, enclose this form with a full permit application package per EQC 7200. Also enclose a copy of the completion report and geologic description and electric logs for this well.
5. Identify and describe all faults, structural features, karst, mines, and lost circulation zones within the area of review that can influence fluid migration, well competency, or induced seismicity. Include a plan for mitigating risks of identifiable features.
6. Attach a proposed plugging and abandonment plan (EQP 7200-6), along with a schematic detailing the depths, volumes, and types of cement and mechanical plugs, and depths where casing will be recovered.
7. Provide information demonstrating that construction of the well will prevent the movement of fluid that causes endangerment to an Underground Source of Drinking Water (USDW).

8. Type of fluids to be injected
☐ Brine ☐ Natural Gas (omit #10 & #15)
☐ Fresh Water (omit #15) ☒ Other Artificial Brine

9. Maximum anticipated daily injection rate (bbls/day or MCF/day)
13,714 bbls/day

10. Specific gravity of injected fluid 1.20 plus a .05 safety factor

11a. Maximum anticipated injection pressure 1,028 psi

11b. Maximum injection pressure 1,028 psi @ .8 FPG
Show calculations (see R324.807) Mineral Well / Part 625
[{0.8 psi/ft - (0.433 psi/ft x 1.25)} x 4,030] - 14.7 psi = 1,028 psi

12. Maximum bottom hole injection pressure 3,209 psi
Show calculations Hyd Head = .433*1.25*4030' = 2,181 psi
0.8 psi/ft - (0.433 psi/ft x 1.25)} x 4,030] - 14.7 + 2,181 = 3,209 psi

13. Fracture pressure of confining interval 3,111 psi
Show calculations (Top of Confining Interval)
0.8 psi/ft * 3889 ft = 3,111 psi

14. Fracture pressure of injection interval 3,224 psi
Show calculations (Top of Injection Interval)
0.8 psi/ft * 4,030 ft = 3,224 (offsets demonstrate 4,030*1.17=4715)

15. Chemical analysis of representative samples of injected fluid
Specific conductance

Cation (mg/l)		**Anions** (mg/l)	
Calcium	<0.2%	Chloride	Var
Sodium	Var	Sulfate	<0.4%
Magnesium	<0.2%	Sulfide	<30mg/l
Total Iron	<10 mg/l	Carbonate	<1mg/l
Barium	8mg/l	Bicarbonate	220mg/l

What was the source of this representative sample? Adjacent Well

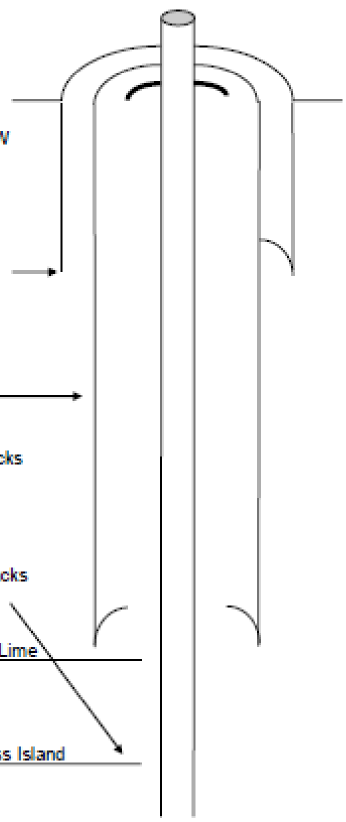
16. Is this well to be completed in a potential, previous, or current oil or gas producing formation? ☐ Yes ☒ No
If yes, provide a list of all offset permittees and proof of service of notification of this application to all permittees by certified mail.

Schematic of wellbore construction

Complete bottom of diagram as needed to conform with proposed construction (e.g. show rat hole below casing, open hole completion, packer loc. etc.)

Underground Source(s) of Drinking Water formation name(s), top & bottom depths
USDW(s) Glacial Till

Depth to top 0.
Depth to base 712.



Vertical distance (in feet) between top of injection interval and base of deepest USDW
3,233

Surface casing 9-5/8 "x 900 '
Amount of cement 500 sacks
T.O.C. Surface

Intermediate casing (if applicable)
"x '
Amount of cement sacks
T.O.C.

Long string casing 7 "x 5,160'
Amount of cement 670 sacks
T.O.C. Surface

Confining Interval(s) Bell Shale /Dundee Lime
Depth to top 3,889 TVD
Depth to base 4,030 TVD

Injection Interval(s) Reed City/Sylvania/Bass Island

Depth to top 4,030 TVD
Depth to base 5,550 TVD
Tubing 4.5" x 3,900'
Packer Depth 3,900
Bottom TD or PBTD5,550 ft

17. Application prepared by (print or type): Theodore A. Pagano P.E., P.G.
Signature [signature]
Date 5/16/2024

EQP 7200-14 (rev. 5/2019) Enclose with *APPLICATION FOR PERMIT TO DRILL* or CONVERT

2. A calculation of the area of review in the injection interval over the anticipated life of the well.

The Area of Review is voluntarily assigned as a two-mile radius around the surface wellhead locations of MPC-3D well locations. Figure A1 presents the location of these wells within the state. Figure A2(a) presents the cumulative AOR assigned by Michigan Potash, as allowed by regulation.

> "Area of review" means ether of the following:
>
> A. For a well disposing of non-hazardous waste, that area the radius of which is the greater of 1/4 mile or the lateral distance in which the pressures in the injection zone are sufficient to increase hydrostatic head in the injection zone above the base of the lowermost underground source of drinking water, but not more than 2 miles.
>
> B. For a well disposing of hazardous waste that area the radius of which is the greater of 2 miles or the lateral distance in which the pressures in the injection zone are sufficient to increase hydrostatic head in the injection zone above the base of the lowermost underground source of drinking water.

The proposed well is a non-hazardous brine well, and therefore the **area of review ("AOR")** is to be the radius of which is greater of ¼ mile or the lateral distance in which the pressures in the injection zone are sufficient to increase hydrostatic head in the injection zone above the base of the lowermost underground source of drinking water, but not more than 2 miles.

<u>A calculation of the area of influence in the injection interval over the anticipated life of the well:</u>

In conjunction with the University of Missouri Rolla, the National Water Well Association and the Municipal Experimental Research Laboratory, and Robert S. Kerr Environmental Research Laboratory, of the EPA, Warner and Lehr established and contributed a means of knowledge essential to establish and enforce control standards on deep water injection, the method of calculation for which is demonstrated herein. The cone of influence for injection is defined as that area around a well within which increased injection zone pressures caused by injection could be sufficient to drive fluids into an underground source of drinking water provided a hypothetical pathway that penetrates all the confining intervals between the injection zone and the base of the lowermost USDW.

The pathway for this theoretical fluid movement must assume a hypothetical, deep, open, and abandoned well, which has penetrated all of the numerous confining zones between the postulated injection zone and the lowermost USDW.

The following calculations are being demonstrated by the applicant for use at the 2-mile AOR boundary, and show that in the event of a hypothetical open path to surface, a cone of influence exceeding the calculated critical pressure is unlikely to exist in the postulated operation; meaning, migration to a USDW would not overcome resident hydrostatic pressure, even in the event of a hypothetical open path.

The critical pressure rise is determined via the following;

$$Pc = 0.433 * [SG_i * (D_i - D_{usdw}) + SG_{usdw} * (D_{usdw} - WL)] - Po;$$

where

Pc = Critical Pressure rise, psi

SG_i	= Specific Gravity of the injectate or resident water, unitless
D_i	= Depth injection interval, feet
D_{usdw}	= Depth to the base of the lowermost USDW
SG_{usdw}	= Specific Gravity of the USDW, unitless
WL	= observed water level below ground level, feet
Po	= original reservoir pressure in the injection horizon, psi

EPA 600/2-77-240, equation 3-9a expresses the pressure rise in injection wells after Warner and Leher, 1977; whereby the rise in pressure in relation as a function of time and distance is given as per the following;

$$dP\ (t,r) = \frac{162.6Qu}{\overline{K}b} * \left[\log \frac{\overline{K}t}{\overline{\emptyset}cr^2} - 3.23 \right]$$

where

dP (t,r)	= Change is reservoir pressure as a function of time, days and radius, feet
Q	= Rate of injection, barrels per day
u	= viscosity of injectate, centipoise
$\overline{K}$	= Average permeability of the injection zone, md
t	= time since injection began, hours
b	= injection zone thickness, feet
c	= injection zone compressibility, 1/psi
$\overline{\emptyset}$	= average injection zone porosity, percent,
r	= radial distance from wellbore, feet

Information summarized and applied in in the following calculations have been determined from real core data, real historical operating data, real historical drilling data, and site specific geophysical logs. The values and calculations are utilized to establish an estimated, theoretical output according to the laws of diffusivity and dispersion following 20 years of theoretical uninterrupted, continuous injection at the site specific location.

The range of inputs can be changed as approximations, ultimately being refined with real, observed site specific injectivity tests, fall off, and step rate tests via real time reservoir monitoring as is done on all brine injection wells during the course of operation.

Base of the Lowermost USDW

The base of the USDW is approximated at Hodges Et Al 1-36, which is in proximity to proposed MPC 3D is determined to be 712' based on sample picks during the original drilling.

As Per Michigan Statute, Part 625 R 299.2302(u) defines "Fresh water" as water which is free of contamination in concentrations that may cause disease or harmful physiological effects and which is safe for human consumption.'

R 299.2304(k) defines Underground Source of Drinking Water, which defines total dissolved solids to not exceed 10,000 mg/L TDS, similar to those standards posed by the U.S. EPA at CFR 40 146.3, which also sets TDS at greater than 10,000 total dissolved solids.

It is known that intervals deeper than 200' in the area of review, may contain naturally occurring arsenic and are not suitable for safe drinking as per Part 625 R 299.2302 (See section 6), and the deeper E-1 aquifer in the glacial till tends to be high in TDS, and calcium sulfate. As per Figure D2, the deepest slotted well in the 2 mile AOR is 340' and is utilized for potash/salt solution mining purposes and is not an underground source of drinking water. A conservative regulatory approach sets the USDW at the base of the glacial till at 712'; rather than at the deepest probable source of 'Fresh Water' which is safe for human consumption. As a result, Surface casing setting depths have been designed to be set at 900', which 188' below the base of the glacial till.

Site Specific Variables and Critical Pressure Rise

Pressure rise calculations are submitted to demonstrate that the proposed injection fluid and volumes into the Reed City Dolomite would not change the hydrostatic head at the base of the lowermost USDW via a hypothetical path to surface.

The values and calculations are utilized to establish an estimated, theoretical output according to the laws of diffusivity and dispersion following 20 years of theoretical uninterrupted, continuous injection. The range of inputs can be changed as approximations, ultimately being refined with real, observed site specific injectivity tests, fall off, and step rate tests via real time reservoir monitoring as is done on all brine injection wells during the course of operation.

The Reed City Dolomite EQP 7200-14 and the variables requested therein, conform to the range as specified in the table below:

Parameter	Value	Comment/Source
SG_i	1.23	Site specific resident water from the Ward 1-11 from the Reed City Formation (1.211) and Injectate high side (1.25) average
D_i	4030'	Top of Reed City Dolomite from site specific geophysical logs.
D_{usdw}	712'	Conservative selection of site specific measured depth of USDW as per US EPA CFR 40 146.3, at 10,000 TDS. Base of the Glacial Till by samples.
SG_{usdw}	1.05	fresh water
WL	97.5	Site specific average as observed in the nearest water wells (120, 75, 105, 90)
Po	1695	0.433 psi/ft

u	0.95	24% NaCl saturated brine at injection horizon site specific temperature of 125 degrees F
b	135	Site specific observed net porosity thickness based on real geophysical well logs
c	0.0000052	Dimensionless per psi, dolomite
$\overline{\emptyset}$	15.0%	Site specific determination based on real geophysical well logs. Effective porosity cross plot average as discussed in part 9.D.
$\overline{K}$	536	Average determination based on permeability determination from step rate data from the Thomas and Woodward (907 md avg) the Park Well Logs (1-12) vs real core observed (~ 350 md average) and measured in DST in the area (Ward 362 md, Pilarski 166 md).

Parameter	Value	A Value/ B Value, Comment/Source
Pc	303	Critical Pressure Rise, Calculated

Due to the proximity of the other potential injection wells, the change in reservoir pressure at the 2 mile AOR Boundary is calculated with 40,114 barrels of injectate per day. Because the AOR is cumulative, as in, it reflects the multiple wells - the proper volume to calculate the anticipated pressure rise at the 2 mile AOR is the cumulative volume that may be injected multiple point sources.

This does not reflect Form 7200-14 because these volumes are unlikely to be accommodated by a single vertical well.

At any given time, disposal may occur to a single well or to all applicant wells simultaneously, thereby reducing or changing the injected rate and volume per well. Maximum total project rates are not expected to exceed 40,114 bbl of injectate per day.

EPA 600/2-77-240, equation 3-9a expresses the pressure rise in injection wells after Warner and Leher, 1977; whereby the rise in pressure in relation as a function of time and distance is given as per the following;

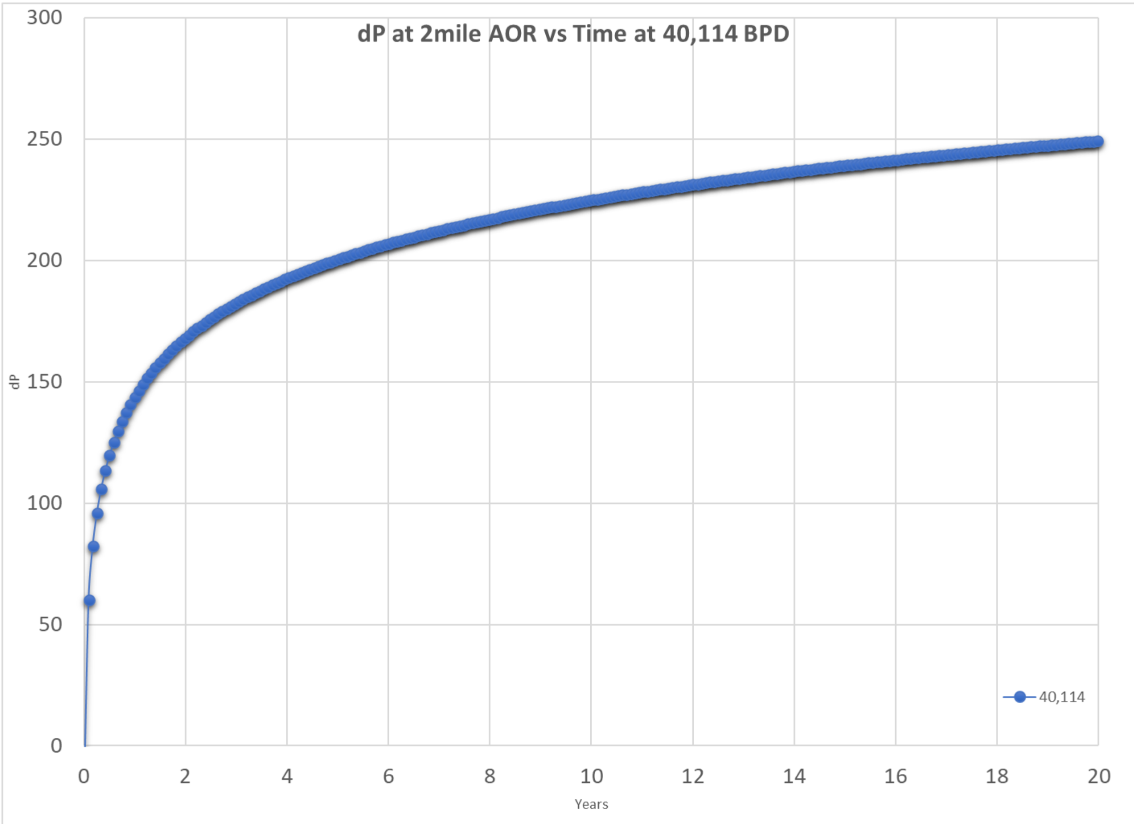
$$dP\ (t,r) = \frac{162.6Qu}{\overline{K}b} * \left[\log \frac{\overline{K}t}{\overline{\emptyset}cr^2} - 3.23\right]$$

where

dP (t,r)	= Change is reservoir pressure as a function of time, days and radius, feet
Q	= Rate of injection, barrels per day
u	= viscosity of injectate, centipoise
$\overline{K}$	= Average permeability of the injection zone, md
t	= time since injection began, hours
b	= injection zone thickness, feet
c	= injection zone compressibility, 1/psi
$\overline{\emptyset}$	= average injection zone porosity, percent,

r = radial distance from wellbore, feet

And therefore, the pressure rise at a 2 mile radial distance away from the well, at the maximum injection rate versus time is expressed below:



3. A discussion of the effect of injection on the present and potential mineral resources in the area of review.

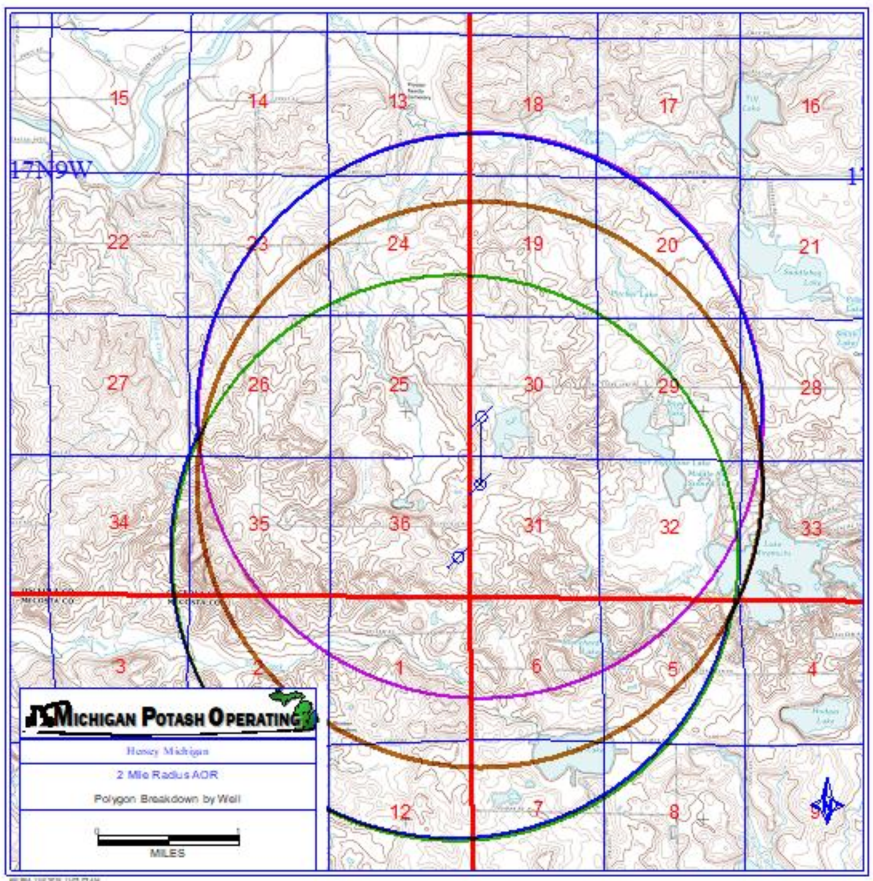
A description of the Area of Review

The area of review has not changed from the previously approved application

The AOR is a two mile radius around the surface locations of proposed wells MPC-1D, MPC-2D, and MPC-3D.

For ease of reference, Figure A2 from the original application is surrendered in this permit modification to support the AOR. It illustrates the 2-mile cumulative AOR utilized to calculate the pressure rise at its boundary.

- **Figure 2 is a map** illustrating the two-mile cumulative AOR that includes a cumulative 2 mile radius around the surface location of MPC-1D, MPC-2D, and MPC-3D.



A discussion of the effect of injection on the present and potential mineral resources in the area of review.

The postulated injection operation in the AOR, as graphically illustrated in Figure A2 will not impact present or potential mineral resources in the area of review, but rather promulgate and enable the development of the potash and salt mineral resources. The proposed action is necessary to administer the production of potash and high grade salt.

The AOR includes three marginally producing, depleted oil and gas wells from the deep Clinton formation at 8100’ or greater.

Injection into the Dundee formation does not interfere with any oil and gas interest, postulated mineral development or offset salt production from the Salina salt formations. Provided surface disturbance is limited to a single drilling pad, surface resources are also preserved.

4. A plat which shows the location and total depth of the proposed well, shows each abandoned, producing, or dry hole within the area of influence, and each operator of a mineral or oil and gas well within the area of influence.

For ease of reference and review, Figure 8 is included from the previously approved permit # 61330.

- **Figure 8 presents the location of all plugged and abandoned wells in the AOR.** Map showing all plugged wells, shallow (that do not penetrate any confining horizon) or deep (that penetrate confining horizon) within the area of review. Total Depths are listed. There are several shallow Michigan Stray wells that do not penetrate the injection or confining horizon.

Figure 8 can be cross referenced with the following tables. There have been no new wells drilled within the AOR since the original application approval:

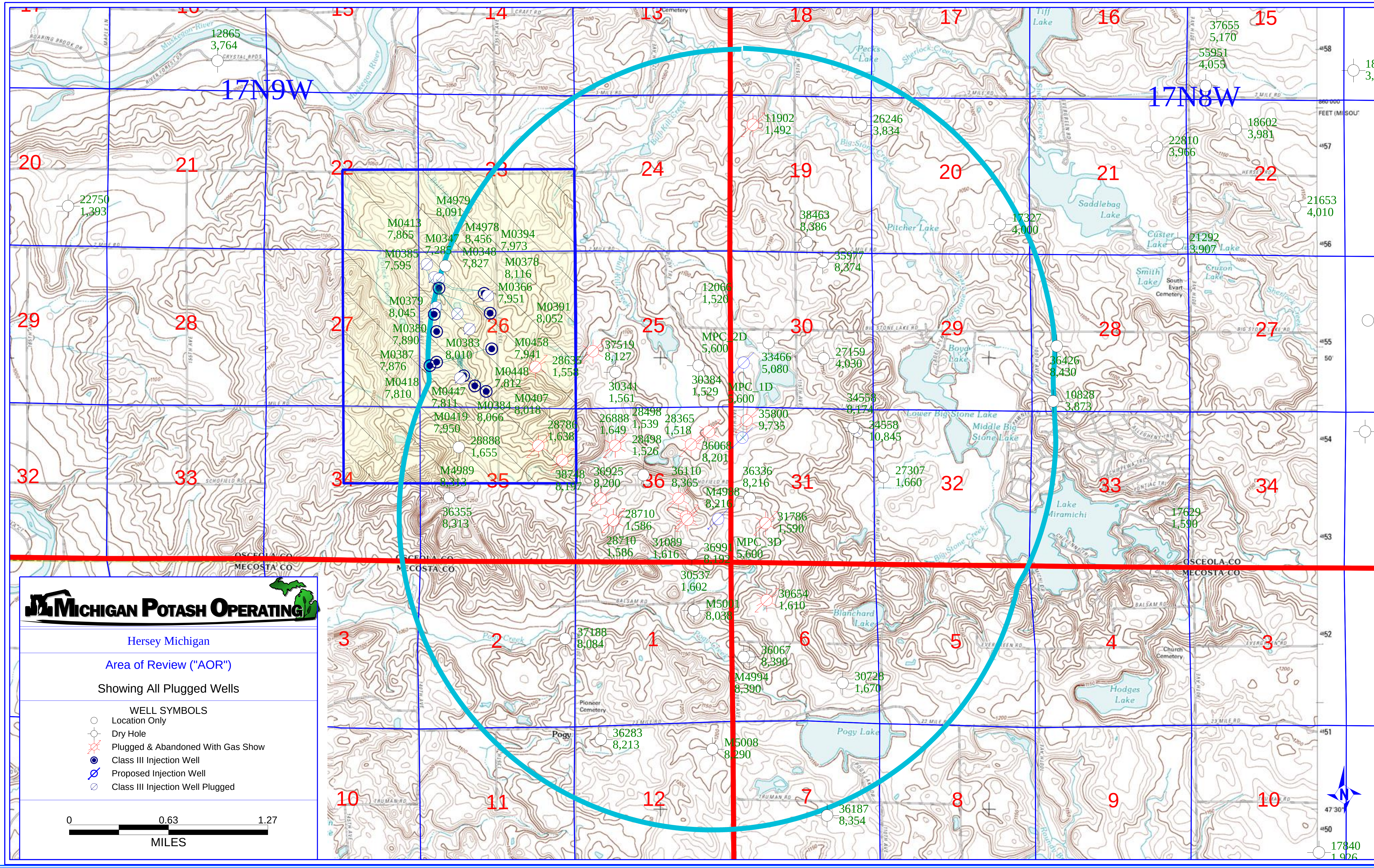


Figure 8. Map showing all plugged wells, shallow (that do not penetrate any confining horizon) or deep (that penetrate confining horizon) within the area of review. Total Depths are listed. There are several shallow Michigan Stray wells that do not penetrate the injection or confining horizon.

Michigan Potash Operating, LLC

For ease of reference, a tabulation of the existing drilled wells in the AOR are provided in the following tables. Records of oil and gas producing wells the state of Michigan are maintained by the EGLE Division of Oil and Gas and Minerals and the Geological Survey Division. Well permits, completions, and plugging records filed with this agency are organized by county, township, range, and section number.

<u>Tabulation of active producing oil and gas wells are as follows:</u>

TRS	API Number	Permit Number	Well Name and Number	Total Depth	Formation at Total Depth	Drill Date	Well Status	Well Type	WH_Lat	WH_Long	Operator Name
17N-9W-36	21-133-36033-00-00	36033	GREIN ET AL 2-36	8141	CABOT HEAD	Aug-83	ACTIVE	NATURAL GAS WELL	43.82640	-85.33910	Mccool John E
17N-9W-35	21-133-36186-00-00	36186	PAINE 1-35	8309	CINCINNATIAN	Dec-82	ACTIVE	NATURAL GAS WELL	43.82740	-85.35080	Mccool John E
17N-9W-26	21-133-37317-00-00	37317	PAINE 1-26	8095	CABOT HEAD	Feb-84	ACTIVE	NATURAL GAS WELL	43.83360	-85.34620	Mccool John E

Cross Reference with **Figure 8** which shows all producing wells in relation to the proposed injection locations.

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Tabulation of Part 625 Mineral Brine Disposal Injection Wells

Within the AOR, there are two qualifying classes of injection well: Part 625 Non Hazardous Brine Disposal Wells (EPA Class I NON HAZARDOUS) and Part 625 Artificial Brine (EPA Class III Solution Wells). They are listed here separately for ease of reference. Records of injection wells are maintained by the US EPA and the state of Michigan EGLE Division of Oil and Gas and the Geological Survey Division. Well permits, completions, and plugging records filed with this agency are organized by county, township, range, and section number.

Active Part 625 Non Hazardous Brine Disposal Wells (EPA Class I, Non Hazardous Injection Wells) are as follows:

TRS	API Number	Permit Number	Well Name and Number	Total Depth	Formation at Total Depth	Drill Date	Well Status	Well Type	WH_Lat	WH_Long	Operator Name
17N-9W-26	21-133-00349-70-00	349	WOODWARD 1-26	8140	A-1 SALT	Oct-83	ACTIVE	PART 625, CLASS I NON HAZARDOUS	43.83460	-85.35680	Cargill Incorporated
17N-9W-26	21-133-00350-70-00	350	THOMAS 1-26	8091	A-1 SALT	Jan-84	ACTIVE	PART 625, CLASS I NON HAZARDOUS	43.84180	-85.36110	Cargill Incorporated

Cross Reference **Figure 8** show active Part 625 Non-Hazardous Brine Disposal Wells, and Class I NON-HAZARDOUS Injection Wells; the Thomas 1-26 (NW4NW4 Section 26) and the Woodward 1-26 (NE4SW4 Section 26), both operating by Cargil Incorporated.

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Tabulation of Part 625 Mineral Production Injection Wells

Within the AOR, there are two qualifying classes of injection well: Class I NON HAZARDOUS and Class III NON HAZARDOUS. This section lists here Class III wells only for ease of reference. Records of injection wells are maintained by the US EPA and the state of Michigan EGLE Division of Oil and Gas and the Geological Survey Division. Well permits, completions, and plugging records filed with this agency are organized by county, township, range, and section number.

Active Class III, Part 625 Injection Wells are as follows:

TRS	API Number	Permit Number	Well Name and Number	Total Depth	Formation at Total Depth	Drill Date	Well Status	Well Type	WH_Lat	WH_Long	Operator Name
17N-9W-26	21-133-00449-70-00	449	KALIUM HERSEY 2042	UNK	A-1 SALT	Jun-00	ACTIVE	PART 625, CLASS III	43.83310	-85.35910	Cargill Incorporated
17N-9W-26	21-133-00474-70-00	474	I M C POTASH HERSEY 1061	UNK	A-1 SALT	Jan-02	ACTIVE	PART 625, CLASS III	43.83910	-85.36170	Cargill Incorporated
17N-9W-26	21-133-00384-70-00	384	KALIUM 2061	8066	A-1 SALT	May-85	ACTIVE	PART 625, CLASS III	43.83290	-85.35920	Cargill Incorporated
17N-9W-26	21-133-00391-70-00	391	KALIUM HERSEY 1044	8052	A-1 SALT	Nov-93	ACTIVE	PART 625, CLASS III	43.83950	-85.36190	Cargill Incorporated
17N-9W-26	21-133-00383-70-00	383	KALIUM 2031	8010	A-1 SALT	Mar-85	ACTIVE	PART 625, CLASS III	43.83330	-85.35920	Cargill Incorporated
17N-9W-26	21-133-00366-70-00	366	KALIUM 1041	7951	A-1 EVAPORITE	May-90	ACTIVE	PART 625, CLASS III	43.84020	-85.36190	Cargill Incorporated
17N-9W-26	21-133-00409-70-00	409	KALIUM HERSEY 2062	7950	A-1 SALT	Aug-96	ACTIVE	PART 625, CLASS III	43.83300	-85.35920	Cargill Incorporated
17N-9W-26	21-133-00380-70-00	380	KALIUM 1051	7890	A-1 SALT	May-85	ACTIVE	PART 625, CLASS III	43.83990	-85.36190	Cargill Incorporated
17N-9W-26	21-133-00387-70-00	387	KALIUM HERSEY 1054	7876	A-1 SALT	Aug-93	ACTIVE	PART 625, CLASS III	43.83980	-85.36190	Cargill Incorporated
17N-9W-26	21-133-00403-70-00	403	KALIUM HERSEY 1014	7865	A-1 SALT	Jul-95	ACTIVE	PART 625, CLASS III	43.83920	-85.36180	Cargill Incorporated
17N-9W-26	21-133-00408-70-00	408	KALIUM HERSEY 2032	7810	A-1 SALT	Jul-96	ACTIVE	PART 625, CLASS III	43.83340	-85.35920	Cargill Incorporated
17N-9W-26	21-133-00385-70-00	385	KALIUM HERSEY 1013	7595	A-1 SALT	May-92	ACTIVE	PART 625, CLASS III	43.83960	-85.36190	Cargill Incorporated

Cross Reference **Figure 8** shows all established Class III *AREA* Injection Permit No. MI-133-3G-A0002 (Yellow Cross Hatch) and Active and Inactive Class III Injection Wells. The AOR has undergone extensive prior regulatory review provided the pre-established injection activity within the AOR.

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Tabulation of Well Data for all Abandoned Wells, Plugged Wells, and Dry Holes

Records of abandoned wells, plugged wells, and dry holes in the state of Michigan are maintained by the EGLE and the Geological Survey Division. Well permits, completions, and plugging records filed with this agency are maintained by county, township, range, and section number. Locations of wells were searched in the following AOR sections:

The following is a list of wells found within or near to the AOR.

TRS	API Number	Permit Number	Well Name and Number	Total Depth	Formation at Total Depth	Drill Date	Well Status	Well Type	WH_Lat	WH_Long	Operator Name
17N-9W-26	21-133-00397-70-00	397	KALIUM HERSEY 1032	8018	A-1 SALT	Nov-94	INACTIVE	PART 625, CLASS III	43.83930	-85.36180	Mosaic Potash Hersey
17N-9W-26	21-133-00438-70-00	438	KALIUM HERSEY 2082	7812	A-1 SALT	Jun-07	INACTIVE	PART 625, CLASS III	43.83270	-85.35920	Mosaic Potash Hersey
17N-9W-26	21-133-00347-70-00	347	KALIUM 1012	7285	A-1 EVAPORITE	Jan-85	INACTIVE	PART 625, CLASS III	43.84050	-85.36190	Mosaic Potash Hersey
17N-9W-36	21-133-3611-00-000	36110	THOMPSON 3-36	8366	CINCINNATIAN	Oct-82	INACTIVE	NATURAL GAS WELL	43.82030	-85.33110	Marathon Oil Co.
17N-9W-36	21-133-36068-00-00	36068	BABCOCK ET AL 1-36	8200	CABOT HEAD	Sep-83	INACTIVE	NATURAL GAS WELL	43.82650	-85.32720	Marathon Oil Co.
17N-9W-36	21-133-36925-00-00	36925	BALDINO 1-36	8200	CABOT HEAD	Sep-83	INACTIVE	NATURAL GAS WELL	43.82030	-85.34100	Marathon Oil Company
17N-9W-36	21-133-36991-00-00	36991	HODGES ET AL 1-36	8198	CLINTON	Oct-83	INACTIVE	DRY HOLE	43.81520	-85.32940	Marathon Oil Co.
17N-9W-36	21-133-26888-00-00	26888	GREIN, DONALD 1	1649	BROWN LIMESTONE	Aug-67	INACTIVE	DRY HOLE	43.82250	-85.33560	Consumers Energy Company
17N-9W-36	21-133-31089-00-00	31089	THOMPSON, DON; HODGES, FRANK; SMITH, RALPH 2-36	1616	MICHIGAN STRAY	Jul-76	INACTIVE	NATURAL GAS WELL	43.81860	-85.33010	Mutch Harry L
17N-9W-36	21-133-30537-00-00	30537	THOMPSON, DON; HODGES, FRANK; SMITH, RALPH 1-36	1602	MARSHALL	Nov-75	INACTIVE	NATURAL GAS WELL	43.81830	-85.32990	Mutch Harry L
17N-9W-36	21-133-2871-00-000	28710	THOMPSON & RANDOLPH 1	1586	MICHIGAN STRAY	Dec-71	INACTIVE	NATURAL GAS WELL	43.81820	-85.33940	Mutch Harry L
17N-9W-36	21-133-28710-01-00	28710	THOMPSON & RANDOLPH 1	1586	MICHIGAN STRAY	Dec-71	INACTIVE	NATURAL GAS WELL	43.81820	-85.33940	Mutch Harry L
17N-9W-36	21-133-28498-01-00	28498	GREIN, DONALD 1	1539	MICHIGAN STRAY	Aug-71	INACTIVE	NATURAL GAS WELL	43.82520	-85.33920	Hersey Oil and Gas Co.
17N-9W-36	21-133-28498-00-00	28498	GREIN, DONALD 1	1526	MICHIGAN STRAY	Aug-71	INACTIVE	NATURAL GAS WELL	43.82520	-85.33920	Hersey Oil and Gas Co.
17N-9W-36	21-133-28365-00-00	28365	THOMPSON, EDITH 1	1518	MICHIGAN STRAY	Jun-71	INACTIVE	NATURAL GAS WELL	43.82530	-85.32950	Mutch Harry L
17N-9W-35	21-133-36627-00-00	36627	STATE HERSEY 1-35			Apr-83	INACTIVE	LOCATION	43.81670	-85.35090	Rovsek Aldolph E and Muskegon Development Company
17N-9W-35	21-133-36355-00-00	36355	STATE HERSEY 2-35	8310	CINCINNATIAN	Jan-83	INACTIVE	DRY HOLE	43.82030	-85.36040	Marathon Oil Co.
17N-9W-35	21-133-38748-00-00	38748	GREIN 1-35	8206	CABOT HEAD	Jun-85	INACTIVE	NATURAL GAS WELL	43.82380	-85.34600	Marathon Oil
17N-9W-35	21-133-28888-00-00	28888	RANDOLPH & PAINE & THIEL UNIT 1	1655	MICHIGAN STRAY	Jul-72	INACTIVE	DRY HOLE	43.82500	-85.35920	Mutch J O
17N-9W-35	21-133-28786-00-00	28786	GREIN, DONALD & PAINE, HENRY 1	1638	MICHIGAN STRAY	Mar-72	INACTIVE	NATURAL GAS WELL	43.82510	-85.34900	Hersey Oil and Gas Co.
17N-9W-26	21-133-37519-00-00	37519	MILLER 1-25	8425	CABOT HEAD	Aug-84	INACTIVE	NATURAL GAS WELL	43.83340	-85.34630	Marathon Oil Co.
17N-9W-26	21-133-36942-00-00	36942	WOODWARD ET AL 1-26	8135	CABOT HEAD	Oct-83	INACTIVE	DRY HOLE	43.83460	-85.35680	PPG Oil and Gas Company, Inc.
17N-9W-26	21-133-00378-70-00	378	KALIUM 1042	8116	A-1 SALT	Feb-85	INACTIVE	PART 625, CLASS III	43.84010	-85.36190	Mosaic USA LLC, DBA Mosaic Potash Hersey, LLC
17N-9W-26	21-133-366-00-0000	36600	THOMAS 1-26	8085	CABOT HEAD	Jan-84	INACTIVE	DRY HOLE	43.84180	-85.36110	PPG Oil and Gas Company, Inc.
17N-9W-26	21-133-00379-70-00	379	KALIUM 1052	8045	A-1 SALT	Mar-85	INACTIVE	PART 625, CLASS III	43.83980	-85.36190	Mosaic USA LLC, DBA Mosaic Potash Hersey, LLC
17N-9W-26	21-133-00394-70-00	394	KALIUM HERSEY 1031	7973	A-1 SALT	Oct-94	INACTIVE	PART 625, CLASS III	43.83940	-85.36180	Mosaic USA LLC, DBA Mosaic Potash Hersey, LLC

TRS	API Number	Permit Number	Well Name and Number	Total Depth	Formation at Total Depth	Drill Date	Well Status	Well Type	WH_Lat	WH_Long	Operator Name
17N-9W-26	21-133-00448-70-00	448	KALIUM HERSEY 2041	7941	A-1 SALT	Jun-00	INACTIVE	PART 625, CLASS III	43.83320	-85.35910	Mosaic USA LLC, DBA Mosaic Potash Hersey, LLC
17N-9W-26	21-133-00348-70-00	348	KALIUM 1011	7827	A-1 EVAPORITE	Nov-84	INACTIVE	PART 625, CLASS III	43.84050	-85.36150	Mosaic USA LLC, DBA Mosaic Potash Hersey, LLC
17N-9W-26	21-133-00437-70-00	437	KALIUM HERSEY 2081	7811	A-1 SALT	Jun-07	INACTIVE	PART 625, CLASS III	43.83270	-85.35920	Mosaic USA LLC, DBA Mosaic Potash Hersey, LLC
17N-9W-26	21-133-00381-70-00	381	KALIUM 1031	4800	A-1 SALT	Feb-92	INACTIVE	PART 625, CLASS III	43.83960	-85.36190	Mosaic USA LLC, DBA Mosaic Potash Hersey, LLC
17N-9W-26	21-133-28635-00-00	28635	PAINE, HENRY 1	1558	MICHIGAN STRAY	Nov-71	INACTIVE	NATURAL GAS WELL	43.83240	-85.34940	Mutch Harry L
17N-9W-25	21-133-30341-00-00	30341	MILLER, DOUGLAS & THIEL, HAULDAH 1-25	1561	BROWN LIMESTONE	Aug-75	INACTIVE	DRY HOLE	43.83190	-85.33920	Mutch Harry L
17N-9W-25	21-133-30384-00-00	30384	JOHNSON, WALT & MILLER, DOUG & THIEL, H 1-25	1529	MICHIGAN STRAY	Aug-75	INACTIVE	DRY HOLE	43.83260	-85.32860	Mutch J O
17N-9W-25	21-133-12066-00-00	12066	JOHNSON-CODY ET AL COMM. 1	1520	MARSHALL	Jan-46	INACTIVE	DRY HOLE	43.83920	-85.32970	Oryx Energy Co. and Carter Oil Co.
17N-8W-32	21-133-27307-00-00	27307	MANEY, NORMAN 1	1660	MARSHALL	Jul-68	INACTIVE	DRY HOLE	43.82230	-85.30490	Consumer Power and Michigan Consolidated Gas
17N-8W-31	21-133-34558-00-00	34558	FREUDENBURG 1-31	10858	PRAIRIE DU CHIEN	Jul-81	INACTIVE	DRY HOLE	43.82650	-85.30830	JEM Petroleum Corp.
17N-8W-31	21-133-358-00-0000	35800	GRAY 1-31	9769	PRAIRIE DU CHIEN	Aug-82	INACTIVE	NATURAL GAS WELL	43.82750	-85.32240	Marathon Oil Co.
17N-8W-31	21-133-36336-00-00	36336	PARK 1-31	8216	CLINTON	Feb-84	INACTIVE	DRY HOLE	43.82030	-85.32200	Marathon Oil Co.
17N-8W-31	21-133-34558-01-00	34852	FREUDENBURG 1-31A	8183	DUNDEE	Aug-81	INACTIVE	DRY HOLE	43.82650	-85.30830	JEM Petroleum Corp.
17N-8W-31	21-133-31786-00-00	31786	KNAPP, GERALD & PARKS, ROBERT 1-31	1590	MICHIGAN STRAY	Sep-77	INACTIVE	NATURAL GAS WELL	43.81800	-85.32000	Hersey Oil and Gas Co.
17N-8W-30	21-133-35977-00-00	35977	WARK 1-30	8371	CINCINNATIAN	Sep-82	INACTIVE	DRY HOLE	43.84210	-85.31280	Willmet Inc.
17N-8W-30	21-133-33466-00-00	33466	MANEY, NORMAN 1-30	5080	AMHERSTBURG	Feb-80	INACTIVE	DRY HOLE	43.83470	-85.31960	Dart Oil and Gas Co.
17N-8W-30	21-133-27159-00-00	27159	MADDERN, H 1	4030	DUNDEE	Feb-68	INACTIVE	DRY HOLE	43.83330	-85.31260	Madlou Inc.
17N-8W-19	21-133-38463-00-00	38463	VUKIN UNIT 1-19	8385	CINCINNATIAN	Feb-85	INACTIVE	DRY HOLE	43.84400	-85.31480	PPG Oil and Gas Company, Inc. and Amoco Production Co.
17N-8W-19	21-133-38463-70-00	5006	VUKIN UNIT 1-19	8385		Dec-84	INACTIVE	DRY HOLE	43.84400	-85.31480	PPG Oil and Gas Company, Inc. and Amoco Production Co.
16N-9W-2	21-107-37188-00-00	37188	JENSEN 1-2	8085	CABOT HEAD	Nov-83	INACTIVE	DRY HOLE	43.80730	-85.34550	Marathon Oil Co.
16N-9W-12	21-107-00340-70-00	340	PILARSKI 1-12	8318	CINCINNATIAN	Aug-84	INACTIVE	DRY HOLE	43.79740	-85.32660	PPG Industries, Inc.
16N-9W-12	21-107-36283-00-00	36283	PARK 1-12	8215	CINCINNATIAN	Jan-83	INACTIVE	DRY HOLE	43.79800	-85.34090	Willmet Inc.
16N-9W-11	21-107-00339-70-00	339	WARD 1-11	8121	CINCINNATIAN	Aug-84	INACTIVE	DRY HOLE	43.79010	-85.34660	PPG Industries, Inc.
16N-9W-11	21-107-36864-00-00	36864	WARD 1-11	8121	CINCINNATIAN	Sep-83	INACTIVE	DRY HOLE	43.79010	-85.34660	PPG Industries, Inc.
16N-9W-1	21-107-00377-70-00	377	JOHNSON 2-1	8085	A-1 SALT	Apr-84	INACTIVE	DRY HOLE	43.80980	-85.32910	PPG Industries, Inc.
16N-9W-1	21-107-00337-70-00	337	JOHNSON 3-1	8073	A-1 EVAPORITE	May-84	INACTIVE	DRY HOLE	43.80980	-85.32900	PPG Industries, Inc.
16N-8W-7	21-107-36187-00-00	36187	STEIN 1-7	8380	CINCINNATIAN	Nov-82	INACTIVE	DRY HOLE	43.79110	-85.31200	Willmet Inc.
16N-8W-6	21-107-36067-00-00	36067	JOHNSON ET AL 1-6	8386	CINCINNATIAN	Oct-82	INACTIVE	DRY HOLE	43.80570	-85.32200	Marathon Oil Co.
16N-8W-6	21-107-30728-00-00	30728	MCLACHLAN, GEORGE 1-6	1670	MICHIGAN STRAY	May-76	INACTIVE	DRY HOLE	43.80330	-85.31010	Mutch Harry L
16N-8W-6	21-107-30654-00-00	30654	KNAPP, GERALD & JOHNSON, DON 1-6	1610	MICHIGAN STRAY	Dec-75	INACTIVE	NATURAL GAS WELL	43.81090	-85.31980	Mutch Harry L
16N-8W-18	21-107-3689-00-000	36890	STEIN 1-18	8264	CINCINNATIAN	Aug-83	INACTIVE	DRY HOLE	43.77650	-85.30740	PPG Oil and Gas Company, Inc.

Cross reference **Figure 8,** which shows all plugged wells, shallow or deep within the area of review. Total depths of the each well is listed next to its well symbol. Also shown on this map are the API Serial number. The serial number is illustrated below:

State	–	County	–	**Serial**	–	Completion
21	-	133	-	**#####**	-	00-00

Mineral wells available to the public record or made known to the applicant are also shown. These wells are preceded with the letter "M" before the listed Serial No. The State of Michigan has adapted a 'pseudo API No,' utilizing the mineral permit number as an API Serial No. As an example; M4999 would have the equivalent Mineral Well API designation of :

State	–	County	–	**Serial**	–	Completion
21	-	133	-	0**4999**	-	**70**-00

These numbers can be quickly cross referenced with public records, and or the tabular section above.

Report of Corrective Action on the Johnson Et Al. 1-6

The Johnson et al 1-6 was a well in the original AOR identified as needing remedial cement across the Dundee and Bell Shale. A remediation job was successfully performed on the Johnson et al. 1-6, placing cement coverage well over the Dundee, with a measured cement top at 2,148 by CBL verification.

The remediation of the Johnson et al 1-6 provides proper cement coverage across the injection and confining intervals allowing for permitted injection into the subject wellbore.

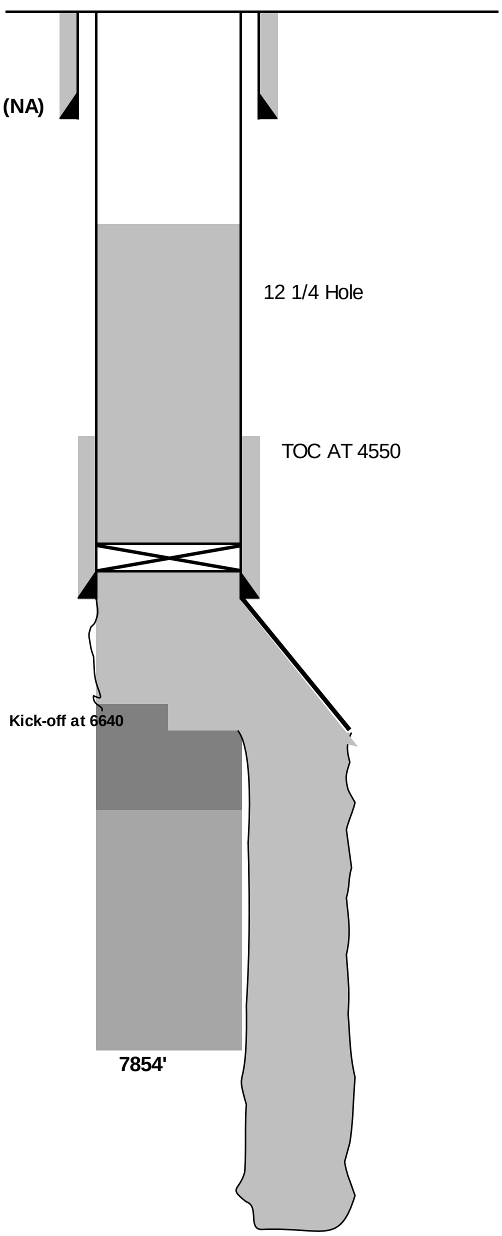
Johnson et al. 1-6 Pre-Workover Wellbore Diagram

JOHNSON ET AL 1-6

NE NW SW Sec 6 T16N R8W
MECOSTA COUNTY, MI

WELLBORE DIAGRAM BEFORE REMEDIATION

API No. 21-107-36067-0000
GL @ 1175'
KB @ 1191.5'
WELL COMPLETION DATE: DRY HOLE (NA)
PLUGGING COMPLETION DATE:
11/1/1982



UPDATED May 2021

SURFACE CASING
13 3/8" 48# H-40
SET @ 904' KB
CMT w/950 SX TO SURFACE

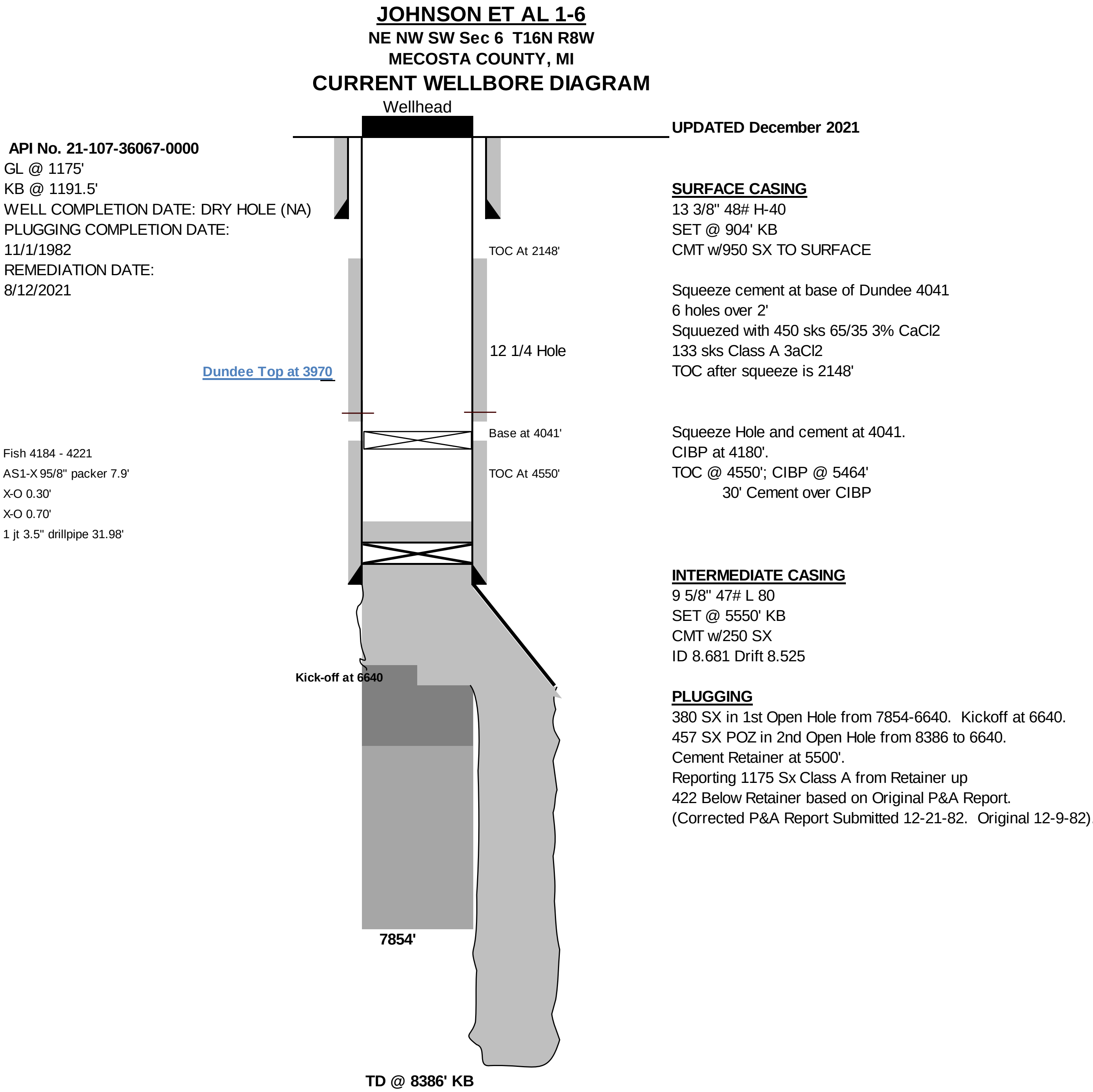
INTERMEDIATE CASING
9 5/8" 47# L 80
SET @ 5550' KB
CMT w/250 SX
ID 8.681 Drift 8.525

TOC @ 4550'; PLUG @ 5464' - PER TEMP SURVEY

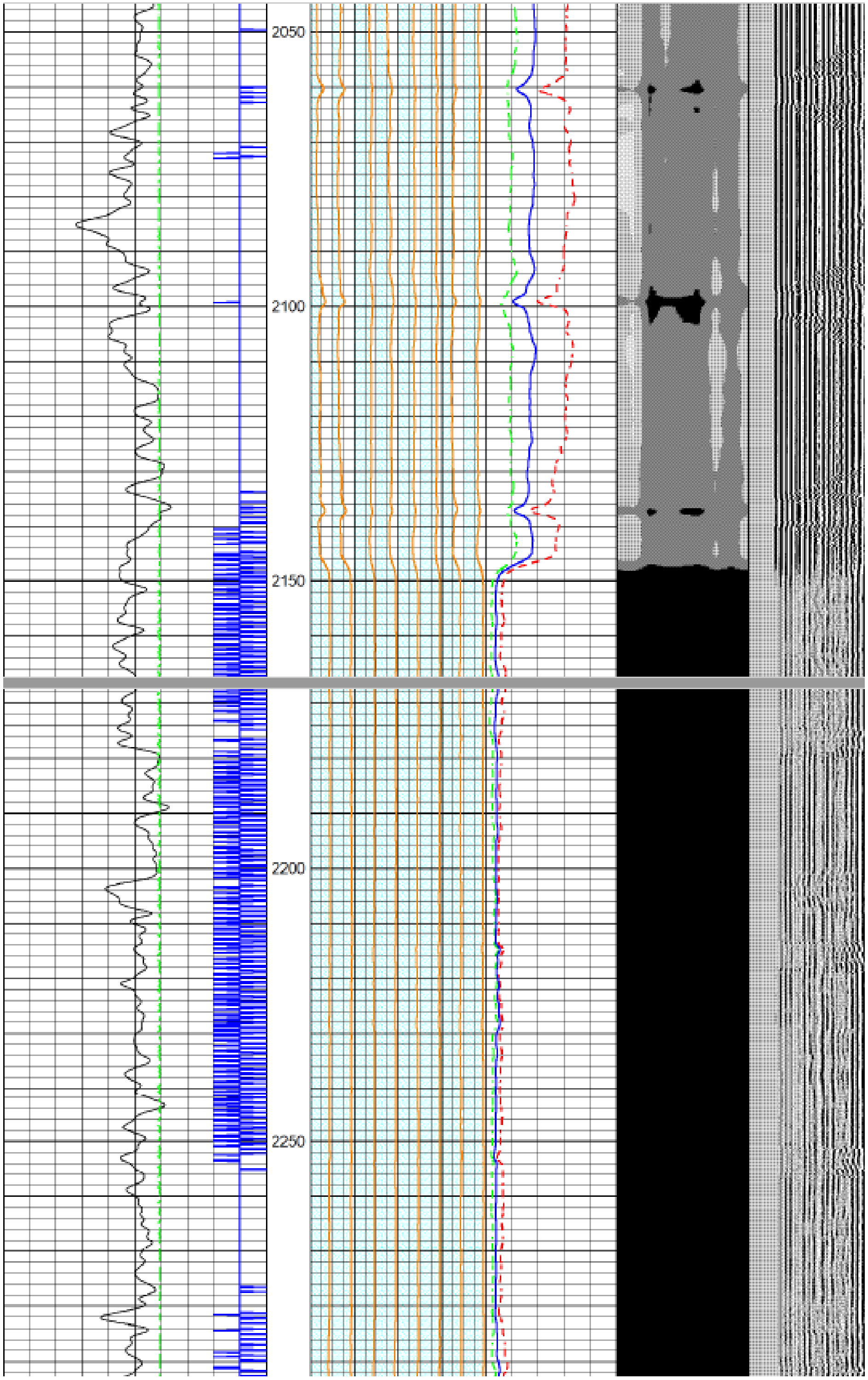
PROD. CASING
NA

PLUGGING
380 SX in 1st Open Hole from 7854-6640. Kickoff at 6640.
457 SX POZ in 2nd Open Hole from 8386 to 6640.
Cement Reatiner at 5500'.
Reporting 1175 Sx Class A from Retainer up
422 Below Retainer based on Original P&A Report.
(Corrected P&A Report Submitted 12-21-82. Original 12-9-82).

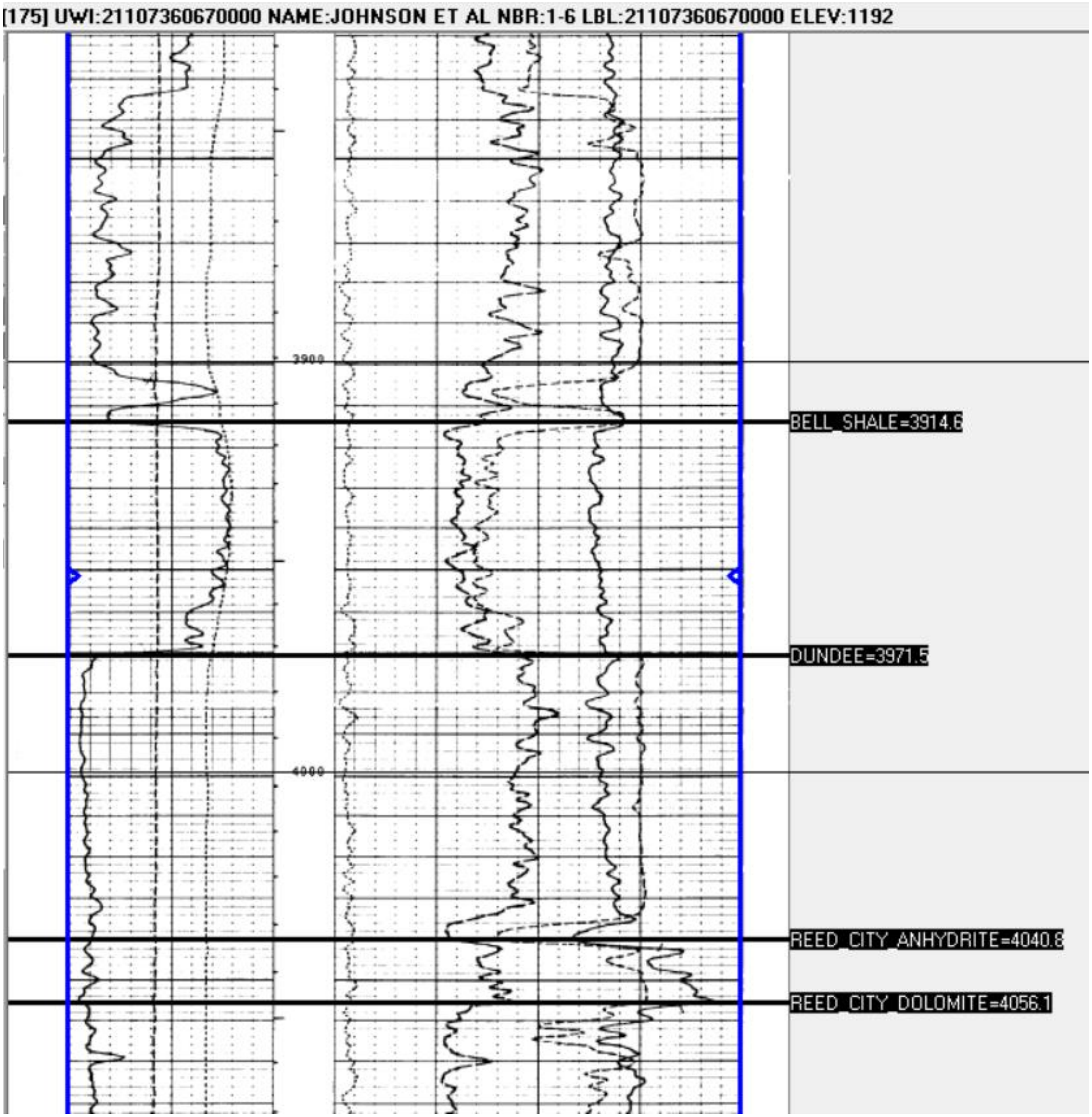
Johnson et al. 1-6 Post-Remediation Wellbore Diagram



Excerpt from Johnson et al. 1-6 CBL, Showing Top of Cement



Johnson et al. 1-6 CDL, Showing Top of Dundee and Bell Shale



5. If a well is proposed to be converted to a disposal well, a copy of the completion report, together with the written geologic description log or record and borehole and stratum evaluation logs for the well.

This is a modification request to a new drill well. The information provided in the previously approved permit application #61330 remains applicable to the above.

6. Plugging records of all abandoned wells and casing, sealing, and completion records of all other wells and artificial penetrations within the area of influence of the proposed well location and a map identifying all such artificial penetrations. An applicant shall also submit a plan reflecting the steps or modifications believed necessary to prevent proposed injected waste products from migrating up, into, or through inadequately plugged, sealed, or completed wells.

The information provided in the previously approved permit application #61330 remains applicable to the above. Appendix 1 of the original of the original application remains valid. *Appendix 1.0; Cement, plugging, and well histories of all wells in the AOR that penetrate the injection or confining horizons*. The Johnson 1-6 et al. has been remediated.

As presented in these previously submitted and approved material, no corrective action plan is required because there are no records indicating any wellbore in the AOR penetrating the confining or injection zone that has not been properly plugged, abandoned, or remediated.

7. A map showing the vertical and areal extent of surface waters and subsurface aquifers containing water with less than 10,000-ppm total dissolved solids. A summary of the present and potential future use of the waters must accompany the map.

The applicant has updated this section to reflect refined definitions and data. This is not to replace, but to compliment what was originally submitted as part of approved permit number 61330.

For ease of reference, surface water features and their areal extent are illustrated in previously submitted Figure 8.

- **Figure 18 is a surface soil map from the original application** collected from soil surveys from over 308 hydrological test holes and approximately 60 piezometers cataloging over 33,833 feet of groundwater and soil data compiled by W.A. Menley over the AOR. Contours present the elevation of the water table within the Upper Unit F and are shown on top of the soil catalogue. This water table maps also demonstrate the direction of flow of water through the AOR.

- **Figure 19 is a map from the original application showing the static water level** as encountered in water wells within the AOR, presented as depth in feet below ground level. These contours are generated principally from reported and measured static water levels as extensively gathered and made available by the Michigan State ground water mapping project and Michigan Department of Environment Great Lakes and Energy, Water Division. Potentiometric surface values are used to determine the general flow direction of water through the AOR, implying a general northwestern depth increase (flow direction) within the AOR.

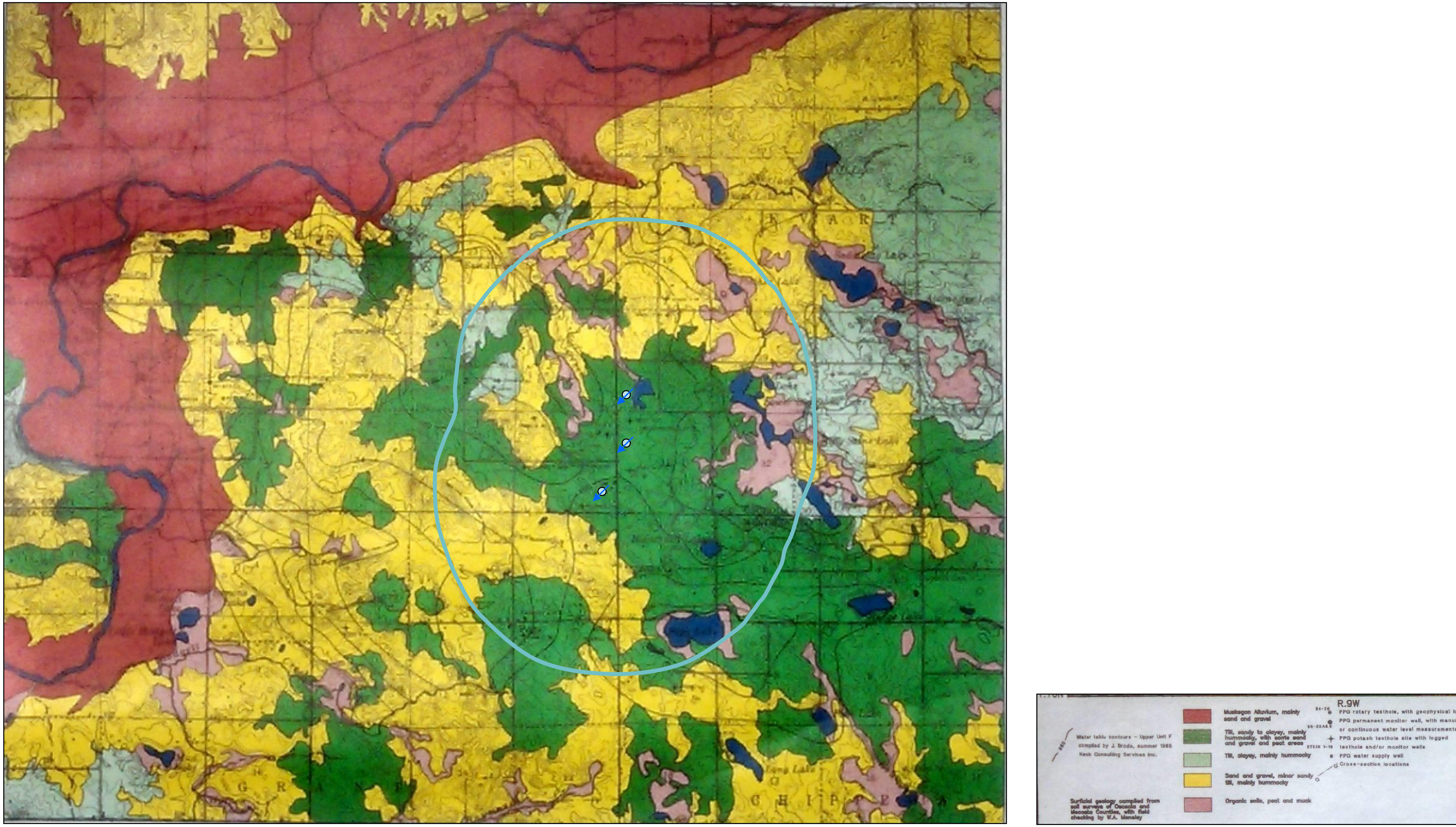


Figure 18. A surfical geological soil map compiled from soil surveys from over 308 hydrological test holes and approximately 60 piezometers cataloging over 33,833 feet of groundwater and soil data compiled by W.A. Menley over the AOR. Contours showing the observed water table of the Upper Unit F are shown on top of the soil catalogue. The AOR radius is also shown.

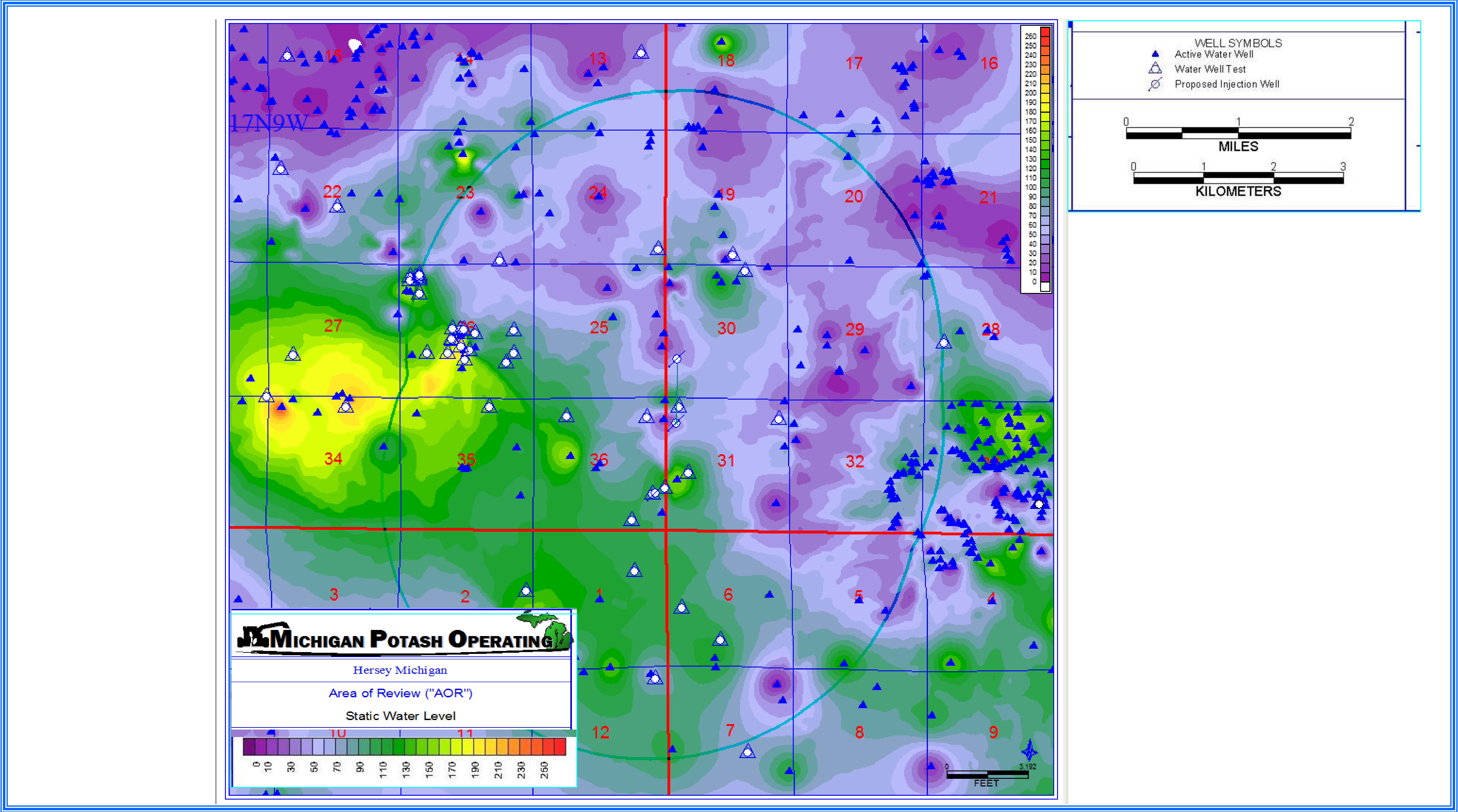


Figure 19. is a map showing the static water level as encountered in every water well within the AOR showing also then, the areal extent. The static water level is shown as feet below ground level.

- **Figure 24 from the original application and shows the vertical and areal extent of subsurface aquifers,** within the AOR, identifying the base of the lowermost aquifer above which groundwater contains less than 10,000-ppm total dissolved solids. The formations are shown in proportion to the depth associated with the proposed injection horizon, on a 1:1 ratio, with no vertical exaggeration. This presentation was done intentionally to illustrate the amount of interlayered and non-permeable intervals between any potential injection zone and the lowermost USDW.

For ease of reference, this figure has been extracted & shown here, and arrows at the Reed City Dolomite Interval have been added to facilitate an understanding of this permit modification request:

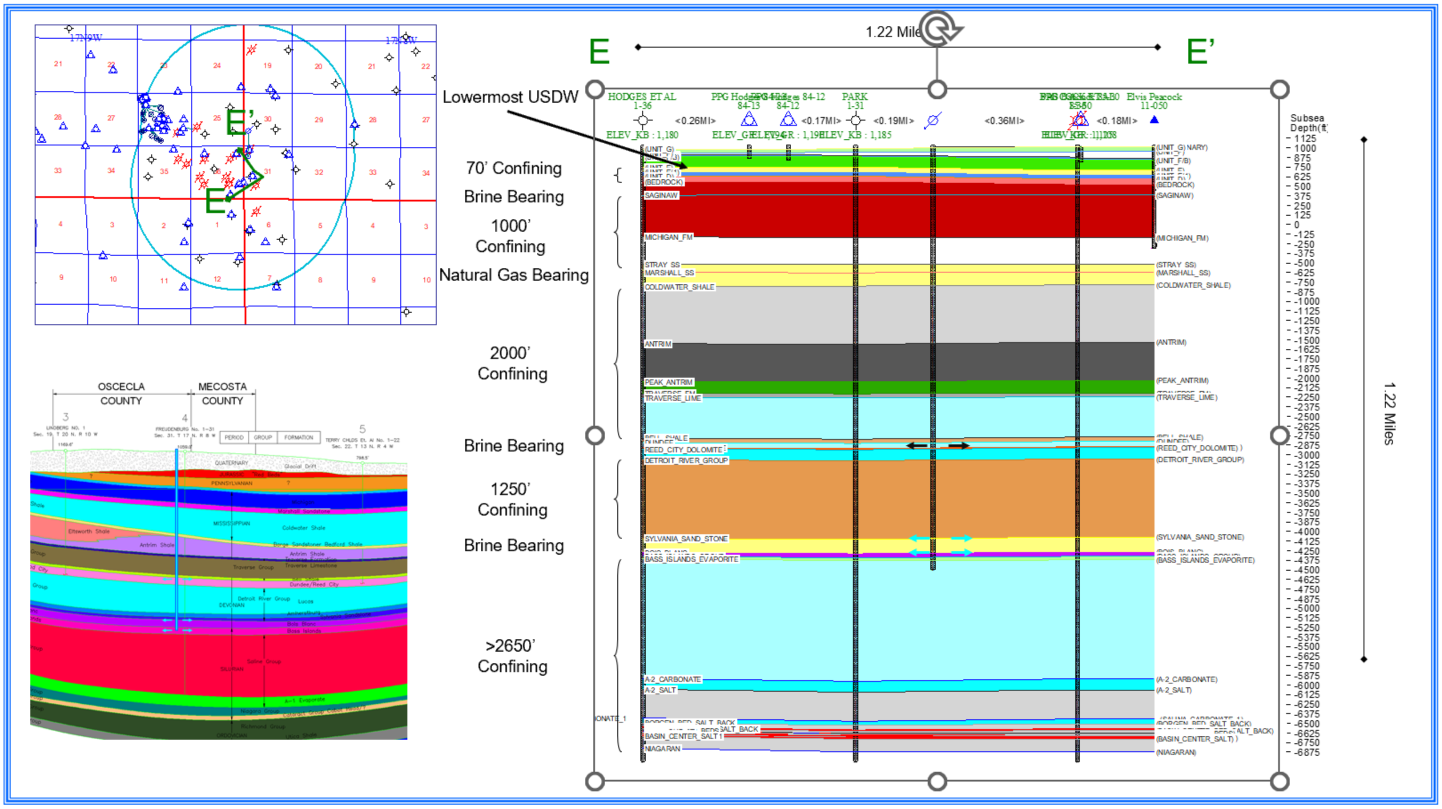


Figure 24 shows the USDWs in relation to the proposed injection zones in the immediate proximity of the AOR. The larger cross section is intentionally shown on a 1:1 ratio, with no vertical exaggeration to illustrate the amount of inte-rlayered and non-permeable intervals between any potential injection zone and any potential USDW.

An Underground Source of Drinking Water is defined by the EPA as 10,000 ppm TDS or less; however a 2018 hydrological investigation identified unsafe levels of naturally occurring arsenic below +/- 200' in an area north of the proposed MPC 8D injection well. Although below 10,000 ppm, this source is prohibited from human consumption, or a source of underground drinking water and can only be used for industrial or agricultural purpose.

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
DRINKING WATER LABORATORY
USEPA Region V Drinking Water Cert. No. MI00003
P.O. Box 30270
Lansing, MI 48909
TEL: (517) 335-8184
FAX: (517) 335-8562

RECEIVED SEP 0 4 2018

Sample Number
LH99842

Official Laboratory Report

Report To: PEARSON DRILLING CO
6100 W BLUE RD
LAKE CITY MI 49651

System Name/Owner: MICHIGAN POTESH
Collection Address: 120TH AVE,HERSEY
Collected By: JORDAN SMITH
Township/Well#/Section: EVART/FILLMORE #1/31
County: Osceola
Sample Point: WELL HEAD
Water System: Other

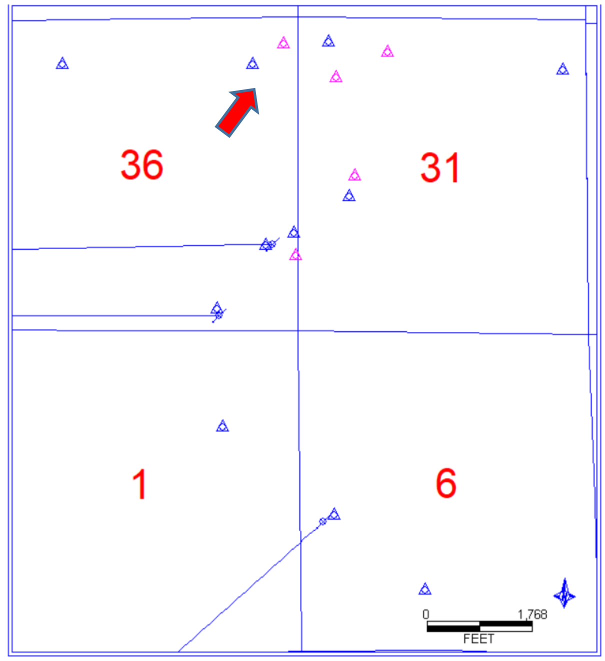
WSSN/Pool ID:
Source: Other
Site Code:
Collector: Other
Date Collected: 08/15/2018 14:41
Date Received: 08/17/2018 11:01
Purpose: Other

TESTING INFORMATION			REGULATORY INFORMATION			
Analyte Name	Result (mg/L)	Date Tested	RL (mg/L)	MCL/AL (mg/L)	Method	CAS #
Arsenic	0.012	08/24/2018	0.002	0.010	EPA 200.8	7440-38-2
Barium	0.05	08/24/2018	0.01	2	EPA 200.8	7440-39-3
Cadmium	Not detected	08/24/2018	0.0003	0.005	EPA 200.8	7440-43-9
Chromium	Not detected	08/24/2018	0.01	0.1	EPA 200.8	7440-47-3
Copper	Not detected	08/24/2018	0.05	1.3	EPA 200.8	7440-50-8
Iron	0.33	08/24/2018	0.02		EPA 200.8	7439-89-6
Lead	Not detected	08/24/2018	0.001	0.015	EPA 200.8	7439-92-1
Manganese	0.04	08/24/2018	0.01		EPA 200.8	7439-96-5
Mercury	Not detected	08/24/2018	0.0001	0.002	EPA 200.8	7439-97-6
Selenium	Not detected	08/24/2018	0.001	0.05	EPA 200.8	7782-49-2
Zinc	0.05	08/24/2018	0.01		EPA 200.8	7440-66-6

The analyses performed by the MDEQ Drinking Water Laboratory were conducted using methods approved by the U.S. Environmental Protection Agency in accordance with the Safe Drinking Water Act, 40 CFR parts 141-143, and other regulatory agencies as appropriate.

Your local health department has detailed information about the quality of drinking water in your area. If you have concerns about the health risks related to the test results of your sample, please contact the Environmental Health Section through the address and telephone number listed below:

Central Michigan District Health Dept.
115 North Sears Street
Reed City, MI 49677
231 832-5532



The well log showing the screened depth at 240-280 in the F Unit with arsenic is shown below.

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No: 67-05-036-010-00	**Permit No:** JBES-AY4LKH	**County:** Osceola	**Township:** Evart

Well ID: 67000007649

Elevation:

Latitude: 43.826035

Longitude: -85.322044

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	**Section:**	**Well Status:**	**WSSN:**	**Source ID/Well No:**
17N 08W	31	Active		

Distance and Direction from Road Intersection:
Filmore Well. Approx 1/4 mile north of intersection of 120th Ave and Schofield Road east side of 120th Ave.

Well Owner: Double ZS Ranch

Well Address:
243 120th Ave
Hersey, MI 49639

Owner Address:
900 NW Monroe
Grand Rapids, MI 49503

Drilling Method: Rotary
Well Depth: 282.00 ft. **Well Use:** Irrigation
Well Type: New **Date Completed:** 8/10/2018

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Spline joint/CertaLok
Casing Fitting: None

Diameter: 6.90 in. to 100.00 ft. depth SDR: 21.00
6.90 in. to 240.00 ft. depth SDR: 17.00

Borehole: 10.62 in. to 283.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 117.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Test pump
Pumping level 206.50 ft. after 2.00 hrs. at 298 GPM

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 5.00 in. **Blank:** 0.00 ft. Above
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
20.00	42.00 ft.	240.00 ft. and 282.00 ft.

Fittings: Other

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	24.00	None	0.00 ft. to 230.00 ft.

Wellhead Completion: Pitless adapter

Formation Description	Thickness	Depth to Bottom
Brown Clay	10.00	10.00
Sand	3.00	13.00
Brown Clay	4.00	17.00
Sand Fine To Medium	22.00	39.00
Gray Clay	57.00	96.00
Sand & Gravel	9.00	105.00
Gray Clay Soft	10.00	115.00
Sand Fine To Medium	6.00	121.00
Gray Clay	19.00	140.00
Sand Fine To Medium	9.00	149.00
Gray Clay	2.00	151.00
Sand Fine	9.00	160.00
Gray Clay	4.00	164.00

(Continued On Page 2)

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name: John Pearson
Employment: Employee

(Continued on page 2)

General Remarks:
Other Remarks: Screen Fittings:6.25"x6"x5"fpt

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Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No: 67-05-036-010-00	Permit No: JBES-AY4LKH	County: Osceola			Township: Evart	
Well ID: 67000007649		Town/Range: 17N 08W	Section: 31	Well Status: Active	WSSN:	Source ID/Well No:
Elevation:		Distance and Direction from Road Intersection: Filmore Well. Approx 1/4 mile north of intersection of 120th Ave and Schofield Road east side of 120th Ave.				
Latitude: 43.825597		Well Owner: Double ZS Ranch				
Longitude: -85.324105		Well Address: 243 120th Ave Hersey, MI 49639			Owner Address: 900 NW Monroe Grand Rapids, MI 49503	
Method of Collection: GPS Std Positioning Svc SA Off						

(Continued from Page 1)

Formation Description	Thickness	Depth to Bottom
Sand Silty	11.00	175.00
Gray Clay	3.00	178.00
Sand Fine To Coarse	17.00	195.00
Gray Clay	2.00	197.00
Sand Fine To Medium	20.00	217.00
Gray Clay	1.00	218.00
Sand Fine To Medium	12.00	230.00
Gray Clay	4.00	234.00
Sand Fine Silty	7.00	241.00
Sand Fine To Medium	41.00	282.00
Gray Clay W/Gravel	11.00	293.00
Gray Clay	6.00	299.00
Sand Fine To Medium	3.00	302.00
Gray Clay Hard	56.00	358.00

OTHER REMARKS:
Screen Fittings:6.25"x6"x5"fpt

Contractor Type: Water Well Drilling Contractor **Reg No:** 57-1943
Business Name: Pearson Drilling Co
Business Address: 6100 W Blue Road, Lake City, MI, 49651

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

[signature] 4-24-19

Signature of Registered Contractor **Date**

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Discussion of Regional Hydrogeology

The area of the proposed facilities are mantled by glacial drift, the result of multiple periods of glaciation in central Michigan.

The surficial geology in the area is made up of water laid moraine and outwash deposits. The area within the AOR occupies an interlobate position between the Michigan Lobe to the west and the Saginaw and Erie Lobes to the east and south during the final glaciation of Michigan. Glaciofluvial and glaciolacustrine sediments were deposited into the interlobate area and the Muskegon Valley formed the major outlet channel for glacial melt water. Because the major ice flow axes were governed by the major topographic elements of the Great Lakes Region, it is probable that similar ice lobes occupied similar positions during earlier glaciations as well. Thus, the stratigraphic sequence encountered in the surface in the plant area may be expected to have sediments which were deposited in similar interlobate depositional environments during each episode of continental glaciation of North America.

Materials representative of sedimentation in several different depositional environments have been identified within the AOR. These include: 1) till - sediment deposited directly from a glacier by lodgment or melt out and without subsequent re-sedimentation by melt water; 2) stagnant ice deposits - sediment deposited in an ice marginal environment where the ice is relatively immobile; 3) glaciolacustrine deposits - sediment deposited in ice marginal glacial 'lakes under relatively low energy conditions; and 4) glaciofluvial deposits - sediment deposited in an ice marginal environment under relatively high energy conditions.

Discussion of Local (AOR) Hydrogeology

Bedrock is identified as Jurassic age ‘Red Beds,’ the top of which occurs at approximately 650’ below ground level, below the glacial till.

According to the Geologic Atlas of Michigan compiled by the Department of Geology, Western Michigan University in 1981, Red Beds of Jurassic age should be encountered at the bedrock surface. All of the test holes which penetrated the bedrock surface have encountered red sandstone and siltstone inter-bedded with gypsum.

The "Red Bed" sequence made up of red sandstone and siltstone inter-bedded with anhydrite of Jurassic age, forms the uppermost bedrock formation encountered in the AOR. The greatest depth at which potable water can be obtained is considered to be the top of the bedrock surface (i.e., base of the glacial till).

The base of local groundwater exploitation, that is, the greatest depth at which potable groundwater can be obtained, has been determined to be the bedrock surface. Historically, all of the water-bearing zones tested in the AOR that are at or below the bedrock surface yield saline water, with greater than > 35,000 mg/L concentration, (Hydrogeology of Part of Osceola and Mecosta Counties, Michigan, W.A. Menley 3/1985).

Between 1983 and 1989, over 308 hydrological test holes and approximately 60 piezometers cataloging over 33,833 feet of groundwater and soil data was amalgamated for the purposes of adequately understanding and protecting groundwater within the Michigan Potash Operating AOR. The area has been extensively studied from 1983 to 1989 for the sole purpose of hydrological investigation. These test holes and all the associated data has been comprehensively reviewed by the applicant and the data incorporated herein.

- **Figure 9 is a map from the original application showing hydro-geological investigation wells** from the original application drilled for the sole purpose of understanding, in order to protect, the groundwater and USDW within the AOR. These well locations have been used, in addition to water wells, to test and map the hydrological units and associated static ground water level.

- **Figure 10 is a stratigraphic column** from the original application describing the glacial till and sources of USDWs and the source of USDWs as extensively mapped and defined by W.A. Menley between 1983 and 1989. Glacial Deposits are highly variable, especially closer to ground level. Depths approximate those encountered throughout the AOR. A detailed description of each hydrological and potential USDW follows Figure 10.

Stratigraphic Column of the Hydrological Units, MPC Area

Stratigraphic Column and Nomenclature of the Hydrological Units in the AOR, as Defined by W.A. Menley

K			Valley train outwash	Sand and gravel coarsening upward, fine to v-coarse sand, pebbles and cobbles, locally cemented, typical of a high energy glacio-fluvial environment.	~ 0’-60’ Below GL
J			Glaciolacustrine	Clay and silty clay, laminated to bedded, some interbeds of silt, massive silty sandy clay with pebbles common, typical of a low energy glacio-fluvial environment	~ 0’-60’ Below GL
H			Stagnant ice/outwash	Silty sandy clay, some pebbles, in part stratified, typical of a stagnant ice depositional environment	~ 0’-60’ Below GL
G			Till	Sandy clay till, sparse coarse fraction, typical of a sub glacial depositional environment	~ 0’-60’ Below GL
		G/1	Glaciolacustrine	Clay and silty clay, laminated to bedded, some interbeds of silt, massive silty sandy clay with pebbles common.	~ 0’-60’ Below GL
F	F/1	F/1/d	Outwash	Medium to coarse sand minor gravel, interbeds of silty clay	~ 60’-220’ Below GL
		F/1/c	Glaciolacustrine	Clay and silty clay, laminated to bedded, some interbeds of silt, massive silty sandy clay with pebbles common.	
		F/1/b	Outwash	Medium to coarse sand minor gravel, interbeds of silty clay	

	F/1/a	Glaciolacustrine	Clay and silty clay, laminated to bedded, some interbeds of silt, massive silty sandy clay with pebbles common.	
	Lower F (F/B)	Outwash	Medium to coarse sand, minor silty clay interbeds, minor fine gravel interbeds, K= 650/gpd/sq.ft. Principle USDW when away from surface charge.	~ -80'-220' Below GL Natural Arsenic detected in AOR
E	Upper E	Stagnant ice	Silty sandy clay, some pebbles, in part stratified	~ 220'-300' Below GL
	E/1	Outwash	Medium to coarse sand minor gravel, interbeds of silty clay, K = 600 gpd/sq.ft, LOWEST USDW.	~ 300'-400' Below GL
D		Till	Sandy clay till, sparse coarse fraction	~ 400-620' Below GL
		BEDROCK	Jurassic Red Beds, >35,000 TDS "BRINE" from here to Center of the Earth	~ 580'-620' Below GL

Figure 10 Stratigraphic description of USDW in the AOR.

When in the immediate proximity to surface charge, such as the Muskegon River or a Lake, it is typical to find static water levels at less than 20'-30' Below GL in Units K, J, H, and/or G.
Unit F/1 serves as a plastic clay barrier and confining layer to Unit F. Above sub Unit F/1, perched water tables or unconfined aquifers may be found.

A detailed description of each glacial till deposition feature from shallowest to deepest, is as follows:

Unit K:
Unit K represents the sand and gravel deposits that form the upper part of the alluvial fill along the course of the Muskegon Valley. This unit is well exposed in the Hersey Sand and Gravel pit east of Hersey, located across the Muskegon River. The texture of this unit becomes coarser upward, with coarse clean gravel beds deposited in channels cut into the dominantly sand size overbank deposits. Excellent exposures of these channel sands and overbank deposits can be seen in the high walls of the quarry.

In the gravel pit, the sand and gravel deposits that are being quarried east of 170th Avenue and south of the washing facility are part of older glacio-fluvial deposits that make up Unit F. The sand and gravel deposits west of 170th Avenue and north of the washing plant are part of the alluvial fill along the Muskegon River (Unit K) laid down as part of the outwash deposits during the final de-glaciation of this part of Michigan.

Unit J:
During the final de-glaciation of the study area the Muskegon Valley functioned as a major melt water outlet stream. A melt water valley was incised through the previously deposited Units G and H into Unit F, eroding and removing Sub-Unit F/1 along the course of the Muskegon Valley down to an elevation of about 875 ft. Unit J is made up of fine textured silt and silty clay beds that were deposited in the channel bottom as the channel was in-filled with fine grained alluvial deposits.

Unit H:

Unit H is made up of inter-bedded sand, gravel and till which mantles the hummocky moraine upland in the eastern part of the study area. This unit represents the stagnant ice depositional environment of the final episode of de-glaciation of the study area. Most of the material in Unit H was deposited by melt water on top of stagnant ice. As the ice eventually melted out these materials were re-deposited by slumping and subject to re-sorting by runoff to form the highly variable and complex deposits which form the present land surface in the upland area east and south of the Muskegon River Valley.

Unit G:

Unit G is a silty clay till which is present beneath parts of the hummocky moraine upland east of the Muskegon River deposited during the final glaciation of the study area.

Unit F:

Unit F is a primary aquifer in the AOR. It is a thick sequence of inter-bedded sand and gravel which was encountered in all of the test holes drilled in the study area. Thin interbeds of clay, silty clay and till were encountered within this unit in all test holes. One such interbed has been separately identified as Sub-Unit F/1. The sand and gravel beds are made up mainly of subrounded clasts of igneous, metamorphic and sedimentary rocks. This unit is considered to represent deposition in a high energy glacial outwash environment.

The Muskegon Valley has been incised into Unit F exposing the sand and gravel deposits which have been quarried at the Hersey Sand and Gravel operations east of Hersey. The sand and gravel deposits east of 170th Avenue and south of Hersey Road are part of Unit F.

The hydraulic conductivity of this unit is considered to be about the same as Sub-Unit E/1, that is, k = 600 gpd/ft^2.

The specific yield is considered to be about 0.20. The specific yield is defined as the volume of water released from storage in the aquifer per unit surface area per unit decline of the water table (Freeze and Cherry, 1979, p.61).

The sand beds which overlie Sub-Unit F/1 become finer upward and more silt interbeds are present. A "perched water table" is typically present in the sand overlying Sub-Unit F/1. Similarly, unsaturated sand and gravel beds are typically present beneath Sub-Unit F/1. The presence of unsaturated sands can be detected from the resistivity log. Resistivity values > 100 ohm ft are considered to be indicative of unsaturated sand and gravel. This interpretation has been verified by comparison of the geophysical logs with the water level in nearby wells and auger holes in which direct observation of the position of the water table can be made.

Sub-Unit F/1:

Sub-Unit F/1 is an extensive layer of plastic silty clay to clayey till that is present throughout the study area except where it has been removed by subsequent erosion along the course of the Muskegon Valley or where its continuity has been disrupted in collapse structures.

The Sub-Unit F/1 is a continuous glacio-lacustrine deposit present within Unit F throughout most of the AOR. It serves as a barrier and confining interval to aquifers below.

The Sub-Unit F/1 is a saturated, plastic, silty clay. The upper part of the clay is indistinctly laminated and mottled pink and gray, grading downward to a drab light gray color. In some test holes, floating sand grains are present in the silty clay, at other locations the texture approaches that of a silty clay till. Sub-Unit F/1 ranges in thickness from about 8 - 15 ft beneath the plant site.

In Section 36, Township 17N, Range 9W, Sub-Unit F/1 thickens to about 70 ft. It is made up of 2 to 3 distinct clay beds separated by sandy till.

In Section 26, Township 17N, Range 9W Sub-Unit F/1 is about 40 ft thick. It is made up of an upper and lower silty clay bed separated by a sandy till layer.

Unit E:

This unit is a complex mixture of inter-bedded sand, gravel, and till, characterized by highly variable resistivity and gamma ray log signatures. It is considered to represent deposition in the marginal region of a stagnant continental glacier.

Sub-Unit E/1:

Sub-Unit E/1 is a principle aquifer in the AOR. This unit is present at the base of Unit E throughout the AOR. It is made up of sand and gravel which is considered to have been deposited in a high energy outwash environment. Sub-Unit E/1 is the lowermost useable aquifer present above the base of groundwater exploration, noting that the base of the lowermost USDW is defined as the base of Unit D/top of the underlying Jurassic Red Beds**.**

Due to the number of accessible sources of ground water above the Sub-Unit E-1 at shallower depths, Sub-Unit E-1 is not used as a common source of household water. Prior to 1984, no well was completed in this interval. In 1984, the PPG Bass 84-06 was completed as an observation well in Sub-Unit E/1. This well provided the first information about the aquifer coefficients of Sub-Unit E/1 as well as the hydraulic head and water quality because there were no existing water wells completed in this aquifer in the AOR.

In November of 1984 a short duration pumping test was run to estimate the transmissivity of Sub-Unit E/1. The test was conducted at a rate of 27 US gpm for 2 hrs, followed by a 40 minute recovery test, with a determinate $\text{Transmissivity}_a = T_a = 36{,}000$ gpd/ft, and $k = T/m = 36{,}000/60 = 600$ gpd/ft^2.

Several of the deeper wells, drawing from the Quaternary Unit E/1 are of industrial purpose, owned and operated by Cargil, Inc. 80.00% of all water wells in the area are 200' or shallower, indicating that while groundwater exhibiting TDS less than 10,000 ppm is present in Sub-Unit E/1, it is not typically used for groundwater consumption. Due to the number of accessible sources of ground water above the Sub-Unit E-1, at shallower depths, it is not used as a common source of household water. Industrial use is preferentially taken to deeper horizons, so as to access water that is not being drawn by household use.

Sub-Unit E/1 water quality in PPG Bass 84-06 was determined on a water sample collected January 16, 1985. Water quality results are present in the table to the left of this text. The water is a calcium-sulphate/bicarbonate water having a concentration of about 730 mg/L and a specific conductance of 1,025 micro ohms/cm @ 25°C. The total hardness of the water is about 463 mg/L as $CaCO_3$. Similar to the F Unit in the AOR, The E/1 also has arsenic in its source in offset analysis at the existing Cargil facility. Other average elements in the F, are also shown in the table. In summary, the E/1 unit, which is principally utilized for industrial purposes, is a calcium sulfate (CaSO4) base water as described by W.A. Menley. $CaSO_4$ is the principle natural composition of gypsum and anhydrite.

		E/1	F
Calcium	mg/l	122.4	76
Magnesium	mg/L	38	39
Sodium	mg/L	40.2	11
Potassium	mg/L	2.1	1.86
Bicarbonate	mg/L	205	230
Carbonate	mg/L	0	10
Sulphate	mg/L	258	29.6
Chloride	mg/l	15.8	17.5
Iron	mg/L.	1.1	1.22
Manganese	mg/1	.03	0.04
Nitrate as N	mg/L		6.3
Total Phosphorous as P, mg/L			0.023
PH			7
Specific Conductivity, uahos/cm@25C		1025	552
Concentration	mg/l	730	404
Total Hardness, mgiL as CaCO3	mg/l	463	335
Sum of cations, epm			6.97
Sum of Anions,epm			5.04

<u>Unit</u> <u>D</u>

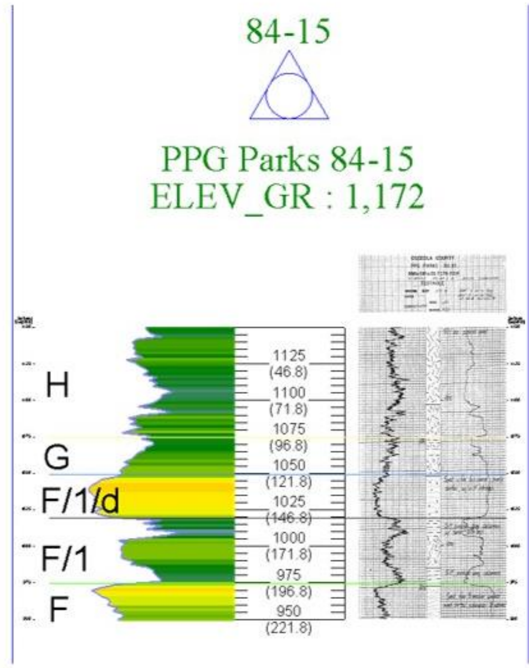
Unit D is glacial till which was encountered overlying the bedrock surface or Unit A throughout the study area. It is a reddish brown to pinkish gray, calcareous sandy till which has very uniform geophysical log characteristics. Unit D represents sedimentation in a glacial depositional environment, either as lodgment till or as till deposited by basal melting of a stagnant ice sheet.

The area is highly rural and future possible use is limited to residential use, agricultural use, or Part 625 use within the immediate area of influence.

No wells are completed within Unit D in the AOR. The deepest screen completion depth within the AOR is no greater than 340’ below ground level (Sub-Unite E/1); another 200’ of Unit D glacial till occurs below and it is assumed that potential sources of water with less than 10,000 TDS may occur until the Jurassic
Red beds. However, it is more likely that the lower most glacial till Unit D, is a clayey, silty, confining layer with minimal to no vertical permeability. Below Unit D, observed TDS is greater than 35,000 in the Jurassic Red beds. This is likely due to the increasing concentration of anhydrite and gypsum deposition as depths are increased.

- **Figure 13 from the original application is a type curve of the natural gamma ray radioactivity of the hydrological unit in the AOR.** This is from the PPG Parks 84-15, located in the NW/4SW/4 Section 31, Evart Township. This is in the immediate proximity to the proposed injection wells. The depth scale shows both measured depth and depth subsea.

Curve at PPG Parks 84-15 Well

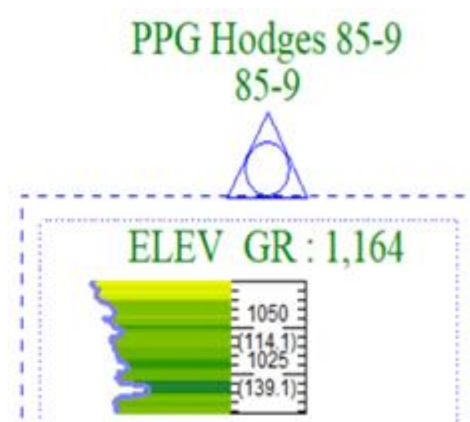


The F/1 Unit which is described as a clay and silty clay, laminated to bedded, some interbeds of silt, massive silty sandy clay with pebbles common, serves as a hydrological barrier between confined and unconfined subsurface water systems.

The F/1 Unit confines the lower F Unit aquifer. It also serves as a vertical transmissibility barrier.

- **Figure 13a is the PPG Hodges 85-9 just to the SW of the proposed** pad location. The F/1 and F Unit were not penetrated at 145' below GL.

- **Figure 14 is a hydrological cross section from the original application** from the original from the above referenced PPG Parks 84-15 hydrological well to the PPG Babcock 85-13 hydrological well located in the NE/4NE/4 Section 36. The cross section moves from South to Northerly. There are control wells in this cross section that penetrate the entire quaternary aquifer system and encounter the Jurassic Bedrock. Also in the cross section is a proposed injection location to give point of reference to the quaternary hydrological units that will be intersected by the proposed injection well.



- **Figure 15 is a hydrological cross section from the original application** extending across the entire AOR, spanning an approximate 3.5 mile length from South to North, crossing the reference wells utilized in Figure **16**.

- **Figure 16 is a hydrological cross section from the original application** extending across the entire AOR, spanning an approximate 5.5 mile length from West to East, crossing the reference wells utilized in Figure D5. Also in the cross section is a proposed injection location to give point of reference to the quaternary hydrological units that will be intersected by the proposed injection well.

- **Figure 17 is a hydrological cross section from the original application** generated by W.A. Menley, spanning and approximate 4.0 mile length from Northwest to Southeast across the AOR.

The extensive geological understanding and well control of the hydrological units within the area give extra assurance that all USDW or potential USDW or any freshwater sources of water of any kind, whatsoever, are thoroughly and adequately protected and monitored.

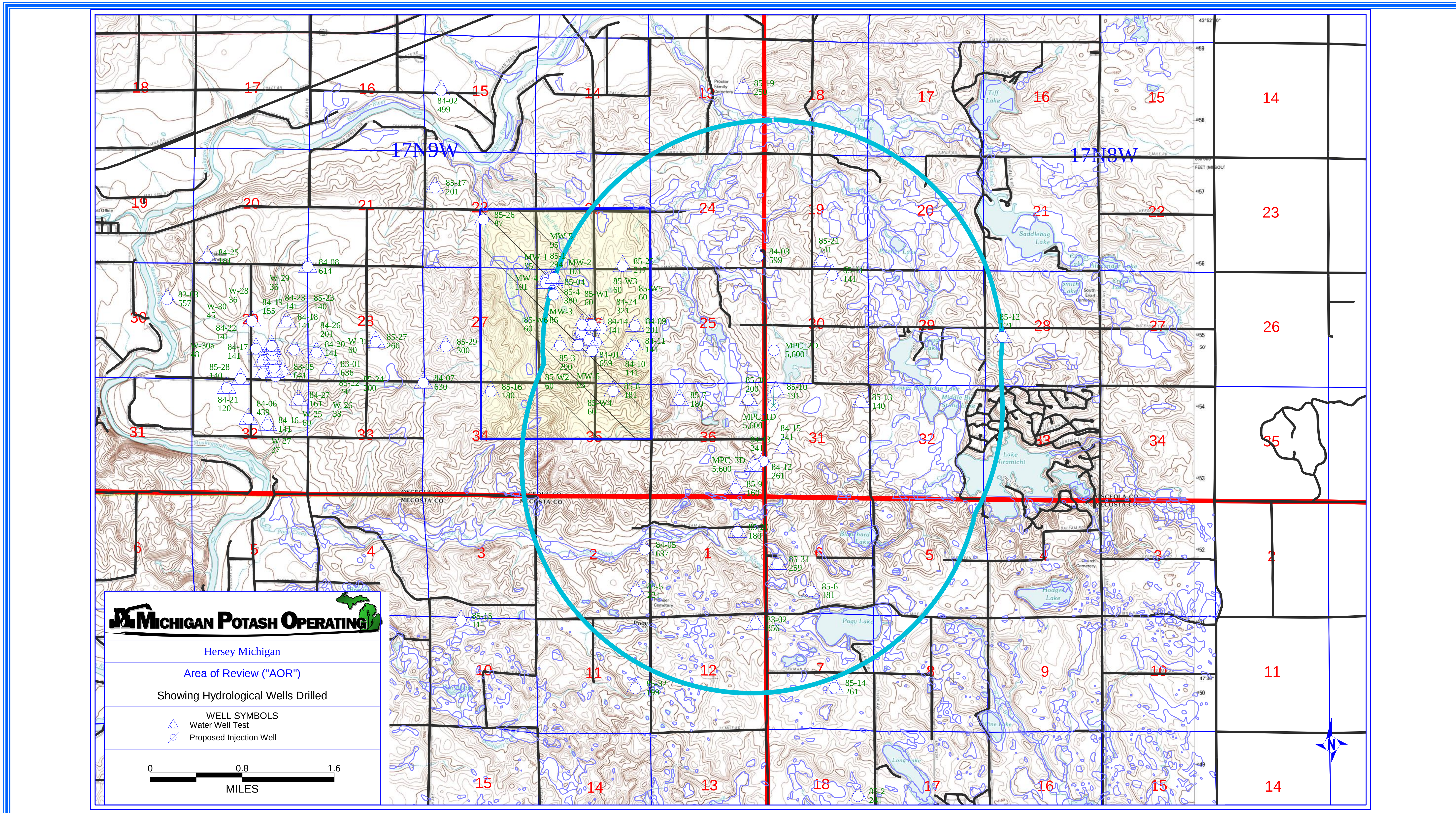


Figure 9. Map showing hydro-geological investigation wells (some, not all) drilled for the sole puporse of understanding, in order to protect, the groundwater and USDW within the AOR.

Michigan Potash Operating, LLC

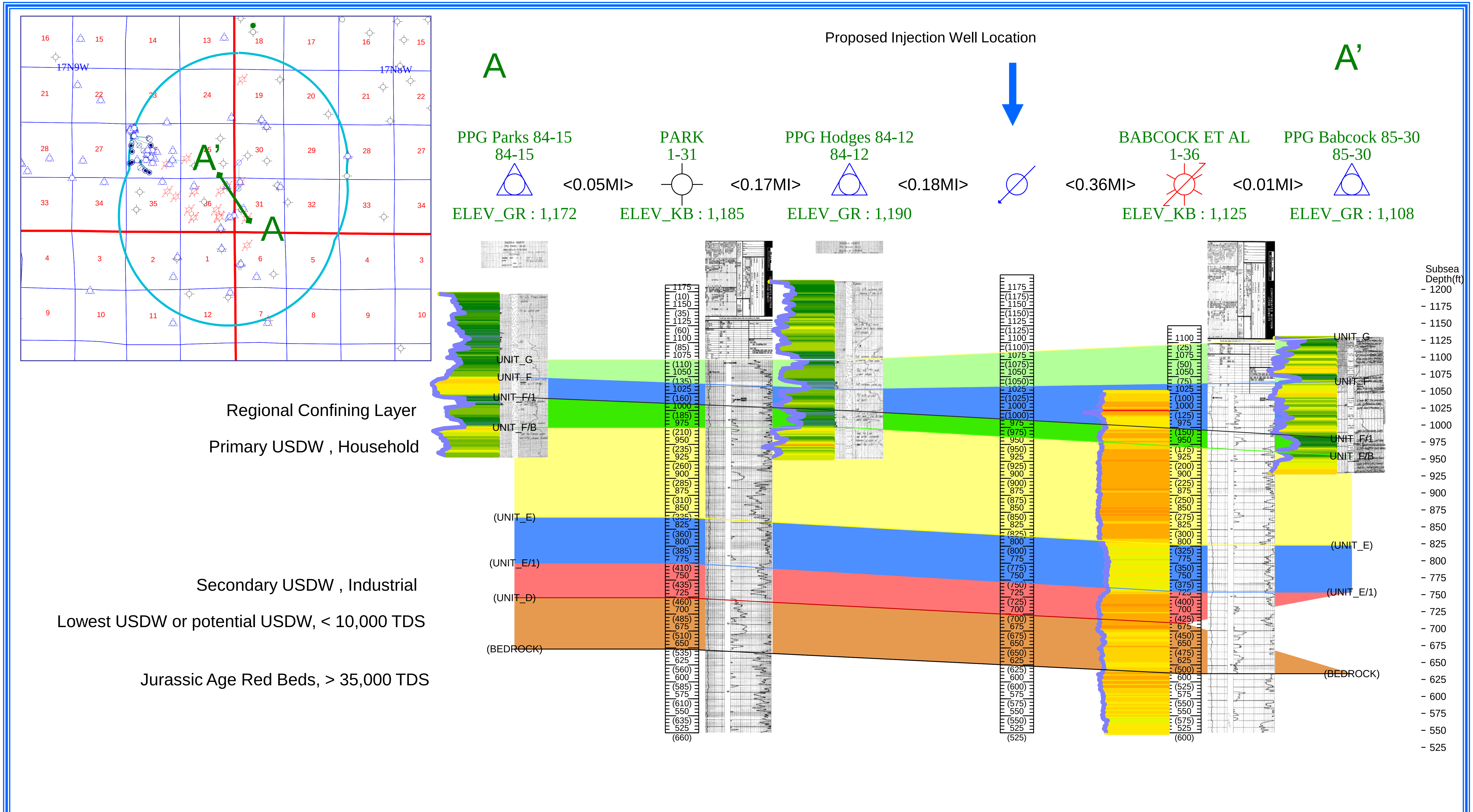


Figure 14. A cross section across in the immediate vicinity of the proposed injection wells. The cross Section A-A’ and the path that it follows from South to Northerly, can be seen in the samll reference map in the upper left corner. This cross section included hydro-geological wells, mineral wells and gas wells.

Michigan Potash Operating, LLC

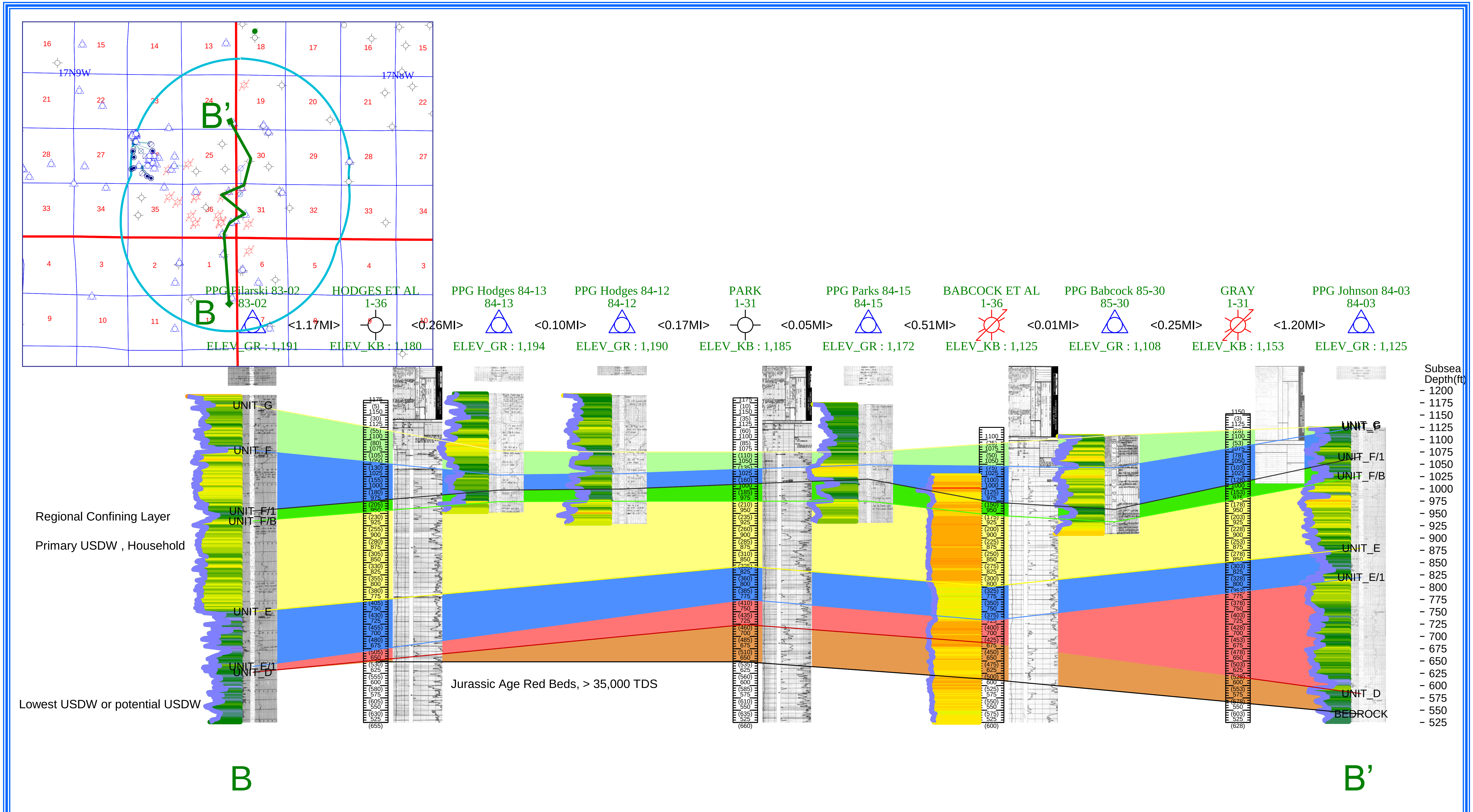


Figure 15. is a cross section extending across the entire AOR, spanning an approximate 3.5 mile length from South to North, crossing the reference wells utilized in Figure D5. The cross section path can be referenced by the small map in the upper left hand corner.

MICHIGAN POTASH OPERATING, LLC

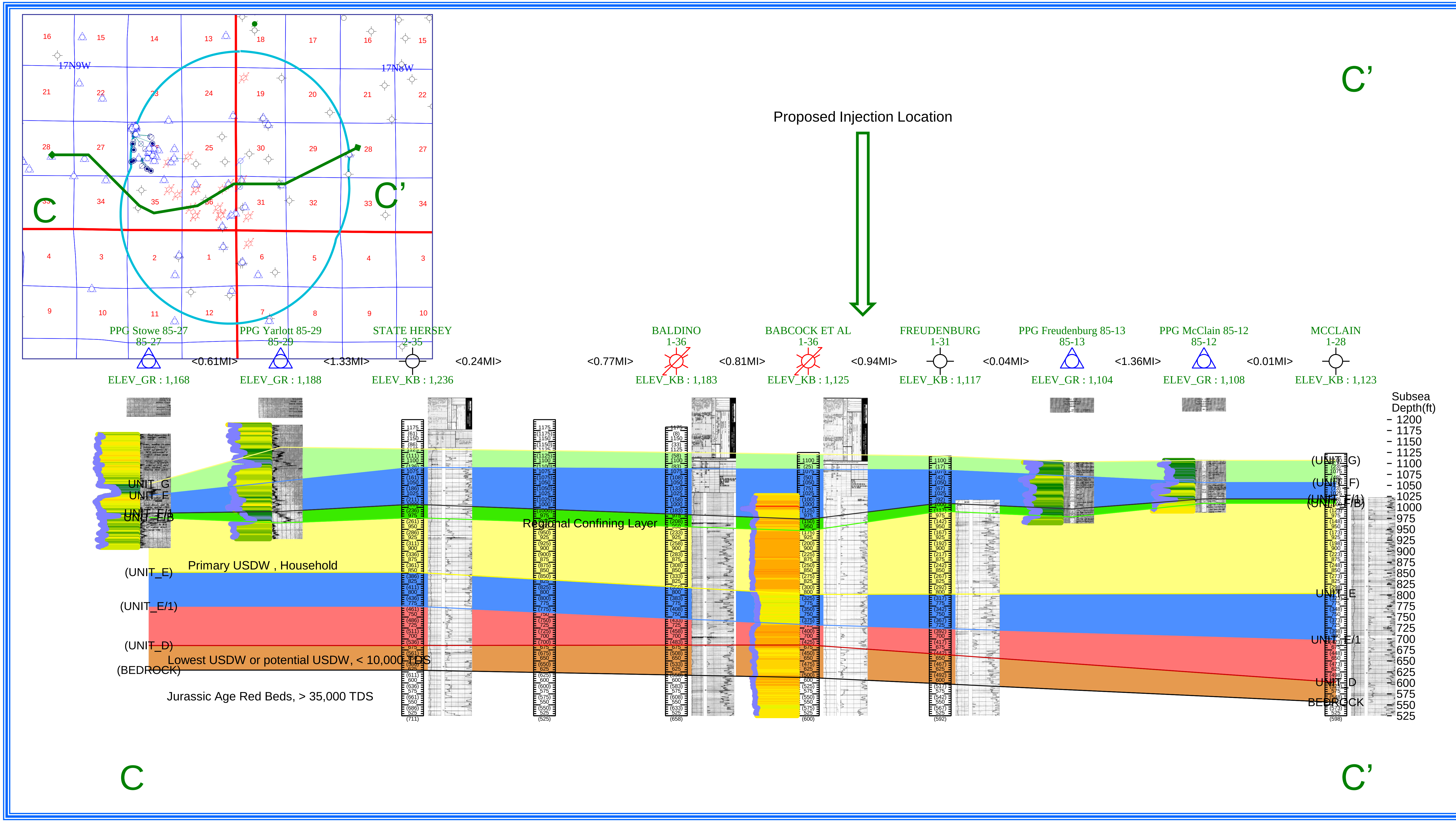


Figure 16. A cross section extending across the entire AOR, spanning an approximate 5.5 mile length from West to East, crossing the reference wells utilized in Figure D5. The cross section path can be referenced by the small map in the upper left hand corner.

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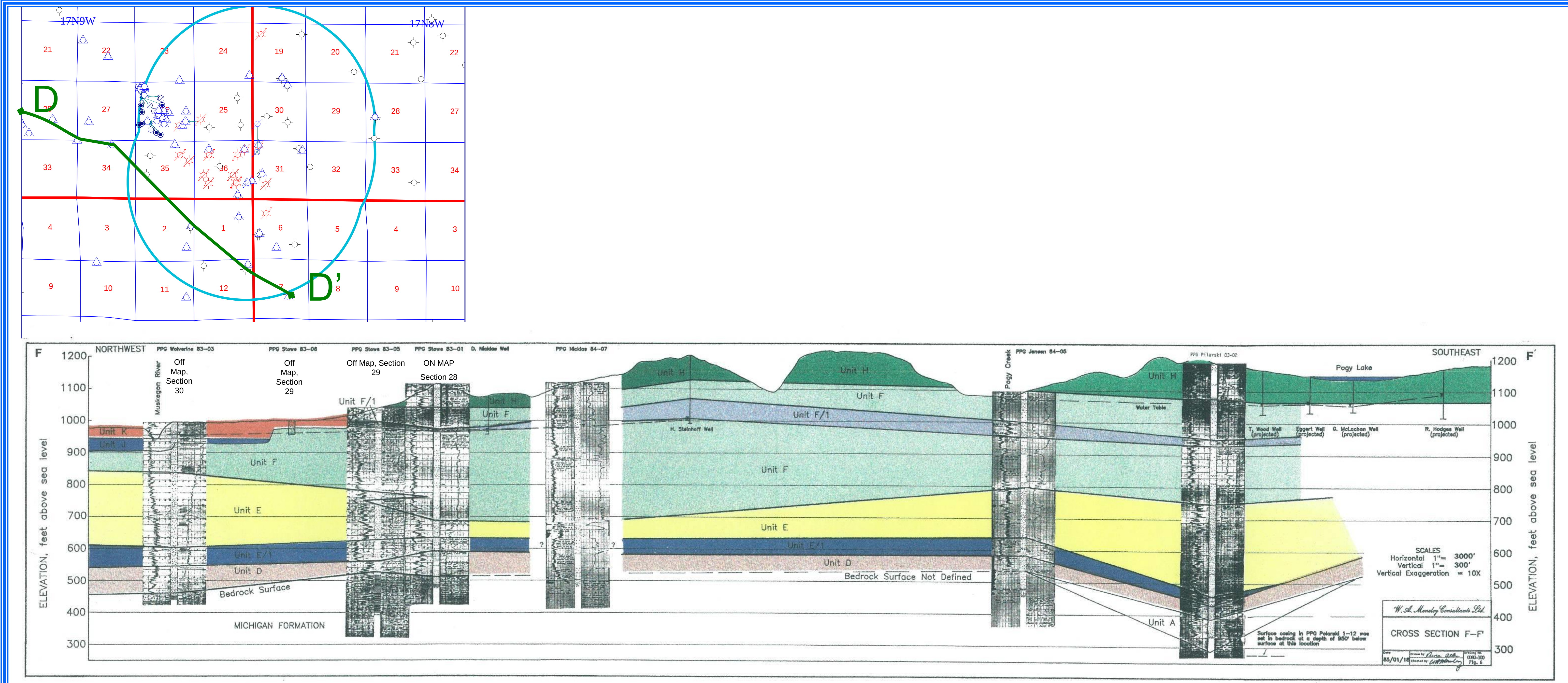

Figure 17. A cross section generated by W.A. Menley, spanning and approximate 4.0 mile length from Northwest to Southeast across the AOR.

Lowermost USDW

As described above, while the lowest underground source of drinking water in the AOR is the Sub Unit E/1 at 340 feet, the base of the lowermost USDW is considered the base of clay/till in unit D above saline Jurassic age Red Beds.

Within the entire AOR, the base of the glacial drift typically occurs approximately 614 feet below ground surface, although the base is at 638 feet below ground surface at the Johnson 1-6D. The base of the glacial till is considered to be the base of the lowermost USDW - an area defined by the USEPA as an aquifer containing less than 10,000 parts per million of total dissolved solids (TDS). Below the glacial till and in the Jurassic Red Beds, , TDS is typically in excess of 35,000.

Quaternary Aquifers

All USDWs described above occur in Quaternary glacial deposits. Quaternary deposits come in direct contact with Jurassic age, bedrock in the AOR, as previously described.

The cross sections and the data compiled by PPG has been incorporated into all regional studies performed over the AOR.

Restated, three main quaternary aquifers exist in the AOR:

- Along Muskegon River - shallow wells (<50 feet) completed in valley fill deposits within the river valley - not a really extensive but can sustain high pumping volumes.
- Unit H - shallow wells (<100 feet) completed in moraine deposits - not a really extensive but adequate for most domestic and agricultural potable water sources.
- Unit F - wells completed from 150 to 250 ft in a really extensive prolific producing outwash deposits

Unit E/1 – 250 to 614 ft water wells are completed principally for industrial use.

Bedrock Aquifers

There are NO Bedrock aquifers in the AOR supplying any water, whether fresh or saline, for any purpose. Within the AOR, which is deep and basin centered, no bedrock aquifers contain water that exhibits a TDS less than 35,000 mg/L (Hydrogeology of Part of Osceola and Mecosta Counties, Michigan, W.A. Menley 3/1985).

For clarification purposes, an aquifer is defined as a system that has the ability to transmit water with porosity and potential permeability. All of the below listed zones within the AOR may have that ability, but are deep, confined, and saturated with extremely highly TDS and chloride content water, and/or oil and natural gas and are not suitable for any use, industrial or otherwise.

Restated, the below systems do not constitute any source of potable or usable source of water for industrial or any other purpose. They are deep, confined, and highly saline. In fact, most of the below mentioned zones are either Oil and Gas bearing reservoirs, or have been used as disposal horizons throughout Michigan and in Osceola or Mecosta County.

Pennsylvanian Aquifer System

Chemical analysis data indicate TDS and chloride content in Palma Sandstone and other Pennsylvanian age systems contain of 234,000 mg/1 and 141,000 mg/1, respectively in Mecosta County.

This system includes the sandstones of the Saginaw and Grand River Formations. It overlies the Mississippian sandstones of the Marshall and Michigan Formations and is overlain by the "Red Beds" of Jurassic time. No areas of subsidence or catastrophic collapse due to solution mining are known to occur in Pennsylvanian rocks.

Mississippian Aquifer System

Chemical analysis data indicates the average TDS and chloride content in the Marshall Sandstone are 254,880 mg/1 and 150,136 mg/l, respectively, in Mecosta County and 267,000 mg/1 and 142,000 mg/l, respectively, in Osceola County.

This system includes the sandstones of the Marshall Sandstone and the Michigan Formation which includes the Bayport Limestone. It overlies the Mississippian Coldwater Shales and is overlain by the Pennsylvanian sandstone and shales. The Mississippian Berea Sandstone is an aquifer in the area of subcrop beneath the glacial drift in southeast Michigan. No areas of subsidence or catastrophic collapse due to solution mining are known to occur in Mississippian rocks.

Devonian Aquifer System

Chemical analysis data indicates an average TDS and chloride content in the Dundee are 305,000 mg/1 and 162,000 mg/1, respectively, in Mecosta County and 270,000 mg/1 and 147,000 mg/1, respectively in Osceola County.

The Devonian Aquifer System includes the sandstones of the Sylvania Sandstone and the carbonate rocks of the Detroit River, Dundee Limestone and Traverse Groups. It overlies evaporate and carbonate rocks of Silurian age and is overlain by shale of Mississippian or Devonian age. No areas of subsidence or catastrophic collapse due to solution mining are known to occur in Devonian rocks.

Silurian Aquifer System

This system includes the carbonate and evaporate rocks of the Niagara Series, the Burnt Bluff and Manistique Groups and the Engadine Dolomite, the Cayugan Series, Salina and Bass Island Groups. It overlies the Silurian shades and carbonates of the Cataract Group and is overlain by Devonian carbonate rocks of the Garden Island Formation and Detroit River Group. Silurian formations are important hydrocarbon producing formations in Michigan. No areas of subsidence or catastrophic collapse due to solution mining are documented for Silurian rocks, though the Salina Group evaporate are the most important source formations for artificial brine production in Michigan.

Source of Information for the Geologic Data and Formation TDS

Chung, P.K., Mississippian Coldwater Formation of the Michigan Basin, Unpublished PhD Dissertation, Michigan State University, 1973.

Dali, A.H., Depositional Environment of the Upper Silurian of the Michigan Basin, Unpublished M.S. Thesis, Michigan State University, 1975.

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Hydrogeology of Parts of Osceola and Mecosta Counties Michigan, Menley, W.A., 1984

Hydrological Supplement, Menley, W.A., May 1986

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Fisher, James H., Traverse Limestone Structure, Plate 4, Dow Chemical Company, Department of Energy, Report No. FE 2346-80, 1980.

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Vugrinovich, R., Patterns of Regional Subsurface Fluid Movement in the Michigan Basin, Michigan Department of Natural Resources, Geological Survey Division, 1986.

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Hydrological Atlas of Michigan, Western Michigan University, Department of Geology, 1981

Oil and gas wells: _IHS Well Data
http://ww2.deq.state.mi.us/GeoWebFace/
Mineral Wells: Michigan Mineral Well Database
http://ww2.deq.state.mi.us/GeoWebFace/
http://gwmap.rsgis.msu.edu//.
http://www. zipcodemapping.com/ez/4993 9.html
http: //www. deq. state.mi.us/part201ss
http:/lwww.deu.state.mi.us/wdspi
http://www.epa.Rov/superftind/sites/npl/rai.htm
http://www.epa. gov/reRion5/waterluic/cUsites.htm

http ://ww2. deq . state. mi.us/mir/
http:/lwww.dnr.state.mi.us/spatialdatalibrary/pdf_maps/mineral_lease_information/osceola lease information.pdf
http://www.dnr.state.mi.us/spatialdataiibrary/pdf_maps/mineral_lease_information/mecosta lease information.pdf
http://www. deq. state. mi.us/well-logs/

Comprehensive Freedom of Information Act Request for prior applications and reviews: Michigan Department of Environment, Great Lakes and Energy, EPA Region V, UIC Division Core and database reviews from the Michigan Geological Repository for Research and Education

8. Geologic maps and stratigraphic cross sections of the local and regional geology.

Section 8 and the corresponding figures contained within previously approved application #61330 are valid and in most cases illustrate the Reed City member of the Dundee formation and the Bell Shale.

- **Figure 32 is a new structure map constructed at the top of the Dundee.**
- **Figure 33 is a new structure map of the Bell Shale**
- **Figure 34 is a new isopach map of the Bell Shale**
- **Figure 35 is a new isopach map of the Reed City Dolomite**

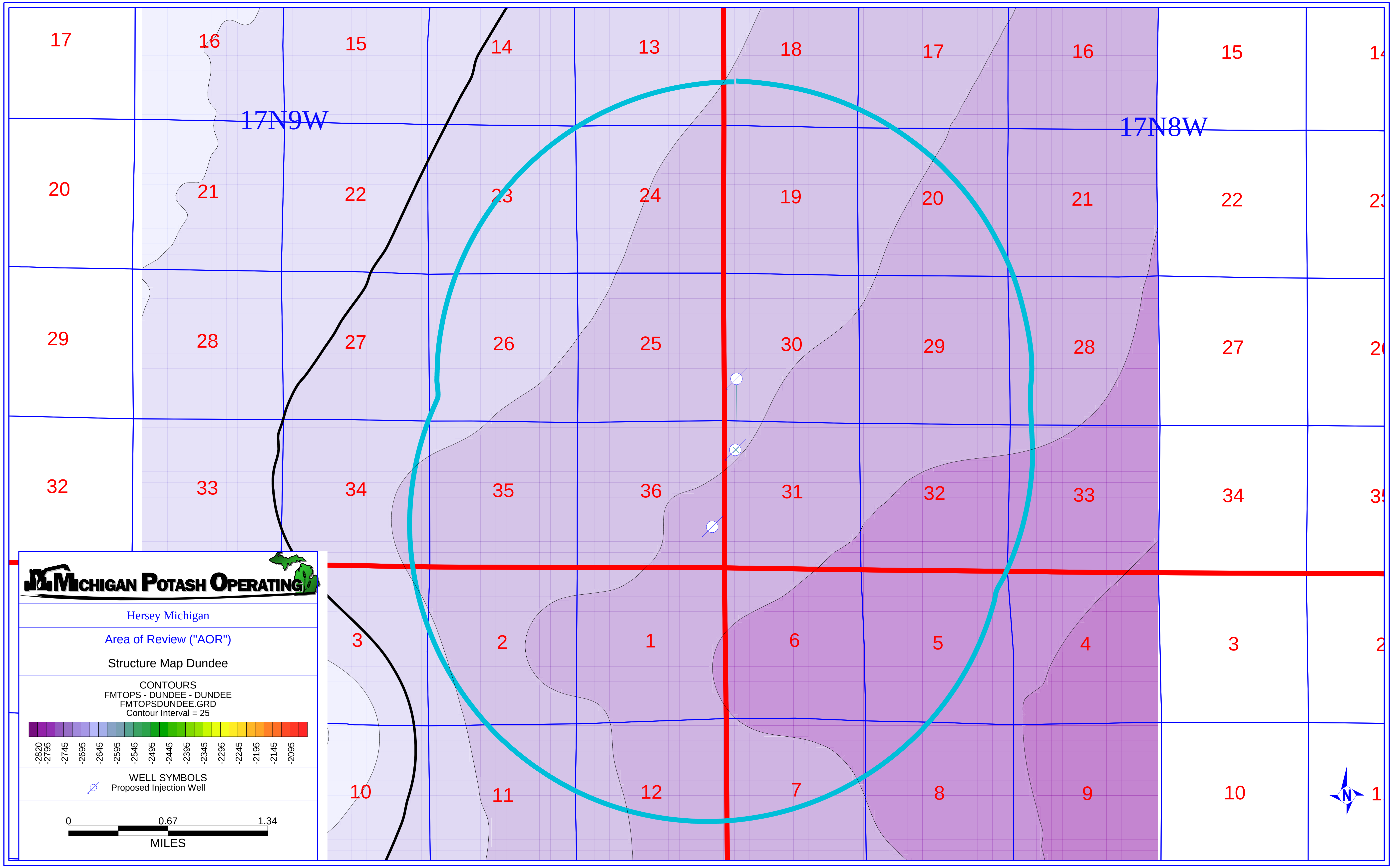

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Figure 32. A Structure map of the Dundee Formation.

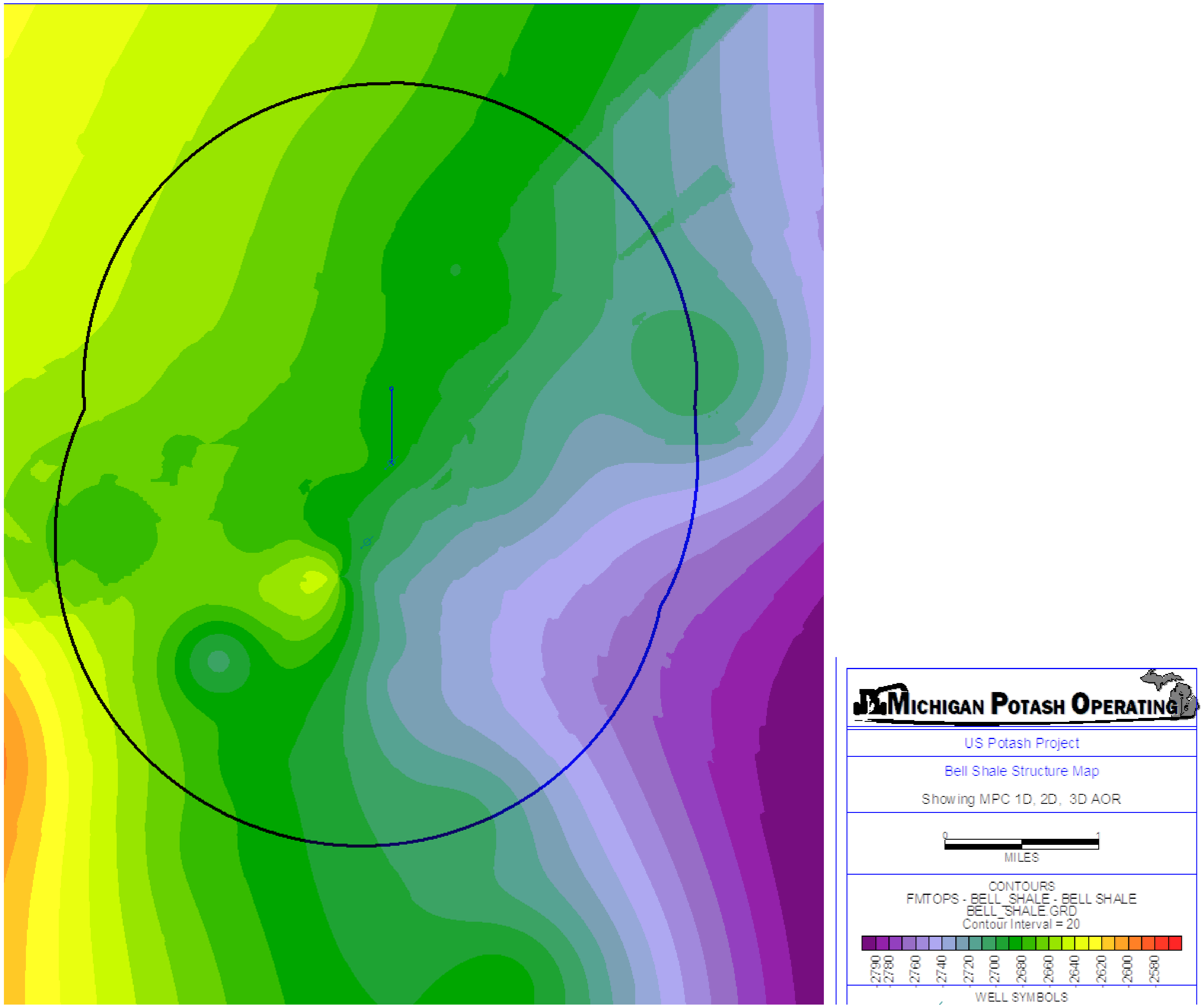


Figure 33. A Structure map of the Bell Shale.

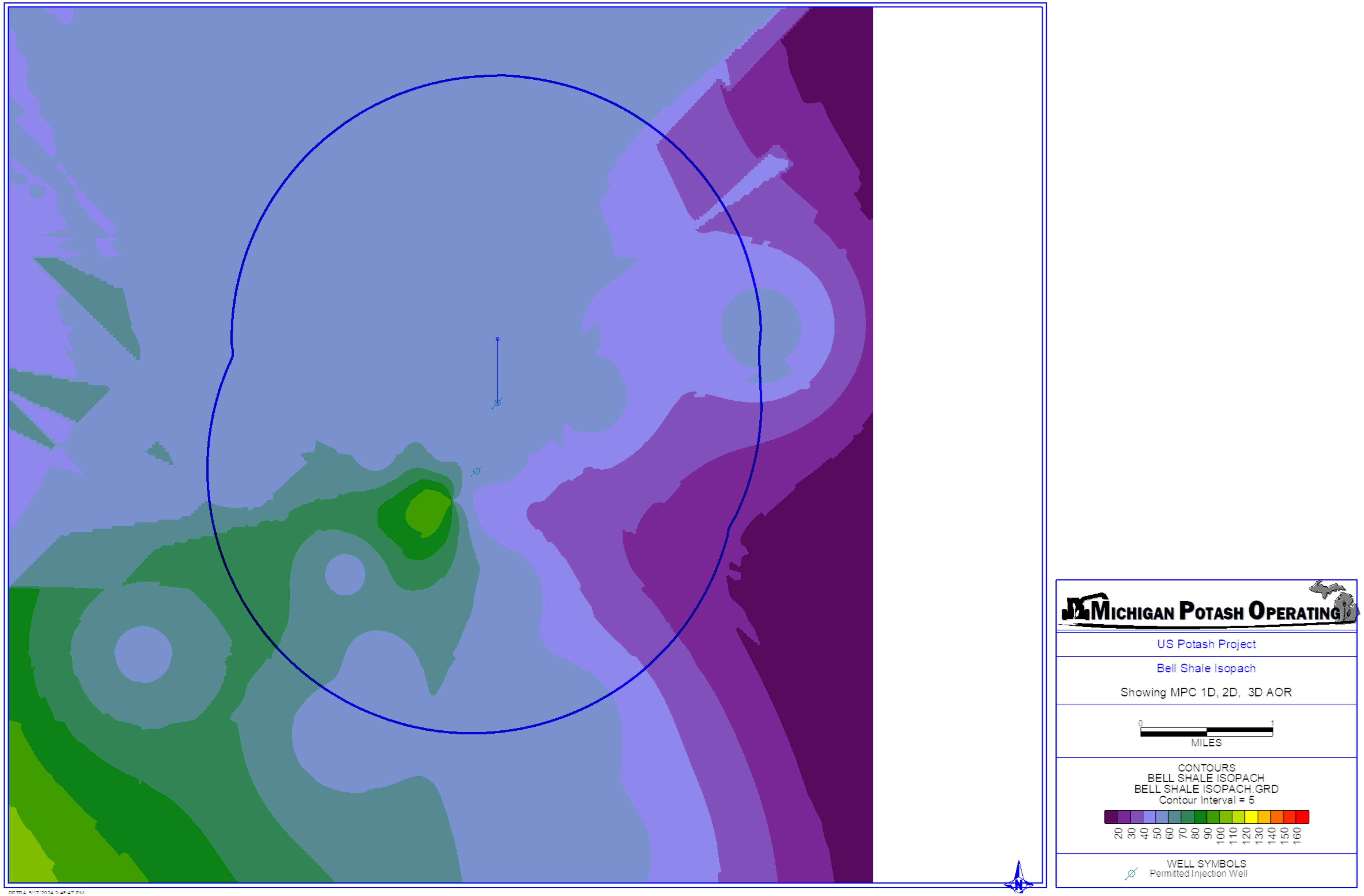


Figure 34. An Isopach map of the Bell Shale.

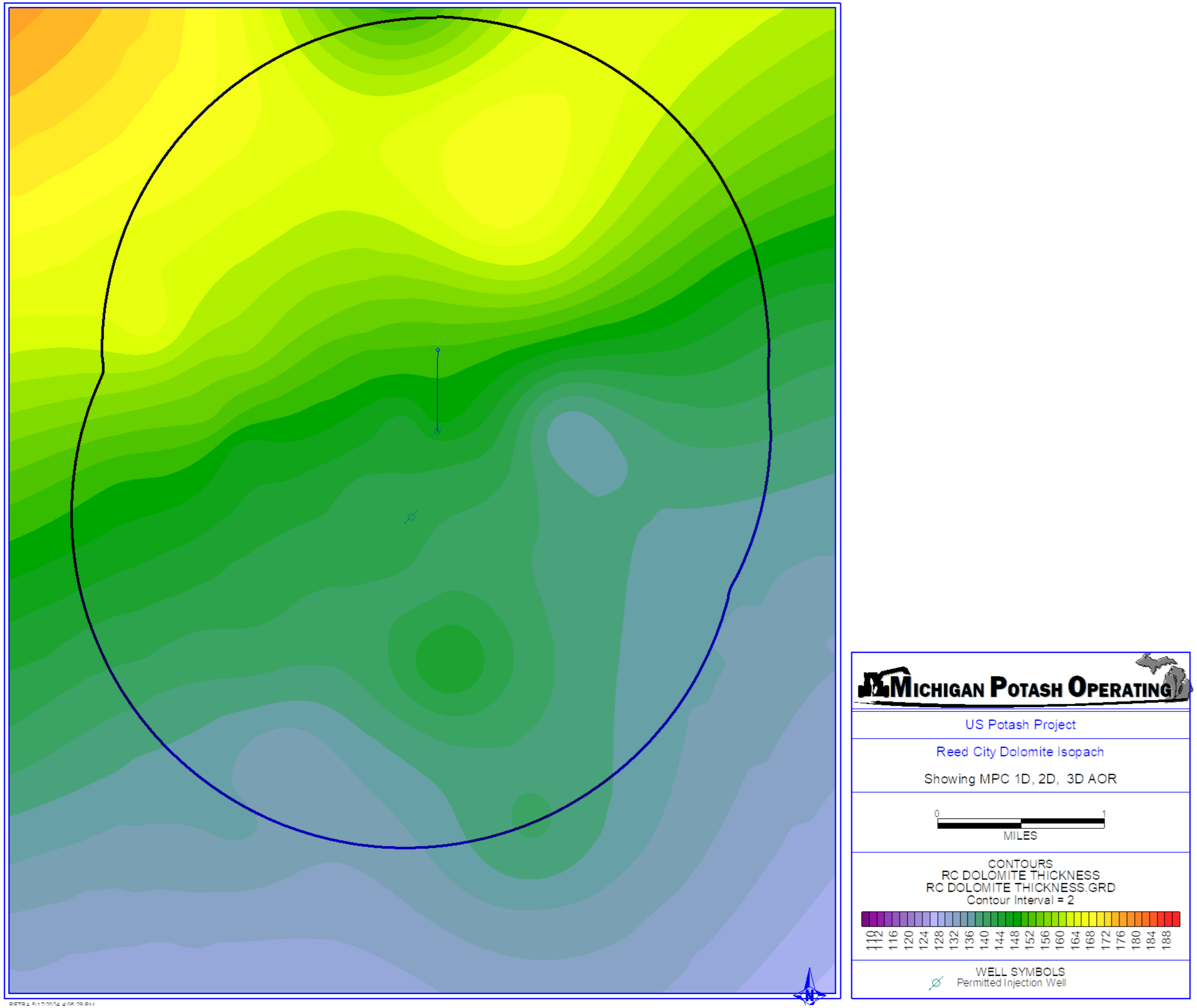


Figure 35. An Isopach map of the Reed City Dolomite.

9. Chemical, physical and bacteriological characterizations of the waste stream before and after treatment and/or filtration. Include a characterization of the compatibility of the injectate with the injection zone and the fluid in the injection zone along with a characterization of the potential for multiple waste streams to react in the well bore or in the injection zone.

Chemical, physical and bacteriological characterizations of the waste stream before and after treatment and/or filtration:

Section 9 and the corresponding information and figures contained within previously approved application #61330 remain valid. The following additional information pertaining to Dundee compatibility is offered.

As it concerns compatibility:

The brine produced by the manufacturing of food grade salt and potash is cleaner than the existing fluid in the injection intervals. There are fewer constituents in the injection fluid, it only contains constituents that already exist in similar or greater concentrations in the resident injection intervals. Historical laboratory experiments have been conducted to evaluate the compatibility of the fluids; results of the PPG studies identified no injectate-formation fluid incompatibility. This is corroborated by long standing injection in analogous operations offset. Provided the injectate is a clean, controlled fluid, and the injected chemical composition contains only those constituents that already exists in the injection horizon as resident, naturally occurring ions, there is no incompatibility, and provided there are not multiple streams, there can be no potential for multiple stream reactions (See Section EGLE checklist 10G for detailed chemical and physical characteristics of the Dundee/Reed City resident brine).

10. Information to characterize the proposed injection zone, including:

A. The geological name of the stratum or strata making up the injection zone and the top and bottom depths of the injection zone.

B. An isopach map showing thickness and areal extent of the injection zone

C. Lithology, grain mineralogy and matrix cementing of the injection zone.

D. Effective porosity of the injection zone including the method of determination.

E. Vertical and horizontal permeability of the injection zone and the method used to determine permeability. Horizontal and vertical variations in permeability expected within the area of influence.

F. The occurrence and extent of natural fractures and/or solution features within the area of influence.

G. Chemical and physical characteristics of the fluids contained in the injection zone and fluid saturations.

H. The anticipated bottom hole temperature and pressure of the injection zone and whether these quantities have been affected by past fluid injection or withdrawal.

I. Formation fracture pressure, the method used to determine fracture pressure and the expected direction of fracture propagation.

J. The vertical distance between the top of the injection zone from the base of the lowest fresh water strata.

K. Other information the applicant believes will characterize the injection zone.

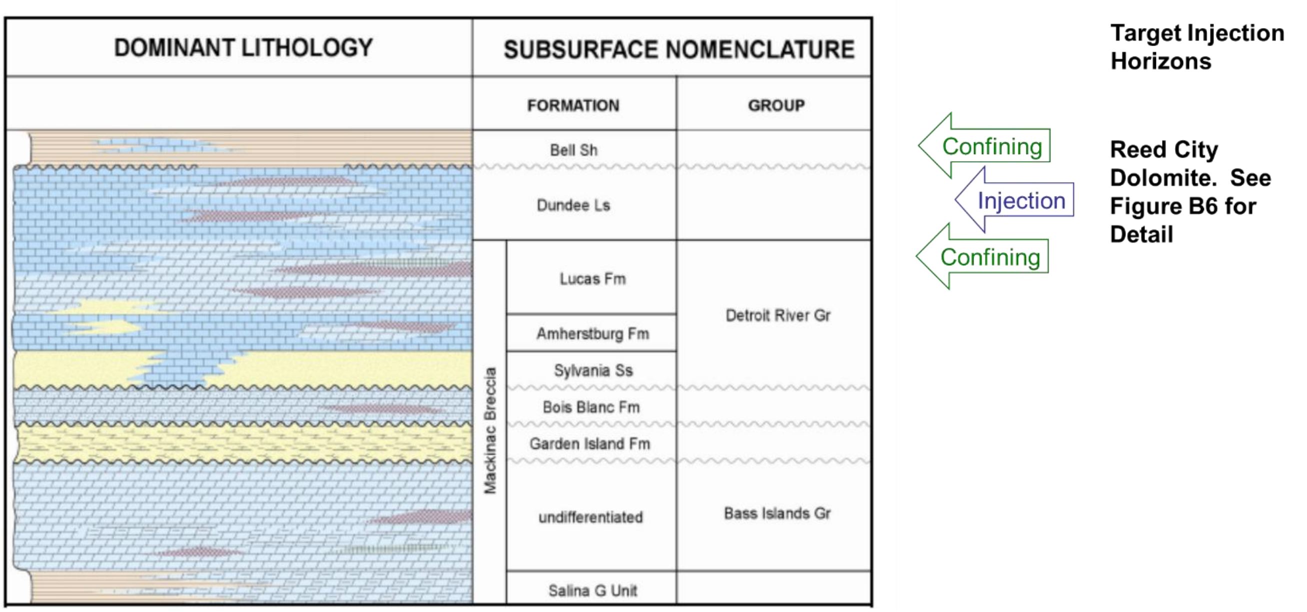
10.A The geological name of the stratum or strata making up the injection zone and the top and bottom depths of the injection zone.

In addition to the Sylvania-Bass Island interval of the MPC-3D, MPO proposes to inject into the Reed City Dolomite, which is a sub member of the Dundee that is below the Reed City Anhydrite and the Dundee limestone. The Dundee limestone is approximately 3,945' below ground surface. The Reed City Dolomite is below an established anhydrite marker in this region, that lies within the "Dundee Limestone group". While the Reed City Dolomite is the principal porosity target, the entire formation group, including the Reed City Dolomite, Reed City Anhydrite, and Dundee Limestone are included in the proposed injection zone, similar to the Thomas and Woodward wellbores.

The Dundee Limestone Group and associated sub intervals have been the subject of extensive study in Michigan as injection horizons, and or have been injected into extensively. Michigan is a historical oil and gas province and rich brine producing province. As a result, there is well established data for injection and rock and fluid interaction with over +/- 2,070 established injection wells.

Figure 36 is a new figure excerpted from the original application Figure 21 with particular focus on the Reed City Dolomite and Bell Shale **(below)**. The Reed City Dolomite occurs in the Dundee LS Formation group. The Reed City Dolomite occurs below an anhydrite layer within the Dundee LS. This figure is presented in great further detail, by horizon on Figures B6, for the proposed injection horizon. The confining interval is the Bell Shale.

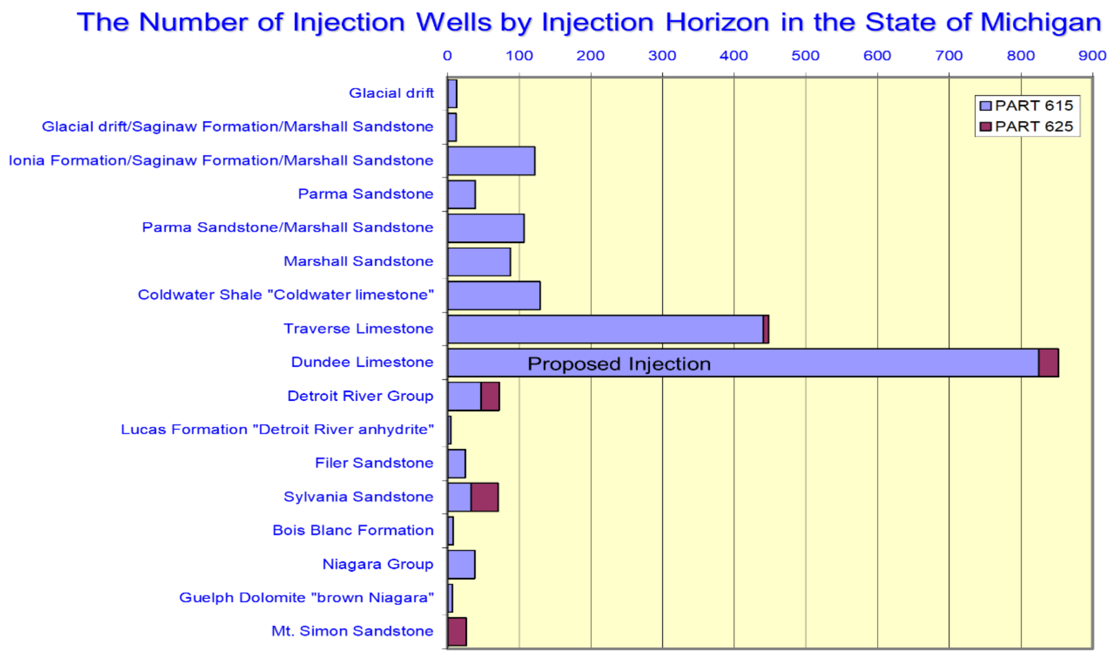
Figure 36 (NEW). Portion of Michigan Stratigraphic Column, Bell Shale-Salina



Michigan is a historical oil and gas province and rich brine producing province. As a result, there is well established data for injection and rock and fluid interaction, with over 2,000 established injection wells.

Figure 37 is an new figure similar to Figure 27 from the original approved permit application, and is a graphical illustration of the stratigraphic horizons currently being utilized in the State of Michigan for fluid injection. It has been modified to conform to the modification request showing the Dundee group as the proposed injection horizon This graph shows both Part 615 Oil and Gas Wells and Part 625 Mineral Wells.

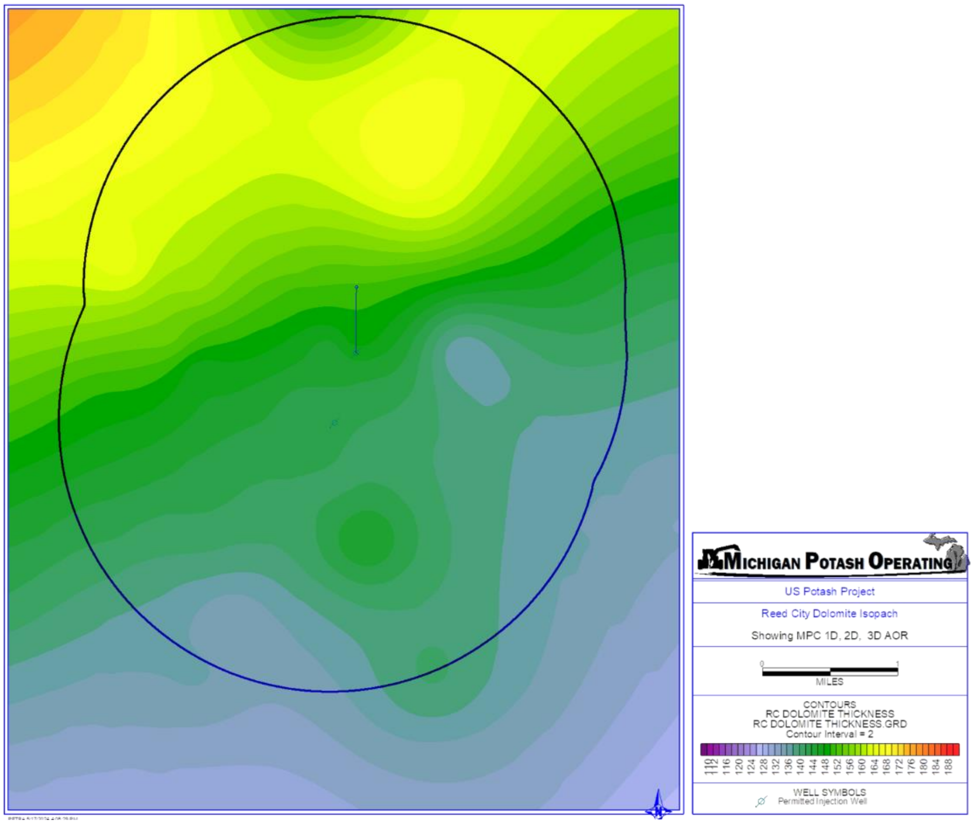
Figure 37 (NEW). Graphical Depiction of Formations Used for Class I and Class II Injection



In the State of Michigan, most injection occurs in the Dundee Limestone or shallower due to the ease of access of shallow injection horizons and excellent confining intervals at shallow depths.

10.B An isopach map showing thickness and areal extent of the injection zone.

- **Figure 35 (NEW)** is an isopach map of the Reed City Dolomite group of the Dundee Formation, and is referenced in Section 8 above showing the area extent of the proposed injection zone and is shown here for ease of reference:



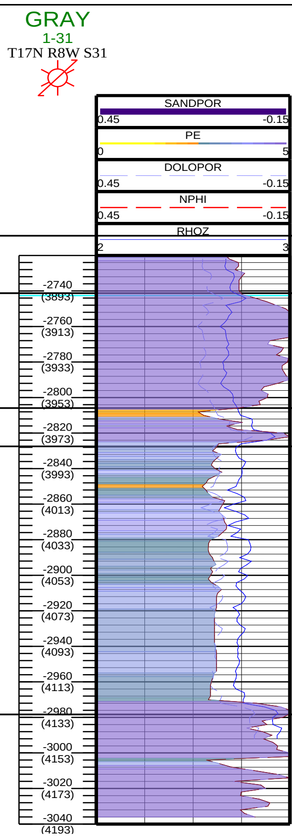
10.C. Lithology, grain mineralogy and matrix cementing of the injection zone.

Figure 38 (NEW) is a new figure that shows the following, noting that a portion of this figure is included below for ease of review:

(1) A regional map of Michigan, showing the net thickness of the Dundee Formation, in the entire state, whereby the Reed City Dolomite is an interval that occurs within the Dundee Limestone group, with a reference to the AOR; and

(2) A geophysical type of curve of the injection and confining horizons from the Grey 1-31, located in the NW/4NW/4 Section 31, which near the proposed MPC-1D, MPC-2D and MPC-3D proposed injection locations; and

(3) The porosity of both the injection and confining intervals as determined from well log analysis and core observations; also shown below for ease of reference, and



	Zone	Footage	Porosity	Permeability	Description
Confining	Bell Shale		0	0	Limestone, buff grey brown, f-micro crystaalin, argolicous, dololithic with grey shale
Confining	Dundee Limestone	60'	0-2%	<.1 md	Limestone, buff grey-brown, fine microcrystaline.
Confining	Reed City Anhydrite	10'	0	0	Anhydrite
Injection	Reed City Dolomite	150'	5-7%	50-100 md	Dolomite, brown, hard, medium to fine crystaline, succroustic, small sl argilicous, good inter crystaline porosity
Confining	Detroit River Anhydrite	60'	0	0	Minor dolomite, brown dark brown anhydrite with small brown limestone and grey-black shale. Anhydrite, white grey.

(4) The real observed and determined permeability from extensive drill stem analysis and step fall-off tests as performed and reported immediately in the AOR; and

(5) Real lithologic descriptions as observed by the wellsite geologist when drilling through the Freudenberg 1-31, located in the NE/4NE/4 Section 31, which is in the same section of the proposed injection location; and the Grey 1-31.

The Reed City Anhydrite, the micro-crystalline limestone of the Dundee Formation, and the Bell Shale, all above the Reed City Dolomite, exhibit no porosity or permeability and while in in the proposed injection zone, would actually serve as additional confining layers. Above the Belle Shale are multiple, tight, dense limestones, shales, and anhydrites, including the Antrim Shale, Ellsworth Shale, Sunbury Shale, and the Coldwater Shale for another approximate 3,000 before any USDW is encountered.

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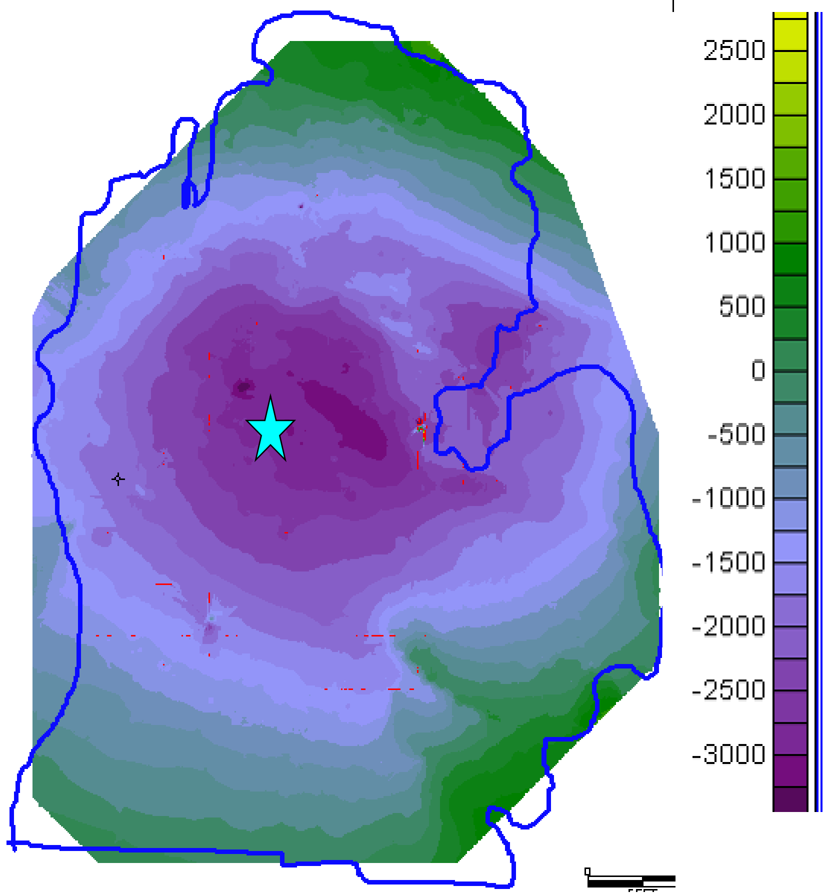
Reed City Dolomite Injection and Confining Interval Detail



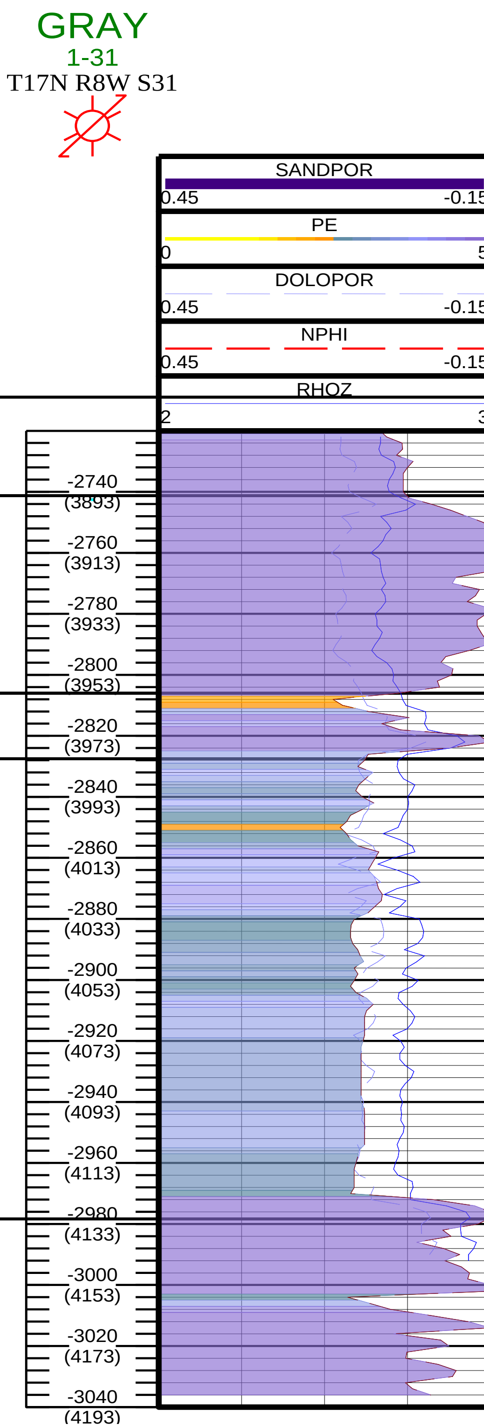
Dundee Structure Map,
Subsea Depth

Measured Permeability In AOR

REED CITY DOLOMITE POROSITY AND PERMEABILITY

WELL	THICKNESS POROSITY	UNCORRECTED LIMESTONE POROSITY (%)	MEASURED PERMEABILITY (MILLIDARCIES)
Johnson 1-1	147	3.69	< 1
McClain 1-28	140	.4.365	7 *
Pilarski 1-12	140	5.6425	166
Ward 1-11	154.5	7.0925	250 **
Grein 2-36	156	8.64	- ***
Compton 1-13	156	10.0325	244 ****
Woodward 1-26	150	5.65	86.5*****
Thomas 1-26	164	5.65	86.5*****

*/ Drill stem test included 2 feet of porous Dundee Formation above the Reed City Dolomite.
**/ Calculated 362 md. Plots do not permit high precision, reduced to 250 md to be conservative.
***/ Drill stem test unreliable due to tool leakage.
****/ Drill stem test included 14 feet of porous Dundee Formation above the Reed City Dolomite.
*****/As reported on Class I Non Hazardous Re-applicaton from Step Rate Tests



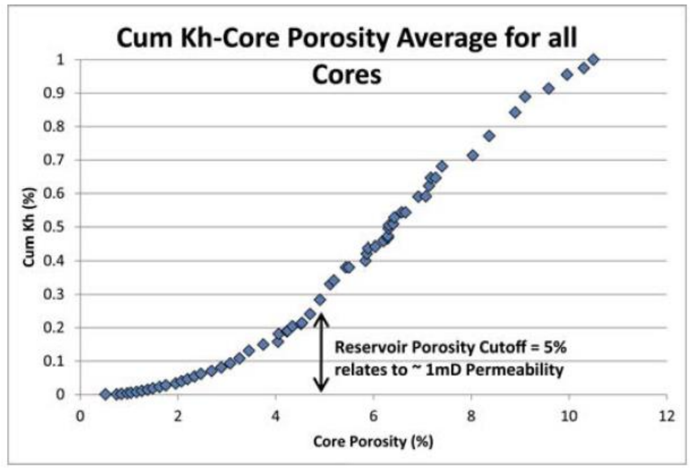
	Zone	Footage	Porosity	Permeability	Description
Confining	Bell Shale		0	0	Limestone, buff grey brown, f-micro crystaalin, argolicous, dololithic with grey shale
Injection	Dundee Limestone	60'	0-2%	<.1 md	Limestone, buff grey-brown, fine microcrystaline.
Injection	Reed City Anhydrite	10'	0	0	Anhydrite
Injection	Reed City Dolomite	150'	5-7%	50-100 md	Dolomite, brown, hard, medium to fine crystaline, succroustic, small sl argilicous, good inter crystaline porosity
Confining	Detroit River Anhydrite	60'	0	0	Minor dolomite, brown dark brown anhydrite with small brown limestone and grey-black shale. Anhydrite, white grey.

Figure 38. Reed City Dolomite Injection Interval and Bell Shale Confining Interval Details. Figure shows (1) a geophysical type curve of the injection and confining horizons in the Reed City Doloimite from the Grey 1-31, located in the NW/4NW/4 Section 31 (2) the calculated porosity (3) the real observed and determined permeability from extensive drill stem analsyis and step fall-off tests as performed and reported immediately in the AOR (4) a structure map of the top of the Dundee Limestone in the entire state, as it relates to the AOR (5) real lithologic descriptions as observed by the wellsite geologist when drilling through the Fruendenberg 1-31, located in the NE/4NE/4 Section 31.

10.D Effective porosity of the injection zone including the method of determination.

Figure 39 (NEW). Dundee Cumulative Permeability feet vs. Core Porosity from McClosky and Grammar (2018)

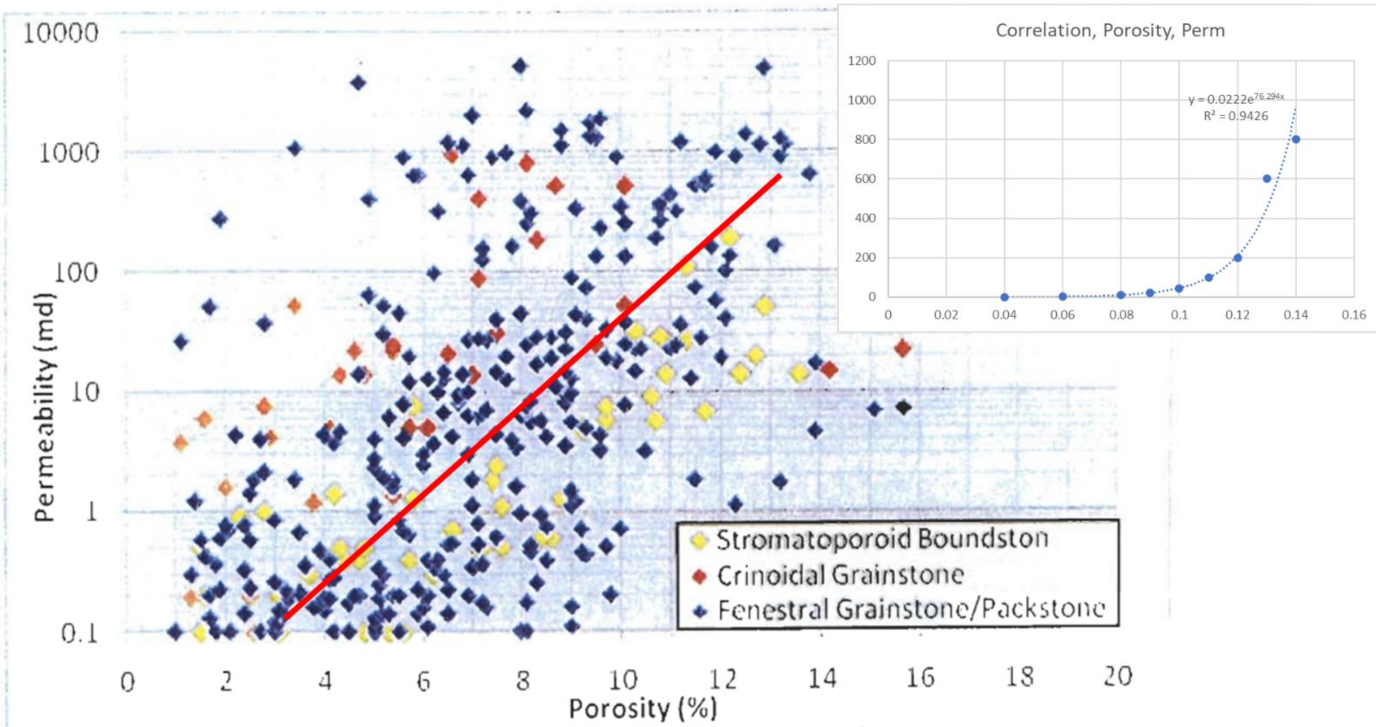
Effective porosity has been identified by both direct and indirect methods. The Dundee formation (Reed City and Roger City Groups Included) has been extensively analyzed by direct porosity-permeability measurements throughout the Michigan Basin. While a direct correlation between the more limestone-based Dundee and the more Dolomitized Character of the Reed City Group may differ slightly, the effective porosity relationships provide reasonable rule of thumbs for the site specific Reed City Member at the proposed project location. The chart to the right is an excerpt from McClosky and Grammar (2018) that shows the cumulative Permeability-Porosity relationship from 26 cored wells through the Dundee formation in Gladwin County. The effective cutoff porosity was determined to be approximately 5.0%.



Cumulative permeability-feet percent (Cum Kh) versus core porosity average for all 26 wells with whole-core analysis reports. Average core porosity 0%–12% is located on *x* axis, and cumulative permeability-feet (decimal percent) 0–1 is on *y* axis. The inflection point occurs at 5% porosity and was used as a reservoir cutoff. This reservoir cutoff value may define economically producible hydrocarbons from noneconomical hydrocarbons.

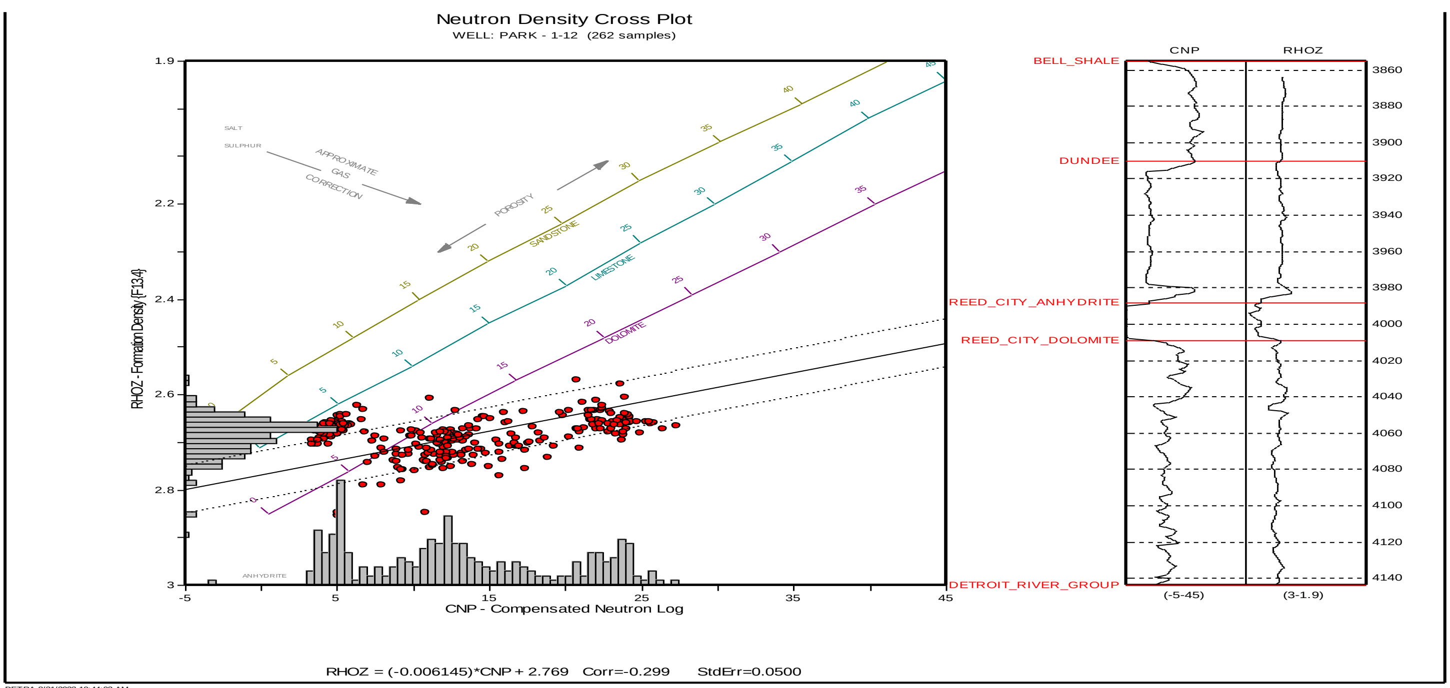
This conclusion is comparable to that of Abduslam (2012) where a similar analysis was performed on extensive direct measure Dundee cores throughout numerous locations in the Michigan Basin. His correlation is shown below left, with MPO's own porosity-permeability relationship analyses presented to the right that determines the proper cutoff also approximates 5.0% porosity, where permeability drops below 1 md.

Figure 40 (NEW). Porosity-Permeability Correlation, Reed City



A site specific porosity crossplot of the Netron Density and Bulk Density log over the Reed City interval in the Park 1-12 well demonstrates fully dolotimized Dundee in the Reed City Member, and high effective porosity in this interval. The occurrence of high porosity is indicative and corroborative of the high measured permeability via DST testing in the offset of the same interval in the Ward 1-11 (>350 md).

Figure 41 (NEW). Density-Neutron Porosity Plot and Correlation to Detroit River-Bell Shale Section



The porosity-permeability relationships demonstrate an increase in effective porosity with higher dolomitization and offer potential cutoffs of effective porosity. Net injection thicknesses have been determined assuming the Reed City appears mostly ineffective below 5% porosity. These direct measurements of core have been utilized and applied to the indirect geophysical well log data. The effective porosity then, above the cutoffs, most likely approximates the true porosity, which has been calculated from the density log, as follows:

DPHI = (RHOMA - RHOB)/(RHOMA - RHOF).

A density of 2.87 is used in the calculation of true porosity from the bulk density log.

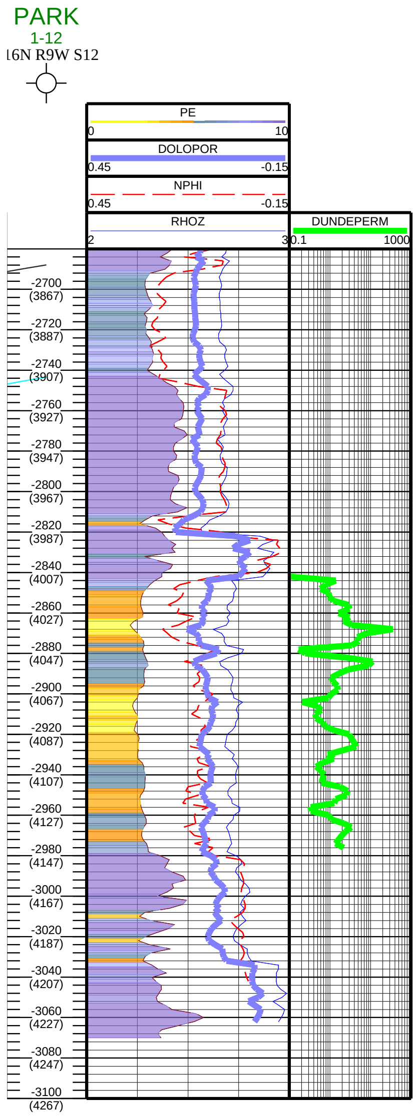
10.E Vertical and horizontal permeability of the injection zone and the method used to determine permeability. Horizontal and vertical variations in permeability expected within the area of influence.

Permeability has been identified by direct method via Klinkinberg permeability analysis on core throughout the Michigan Basin. These analysis have then been applied to the porosity-permeability relationship of Abduslam (2012) as shown above via the following observed relationship expressed as follows:

The direct porosity permeability relationship in the Dundee/Reed City Member is expressed as follows:
Permeability = 0.00222* e^(76.294*porosity), (provided a 5% porosity cutoff).

Vertical permeability tends to be 1/10 of Horizontal permeability in most sedimentological applications. The direct core measurements of porosity permeability relationships applied to the calculated true porosity are shown below at the Park 1-12, which is a typecurve in the immediate proximity of the subject well. The permeability correlations are verified by resistivity log separation and Caliper log indications of filter cake.

Figure 42 (NEW). Park 1-12 Log Permeability Correlations



10.F The occurrence and extent of natural fractures and/or solution features within the area of influence.

There are no known faults within the area. There is no seismic activity in the area. Michigan is one of the lowest areas of seismic activity in the United States. When activity does occur, it tends to occur in the southern area of the state, or roughly 200 miles southward from the AOR. In the last six years, Michigan has recorded only one 4.0 magnitude or greater earthquake. The epicenter was 2.5 miles below ground, in Galesburg, Michigan.

10.G Chemical and physical characteristics of the fluids contained in the injection zone and fluid saturations.

The physical and chemical characteristics of the Dundee/Reed City formation fluids have been gathered from the Ward 1-11 in the AOR is summarized as follows:

Property	Result
pH	5.5
Color	light brown
Specific gravity	1,2118
Specific conductance	94,000 microohms/crn @ 25°C
Viscosity	18 centipoise @ 23°C

Constituent	Concentration
Dissolved CO2	132 mg/1
Dissolved Oxygen	0.1 mg/l
Sulfide as H2S	<30 mg/1
Calcium	3,9%
Magnesium	0.59%
Potassium	1.6%
Sodium	5.9%
Barium	8 mg/1
Boron	57.5 mg/1
Cadmium	0.2 mg/1
Iron	<10 mg/1
Manganese	2.7 mg/I
Silica	2.4 mg/1
Strontium	0.14%
Bicarbonate	220 mg/l
Carbonate	<1 mg/1
Bromide	0.16%
Chloride	19%
Fluoride	0.4 mg/1
Iodide	28 mg/1
Nitrate	<0.1 mg/1
Sulfate	210 mg/1
Oil content	74 mg/1
Suspended solids	0.6%
Total dissolved solids	27%

The above data indicates that the Reed City Dolomite porosity is saturated with a very briny formation fluid exhibiting over 320,000 mg/ liter total dissolved solids.

Fluid saturations would be 100% of porosity.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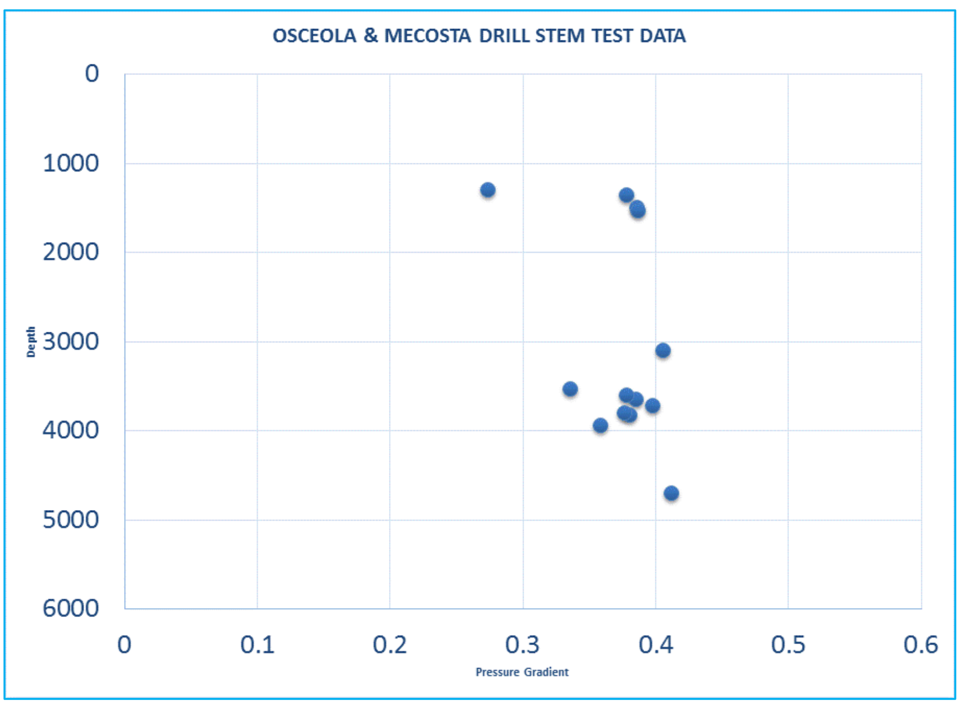
10.H The anticipated bottom hole temperature and pressure of the injection zone and whether these quantities have been affected by past fluid injection or withdrawal.

Due to the extensive geological and historical injection data in the area, casing will be run across the proposed injection horizon. Historically observed fluid pressure is 1600-1700 psi, fluid temperature is 80 degrees F, physical and chemical characteristics of the formation fluids have been gathered (see Ward 1-11 data below). Following the running of casing, corroborative data will be gathered by perforating the injection horizon, swabbing back the formation fluid to gather a sample for corroborative analysis of physical and chemical testing. Thereafter, a step rate injection test will be performed on the injection horizon to determine the fracture pressure. Further, open hole logs will be run to gather the physical, chemical, and radiological characteristics of the injection zone. These logs will include, Resistivity, Spontaneous Potential, Neutron Density, Compensated Formation Density, Gamma Ray, Caliper, Photo-Electric Effect.

DSTs gathered in the AOR are graphically summarized in **Figure 43** have indicated a fluid pressure in the range of 1,600-1,700 psi in the Reed City Dolomite. This equates to a under-pressured gradient 0.41 psi/foot depth. Average horizontal permeability to fluid ranges from 10 to over 250 millidarcies in the more favorable areas of Injection. Drill stem tests have yielded up to 3,300 feet of formation fluid, with most of the flow occurring in the first 15 minutes in wells having very good porosity and permeability.

The following chart is actual well data pressure gradients experienced via drill stem testing in Osceola and Mecosta County Michigan between 0 and 6000' KB as compiled from AASG Geothermal Data. Pressure gradients are determined via the greater of initial shut in pressure or final shut in pressure divided by the top point of the test depth. Tabular data is also provided.

Figure 43. Osceola and Mecosta DST Data With Well Information Table Presenting Pressure Gradient vs. Depth



WellName	ZONE	GREATER OF ISIP/FSIP	Pressure Gradient	At Depth
Golupski, Cleo M Mrs1-22	Traverse Limestone	1253	**0.405764249**	3088.0
Lindell, Carl1	Dundee Limestone "Reed City zone"	1455	**0.380790369**	3821.0
Mott, Charles Stewart Foundation1	Michigan Formation "Stray sandstone"	575	**0.386165212**	1489.0
Leach1	Dundee Limestone	1401	**0.384995878**	3639.0
Johnson & State Rose Lake1-27	Traverse Limestone	1183.7	**0.335325779**	3530.0
HAMPLE, LAWRENCE & JANE ET AL	Stray	355	**0.273708558**	1297.0
HAMPLE, LAWRENCE & JANE ET AL	Reed city	1430	**0.376811594**	3795.0
HAMPLE, LAWRENCE & JANE ET AL	Richfield	1935	**0.411789742**	4699.0
PEDERSEN, PATTY ANN	Stray	511	**0.378238342**	1351.0
PEDERSEN, PATTY ANN	Dundee	1479	**0.39768755**	3719.0
BURRETT, LILA	Dundee	1360.4	**0.378309232**	3596.0
Seger	Dundee	1409	**0.358250699**	3933.0
Mott Foundation	Stray	590	**0.38637852**	1527.0

For injection pressure calculations, a conservative, normal pressure gradient of 0.433 psi/ft is adequate and has been reported on Form 7200-14.

A DST in the Grey 1-31 in the Richfield Detroit River Group from 4,700 to 5,030 opened with no blow a recovered only 480' of drilling fluid, corroborating a weakly, under pressured gradient just below the propositioned injection horizons. It is not anticipated that the Dundee has been affected by past fluid injection. There has been no historical fluid withdrawal from this interval within the AOR.

Measured bottom hole temperature is catalogued by numerous drilling logs in the area, and is 115 degrees F.

Historical pressure injection fall off tests performed between 2005 and 2016 on behalf of, or by the U.S. EPA and on the Thomas 1-26 and Woodward 1-26 has been compiled and surrendered to the regulatory authorities, and is shown below. These tests are specific to the Reed City Dolomite member of the Dundee Group.

Comparison of Prior Tests and Evaluations								
Cargill Thomas 1-26 and Woodward 1-26								
Date of Test	Well Name	Analyst	Inj. Rate, gpm	P_{final}, psi	P*, psi	k, md	S	Bound Dist, ft
3/19/2005	Thomas 1-26	Subsurface	337.1		2275.6	1315	-1.74	892?
3/19/2005	Thomas 1-26	USEPA, Steve Roy	337.1	2227		1232.3	-2	525
3/21/2006	Thomas 1-26	Subsurface	324.2		2294.4	1521	-1.5	918
3/21/2006	Thomas 1-26	USEPA, Gerrish	324.2	2205	2284	1394	-1.1	88
3/24/2007	Thomas 1-26	Subsurface	288.54		2250.6	1403	-2.09	920
3/24/2007	Thomas 1-26	USEPA, Patterson	288.54	2173		1567.6	4	386
8/12/2008	Thomas 1-26	Subsurface	128		2177.1	1510	-1.72	351-456?
8/12/2008	Thomas 1-26	USEPA, Simmons	128	2115		674.5	-2.6	248
8/3/2010	Thomas 1-26	Petrotek	n/a		2177.8	1291.9	-3.5	n/a
7/31/2012	Thomas 1-26	Brock Engineering	422		1974	383	-6.9	n/a
7/31/2012	Thomas 1-26	USEPA, Bill Bates	421.7	2165	2220	3954	-3	
7/24/2014	Thomas 1-26	Brock Engineering	255		2008	295	-6.7	n/a
7/24/2014	Thomas 1-26	USEPA, Steve Roy	255	2077.9	n/a	n/a	n/a	n/a
3/19/2005	Woodward 1-26	Subsurface	122		2126.8	410	16.4	774?
3/19/2005	Woodward 1-26	USEPA, Steve Roy	122	2250	2314.1	355.4	13.5	420
3/21/2006	Woodward 1-26	Subsurface	205		2316.4	516.7	2.27	692
3/21/2006	Woodward 1-26	USEPA, Patterson	205	2257		497.8	2	351
8/22/2007	Woodward 1-26	Subsurface	140		2191.4	491.6	4.14	n/a
8/22/2007	Woodward 1-26	USEPA, Gerrish	140	2144		n/a	n/a	n/a
8/5/2009	Woodward 1-26	Petrotek	105		2138.5	337	7.94	n/a
8/5/2009	Woodward 1-26	USEPA, J. Wawczak	105	2142	2176	290.8	4.9	n/a
8/3/2011	Woodward 1-26	Brock Engineering	124		2176	163	-8.7	n/a
8/3/2011	Woodward 1-26	USEPA, Greenhagen	124	2224.1	2254	428.4	5.3	
7/31/2013	Woodward 1-26	Brock Engineering	96.45		2136	118	-8.5	n/a
7/21/2015	Woodward 1-26	Brock Engineering	128.99		2105.2	691	-14.3	n/a

Historical pressure injection tests performed between 2005 and 2016 on behalf of, or by the U.S. EPA and on the Thomas 1-26 and Woodward 1-26 has been compiled and surrendered to the regulatory authorities, and is shown below. These tests are specific to the Reed City Dolomite member of the Dundee Group.

Average Measured Bottom Hole Reservoir Pressure (P*) = 2,189 psi.

Depth to the Injection Interval in these two wells is 3,980. This is an observed pressure gradient of 0.55 psi/foot.

Average Measured Permeability (k) was measured as (k) 907 md. Pressure rise between 2005 and 2016 was not observed.

10.I Formation fracture pressure, the method used to determine fracture pressure and the expected direction of fracture propagation.

Historical injection tests were conducted in injection wells Woodward 1-26 and Thomas 1-26, both of which are in the AOR; tests were performed by pumping treated water into the Reed City Dolomite at rates of 28 bbls (1,176 gallons) per minute at a surface pressure of 2,960 psi. After deduction of calculated friction losses of 38 psi within the well, the pressure at the top of the Reed City Dolomite, while injecting treated fresh water, was 4,647 psi. No parting or fracturing of the formation was noted, indicating the fracture pressure must be greater than 4,647 psi, with a top perf at 3985'. For ease of reference, the offset data has been incorporated below:

Woodward 1-26:

H.2 Average and Maximum Injection Pressures

The maximum injection pressure has been set by permit at 2,576 psig for the Woodward 1-26 well.

Injection fluid may be water (specific gravity of 1.0) or a partially saturated sodium chloride/potassium chloride brine solution with a specific gravity as high as 1.2.

Previous documents submitted to the USEPA (*1995 Re-Permit Application (Attachment H-2 and Appendix A); 1984 Permit Application)* indicated a maximum injection pressure for water of 2,928 psi and for brine of 2,589 psi. This information was based upon previously conducted fracture testing at the top perforation of the injection zone (4,647 psi). A pressure gradient of 1.18 psi per foot was calculated.

Upon review of the previous ten years of operation records, the average injection pressure remains between 600 to 900 psi as stated in the previous *1995 Permit Re-Application.*

The Thomas 1-26:

H.2 Average and Maximum Injection Pressures

The maximum injection pressure has been set by permit at 2,533 psig for the Thomas 1-26 well.

Injection fluid may be water (specific gravity of 1.0) or a partially saturated sodium chloride/potassium chloride brine solution with a specific gravity as high as 1.2.

Previous documents submitted to the USEPA (*1995 Re-Permit Application (Attachment H-2 and Appendix A); 1984 Fenix & Scisson Permit Application)* indicated a maximum injection pressure for water of 2,928 psi and for brine of 2,589 psi. This information was based upon previously conducted fracture testing at the top perforation of the Reed City Dolomite injection interval (4,647 psi). A pressure gradient of 1.18 psi per foot was calculated.

Upon review of the previous ten years of operation records, the average injection pressure remains between 600 to 900 psi as stated in the previous *1995 Permit Re-Application.*

Final Fracture Pressure Gradient Values

In 1992 and 1993, the Region 5 Underground Injection Control Program public noticed draft and final values for fracture pressure gradients for specific oil fields in Michigan. These values were published in the *Federal Register* in three groups. The column headed "FRN" indicates in which *Federal Register* Notice the final fracture pressure gradient (FPG) value for each field was published. (Internet-accessible copies of the *Federal Register* do not go back this far, so these notices are not viewable over the Internet at this time.)

County	Field	Formation	Township/Range/Section	FPG (psi/ft)	FRN*
Bay	Kawkawlin	Dundee	T15N, R4E, S27, 28, 33, 34 and T14N, R4E, S3	1.23	3
Calhoun	Pennfield 35	Niagaran Reef	T1S, R7W, S35	0.60	1
Clare	Cranberry Lake	Richfield	T20N, R6W, S1, 2, 11, 12	1.10	1
	Hamilton	Richfield	T19N, R3W, S5-8 and T19N, R4W, S1, 2 and T20N, R4W, S35,36	1.06	2
Crawford/Kalkaska	Beaver Creek	Richfield	T25N, R5W, S12, 13, 24 and T25N, R4W, S7, 8, 16-21, 28, 29	1.07	1
Gladwin	Beaverton	Dundee	T17N, R2W, S19	1.11	3
	Bentley-Dundee	Dundee	T17N, R2E, S18, 19, 20	1.15	1
	Billings:				
	Billings 2 Unit	Dundee	T17N, R1E, S2, 3, 10, 11	1.12	1
	Billings-Bentley Unit		T17N, R1E, S12, 13 and T17N, R2E, S18		
	Grout	Richfield	T18N, R2W, S10, 11, 14, 15	1.05	3
Ingham	Aurelius 35	Niagaran Reef	T2N, R2W, S26, 35, 36	0.65	1
	Ingham 13	Salina-Niagaran	T2N, R1E, S13	0.76	1
	Onondaga 10	Salina-Niagaran	T1N, R2W, S2-4, 10, 11, 14	0.61	1
	Onondaga 21A	A-1 Carbonate (Salina)	T1N, R2W, S15-17, 21, 22	0.81	3
Isabella	North Wise	Dundee	T16N, R3W, S17	1.12	3
Kalkaska	Kalkaska "21"	Salina-Niagaran	T27N, R8W, S22	0.92	1
Lapeer	Richfield	Richfield	T10N, R10E, S21-23, 26-28, 33-35	1.09	3
Manistee	Manistee	Niagaran	T22N, R17W, S36	0.82	2
	Bear Lake	Niagaran	T23N, R15W, S12	0.58	3
Missaukee	Enterprise	Richfield	T23N, R4W, S18 and T23N, R5W, S10-14	1.10	2
	East Norwich	Richfield	T24N, R5W, S1-3, 9-16, 21, 22 [illegible]	1.14	2
	Falmouth	Richfield	T22N, R6W, S30, 31 and T22N, R7W, S25, 36	1.10	3
Ogemaw	Rose City:				
	Rose City Unit	Richfield	T23, 24N, R2E, S3, 19-21, 27-30, 32-35	1.07	1
	Rose City Central Unit		T24N, R1E, 2E, S25		
	Rose City West Unit		T24N, R1E, S21		
	West Branch:				
	West Branch Unit (excluding West Branch 28: see below)	Dundee	T21N, R2E, S2 and T22N, R2E, S21, 26, 27, 33-36 and all of S28 except the S/2 of the NW/4	1.15	2
	Country Club Unit		T22N, R1E, S13, 24 and T22N, R2E, S18-21, 29		
	West Branch 28	Dundee	T22N, R2E, S28, S/2 of NW/4	1.25	3
Otsego	Chester:				
	Chester 18 Unit	A1 Carbonate & Niagaran	T30N, R2W, S7, 8, 17, 18, 19, 20	0.99	1
	Chester 21 Unit		T30N, R2W, S21, 22	0.78	1
	Hayes:				
	Hayes 15 Unit	Salina-Niagaran	T29N, R4W, S15	0.67	1
	Hayes 21A Unit		T29N, R4W, S21, 28		
Roscommon	Headquarters:				
	Headquarters Unit	Richfield	T21N, R3W, S19, 29, 30	1.22	1
	Headquarters-Sour Unit		T21N, R3W, S29, 30, 32, 33		
	St. Helen	Richfield	T24N, R1W, S16, 19-21, 27-30	1.16	2
St. Clair	Columbus 3	Niagaran	T5N, R15E, S3, 10 and T6N, R15E, S34	0.79	1

*FRN = *Federal Register* Notice:

Ref. No.	Page	Date
1	*FR* 57 (247): 61084	12/23/92
2	*FR* 58 (224): 61910	11/23/93
3	*FR* 58 (240): 65711	12/16/93

Utilizing this data, an estimate fracture pressure for the proposed well can be determined as follows:

Surface Pressure = 2,960
Treated freshwater gradient = 0.433 psi/ft, where SG = 1.0
Top perf at 3985 ft

Surface Pressure + 0.433 psi/ft x depth – 14.7 = BHP

4,647 +0.433 psi/ft x 3985 – 14.7 = 4,685 psi

Fracture Gradient = 4,685psi/3985ft = 1.18 psi/ft

The current fracture gradient utilized on the permitted
Thomas and Woodward is 1.17 psi/ft.

Form EQP 7400-14, *has been filed with a default 0.8 psi/ft fracture gradient as directed by regulatory direction from the U.S. EPA despite substantial offset data available. Upon completion of the wells, step rate injection testing will be performed to obtain site specific data that will match the offsets and expected operating parameters listed in this section are anticipated; with 1.17 psi/ft FRACTURE GRADIENT.*

The expected direction of fracture propagation would be in the direction perpendicular to maximum stress. In the Michigan Basin, maximum stress is North-Northeast to South-southwest, approximating 45 degrees. The direction of minimum stress then would be at 135 degrees, if any fracture propagation at all were to occur. It is highly unlikely.

10.J The vertical distance between the top of the injection zone from the base of the lowest fresh water strata.

The estimated base of the glacial till is 712’. The estimated top of the injection zone is 3,945’ (Base of the Bell Shale). The difference is 3,323’.

Please reference **Figure 24** for a graphical illustration and cross section through the area visually representing the above statement.

11. Information to characterize the proposed confining zone, including

A. The geological name of the stratum or strata making up the confining zone and the top and bottom depths of the confining zone.

B. An isopach map showing thickness and areal extent of the confining zone

C. Lithology, grain mineralogy and matrix cementing of the confining zone.

D. Effective porosity of the confining zone including the method of determination.

E. Vertical and horizontal permeability of the confining zone and the method used to determine permeability. Horizontal and vertical variations in permeability expected within the area of influence.

F. The occurrence and extent of natural fractures and/or solution features within the area of influence.

G. Chemical and physical characteristics of the fluids contained in the confining zone and fluid saturations.

H. Formation fracture pressure, the method used to determine fracture pressure and the expected direction of fracture propagation.

I. The vertical distance between the top of the confining zone from the base of the lowest fresh water strata.

J. Other information the applicant believes will characterize the confining zone.

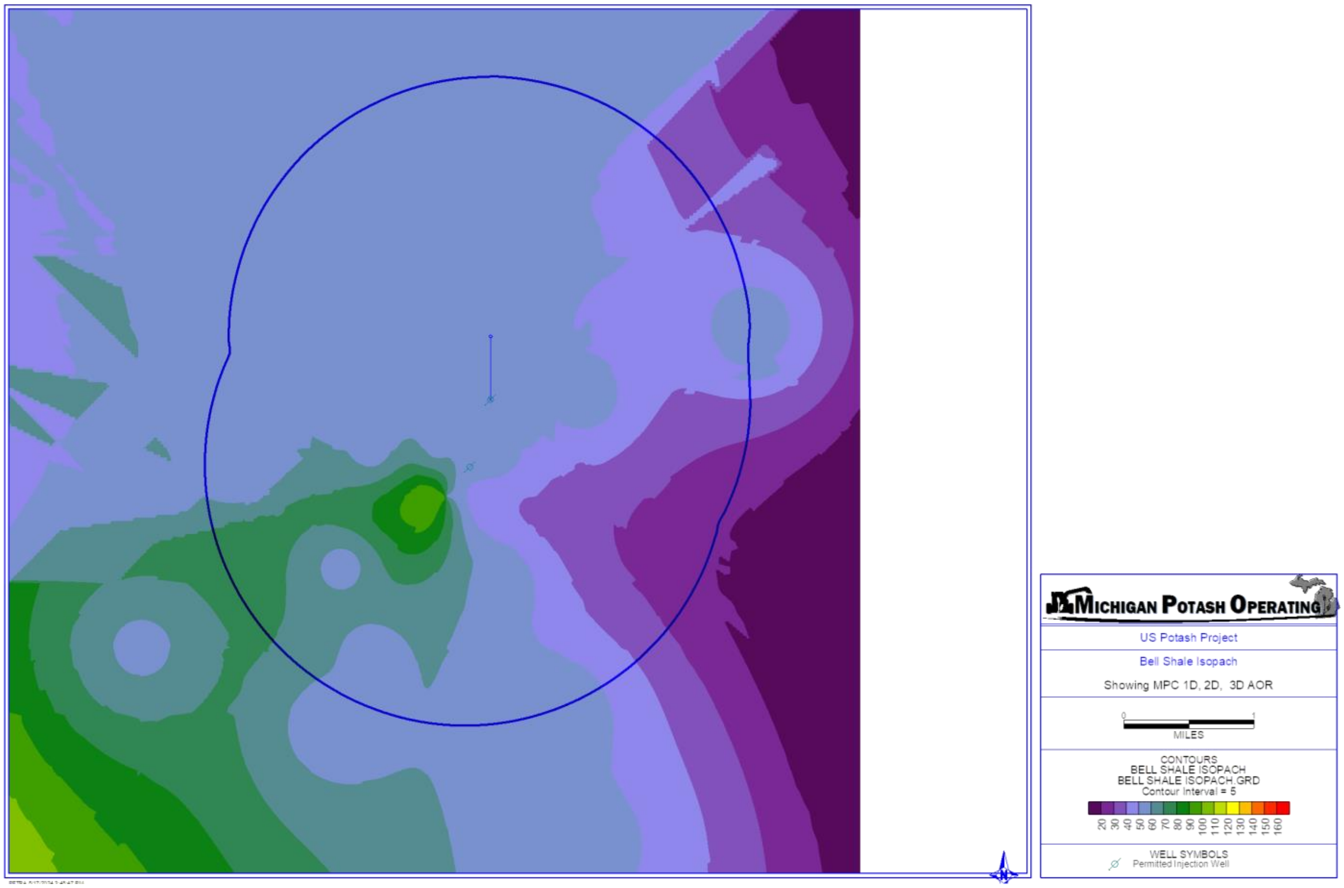
11.A The geological name of the stratum or strata making up the confining zone and the top and bottom depths of the confining zone.

The Bell Shale is the requested confining zone and is approximately 76 feet thick in the MPC well area. Although the Bell Shale serves as 'technical' confining zone, the Dundee Limestone likely exhibits 50-60' of zero porosity above the Reed City Anhydrite, which also is a confining interval. Both the Dundee Limestone and Reed City Anhydrite would offer secondary confinement of the targeted porosity intervals in the Reed City Group.

The Bell Shale top is estimated to be 3,889' and the base is estimated to occur at 3,945' below surface.

11.B An isopach map showing thickness and areal extent of the confining zone

Figure 34 is an isopach map of the Bell Shale showing the areal extent of the confining zone.



11.C Lithology, grain mineralogy and matrix cementing of the confining zone.

The Belle shale is described as a shale, grey, blue, non-calcareous interval.

11.D Effective porosity of the confining zone including the method of determination.

There is porosity, but no effective permeability in the confining interval given it is a shale. This has been verified via well logs.

11.E Vertical and horizontal permeability of the confining zone and the method used to determine permeability. Horizontal and vertical variations in permeability expected within the area of influence.

Provided the Bell Shale is a shale, there is no to little permeability in the confining interval. There is no anticipated variation in expected Bell Shale porosity or permeability within the AOR.

11.F The occurrence and extent of natural fractures and/or solution features within the area of influence.

There are no known natural fractures or solution features within the confining zone, either observed via indirect or direct methods.

11.G Chemical and physical characteristics of the fluids contained in the confining zone and fluid saturations.

Any porosity encountered above the injection horizons is sporadic, thin, and immediately interlayered with confining anhydrites, dolomites, cherts, or limestones, which will render data collection near impossible, impractical, or dangerous. Provided this is a shale, fluids will not flow, and they cannot be recovered.

11.H Formation fracture pressure, the method used to determine fracture pressure and the expected direction of fracture propagation.

The high differential rock properties, (young modulus, Poisson's ratio and fracture toughness) associated with the Bell Shale, but also the dense limestone just below it in the Upper Dundee, and just above it in the lower Traverse lime; there should be reasonable assurance that the confining interval will not be inadvertently fractured, provided the substantially greater permeable character of the Reed City Dolomite member of the Dundee. In the event fracture were to occur, theoretically, it would occur under the same conditions and directions as those described for the injection horizon.

At the direction of regulatory, a very conservative fracture gradient of 0.8 psi/ft has been applied to the Bell Shale. It should be well noted and understood that the confining interval is actually the Dundee Lime, in the Dundee Group; which is above the Reed city Anhydrite, which also serves as a confining interval. Measured fracture gradients of the injection interval (Reed City Dolomite) are substantially above the recommended 0.8 psi/ft gradient suggested by regulatory default, but actually measured at 1.17 psi/ft in the AOR.

11.I The vertical distance between the top of the confining zone from the base of the lowest fresh water strata.

The top of the Bell Shale is approximately 3,889' below surface. The base of the lowermost fresh water source ranges from approximately 712' below surface. Therefore, the vertical distance between the top of the confining zone from the base of the lowest freshwater strata is 3,177' below surface.

Please see **Figure 24** for a graphical representation of this statement.

12. Information demonstrating injection of liquids into the proposed zone will not exceed the fracture pressure gradient and information showing injection into the proposed geological strata will not initiate fractures through the confining zone. Information showing the anticipated dispersion, diffusion and/or displacement of injected fluids and behavior of transient pressure gradients in the injection zone during and following injection.

Please see Section EGLE BRINE DISPOSAL WELL CHECKLIST ITEM 2, where pressure wave data based on the laws of transient pressure and fluid dispersion given real observed subsurface rock parameters was provided.

Pressure transient and injectivity, step rate data will be performed, while being witnessed by the US EPA and/or EGLE in the step rate analysis.

There is also legacy data available within the AOR for Non-Hazardous Class I wells currently injecting in the into the Reed City Dolomite, which is summarized below, in expectation that measurements at the proposed locations may be similar. The following is a summary of data from historical reports, also for reference.

Woodward 1-26

Parameter	2005	2006
Permeability (k)	410 md	516.7 md
Perm-thick product (kb)	61,090 md-ft	76,988 md-ft
Skin factor (s)	16.4	2.27
Pressure change due to skin (Δp_{skin})	158.9 psi	29.22 psi
Flow efficiency (E)	0.36	0.80

Results of the pressure transient testing indicated the Woodward 1-26 well is positioned between parallel no-flow boundaries. A radial flow model with the Woodward 1-26 well positioned between parallel no-flow boundaries was utilized to evaluate the pressure transient data.

Please also see Section EGLE BRINE DISPOSAL WELL CHECKLIST ITEM 9.I which utilizes real injection step rate testing that was initiated in the offset Class I Disposal wells, the Thomas and the Woodward, where actual data was deployed to demonstrate that the injection rates did not, and still do not, initiate fractures under current regulatory observation.

The proximity of multiple wells enables the possibility of observation and interference testing. Therefore, while one well is undergoing a step rate injection test, or injection volume, the offset well will be utilized as an observation well, allowing additional information as it concerns the proposed injection horizons and injectivity. This can be done for all injection horizons provided proper planning once injection is established. The procedures for estimating reservoir reaction to injected fluid are made by determination of the porosity, permeability, thickness, extent, and pressure of the reservoir. Formation samples and cores, geophysical logs, and drill stem tests, and observation of pressures between two points enables an analysis of reservoir extent by comparing and deducing this data.

13. Proposed operating data including all of the following data

A. The anticipated daily injection rates and pressures.

B. The types of fluids to be injected.

C. A plan for conducting mechanical integrity tests.

13.A The anticipated daily injection rates and pressures.

At any given time, disposal may occur to a single well or to all applicant wells simultaneously, thereby reducing or changing the injected rate and volume per well. Maximum instant rates and volumes are not expected to exceed the following, per well. It is more likely than not, than injection pressures, or injection volumes will be the limiting threshold. The MPC-1D and MPC-3D, as vertical wells will have less injection capacity than the propositioned horizontal MPC-2D.

Single Vertical Well Injection Rates

Average Rate	Maximum Rate	Average Volume	Maximum Volume
Bpm	bpd	Bpd	bpd
9.5	27.85	13,680	40,104

All proposed injection zones are under-pressured in the area, with an anticipated pore pressure gradient of 0.41 psi/ft or less. In the state of Michigan, intermediate casing is typically set across the Bass Island Group as a result of lost circulation. Open hole logs suggest good injectivity across all proposed injection horizons.

Step rate and fracture data will be gathered for the target injection horizons in the subject wells.

Reed City Dolomite injection in the AOR over the previous ten years of operation demonstrates an average injection pressure into the Reed City Dolomite of 900 psi. This is reported regularly and summarized in re-application permits by the owner and operator of MI-133-1I-0002 and MI-133-1I-0001. These wells are injecting into the same Reed City Dolomite horizon as is proposed by Michigan Potash Operating. It is logical and expected that similar rates and pressures will be observed. MI-133-1I-0002 and MI-133-1I-0001 have under gone fracture testing in the AOR in the Reed City Dolomite. Injection tests were made by pumping treated water in the Reed City Dolomite at rates up to 1,176 gallons per minute at a surface pressure of 2,960 psi. After deduction of calculated friction loses of 38 psi within the well, the pressure at the top of the Reed City Dolomite, while injected treating fresh water was 4,647 psi. No parting or fracturing of the formation was noted, indicated the fracture pressure must be greater than 4,647 psi. A pressure gradient of 1.18 psi per foot was calculated. No further attempts were made to facture the injection zone.

This is typical of the Dundee, which has fracture gradients in typically in excess of 1.10 (EPA Michigan Field Fracture Gradients by County).

The permitted maximum injection pressure for the Thomas 1-26 well and Woodward 1-26 well is 2,393 psi and 2,453 psig respectively. Both are in the immediate vicinity of the applicant wells, into the same horizon, and up structure.

If capable, MPO proposes operating the disposal wells at higher pressure to obtain greater, more efficient disposal capacity than that currently sought at the offset operation operating at 900 psi. Based on available data, the following operating pressures are expected.

Average Pressure psi	Maximum Pressure psi
1,700	2,580

Injection fluid may be water (specific gravity of 1.05) or a partially saturated sodium chloride/potassium chloride brine solution with a specific gravity of up to 1.20, with a safety factor of 0.05 applied to operating conditions.

[{1.17 psi/ft - (0.433 psi/ft x specific gravity)} x depth] - 14.7 psi =

[{1.17 psi/ft - (0.433 psi/ft x 1.25)} x 4065ft] - 14.7 psi =

2541 psi.

Form EQP 7200-14, *has been filed with a default 0.8 psi/ft fracture gradient as directed by regulatory direction from the U.S. EPA despite substantial offset data available. Upon completion of the wells, step rate injection testing will be performed to obtain site specific data that will match the offsets and expected operating parameters listed in this section are anticipated; with 1.17 psi/ft FRACTURE GRADIENT.*

13.B. The types of fluids to be injected

The waste stream injected into the proposed Class I Non-Hazardous injection wells are non-hazardous brines (salt water) generated by the simple processing of food grade table salt (i.e. sodium chloride, NaCl) utilized on dinner tables across the world, and potassium chloride (KCl) “potash”, which is a natural, food safe fertilizer, applied to staple crops for food generation and consumption.

Salt and potash brine is sent to a natural gas fired evaporator, which concentrates the salt and potash water. Concentration of the water crystallizes the salt from solution, and increases the concentration of the potash in the water. The water is then sent to potash crystallization processes, where temperature contrasts crystallize the potash from the water. The remaining water is recycled back for injection, or in the case of excess water, is sent to Class I wells.

The facility is a food grade facility, and therefore, no hazardous, or non-naturally occurring materials are introduced into the system.

There may be traces of sodium hydroxide, used to strip naturally occurring H2S from the brine that comes from the salt and potash bearing formation (Salina A1). Pump packing seal water (<10gpm), and a bleed system (<10gpm) containing some sodium bisulfite may be added to the injection stream.

Class III wells under Area Permit MI-133-3G-0028, is the source of non-commercial, non-hazardous feed brine to the facility, and at times, to the proposed disposal wells. The field name has been dubbed the US Potash Project, Evart, MI.

Please also see Section EGLE BRINE DISPOSAL CHECKLIST ITEM 8.

13.C A Plan for Mechanical Integrity Tests

All required logs will be run at before any perforations are added to the casing and before fluid injection commences.

The mechanical integrity of all the proposed injection wells will be tested according to the requirements of 40 CPR 146.8 to demonstrate that (1) there are no significant leaks in the casing, tubing, or packer and (2) there is no significant fluid movement into a USDW through vertical channels adjacent to the injection wellbores. As required by permit, mechanical integrity tests shall be conducted at the required frequency, and especially before any injection commences. The timing of these test shall be dictated according to pro-active best practice.

Required tests include:

1) an approved pressure test in accordance with 40 CFR 146.8(b)(1) [annually];
2) an approved radioactive tracer survey [every five years]; and

3) an approved temperature, noise, oxygen activation or other approved log [every five years];

or 1,2, & 3 above as otherwise directed by permit.

Gauges used in performance of the MIT will be calibrated to an accuracy of not less than 0.5 percent of full-scale prior to field use. A copy of the calibration certificate will be submitted to USEPA each time the gauge is calibrated.

Notice will be made to the EGLE at least thirty days prior to the date of the schedule MIT. Tests must be witnessed by a representative of the USEPA and/or EGLE. A written report of the results of the MIT will be made to the EGLE within 45 days following completion of the MIT.

Brine is transmitted through the wells in tubing suspended from the wellhead and extending to a point near the top of the receiving formation. At or near the bottom of the tubing, the annulus between the tubing and the cemented casing is sealed with a packer; thus, the entire annulus from the wellhead to the packer is sealed off from the injected brine. The annulus is filled with an inhibited brine to a point slightly below the freeze line where the remainder of space is filled with oil. The annulus pressure is maintained to hold 20 psi at all times at surface and is monitored with a continuously recording pressure gauge.

If mechanical integrity was compromised the annulus fluid pressure would change and any change would be immediately detected by a change in the annulus pressure. If the injection tubing or packer developed a leak, a change in the annulus pressure would develop and would also be immediately detected by the continuously recording pressure gauge. In either case, investigative and remedial action would be promptly taken to replace or repair the part damaged following immediate notification and contingent operating procedures.

The multiple well application allows for an excess of disposal capacity and optionally to allow for system upsets, emergency shut-in, and contingent disposal capacity.

If failure were to occur to one well, that well would be shut-in immediately, and the entire disposal flow would be directed to the other well(s). If necessary , flow rates would be reduced as needed to remain below permitted injection pressure limits.

14. For a proposed disposal well to dispose of waste products into a zone that would likely constitute a producing oil or gas pool or natural brine pool, a list of all offset operators and certification that the person making application for a well has notified all offset operators of the person's intention by certified mail. If within 21 days after the mailing date an offset operator files a substantive objection with the supervisor, then the application shall not be granted without a hearing pursuant to part 12 of these rules. A hearing may also be scheduled by the supervisor to determine the need or desirability of granting permission for the proposed well.

The proposed injection horizons are not in a producing oil or gas pool or natural brine pool.

15. A proposed plugging and abandonment plan

Proposed Plugged Wellbore Diagrams.

Figure 44. Wellbore Plugging Diagram MPC-3D

MPC 3D

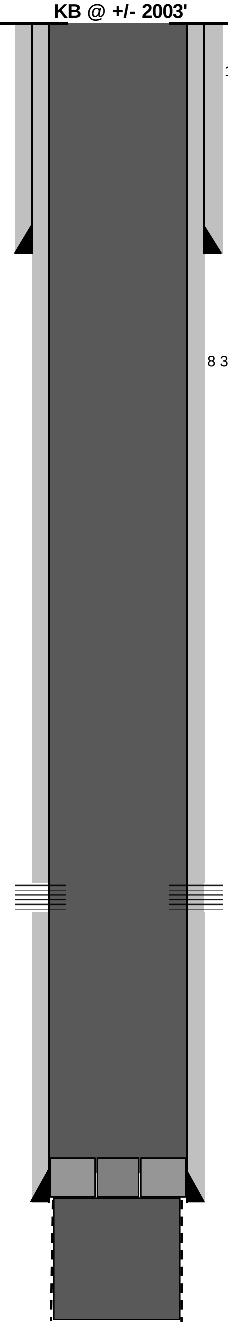
SURFACE: NE/4 SEC 36, T17N R09W, 43.818448, - 85.326073
VERTICAL WELL
OSCEOLA COUNTY, MI

P&A WELLBORE DIAGRAM

GL @ +/-1,190'
KB @ +/- 2003'

UPDATED SEP 2024 by CJS

Geological Zone	TVD	MD
Quaternary H	0	0
Quaternary G	117	117
Quaternary F1	165	165
Quaternary F	196	196
Quaternary E	342	342
Quaternary E/1	410	410
Quaternary D	461	461
Jurrasic Red Beds	712	712
Pennsylvantian		
Michigan	1261	1261
Marshall Sandstone	1719	1719
Coldwater Shale	1893	1893
Antrim Shale	2653	2653
Traverse Formation	3296	3296
Bell Shale	3889	3889
Dundee	3945	3945
Reed City Dolomite	4030	4030
Detroit River Group	4170	4170
Amherstburg	4962	4962
Sylvania Sand Stone	**5143**	**5143**
Bois Blanc	5337	5337
Bass Islands Group	**5390**	**5390**



16. Identify the source or sources of proposed injected fluids. Identify if injected fluids will be considered hazardous or non-hazardous as defined by Part 111, Hazardous Waste Management, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA)

Unchanged from Original Submission.

Please see EGLE Brine Disposal well Checklist Item 8.

The waste stream injected into the proposed Class I Non Hazardous injection wells are non-hazardous brines (salt water) generated by the simple processing of food grade salt utilized on dinner tables across the world, Sodium Chloride (NaCl), i.e. table salt or "salt", and potassium chloride (KCl) "potash", which is a natural, food safe fertilizer, applied to staple crops for food generation and consumption.

Salt and potash brine is sent to a natural gas fired evaporator, which concentrates the salt and potash water. The concentration of the water, crystallizes the salt from solution, and increases the concentration of the potash in the water. The water is then sent to potash crystallization processes, where temperature contrasts crystallize the potash from the water. The remaining water is recycled back for injection, or in the case of excess water, is sent to Class I wells.

The facility is a food grade facility. No hazardous materials as defined by Part 111 of Act 451 are anticipated.

17. Whether the well is to be a multisource commercial hazardous waste disposal well.

Unchanged from Original Submission.

The well is expressly NOT a multisource commercial well and is expressly not a hazardous waste disposal well.