PETROLEUM MANAGEMENT, INC.
Environmental Services Division
1030 E. Patapsco Avenue ♦ Baltimore, Maryland 21225
Phone: (410) 354-0200 ♦ Fax: (410) 721-1390

March 25, 2022

Maryland Department of the Environment
Oil Control Program
Attn: Susan Bull
1800 Washington Blvd., Suite 620
Baltimore, MD 21230

Re: Step Drawdown Test
Bates Middle School
Annapolis, Maryland
MDE Facility ID# 3200
MDE Case# 18-0559 AA

STEP DRAWDOWN TEST RESULTS REPORT

Dear Ms. Bull:

Petroleum Management, Inc. (PMI) has completed a step drawdown test of the shallow unconfined aquifer at the referenced Site and has prepared this report to present the results of the test. The test was performed on monitoring well MW-1 in an effort to evaluate the possible presence of light non-aqueous phase liquid (LNAPL) in stratigraphic layer(s) below the normal groundwater table elevation. The Site is located at 700 Chase Street in Annapolis, Maryland 21401 (Figure 1).

Background

Prior releases of #2 heating oil have been reported at the Site resulting from spills within the boiler room. These releases have impacted stormwater quality in the nearby outfall to Spa Creek. Groundwater remediation has included the completion of enhanced fluid recovery events and the current and ongoing recovery of LNAPL from wells MW-1 and MW-2 using
QED Environmental Systems Genie skimmer pumps. Historically LNAPL thickness in MW-1 has been up to 13.5 feet. The most recent groundwater measurements detected a LNAPL thickness of 1.66 feet in MW-1 and 0.06 feet in MW-2. Prior to the removal of the skimmer pumps on June 23, 2021, the product thicknesses in these two wells had been 0.01 feet or less.

Drawdown Test Design

The goal of this drawdown test was to acquire specific hydrologic data (i.e., hydraulic conductivity and/or transmissivity) about the impacted unconfined aquifer and to depress the groundwater table in MW-1 to specific depths to investigate the possibility that there were one or more stratigraphic layers at depth(s) below the elevation of the water table that may contain trapped LNAPL that would be released when the water table was depressed to intersect the impacted lithologic layer.

To achieve this goal PMI performed a 10-hour drawdown test. Groundwater recovered during the test was pumped into an open top, 9,000-gallon capacity frac tank equipped with weir boards that acted as an oil/water separator and allowed for the visual assessment and physical measurement of recovered LNAPL. The effluent from the frac tank was originally planned to be pumped though a bag filter assembly and then two activated carbon vessels set in series prior to being discharged to a permeable bladder that would release the water onto the ground surface in the vicinity of MW-8. However, a low volume of fluid was generated during the draw down test, so the fluids were removed from the Site by vacuum truck for offsite disposal. A copy of the disposal manifest is included in Attachment 1.

The drawdown test was designed in large part based on flow rates, product thicknesses, and depths derived from prior enhanced fluid recovery (EFR) events performed at the Site. That data indicated that the anticipated recovery rate required to draw down and hold a specific water table elevation was approximately 2.5 gallons per minute (GPM). The EFR events had drawn the water table down to depths of 20 and 25 feet below grade which resulted in substantial accumulation of LNAPL in MW-1. For this test HPE set the pump intake at 25 feet below grade. The pump was equipped with a flow control box to allow the operator to vary the pump flow rate to maintain the required drawdown for each step, as groundwater flow into the well reduced after initial drawdown as expected.

Drawdown Test Procedures and Results

On February 2, 2022, a step drawdown test was performed at Bates Middle School on MW-1. Water and product levels were recorded for monitoring wells MW-1, MW-2, MW-3, MW-5, and MW-8. Prior to beginning the test HOBO data logging sensors were deployed in MW-1, MW-2, MW-3, MW-5, and MW-8. Additionally, a sixth barometric sensor was placed at ground level near MW-5 to improve the data across any weather changes that might affect the sensors in the monitoring wells. The test had been planned for drawdown intervals as shown in Table 1.

Table 1
Designed Drawdown Depths and Times

Depth of pump intake	Drawdown Depth	Hold Duration
25 feet below grade	18 feet below grade (fbg)	4 Hours
	20 fbg	4 Hours
	22 fbg	4 Hours
	24 fbg	4 Hours

Steps 1 and 2 were completed while Maryland Department of the Environment (MDE) staff were on site. It was clear that, during the completion of step 1, no free product accumulation was occurring. As such, MDE personnel agreed to reduce the duration of steps 1 and 2 to one hour each. Steps 3 and 4 were left at the planned four-hour interval. Table 2 presents the utilized hold durations for the steps and water table depression depths completed as a part of this investigation.

Table 2
Actual Drawdown Depths and Times

Depth of pump intake	Drawdown Depth	Hold Duration
25 feet below grade	18 feet below grade (fbg)	1 Hour
	20 fbg	1 Hour
	22 fbg	4 Hours
	24 fbg	4 Hours

Once the step drawdown test was initiated every effort was made to avoid contact with the HOBO data loggers or their tethers. At MW-1 the recorded data reflect a few incidents during which the cabled logger or pump needed to be retracted for inspection and subsequently snagged the tether of the data logger. It is thought that an abundance of roots in MW-5 caused a similar singular disruption in the data after the start of the test as the logger was initially snagged in the roots above the bottom elevation of the monitoring well and then dropped into its final position about 87 minutes after initiation of the drawdown test.

Actual results of the step drawdown test indicate the greatest variation during the test outside of MW-1 was in MW-8. The HOBO data logger recorded all four steps with a total depression of the groundwater table in MW-8 of -0.38 feet. Unexpectedly, MW-2 showed almost no variation (-0.05') across the test duration while MW-3 had a decrease in head of -0.15'.

Post-test groundwater recovery data reveal that MW-3 had only recovered about half of its drawdown value by the time MW-1 was fully recovered back to pre-test levels. This may indicate a different hydraulic conductivity in the area of MW-3 or demonstrate an

influence on its recovery from the nearby sump at the corner of the building. MW-5 showed a total change in head of -0.27'. MW-1 throughout the draw-down test was decreased by approximately 9.5' in head from initial gauging to the final interval at a drawdown depth of 24' below top of casing.

Given the limited change in head within the nearby wells, the only data logger groundwater recovery curve that did not have an excess amount of "noise" in the data was from MW-1, with the interval from 7:30:30 PM to 9:49:00 PM reflecting the majority of the recovery (+9.337'). AQTEsolv was applied to the recovery curve to analyze the hydraulic conductivity and transmissivity in MW-1. Several methods and curve matching techniques were utilized before finding the best match to the generated dataset. That match was obtained by using the Neuman solution method for unconfined aquifers with partially penetrating well screened across the water-table. The results indicate a transmissivity (T) of 1.392 ft^2/day, and a hydraulic conductivity (K) of 0.0968 ft/day or 35.33 ft/year. The K value derived from the step drawdown test thought to be more representative of the actual groundwater flow rate as opposed to the prior K-value of 0.703 ft/day derived from slug tests performed in September 2019. This discrepancy is likely the result of the slug test data being more sensitive to the K-value of the monitoring well sand pack as opposed to the drawdown test data. PMI believes that the K value derived from the drawdown test recovery is more representative of site geologic conditions.

Groundwater Flow Rates

Groundwater flow rates required to maintain the desired groundwater drawdown elevations were determined in the field by directing the pump discharge into a graduated 5-gallon bucket and timing the water accumulation rate. The measured flow rates are presented in Table 3 below and range from 0.25 gallons per minute (gpm) to just over 0.5 gpm. In general, the flow rate required to achieve and maintain each step increased. Albeit slightly, with depth.

Table 3
Groundwater Flow Rates

Step #	Time	Depth	Flow Rate
1	9:00	18 feet below grade (fbg)	0.25 gallons per minute (gpm)
2	10:30	20 fbg	0.33 gpm
3	15:30	22 fbg	0.36 gpm
4	19:00	24 fbg	0.51 gpm

Free Product Occurrence

Measurements were taken prior to (8:00am), during, and after the step draw-down test for depth to water and depth to free product from top of casing. MW-1 was bailed of all but 0.07' of apparent free product prior to initiating the step drawdown test. This amount declined to 0.02' through the first three steps of the test. By the last step there

was no measurable free product present. Depth to water and depth to product measurements taken during the drawdown test are presented in Table 4. These measurements indicate that no measurable free product entered into the well screen during the drawdown test indicating that there were no "trapped" layers of free product below the normal groundwater table elevation.

Table 4
Groundwater Gauging Data

Time	MW-1		MW-2	
	DTP[1]	DTW[2]	DTP	DTW
Step 1				
8:30	15.11	15.18	13.83	14.26
9:03	18.16	18.21	13.82	14.24
9:17	18.16	18.21	13.83	14.26
9:27	18.04	18.14	13.83	14.25
9:40	17.96	17.99	13.83	14.26
10:07	18.09	18.13	13.83	14.25
Step 2				
10:16	20.11	20.14	13.83	14.25
10:45	20.07	20.09	13.83	14.25
11:00	20.08	20.11	13.83	14.26
11:10	20.06	20.08	13.84	14.27
Step 3				
11:23	22.08	22.09	13.82	14.26
11:42	22.00	22.02	13.83	14.26
12:01	22.07	22.09	13.83	14.26
12:16	22.05	22.07	13.84	14.26
12:43	22.05	22.07	13.84	14.26
13:04	22.09	22.11	13.83	14.26
13:32	22.07	22.09	13.84	14.27
13:58	22.09	22.10	13.83	14.26
Step 4				
15:30	24.20	24.20	13.84	14.28
16:18	24.52	24.52	13.84	14.28
17:16	24.48	24.48	13.85	14.29
18:11	24.48	24.48	13.84	14.29
18:46	24.52	24.52	13.85	14.28

[1] - DTP – depth to product layer from well casing
[2] - DTW – depth to water from well casing

Depth to water measurements were taken on February 3, 2022, at 10:50 a.m., the next morning after the test, and indicated a total of 0.11' of free product had entered the well, or approximately 0.04' more than the 0.07' of free product in MW-1 before the step draw-down test was initiated. Groundwater flow at the site is to the south (Figures 2 and 3).

By the morning of February 4, 2022, at 6:10 a.m. the measured apparent free product thickness was 0.45'. It is thought that either the draw-down test created a significant cone of depression with an associated smear zone of product that was then re-mobilized toward the well during the post-test groundwater recovery or that the free product is held within the pore spaces of the sandy clay lithology and is only mobile when a pressure differential is present between the water table and the product filled pore spaces. The next reading was on February 9, 2022, at 1:25pm and indicated a further 0.46' increase in free product over the course of the previous five days or approximately 0.09'/day. The accumulation of free product in MW-1 is thought to be the result of the water table applying a pressure to the product filled soil pore spaces and creating a pressure gradient from the formation into the monitoring well screen. Thus, the measured thicknesses within MW-1 are thought to be enhanced from the thickness that is actually present in the formation itself. The field measured free product thicknesses should be considered to be "apparent" thicknesses as opposed to "actual" representation of the thickness of the free product zone within the formation.

Conclusions and Recommendations

The completed step drawdown test indicates that there were no indications of trapped lenses of free product beneath the normal groundwater table elevation. The local groundwater flow rate, as determined by modeling post-test groundwater recovery rates, was 0.0968 ft/day or 35.33 ft/year.

Historical data indicate that the occurrence of free product has been limited to the immediate vicinity of the boiler room foundation wall as evidenced by measurable product being present in monitoring wells MW-1 and MW-2 (and previously in MW-3). There is no indication of the migration of free product away from this area. Minor dissolved phase contamination has historically been documented in monitoring well MW-8. In total, the analytical data and physical measurements of free product thicknesses indicate that the petroleum plume at the Site is relatively stable. Absent any control measures, free product has been shown to accumulate in MW-1, and, to a lesser extent, in MW-2 at thicknesses that could lead to possible migration of product away from the source area. As such it is prudent to redeploy a control technology to prevent this. Product only recovery pumps were installed in MW-1 and MW-2 on April 29, 2020, and have been successful at maintaining product thicknesses within the wells in a cost-effective manner. As such PMI recommends that a formal Pump Operation

and Monitoring Plan be developed and implemented at the Site to operate these pumps for the foreseeable future to control any migration of free product away from the source area. The plan should include a decision tree outlining how the system performance and product recovery efforts should be evaluated to provide for the eventual removal of the recovery pump system and closure of the current OCP Case.

Please respond accordingly upon review of this report. Thank you for your attention to this case.

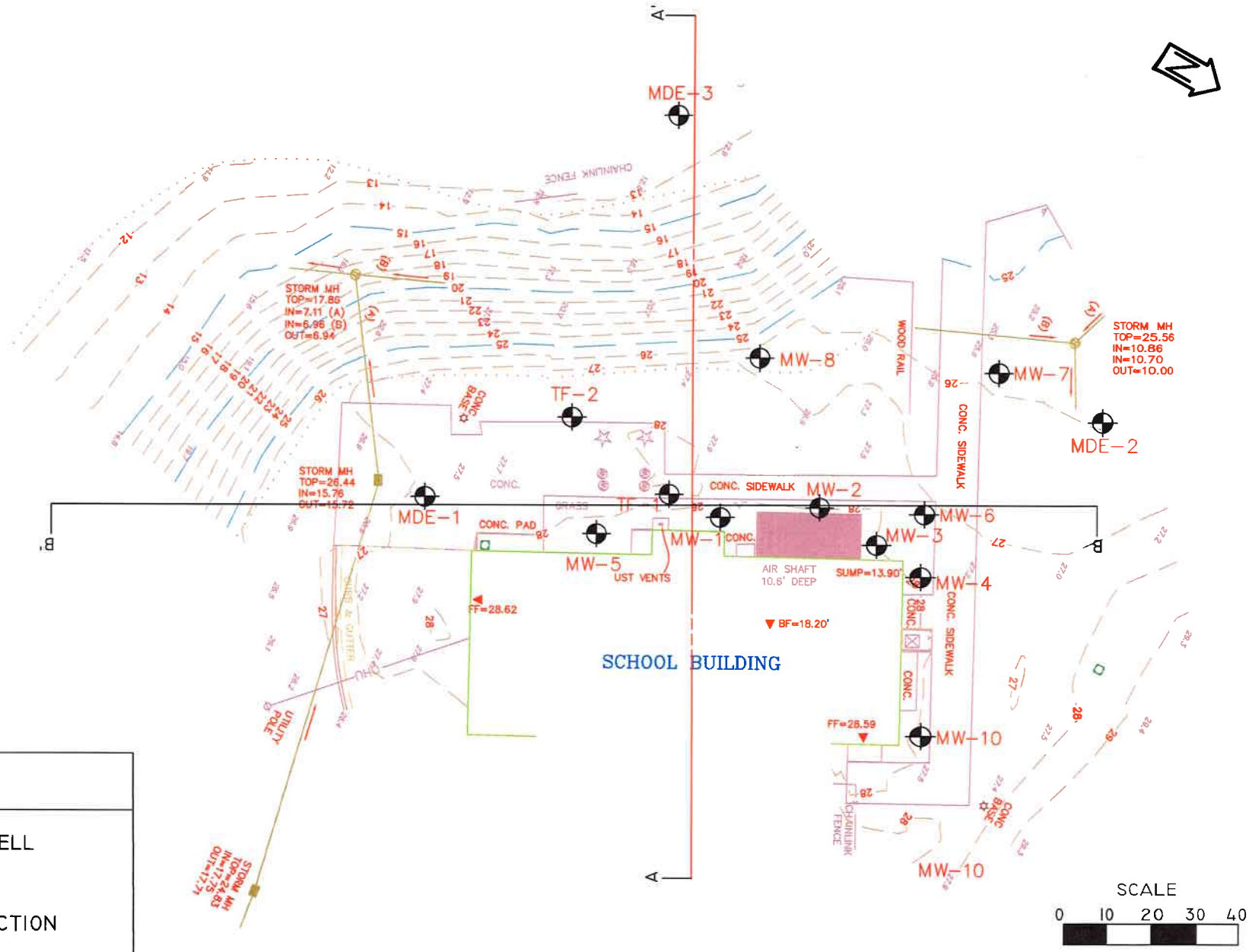
Respectfully Submitted,

W. Scott Alexander
Environmental Projects Manager

Enc.

cc: *Mr. Chris Williams (AACPS)*
Mr. Brian Wells (AACPS)
Mr. Kent Campbell (HPE)

FIGURES



LEGEND

MONITORING WELL

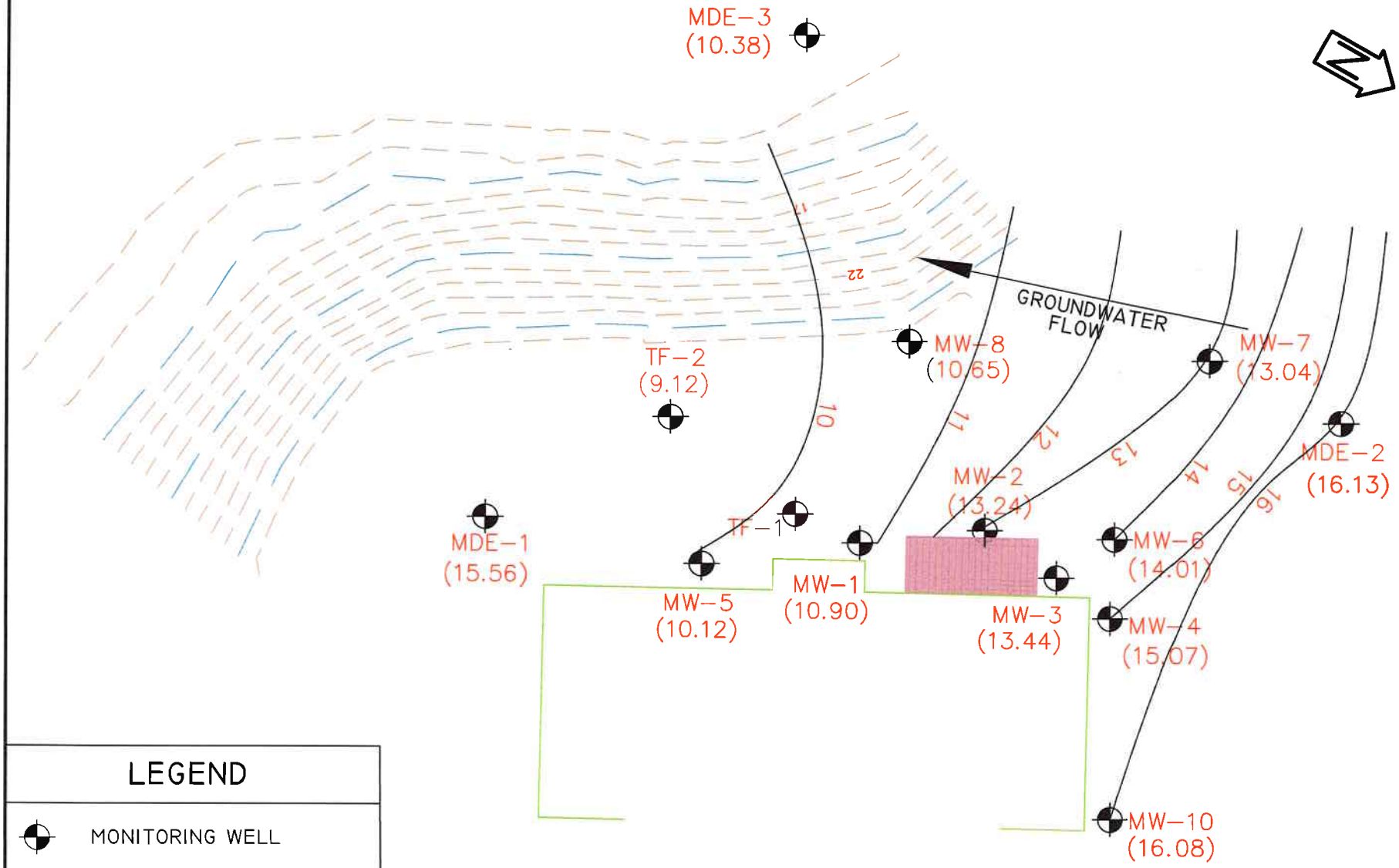
B B' CROSS SECTION

HP ENVIRONMENTAL, INC.
104 ELDEN STREET, SUITE H
HERNDON, VIRGINIA 20170
TELEPHONE 703 471 4200 FAX 703 471 0020

FIGURE 1
SITE SKETCH

BATES MIDDLE SCHOOL
701 CHASE STREET
ANNAPOLIS, MARYLAND

DRAWN BY:	CAD FILE:	SCALE:
KDC	BATES FIG X	AS SHOWN

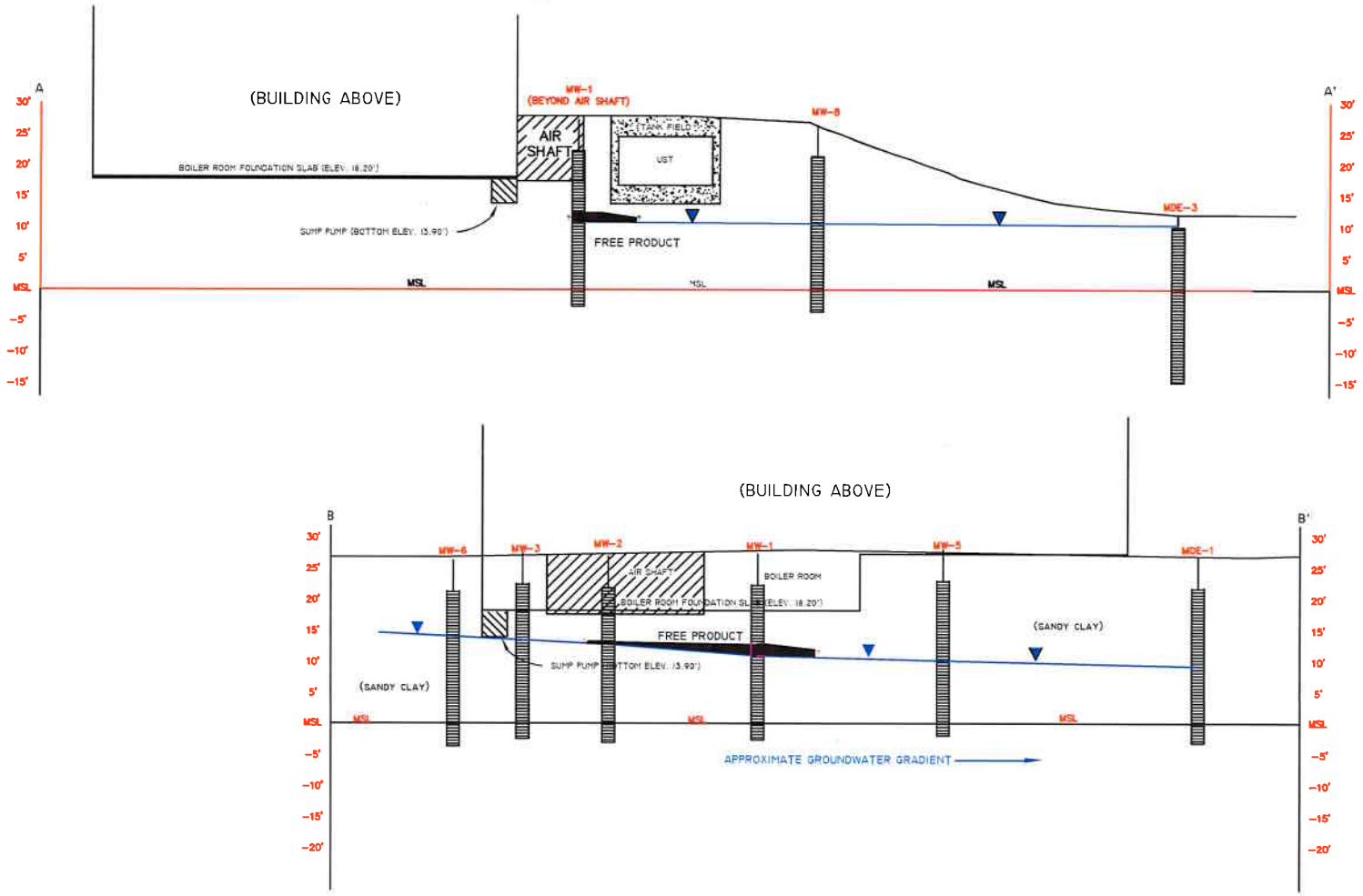


HP ENVIRONMENTAL, INC.
104 ELDEN STREET, SUITE H
HERNDON, VIRGINIA 20170
TELEPHONE 703 471 4200 FAX 703 471 0020

FIGURE 2
GROUNDWATER FLOW
02/23/2022

PROJECT: BATES MIDDLE SCHOOL
701 CHASE STREET
ANNAPOLIS, MARYLAND

DATE:	DRAWN BY:	CAD FILE:	SCALE:
03-18-22	KDC	BATES FIG X	AS SHOWN



LEGEND

GROUNDWATER TABLE

SCALE

0 10 20 30 40

HP ENVIRONMENTAL, INC.
104 ELDEN STREET, SUITE I
HERNDON, VIRGINIA 20170
TELEPHONE 703 471 4200 FAX 703 471 0020

FIGURE 3
CROSS SECTIONS

BATES MIDDLE SCHOOL
701 CHASE STREET
ANNAPOLIS, MARYLAND

DRAWN BY:	CAD FILE:	SCALE:
KDC	BATES FIG X	AS SHOWN