Pits and Impoundments Final Report

For

Assessing Environmental Impacts of Horizontal Gas Well Drilling Operations (ETD-10 Project)

Prepared for:

Office of Oil and Gas
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Background

On December 14, 2011, the Natural Gas Horizontal Well Control Act §22-6A was enacted by the State of West Virginia. With this Act, the West Virginia Department of Environmental Protection (WVDEP) was mandated to conduct studies regarding horizontal drilling and related potential environmental impacts in order to provide recommendations for the next legislative session.

In order to examine the potential environmental effects associated with horizontal drilling, a research project was implemented with West Virginia University and managed by the West Virginia Water Research Institute (WVWRI). The research concentrated on the potential health and safety concerns related to natural gas wells. The three key task areas of the study were i) air and water quality; ii) generated light and noise; and iii) structural integrity and safety of the flowback water pits and freshwater impoundments for the gas wells. The purpose of studying pits and impoundments to determine the suitability of the construction and use of these structures in minimizing the potential environmental effects related to horizontal drilling. This task was performed by researchers from the West Virginia University Department of Civil and Environmental Engineering (CEE).

CEE Scope of Work

The broad scope of the CEE research included the following areas:

- review of field construction practices
- engineering reviews of approved permit plans for consistency with requirements
- field evaluations to assess the as-built sites with the permitted plans
- limited geotechnical soil property testing
- assessment of data findings related to construction and evaluation of mechanisms for groundwater contamination such as pumps, piping, and geomembrane liners
- preparation of a final topical report of findings

Review of Construction Practices

The CEE researchers coordinated with the WVDEP for the review of oil and gas permit files and the selection of candidate sites. A short-list of 18 sites was provided for review based on a set of CEE criteria that included the age, size, use, construction material and method, and placement of the structure. Certain sites selected were known by the WVDEP to have problems. The selection incorporated sites constructed before and after the enactment of §22-6A in order to assess the implementation and effects of the new regulations on industry practices. Initially, 14 sites were selected for evaluation, but prior to the completion of the project, one additional site was added, making 15 total sites visited.

Field evaluations and soil property testing were used to ascertain and document the safety and structural integrity of the pits and impoundments. The field observations were performed using an evaluation form developed for the project to maintain consistent data collection across all sites. The evaluation form contained the following sections: permit information, field as-built construction and site conditions, observation checklist, and site operations and maintenance questionnaire. Using this approach, researchers made visual observations of the site and the surrounding environment, documenting items of concern with Global Positioning System (GPS) referenced pictures. Field soil samples were collected using hand shovels at various locations on each site and were subsequently tested in the WVU CEE geotechnical laboratory in accordance with the American Society for Testing and Materials (ASTM) Standards. The specific laboratory soil property tests performed were field moisture content, grain-size distribution and hydrometer analysis, Atterberg limits, specific gravity, Standard Proctor, hydraulic conductivity, and shear strength. Of the 15 sites evaluated, six were chosen for *in situ* field compaction density and moisture content testing. The laboratory testing and the data collected in the field were compiled and served as the basis for the results of this study.

Results of Permit Reviews

The permit reviews of the candidate sites revealed that the permit files for 10 sites constructed prior to the enactment of §22-6A lacked geotechnical investigation reports. The permits for the three sites constructed after the enactment of §22-6A contained this information. Additionally, the permit information for two sites was not provided by the WVDEP at the time of the evaluation.

An analysis of the permits compared the permitted storage volumes with the storage volume requirements of dams as regulated by the WVDEP (WVCSR §22-14 & WVCSR §47-34). No sites were found to meet the requirements of a dam. However, the large quantities of water could be a potential hazard to the public and the environment if a failure were to occur because of the ridge-top location of several sites.

Results of Field Evaluation

At the start of each field evaluation, measurements of the pit or impoundment as-built construction were made and compared to the permitted design. Findings identified discrepancies between the permit and as-built dimensions for eight sites. The measurement discrepancies included larger as-built volume capacities, smaller crest berm widths, and steeper upstream and downstream slopes than the permitted design specified. The significance of these deficiencies is summarized as follows:

- The as-built dimension discrepancies result in the pit or impoundment holding larger volumes of flowback water or freshwater than the permitted design.
- The differences in the crest berm width distances and the steepness of the slopes can negatively affect the safety and slope stability of the pit or impoundment.
- These deficiencies introduce uncertainty into the safety of the pit or impoundment due to unknown storage volumes and stresses on the foundation, slopes, and geomembrane liner systems.

The analysis of the field evaluations consisted of ranking the field data into a numeric scoring system. Using this method, a numerical score was obtained, and each site was ranked in terms of the field anomaly severity and frequency of occurrence. This score was based on a total of 100%, and the results ranged from a low of 59% to a high of 88%.

Results of Laboratory and Field Geotechnical Evaluation

Results of the laboratory testing indicated that none of the post §22-6A sites had soil conforming to the soil types specified by the WVDEP Design and Construction Standards for Centralized Pits. Of the remaining twelve pre §22-6A sites, only one site met the soil standards. However, the laboratory testing indicated that the soil types present at the sites may be suitable for the construction of pits and impoundments if proper compaction is achieved.

An assessment of the soil properties in the available site geotechnical investigations revealed several discrepancies when compared with laboratory data. The soil properties contained within the permit were characteristic of the top layers of excavation, which are not necessarily representative of the soils at the bottom of the excavation. Thus, the engineering properties of the soil tested during the excavation may not be consistent with the properties of the fill material used during construction. Furthermore, the foundation and slope designs of the structure may include soil properties that are not representative of site soil, which can contribute to post-construction issues. For the six sites where *in situ* field compaction density and moisture content testing was performed, the field data was compared with laboratory Standard Proctor density data. This analysis consisted of ascertaining the distribution of field data points in relation to the optimum compaction range for each site. The following areas of concern were identified:

- Three of the six sites had field data points within the optimum compaction range. Two of the sites had 14% of data points in compliance, and the other site had 22% of data points in compliance.

- The field data from the remaining three sites had 0% compliance with the optimum compaction range.
- Based on a total of 70 samples taken across all six sites, only six data points were within the acceptable range (8.5%).
- As a result of insufficient soil compaction density, the slopes of the pits and impoundments have a higher potential of developing subsurface erosion and elevated pore water pressures leading to slope instability.

In summary, the recurring problems and deficient areas from the field evaluations include the following:

- insufficient compaction density of site soil and excessive soil lift height
- surface soil erosion
- slope movement
- buried woody debris
- seepage and wet zones
- geomembrane liner deficiencies
- unsupported pipes

Overall, these deficiencies reflect a lack of adherence to the best management practices set forth in the West Virginia Erosion and Sediment Control Field Manual, as well as poor construction knowledge. These construction practices combined with a lack of field quality control and assurance are indicators of the source and frequency of the problems observed across all evaluated sites.

Site Operations and Infrastructure Evaluation

The Site Operations and Infrastructure Evaluation consisted of a questionnaire for the WVDEP Office of Oil and Gas Inspector and on-site company representative, although the company personnel present at the time of the field visit may or may not have been the principle site inspectors. The responses obtained for each question were compiled for analysis, and trends were established across all sites. The results indicate that none of the WVDEP inspectors had any formal training related to pits and impoundments inspection. In addition, no standardized method was used by the inspectors, which resulted in the use of the state regulations as an inspection guide. Consequently, the inspectors only targeted the readily-apparent problems such as slips and slides, while not recognizing, or fully understanding, the smaller problem indicators.

Another area of concern was that the responses from WVDEP inspectors and company representatives revealed that there was no set frequency for site inspections to be performed. The actual frequency of inspections, by the WVDEP or the company, varied from every three days to once every two months, and the inspection frequency by a Professional Engineer (PE) ranged from weekly to never. Infrequent inspections may allow problem areas to go unnoticed or delay corrective actions.

Emergency Action Plans (EAPs)

Emergency Action Plans (EAPs) were not required prior to the enactment of §22-6A, and the new regulations stipulate that EAPs are only required for centralized pits and impoundments. The company representative at the post §22-6A sites in this study was not aware that the sites had an EAP, had not received training, and did not know if the EAP had been evaluated for practicality in an emergency situation. Also, at the time of the field visit, the EAP was not available on-site. Therefore, the company representative on-site was unprepared to act in a timely and efficient manner if an emergency situation were to occur.

The EAPs for the post §22-6A sites did not contain any evacuation protocol, with the justification that there were no nearby structures that would be impacted by a failure. No inundation maps were provided in the EAPs to support this statement. During the field evaluations for these sites, a slope failure was found, which is illustrated and described in this report. These site conditions demonstrate the necessity of properly developed and implemented EAPs at Marcellus Shale pits and impoundments.

Recommendations

Based on the findings in the study, the following recommendations were developed:

- Improve WVDEP inspector training requirements and methods.
- Improve the field quality control and assurance for construction and inspection to ensure that the as-built dimensions do not exceed the permitted design.
- Thoroughly test the site soil to determine the geotechnical properties for all fill materials.
- Review the allowable soil type specifications so that suitable soils may be used, or remove the stipulation from the WVDEP Design and Construction Standards for Centralized Pits.
- Develop EAPs for all pits and impoundments, pre and post §22-6A, to improve the safety of these sites.
- Do not allow pre §22-6A sites to be re-permitted as centralized pits or impoundments because the designs do not incorporate §22-6A design standards.

Preparation of Final Topical Report

The preparation of this final report included two reviews performed by representatives of the WVDEP Office of Oil and Gas. The first review was performed in October 2012 and the second in early December 2012. The WVDEP prepared written comments for each report draft which were then addressed by WVU. The reviews focused on identifying terminology, permitting issues, and initial report findings for corrective action purposes. This process served to provide an internal level of quality assurance for the report development (WVU Review and Back-Check Memorandum, 2012).

An immediate benefit from this process was that the WVDEP was able to implement corrective actions that included developing and presenting an industry construction training seminar on October 24, 2012 and initiating internal WVDEP inspector training.

Concluding Remarks

There were several construction deficiencies out of compliance with the West Virginia Erosion and Sediment Control Field Manual, and the WVDEP Design and Construction Standards for Centralized Pits. However, none of the deficiencies indicated imminent pit or impoundment failure potential at the time of the site visit. The problems identified do constitute a real hazard and present risk if allowed to progress, but all problems that were observed in the field could be corrected. Future construction, if done in conformance with the WVDEP guidelines, should pose minimal risk.

1.0 Background and Objectives

Marcellus Shale is a rock formation located under regions of West Virginia, Pennsylvania, and New York. This formation contains large reserves of natural gas that are commonly being explored using recently developed horizontal drilling and hydraulic fracturing techniques. The West Virginia Legislature enacted the Natural Gas Horizontal Well Control Act §22-6A on December 14, 2011. As part of this Act, the West Virginia Department of Environmental Protection (WVDEP) is to perform studies concerning the practices involved with horizontal drilling and the associated environmental impacts, followed by a report of the findings and recommendations.

In order to examine these environmental impacts, the WVDEP contracted with the West Virginia Water Research Institute (WVWRI) who organized and directed a research study focusing on the potential health and safety concerns resulting from horizontal drilling techniques. Among the key areas of research were the surrounding air and water quality, the generated light and noise, and the structural integrity and safety of the pits and impoundments retaining fluids for the gas wells. The intent of the pits and impoundments component of this study was to ascertain and document the suitability of the construction and use of these structures in minimizing the potential environmental effects related to horizontal drilling. The pits and impoundments research was performed by the Department of Civil and Environmental Engineering (CEE) at West Virginia University (WVU). Specific objectives of this aspect of the research are listed below.

1) Conduct an engineering review of pits and impoundments to determine the current state of practice used in field construction.

2) Perform engineering reviews of submitted and approved permit plans from various energy companies operating in West Virginia.

3) Conduct site investigations of various pits and impoundments to include audits of submitted plans versus actual field practices and limited geotechnical soil property testing.

4) Assess data findings from field studies to address topics such as leak detection, methodology, and data evaluation to determine methods for locating and detecting sources of groundwater contamination, such as pumps, piping, and geomembrane liners.

5) Compile a final report of field studies of pits and impoundments including recommendations for improving industry standards and practices.

2.0 Study Design

The intent of the field evaluations and soil property testing in this study was to ascertain and document the safety and structural integrity of the pits and impoundments used to retain hydraulic fracturing and flowback fluids for Marcellus Shale horizontal gas wells. Pits are man-made excavations that contain waste fluids from the development of horizontal wells which could impact surface water or groundwater. Conversely, an impoundment is a man-made excavation that contains only freshwater. In order to examine current industry practices for the construction, operation, and maintenance of these structures, both pits and impoundments were considered for evaluation in the study. Cooperating with the WVDEP, WVU personnel received eighteen candidate permit files for pits and impoundments with varying characteristics. Based on the permit files and site availability, twelve sites were initially selected for evaluation, six of which were chosen for further in-depth soil property testing. Because of scheduling and site access availability, three additional sites were visited in this study, resulting in a total of fifteen sites.

The WVDEP established site access by contacting the natural gas developers. Researchers coordinated with the regional WVDEP Office of Oil and Gas Inspectors to schedule and conduct field evaluations and soil property testing on the sites. During the field visits, research personnel made visual observations of the surrounding environment and collected pictures to document areas of concern. Site soil was collected using shovels at various locations on each site. These locations were predetermined based on WVDEP permit reviews. The site soil was tested in accordance with American Society for Testing and Materials (ASTM) Standards at the WVU Department of Civil and Environmental Engineering Soil Mechanics Laboratory. The specific soil property tests performed were field moisture content, grain-size distribution and hydrometer analysis, Atterberg limits, specific gravity, Standard Proctor, hydraulic conductivity (rigid wall), and shear strength.

3.0 Site Selection

Site selection was conducted by analyzing a set of 18 candidate permits provided by the WVDEP based on a set of criteria set forth by WVU. These criteria were used to choose sites with a variety of pit and impoundment characteristics for evaluation. The factors encompassed in the criteria include the following:

- Location within the State of West Virginia
- Company Size: small, medium, or large
- Pit Characteristics:
    - Permit Number/Site Name
    - Age
    - Size (area, depth)
    - Use (flowback water, freshwater, centralized, associated)
    - Construction Material (natural soil, HDPE lined)
    - Construction Method (incised, berm)
    - Placement (hill crest, cut into slope, valley)

Based on these criteria, twelve sites were selected for evaluation, but the determination was made to evaluate the three SHL pits individually, bringing the total number of sites to fourteen. One additional site, Shields FWI, was visited to observe current construction practices. Certain sites selected were known by the WVDEP to have problems. In Table 1, the fifteen sites are listed, along with the company, county, and whether the site was constructed before or after the enactment of new regulations stipulated by the Natural Gas Horizontal Well Control Act §22-6A. Of the fifteen sites evaluated, further in-depth soil testing was performed on six sites. These six sites had field density and moisture content tests performed by a subcontractor, Potesta and Associates, Inc. Figure 1 displays the names and locations of the sites overlain on a county map of West Virginia.

Site Name	Company	County	Pre/Post §22-6A
Donna Completion Pit	Energy Corporation of America	Marion	Pre §22-6A
Donna Completion Impoundment	Energy Corporation of America	Marion	Pre §22-6A
Pribble Freshwater Impoundment	Stone Energy Company	Wetzel	Pre §22-6A
Burch Ridge Wastewater Pit	Gastar Exploration USA, Inc.	Marshall	Pre §22-6A
MIP Freshwater Impoundment	Northeast Natural Energy	Monongalia	Pre §22-6A
Ball 1H Impoundment #2	PetroEdge Energy, LLC.	Tyler	Pre §22-6A
Mills-Wetzel Freshwater Impoundment	Stone Energy Company	Wetzel	Pre §22-6A
SHL 2 Centralized Pit	Noble Energy, Inc.	Marshall	Post §22-6A
SHL 3 Centralized Pit	Noble Energy, Inc.	Marshall	Post §22-6A
SHL 4 Centralized Pit	Noble Energy, Inc.	Marshall	Post §22-6A
Shields FWI	Gastar Exploration USA, Inc.	Marshall	Pre §22-6A
Flanigan Pit	Antero Resources Appalachian Corp.	Harrison	Pre §22-6A
Larry Pad	Antero Resources Appalachian Corp.	Harrison	Pre §22-6A
MWV Large Water Storage Pond 1	Bluescape Resources Company, LLC.	Nicholas	Pre §22-6A
Plum Creek South Fork	Bluescape Resources Company, LLC.	Greenbrier	Pre §22-6A

Table 1: Evaluation Sites

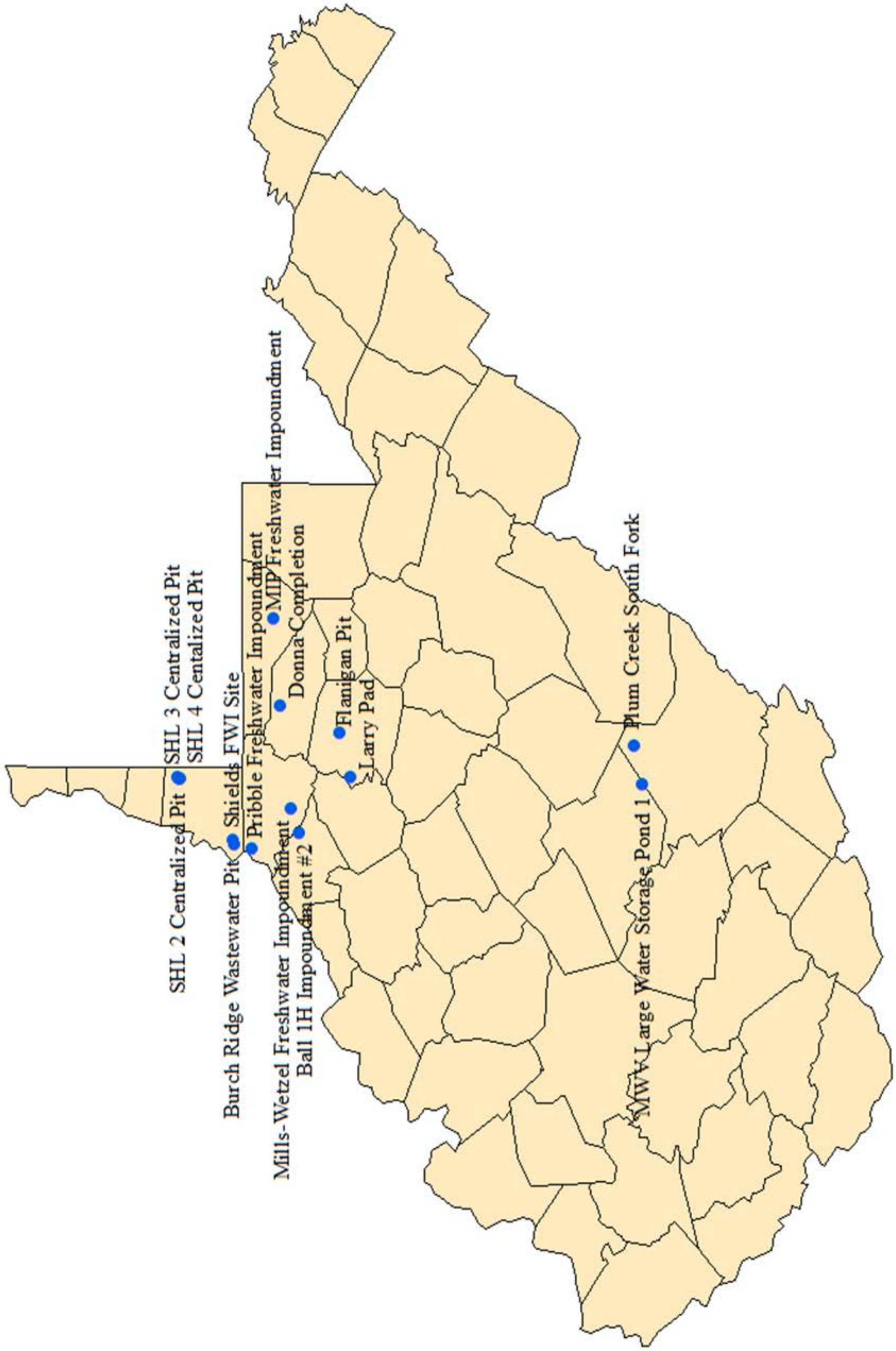

Figure 1: Site Locations

4.0 Field Evaluation Methods

Prior to conducting field evaluations, WVU researchers completed the 40-hour HAZWOPER (Hazardous Waste Operations and Emergency Response) training. On each field evaluation, at least four WVU personnel were present. Each member wore all required personal protective equipment (PPE) as specified by the company to perform field evaluations and soil collection on horizontal gas drilling sites.

In compliance with WVU Environmental Health & Safety policies and HAZWOPER training requirements, all WVU personnel underwent a medical screening to determine a medical health baseline for each member prior to any field work. Personnel will also receive medical screenings within one year of the project's completion. Further medical monitoring will be conducted if recommended by WVU's Department of Occupational Medicine.

Before each field evaluation, WVU field personnel attended site safety meetings to identify potential hazards and all procedures in place in the event an incident/accident occurred. If a hazard or danger had been found at a sampling site, the field personnel would have exited without delay, and the situation immediately reported to the WVDEP.

4.1 Site Evaluation Methods

Once the 15 sites for evaluation were selected, field visits to those sites were conducted for verification, visual evaluation, and data collection. To evaluate the pits and impoundments, a standardized checklist form was developed to ensure the field observations were recorded in a consistent method and format for comparison between sites. The evaluation form is shown in Figure 2.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME	County		Company	
WEATHER	Latitude		Pit Name	
	Longitude		API No.	

A. PERMIT INFORMATION

Pit Width (ft.)		Minimum Berm Crest Width (ft.)		Construction Type	
Pit Length (ft.)		Upstream Slope (H:V)		Liner Type	
Depth (ft.)		Downstream Slope (H:V)		Date Built	
Freeboard(ft.)				Date Reclaimed	

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)		Berm Crest Width (ft.)		Crest Height (ft.)	
Pit Length (ft.)		Upstream Slope (H:V)		Up Slope Length (ft.)	
Depth (ft.)		Downstream Slope (H:V)		Down Slope Length (ft.)	
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?		Is the pit/impoundment within 1000 feet of a public water source?	
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?		Is the pit/impoundment within 100 feet of a wetland?	

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?					
2	Are there any slope movements or animal burrows?					
3	Are there any depressions, sinkholes, or slides into the pit present?					
4	Are there any signs of mine subsidence on or adjacent to the embankment?					
5	Are there any observed trees, tall weeds, or other vegetation?					
6	Are there any seeps, wet zones, or losses of soil?					
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?					
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?					
9	Are there any areas where the liner is strained?					
10	Are there any areas where the liner has rock or debris on top of it?					
11	Is there any tear potential for the liner?					
12	Are there any deformations, cracks, or settlements around the anchor trench?					
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?					
14	Are there any areas where the pipe is not properly supported?					
15	Are there any signs of pipes having significant sagging in line?					
16	Are there any signs of obstructions (trees, garbage, etc.)?					
17	Are there any signs of water in ditch associated with pit?					
18	Are there any obstructions around the discharge outlet?					
19	Are there any signs of downstream slope movement into ditch?					

WVU (Name / Signature)	DATE
WVDEP (Name / Signature)	
Company Representative (Name / Signature)	

Figure 2: Evaluation Form

The first section of the evaluation form was used to document the weather conditions at the time of the field visit and general information regarding the site such as location, company, and site identification.

Section A was used to record key permitted characteristics of the site such as dimensions, slopes, and construction type. However, the permit information lacked geotechnical investigation reports for ten sites, and the permit information for two sites was not provided by the WVDEP at the time of the evaluation.

In Section B, the pit or impoundment characteristics were measured in the field to compare the permitted design with the as-built construction. Also, Section B outlined the WVDEP areas where construction of these structures is prohibited.

Section C is the observation checklist containing the specific areas of concern associated with the integrity of the structure. In Questions 1 through 6, the embankment slopes were evaluated to determine the severity of erosion present. In Question 1, the effects of surface water at the site which may indicate insufficient erosion control measures, soil compaction, and drainage were dealt with. Slope movements and animal burrows were evaluated in Question 2 to determine if the downstream face was stable and providing the necessary support against slope slippage and failure. In Question 3, the upstream face was assessed for any depressions, sinkholes, or slides that may compromise the containment of the pit or impoundment. Mine subsidence was an area of concern in Question 4 because any noticed subsidence around these structures would indicate the possibility of movement or unstable ground that could lead to slope deformation. Question 5 pertains to the prevalence of trees, tall weeds, and other vegetation that may inhibit the detection of critical problems during inspections. Additionally, woody debris was included in this question because the presence of woody debris in the fill material may increase the potential for surface erosion or slope movements. Seeps, wet zones, and losses of soil were covered in Question 6, as these problems are indicative of subsurface water movement that could cause slope failures.

Questions 7 through 12 focus on the containment system at the pit or impoundment and any potential for leakage. In Question 7, the presence of eddies and whirlpools was evaluated to determine if the liner system had a leak or puncture and whether the structure was losing fluid. Question 8 was used to assess liner tears, bulges, holes, wind uplift, and seam separation in order to ensure the containment system was functional and intact. Question 9 relates to strain in the liner that may result in tears or displacement of the liner. Rock and debris on the liner was covered by Question 10, as the added weight from the material may cause the anchor trench to pull out of the soil and impair the functionality of the liner. Question 11 pertains to the tear potential of the liner, including areas where the liner was stretched over rock and other debris. In Question 12, the anchor trench was examined for deformations, cracks, or settlements which may indicate improper soil compaction on the crest leading to pathways for water seepage. Furthermore, Question 12 addresses the embedment of the anchor trench to ensure that the liner was secured in place.

Another potential area of concern was the condition of the pipes at the site, which was covered in Questions 13 through 15. Any leakage or rupture of the pipes which convey water or flowback fluids would have an environmental impact to the surface water and groundwater. Pipe abnormalities were evaluated using Question 13, focusing on gouges, leaks, and cracks that may impair the pipe's ability to sustain an open cross-section and transport fluids under pressure. In Question 14, the placement of pipes at the site was dealt with because unsupported pipes present safety and health hazards due to the potential for rolling, slipping, pinching, and leaking. In Question 15, sagging in the pipe was assessed to determine the potential for flow restrictions, buckling, and leakage which may lead to environmental problems.

In Questions 16 through 19, the drainage measures at the site were evaluated to determine their functionality in removing excess surface water. Question 16 pertains to any signs of obstructions found inside the pits or impoundments such as trees or garbage that could possibly clog transfer pumps. Standing water in ditches was evaluated using Question 17 in order to ascertain the ability of the ditches to remove excess surface water from the sites. Obstructions around the discharge outlet that may interfere with the discharge of water when required was the focus of Question 18. In Question 19, slopes on the downstream face were examined to determine whether slope movements were restricting flow in the ditch, thereby impairing drainage.

Two WVU personnel discussed the ranking for each question on the evaluation form during the field assessments. Data was written in the evaluation form, and a review was conducted on-site to ensure that all items had been evaluated. Field signatures were obtained from the WVDEP and company personnel observing the evaluation.

The second part of the field visits consisted of the Site Operations and Infrastructure Evaluation, shown in Figure 3. This evaluation was a questionnaire for the WVDEP Office of Oil and Gas Inspector on site and/or the company representative, although the company personnel present during the field visit may or may not have been the party primarily responsible for the site inspections.

The questionnaire addressed inspector training and background in regards to pit and impoundment safety. Other questions pertained to the operation and maintenance procedures for the site as well as safety plans such as Emergency Action Plans (EAPs), which are required for sites permitted after the enactment of §22-6A.

Site Operations & Infrastructure Evaluation	
Date:	Pit/Impoundment Name:
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking)
2	What type of training or background does the inspector possess relative to pit/impoundment inspection?
3	How many years of training does the inspector have in evaluating pits/impoundments?
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection?
5	Who developed the form and how is the information used to evaluate pit/impoundment safety?
6	Are there safety and emergency procedures for the pit/impoundment?
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers?
8	Has the pit/impoundment inspector been trained on how to use the EAP?
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?)
10	Does the company have a policy on pit/impoundment safety?
11	How frequently does a Professional Engineer inspect the site?
12	Other comments:

Figure 3: Evaluation Questionnaire

4.2 Field Sampling Methods

The field sampling was performed by WVU researchers and consisted of digging several test holes with hand shovels at key locations across each site, such as the toe, face, and crest of the pit or impoundment slope. The test hole locations were planned prior to the site visit based on the information gathered from WVDEP permit files. One bucket of site soil was collected during each field visit in order to perform soil classification testing. On sites where *in situ* field compaction and moisture content testing was performed, two additional buckets of soil were collected to perform further in-depth engineering testing, such as compaction, permeability, and strength. Table 2 contains the date of each site visit and the type of soil testing performed for each site.

Site Name	Date of Site Visit	Type of Soil Testing
Donna Completion Pit	7/12/12	Classification
Donna Completion Impoundment	7/12/12	Classification
Pribble Freshwater Impoundment	7/16/12	Classification
Burch Ridge Wastewater Pit	7/16/12	Classification
MIP Freshwater Impoundment	7/18/12	Classification & In-Depth
Ball 1H Impoundment #2	7/24/12	Classification & In-Depth
Mills-Wetzel Freshwater Impoundment	7/24/12	Classification & In-Depth
SHL 2 Centralized Pit	7/30/12	Classification & In-Depth
SHL 3 Centralized Pit	7/30/12	Classification & In-Depth
SHL 4 Centralized Pit	7/30/12	Classification & In-Depth
Shields FWI	8/1/12	Classification
Flanigan Pit	8/2/12	Classification & In-Depth
Larry Pad	8/2/12	Classification & In-Depth
MWV Large Water Storage Pond 1	8/6/12	Classification
Plum Creek South Fork	8/6/12	Classification

Table 2: Site Visits and Soil Testing Plan

The soil gathered from the test holes was labeled with the site name, date, and location of the test hole. The sample locations were restored to the original conditions to ensure that no damage was made to the pit or impoundment. WVU personnel also made visual observations of the surrounding environment and collected geo-referenced pictures during sampling visits. After the collection of soil samples, all tools were cleaned and stored in containers to avoid cross-contamination between sites. In addition, the tools were inspected for damage after each use. All personal protective equipment (PPE) was similarly decontaminated, and all disposable materials were removed from the site in a garbage bag. Once collected, the soil was taken to the WVU Department of Civil and Environmental Engineering Soil Mechanics Laboratory for soil property testing and further analysis.

In addition to the field sampling performed by the WVU researchers, *in situ* field compaction and moisture content data on the six in-depth soil testing sites was collected by Potesta and

Associates, Inc. The testing was performed at various locations on each site, including the crest, mid-slope, and toe of the downstream face. These results were incorporated into the analysis along with the laboratory soil testing performed by WVU.

4.3 Data Management

Once WVU field personnel returned to the office, the evaluation forms were transferred to project computers located in the WVU Department of Civil and Environmental Engineering Soil Mechanics Laboratory. Information regarding times, dates, and personnel involved in data collection were also transferred to the electronic data file. The electronic copies were saved on an external hard-drive, and one back-up was created. As needed, once the data was transferred to the electronic data file, a review of the information was conducted and reported to the WVDEP as part of the monthly progress updates. Photographs were used to assist with documenting field activities and conditions. All hardcopy and electronic records were delivered to the WVWRI Project Manager for retention and were available to the WVDEP upon request. All raw and processed data was made available to the WVDEP as part of the monthly progress updates, and the intermittent and final reporting activities.

5.0 Laboratory Soil Testing Methods

Geotechnical soil property testing consisted of collecting soil samples for laboratory testing in order to obtain independent verification of soil properties and site conditions. This work was specific to the soils used to construct the pits and impoundments. Specific soil testing was performed at the WVU Department of Civil and Environmental Engineering Soil Mechanics Laboratory and included the following: field moisture content, grain-size distribution and hydrometer, Atterberg limits, specific gravity, Standard Proctor, hydraulic conductivity (rigid wall), and shear strength. The soil property tests and associated ASTM Standards are listed in Table 3. The necessary equipment and the procedure for each of these soil property tests are detailed in Appendix P.

Soil Property Test	ASTM Standard
Field Moisture Content	D2216
Grain-Size Distribution and Hydrometer	D422
Atterberg Limits	D4318
Specific Gravity	D854
Standard Proctor	D698
Hydraulic Conductivity (Rigid Wall)	D5856
Shear Strength	D3080/D3080M

Table 3: Soil Tests and Standards

6.0 Data Reduction and Results

Following laboratory soil testing, the results were compiled into a tabular format for comparisons to permit reviews and other published site data. This analysis led to a determination of the suitability and relative importance of the findings. Graphical outputs were generated to illustrate data trends and meaningful observations. The results are organized into three sections: Field Evaluation Results, Questionnaire Responses, and Laboratory Testing Results.

6.1 Field Evaluation Results

In order to provide an understanding of how the evaluations were conducted, the field observations for the Donna Completion Impoundment are shown in Table 4. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specified that the problem was very prevalent at the site and carried a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicated that the problem was not observed at the site. By summing the rankings for each question, a total score was obtained out of 76 total points. Using this point system, a percentage was assigned, which was used as a comparison for the sites. To illustrate the conditions that were marked as Moderate or High at the Donna Completion Impoundment, pictures collected during the field visit are presented with notes describing the specific observations depicted.

Fifteen sites were evaluated in this study, each having site conditions with varying problem areas and levels of severity. The Donna site was selected for discussion because the observed deficiencies best illustrated the field evaluation methodology used throughout the study. The WVDEP indicated full awareness of the Donna site’s conditions prior to and during the evaluation.

Donna Completion Impoundment		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	1
2	Are there any slope movements or animal burrows?	Yes			✓	1
3	Are there any depressions, sinkholes, or slides into the pit present?	Yes			✓	1
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			3
6	Are there any seeps, wet zones, or losses of soil?	No				4
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		2
9	Are there any areas where the liner is strained?	Yes			✓	1
10	Are there any areas where the liner has rock or debris on top of it?	Yes			✓	1
11	Is there any tear potential for the liner?	Yes			✓	1
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				4
14	Are there any areas where the pipe is not properly supported?	Yes			✓	1
15	Are there any signs of pipes having significant sagging in line?	Yes		✓		2
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	No				4
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	Yes			✓	1

Total:	**45**	(Out of 76)
Percentage:	**59.2%**	

Table 4: Observation Checklist for Donna Completion Impoundment

Figure 4: Settlement Cracks in Anchor Trench

Figure 4 shows settlement cracks on the crest of the impoundment around the anchor trench. The significance of this observation is that these cracks can serve as pathways for water to infiltrate and saturate the soil. The wet soil adds weight to the top of the slopes and is a recognized mechanism for surface water infiltration leading to slope instability.

Figure 5: Bulges on Downstream Face

In Figure 5, the bulges underneath the liner indicate slope movements on the downstream face. The slope movements are evidence that the slope is no longer stable and that the ability for the structure to retain fluid has been compromised.

Figure 6: Slope Movement into Impoundment

Figure 6 depicts a slide into the impoundment. This slide is putting strain on the liner, endangering the anchor trench and increasing the tear potential for the liner. Additionally, the slide is just below the site access road and is thereby threatening the integrity of the roadway. The displacement of the liner threatens the entire containment system due to an increased potential for tears or punctures leading to impounding water loss.

Figure 7: Vegetation on Berm

The vegetation shown in Figure 7 poses a problem for inspection procedures. The excessive vegetative growth on the crest may conceal potential areas of concern. Thus, corrective actions may not be implemented at an appropriate time.

Figure 8: Rock and Debris on Liner

In Figure 8, a high amount of soil and rock is present on the liner, including a large boulder in danger of sliding into the impoundment or puncturing the liner. A possible consequence related to this problem is that the rock and debris add weight to the liner, straining the embedment of the anchor trench and posing a hazard to the containment system.

Figure 9: Anchor Trench Exposed

Figure 9 illustrates an improper anchor trench for the liner. With the liner exposed, the potential for wind uplift is greatly increased, which could lead to displacement of the liner and possible failure of the containment system.

Figure 10: Unsupported Pipe

Figure 10 shows unsupported pipes along the hillside above the access road. Due to this placement, there is a greater likelihood of damage to the pipes that may lead to leakage and uncontrolled release of liquids. Any leakage or rupture of the pipes which convey water or flowback fluids would have an environmental impact to the surface water and groundwater.

Figure 11: Downstream Slope Movement into Ditch

Figure 11 depicts a downstream slope movement, as evidenced by the bulges underneath the liner and the movement of the grade stakes. A stream is located at the top right-hand corner of the picture. Thus, the slope movement is encroaching on the stream and threatening to disrupt the natural ecosystem.

In order to determine the recurring problem areas across all sites, each question on the observational checklist was analyzed individually. First, the number of No, Low, Moderate, and High rankings was totaled for each question. Next, the total number of points for the question was computed by multiplying the number of occurrences in each category by the numerical ranking for that category, and then summing the values for all the categories. Lastly, the weighted average for the question was calculated by dividing the total number of points by the number of sites evaluated.

Table 5 contains a breakdown of each question on the observation checklist, including the number of occurrences for each category and the average ranking for each question. To further illustrate this procedure, the average ranking for Question 5 is presented. For Question 5, two sites received a No ranking (4 points), seven sites were ranked Low (3 points), three sites were ranked Moderate (2 points), and two sites were ranked High (1 point). To calculate the total points for Question 5, the number of sites is multiplied by the points for each category, and these values are summed, as shown below:

$$\text{Total number of points} = (2 \times 4) + (7 \times 3) + (3 \times 2) + (2 \times 1) = 37$$

Once the total number of points is calculated, the average ranking for the question is computed by dividing the total points by the total number of sites evaluated. Since the Shields FWI site was still under construction, no evaluation was completed for this site, resulting in a total of 14 sites. The average ranking calculation is illustrated below:

$$\text{Average ranking} = 37 \div 14 = 2.64$$

Using this procedure, the average ranking for each question was calculated. Since an average ranking of three or above corresponds to a Low Significance or No Occurrence, all rankings below three were considered recurring problem areas across all sites. These problem areas are highlighted in Table 5. As examples of the significance of these problem areas, pictures collected during the field evaluations from several sites are presented.

Question		No (4)	Yes			Average Ranking (Out of 4)
			Low (3)	Moderate (2)	High (1)	
1	Are there any observed surface erosions, cracks, settlements, or scarps?	0	6	2	6	2.00
2	Are there any slope movements or animal burrows?	6	0	2	6	2.43
3	Are there any depressions, sinkholes, or slides into the pit present?	12	0	1	1	3.64
4	Are there any signs of mine subsidence on or adjacent to the embankment?	14	0	0	0	4.00
5	Are there any observed trees, tall weeds, or other vegetation?	2	7	3	2	2.64
6	Are there any seeps, wet zones, or losses of soil?	2	4	3	5	2.21
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	14	0	0	0	4.00
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	0	7	4	3	2.29
9	Are there any areas where the liner is strained?	11	1	0	2	3.50
10	Are there any areas where the liner has rock or debris on top of it?	1	11	1	1	2.86
11	Is there any tear potential for the liner?	10	2	0	2	3.43
12	Are there any deformations, cracks, or settlements around the anchor trench?	1	10	3	0	2.86
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	7	7	0	0	3.50
14	Are there any areas where the pipe is not properly supported?	6	4	1	3	2.93
15	Are there any signs of pipes having significant sagging in line?	11	0	2	1	3.50
16	Are there any signs of obstructions (trees, garbage, etc.)?	5	9	0	0	3.36
17	Are there any signs of water in ditch associated with pit?	4	8	1	1	3.07
18	Are there any obstructions around the discharge outlet?	14	0	0	0	4.00
19	Are there any signs of downstream slope movement into ditch?	12	1	0	1	3.71

Table 5: Average Ranking By Question

Figure 12: Surface Erosion at Mills-Wetzel

One problem area observed at all sites was surface erosion, found in Question 1 on the observation checklist. This problem was the most observed and, hence, received the lowest average ranking of 2.00. Figure 12 shows an example of the surface erosion present at the Mills-Wetzel Freshwater Impoundment. The gully shown formed rapidly, as evidenced by the lack of vegetation. The formation of the gully may be a result of excessive slope length or angle on the downstream face. The West Virginia Erosion and Sediment Control Field Manual states that terracing shall be constructed for each additional 50 vertical feet of slope and shall be a minimum of 10 feet wide. This best management practice was not followed on the Mills-Wetzel site.

Figure 13: Slope Movement at SHL 4

Question 2 on the checklist related to the prevalence of slope movements on the downstream face. Two sites were found to have moderate slope movements, and severe slope movements were present on six sites. Figure 13 shows a severe slope movement on the SHL 4 Centralized Pit. Above the slope movement, there was a significant amount of standing water on the crest, and signs of seepage were found in the form of wet soil inside the depleted soil zone. Slope movements are a problem because the structural integrity of the downstream face has been compromised. This slope failure is an example of a shallow face failure with characteristics including a pronounced scarp, zones of depletion and accumulation, and flanks defining the width of the failed soil, which is approximately where the WVU field personnel are located.

Figure 14: Woody Debris at SHL 2

Question 5 was used to evaluate any observed trees, tall weeds, or other vegetation, but the most prevalent concern was woody debris found in the fill of the slopes on all but two sites. Figure 14 depicts one instance of woody debris found on the SHL 2 Centralized Pit, where a log was compacted into the fill material on the downstream face of the pit. Woody debris is a problem due to the complications that may arise over time. One possible consequence is that the woody debris may form a barrier preventing the infiltration of water into the soil, causing erosion around the woody debris and on the slope directly below the debris. Another possible consequence is that the decomposition of the woody debris may result in pathways for surface water to seep into the slope, which reduces slope stability.

Figure 15: Seepage at Pribble

Seepage and wet zones (addressed in Question 6) were problem areas found at all but two sites. Figure 15 shows a seepage area on the downstream face of the Pribble Freshwater Impoundment. Due to the lack of vegetation on the slope, the area where the grass is growing depicts seepage and moving water on the slope. Thus, water is being transported through the soil, which may lead to instability in this area.

Figure 16: Liner Bulges at MWV

Another area of concern was bulges, tears, or holes in the liner, as indicated by Question 8. This problem was present at every site evaluated, with seven sites ranked as Low, four ranked as Moderate, and three ranked as High. Figure 16 depicts a liner stretched over an improperly prepared slope at the MWV Large Water Storage Pond 1. The underlying rock pressing on the liner and the strain caused by the bulges have a high likelihood to create tears or punctures in the liner and threaten the integrity of the containment system.

Figure 17: Debris on Liner at Flanigan

Question 10 involved the presence of rock or debris on top of the liner. This problem was observed at all sites except one. Figure 17 illustrates an example of a severe case of debris on the liner at the Flanigan Pit. At the Flanigan Pit as well as other sites visited, surface water was present on the berm and in the anchor trench. This practice is not in accordance with the West Virginia Erosion and Sediment Control Field Manual, which states that surface water must be diverted from the pit. The water washing the rock and debris into the pit adds weight to the containment system which can lead to strain and dislodgement of the anchor trench. Also, with the rock washing down over the liner, there is a higher potential for tears to form.

Figure 18: Improper Anchor Trench Embedment at Ball 1H

Deformations, cracks, and settlements around the anchor trench affect the integrity of the liner, and these concerns were addressed in Question 12 of the observation checklist. During field evaluations, this question was expanded to include the embedment of the anchor trench. All sites with the exception of one were found to have issues related to the anchor trench. Figure 18 illustrates improper anchor trench embedment at the Ball 1H Impoundment #2, as indicated by the liner protruding out of the ground. Improper embedment may result in an increased likelihood of the anchor trench pulling out of the soil, affecting the ability of the liner to retain fluids. Another potential issue is the possibility of wind lifting the liner and causing tears leading to a failure of the containment system.

Figure 19: Unsupported Pipe at Plum Creek

The last observed trend was unsupported pipes. Question 14 addressed this concern, and pipes were not properly supported on eight of the fourteen sites. Figure 19 depicts a severe instance at the Plum Creek South Fork Impoundment. At this site, the pipe was unsupported along the crest of the impoundment and the adjoining hillside, hanging across a depression. Associated areas of concern include the pipe having the freedom to roll or slide, the possibility of the pipe buckling or pinching and restricting flow, and the increased potential for gouges and leakage. Any leakage or rupture of the pipes which convey water or flowback fluids would have an environmental impact to the surface water and groundwater.

Table 6 shows the score for each site, ranked from lowest to highest. The Donna Completion Impoundment received the lowest score among all sites visited. Of the three sites constructed after the enactment of the Natural Gas Horizontal Well Control Act §22-6A, two sites (SHL 2 and SHL 3) were among the sites receiving the highest scores, although SHL 4 received a low score due to a slope failure on the downstream face. As a result, slope failures may be an issue for SHL 2 and SHL 3 in the future.

Site #	Site Name	Score
1	Donna Completion Impoundment	59.2%
2	Mills-Wetzel Freshwater Impoundment	68.4%
3	Pribble Freshwater Impoundment	72.4%
4	MWV Large Water Storage Pond 1	75.0%
5	SHL 4 Centralized Pit	76.3%
6	Ball 1H Impoundment #2	77.6%
7	Plum Creek South Fork	77.6%
8	MIP Freshwater Impoundment	80.3%
9	Larry Pad	82.9%
10	Donna Completion Pit	84.2%
11	Flanigan Pit	85.5%
12	Burch Ridge Wastewater Pit	88.2%
13	SHL 2 Centralized Pit	88.2%
14	SHL 3 Centralized Pit	88.2%

Table 6: Summary of Site Scores

While certain sites evaluated were known to have problems prior to the field evaluations, a visit to the Shields FWI site illustrated that current construction practices were characteristic of the problem areas observed in all the site visits. Thus, poor construction methods may be an initiator of the problems observed in the field. As an illustration of the construction practices at the Shields FWI site, pictures collected during the visit are presented.

Figure 20: Improper Compaction Practices

In Figure 20, the excavator is placing the lift of soil, and the lift is being compacted by a sheepsfoot roller, followed by a vibratory roller. According to the West Virginia Erosion and Sediment Control Field Manual, each lift shall be compacted by compaction equipment, sheepsfoot or pad roller, with compaction to visible non-movement of the embankment material. Thus, the use of both a sheepsfoot roller and a vibratory roller violates the best management practice in the manual. This construction practice is creating a shear plane on which water can move through the soil, possibly resulting in a slope failure. The sheepsfoot roller kneads the soil, interlocking the soil lifts and benefiting compaction efforts, but the vibratory roller is negating this interlocking by smoothing the soil.

Figure 21: Woody Debris in Soil Lift

Figure 21 depicts woody debris that has been compacted into the fill, which was a recurring area of concern on a majority of the sites evaluated. The West Virginia Erosion and Sediment Control Field Manual states that the fill material shall be clean mineral soil, free of roots, woody vegetation, stumps, sod, large rocks, or other objectionable material. As Figure 21 shows, this best management practice is not being followed at the Shields FWI site. Organic material compacted into the fill may create pathways for water to infiltrate the soil and cause internal erosion, which is a possible failure mode for the structure.

Figure 22: Excessive Lift Thickness

According to the West Virginia Erosion and Sediment Control Field Manual, soil lifts must be as thin as the suitable random excavated material will permit, typically from 6 to 12 inches. In Figure 22, the lift thickness is 16 inches, so this construction practice is not in accordance with the best management practice specified in the manual.

6.2 Questionnaire Responses

Once the evaluation of the site conditions was completed, the Site Operations and Infrastructure Evaluation was conducted. This evaluation consisted of questions for the WVDEP Office of Oil and Gas Inspector on site and/or the company representative. However, the company personnel present at the time of the field visit may or may not have been the principle site inspectors. The questionnaire covered the inspector training and background in regards to pit and impoundment safety, the operation and maintenance procedures for the site, and safety plans such as Emergency Action Plans (EAPs). The responses to the questionnaire are contained within the appropriate sites' Appendices. By comparing the responses across all sites, several conclusions were made about the overall inspection, operation, and maintenance of these structures.

Questions 1 and 11 concerned the type and frequency of company site inspections performed by field personnel and Professional Engineers (PEs). The responses from WVDEP inspectors and company representatives varied from every three days to once every two months. Thus, there is no set frequency for site inspections to be performed at pits and impoundments. Infrequent inspections allow for problem areas to progress and may lead to failure if the problems are not addressed in a timely manner. Another concern is the varied responses for the frequency of site inspections by a PE, which ranged from weekly to never. The PE for the site may offer additional insight into the site conditions, so irregular visits may result in problem areas going unnoticed or a delay in the implementation of corrective actions.

The background and type of training that the site inspectors possessed was the focus of Questions 2 and 3. A majority of the WVDEP inspectors had prior oil and gas industry experience, but neither the WVDEP inspectors nor the company representatives had any background in regards to the inspection of structures that impound water. Despite this lack of experience, the inspectors had not received any type of formal training. As a result, the inspectors may not fully understand how to identify problem areas that need to be addressed or the possible consequences associated with those issues. This lack of training may have significant impacts on the safety of the structure at all stages from construction through reclamation.

In addition to the lack of training for inspectors, the site inspection procedures were also found to contribute to the areas of concern observed during field evaluations. Responses to Questions 4 and 5 revealed that no standardized form existed for the WVDEP inspectors to refer to during inspections, which resulted in the inspectors using state regulations as a guide. Furthermore, the inspectors only focused on readily apparent problems such as slips and slides, while not recognizing the smaller issues such as tension cracks and slope deformation that may lead to large-scale problems.

Another important aspect of pit and impoundment safety is the development of safety and emergency plans, which was covered in Questions 6, 7, 8, 9, and 10. While the majority of sites had safety plans covering the normal daily operations, only four sites had plans in place in the event of an emergency. Emergency Action Plans (EAPs) were not required before the enactment of the Natural Gas Horizontal Well Control Act §22-6A, and under the new law, only centralized pits and impoundments are required to develop EAPs. As a result, the only sites evaluated in this study which were required to have EAPs were the SHL 2, SHL 3, and SHL 4 Centralized Pits. The company representative at the SHL sites was not aware that an EAP existed, was not trained on the EAP, and did not know whether the EAP had been evaluated for practicality in the event of an emergency. In addition, the EAP was not available on-site during the field evaluation. As a result, the company representative was unprepared to respond to an emergency, which could lead to the endangerment of lives or the destruction of property. In the EAP for the SHL sites, no evacuation protocol was provided, with the following justification:

> "*Due to the location of the pit described in this plan, no evacuation will be necessary in any case. The pit is a temporary structure that is fully incised in existing ground and that will be reclaimed once the Marcellus drilling in the surrounding region is complete. There are no nearby structures or facilities that would be affected by its breach or failure.*"

While the location of the pit may be remote, no inundation maps are provided in the EAP to support this statement. The SHL site also exhibited a slope failure as referenced in Figure 13. The incorporation of these maps would increase awareness of the full extent of the damage resulting from a failure and possibly highlight endangered areas that were not previously considered. Therefore, the addition of inundation maps to EAPs for all pits and impoundments constructed after the enactment of §22-6A would facilitate emergency planning for the structures. Additionally, the development of EAPs for all pits and impoundments, including those already constructed, would further benefit the safety of these structures and the surrounding areas.

6.3 Laboratory Testing Results

Once the laboratory testing was completed, the results from the various tests were compiled into tables and graphs in order to present the results in a convenient manner. Figure 23 illustrates the results of the Atterberg limits testing for each site. The range of moisture content values between the Plastic Limit (PL) and Liquid Limit (LL) is shown for each site, and the field moisture content is graphed as an illustration of the soil condition at the site. These values are displayed numerically in Table 7, where the results from the grain-size distribution and Atterberg limits tests for each site were used to classify the soil according to the ASTM D2487 Standard. According to the WVDEP Design and Construction Standards for Centralized Pits, the following soil classifications are acceptable for post §22-6A sites: Clayey Gravel (GC), Silty Gravel (GM), Clayey Sand (SC), Silty Sand (SM), Clay (CL), and Silt (ML). The laboratory testing results indicated that none of the post §22-6A sites met this requirement, and of the remaining 12 pre §22-6A sites, only one site met the soil standards.

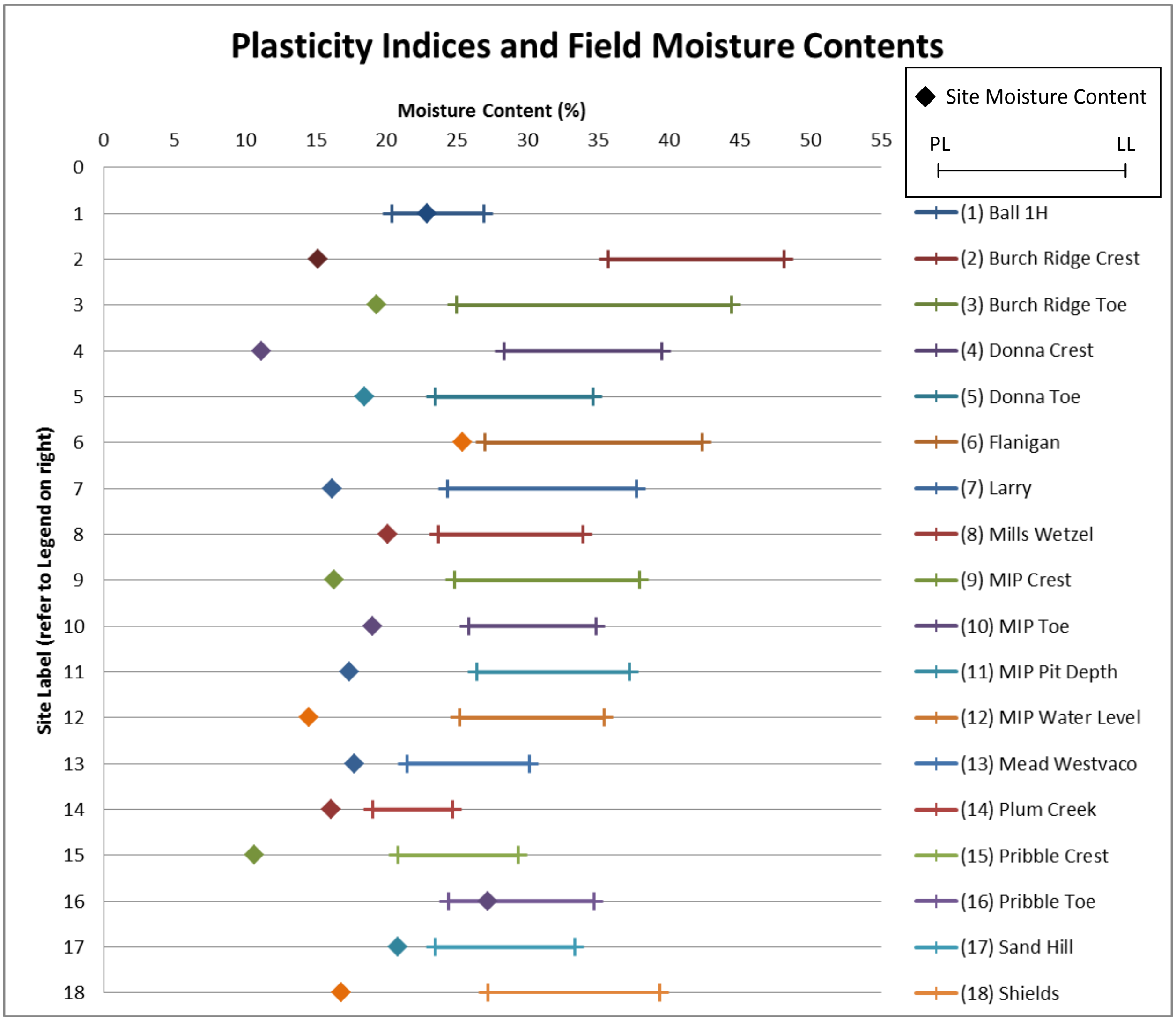

Figure 23: Atterberg Limits and Field Moisture Content

SITE SOIL CLASSIFICATION AND COMPLIANCE WITH WVDEP DESIGN AND CONSTRUCTION STANDARDS FOR CENTRALIZED PITS										
	Grain size distribution (ASTM D422)				Atterberg Limits (ASTM D4318)			Classification (ASTM D2487)		
Site Name	% Retained on #4 Sieve	% Retained on 200 Sieve	% Passing 200 Sieve	Gradation Profiles Cu &Cc	PL	LL	PI	Group Symbol	Group Name	Criterion Compliance to WVDEP Design and Construction Standards (GC,GM,SC,SM, CL, ML)
Ball 1H	11%	88%	12%	CU = 14.3 CC = 1.5	20.4	26.9	6.5	SC	Clayey Sand	YES & Not Required
Burch Ridge Crest	46.50%	98%	2%	CU = 13.7 CC = 1.5	35.7	48.1	12.4	SP	Poorly Graded Sand	NO & Not Required
Burch Ridge Toe	9.50%	90%	10%	CU = 18.8 CC = 2.3	25	44.4	19.4	SW-SC	Well Graded Sand w/ Clay	NO & Not Required
Donna Crest	25.50%	95%	5%	CU = 13.2 CC = 1.4	28.3	39.5	11.2	SW	Well Graded Sand	NO & Not Required
Donna Toe	18.50%	95.50%	4.50%	CU = 12.1 CC = 1.1	23.5	34.6	11.1	SW	Well Graded Sand	NO & Not Required
Flanigan	12%	94%	6%	CU = 11.5 CC = 1.3	27	42.3	15.3	SW-SC	Well Graded Sand w/ Clay	NO & Not Required
Larry	12.50%	96.50%	3.50%	CU = 9.0 CC = 1.1	24.3	37.7	13.4	SW	Well Graded Sand	NO & Not Required
Mills-Wetzel	12%	90.50%	9.50%	CU = 11.6 CC = 1.1	23.7	33.9	10.2	SW-SC	Well-Graded Sand w/ Clay	NO & Not Required
MIP Crest	16%	95%	5%	CU = 11.2 CC = 1.3	24.8	37.9	13.1	SW	Well-Graded Sand	NO & Not Required
MIP Toe	9%	91%	9%	CU = 15.6 CC = 1.4	25.8	34.8	9	SW-SC	Well Graded Sand w/ Clay	NO & Not Required
MIP Pit Depth	12.50%	94.50%	~5%	CU = 12.6 CC = 1.1	26.4	37.2	10.8	SW	Well Graded Sand	NO & Not Required
MIP Water Level	10%	93%	7%	CU = 13.1 CC = 1.1	25.2	35.4	10.2	SW-SC	Well Graded Sand w/ Clay	NO & Not Required
Mead Westvaco	13%	90.50%	9.50%	CU = 24.0 CC = 2.6	21.5	30.1	8.6	SW-SC	Well Graded Sand w/ Clay	NO & Not Required
Plum Creek	6%	86.50%	13.50%	CU = 12.3 CC = 0.885	19	24.7	PI = 5.7% (plots above A line)	CH	Fat Clay	NO & Not Required
Pribble Crest	41%	97%	3%	CU = 10.9 CC = 1.3	20.8	29.3	8.5	SW	Well Graded Sand	NO & Not Required
Pribble Toe	9.50%	89%	11%	CU = 31.7 CC = 3.3	24.4	34.7	10.3	SP-SC	Poorly Graded Sand w/ Clay	NO & Not Required
SHL (2, 3, 4)	46%	97%	3%	CU = 8.3 CC = 0.8	23.5	33.3	9.8	SP	Poorly Graded Sand	NO
Shields	26.50%	97.50%	2.50%	CU = 10.7 CC = 1.1	27.2	39.3	12.1	SW	Well Graded Sand	NO & Not Required

Table 7: Soil Classification

In addition to the classification testing, further soil testing was performed on six sites. During the field visits to these sites, WVU subcontractor Potesta and Associates, Inc. collected *in situ* field compaction and moisture content data using a nuclear density gauge. Readings were taken at various locations on each site, including the crest, mid-slope, and toe of the downstream face. Furthermore, WVU researchers collected two additional buckets of soil on these sites in order to perform laboratory compaction, hydraulic conductivity, and strength testing on the soil.

After performing the laboratory compaction tests for each of the six sites, a graph was generated showing the relationship between the dry density of the soil and the moisture content. Thus, the optimum dry density and moisture content for each site were determined. Saturation curves depicting the values where the soil was 100% and 90% saturated were computed using the following equation:

$$\gamma_{\mathrm{d}} = \frac{G_s \gamma_w}{1 + (\frac{\omega G_s}{S})}$$

In this equation, G_s is the specific gravity of the soil, as determined by the laboratory testing performed at WVU. γ_w is the unit weight of water, which is 62.4 lb/ft^3; ω is the moisture content of the soil, for which a range of values was used in accordance with the observed moisture contents at the site; and S is the degree of saturation, expressed as a decimal rather than a percentage. Entering these values into the equation yielded a range of dry densities (γ_{d}), which were plotted on the compaction graph. To better illustrate this procedure, a sample table showing the results of these calculations for the Mills-Wetzel Freshwater Impoundment is shown in Table 8.

S = 100%			
Moisture Content (%)	Specific Gravity	Water Density (lb/ft^3)	Dry Density (lb/ft^3)
6	2.78	62.4	148.67
8	2.78	62.4	141.91
10	2.78	62.4	135.74
12	2.78	62.4	130.08
14	2.78	62.4	124.87
16	2.78	62.4	120.07
18	2.78	62.4	115.62
20	2.78	62.4	111.49
22	2.78	62.4	107.64

Table 8: Saturation Calculations

The West Virginia Erosion and Sediment Control Field Manual requires that soil lifts shall be compacted to a standard Proctor density of at least 95% and that compaction effort shall not exceed optimum moisture contents. In order to compare the adherence of site construction practices to this standard, a standard Proctor density of 95% of the optimum dry density was computed for each site. To achieve proper compaction on-site, the moisture content should be on the dry side of the optimum moisture content. Therefore, the appropriate compaction density and moisture content range was plotted on the graphs, signified by red lines. Lastly, the field data obtained by the nuclear density gauge readings was organized by the location of the reading (crest, mid-slope, toe) and graphed to determine how the field compaction compared with the laboratory results. The graphs for the Mills-Wetzel Freshwater Impoundment and the Larry Pad are presented in Figures 24 and 25, respectively, while the graphs for the remaining sites are contained in the corresponding Appendices.

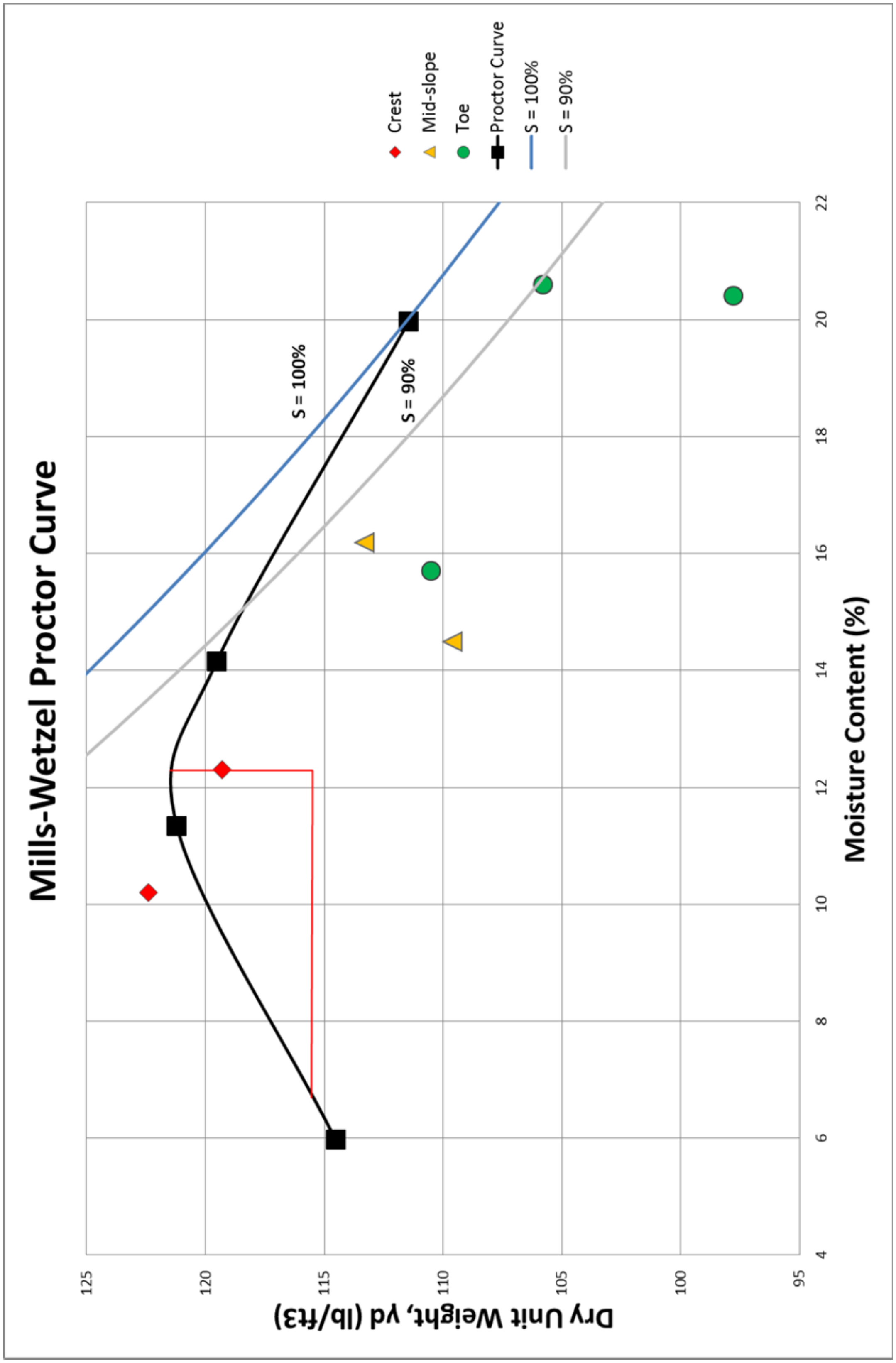

Figure 24: Mills-Wetzel Compaction

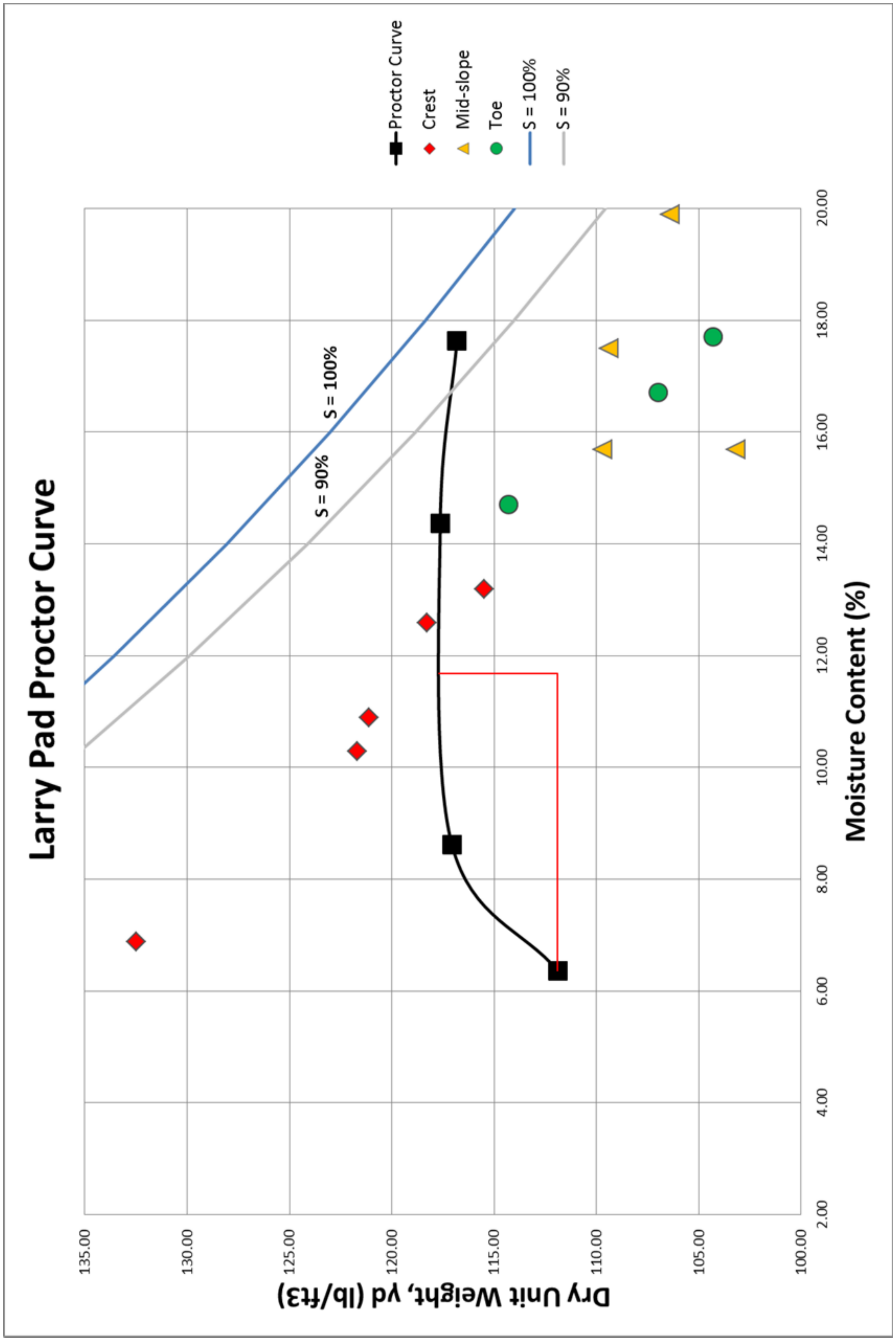

Figure 25: Larry Compaction

The compaction results show that the soils on the crests tended to be overcompacted, which would render the point on the wet side of optimum if compared with a higher compaction energy. Also, the soils at the mid-slopes and toes of the downstream faces were consistently under-compacted and contained moisture content values higher than optimum. As a result, the soils at these locations exhibited high saturation values. These conditions may result in lower unit weight and strength for the soil, leading to a higher potential for slope deformation, internal erosion, and seepage. These observations were found to be trends across all sites, as only three of the six sites contained data points within the appropriate compaction range. Only 14% of field data points were in compliance at two of the sites, and 22% were in compliance at the third site. Overall, a total of seventy data points were taken across all six sites, and only six points were within the acceptable compaction range, which corresponds to 8.5% compliance with WVDEP standards. Table 9 further illustrates these trends by comparing the optimum moisture content and density with the ranges observed in the field for each site. Based on these findings, the compaction practices at the sites evaluated do not conform to the best management practices specified in the West Virginia Erosion and Sediment Control Field Manual.

Site Name	Optimum Moisture Content	Optimum Density (lb/ft^3)	Field Moisture Content	Minimum Moisture Content	Maximum Moisture Content	Minimum Density (lb/ft^3)	Maximum Density (lb/ft^3)
MIP Freshwater Impoundment	17.2%	113.8	16.83%	11.5%	25.5%	72.0	112.6
Ball 1H Impoundment #2	15.6%	117.5	22.91%	14.8%	22.7%	95.9	113.1
Mills-Wetzel Freshwater Impoundment	12.2%	121.5	20.14%	10.2%	20.6%	97.8	122.4
SHL 2 Centralized Pit	13.7%	122.1	20.83%	7.1%	20.7%	86.3	109.5
SHL 3 Centralized Pit	13.7%	122.1	20.83%	6.5%	37.9%	88.0	115.5
SHL 4 Centralized Pit	13.7%	122.1	20.83%	11.4%	23.5%	89.1	120.4
Flanigan Pit	15.8%	114.5	25.39%	12.2%	18.5%	108.9	123.1
Larry Pad	11.7%	117.8	16.19%	6.9%	19.9%	103.2	132.5

Table 9: Laboratory and Field Moisture Content and Compaction Results

Once the Standard Proctor testing was completed, hydraulic conductivity and shear strength testing was performed. The hydraulic conductivity testing consisted of preparing two samples for each site, one compacted at the field moisture content and one compacted at the optimum moisture content determined by laboratory testing. After the hydraulic conductivity was determined, the sample compacted at the optimum moisture content was used for shear strength testing to obtain the internal angle of friction (ϕ). The results of these tests are contained in the appropriate site Appendices and are summarized in Table 10.

Site Name	ASTM Soil Classification	Hydraulic Conductivity		Angle of Friction (ϕ)
		Field (cm/s)	Lab (cm/s)	
MIP Freshwater Impoundment	SW-SC	3.0E-08	7.0E-08	40.2°
Ball 1H Impoundment #2	SC	6.4E-08	2.2E-08	43.7°
Mills-Wetzel Freshwater Impoundment	SW-SC	2.8E-08	2.0E-08	40.6°
SHL Centralized Pits	SP	1.5E-08	2.0E-08	40.2°
Flanigan Pit	SW-SC	1.2E-08	4.4E-09	42.6°
Larry Pad	SW	1.3E-08	1.8E-08	40.7°

Table 10: Hydraulic Conductivity and Friction Angle

The hydraulic conductivity values obtained were comparable between the field and laboratory conditions at each site. The differences in the values are attributed to the moisture contents under which the soils were prepared. The internal friction angles obtained indicate that the soils have high shear strength potential. Although the Ball 1H Impoundment #2 was the only site that contained soil conforming to the post §22-6A soil classification types specified by the WVDEP, these results indicate that the site soils are adequate if proper compaction is achieved. Therefore, the WVDEP should review the acceptable soil types specified in the WVDEP Design and Construction Standards for Centralized Pits.

After the completion of the laboratory testing at WVU, a comparison was made between the results obtained in the laboratory and the geotechnical investigations performed prior to the construction of the pit or impoundment. Since several permits lacked geotechnical investigation reports or were not provided at the time of the evaluation, the WVDEP permits that contained geotechnical investigations were analyzed. As an example, the review of the SHL 3 Centralized Pit is presented.

According to the SHL 3 permit, three boring holes were drilled at opposite ends and in the middle of the pit to evaluate the subsurface conditions at the site. The test borings were drilled to depths ranging from 26 feet to 42 feet, which corresponded to depths of five feet to 20 feet below the final elevation of the bottom of the pit. The results of the borings indicate that clay was found at the site to a depth of eight feet and that bedrock was found underlying the clay. Laboratory testing was performed on representative samples of the clay soil and soft bedrock, and the specific tests conducted were field moisture content, Atterberg limits, grain-size distribution, standard Proctor, and hydraulic conductivity.

The laboratory results in the permit contained values differing from those obtained through the testing performed at WVU for the SHL 3 Centralized Pit. The results from the three boring holes are compared with the results obtained by WVU in Table 11.

Property	Permit Results	WVU Results
Field Moisture Content	12.9% - 19.7%	20.83%
Plasticity Index	14 - 21	9.8
Soil Classification	Clay (CL)	Poorly Graded Sand (SP)
Optimum Density (lb/ft^3)	108.1 - 115.0	122.1
Optimum Moisture Content	14.7% - 17.6%	13.7%
Hydraulic Conductivity (cm/s)	5.8E-08	1.5E-08

Table 11: Comparison of Permit to WVU Laboratory Results for SHL 3

The reason for the discrepancies between the laboratory results may be linked to the field sampling procedures. According to the boring logs and testing results in the SHL 3 permit, the soil samples used for the engineering properties testing were taken from a depth of zero feet to five feet. The natural elevation of the site ranged from 1,308 feet to 1,325 feet, and the bottom of the pit was excavated to slope from elevation 1,298 feet to 1,294 feet. As a result, the soil from the top five feet of the excavation may not be representative of the fill material used to construct the bottom of the pit, the upstream faces, and the downstream faces. This observation may be supported by the testing performed on soil from a depth of 10 feet to 15 feet in one of the boring holes. While this soil was not classified, the optimum density was found to be 117.1 lb/ft^3, which is closer to the 122.1 lb/ft^3 determined by the testing performed by WVU personnel. Also, the optimum moisture content for this soil was 13.7%, which is in agreement with the optimum moisture content found by WVU for the site. Thus, the fill soil exhibits engineering properties that differ from those obtained by testing the top layers of the site soil prior to construction, which may be another factor contributing to the post-construction issues observed during the field evaluations. By expanding the geotechnical investigations to include the soils at pit depth, the appropriate engineering properties for the fill soil can be determined, thereby benefiting the overall stability of the pit or impoundment.

7.0 West Virginia Dam Safety

While the pits and impoundments evaluated in this study are not classified as dams, the quantities of fluids impounded by these structures are comparable to the storage volumes of dams. According to the Dam Control and Safety Act – WV Code 22-14 and the Dam Safety Rule (47CSR34), Sections 3.2 a and c denote that for incised reservoirs the volume of water retained below ground surface is not included in determining whether the pit or impoundment meets the dam criteria.

Table 12 contains the permitted storage volume for each site evaluated in the study. No site met the designation for status as a dam per the Dam Control and Safety Act.

Site Name	Permit Volume (Acre-Feet)	WV Dam Status
Donna Completion Impoundment	N/A	N/A
Mills-Wetzel Freshwater Impoundment	~20.56	No
Pribble Freshwater Impoundment	37.83	No
MWV Large Water Storage Pond 1	55.98	No
SHL 2 Centralized Pit	12.07	No
SHL 3 Centralized Pit	11.47	No
SHL 4 Centralized Pit	12.39	No
Ball 1H Impoundment #2	23.28	No
Plum Creek South Fork	45.85	No
MIP Freshwater Impoundment	7.32	No
Larry Pad	N/A	N/A
Donna Completion Pit	7.81	No
Flanigan Pit	12.41	No
Burch Ridge Wastewater Pit	11.19	No

Table 12: Comparison of Storage Volumes and Dam Requirements

The permit file for the Donna Completion Impoundment was not provided, and the permit file for the Larry Pad did not contain the storage volume; thus, no determination could be reached regarding these structures.

8.0 Conclusions and Recommendations

The goals of this study were to conduct engineering reviews of submitted and approved permit plans, construction practices, and geotechnical investigations of pits and impoundments associated with Marcellus Shale horizontal gas wells. The overall purpose was to ascertain and document the suitability of the construction and use of these structures in minimizing the potential environmental effects related to horizontal drilling.

After obtaining the permits for various pits and impoundments from the WVDEP, engineering reviews revealed areas of concern. The permit files provided to WVU researchers for 10 sites constructed prior to the enactment of the Natural Gas Horizontal Well Control Act §22-6A lacked geotechnical investigations. However, the permits for the three post §22-6A sites contained geotechnical information. Also, the WVDEP did not provide the permits for two sites at the time of the evaluation.

An analysis of the permits compared the permitted storage volumes with the storage volume requirements of dams as regulated by the WVDEP (WVCSR §22-14 & WVCSR §47-34). No sites were found to meet the requirements of a dam. However, the large quantities of water could be a potential hazard to the public and the environment if a failure were to occur because of the ridge-top location of several sites.

While issues were found in the development of the permits for the pits and impoundments, further concerns were observed during the field evaluations of the construction practices for these structures. The as-built construction dimensions were inconsistent with those found in the permit, including larger capacities, smaller berm widths, and steeper slopes than the permitted designs specified. These discrepancies create unknown stresses on the structure that may lead to instability. Additionally, quality control and assurance were found to be lacking during the construction of the structures, with no field compaction standards, improper soil types, excessive slope lengths, insufficient erosion control, and buried debris. Furthermore, the placement of pipelines and geosynthetic liners was found to be inconsistent with industry practices, posing potential safety and environmental concerns. Any leakage or rupture of the pipes or liner systems would have an adverse environmental impact to the surface water and groundwater. Therefore, the best management practices set forth by the WVDEP are not being adhered to throughout the construction process for pits and impoundments. A stricter application of WVDEP best management practices and an increased quality assurance and control process during construction and operation are recommended to significantly improve the long-term safety of these structures by mitigating possible problems.

Based on hydraulic conductivity and shear strength testing, the site soils in this study appear to be suitable even though none of the post §22-6A sites had soil conforming to the soil classifications specified by the WVDEP. Therefore, the soil classifications in the WVDEP Design and Construction Standards for Centralized Pits should be reviewed for applicability. A comparison of the field compaction data on six sites with the Standard Proctor results revealed that only 8.5% of the field data points met the optimum compaction density and moisture content range. Insufficient compaction density can result in lower shear strength potential, the development of subsurface erosion, and elevated pore water pressures in the slopes of pits and impoundments, which may contribute to slope instability.

On sites that provided geotechnical investigations, such as the SHL 3 Centralized Pit, discrepancies were found with the soil properties and classification. Properties such as field moisture content, plasticity index, optimum density, optimum moisture content, and soil classification differed from WVU laboratory testing results. These differences show that the soil reported by the company may not be representative of the fill material used to construct the structure, and may be a contributing factor to any post-construction issues. Therefore, thorough geotechnical property testing of site soil is recommended to evaluate all fill material at the pit or impoundment foundation depth rather than only the top soil layers excavated.

The operation and maintenance of the pits and impoundments contributed to the problems observed in the field. The frequency of site inspections varied across the sites, and no standardized method for performing the inspections existed. Also, the inspectors and field personnel had not received any formal training related to pit and impoundment inspection, resulting in the observed areas of concern being overlooked. Proper training for company and state inspectors is recommended so that the competency and quality of inspections can be increased and problem areas can be identified and addressed in an effective manner. Although §22-6A requires that all centralized pits and impoundments have EAPs, the EAPs must be evaluated for emergency situations, and all company personnel must be properly trained on how to use the plans. Also, the expansion of this requirement to sites constructed prior to the enactment of §22-6A is recommended to benefit the safety of these structures and the surrounding areas.

During the study, the WVDEP discussed that the MIP Freshwater Impoundment permit was to be evaluated for converting this pre §22-6A site to a centralized impoundment. This practice is not recommended for this site, or for any pre §22-6A sites, as these sites were not designed for this function and exhibited a high frequency of latent construction problems.

There were several construction deficiencies out of compliance with the West Virginia Erosion and Sediment Control Field Manual, and the WVDEP Design and Construction Standards for Centralized Pits. However, none of the deficiencies indicated imminent pit or impoundment failure potential at the time of the site visit. The problems identified do constitute a real hazard and present risk if allowed to progress, but all problems that were observed in the field could be corrected. Future construction, if done in conformance with the WVDEP guidelines, should pose minimal risk.

9.0 References

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Appendix A: WVU Project Personnel

A list of West Virginia University (WVU) personnel directly involved in this study is included below.

John Quaranta, Ph.D., P.E., Principal Investigator

- Provided oversight and direction of project
- Provided technical oversight concerning soil property testing on pits and impoundments
- Served as lead investigator for pits and impoundments
- Oversaw field sampling efforts for soil property testing

Richard Wise, MSCE, EIT, Research Engineer

- Selected, scheduled, and directed activities of the field staff to complete the planned sampling activities
- Served as primary point of contact for pits and impoundments team
- Assisted with preparation of reports and presentations to WVDEP

Andrew Darnell, MSCE, EIT, Research Engineer

- Assisted with selecting and scheduling to complete the planned sampling activities
- Oversaw and assisted with preparation of reports and presentation to WVDEP

Michael Kulbacki, BSCE, Research Associate

- Conducted field sampling activities
- Assisted with compilation and reporting of field and laboratory data and results

Matthew Idleman, BSCE, Research Associate

- Conducted field sampling activities
- Assisted with compilation and reporting of field and laboratory data and results

Justin Pentz, BSCE, Research Associate

- Assisted with compilation and reporting of field and laboratory data and results

Appendix B: Donna Completion Pit

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Donna Completion Pit
Date of Site Evaluation: 7/12/12

Permit Observations / Anomalies:

Measurements of the field as-built construction were consistent with the permitted design, except for the berm width. The berm crest width measured a minimum width of 9.83 feet, while the permitted dimension is 17 feet in width. Thus, berm width is a deficiency.

The as-built dimensions of the pit were in agreement the permitted dimensions. The permitted size is 142 feet wide by 355 feet long, and the as-built dimensions are 141 feet wide by 357 feet long.

Hydrology

Visual evaluation of the berm and downstream faces found several instances of rill and gully formation. Furthermore, rock movement was noted at the crest and on the slopes. No slope movements were observed on the downstream faces as a result of erosion control measures.

Containment

The liner for the pit is an HDPE geomembrane. Bulges in the liner were noticed at several locations, and there was a minor amount of soil and rock on the liner. The anchor trench was exposed in places due to insufficient embedment, and settlement cracks were found on the berm near the anchor trench.

Slope

Rills, gullies, and rock movement were observed in several locations on the downstream faces. Woody debris was found in the fill on the downstream slopes. Erosion control fabric was in place on the eastern downstream face.

Other Comments

There was an unsupported pipe that ran along the roadway and berm. One pipe was lying across the safety fence. A trash pile was found in a ditch below the pit. The thickness of the HDPE liner appeared to be thinner than 60 millimeters. No company representative was present for the site evaluation.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/12/12 9:00 AM	County	Marion	Company	Energy Corporation of America
	Latitude	N 39° 34' 29.5"	Pit Name	Donna Completion Pit
WEATHER Mostly Sunny	Longitude	W 80° 17' 33.1"	ID No.	

A. PERMIT INFORMATION

Pit Width (ft.)	142 ft.	Minimum Berm Crest Width (ft.)	17 ft.	Construction Type	Incised Crest
Pit Length (ft.)	355 ft.	Upstream Slope (H:V)	3:1	Liner Type	HDPE
Depth (ft.)	14.5 ft.	Downstream Slope (H:V)	2:1	Date Built	2011
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	141 ft.	Berm Crest Width (ft.)	9.83 ft.	Crest Height (ft.)	
Pit Length (ft.)	357 ft.	Upstream Slope (H:V)	3:1	Up Slope Length (ft.)	12 ft.
Depth (ft.)		Downstream Slope (H:V)		Down Slope Length (ft.)	64.5 ft.
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

	C. PIT/IMPOUNDMENT	Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			Rills, rock movement at crest and face
2	Are there any slope movements or animal burrows?	No				
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			Woody debris
6	Are there any seeps, wet zones, or losses of soil?	No				
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes		✓		Soil/rock on top of liner
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes		✓		Anchor trench exposed in places, cracking
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	No				
14	Are there any areas where the pipe is not properly supported?	Yes			✓	Unsupported along road
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Bottles in pit
17	Are there any signs of water in ditch associated with pit?	No				
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

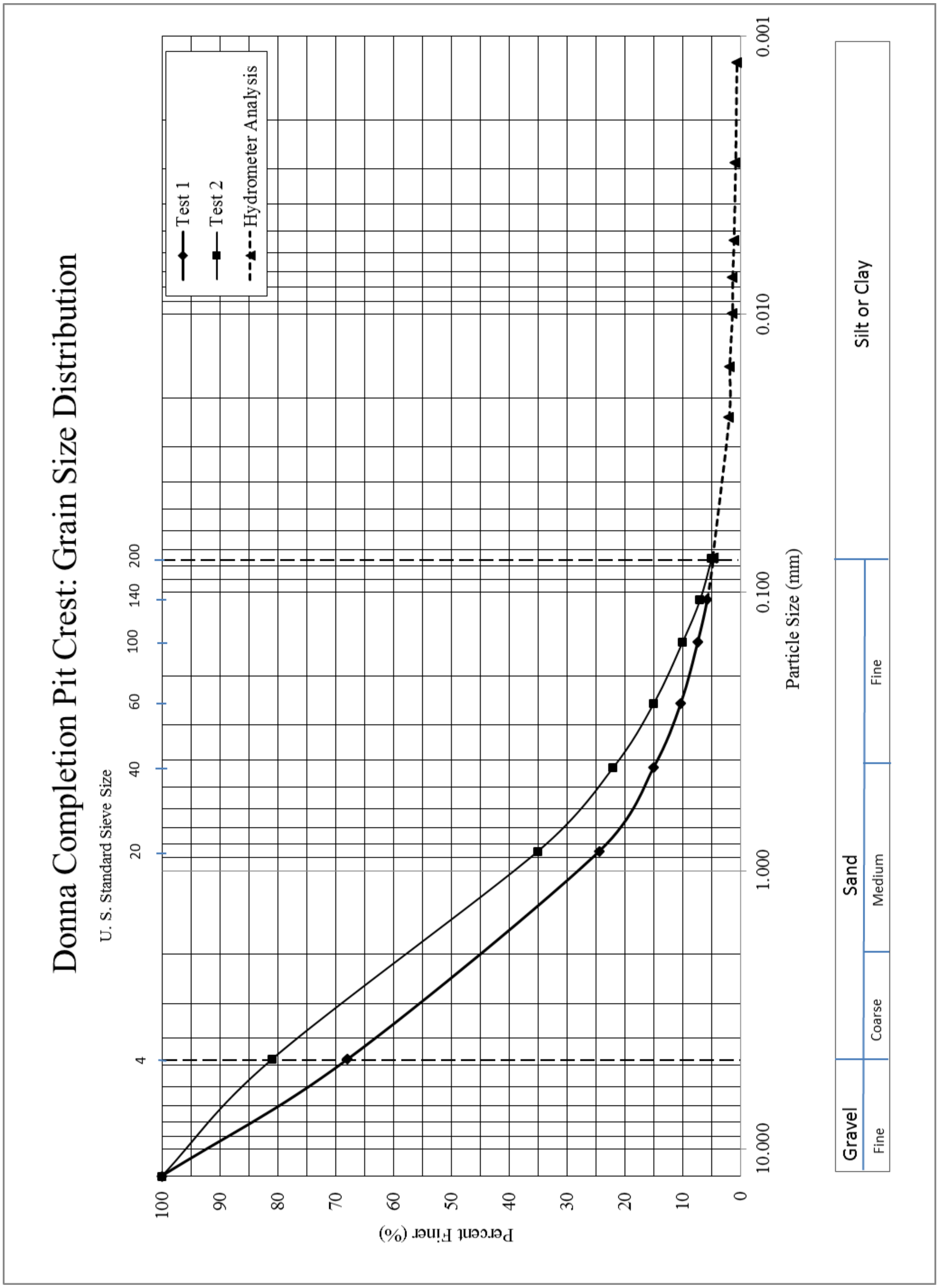
WVU (Name / Signature) Andrew Darnell	DATE 7/12/12
WVDEP (Name / Signature) William Hendershot	7/12/12
Company Representative (Name / Signature)	

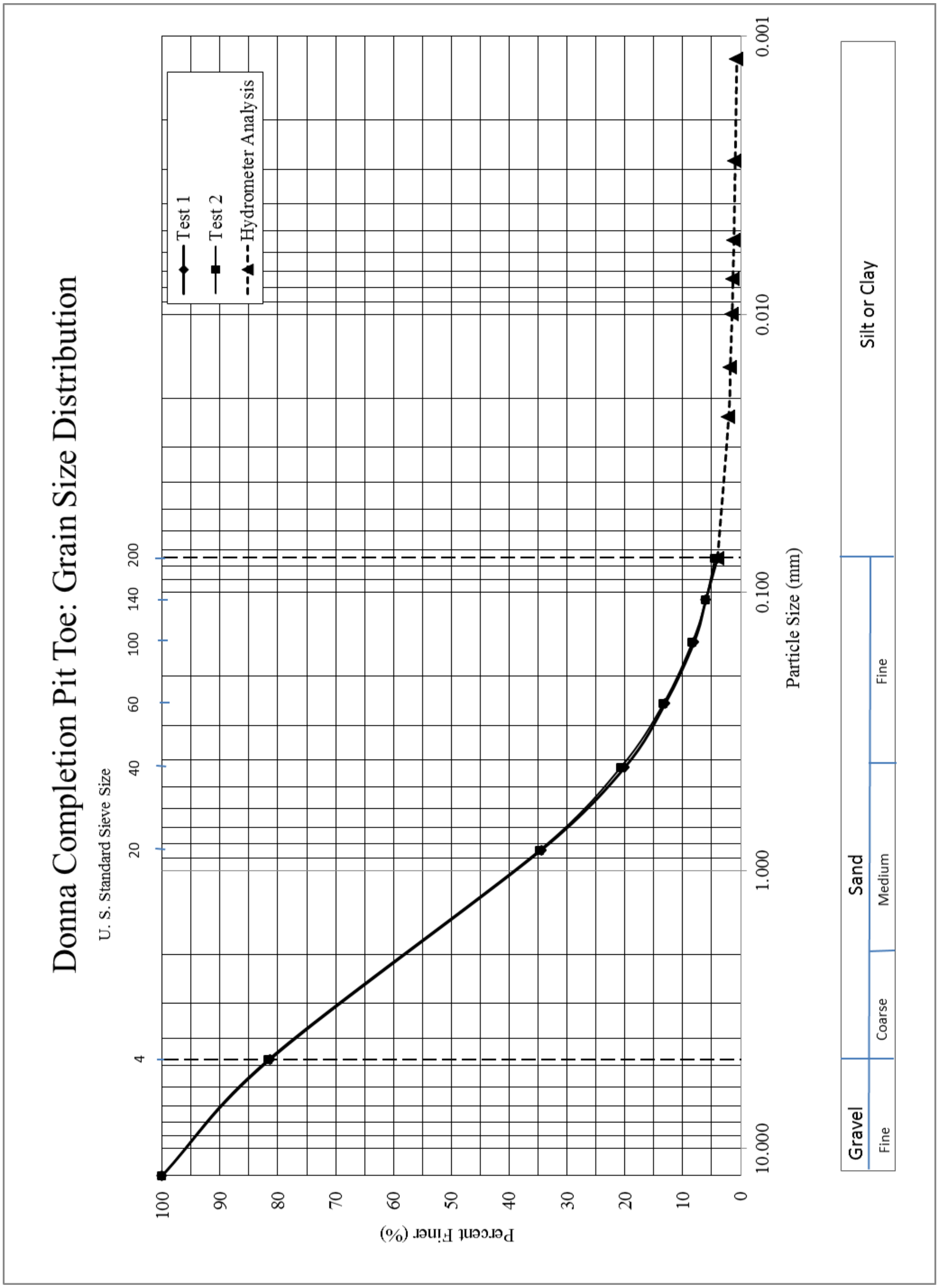
Site Operations & Infrastructure Evaluation	
Date: 7/12/12	Pit/Impoundment Name: Donna Completion Pit
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Routine inspection performed once every two months
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Worked in the oil and gas industry 21 years but has no formal state training
3	How many years of training does the inspector have in evaluating pits/impoundments? 0, he has been on the job for 36 months
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No standardized form, he performs general inspections looking for slips
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? The state of West Virginia
6	Are there safety and emergency procedures for the pit/impoundment? He doesn't know of any procedures, but he reports any issues
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? He believes there is one, but he doesn't know it
8	Has the pit/impoundment inspector been trained on how to use the EAP? No
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) He doesn't know
10	Does the company have a policy on pit/impoundment safety? Would have to contact the company to find out
11	How frequently does a Professional Engineer inspect the site? Every 7 days
12	Other comments: Liner is thinner than 60 mil There are trees marked to be cut down on the eastern downstream face Woody debris is present on the berm and downstream faces There is a trash pile in a ditch below the pit

The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

Donna Completion Pit		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			**3**
2	Are there any slope movements or animal burrows?	No				**4**
3	Are there any depressions, sinkholes, or slides into the pit present?	No				**4**
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				**4**
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			**3**
6	Are there any seeps, wet zones, or losses of soil?	No				**4**
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				**4**
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		**2**
9	Are there any areas where the liner is strained?	No				**4**
10	Are there any areas where the liner has rock or debris on top of it?	Yes		✓		**2**
11	Is there any tear potential for the liner?	No				**4**
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes		✓		**2**
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				**4**
14	Are there any areas where the pipe is not properly supported?	Yes			✓	**1**
15	Are there any signs of pipes having significant sagging in line?	No				**4**
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			**3**
17	Are there any signs of water in ditch associated with pit?	No				**4**
18	Are there any obstructions around the discharge outlet?	No				**4**
19	Are there any signs of downstream slope movement into ditch?	No				**4**

Total:	**64**	(Out of 76)
Percentage:	**84.2%**	


Donna Completion Pit Crest: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay



Donna Completion Pit Toe: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay

Appendix C: Donna Completion Impoundment

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Donna Completion Impoundment
Date of Site Evaluation: 7/12/12

Permit Observations / Anomalies:

The as-built dimensions of the impoundment measured 276 feet long by 129 feet wide, and the berm width was 10 feet. No permit information was provided for this impoundment.

Hydrology

Numerous slips, settlements, and slope movements were observed on the berm, upstream face, and downstream face. A large slip was found on the upstream face, where a large rock was sliding into the impoundment. Also, downstream slope movement into the ditch was noted.

Containment

The liner for the impoundment is an HDPE geomembrane. Bulges in the liner were noticed at several locations, and there were holes in the liner where posts had been removed. The liner was strained in several areas as a result of the slips and settlements, increasing tear potential. The anchor trench was exposed in places due to insufficient embedment. A high amount of rock and soil were on top of the liner, including the large rock in the slip on the upstream face.

Slope

Slips, settlements, and slope movements were observed in multiple locations on both the upstream and downstream faces. The soil on the downstream slopes appeared to be uncompacted.   Cracks were also present at the crest of the slope. The slope movements at the impoundment were significant and may lead to a failure.

Other Comments

Garbage was found in the impoundment. Vegetation was observed on the berm. Floatation devices were tied up and covered by the fencing. No company representative was present for the site evaluation.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/12/12 10:15 AM	County	Marion	Company	Energy Corporation of America
WEATHER Mostly Sunny	Latitude	N 39° 34' 29.5"	Pit Name	Donna Impoundment
	Longitude	W 80° 17' 33.1"	ID No.	

A. PERMIT INFORMATION

Pit Width (ft.)		Minimum Berm Crest Width (ft.)		Construction Type	Incised
Pit Length (ft.)		Upstream Slope (H:V)		Liner Type	HDPE
Depth (ft.)		Downstream Slope (H:V)		Date Built	
Freeboard(ft.)				Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	129 ft.	Berm Crest Width (ft.)	10 ft.	Crest Height (ft.)	
Pit Length (ft.)	276 ft.	Upstream Slope (H:V)		Up Slope Length (ft.)	13 ft.
Depth (ft.)		Downstream Slope (H:V)		Down Slope Length (ft.)	14 ft.
Freeboard (ft.)	3 ft.	Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	Yes	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	Settlements on upstream face, berm
2	Are there any slope movements or animal burrows?	Yes			✓	Upstream face
3	Are there any depressions, sinkholes, or slides into the pit present?	Yes			✓	Slip on upstream face
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			Grown up around fence
6	Are there any seeps, wet zones, or losses of soil?	No				
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		Bulges, holes from driven posts
9	Are there any areas where the liner is strained?	Yes			✓	Slips, settlements
10	Are there any areas where the liner has rock or debris on top of it?	Yes			✓	Large rock in slip
11	Is there any tear potential for the liner?	Yes			✓	Holes, strains
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Anchor trench exposed in places, cracking
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	No				
14	Are there any areas where the pipe is not properly supported?	Yes			✓	Unsupported
15	Are there any signs of pipes having significant sagging in line?	Yes		✓		Sagging in line
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Garbage
17	Are there any signs of water in ditch associated with pit?	No				
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	Yes			✓	Ground uncompacted

WVU (Name / Signature) Richard Wise	DATE 7/12/12
WVDEP (Name / Signature) William Hendershot	7/12/12
Company Representative (Name / Signature)	

Site Operations & Infrastructure Evaluation	
Date: 7/12/12	Pit/Impoundment Name: Donna Completion Impoundment
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Routine inspection performed once every two months
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Worked in the oil and gas industry 21 years but has no formal state training
3	How many years of training does the inspector have in evaluating pits/impoundments? 0, he has been on the job for 36 months
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No standardized form, he performs general inspections looking for slips
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? The state of West Virginia
6	Are there safety and emergency procedures for the pit/impoundment? He doesn't know of any procedures, but he reports any issues
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? He believes there is one, but he doesn't know it
8	Has the pit/impoundment inspector been trained on how to use the EAP? No
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) He doesn't know
10	Does the company have a policy on pit/impoundment safety? Would have to contact the company to find out
11	How frequently does a Professional Engineer inspect the site? Every 7 days
12	Other comments: Holes in HDPE liner where posts were driven in for the fence and removed Fence runs through center of berm Fish in impoundment

The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

Donna Completion Impoundment		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	1
2	Are there any slope movements or animal burrows?	Yes			✓	1
3	Are there any depressions, sinkholes, or slides into the pit present?	Yes			✓	1
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			3
6	Are there any seeps, wet zones, or losses of soil?	No				4
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		2
9	Are there any areas where the liner is strained?	Yes			✓	1
10	Are there any areas where the liner has rock or debris on top of it?	Yes			✓	1
11	Is there any tear potential for the liner?	Yes			✓	1
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				4
14	Are there any areas where the pipe is not properly supported?	Yes			✓	1
15	Are there any signs of pipes having significant sagging in line?	Yes		✓		2
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	No				4
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	Yes			✓	1

Total:	**45**	(Out of 76)
Percentage:	**59.2%**	

Appendix D: Pribble Freshwater Impoundment

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Pribble Freshwater Impoundment
Date of Site Evaluation: 7/16/12

Permit Observations / Anomalies:

Measurements of the field as-built construction agreed with the minimum berm crest width; the permit specified a minimum berm width of 24 feet, and the measured berm widths were all greater than 25 feet.

The as-built dimensions of the impoundment exceeded the permitted dimensions. Therefore, the impoundment has a larger volume capacity than permitted. The permitted size is 260 feet wide by 390 feet long, while the as-built dimensions are 271.5 feet wide by 405 feet long. As a result, the as-built size and volume exceed the permit.

Hydrology

The visual evaluation of the impoundment found several areas requiring attention. Numerous rills, gullies, and slope movements were observed on the northern, western, and eastern downstream faces. Also, seepage was noted on the downstream faces, as evidenced by increased vegetation growth on the slope and discharge from the pipes on the western and eastern faces. Surface erosion was observed as a result of drainage from the pipes on the downstream faces. Additionally, there was a storage tank collecting water seeping off the eastern face, and the tank was beginning to overflow at the time of the site evaluation. Water was found in the ditch at the toe of the eastern face.

Containment

The liner for the impoundment is a 30-millimeter geomembrane. Several patches were found on the liner at the upstream face, as well as poor seals on the seams. Additionally, small tears were observed, and a minor amount of rock and soil was found on the liner, increasing the tear potential. Bulges in the liner were also noticed at a few locations. The anchor trench was exposed in places due to insufficient embedment.

Slope

Rills, gullies, and cracks were observed in multiple locations on the downstream faces. Slope movements were found below the access road on the northern face, above and below the tram road on the western face, and on the eastern face. Woody debris was prevalent on the downstream faces in the fill material as well as resting on top of the fill in several locations.

Other Comments

Trash was found in the impoundment. Gouges were observed in an unsupported pipe on the western face. There was a drainage pipe that directed water over the western face, causing gully formation.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/16/12 11:00 AM	County	Wetzel	Company	Stone Energy Company
	Latitude	N 39° 41' 9.28"	Pit Name	Pribble Freshwater Impoundment
WEATHER Mostly Sunny	Longitude	W 80° 49' 16.3"	ID No.	Permit #: WMP-00277

A. PERMIT INFORMATION

Pit Width (ft.)	260 ft.	Minimum Berm Crest Width (ft.)	24 ft.	Construction Type	Hill Crest
Pit Length (ft.)	390 ft.	Upstream Slope (H:V)	2:1	Liner Type	30 mil.
Depth (ft.)	24 ft.	Downstream Slope (H:V)	2:1	Date Built	
Freeboard(ft.)	1 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	271.5 ft.	Berm Crest Width (ft.)	>25 ft.	Crest Height (ft.)	65.6 ft.
Pit Length (ft.)	405 ft.	Upstream Slope (H:V)	2:1	Up Slope Length (ft.)	37.5 ft.
Depth (ft.)		Downstream Slope (H:V)	2.5:1	Down Slope Length (ft.)	181.5 ft., 84 ft
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

	C. PIT/IMPOUNDMENT	Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	Gullies on downstream face, erosion at pipe
2	Are there any slope movements or animal burrows?	Yes			✓	Above tram road
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes		✓		Woody debris on faces
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	Discharge from pipe
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes			✓	Many repairs, poor seams
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rocks and soil
11	Is there any tear potential for the liner?	Yes	✓			Seams, small tears
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			HDPE exposed
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	Yes	✓			Gouges in pipe on downstream face
14	Are there any areas where the pipe is not properly supported?	Yes	✓			Unsupported
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Bottles in impoundment
17	Are there any signs of water in ditch associated with pit?	Yes	✓			
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

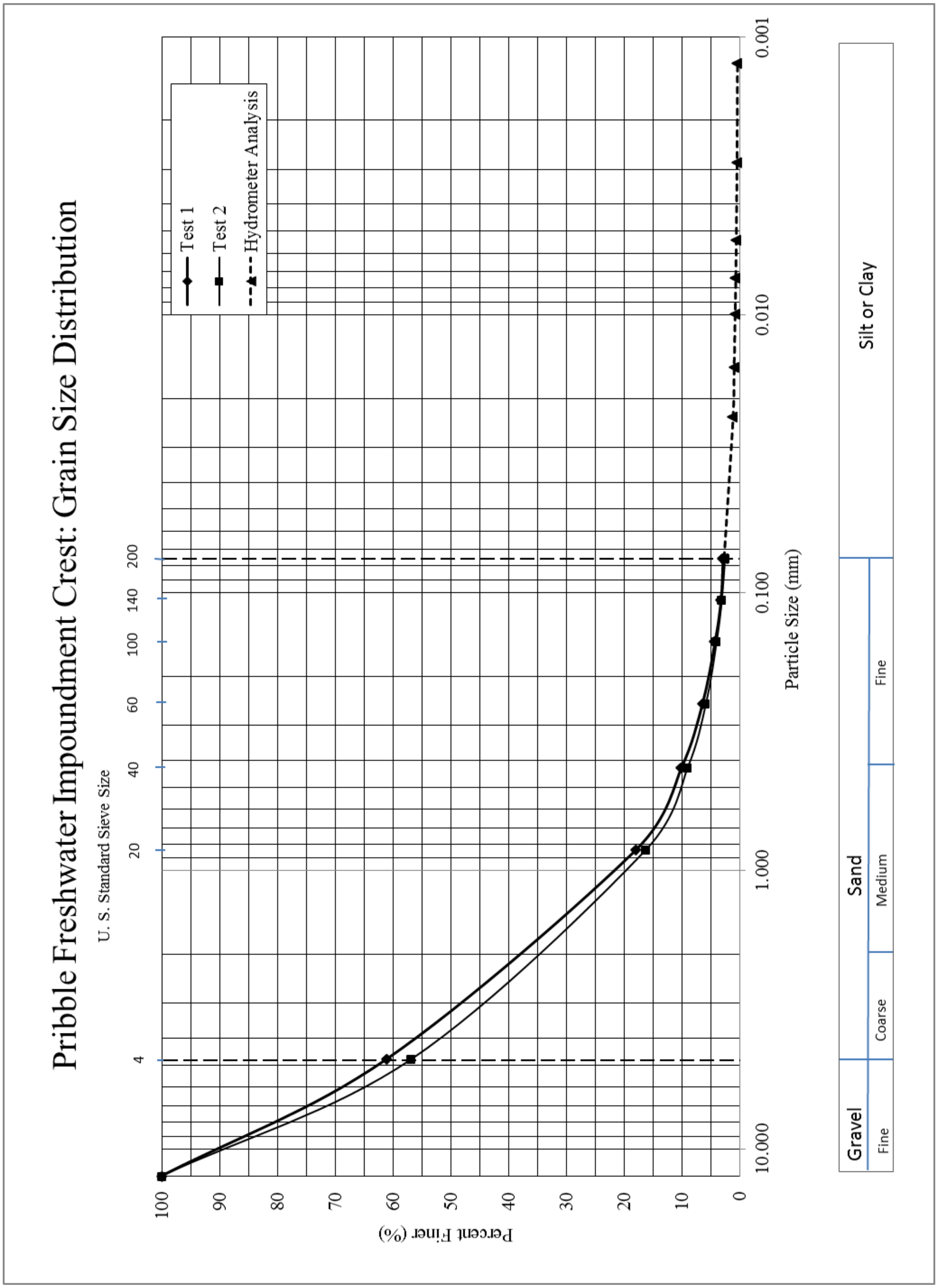
WVU (Name / Signature) Andrew Darnell	DATE 7/16/12
WVDEP (Name / Signature) Derek Haught	7/16/12
Company Representative (Name / Signature) Ron Shafer	7/16/12

Site Operations & Infrastructure Evaluation	
Date: 7/16/12	Pit/Impoundment Name: Pribble Freshwater Impoundment
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Walking and visual inspections, no set frequency (once a month usually)
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Worked in oil and gas industry for 10 years, has no specific training
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? Uses a well report form, nothing specific to pits and impoundments
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? General form developed around 50 years ago
6	Are there safety and emergency procedures for the pit/impoundment? Life vests, fences, notifications
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? No action plan except for fixing leaks and damage control, best construction practices
8	Has the pit/impoundment inspector been trained on how to use the EAP? No
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) No
10	Does the company have a policy on pit/impoundment safety? An alarm goes off when the water level gets too high, and they pump out water
11	How frequently does a Professional Engineer inspect the site? Once a year, consultants do bi-monthly inspections
12	Other comments: Erosion problems on slope originally outside construction zone, didn't experience problems until after construction, engineering fix on erosion Previous slip on face caused by liner breaches, patched bad seams and corrected slip Company representative mentioned that there was no way to communicate downstream if there was a failure

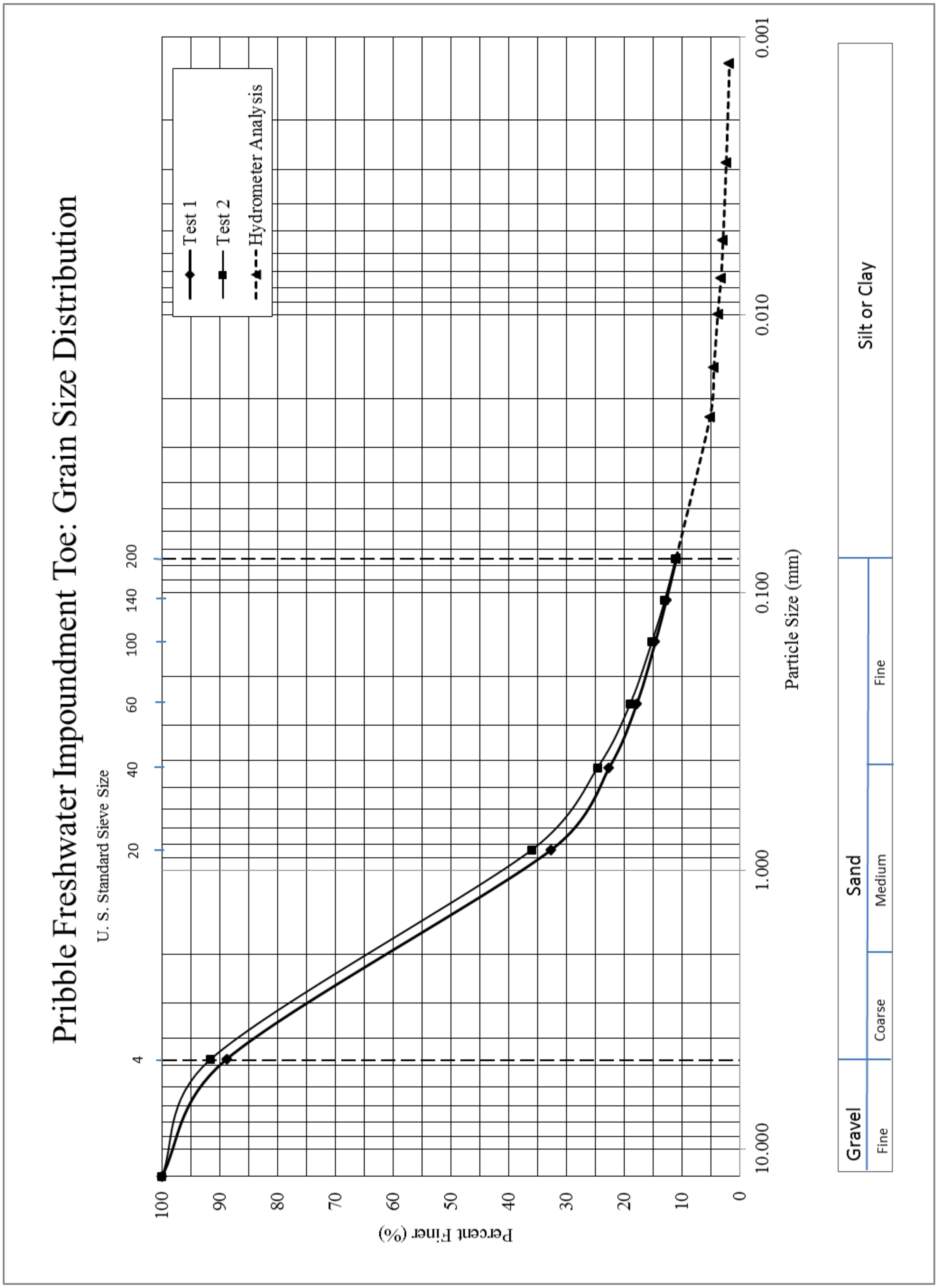
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

Pribble Freshwater Impoundment		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	1
2	Are there any slope movements or animal burrows?	Yes			✓	1
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes		✓		2
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	1
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes			✓	1
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	Yes	✓			3
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	Yes	✓			3
14	Are there any areas where the pipe is not properly supported?	Yes	✓			3
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	Yes	✓			3
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

Total:	**55**	(Out of 76)
Percentage:	**72.4%**	



Pribble Freshwater Impoundment Crest: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
Particle Size (mm)
10.000
1.000
0.100
0.010
0.001
Gravel
Fine
Coarse
Sand
Medium
Fine
Silt or Clay


Pribble Freshwater Impoundment Toe: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay

Appendix E: Burch Ridge Wastewater Pit

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Burch Ridge Wastewater Pit
Date of Site Evaluation: 7/16/12

Permit Observations / Anomalies:

The field as-built construction of the pit measured consistently with the permitted design. The berm crest width measured a minimum width of 20 feet, in accordance with the permit.

The as-built dimensions of the pit were reasonably close to the permitted dimensions. The permitted size is 158.5 feet wide by 378.9 feet long, while the as-built dimensions are 165 feet wide by 375 feet long.

Hydrology

A visual evaluation of the berm found tension cracks forming along the crest and at the toe of the downstream faces. Also, rills and gullies were observed at various locations on the downstream faces due to surface erosion. While there were no observed slope movements, the lack of vegetation on the downstream faces makes those faces susceptible to additional surface erosion and possible movements. Furthermore, moist soil was found along the toe of the downstream faces.

Containment

The liner for the pit is a 60-millimeter geomembrane. Patches were found on the liner at the upstream face. Bulges in the liner were also noticed at a few locations. Settlement cracks were found around the anchor trench of the geomembrane, and the anchor trench was exposed in places.

Slope

Rills, gullies, and cracks were observed in multiple locations on the downstream faces, but no slope movements were found. Woody debris was prevalent on the downstream faces in the fill material as well as resting on top of the fill in several locations.

Other Comments

There was an unsupported pipe along the access road.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/16/12 1:00	County	Marshall	Company	Gastar Exploration USA, Inc.
WEATHER Mostly Sunny	Latitude	N 39° 45' 15.6"	Pit Name	Burch Ridge Wastewater Pit
	Longitude	W 80° 48' 17.4"	ID No.	051-01508

A. PERMIT INFORMATION

Pit Width (ft.)	158.5 ft.	Minimum Berm Crest Width (ft.)	20 ft.	Construction Type	Incised
Pit Length (ft.)	378.9 ft.	Upstream Slope (H:V)	2:1	Liner Type	60 mil
Depth (ft.)	15 ft.	Downstream Slope (H:V)	2:1	Date Built	5/2012
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	165 ft.	Berm Crest Width (ft.)	20 ft.	Crest Height (ft.)	49.7 ft.
Pit Length (ft.)	375 ft.	Upstream Slope (H:V)	1.2:1	Up Slope Length (ft.)	11 ft.
Depth (ft.)		Downstream Slope (H:V)	2.1:1	Down Slope Length (ft.)	115.5 ft., 75 ft
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes		✓		Gullies, cracks at crest Little vegetation
2	Are there any slope movements or animal burrows?	No				
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes			✓	Woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			Moist soil at toe
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	No				
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Anchor trench exposed, cracks in places
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	No				
14	Are there any areas where the pipe is not properly supported?	Yes	✓			Unsupported
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	No				
17	Are there any signs of water in ditch associated with pit?	N/A				
18	Are there any obstructions around the discharge outlet?	N/A				
19	Are there any signs of downstream slope movement into ditch?	N/A				

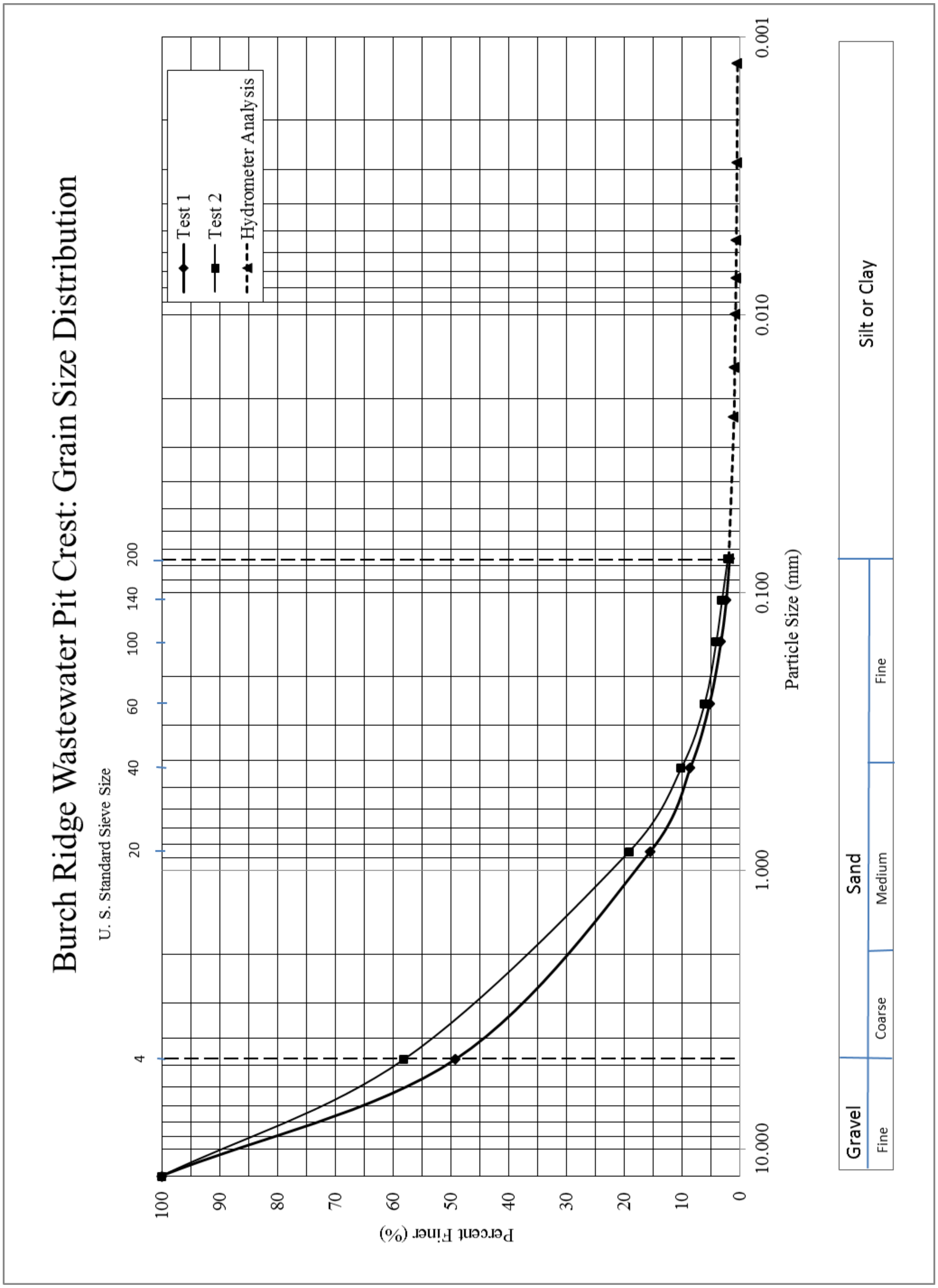
WVU (Name / Signature) Andrew Darnell	DATE 7/16/12
WVDEP (Name / Signature) Derek Haught	7/16/12
Company Representative (Name / Signature) Jerry Duelley	7/16/12

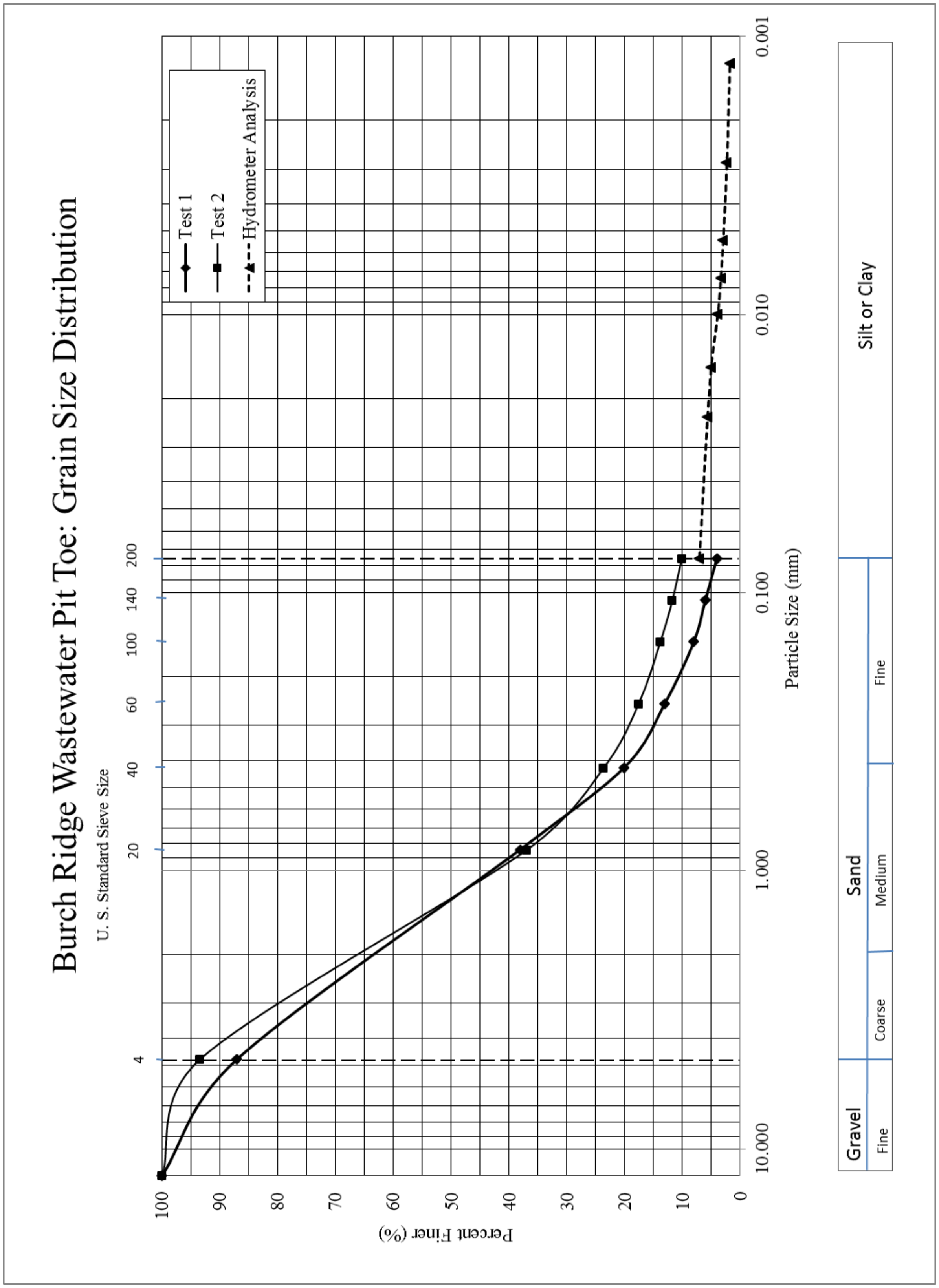
Site Operations & Infrastructure Evaluation	
Date: 7/16/12	Pit/Impoundment Name: Burch Ridge Wastewater Pit
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Visual inspection every 3 days
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Worked in oil and gas industry for 10 years, has no specific training
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? Uses a well report form, nothing specific to pits and impoundments
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? General form developed around 50 years ago
6	Are there safety and emergency procedures for the pit/impoundment? Buoys, fences
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Site safety plan posted in site trailers, call 911 (seemed to be guessing on who to contact and in what order)
8	Has the pit/impoundment inspector been trained on how to use the EAP? Inspector is the first to review the site safety plan prior to the permit
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) N/A
10	Does the company have a policy on pit/impoundment safety? Site safety plan posted in site trailers, call 911 (seemed to be guessing on who to contact and in what order)
11	How frequently does a Professional Engineer inspect the site? At construction, bi-monthly inspections certified every month
12	Other comments:

The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

Burch Ridge Wastewater Pit		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes		✓		2
2	Are there any slope movements or animal burrows?	No				4
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes			✓	1
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			3
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			3
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	No				4
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				4
14	Are there any areas where the pipe is not properly supported?	Yes	✓			3
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	No				4
17	Are there any signs of water in ditch associated with pit?	No				4
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

Total:	**67**	(Out of 76)
Percentage:	**88.2%**	


Burch Ridge Wastewater Pit Crest: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Coarse
Sand
Medium
Fine
Silt or Clay



Burch Ridge Wastewater Pit Toe: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay

Appendix F: MIP Freshwater Impoundment

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: MIP Freshwater Impoundment
Date of Site Evaluation: 7/18/12

Permit Observations / Anomalies:

Measurements of the field as-built construction differed from the permitted design. The berm crest width measured a minimum width of 7 feet, while the permitted dimension is a uniform 20 feet in width. Therefore, berm width is a deficiency.

The as-built dimensions of the impoundment exceeded the permitted dimensions. Therefore, the impoundment has a larger volume capacity than permitted. The permitted size is 121.3 feet wide by 266.5 feet long, while the as-built dimensions are 135 feet wide by 279 feet long. The as-built size and volume exceed the permit.

Hydrology

There were observed surface erosions at several locations on the site. Tension cracks were noticed at the berm and along the downstream face. Slope movements were observed on the hillside above the impoundment. Rills and gullies were also found at various locations on the downstream face due to surface erosion. There was a high degree of slope deformation observed above the impoundment. Some moist soil was found in the ditch above the impoundment.

Containment

The liner for the impoundment is a textured 30-millimeter geomembrane. Patches were found on the liner at the upstream face. Bulges in the liner were also noticed at a few locations, and there was minor rock and soil debris on the liner. Settlement cracks were found around the anchor trench of the geomembrane, and the anchor trench was exposed in places due to insufficient embedment.

Slope

Rills, gullies, and cracks were observed in multiple locations on the downstream face. Slope movements towards the impoundment were found on the up-gradient hillside. Woody debris was noticed in the fill on the downstream face. Minor slope movement into the ditch was observed around a non-functioning drainage pipe. Overall slope movement appears to have stabilized with no observed bulges at the down-gradient toe or scarps on the slope face.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the impoundment. Data was collected up-gradient, at the perimeter of the impoundment crest, and on the down-gradient slope of the impoundment.

Other Comments

There was some erosion due to a drainage pipe under the berm emptying into the ditch.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/18/12 9:45 AM	County	Monongalia	Company	Northeast Natural Energy
	Latitude	N 39° 36' 00.7"	Pit Name	MIP Freshwater Impoundment
WEATHER Mostly Cloudy	Longitude	W 79° 58' 32.8"	ID No.	47-6101622

A. PERMIT INFORMATION

Pit Width (ft.)	121.3 ft.	Minimum Berm Crest Width (ft.)	20 ft.	Construction Type	Incised
Pit Length (ft.)	266.5 ft.	Upstream Slope (H:V)	2.5:1	Liner Type	30 mil
Depth (ft.)	14.12 ft.	Downstream Slope (H:V)	2:1	Date Built	
Freeboard(ft.)				Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	135 ft.	Berm Crest Width (ft.)	7 ft.	Crest Height (ft.)	26.2 ft.
Pit Length (ft.)	279 ft.	Upstream Slope (H:V)	1.8:1	Up Slope Length (ft.)	14 ft.
Depth (ft.)	11 ft.	Downstream Slope (H:V)	1.8:1	Down Slope Length (ft.)	54 ft.
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	
2	Are there any slope movements or animal burrows?	Yes			✓	Above impoundment
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes		✓		Woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			Above impoundment
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor soil/rock
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Anchor trench exposed in places
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	No				
14	Are there any areas where the pipe is not properly supported?	No				
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Bottles in impoundment
17	Are there any signs of water in ditch associated with pit?	Yes	✓			Moist soil
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	Yes	✓			By pipe

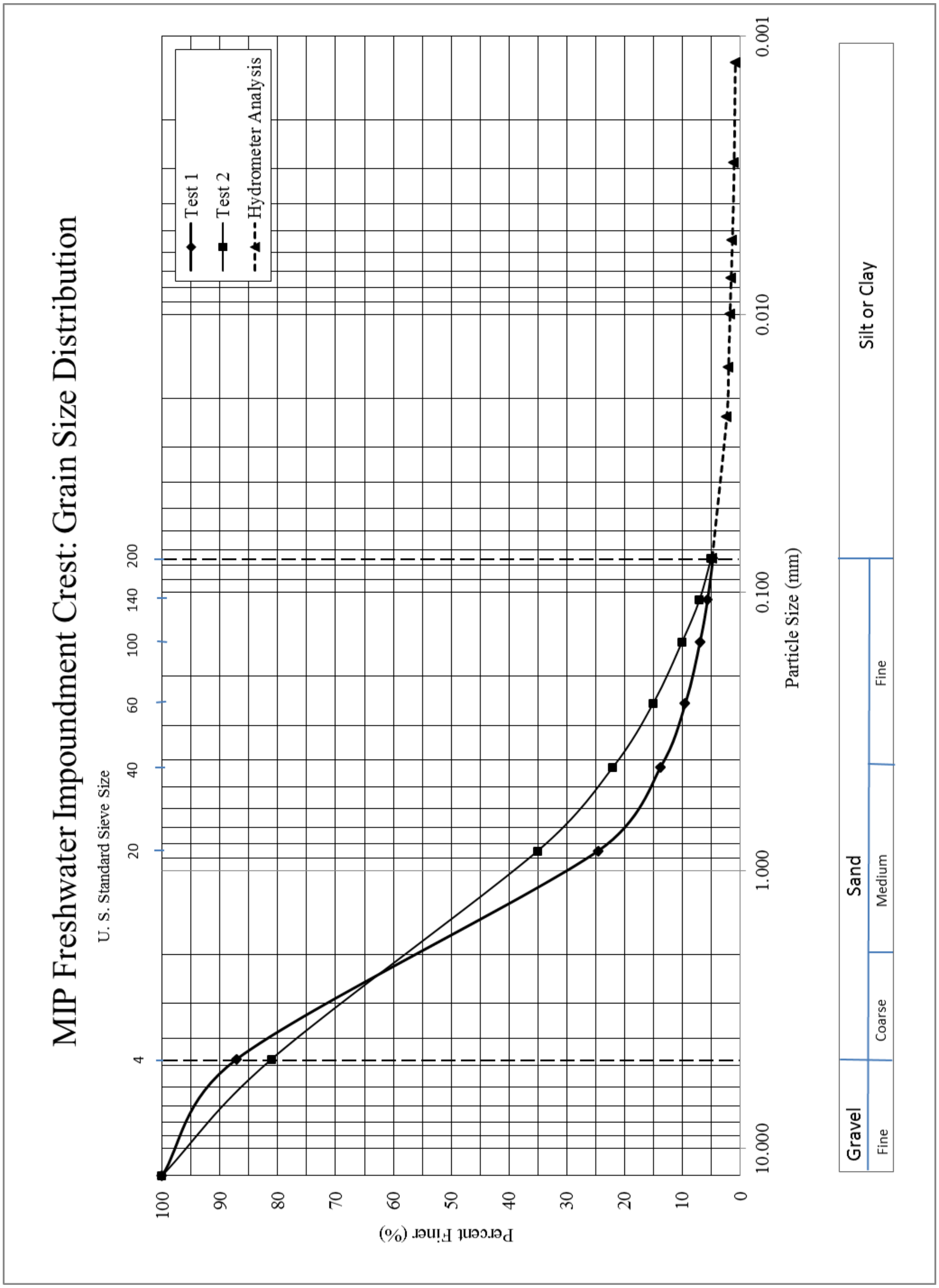
WVU (Name / Signature) Richard Wise	DATE 7/18/12
WVDEP (Name / Signature) Samuel D. Ward II	7/18/12
Company Representative (Name / Signature) David A. McDougal	7/18/12

Site Operations & Infrastructure Evaluation	
Date: 7/18/12	Pit/Impoundment Name: MIP Freshwater Impoundment
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Once a week during drilling operations, once a month during post-drilling operation
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? None, follows state regulations
3	How many years of training does the inspector have in evaluating pits/impoundments? None, follows state regulations
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No, follows state regulations, looks at freeboard, slips, and movements and reports to company if any serious problems are observed
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? N/A
6	Are there safety and emergency procedures for the pit/impoundment? Northeast Natural Energy safety policy, fence, and floatation devices
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? No, not required due to volume, location, and state law
8	Has the pit/impoundment inspector been trained on how to use the EAP? N/A
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) N/A
10	Does the company have a policy on pit/impoundment safety? Yes, safety policy during drilling operations
11	How frequently does a Professional Engineer inspect the site? Once after post-construction to sign-off on as-built drawings
12	Other comments: West side of impoundment relatively flat outside of berm (slight upward slope) Cracking at anchor trench, berm, and ditch outside of safety fence Textured 30 mil geomembrane Minor bulging of liner Liner not secured on South berm

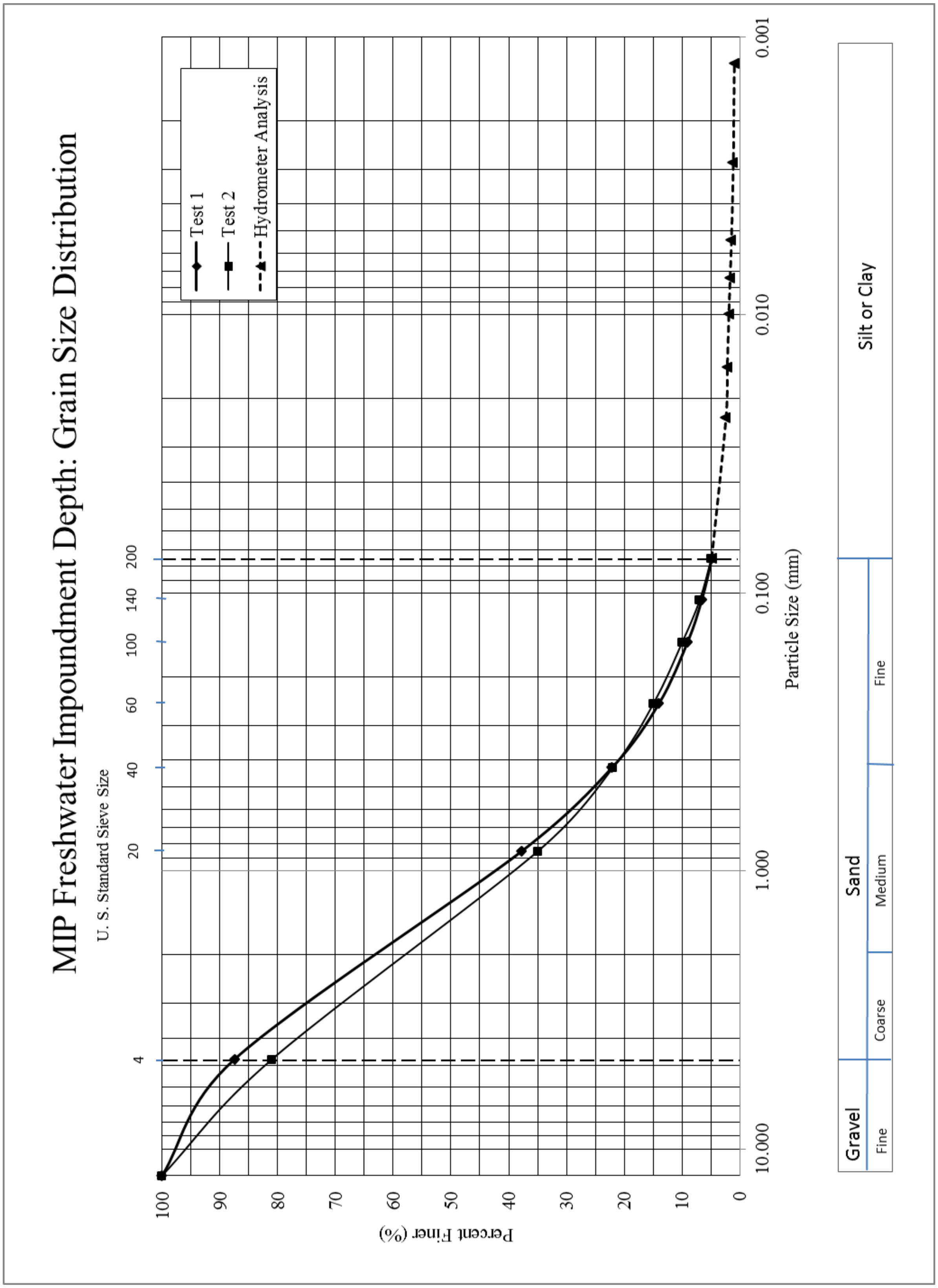
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

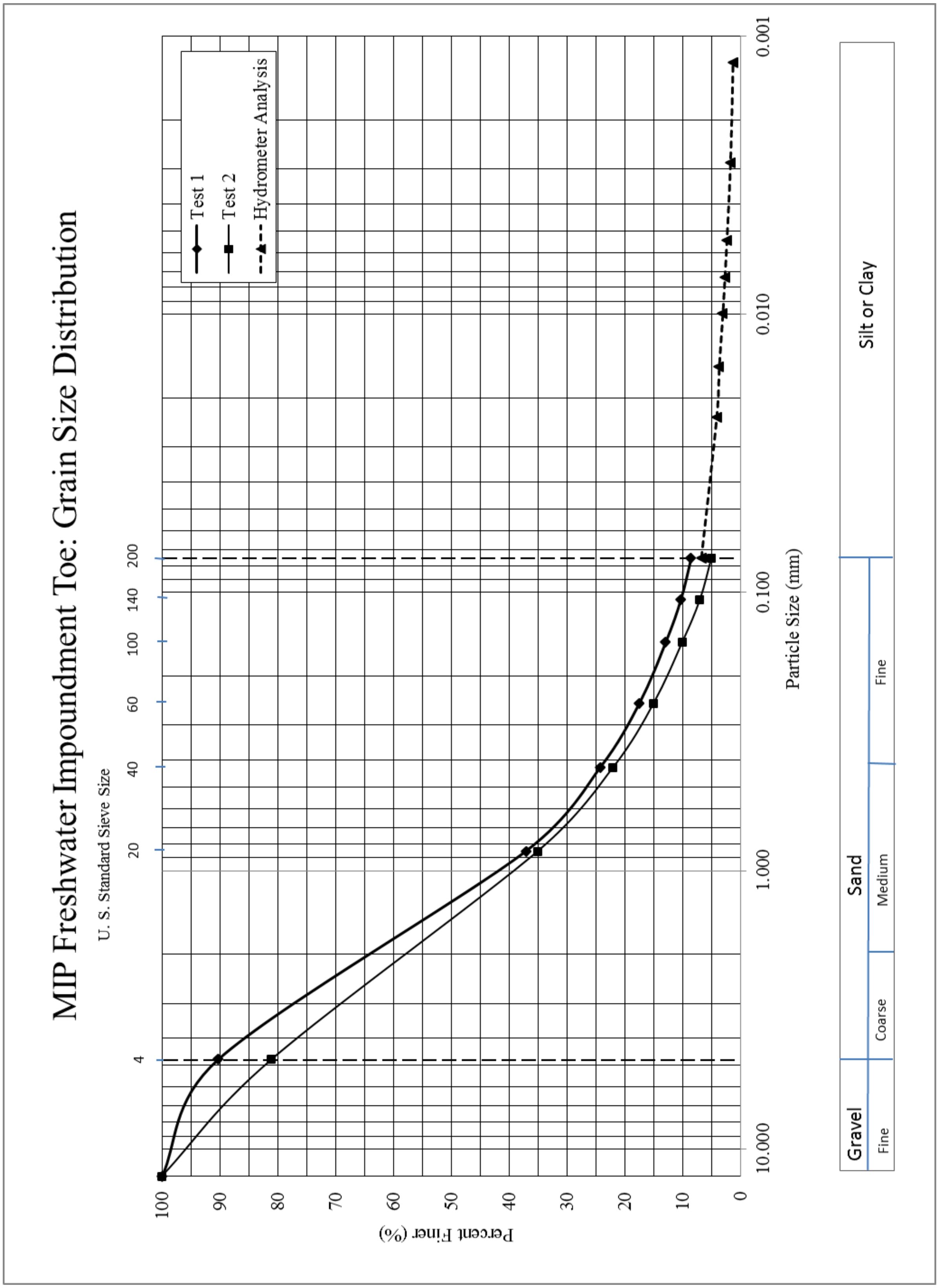
MIP Freshwater Impoundment		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	1
2	Are there any slope movements or animal burrows?	Yes			✓	1
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes		✓		2
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			3
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			3
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				4
14	Are there any areas where the pipe is not properly supported?	No				4
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	Yes	✓			3
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	Yes	✓			3

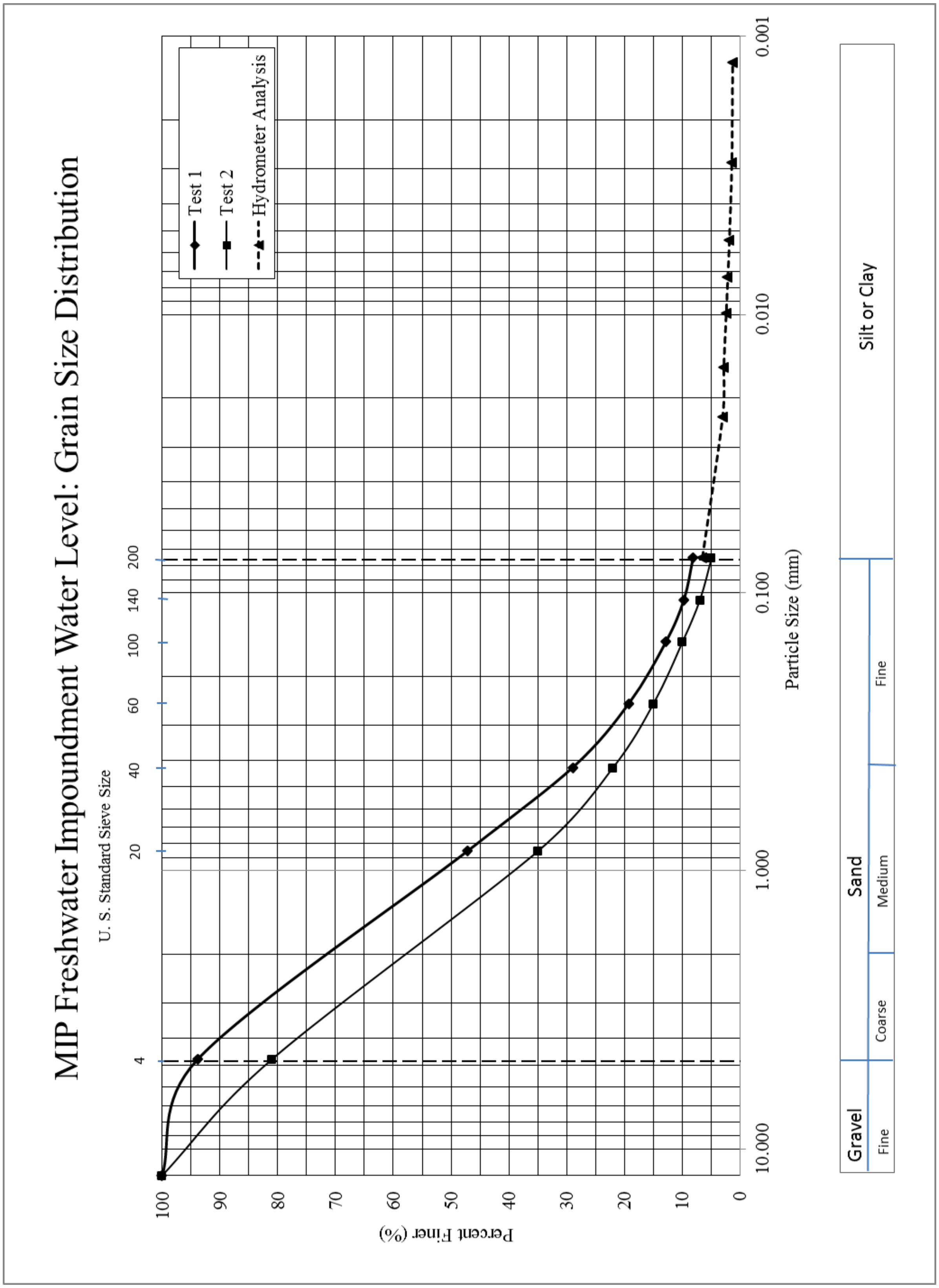
Total:	**61**	(Out of 76)
Percentage:	**80.3%**	

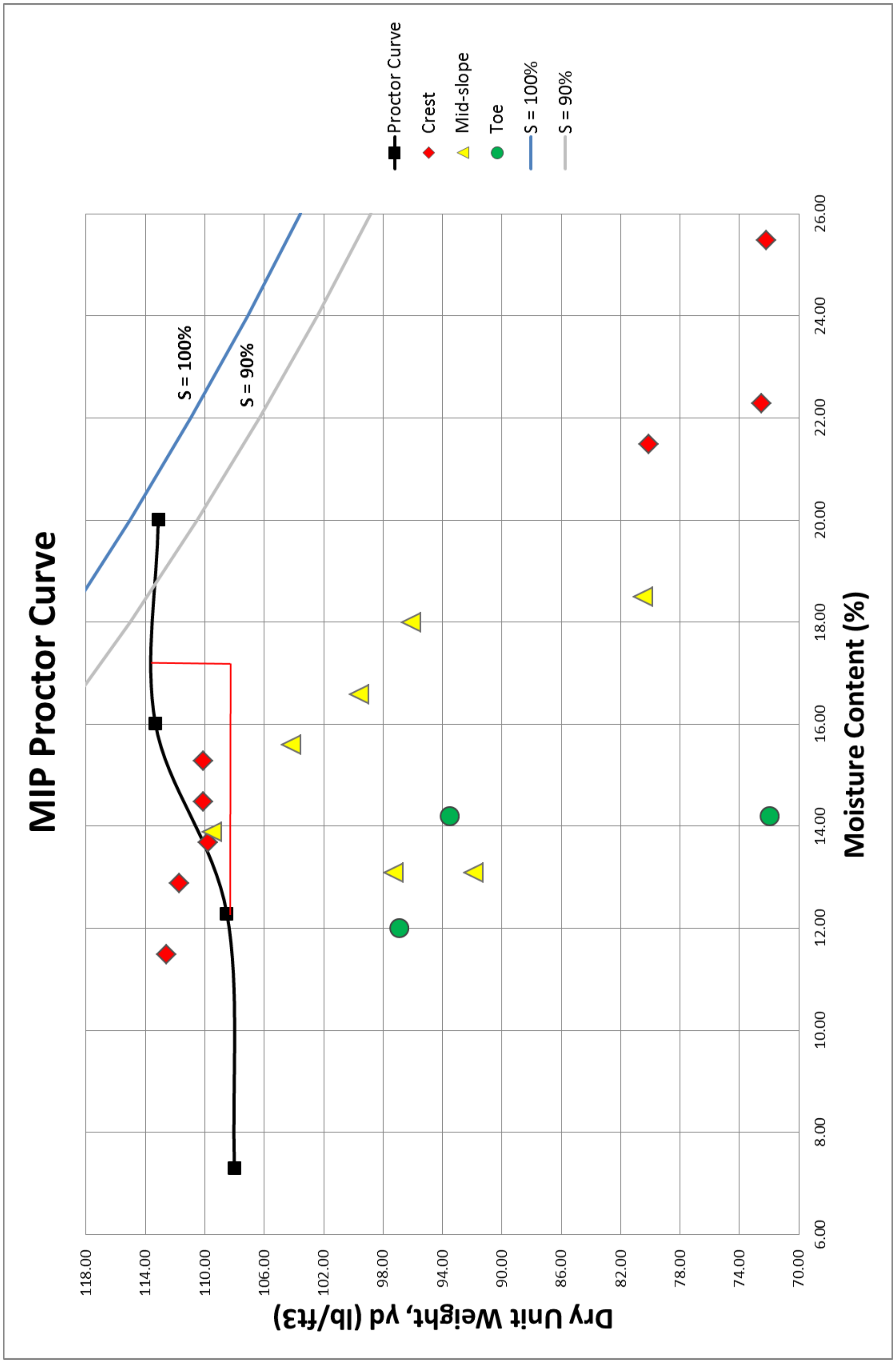


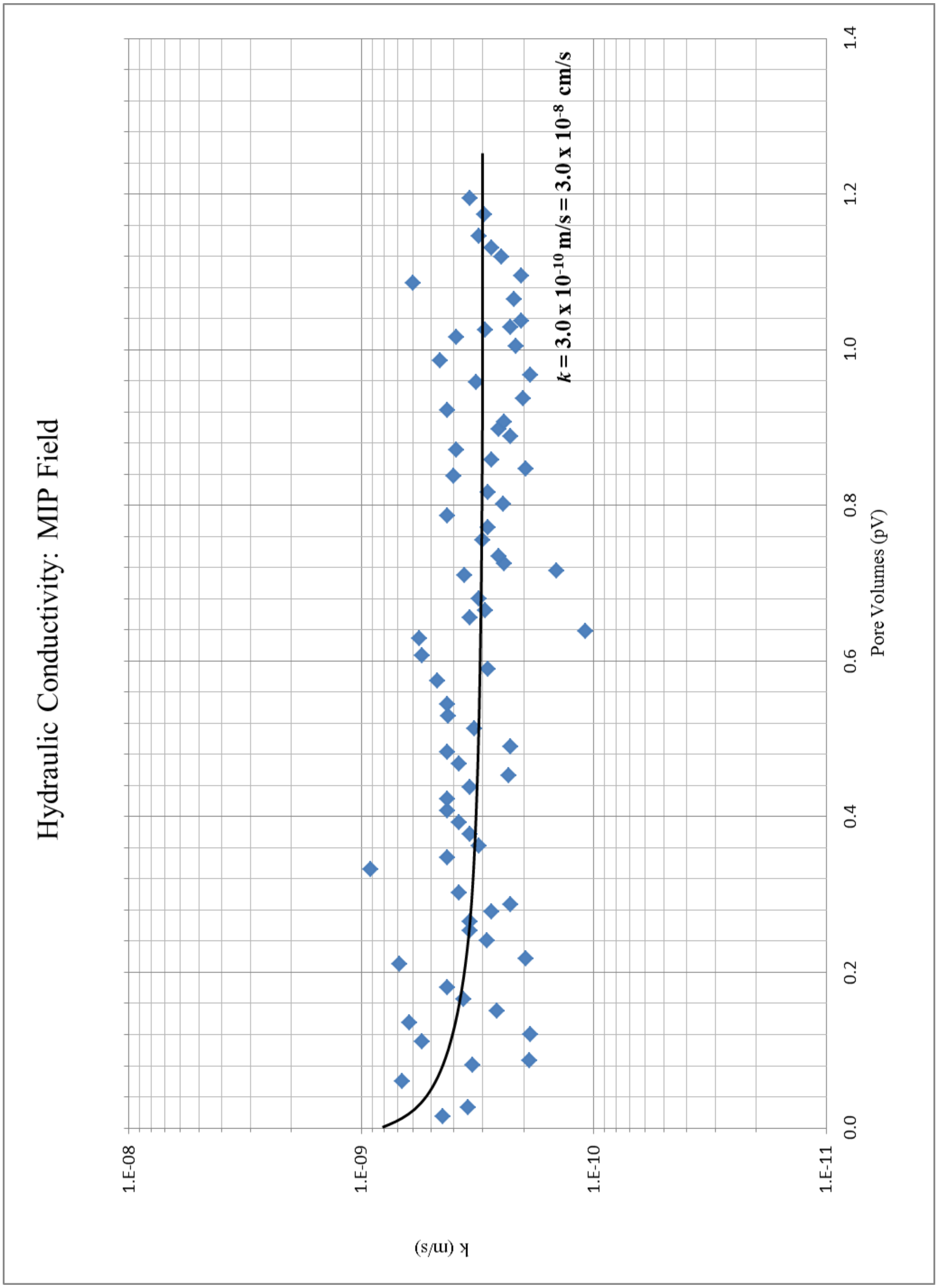
MIP Freshwater Impoundment Crest: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay

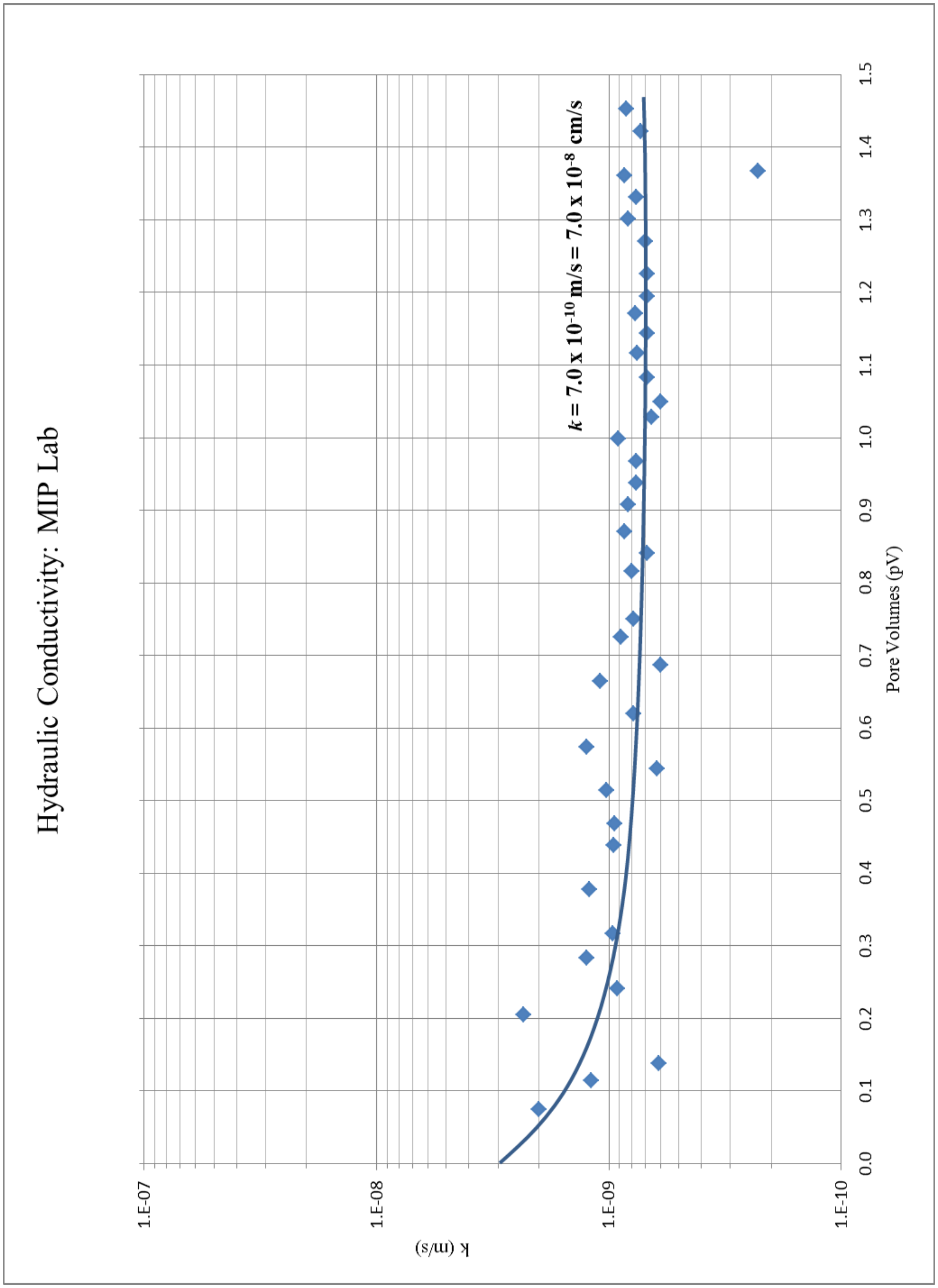

MIP Freshwater Impoundment Depth: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


MIP Freshwater Impoundment Toe: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay

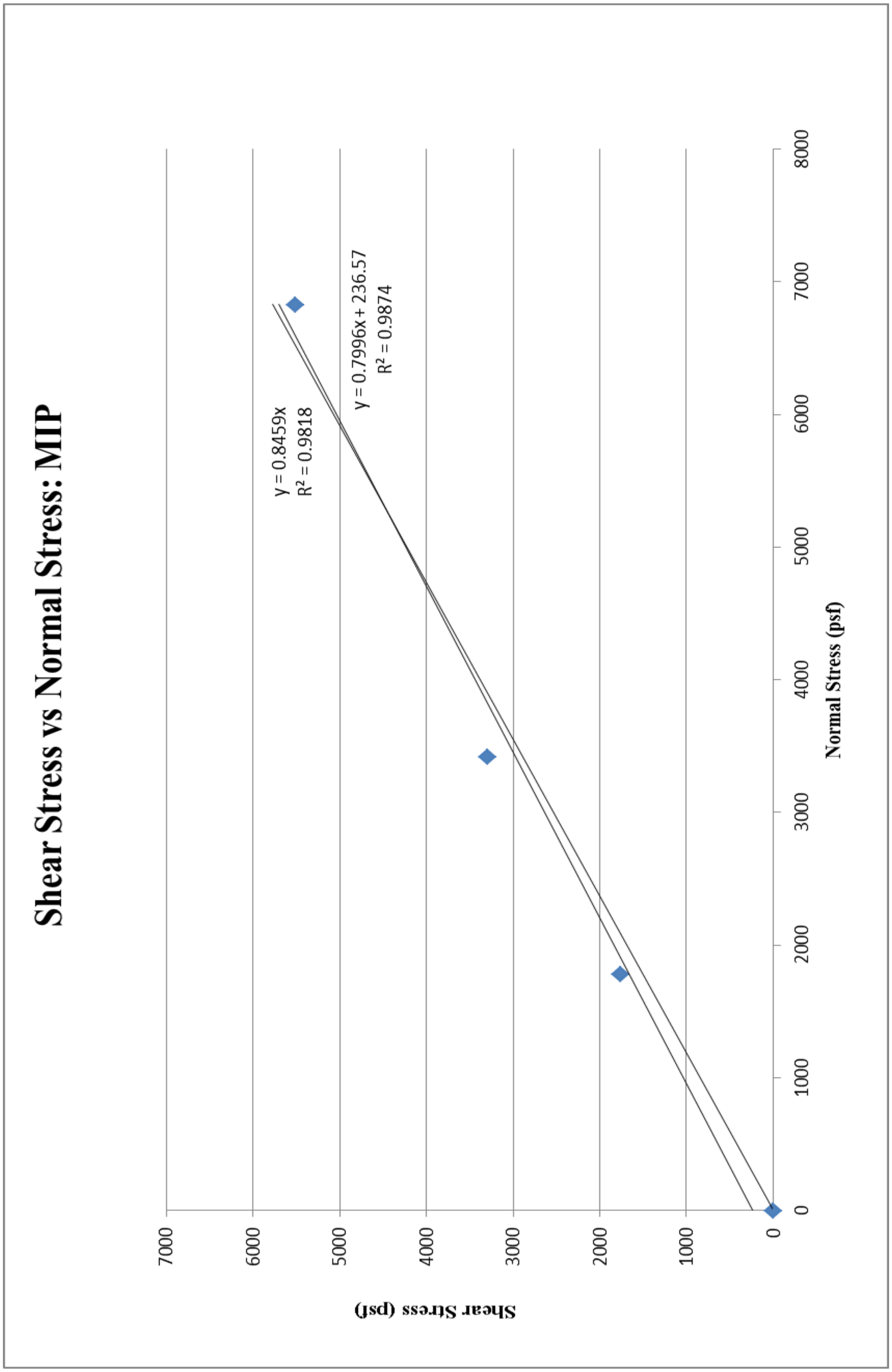

MIP Freshwater Impoundment Water Level: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


MIP Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
S = 100%
S = 90%
Proctor Curve
Crest
Mid-slope
Toe
S = 100%
S = 90%
118.00
114.00
110.00
106.00
102.00
98.00
94.00
90.00
86.00
82.00
78.00
74.00
70.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
26.00


Hydraulic Conductivity: MIP Field
k = 3.0 x 10^-10 m/s = 3.0 x 10^-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4



Hydraulic Conductivity: MIP Lab
k = 7.0 x 10^-10 m/s = 7.0 x 10^-8 cm/s
k (m/s)
1.E-07
1.E-08
1.E-09
1.E-10
Pore Volumes (pV)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5


Shear Stress vs Normal Stress: MIP
y = 0.8459x
R² = 0.9818
y = 0.7996x + 236.57
R² = 0.9874
Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000

Max Shear Stress vs. Normal Stress (MIP)			
Date	**Sample**	**Compaction**	**Material**
11/5/2012	MIP	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress (psf)**	**Normal Stress (psf)**
High	5.509	5509	6830
Medium	3.296	3296	3421
Low	1.766	1766	1786
4	0	0	0
m	0.7996	m	0.8459
ϕ' (degrees)	38.646	$\phi'_{c'=0}$ (degrees)	40.228
c' (psf)	236.570	c' (psf)	0.0

Appendix G: Ball 1H Impoundment #2

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Ball 1H Impoundment #2
Date of Site Evaluation: 7/24/12

Permit Observations / Anomalies:

Measurements of the field as-built construction differed from the permitted design. The berm crest width measured a minimum of 7 feet, as opposed to the 6 feet noted in the permit.

The as-built dimensions of the impoundment were smaller than the permitted dimensions. The permitted size is 176 feet wide by 1,095 feet long, while the as-built dimensions measured 154.5 feet wide by 978 feet long. Thus, the as-built capacity is smaller than the permitted design.

Hydrology

Visual evaluations of the berm and downstream faces found cracks, rills, and gullies under the erosion control fabric. Slope movements such as scarps and slides were also observed in several places on the downstream faces. Wet zones were observed on the berm as well as on the downstream toe. A sinkhole was found on the berm on the northeastern side of the impoundment.

Containment

The liner for the impoundment is a 15-millimeter geomembrane. Patches were found on the liner at the upstream face. Bulges in the liner and seam separations were also noticed at a few locations. Settlement cracks were found around the anchor trench of the geomembrane, and the anchor trench was exposed in places due to insufficient embedment. A minor amount of rock and soil were on top of the liner.

Slope

Rills, gullies, and cracks were observed in multiple locations on the downstream face, and several slope movements were found. Woody debris was noticed on the downstream faces in the fill material. Erosion control fabric was in place on the berm and downstream faces.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the impoundment. Data was collected at the perimeter of the impoundment crest and on the down-gradient slope of the impoundment.

Other Comments

The impoundment was constructed within 36 feet of a perennial stream and within 200 feet of a dwelling. Cut material was heaped into a pile near the southeastern corner of the impoundment.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/24/12 9:45am	County	Tyler	Company	PetroEdge Energy, LLC.
	Latitude	N 39° 30' 2.12"	Pit Name	Ball 1H Impoundment #2
WEATHER Partly Cloudy	Longitude	W 80° 45' 41.9"	API No.	095-02032

A. PERMIT INFORMATION

Pit Width (ft.)	176 ft.	Minimum Berm Crest Width (ft.)	6 ft.	Construction Type	Incised
Pit Length (ft.)	1,095 ft.	Upstream Slope (H:V)	2:1	Liner Type	15 mil.
Depth (ft.)	10 ft.	Downstream Slope (H:V)	2:1	Date Built	
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	154.5 ft.	Berm Crest Width (ft.)	7 ft.	Crest Height (ft.)	4.7 ft.
Pit Length (ft.)	978 ft.	Upstream Slope (H:V)	1.6:1	Up Slope Length (ft.)	13 ft.
Depth (ft.)		Downstream Slope (H:V)	2:1	Down Slope Length (ft.)	49.5 ft., 13 ft.
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	Yes	Is the pit/impoundment within 100 feet of a wetland?	No

	C. PIT/IMPOUNDMENT	Existence Yes/No/NA	If YES then Evaluate Significance of Problem: Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	Cracks, scarps, slides, rills, gullies
2	Are there any slope movements or animal burrows?	Yes			✓	On downstream faces
3	Are there any depressions, sinkholes, or slides into the pit present?	Yes		✓		Sinkhole on berm
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			Woody debris, weeds
6	Are there any seeps, wet zones, or losses of soil?	Yes		✓		Berm, toe
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		Bulges, seam separation
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Rocks/soil on liner
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes		✓		Cracks, anchor trench exposed in places
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	No				
14	Are there any areas where the pipe is not properly supported?	No				
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Fabric, woody debris
17	Are there any signs of water in ditch associated with pit?	No				
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

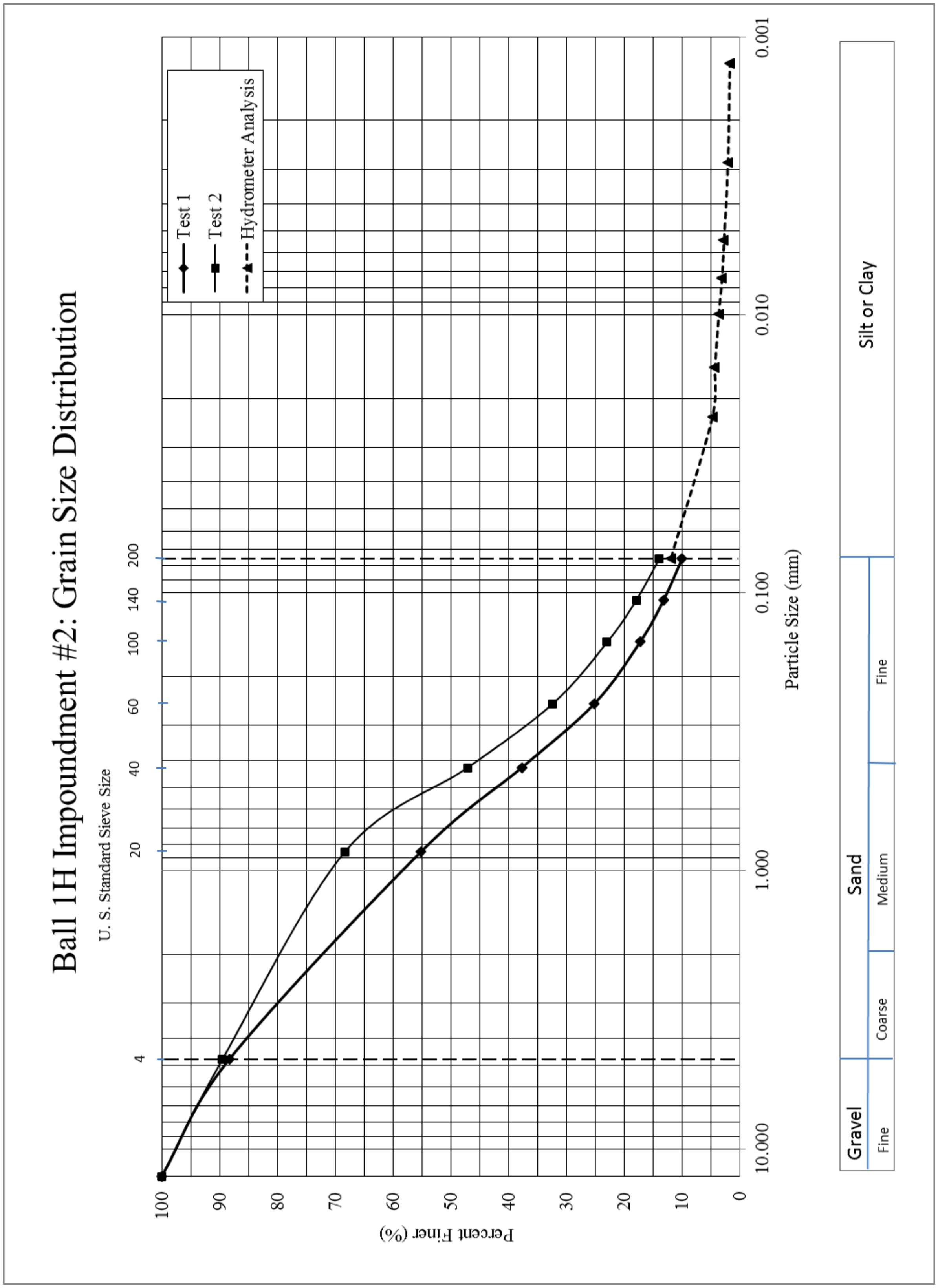
WVU (Name / Signature) Andrew Darnell	DATE 7/24/12
WVDEP (Name / Signature) Joe Taylor	7/24/12
Company Representative (Name / Signature) Dan Mullins	7/24/12

Site Operations & Infrastructure Evaluation	
Date: 7/24/12	Pit/Impoundment Name: Ball 1H Impoundment #2
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Walking and visual inspections every 2 weeks or after a heavy rain
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Dan Mullins has worked in the field for 15 years Joe Taylor has worked 10 years in the oil and gas industry, and he has been with the WVDEP for 3 years
3	How many years of training does the inspector have in evaluating pits/impoundments? No formal training
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? General state form submitted to WVDEP
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? The state of West Virginia
6	Are there safety and emergency procedures for the pit/impoundment? No formal written plans
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? No, evacuation notifications exist, residents have the company's contact information
8	Has the pit/impoundment inspector been trained on how to use the EAP? N/A
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) N/A
10	Does the company have a policy on pit/impoundment safety? Safety measures such as fences
11	How frequently does a Professional Engineer inspect the site? At least once a month
12	Other comments: Cracks and slides under erosion control mat Pieces of liner in impoundment Impoundment within 36 ft. of a perennial stream

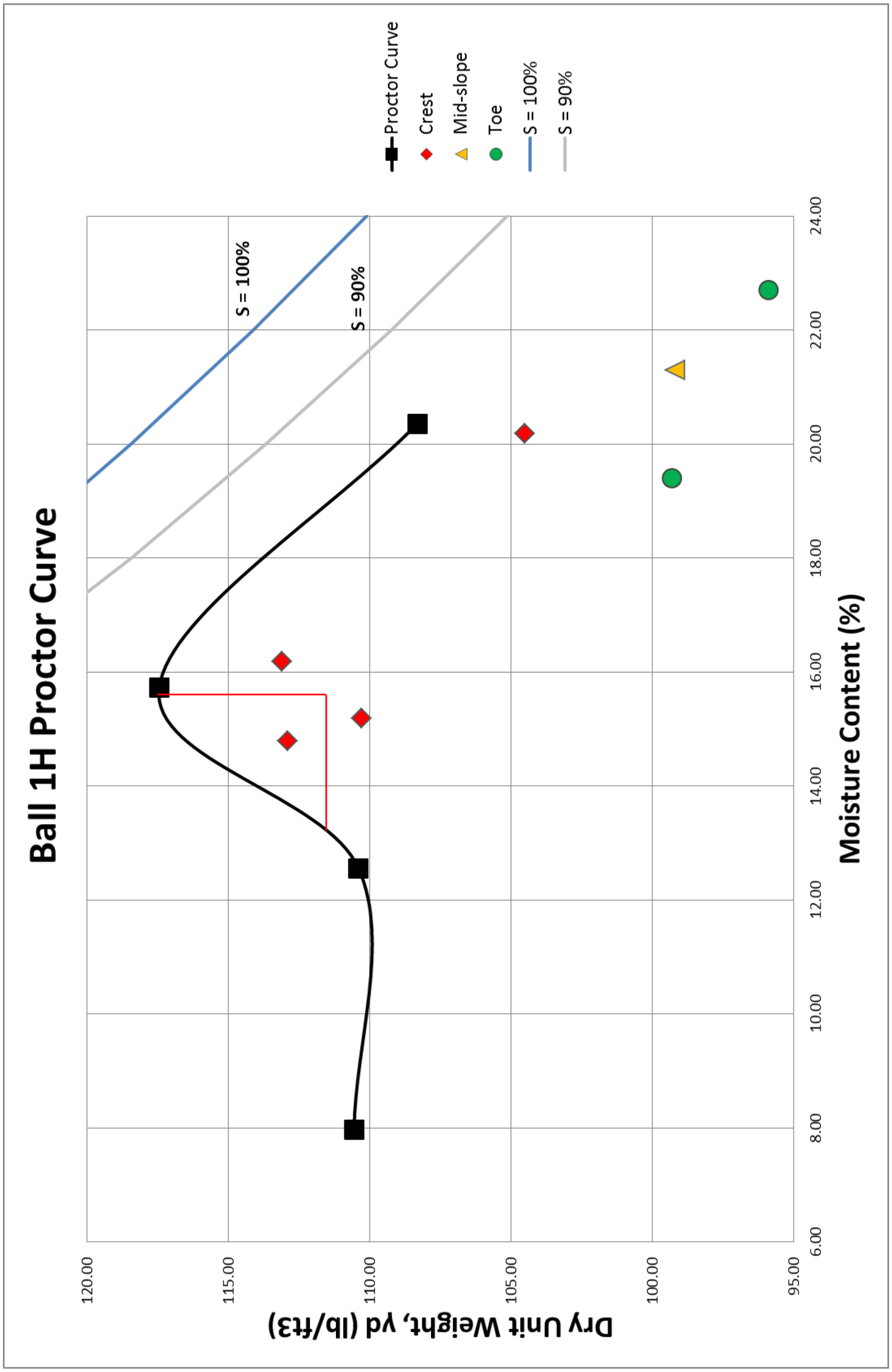
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

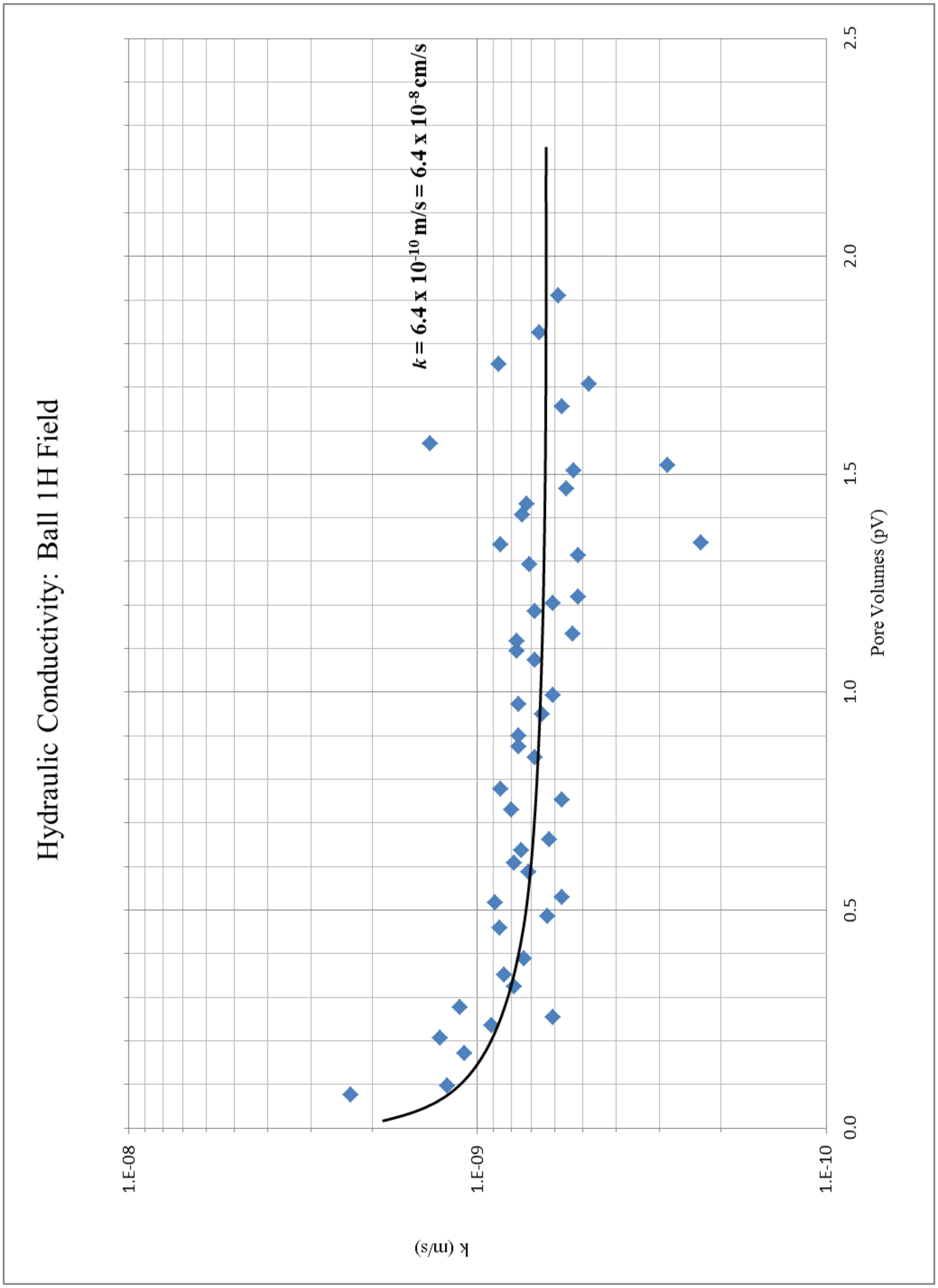
Ball 1H Impoundment #2		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	1
2	Are there any slope movements or animal burrows?	Yes			✓	1
3	Are there any depressions, sinkholes, or slides into the pit present?	Yes		✓		2
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			3
6	Are there any seeps, wet zones, or losses of soil?	Yes		✓		2
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		2
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes		✓		2
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				4
14	Are there any areas where the pipe is not properly supported?	No				4
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	No				4
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

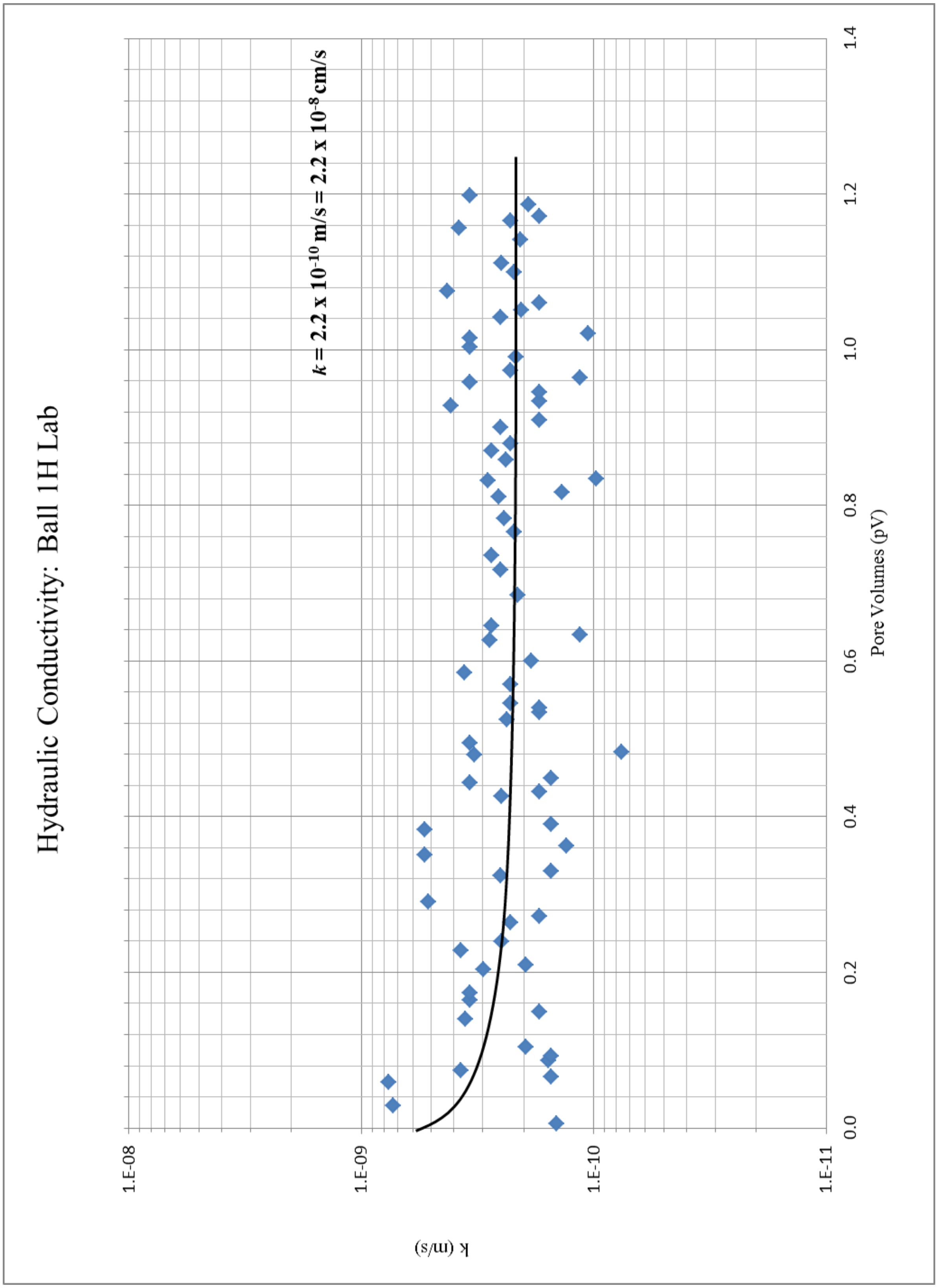
Total:	**59**	(Out of 76)
Percentage:	**77.6%**	

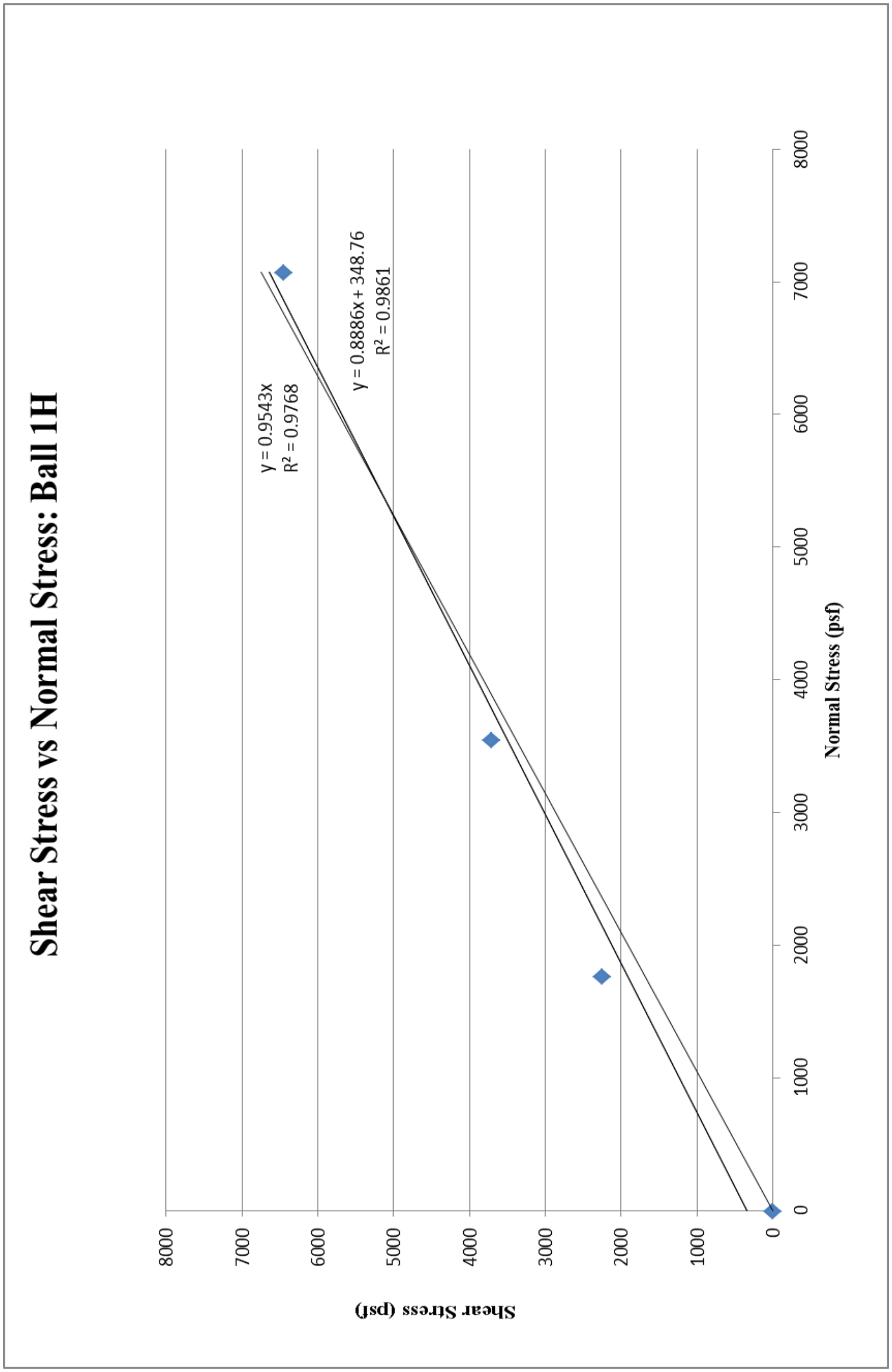


Ball 1H Impoundment #2: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


Ball 1H Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
120.00
115.00
110.00
105.00
100.00
95.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
S = 100%
S = 90%
Proctor Curve
Crest
Mid-slope
Toe
S = 100%
S = 90%


Hydraulic Conductivity: Ball 1H Field
k = 6.4 x 10-10 m/s = 6.4 x 10-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
Pore Volumes (pV)
0.0
0.5
1.0
1.5
2.0
2.5


Hydraulic Conductivity: Ball 1H Lab
k = 2.2 x 10^-10 m/s = 2.2 x 10^-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4



Shear Stress vs Normal Stress: Ball 1H
y = 0.9543x
R² = 0.9768
y = 0.8886x + 348.76
R² = 0.9861
Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000

Max Shear Stress vs. Normal Stress (Ball 1H)			
Date	**Sample**	**Compaction**	**Material**
11/5/2012	Ball 1H	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress (psf)**	**Normal Stress (psf)**
High	6.451	6451	7075
Medium	3.705	3705	3548
Low	2.249	2249	1768
4	0.00	0	0
m	0.8886	m	0.9543
ϕ' (degrees)	41.624	$\phi'_{c'=0}$ (degrees)	43.660
c' (psf)	348.760	c' (psf)	0.0

Appendix H: Mills-Wetzel Freshwater Impoundment

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Mills-Wetzel Freshwater Impoundment
Date of Site Evaluation: 7/24/12

Permit Observations / Anomalies:

Measurements of the field as-built construction were consistent with the permitted design. The berm crest width measured a minimum of 13 feet, which is in agreement with the permitted berm width of 12.5 ft.

The as-built dimensions of the impoundment were also consistent with the permitted dimensions. The permitted size is 812.5 feet long with a minimum width of 100 feet and a maximum width of 325 feet; the as-built dimensions measured 810 feet long with a minimum width of 99 feet and a maximum width of 333 feet.

Hydrology

Visual observations of the downstream faces revealed several areas of concern. The slope had little vegetation in most areas, leading to rill and gully formation on the slope as well as slips. Also, several areas of seepage were noted, as indicated by wet zones and vegetation such as the growth of cattails on the slope.

Containment

The liner for the impoundment is a 30-millimeter geomembrane. Patches were found on the liner at the upstream face. Bulges in the liner were also noticed at a few locations. The anchor trench was exposed in places due to insufficient embedment, leading to an increased susceptibility to uplift. The liner was held down by rocks in places, and a minor amount of rock and soil were on top of the liner.

Slope

Rills, gullies, and slips were observed in multiple locations on the downstream face, and several areas of seepage were found. Woody debris was noticed on the downstream faces in the fill material. Cracks and wet zones were also present at the berm and the toe of the slope.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the impoundment. Data was collected at the perimeter of the impoundment crest, at the midpoint of the downstream face, and at the toe of the downstream face.

Other Comments

Unsupported pipes were observed at the site, one along the access road and one on the eastern side of the impoundment. Gouges in the pipes were also noted.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/24/12 1:45	County	Wetzel	Company	Stone Energy Company
	Latitude	N 39° 31' 56.8"	Pit Name	Mills-Wetzel Freshwater Impoundment
WEATHER Mostly Sunny	Longitude	W 80° 40' 19.1"	API No.	

A. PERMIT INFORMATION

Pit Width (ft.)	100 ft., 325 ft.	Minimum Berm Crest Width (ft.)	12.5 ft.	Construction Type	Hill Crest
Pit Length (ft.)	812.5 ft.	Upstream Slope (H:V)	2:1	Liner Type	30 mil.
Depth (ft.)	10 ft.	Downstream Slope (H:V)	2.5:1	Date Built	3/2010
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	99 ft., 333 ft.	Berm Crest Width (ft.)	13 ft.	Crest Height (ft.)	121.7 ft.
Pit Length (ft.)	810 ft.	Upstream Slope (H:V)	1.7:1	Up Slope Length (ft.)	24.5 ft.
Depth (ft.)		Downstream Slope (H:V)	2.1:1	Down Slope Length (ft.)	288 ft., 252 ft.
Freeboard (ft.)	6.2 ft.	Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	Cracks at toe, rills and gullies
2	Are there any slope movements or animal burrows?	Yes		✓		Some slides
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes			✓	Woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	Major seepage
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes			✓	Uplift, bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor soil/rock
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes		✓		Anchor trench exposed in places
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	Yes	✓			Gouges
14	Are there any areas where the pipe is not properly supported?	Yes		✓		Along roadway
15	Are there any signs of pipes having significant sagging in line?	Yes		✓		Unsupported
16	Are there any signs of obstructions (trees, garbage, etc.)?	No				
17	Are there any signs of water in ditch associated with pit?	Yes		✓		Moist soil
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

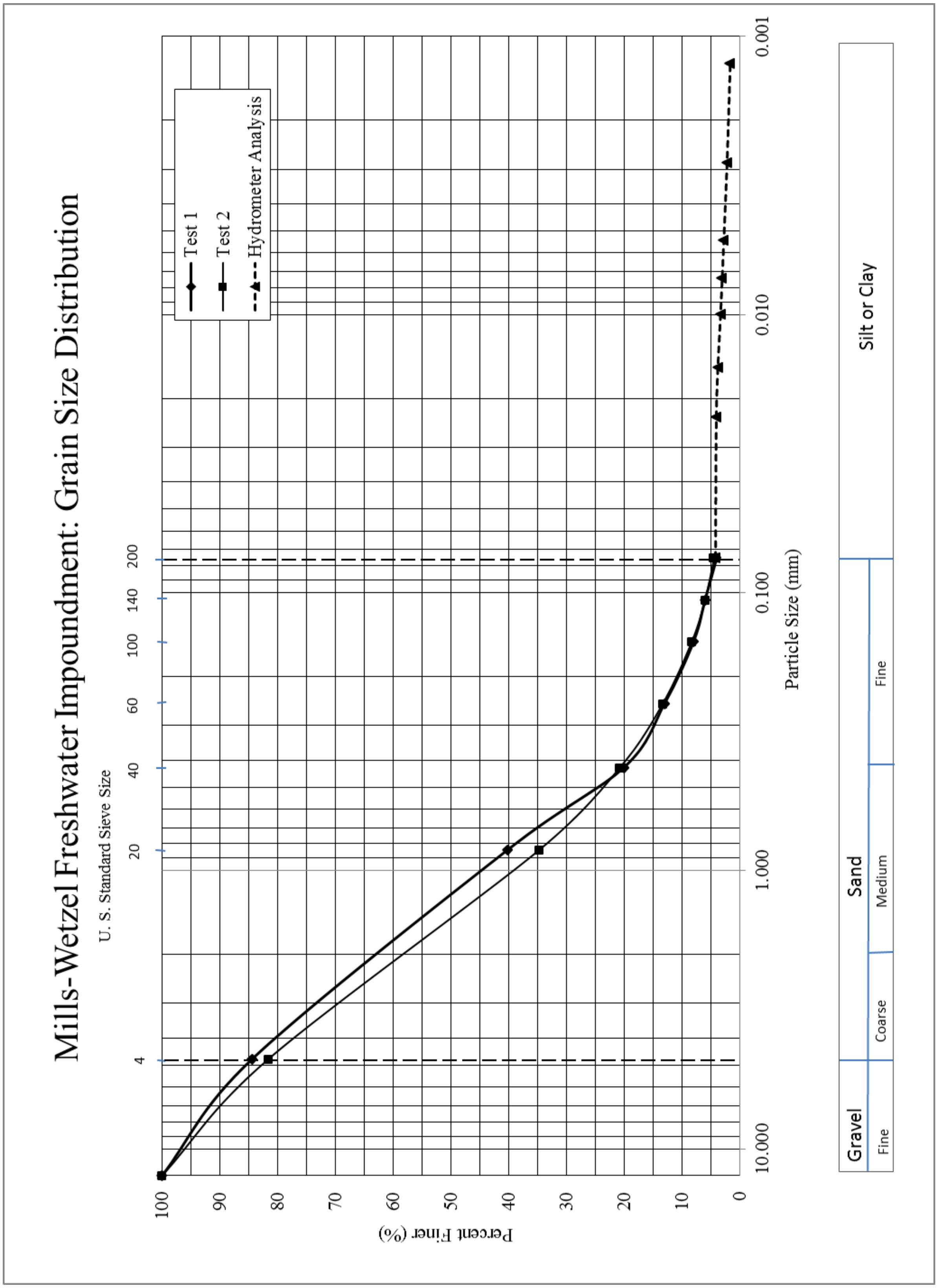
WVU (Name / Signature) Richard Wise	DATE 7/24/12
WVDEP (Name / Signature) Derek M. Haught	7/24/12
Company Representative (Name / Signature) Donald John Ellender	7/24/12

Site Operations & Infrastructure Evaluation	
Date: 7/24/12	Pit/Impoundment Name: Mills-Wetzel Freshwater Impoundment
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Weekly visual and walking inspections, separate inspectors for construction and environmental
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Environmental inspector has a Master's Degree
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? Yes
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? Stone Energy
6	Are there safety and emergency procedures for the pit/impoundment? Yes, written plan, safety measures such as fence, ropes, and buoys
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Yes, O'Brien's Response Management plans
8	Has the pit/impoundment inspector been trained on how to use the EAP? Yes, inspectors are members of the Incident Management Team
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) Yes, Table Top Reviews performed every year (next one scheduled for October)
10	Does the company have a policy on pit/impoundment safety? Yes, follow WVDEP guidelines, fencing being replaced by chain-link
11	How frequently does a Professional Engineer inspect the site? Right after construction, every year once new regulations are passed
12	Other comments: Cracks at the toe of the slope Some woody debris in the slope Rill and gully formation on the slope Downstream face has three drainage ditches, each with a check Wet zones at toe of slope Major seepage problem on downstream face, cattails growing

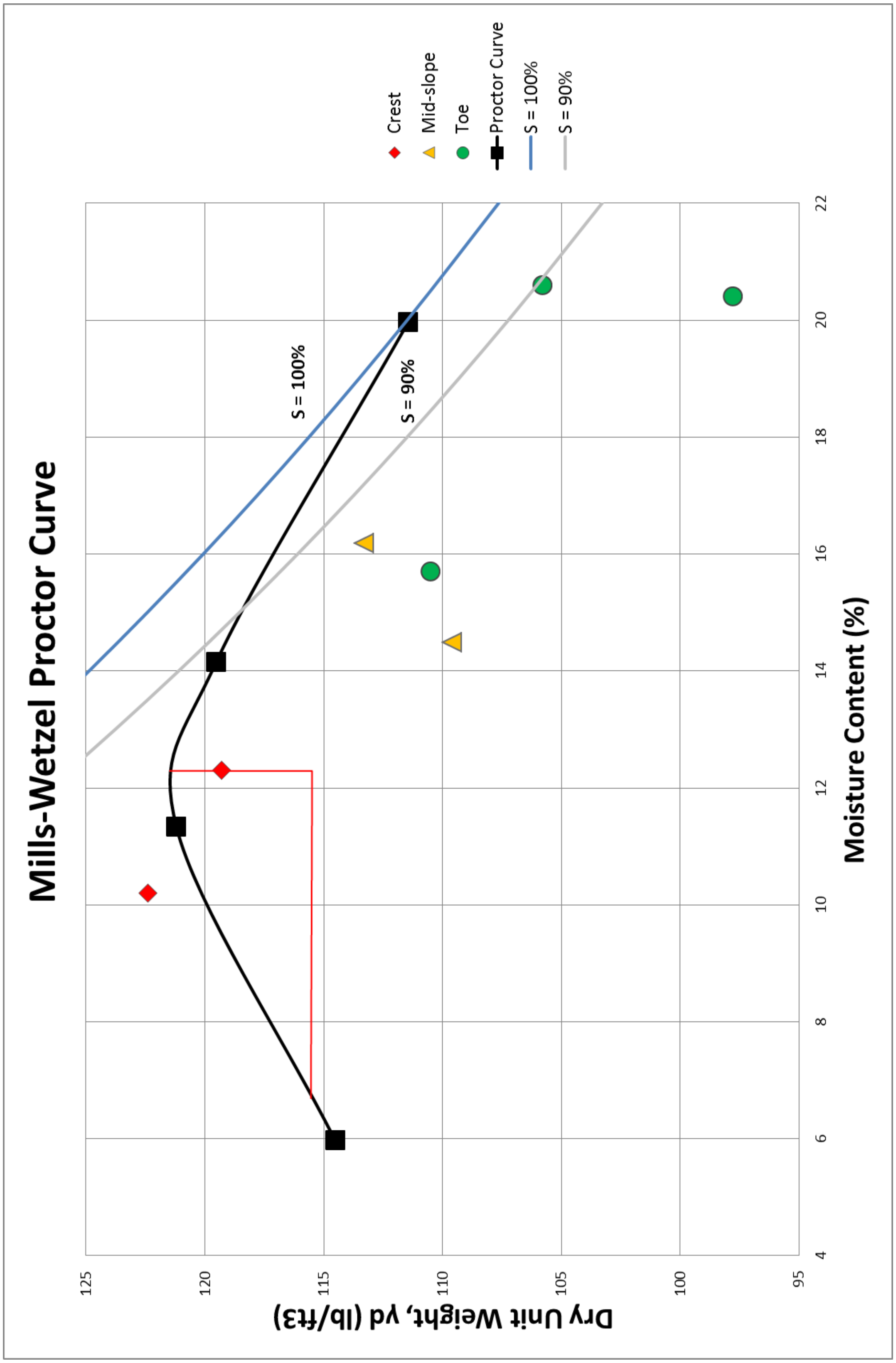
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

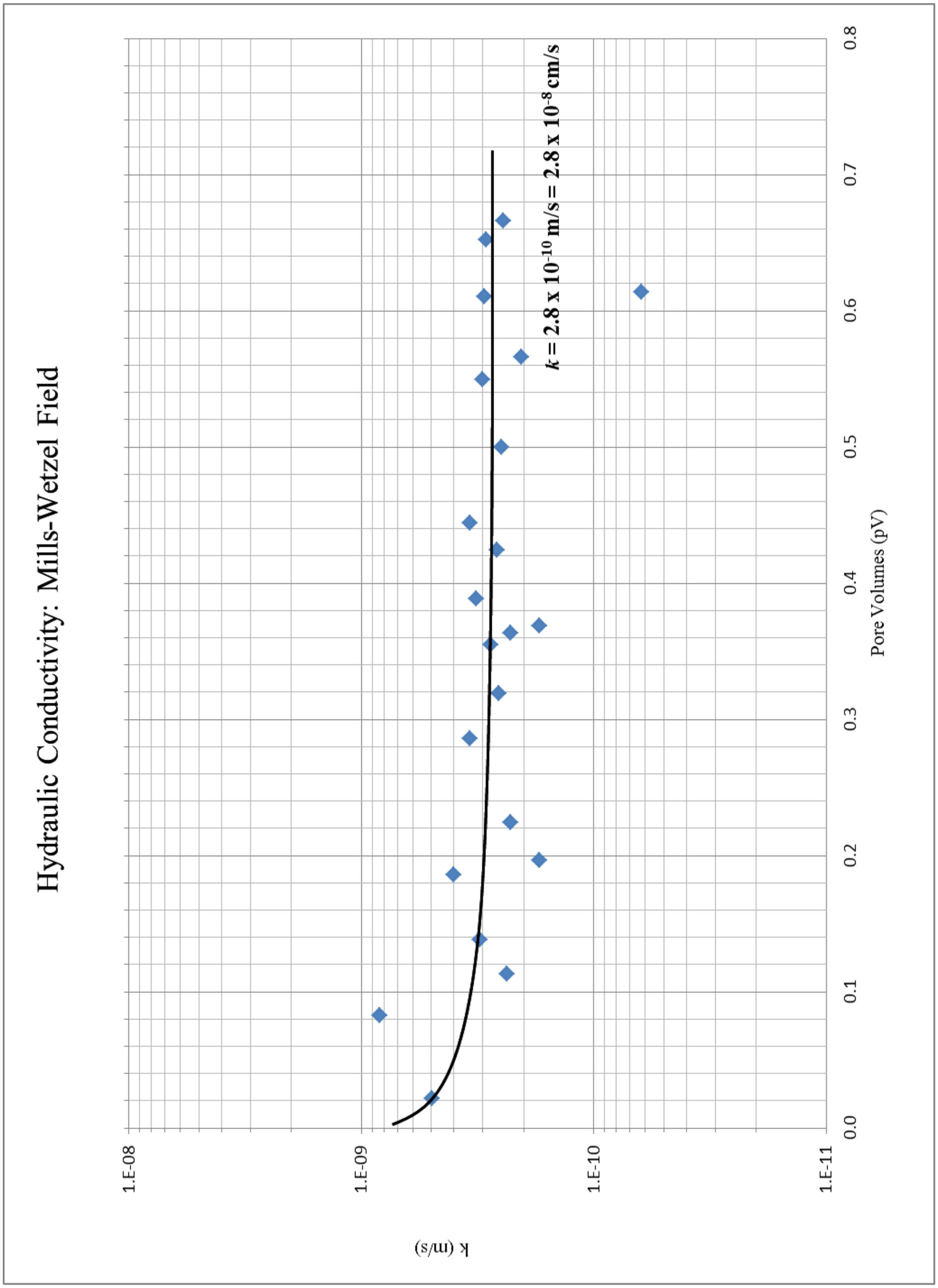
Mills-Wetzel Freshwater Impoundment		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	1
2	Are there any slope movements or animal burrows?	Yes		✓		2
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes			✓	1
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	1
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes			✓	1
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes		✓		2
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	Yes	✓			3
14	Are there any areas where the pipe is not properly supported?	Yes		✓		2
15	Are there any signs of pipes having significant sagging in line?	Yes		✓		2
16	Are there any signs of obstructions (trees, garbage, etc)?	No				4
17	Are there any signs of water in ditch associated with pit?	Yes		✓		2
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

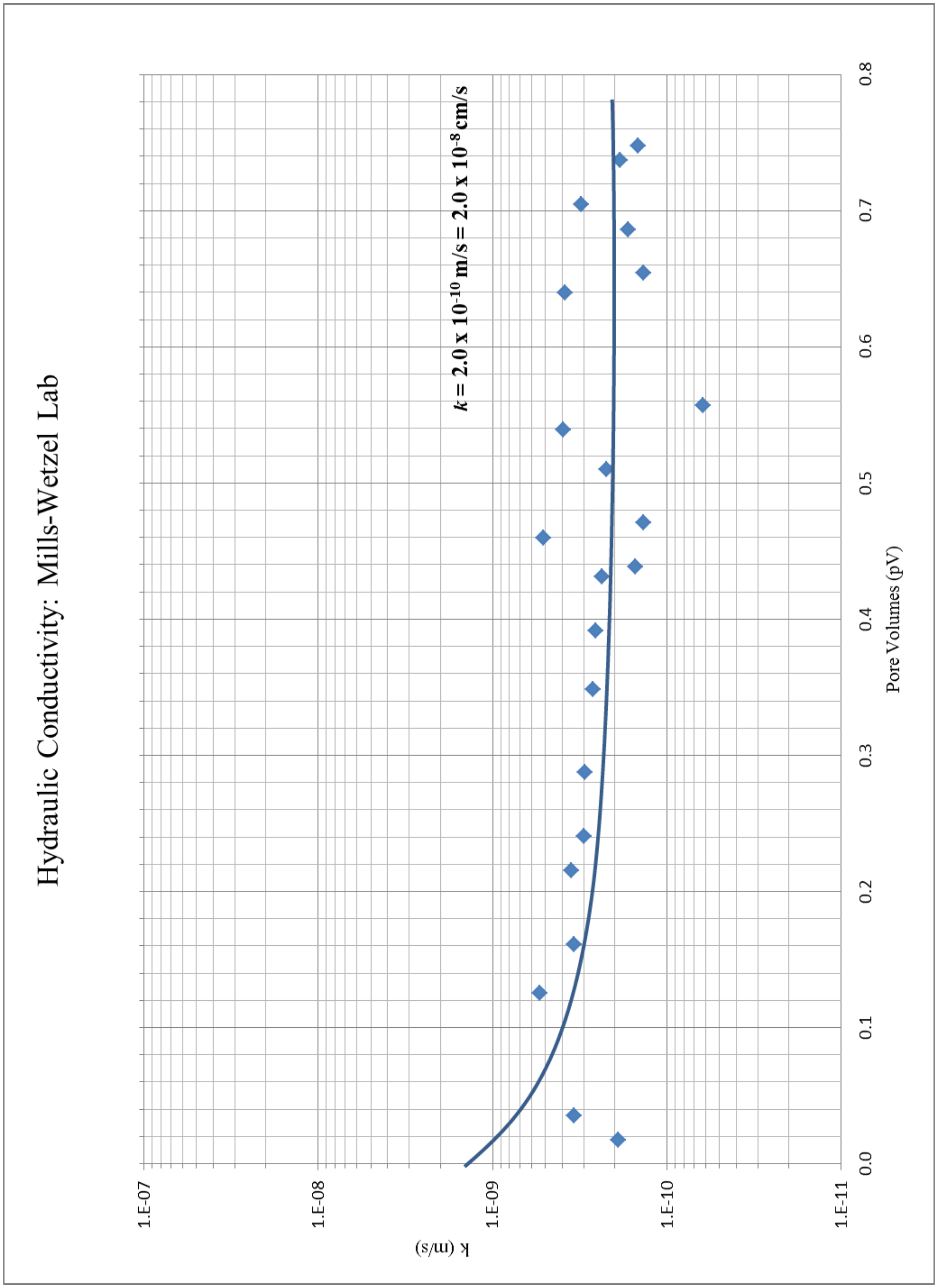
Total:	**52**	(Out of 76)
Percentage:	**68.4%**	

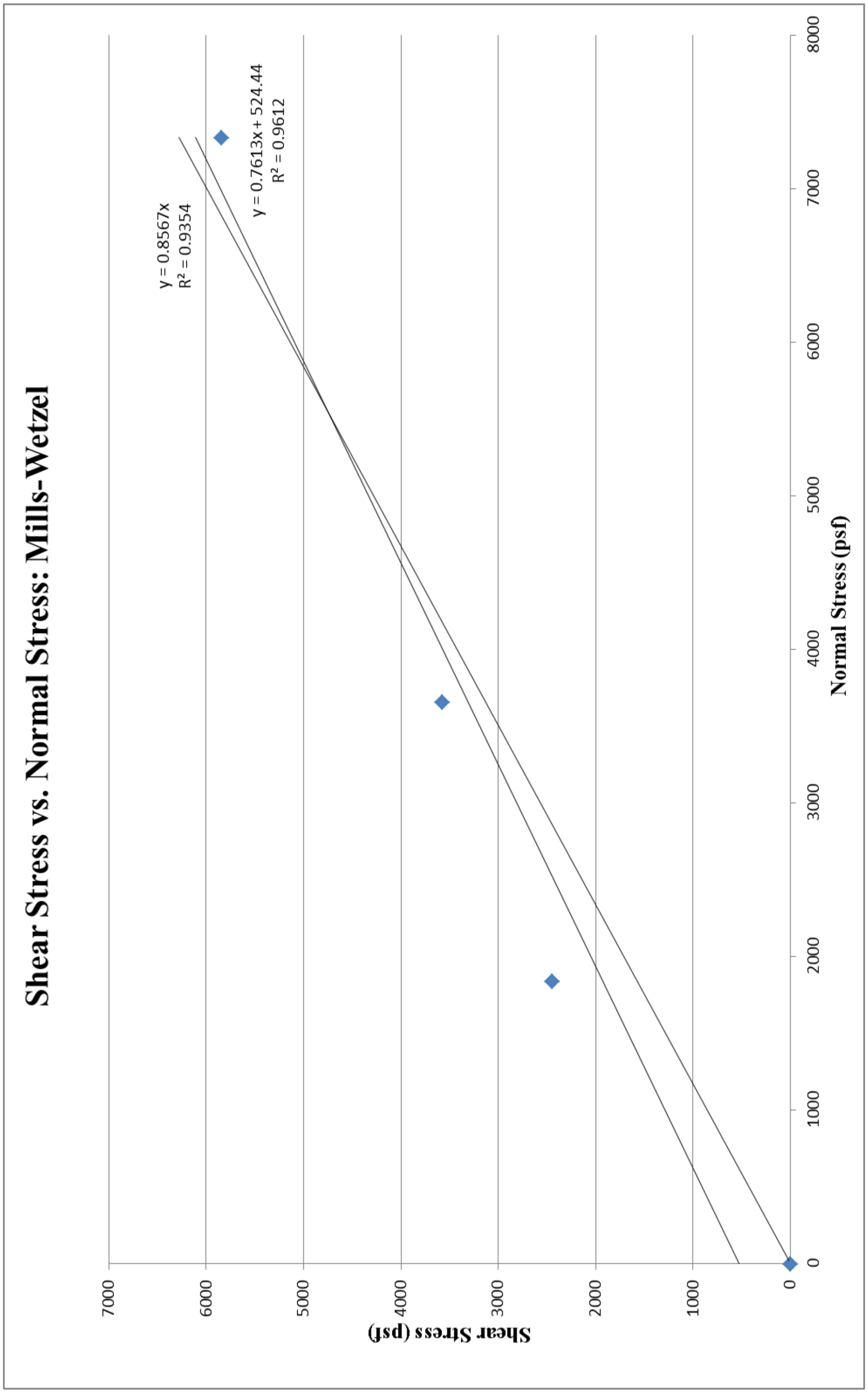


Mills-Wetzel Freshwater Impoundment: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


Mills-Wetzel Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
S = 100%
S = 90%
Crest
Mid-slope
Toe
Proctor Curve
S = 100%
S = 90%
125
120
115
110
105
100
95
4
6
8
10
12
14
16
18
20
22


Hydraulic Conductivity: Mills-Wetzel Field
k = 2.8 x 10-10 m/s = 2.8 x 10-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


Hydraulic Conductivity: Mills-Wetzel Lab
k = 2.0 x 10^-10 m/s = 2.0 x 10^-8 cm/s
k (m/s)
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


Shear Stress vs. Normal Stress: Mills-Wetzel
y = 0.8567x
R² = 0.9354
y = 0.7613x + 524.44
R² = 0.9612
Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000

Max Shear Stress vs. Normal Stress (Mills-Wetzel)			
Date	**Sample**	**Compaction**	**Material**
11/28/2012	Mills-Wetzel	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress(psf)**	**Normal Stress (psf)**
High	5.847	5847	7337
Medium	3.577	3577	3661
Low	2.447	2447	1839
4	0	0	0
m	0.7613	m	0.8567
ϕ' (degrees)	37.282	$\phi_{c'=0}'$ (degrees)	40.587
c' (psf)	524.440	c' (psf)	0.0

Appendix I: SHL 2 Centralized Pit

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: SHL 2 Centralized Pit
Date of Site Evaluation: 7/30/12

Permit Observations / Anomalies:

Field measurements of the as-built construction differed from the permitted design. The berm crest width measured a minimum of 6 feet, as opposed to the 40 feet in the permit.

The as-built dimensions of the pit were larger than the permitted dimensions. The permitted size is 135 feet wide by 450 feet long, while the as-built dimensions measured 145.5 feet wide by 474 feet long. As a result, the as-built capacity is larger than the permitted design.

Hydrology

Visual evaluations of the pit found rill and gully formation on the crest and downstream faces, but no slope movements were observed. A moderate amount of wet zones were present in the form of standing water in the ditches and on the berm, as well as seepage and wet zones on the northeast downstream face.

Containment

The liner for the pit is a 60-millimeter geomembrane. Bulges in the liner were noticed at a few locations, and a minor amount of rock and soil were on top of the liner. Furthermore, the anchor trench was exposed in places due to insufficient embedment.

Slope

Minor rills and gullies were present on the downstream faces. No slope movements were noted, but woody debris was noticed on the downstream faces in the fill material. Possible seepage was found on the downstream face, as evidenced by wet zones.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the pit. Data was collected at the pit crest and on the down-gradient slope of the pit.

Other Comments

Minor gouge marks were noticed in the pipes. Water from Wheeling Creek and mine operations on the Ohio River were being pumped into the pit.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/30/12 12:30 pm WEATHER Mostly Sunny	County	Marshall	Company	Noble Energy, Inc.
	Latitude	N 39° 58' 1.05"	Pit Name	SHL 2 Centralized Pit
	Longitude	W 80° 33' 41.6"	ID No.	051-WPC-00001

A. PERMIT INFORMATION

Pit Width (ft.)	135 ft.	Minimum Berm Crest Width (ft.)	40 ft.	Construction Type	Incised
Pit Length (ft.)	450 ft.	Upstream Slope (H:V)	3:1	Liner Type	60 mil.
Depth (ft.)	15 ft.	Downstream Slope (H:V)	2:1	Date Built	4/2012
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	145.5 ft.	Berm Crest Width (ft.)	6 ft.	Crest Height (ft.)	31.1 ft.
Pit Length (ft.)	474 ft.	Upstream Slope (H:V)	3:1	Up Slope Length (ft.)	8 ft.
Depth (ft.)		Downstream Slope (H:V)	2.2:1	Down Slope Length (ft.)	76.5 ft.
Freeboard (ft.)	2 ft.	Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			Rills/gullies
2	Are there any slope movements or animal burrows?	No				
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			Woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes		✓		Wet zones on NE face
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rock and soil
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Anchor trench exposed in places
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	Yes	✓			Minor gouge marks
14	Are there any areas where the pipe is not properly supported?	No				
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	No				
17	Are there any signs of water in ditch associated with pit?	Yes	✓			Standing water
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

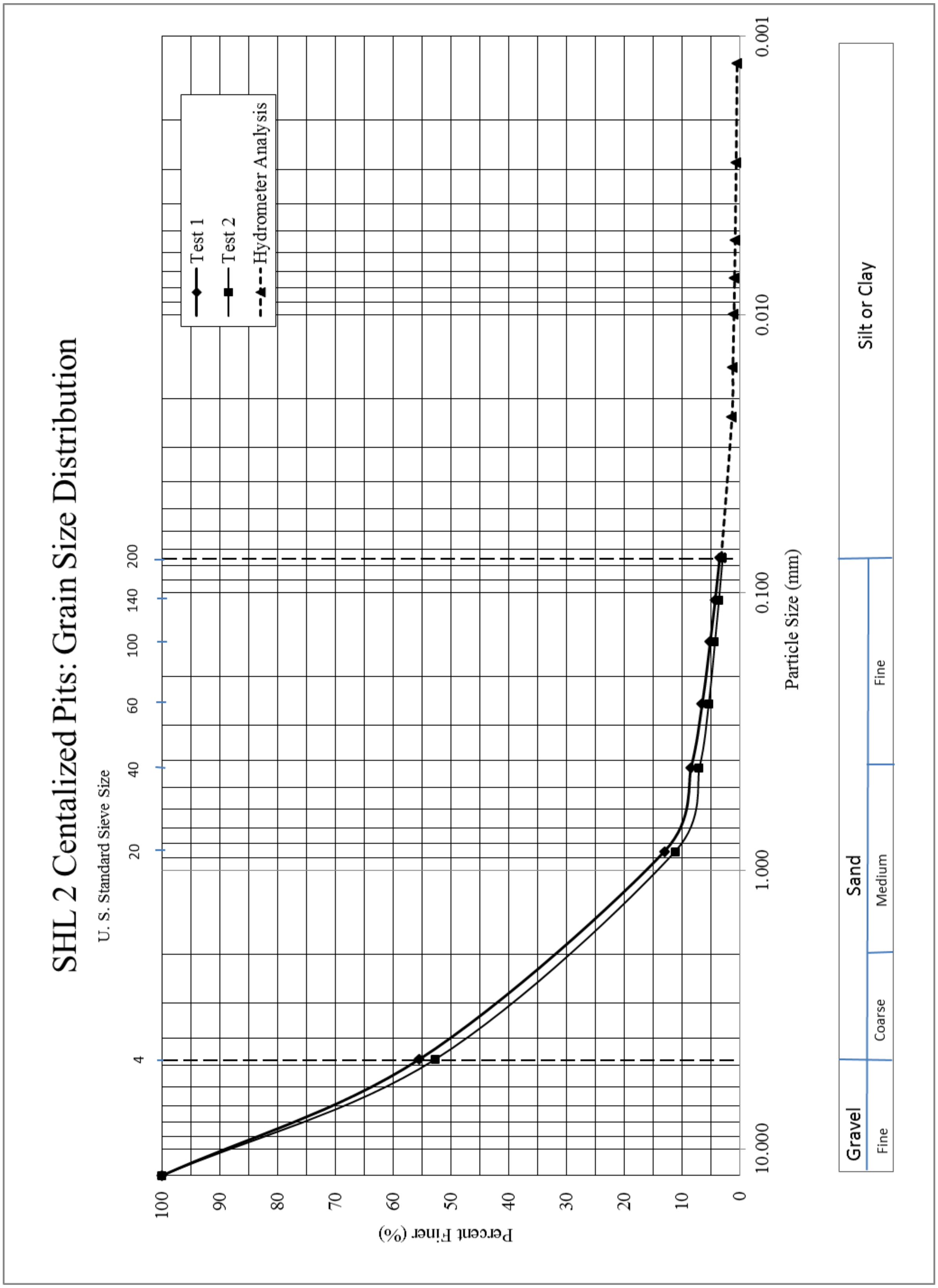
WVU (Name / Signature) Andrew Darnell	DATE 7/30/12
WVDEP (Name / Signature) John Kearney	7/30/12
Company Representative (Name / Signature) Bob Fedinetz	7/30/12

Site Operations & Infrastructure Evaluation	
Date: 7/30/12	Pit/Impoundment Name: SHL 2 Centralized Pit
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Inspector is on site usually every day, performs walking/visual inspection weekly at minimum
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Just follows state regulations while the sites are in start-up mode, will be hiring a compliance person specializing in inspection
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No, records visual operations of cracks, seeps, etc. and reports to environmental coordinator
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? N/A
6	Are there safety and emergency procedures for the pit/impoundment? Fencing, floatation devices, signage, early leak detection system (inspected weekly), future fencing plans include complete enclosure, emergency number at the entrance to the sites
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Sites have an emergency access number for failure/warnings (if something goes wrong, someone will know what to do)
8	Has the pit/impoundment inspector been trained on how to use the EAP? No, would call back to the office if a problem occurs
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) No
10	Does the company have a policy on pit/impoundment safety? Regulatory group would know
11	How frequently does a Professional Engineer inspect the site? Regulatory group would know
12	Other comments: Water from Wheeling Creek and mine operations on the Ohio River were being pumped into the pit Signs of seepage on downstream face of pit

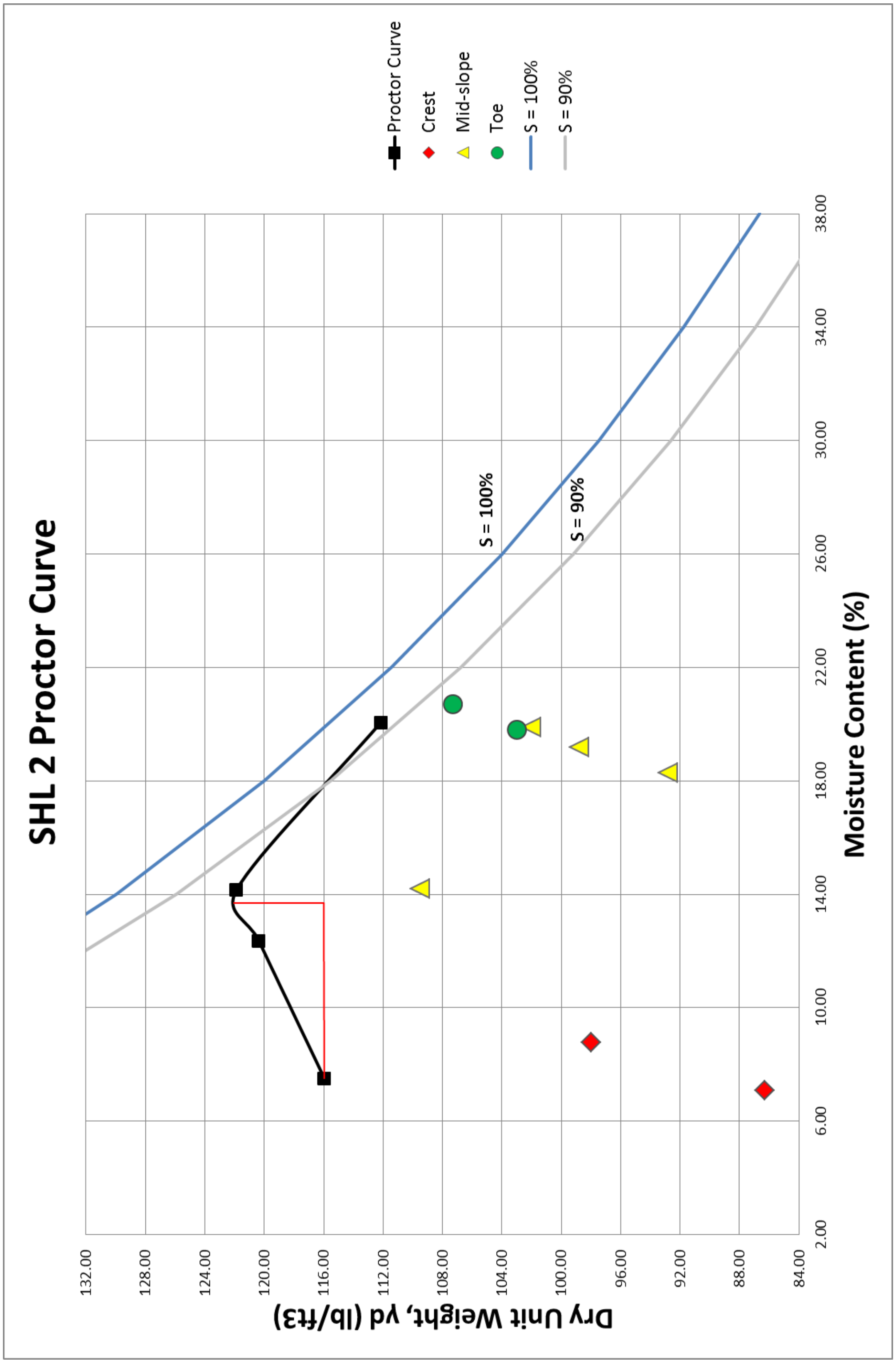
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

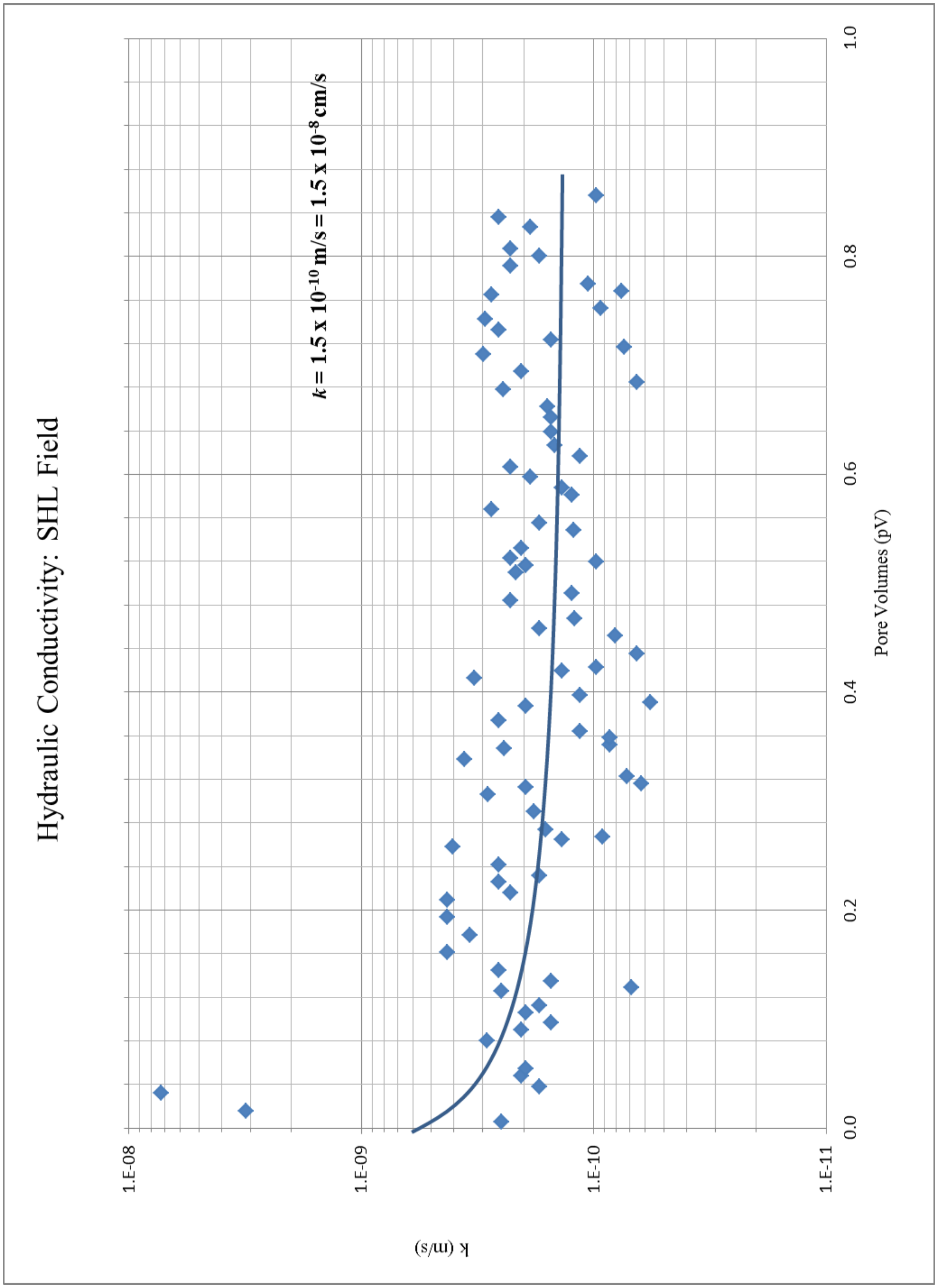
SHL 2 Centralized Pit		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			3
2	Are there any slope movements or animal burrows?	No				4
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			3
6	Are there any seeps, wet zones, or losses of soil?	Yes		✓		2
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			3
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	Yes	✓			3
14	Are there any areas where the pipe is not properly supported?	No				4
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	No				4
17	Are there any signs of water in ditch associated with pit?	Yes	✓			3
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

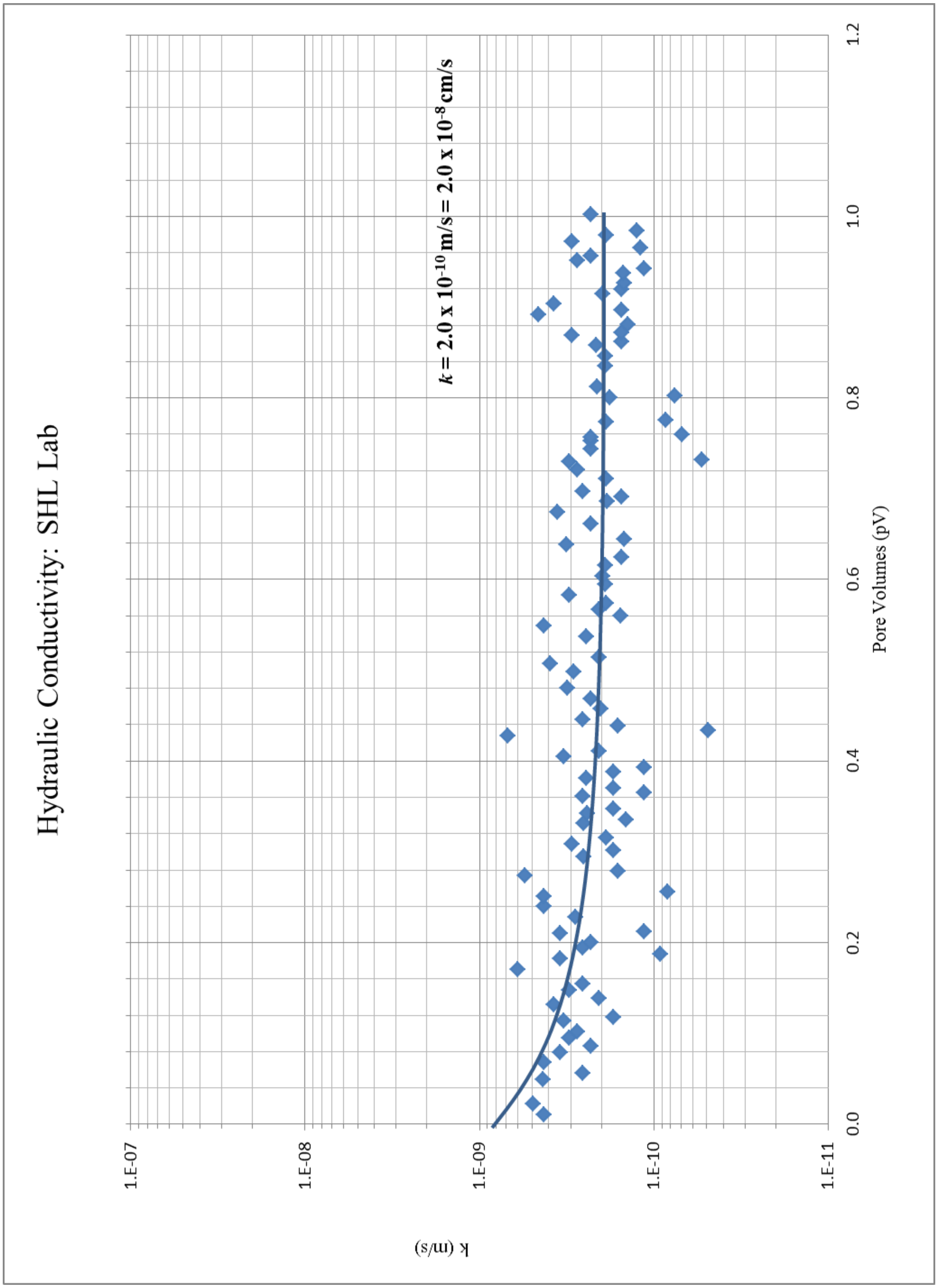
Total:	**67**	(Out of 76)
Percentage:	**88.2%**	

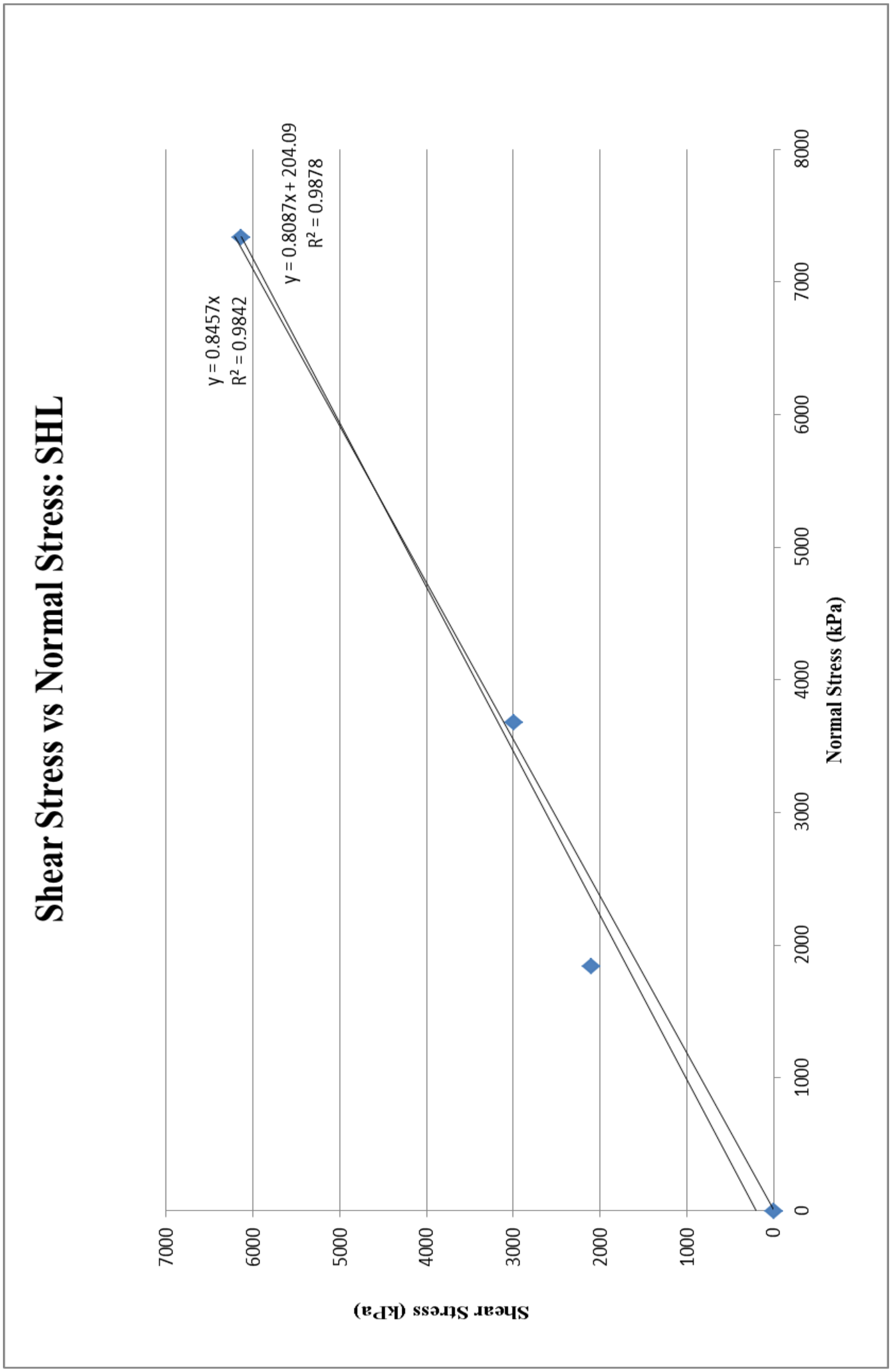


SHL 2 Centalized Pits: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


SHL 2 Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
132.00
128.00
124.00
120.00
116.00
112.00
108.00
104.00
100.00
96.00
92.00
88.00
84.00
2.00
6.00
10.00
14.00
18.00
22.00
26.00
30.00
34.00
38.00
S = 100%
S = 90%
Proctor Curve
Crest
Mid-slope
Toe
S = 100%
S = 90%


Hydraulic Conductivity: SHL Field
k = 1.5 x 10-10 m/s = 1.5 x 10-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.2
0.4
0.6
0.8
1.0


Hydraulic Conductivity: SHL Lab
k = 2.0 x 10^{-10} m/s = 2.0 x 10^{-8} cm/s
k (m/s)
Pore Volumes (pV)
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
0.0
0.2
0.4
0.6
0.8
1.0
1.2


Shear Stress vs Normal Stress: SHL
y = 0.8457x
R² = 0.9842
y = 0.8087x + 204.09
R² = 0.9878
Shear Stress (kPa)
Normal Stress (kPa)
0
1000
2000
3000
4000
5000
6000
7000
8000

Max Shear Stress vs. Normal Stress (SHL)

Date	Sample	Compaction	Material
11/5/2012	SHL	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress (psf)**	**Normal Stress (psf)**
High	6.137	6137	7342
Medium	2.995	2995	3688
Low	2.095	2095	1844
4	0	0	0
m	0.8087	m	0.8457
ϕ' (degrees)	38.962	$\phi'_{c'=0}$ (degrees)	40.221
c' (psf)	204.090	c' (psf)	0.0

Appendix J: SHL 3 Centralized Pit

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: SHL 3 Centralized Pit
Date of Site Evaluation: 7/30/12

Permit Observations / Anomalies:

Field measurements of the as-built construction differed from the permitted design. The berm crest width measured a minimum of 12 feet, as opposed to the 24 feet in the permit.

The as-built dimensions of the pit were larger than the permitted dimensions. The permitted size is 185 feet wide by 387 feet long, while the as-built dimensions measured 208.5 feet wide by 417 feet long. As a result, the as-built capacity is larger than the permitted design.

Hydrology

Rills and gullies were noticed on the downstream face of the pit; however, no slope movements were observed. Standing water was found in the ditch above the pit, which may indicate that the gradient of the ditch is insufficient for drainage. Moist soil was found on the northeast area of the downstream face, which may be a sign of seepage.

Containment

The liner for the pit is a 60-millimeter geomembrane. Bulges in the liner were noticed at a few locations, and a minor amount of rock and soil were on top of the liner. Furthermore, the anchor trench was exposed in two locations due to insufficient embedment.

Slope

Minor rill and gully formation was present on the downstream face. No slope movements were noted, but woody debris was noticed on the downstream face in the fill material. Possible seepage was found on the downstream face, as evidenced by a wet zone.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the pit. Data was collected at the pit crest and on the down-gradient slope of the pit.

Other Comments

Minor gouge marks were noticed in the pipes, and garbage was found in the pit. A buried telephone line is located below the drainage ditch at the toe of the downstream face.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/30/12 11:00 am WEATHER Mostly Sunny	County	Marshall	Company	Noble Energy, Inc.
	Latitude	N 39° 58' 27.1"	Pit Name	SHL 3 Centralized Pit
	Longitude	W 80° 33' 17.8"	ID No.	051-WPC-00002

A. PERMIT INFORMATION

Pit Width (ft.)	185 ft.	Minimum Berm Crest Width (ft.)	24 ft.	Construction Type	Incised
Pit Length (ft.)	387 ft.	Upstream Slope (H:V)	3:1	Liner Type	60 mil.
Depth (ft.)	15 ft.	Downstream Slope (H:V)	2:1	Date Built	4/2012
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	208.5 ft.	Berm Crest Width (ft.)	12 ft.	Crest Height (ft.)	68.6 ft.
Pit Length (ft.)	417 ft.	Upstream Slope (H:V)	2:1	Up Slope Length (ft.)	
Depth (ft.)		Downstream Slope (H:V)	2.4:1	Down Slope Length (ft.)	175.5 ft.
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	Yes	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			Rills/gullies
2	Are there any slope movements or animal burrows?	No				
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			Woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			Moist soil on face
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rock and soil
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Anchor trench exposed in two places
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	Yes	✓			Minor gouge marks
14	Are there any areas where the pipe is not properly supported?	No				
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Bottles/garbage
17	Are there any signs of water in ditch associated with pit?	Yes	✓			Water in ditch above
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

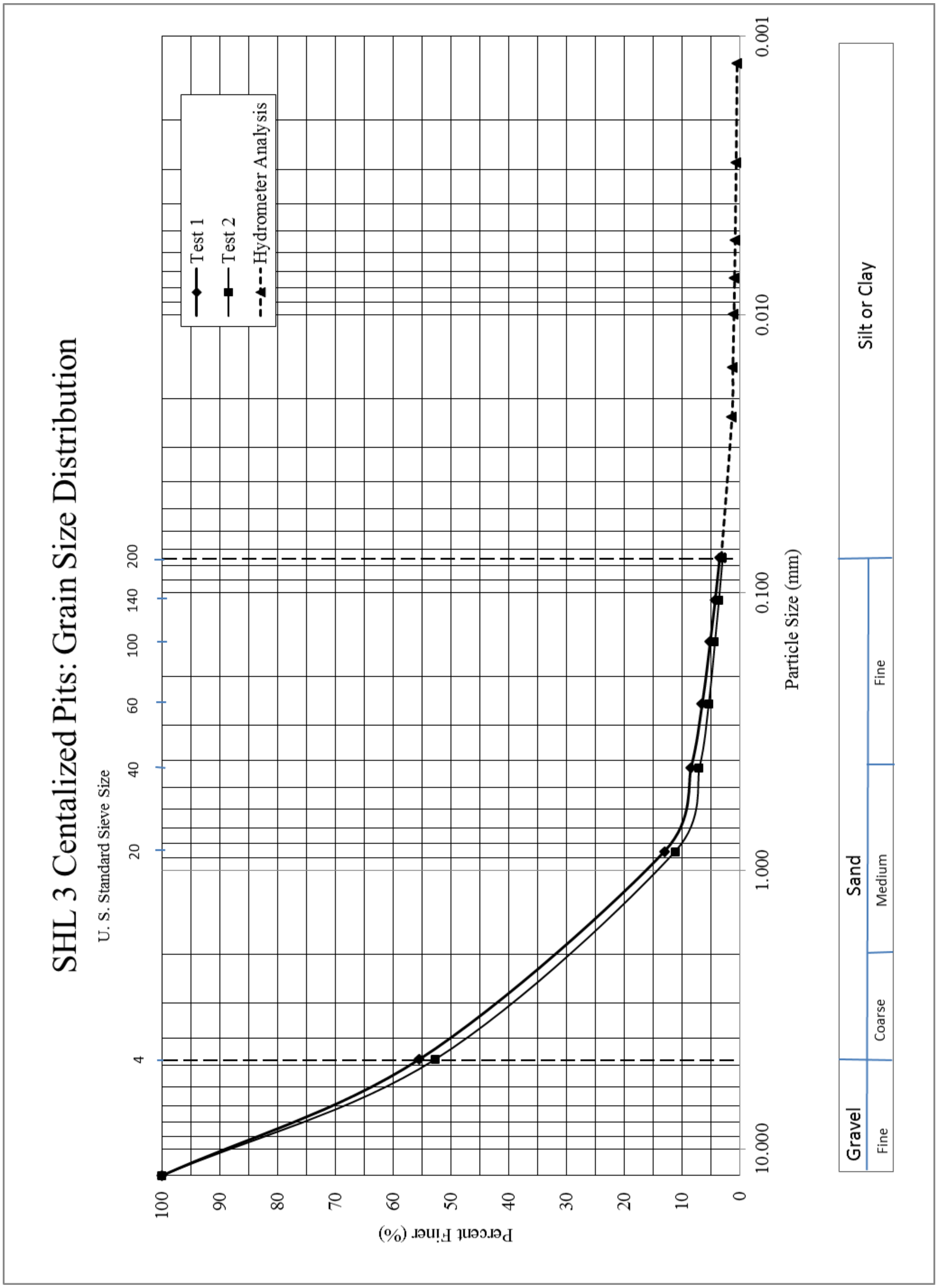
WVU (Name / Signature) Richard Wise	DATE 7/30/12
WVDEP (Name / Signature) John Kearney	7/30/12
Company Representative (Name / Signature) Bob Fedinetz	7/30/12

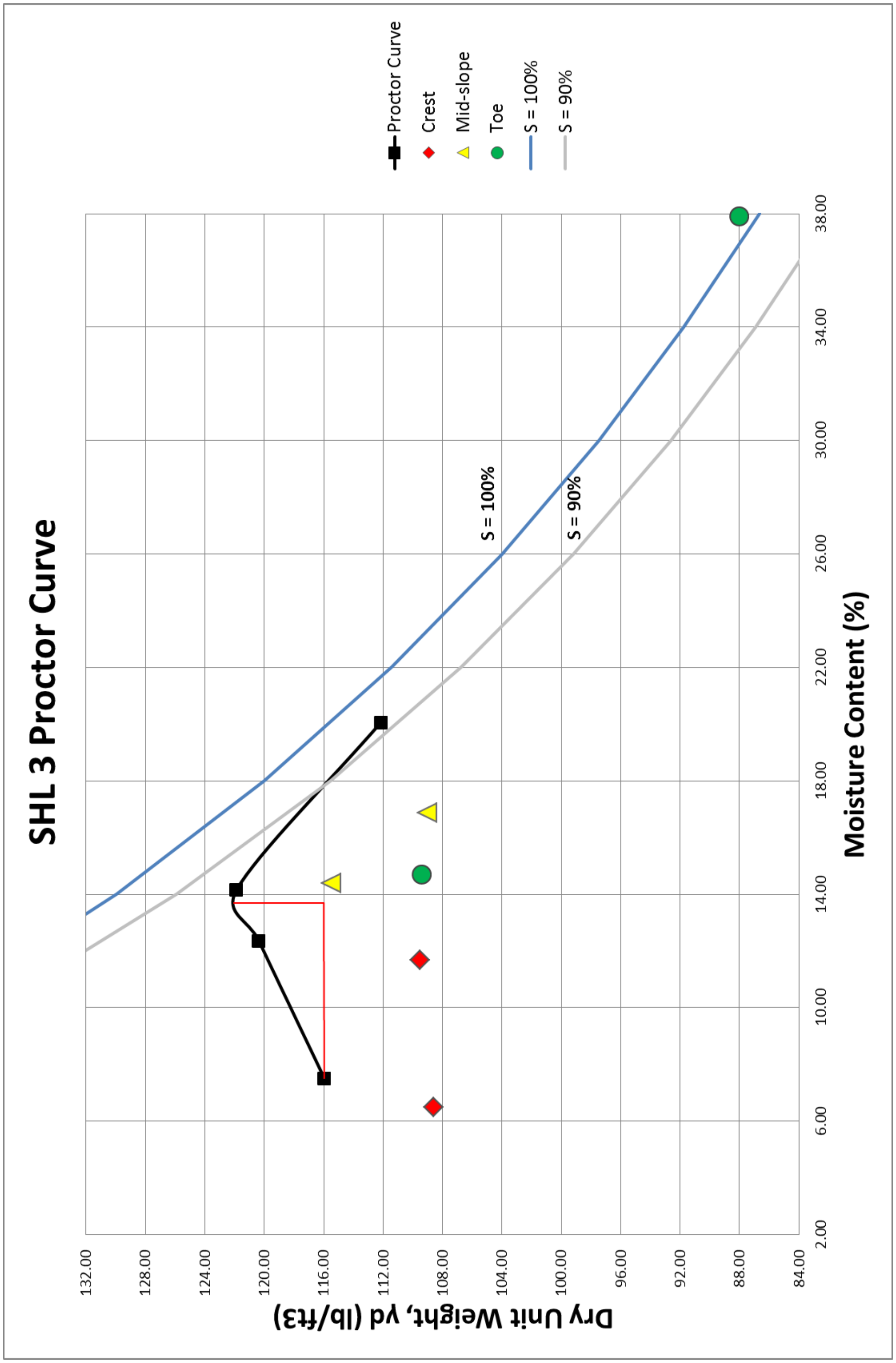
Site Operations & Infrastructure Evaluation	
Date: 7/30/12	Pit/Impoundment Name: SHL 3
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Inspector is on site usually every day, performs walking/visual inspection weekly at minimum
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Just follows state regulations while the sites are in start-up mode, will be hiring a compliance person specializing in inspection
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No, records visual operations of cracks, seeps, etc. and reports to environmental coordinator
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? N/A
6	Are there safety and emergency procedures for the pit/impoundment? Fencing, floatation devices, signage, early leak detection system (inspected weekly), future fencing plans include complete enclosure, emergency number at the entrance to the sites
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Sites have an emergency access number for failure/warnings (if something goes wrong, someone will know what to do)
8	Has the pit/impoundment inspector been trained on how to use the EAP? No, would call back to the office if a problem occurs
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) No
10	Does the company have a policy on pit/impoundment safety? Regulatory group would know
11	How frequently does a Professional Engineer inspect the site? Regulatory group would know
12	Other comments: Moist soil on the northeast downstream face Buried telephone line below drainage ditch Standing water in ditch Nearest dwelling is 414 feet away

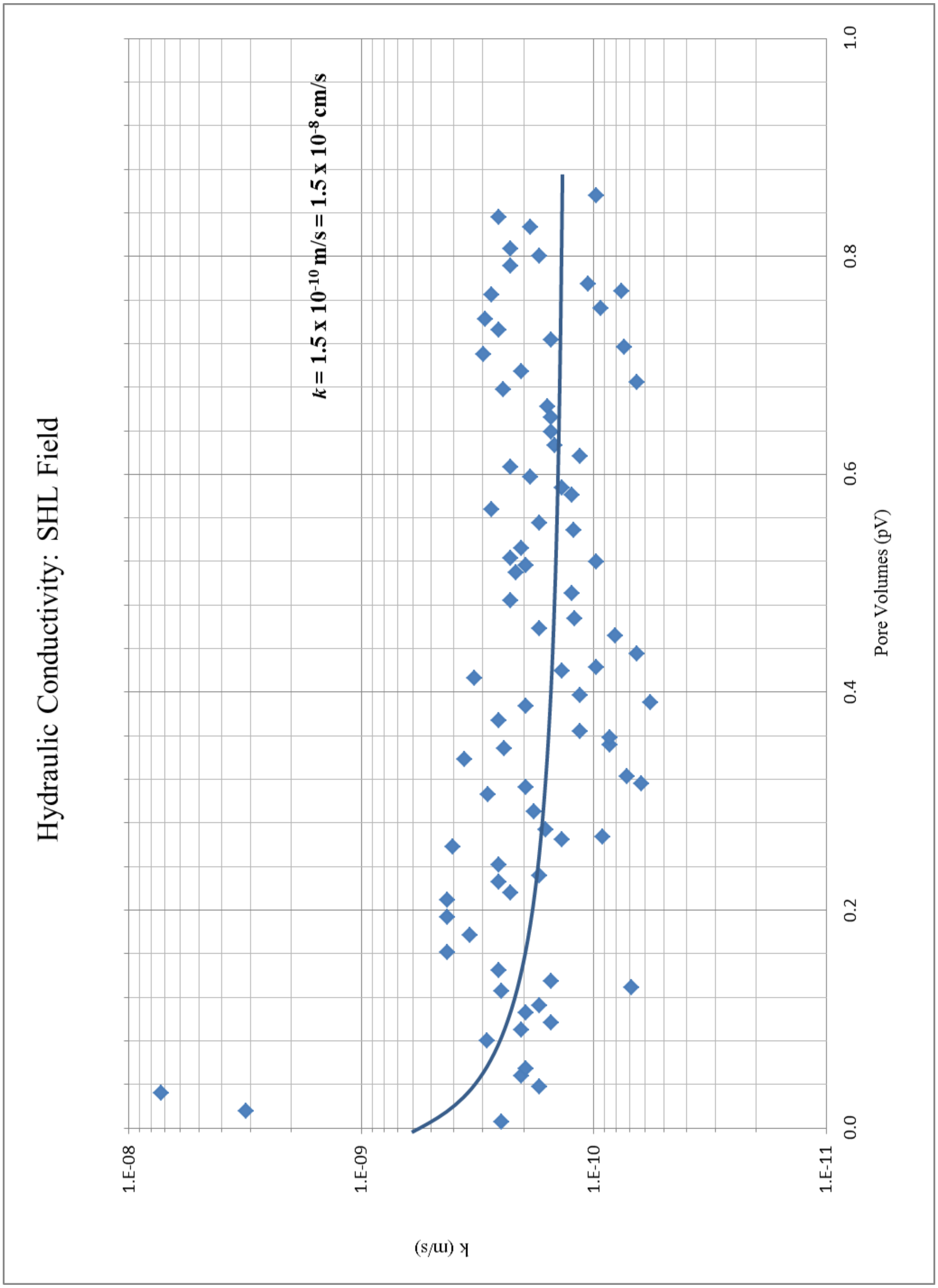
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

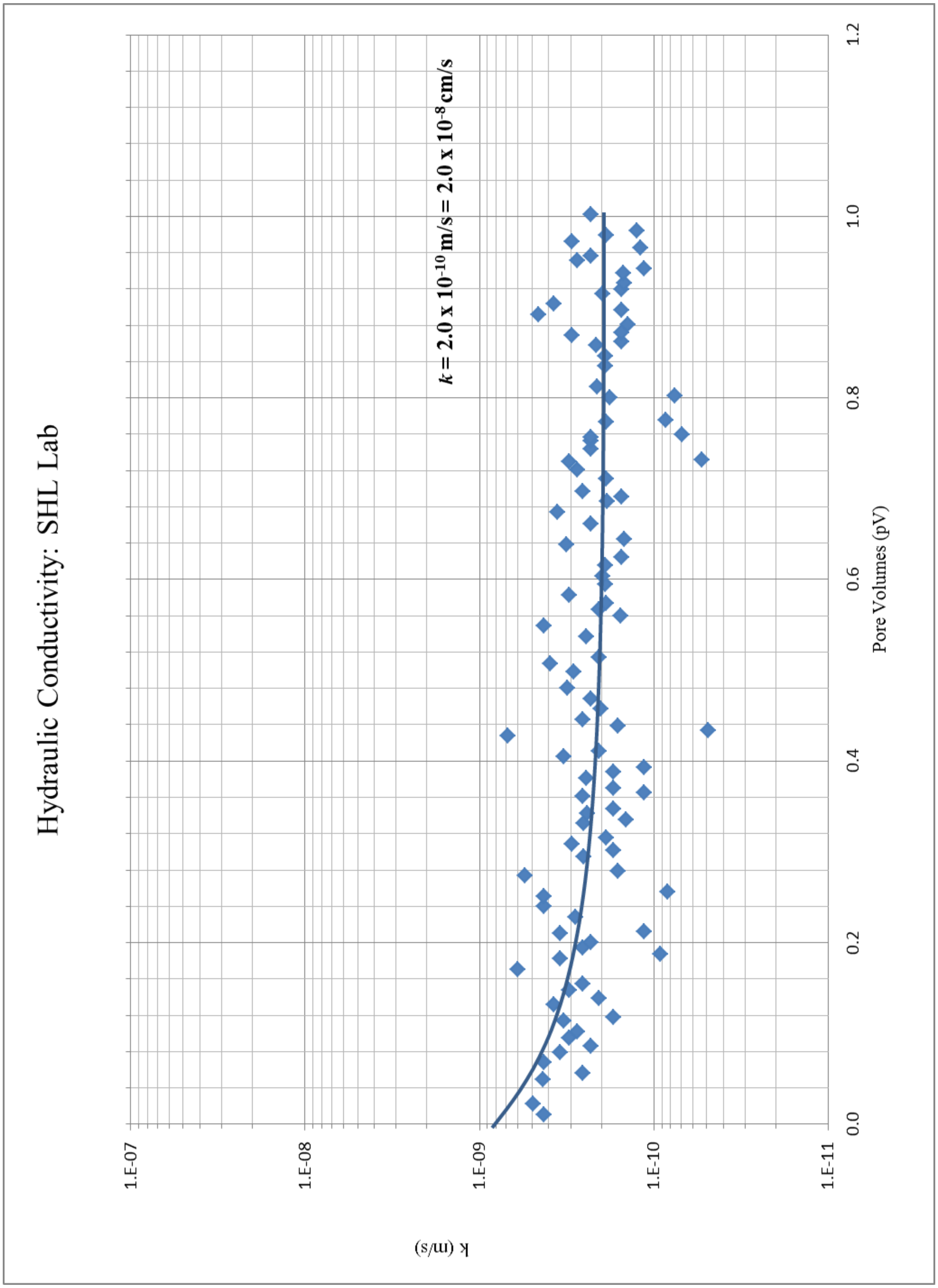
SHL 3 Centralized Pit		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			3
2	Are there any slope movements or animal burrows?	No				4
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			3
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			3
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			3
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	Yes	✓			3
14	Are there any areas where the pipe is not properly supported?	No				4
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	Yes	✓			3
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

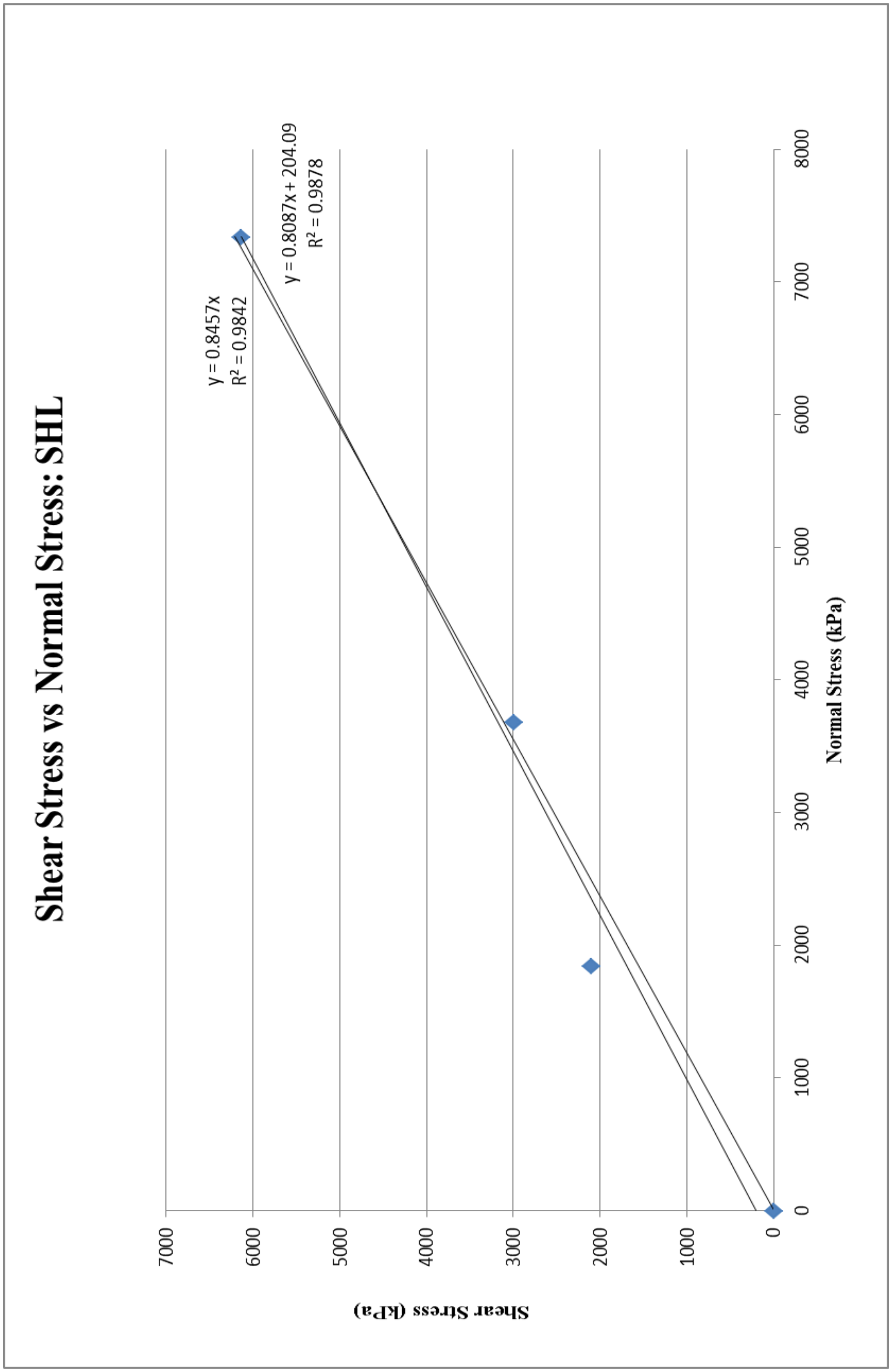
Total:	**67**	(Out of 76)
Percentage:	**88.2%**	


SHL 3 Centalized Pits: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


SHL 3 Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
132.00
128.00
124.00
120.00
116.00
112.00
108.00
104.00
100.00
96.00
92.00
88.00
84.00
2.00
6.00
10.00
14.00
18.00
22.00
26.00
30.00
34.00
38.00
S = 100%
S = 90%
Proctor Curve
Crest
Mid-slope
Toe
S = 100%
S = 90%


Hydraulic Conductivity: SHL Field
$k = 1.5 \times 10^{-10}$ m/s = 1.5×10^{-8} cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.2
0.4
0.6
0.8
1.0


Hydraulic Conductivity: SHL Lab
k = 2.0 x 10^-10 m/s = 2.0 x 10^-8 cm/s
k (m/s)
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.2
0.4
0.6
0.8
1.0
1.2


Shear Stress vs Normal Stress: SHL
Shear Stress (kPa)
Normal Stress (kPa)
0
1000
2000
3000
4000
5000
6000
7000
8000
y = 0.8457x
R² = 0.9842
y = 0.8087x + 204.09
R² = 0.9878

Max Shear Stress vs. Normal Stress (SHL)			
Date	**Sample**	**Compaction**	**Material**
11/5/2012	SHL	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress (psf)**	**Normal Stress (psf)**
High	6.137	6137	7342
Medium	2.995	2995	3688
Low	2.095	2095	1844
4	0	0	0
m	0.8087	m	0.8457
ϕ' (degrees)	38.962	$\phi'_{c'=0}$ (degrees)	40.221
c' (psf)	204.090	c' (psf)	0.0

Appendix K: SHL 4 Centralized Pit

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: SHL 4 Centralized Pit
Date of Site Evaluation: 7/30/12

Permit Observations / Anomalies:

Field measurements of the as-built construction differed from the permitted design. The berm crest width measured a minimum of 7.5 feet, as opposed to the 27 feet in the permit.

The as-built dimensions of the pit were larger than the permitted dimensions. The permitted size is 150 feet wide by 400 feet long, while the as-built dimensions measured 165 feet wide by 405 feet long. As a result, the as-built capacity is larger than the permitted design.

Hydrology

Visual evaluations of the pit found several areas of concern. The downstream faces both had minor rill and gully formation, although woody debris was prevalent on the slopes which may contribute to further erosion. Also, wet zones were present in the anchor trench and in several areas on the berm, especially on the east side of the pit. This wet zone may have contributed to a large slope movement which was found on the eastern downstream face. The soil in the slip was moist, and signs of seepage were found on the slope both above and in the slip. The collection ditch at the bottom of the western downstream face also contained water.

Containment

The liner for the pit is a 60-millimeter geomembrane. Bulges in the liner were noticed at a few locations, and a minor amount of rock and soil were on top of the liner. Furthermore, the anchor trench was exposed in places due to insufficient embedment.

Slope

Rills and gullies were observed on the downstream faces, and a large slope movement was present on the eastern downstream face. Woody debris was noticed on the downstream faces in the fill material.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the pit. Data was collected at the pit crest and on the down-gradient slope of the pit, including above and below the slip on the eastern downstream face.

Other Comments

Minor gouge marks were noticed in the pipes, and one pipe was resting on a bucket and thus was not supported properly. Additionally, garbage was found in the pit. The eastern downstream face had three drainage pipes.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 7/30/12 1:30 pm	County	Marshall	Company	Noble Energy, Inc.
	Latitude	N 39° 57' 46.1"	Pit Name	SHL 4 Centralized Pit
WEATHER Mostly Sunny	Longitude	W 80° 33' 46.8"	ID No.	051-WPC-00003

A. PERMIT INFORMATION

Pit Width (ft.)	150 ft.	Minimum Berm Crest Width (ft.)	27 ft.	Construction Type	Incised
Pit Length (ft.)	400 ft.	Upstream Slope (H:V)	3:1	Liner Type	60 mil.
Depth (ft.)	15 ft.	Downstream Slope (H:V)	2:1	Date Built	4/2012
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	165 ft.	Berm Crest Width (ft.)	7.5 ft.	Crest Height (ft.)	40.2 ft.
Pit Length (ft.)	405 ft.	Upstream Slope (H:V)	3:1	Up Slope Length (ft.)	13 ft.
Depth (ft.)		Downstream Slope (H:V)	2.4:1	Down Slope Length (ft.)	105 ft.
Freeboard (ft.)		Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			Minor rills/gullies
2	Are there any slope movements or animal burrows?	Yes			✓	Huge slope movement
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes		✓		Woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	At slope movement
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rock/soil
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Anchor trench exposed
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	Yes	✓			Minor gouge marks
14	Are there any areas where the pipe is not properly supported?	Yes	✓			Resting on bucket
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Garbage in pit
17	Are there any signs of water in ditch associated with pit?	Yes			✓	Water east side on berm
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

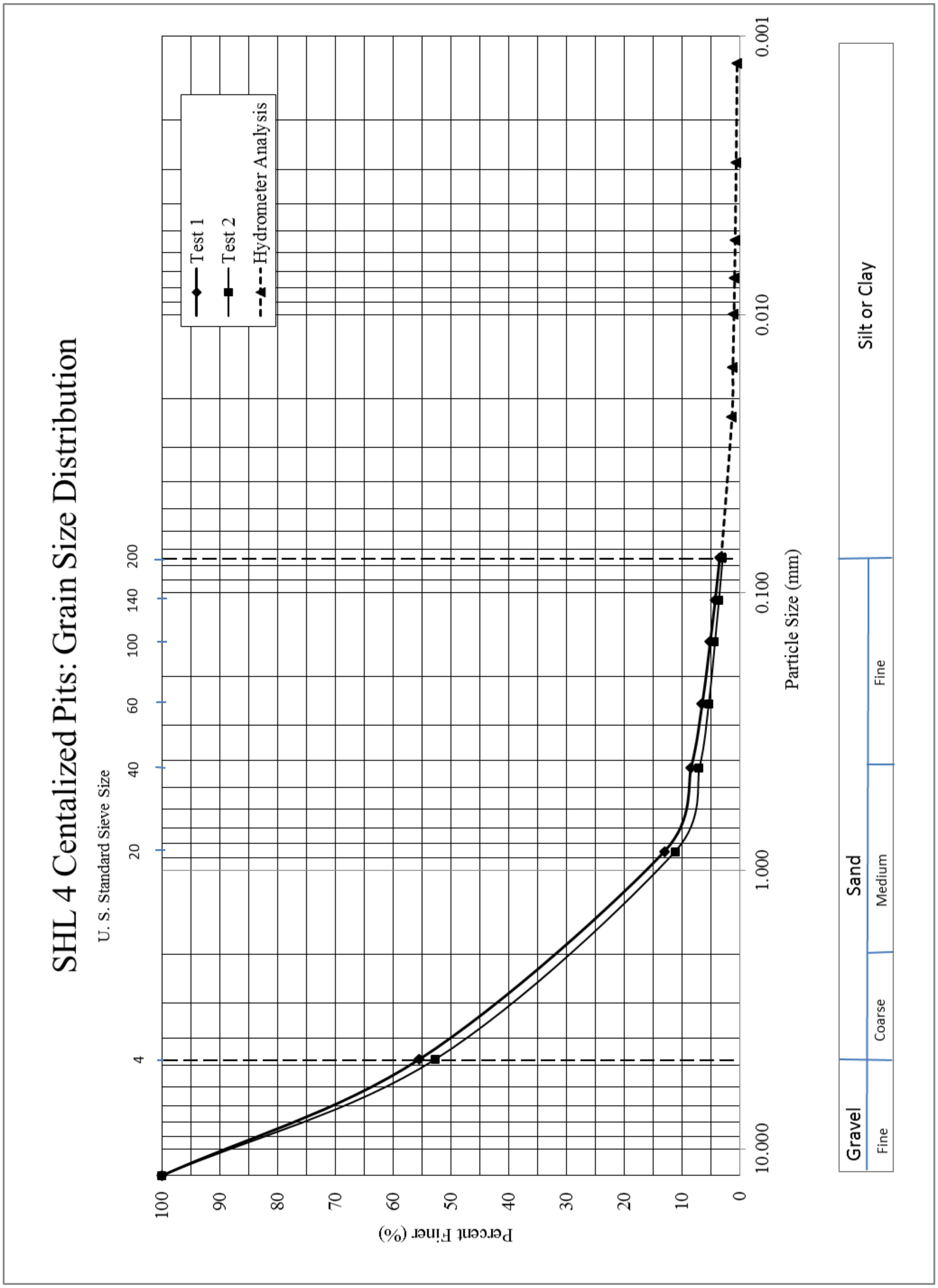
WVU (Name / Signature) Richard Wise	DATE 7/30/12
WVDEP (Name / Signature) John Kearney	7/30/12
Company Representative (Name / Signature) Bob Fedinetz	7/30/12

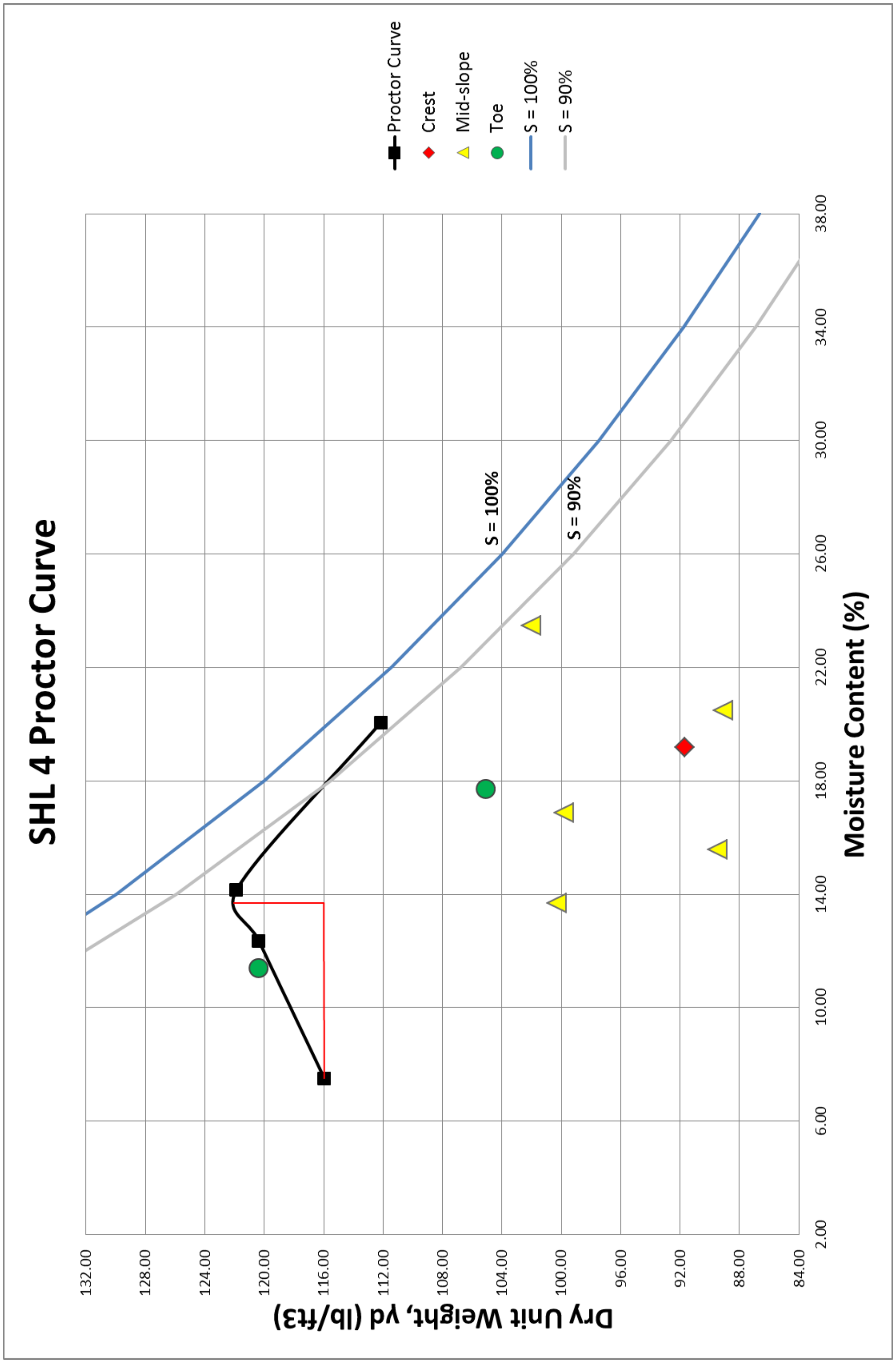
Site Operations & Infrastructure Evaluation	
Date: 7/30/12	Pit/Impoundment Name: SHL 4
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Inspector is on site usually every day, performs walking/visual inspection weekly at minimum
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Just follows state regulations while the sites are in start-up mode, will be hiring a compliance person specializing in inspection
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No, records visual operations of cracks, seeps, etc. and reports to environmental coordinator
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? N/A
6	Are there safety and emergency procedures for the pit/impoundment? Fencing, floatation devices, signage, early leak detection system (inspected weekly), future fencing plans include complete enclosure, emergency number at the entrance to the sites
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Sites have an emergency access number for failure/warnings (if something goes wrong, someone will know what to do)
8	Has the pit/impoundment inspector been trained on how to use the EAP? No, would call back to the office if a problem occurs
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) No
10	Does the company have a policy on pit/impoundment safety? Regulatory group would know
11	How frequently does a Professional Engineer inspect the site? Regulatory group would know
12	Other comments: Water in collection ditch at toe of west downstream face Large slide, three pipes on east downstream face

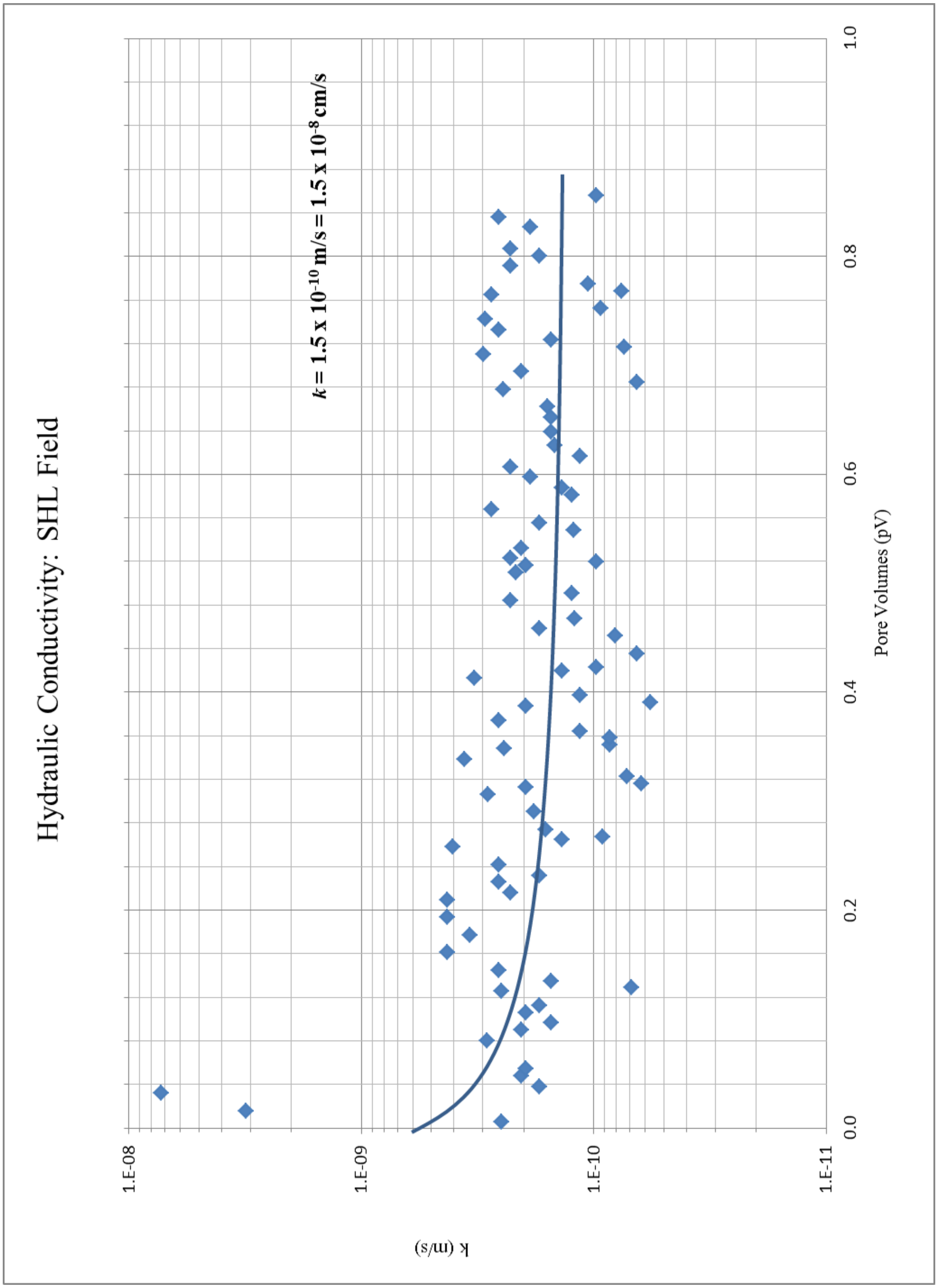
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

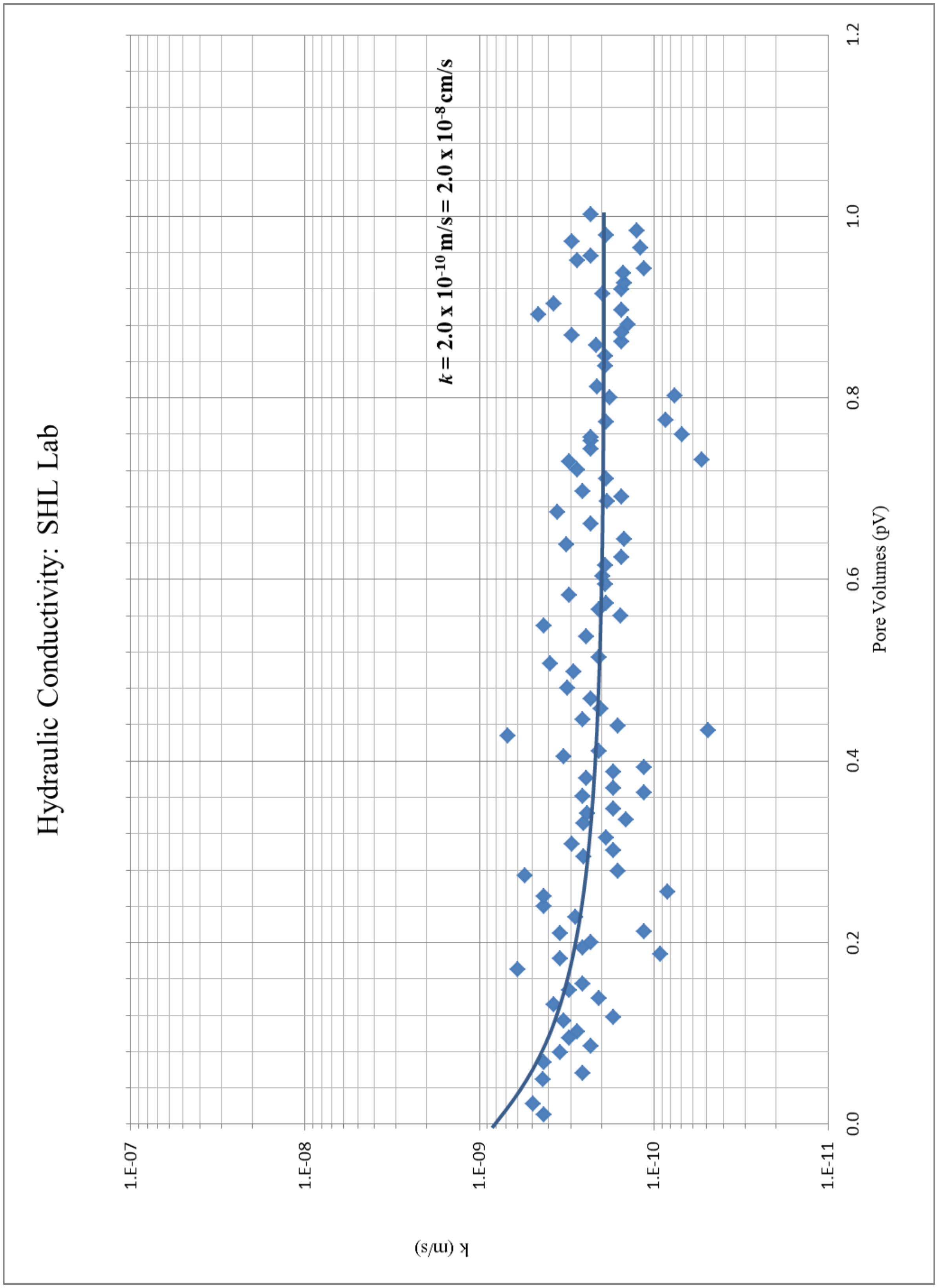
SHL 4 Centralized Pit		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			3
2	Are there any slope movements or animal burrows?	Yes			✓	1
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes		✓		2
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	1
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			3
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	Yes	✓			3
14	Are there any areas where the pipe is not properly supported?	Yes	✓			3
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	Yes			✓	1
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

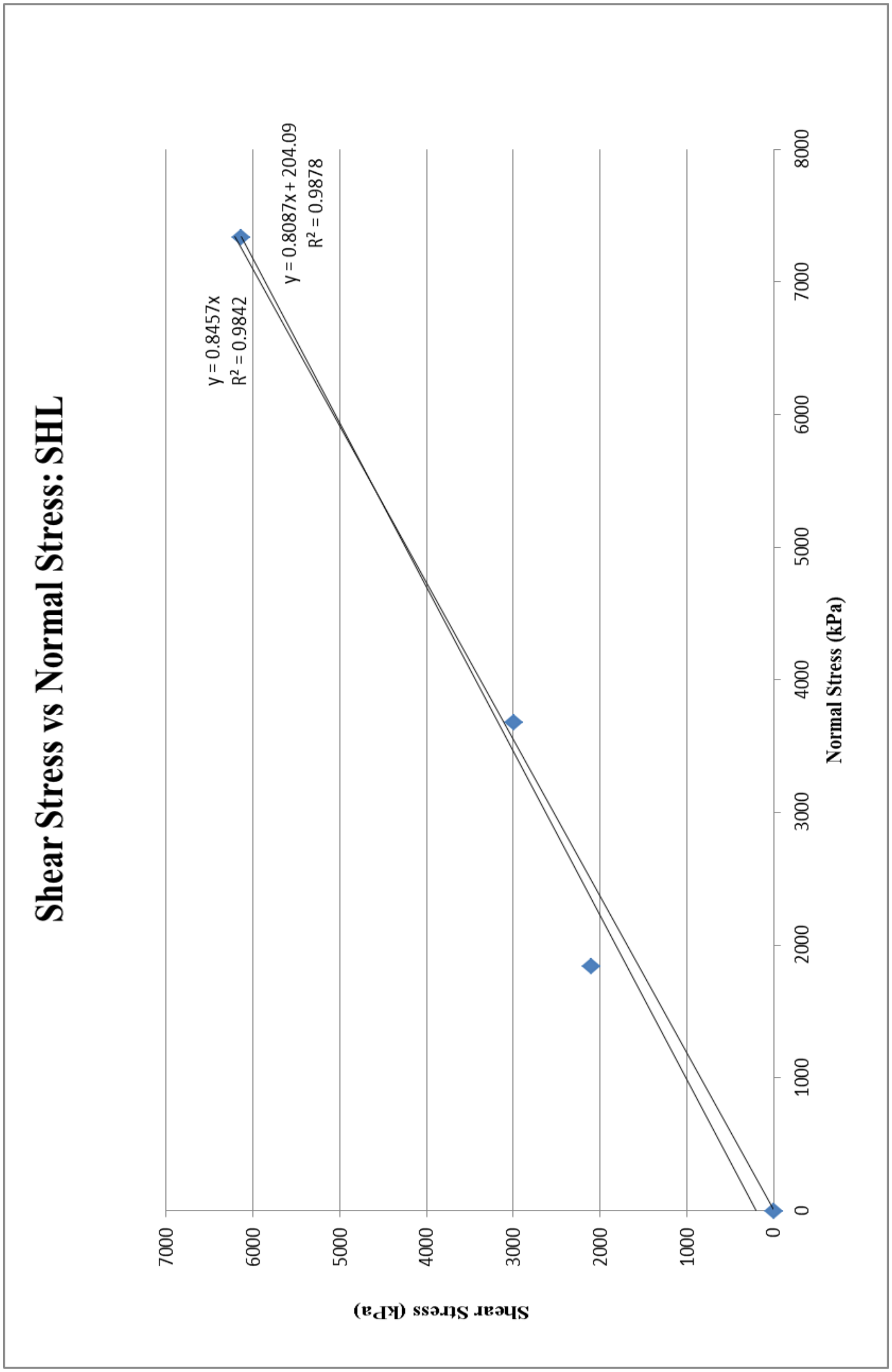
Total:	**58**	(Out of 76)
Percentage:	**76.3%**	


SHL 4 Centalized Pits: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


SHL 4 Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
132.00
128.00
124.00
120.00
116.00
112.00
108.00
104.00
100.00
96.00
92.00
88.00
84.00
2.00
6.00
10.00
14.00
18.00
22.00
26.00
30.00
34.00
38.00
S = 100%
S = 90%
Proctor Curve
Crest
Mid-slope
Toe
S = 100%
S = 90%


Hydraulic Conductivity: SHL Field
k = 1.5 x 10-10 m/s = 1.5 x 10-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.2
0.4
0.6
0.8
1.0


Hydraulic Conductivity: SHL Lab
k = 2.0 x 10-10 m/s = 2.0 x 10-8 cm/s
k (m/s)
Pore Volumes (pV)
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
0.0
0.2
0.4
0.6
0.8
1.0
1.2


Shear Stress vs Normal Stress: SHL
y = 0.8457x
R² = 0.9842
y = 0.8087x + 204.09
R² = 0.9878
Shear Stress (kPa)
Normal Stress (kPa)
0
1000
2000
3000
4000
5000
6000
7000
8000

Max Shear Stress vs. Normal Stress (SHL)			
Date	**Sample**	**Compaction**	**Material**
11/5/2012	SHL	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress (psf)**	**Normal Stress (psf)**
High	6.137	6137	7342
Medium	2.995	2995	3688
Low	2.095	2095	1844
4	0	0	0
m	0.8087	m	0.8457
ϕ' (degrees)	38.962	$\phi'_{c'=0}$ (degrees)	40.221
c' (psf)	204.090	c' (psf)	0.0

Appendix L: Flanigan Pit

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Flanigan Pit
Date of Site Evaluation: 8/2/12

Permit Observations / Anomalies:

Field measurements of the as-built construction differed from the permitted design. The berm width measured a minimum of 12 feet, while the permitted berm width is 15 feet.

The as-built dimensions were larger than the permitted design. The as-built dimensions of the pit were 178.5 feet wide by 289.5 feet long, as opposed to the permitted dimensions of 152.72 feet wide by 277.81 feet. Thus, the as-built capacity is larger than the permitted design.

Hydrology

Minor rills and gullies were found at the crest of the pit and on the downstream face, and numerous wet zones were observed at the anchor trench and berm. Water was found at the toe of the downstream face, and moist soil was noticed in the ditch associated with the pit.

Containment

The liner for the pit is a 60-millimeter geomembrane. Bulges in the liner were observed on the upstream face of the pit. A minor amount of rock and soil were on top of the liner. Settlements and sinkholes were also observed at the anchor trench.

Slope

Rills and gullies were observed at the crest and on the downstream face, but no slope movements were found. Minor woody debris was present in the fill material on the berm and downstream face.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the crest of the pit and at the toe of the downstream face.

Other Comments

The fence measured 6’ 11” high, and the base of the fence was 11” off the ground. The pipe was unsupported across the well pad, and gouges were found on the pipe.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 8/2/12 10:45 am	County	Harrison	Company	Antero Resources Appalachian Corp.
WEATHER Sunny	Latitude	N 39° 20' 46.0"	Pit Name	Flanigan Pit
	Longitude	W 80° 23' 44.2"	ID No.	

A. PERMIT INFORMATION

Pit Width (ft.)	152.72 ft.	Minimum Berm Crest Width (ft.)	15 ft.	Construction Type	Incised
Pit Length (ft.)	277.81 ft.	Upstream Slope (H:V)	2:1	Liner Type	60 mil.
Depth (ft.)		Downstream Slope (H:V)	2:1	Date Built	3/2012
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	178.5 ft.	Berm Crest Width (ft.)	12 ft.	Crest Height (ft.)	
Pit Length (ft.)	289.5 ft.	Upstream Slope (H:V)	1.7:1	Up Slope Length (ft.)	34.5 ft.
Depth (ft.)	22 ft.	Downstream Slope (H:V)		Down Slope Length (ft.)	26 ft.
Freeboard (ft.)	2 ft.	Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			Rills/gullies
2	Are there any slope movements or animal burrows?	No				
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			Minor woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	Water on anchor trench
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rock/soil
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Cracks, anchor trench exposed in places
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	Yes	✓			Gouges
14	Are there any areas where the pipe is not properly supported?	Yes	✓			
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc)?	No				
17	Are there any signs of water in ditch associated with pit?	Yes	✓			Moist soil in ditch
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

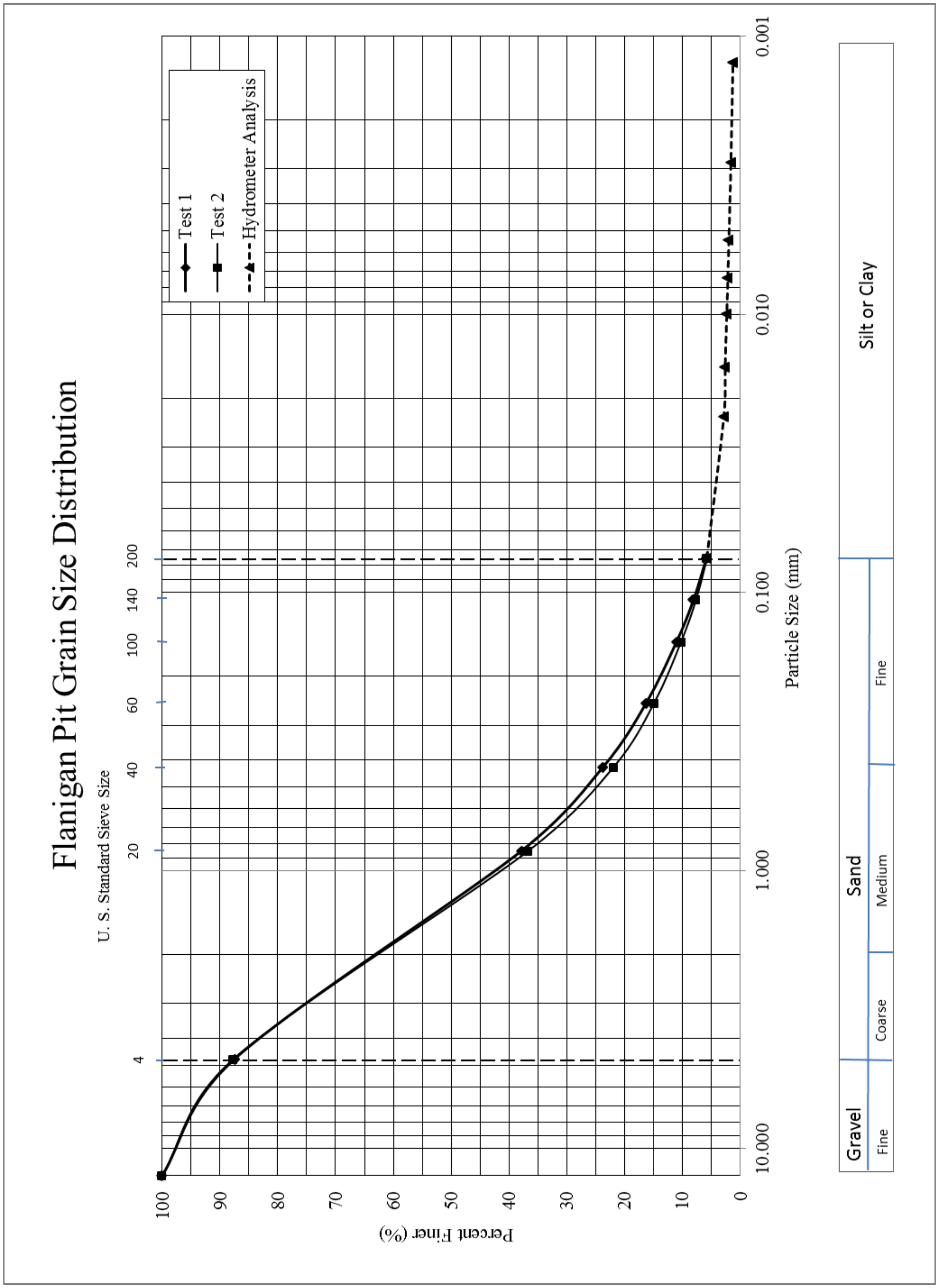
WVU (Name / Signature) Andrew Darnell	DATE 8/2/12
WVDEP (Name / Signature) John Kearney	8/2/12
Company Representative (Name / Signature) Jason Parson	8/2/12

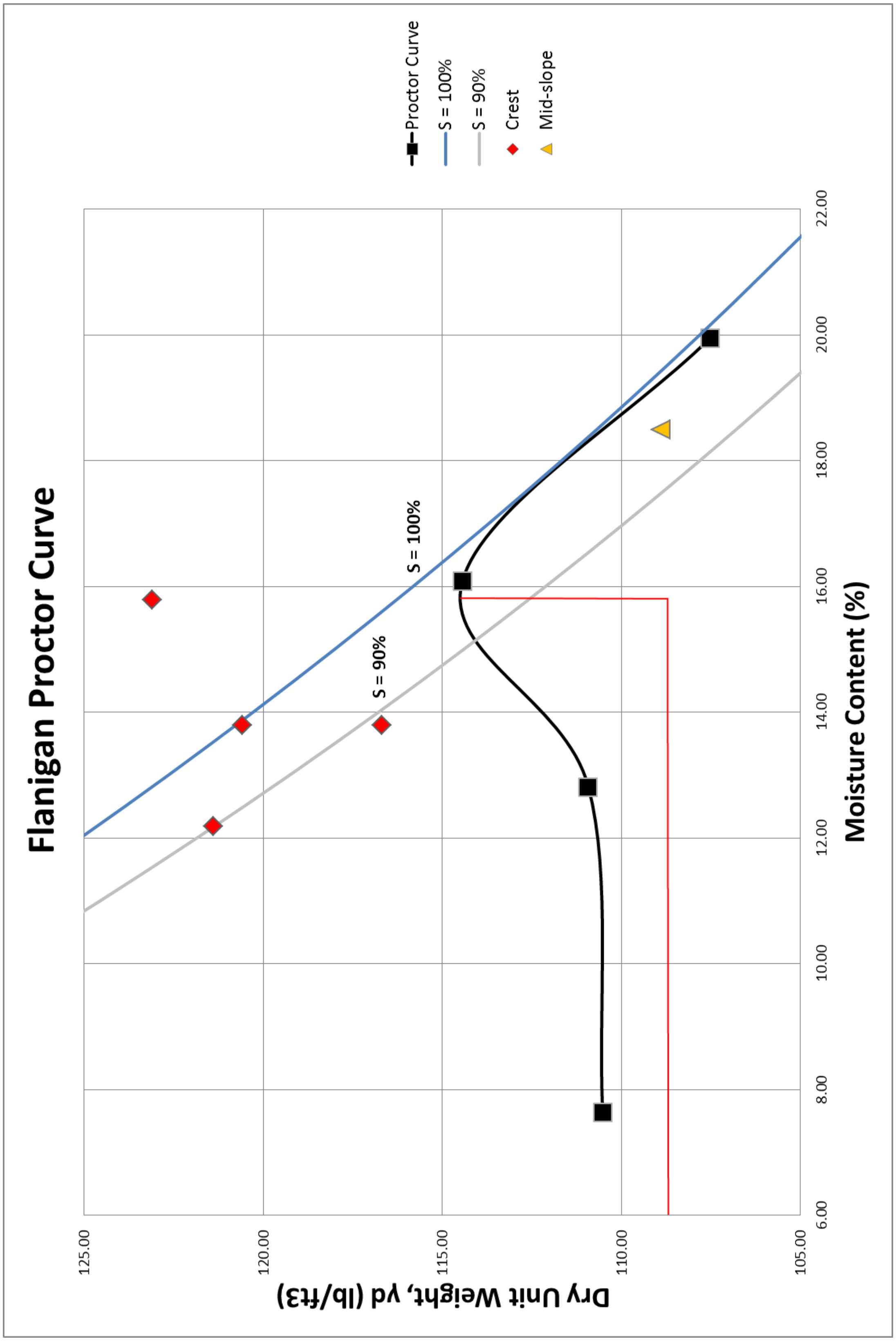
Site Operations & Infrastructure Evaluation	
Date: 8/2/12	Pit/Impoundment Name: Flanigan Pit
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Walking inspection twice a week, checks water levels
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Not very much
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No, emails comments/readings to Denver
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? N/A
6	Are there safety and emergency procedures for the pit/impoundment? Yes, kept at the office
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Yes, CEC out of Pittsburgh develops the safety plans
8	Has the pit/impoundment inspector been trained on how to use the EAP? Yes, keeps a list of people to call
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) Doesn't know
10	Does the company have a policy on pit/impoundment safety? Yes, have to contact the safety group for the plans
11	How frequently does a Professional Engineer inspect the site? Weekly
12	Other comments: Water in anchor trench and on berm The fence is 6' 11" high and is 11" off the ground Rills at crest Minor woody debris

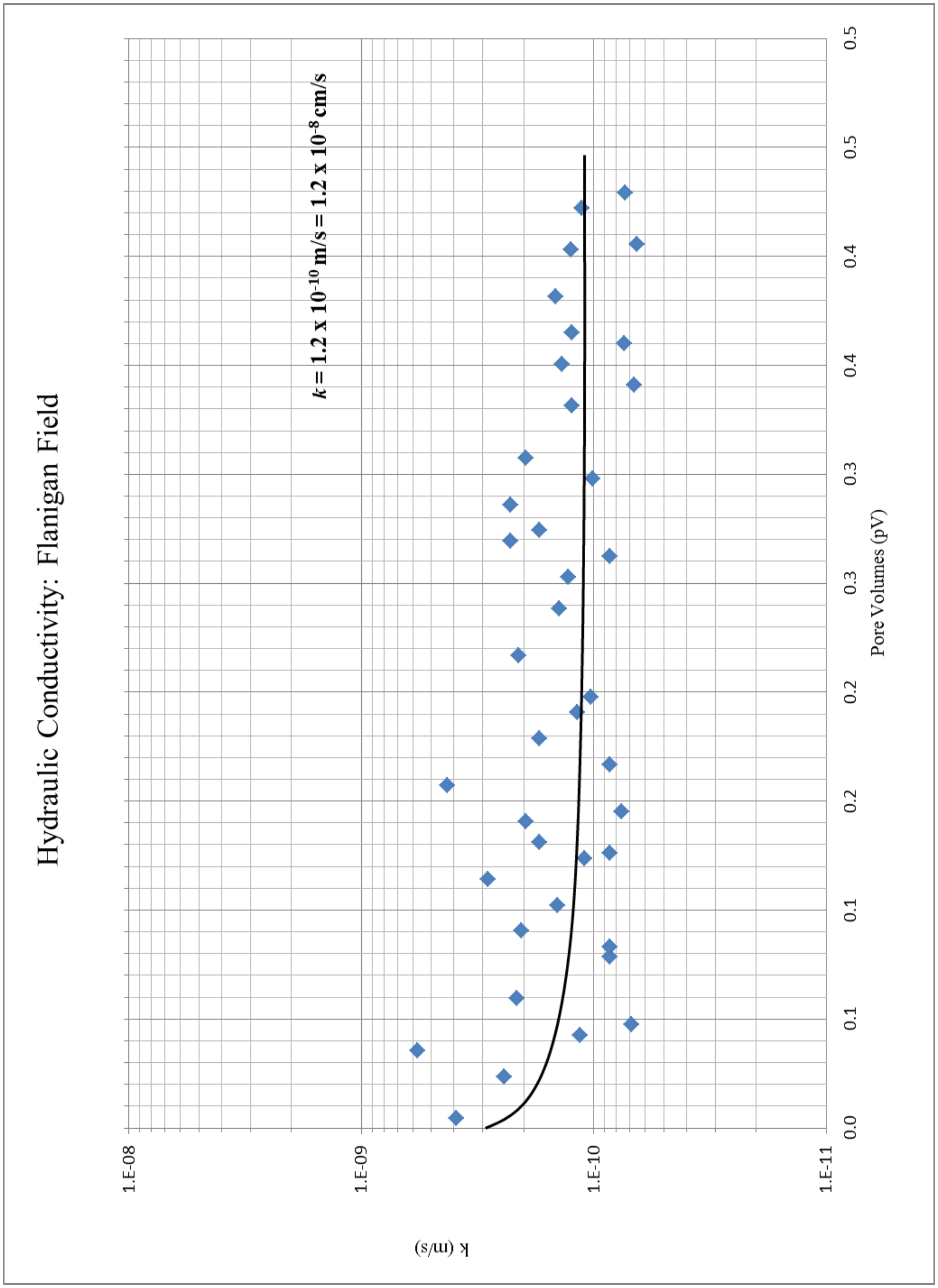
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

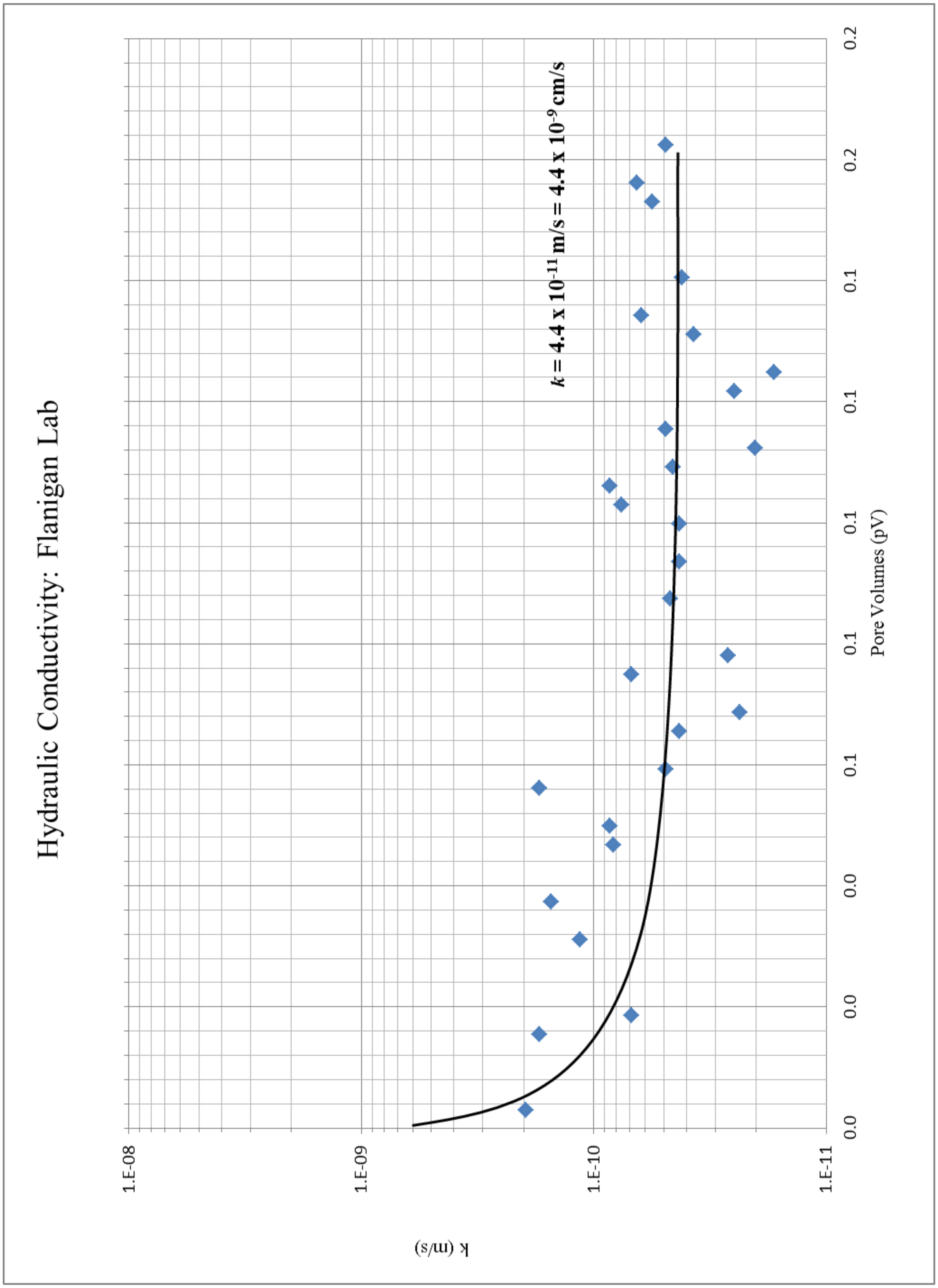
Flanigan Pit		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			3
2	Are there any slope movements or animal burrows?	No				4
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			3
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	1
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			3
9	Are there any areas where the liner is strained?	No				4
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	No				4
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	Yes	✓			3
14	Are there any areas where the pipe is not properly supported?	Yes	✓			3
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	No				4
17	Are there any signs of water in ditch associated with pit?	Yes	✓			3
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

Total:	**65**	(Out of 76)
Percentage:	**85.5%**	

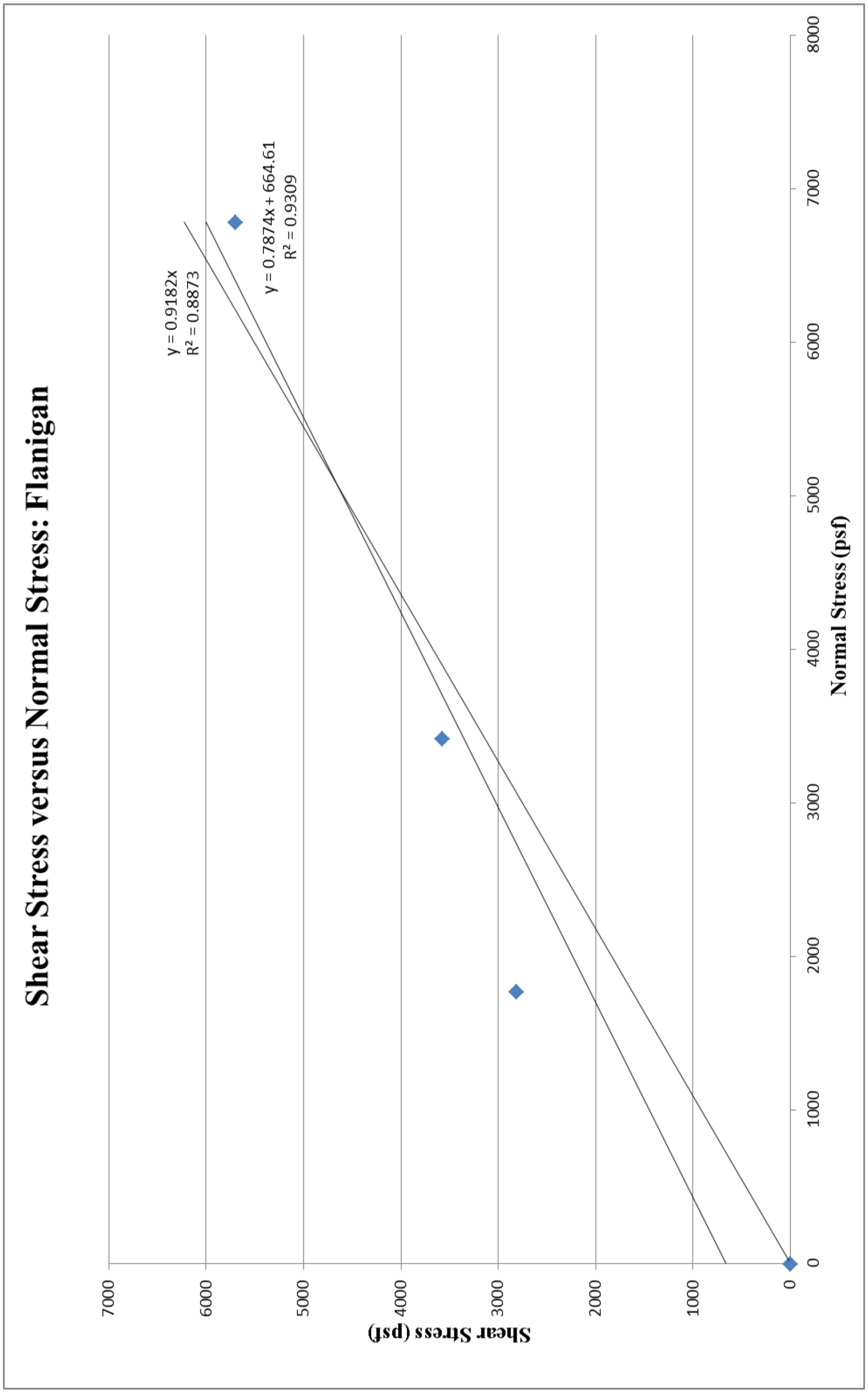

Flanigan Pit Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Coarse
Sand
Medium
Fine
Silt or Clay


Flanigan Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
125.00
120.00
115.00
110.00
105.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
S = 100%
S = 90%
Proctor Curve
S = 100%
S = 90%
Crest
Mid-slope


Hydraulic Conductivity: Flanigan Field
k = 1.2 x 10^-10 m/s = 1.2 x 10^-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.1
0.1
0.2
0.2
0.3
0.3
0.4
0.4
0.5
0.5



Hydraulic Conductivity: Flanigan Lab
k = 4.4 x 10-11 m/s = 4.4 x 10-9 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.0
0.0
0.1
0.1
0.1
0.1
0.1
0.2
0.2


Shear Stress versus Normal Stress: Flanigan
y = 0.9182x
R² = 0.8873
y = 0.7874x + 664.61
R² = 0.9309
Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000

Max Shear Stress vs. Normal Stress (Flanigan)			
Date	**Sample**	**Compaction**	**Material**
11/30/2012	Flanigan	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress(psf)**	**Normal Stress (psf)**
High	5.703	5703	6786
Medium	3.574	3574	3423
Low	2.815	2815	1771
4	0	0	0
m	0.7874	m	0.9182
ϕ' (degrees)	38.217	$\phi_{c'=0}'$ (degrees)	42.558
c' (psf)	664.610	c' (psf)	0.0

Appendix M: Larry Pad

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Larry Pad
Date of Site Evaluation: 8/2/12

Permit Observations / Anomalies:

The berm width measured a minimum of 13 feet, and the as-built dimensions of the pit were 171 feet wide by 468 feet long. No permit information was provided for this pit.

Hydrology

A high amount of rills and gullies were found at the crest of the pit and on the downstream face, and slope movements were also observed on the downstream face. Wet zones were present on the berm and at the toe of the downstream face. Water was present in the ditch associated with the pit.

Containment

The liner for the pit is an HDPE geomembrane. Bulges in the liner were observed on the upstream face of the pit. A minor amount of rock and soil were on top of the liner. Cracks were observed in the soil on the berm and at the anchor trench.

Slope

Rills and gullies were observed at the crest of the pit and on the downstream face, and several slope movements were found. Woody debris was present in the fill material on the berm and downstream face.

Soil Density Testing

In situ soil density and moisture content testing was performed at various locations around the pit. Data was collected at the pit crest and on the down-gradient slope of the pit.

Other Comments

Sandbags were noticed in the pit on top of the liner. A slope movement was observed on the hillside above the pit.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 8/2/12 12:00pm	County	Harrison	Company	Antero Resources Appalachian Corp.
WEATHER Sunny	Latitude		Pit Name	Larry Pad
	Longitude		ID No.	

A. PERMIT INFORMATION

Pit Width (ft.)		Minimum Berm Crest Width (ft.)		Construction Type	
Pit Length (ft.)		Upstream Slope (H:V)		Liner Type	
Depth (ft.)		Downstream Slope (H:V)		Date Built	
Freeboard (ft.)				Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	171 ft.	Berm Crest Width (ft.)	13 ft.	Crest Height (ft.)	9.1 ft.
Pit Length (ft.)	468 ft.	Upstream Slope (H:V)	1.5:1	Up Slope Length (ft.)	25 ft.
Depth (ft.)	14 ft.	Downstream Slope (H:V)	3.5:1	Down Slope Length (ft.)	33 ft.
Freeboard (ft.)	2 ft.	Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	Rills/gullies
2	Are there any slope movements or animal burrows?	Yes		✓		Slope movements
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			Woody debris
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	Berm, downstream face
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			Bulges
9	Are there any areas where the liner is strained?	No				
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rock/soil
11	Is there any tear potential for the liner?	No				
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Cracks
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	No				
14	Are there any areas where the pipe is not properly supported?	No				
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	No				
17	Are there any signs of water in ditch associated with pit?	Yes	✓			Standing water
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

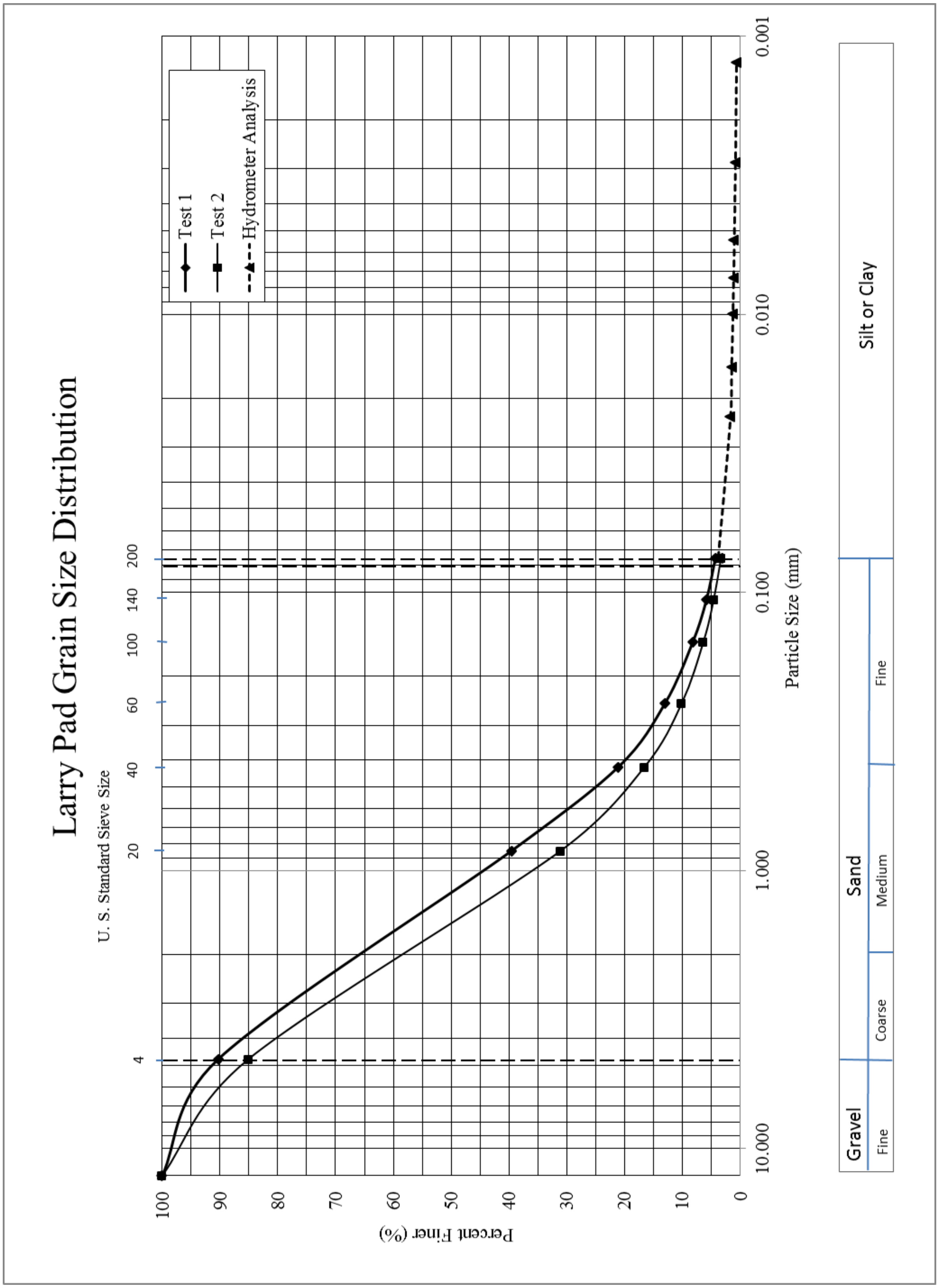
WVU (Name / Signature) Richard Wise	DATE 8/2/12
WVDEP (Name / Signature) John Kearney	8/2/12
Company Representative (Name / Signature) Jason Parson	8/2/12

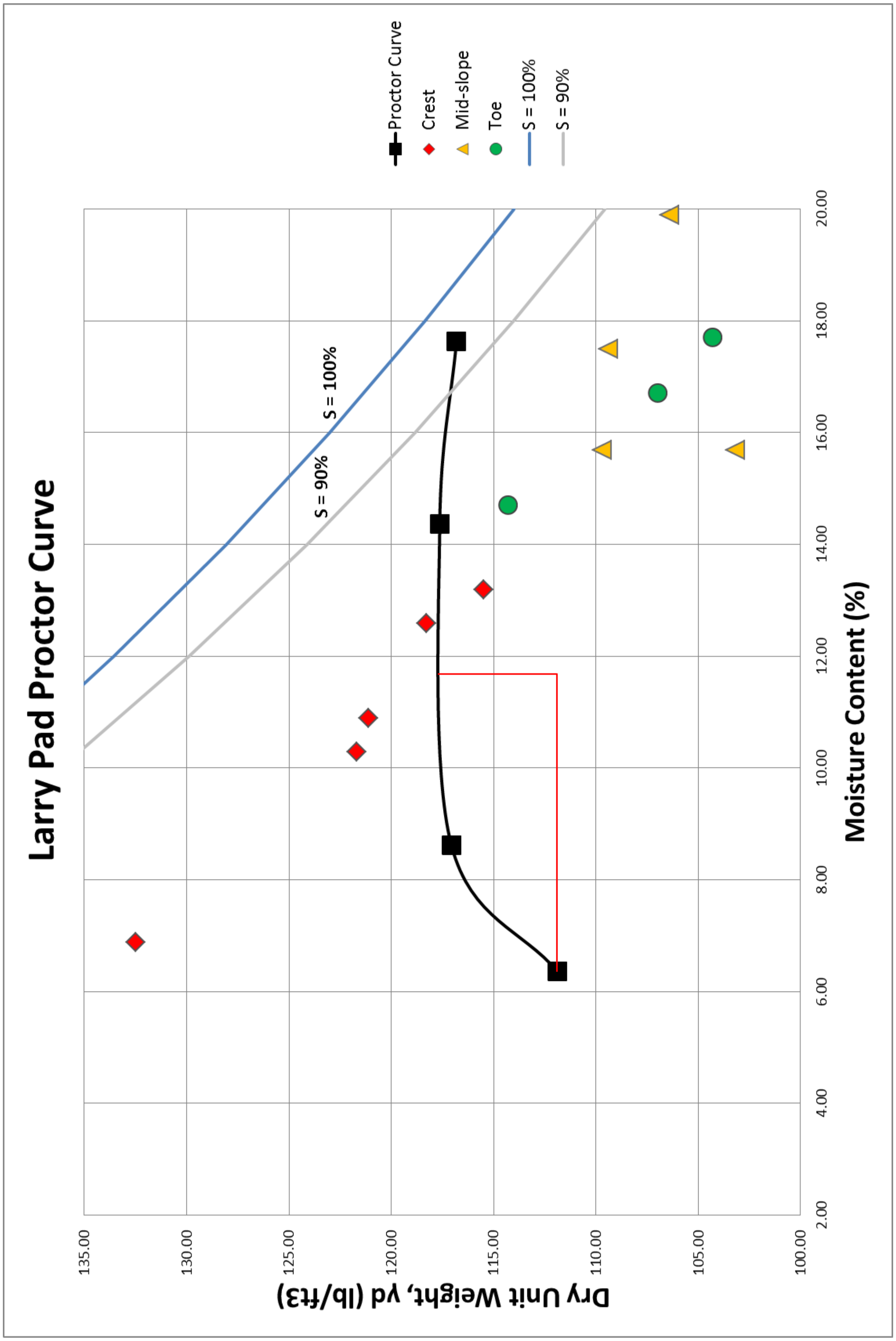
Site Operations & Infrastructure Evaluation	
Date: 8/2/12	Pit/Impoundment Name: Larry Pad
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Walking inspection twice a week, checks water levels
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Not very much
3	How many years of training does the inspector have in evaluating pits/impoundments? 0
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? No, emails comments/readings to Denver
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? N/A
6	Are there safety and emergency procedures for the pit/impoundment? Yes, kept at the office
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Yes, CEC out of Pittsburgh develops the safety plans
8	Has the pit/impoundment inspector been trained on how to use the EAP? Yes, keeps a list of people to call
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) Doesn't know
10	Does the company have a policy on pit/impoundment safety? Yes, have to contact the safety group for the plans
11	How frequently does a Professional Engineer inspect the site? Weekly
12	Other comments: Woody debris dug out of slope Water in anchor trench, at the toe of the downstream face, and on the berm Wet zones are present on the downstream face Sand bags are in the pit Cattails growing in the drainage ditch Slides are present on the hillside above the pit

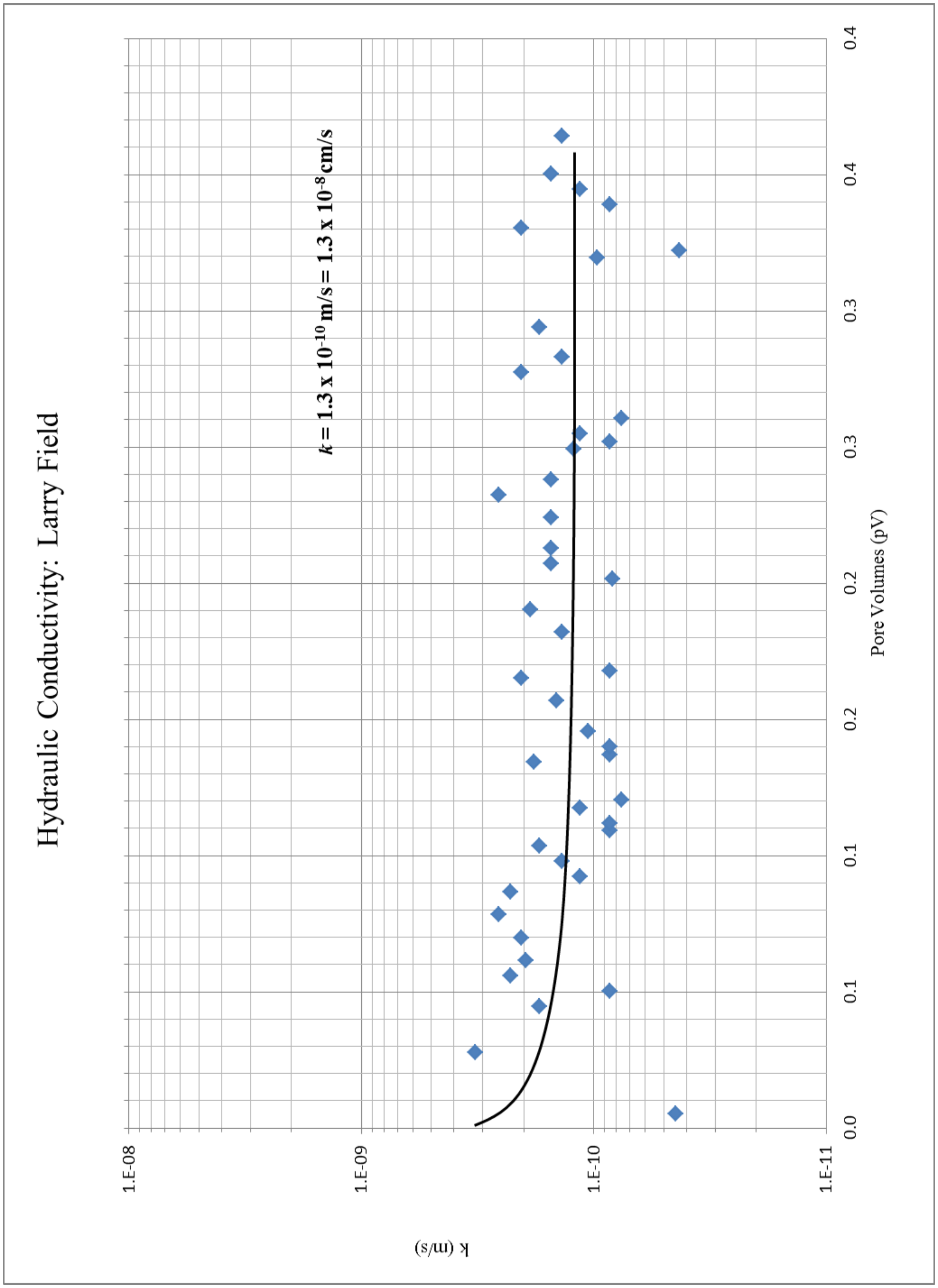
The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

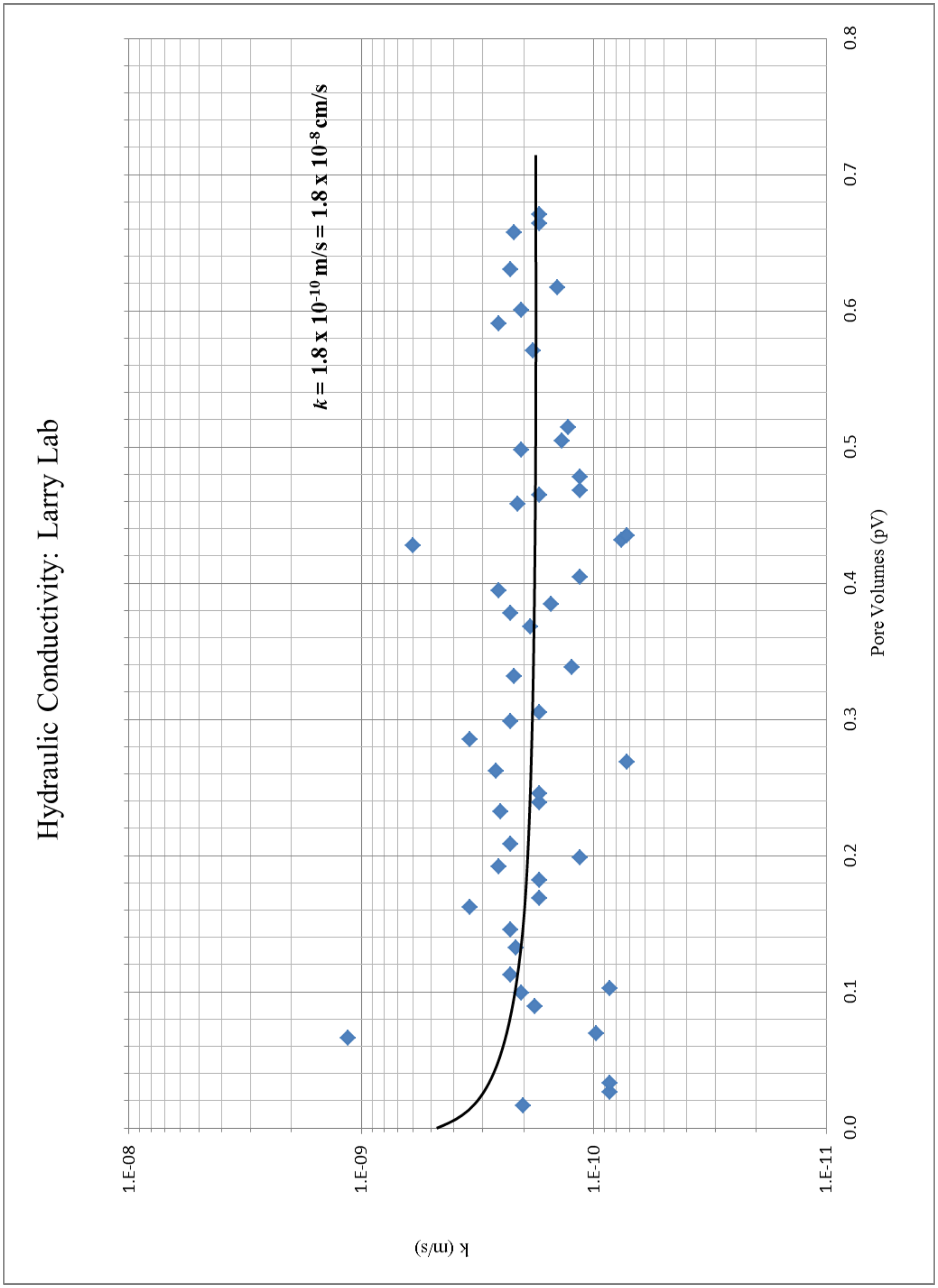
Larry Pad		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes			✓	**1**
2	Are there any slope movements or animal burrows?	Yes		✓		**2**
3	Are there any depressions, sinkholes, or slides into the pit present?	No				**4**
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				**4**
5	Are there any observed trees, tall weeds, or other vegetation?	Yes	✓			**3**
6	Are there any seeps, wet zones, or losses of soil?	Yes			✓	**1**
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				**4**
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes	✓			**3**
9	Are there any areas where the liner is strained?	No				**4**
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			**3**
11	Is there any tear potential for the liner?	No				**4**
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			**3**
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				**4**
14	Are there any areas where the pipe is not properly supported?	No				**4**
15	Are there any signs of pipes having significant sagging in line?	No				**4**
16	Are there any signs of obstructions (trees, garbage, etc)?	No				**4**
17	Are there any signs of water in ditch associated with pit?	Yes	✓			**3**
18	Are there any obstructions around the discharge outlet?	No				**4**
19	Are there any signs of downstream slope movement into ditch?	No				**4**

Total:	**63**	(Out of 76)
Percentage:	**82.9%**	

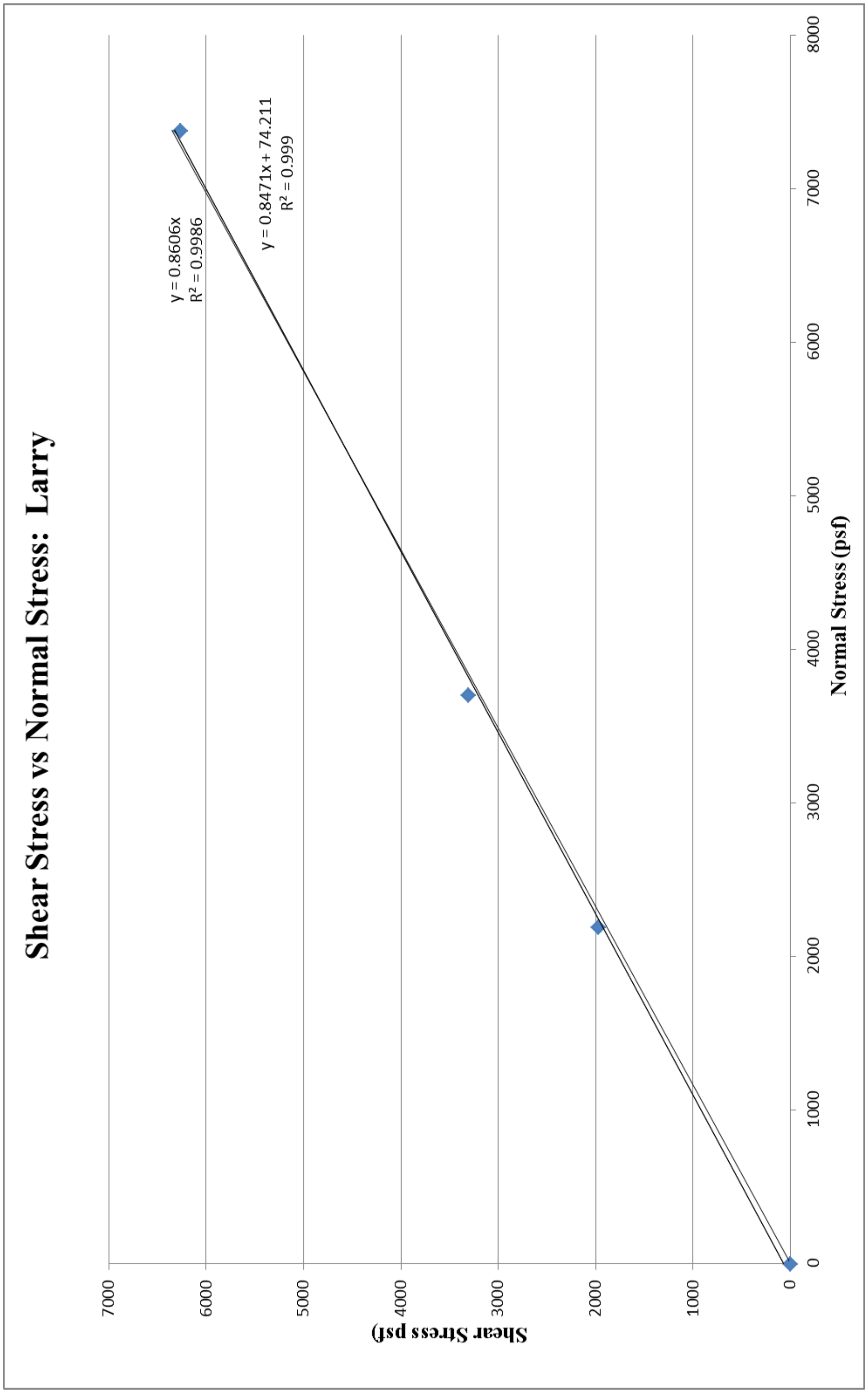

Larry Pad Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay


Larry Pad Proctor Curve
Dry Unit Weight, γd (lb/ft3)
Moisture Content (%)
135.00
130.00
125.00
120.00
115.00
110.00
105.00
100.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
S = 100%
S = 90%
Proctor Curve
Crest
Mid-slope
Toe
S = 100%
S = 90%


Hydraulic Conductivity: Larry Field
k = 1.3 x 10^-10 m/s = 1.3 x 10^-8 cm/s
Pore Volumes (pV)
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
0.0
0.1
0.1
0.2
0.2
0.3
0.3
0.4
0.4



Hydraulic Conductivity: Larry Lab
k = 1.8 x 10-10 m/s = 1.8 x 10-8 cm/s
k (m/s)
1.E-08
1.E-09
1.E-10
1.E-11
Pore Volumes (pV)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


Shear Stress vs Normal Stress: Larry
y = 0.8606x
R² = 0.9986
y = 0.8471x + 74.211
R² = 0.999
Shear Stress psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000

Max Shear Stress vs. Normal Stress (Larry)			
Date	**Sample**	**Compaction**	**Material**
11/28/2012	Larry	25 Blows/Layer, 5 Layers	Passing No. 4
Specimen Number	**Max Shear Stress (ksf)**	**Max Shear Stress(psf)**	**Normal Stress (psf)**
High	6.268	6268	7382
Medium	3.31	3310	3705
Low	1.97	1970	2195
4	0	0	0
m	0.8471	m	0.8606
ϕ' (degrees)	40.268	$\phi_{c'=0}'$ (degrees)	40.715
c' (psf)	74.210	c' (psf)	0.0

Appendix N: MWV Large Water Storage Pond 1

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: MWV Large Water Storage Pond 1
Date of Site Evaluation: 8/6/12

Permit Observations / Anomalies:

Measurements of the field as-built construction were consistent with the permitted design for berm crest width. The berm width measured a minimum of 15 feet, as noted in the permit.

The as-built dimensions of the impoundment were larger than the permitted dimensions. The permitted size is 265 feet wide by 760 feet long, while the as-built dimensions measured 282 feet wide by 780 feet long. Thus, the as-built capacity is larger than the permitted design.

Hydrology

A moderate amount of rills and gullies were found on the downstream faces of the impoundment. Also, a slope movement was noted on the eastern downstream face. Wet zones were present on the berm, in the anchor trench, and at the toe of the southeastern downstream face. Standing water was also observed in the ditch associated with the impoundment.

Containment

The liner for the impoundment is an HDPE geomembrane. Bulges in the liner were observed at numerous locations on the upstream face of the impoundment. These bulges seemed to be formed by stretching the liner over rock, thus straining the liner and resulting in increased tear potential for the liner. A minor amount of rock and soil was on top of the liner.

Slope

Rills and gullies were observed in multiple locations on the downstream face, and a slope movement was found. The downstream slopes appeared to be unprepared, with material pushed over the side of the impoundment and placed at the bottom of the slope. There was no silt fence at the bottom of the slopes.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 8/6/12 11:20 am	County	Nicholas	Company	Bluescape Resources Company, LLC.
	Latitude	N 38° 10' 12.17"	Pit Name	MWV Large Water Storage Pond 1
WEATHER Mostly Cloudy	Longitude	W 80° 34' 49.40"	ID No.	

A. PERMIT INFORMATION

Pit Width (ft.)	265 ft.	Minimum Berm Crest Width (ft.)	15 ft.	Construction Type	Incised
Pit Length (ft.)	760 ft.	Upstream Slope (H:V)	2:1	Liner Type	HDPE
Depth (ft.)	13.7 ft.	Downstream Slope (H:V)	2:1	Date Built	
Freeboard(ft.)	2 ft.			Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft.)	282 ft.	Berm Crest Width (ft.)	15 ft.	Crest Height (ft.)	17.5 ft.
Pit Length (ft.)	780 ft.	Upstream Slope (H:V)	Varies	Up Slope Length (ft.)	Varies
Depth (ft.)	21.5 ft.	Downstream Slope (H:V)	1.6:1	Down Slope Length (ft.)	33 ft.
Freeboard (ft.)	5 ft.	Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes		✓		Rills/gullies
2	Are there any slope movements or animal burrows?	Yes			✓	Slope movement
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	No				
6	Are there any seeps, wet zones, or losses of soil?	Yes		✓		Water in anchor trench
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes			✓	Bulges
9	Are there any areas where the liner is strained?	Yes			✓	Strained from below
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rock/soil
11	Is there any tear potential for the liner?	Yes			✓	From rock below
12	Are there any deformations, cracks, or settlements around the anchor trench?	No				
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	No				
14	Are there any areas where the pipe is not properly supported?	No				
15	Are there any signs of pipes having significant sagging in line?	No				
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Garbage
17	Are there any signs of water in ditch associated with pit?	Yes	✓			Standing water
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

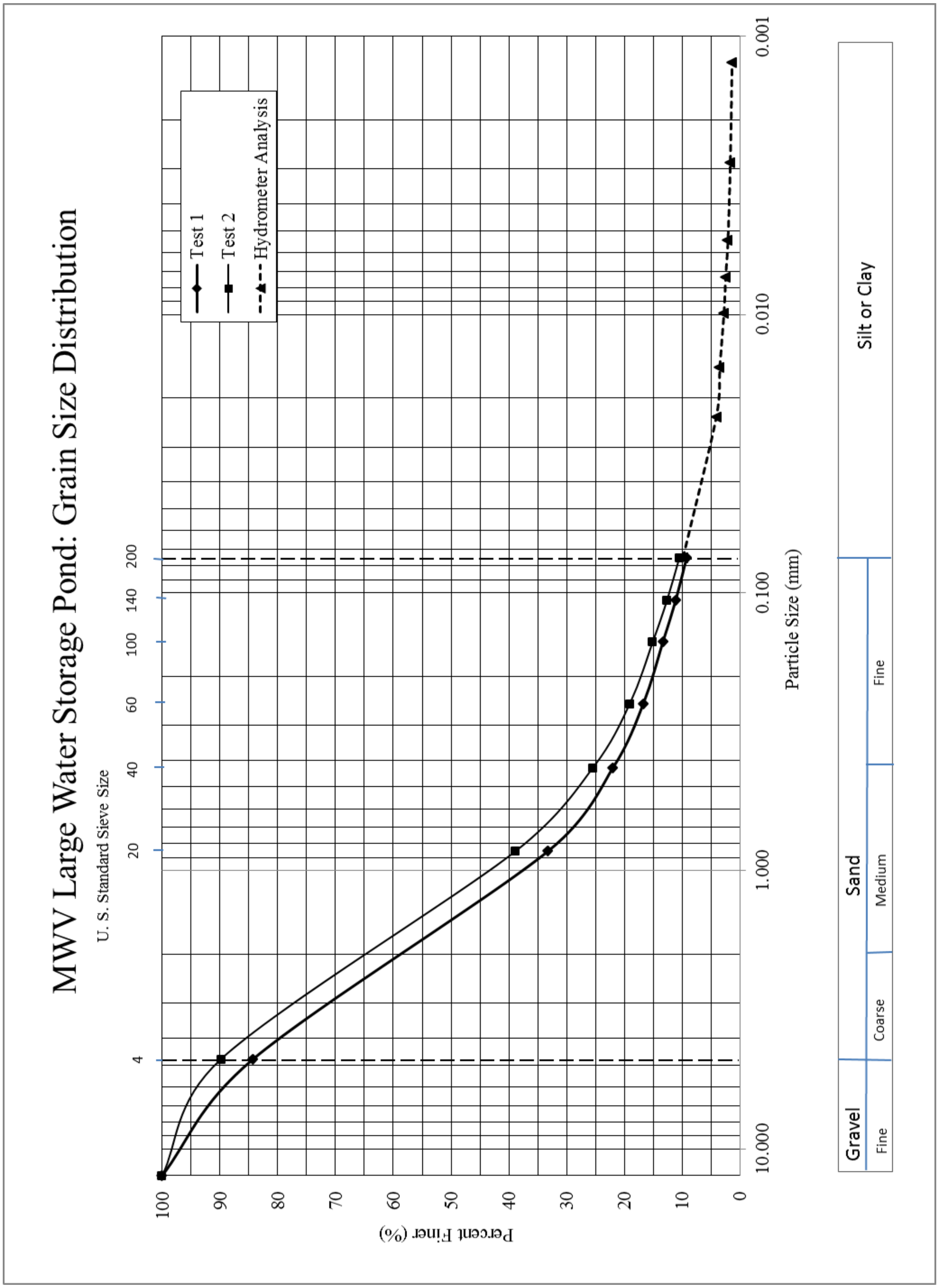
	DATE
WVU (Name / Signature) Richard Wise	8/6/12
WVDEP (Name / Signature) John Kearney	8/6/12
Company Representative (Name / Signature) Walter Jenko	8/6/12

Site Operations & Infrastructure Evaluation	
Date: 8/6/12	Pit/Impoundment Name: MWV Large Water Storage Pond 1
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Weekly inspections, or after heavy rains
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Doesn't know
3	How many years of training does the inspector have in evaluating pits/impoundments? N/A
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? Yes, made the inspection form one month ago
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? Walter Jenko
6	Are there safety and emergency procedures for the pit/impoundment? Doesn't know
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Doesn't know
8	Has the pit/impoundment inspector been trained on how to use the EAP? N/A
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) N/A
10	Does the company have a policy on pit/impoundment safety? Doesn't know
11	How frequently does a Professional Engineer inspect the site? No PE inspecting the site
12	Other comments: Downstream slopes appeared to be unprepared with material just pushed over the side Standing water at toe on southeastern downstream face Slip on eastern downstream face No silt fence at the bottom of the slopes

The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

MWV Large Water Storage Pond 1		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes		✓		2
2	Are there any slope movements or animal burrows?	Yes			✓	1
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	No				4
6	Are there any seeps, wet zones, or losses of soil?	Yes		✓		2
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes			✓	1
9	Are there any areas where the liner is strained?	Yes			✓	1
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	Yes			✓	1
12	Are there any deformations, cracks, or settlements around the anchor trench?	No				4
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	No				4
14	Are there any areas where the pipe is not properly supported?	No				4
15	Are there any signs of pipes having significant sagging in line?	No				4
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	Yes	✓			3
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

Total:	**57**	(Out of 76)
Percentage:	**75.0%**	


MWV Large Water Storage Pond: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay

Appendix O: Plum Creek South Fork

ETD-10 Pits and Impoundments Evaluation Report Site Observations / Comments

Site: Plum Creek South Fork
Date of Site Evaluation: 8/6/12

Permit Observations / Anomalies:

The berm width measured a minimum of 12 feet, and the as-built dimensions of the impoundment were 369 feet wide by 420 feet long. No permit information was provided for this impoundment.

Hydrology

Minor rills were found at the crest of the impoundment, and wet zones were observed at the anchor trench and berm. Water was present in the ditch associated with the impoundment.

Containment

The liner for the impoundment is an HDPE geomembrane. Bulges in the liner were observed at several locations on the upstream face of the impoundment. These bulges seemed to be formed by stretching the liner over rock, thus straining the liner and resulting in increased tear potential for the liner. A minor amount of rock and soil was on top of the liner. Settlements were observed at the anchor trench.

Slope

Rills were observed at the crest of the downstream face, but no slope movements were found. Large rocks were present on the downstream face.

Other Comments

The pipe running along the crest of the downstream face was unsupported along its length. Also, the pipe had significant sagging where it was spanning a depression in the topography. Garbage was noticed in the impoundment, and oil was spilled on the access road to the impoundment.

West Virginia University – Civil & Environmental Engineering ETD-10
Marcellus Horizontal Gas Well Flowback Water and Centralized Pits Evaluation Form

DATE & TIME 8/6/12 1:30 pm	County	Greenbrier	Company	Bluescape Resources Company, LLC.
WEATHER Mostly Cloudy/Rainy	Latitude	N 38° 12' 10.29"	Pit Name	Plum Creek South Fork
	Longitude	W 80° 26' 28.48"	API No.	47-025-00035, 47-025-00039

A. PERMIT INFORMATION

Pit Width (ft.)		Minimum Berm Crest Width (ft.)		Construction Type	
Pit Length (ft.)		Upstream Slope (H:V)		Liner Type	
Depth (ft.)		Downstream Slope (H:V)		Date Built	
Freeboard(ft.)				Date Reclaimed	N/A

B. FIELD AS-BUILT CONSTRUCTION AND SITE CONDITIONS

Pit Width (ft)	369 ft.	Berm Crest Width (ft)	12 ft.	Crest Height (ft)	14 ft.
Pit Length (ft)	420 ft.	Upstream Slope (H:V)	1.7:1	Up Slope Length (ft)	7.8 ft.
Depth (ft)	35 ft.	Downstream Slope (H:V)	2.4:1	Down Slope Length (ft)	36 ft.
Freeboard (ft)	4 ft.	Water Elevation		Groundwater Elevation	

Is the pit/impoundment in the NFIP 100-yr floodplain?	No	Is the pit/impoundment within 1000 feet of a public water source?	No
Is the pit/impoundment within 500 feet of a dwelling, perennial stream, or private water source?	No	Is the pit/impoundment within 100 feet of a wetland?	No

C. PIT/IMPOUNDMENT		Existence	If YES then Evaluate Significance of Problem			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Remarks
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			At crest
2	Are there any slope movements or animal burrows?	No				
3	Are there any depressions, sinkholes, or slides into the pit present?	No				
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				
5	Are there any observed trees, tall weeds, or other vegetation?	No				
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			Anchor trench and berm
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		Bulges
9	Are there any areas where the liner is strained?	Yes	✓			Strained from below
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			Minor rock/soil
11	Is there any tear potential for the liner?	Yes	✓			Rocks underneath
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			Settlements
13	Are there any signs of pipe abnormalities (gouge marks, leaks, cracks)?	Yes	✓			Gouges
14	Are there any areas where the pipe is not properly supported?	Yes			✓	For entire length
15	Are there any signs of pipes having significant sagging in line?	Yes			✓	On hillside
16	Are there any signs of obstructions (trees, garbage, etc.)?	Yes	✓			Garbage
17	Are there any signs of water in ditch associated with pit?	Yes	✓			Water
18	Are there any obstructions around the discharge outlet?	No				
19	Are there any signs of downstream slope movement into ditch?	No				

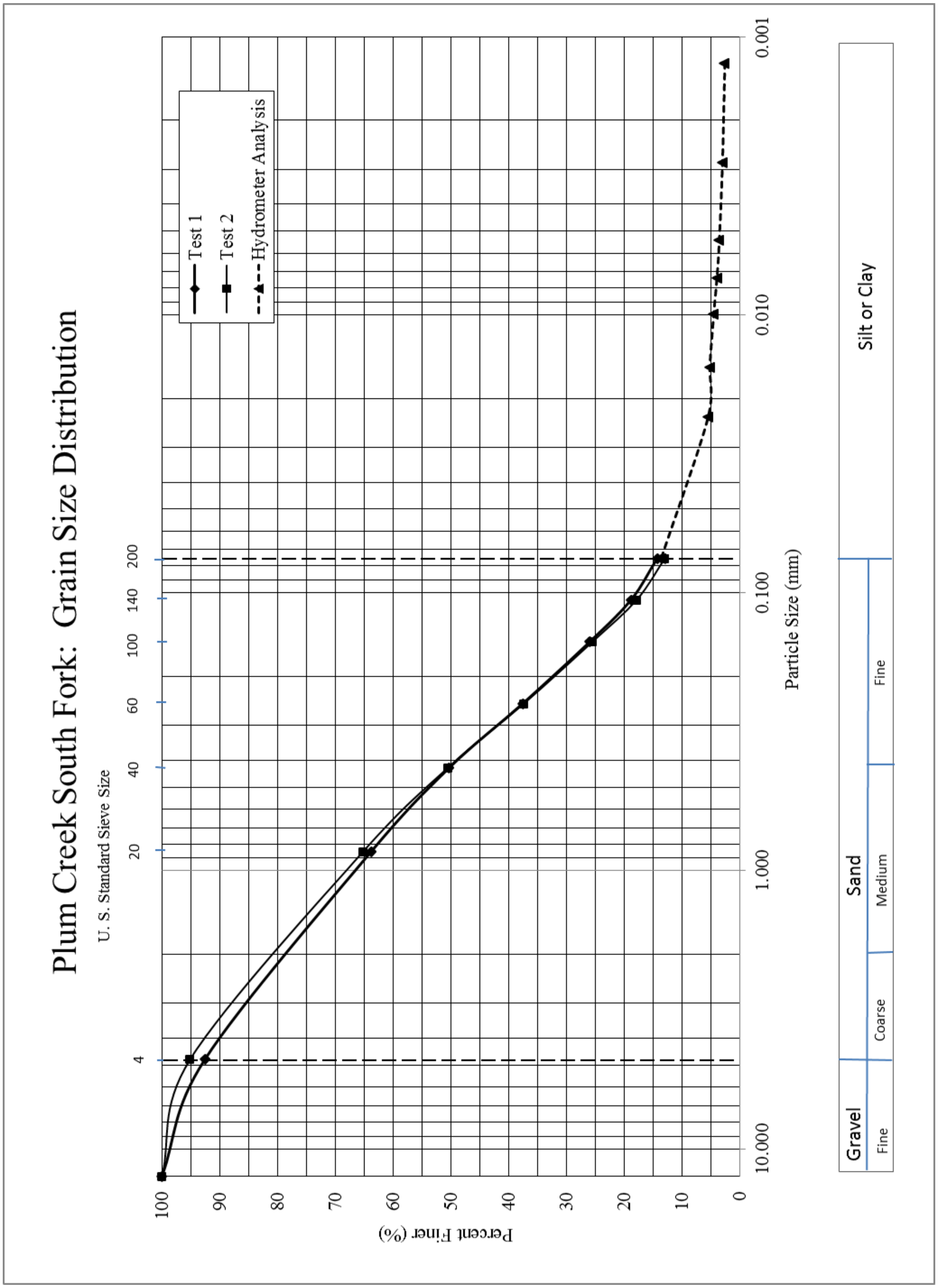
WVU (Name / Signature)	DATE
Andrew Darnell	8/6/12
WVDEP (Name / Signature) John Kearney	8/6/12
Company Representative (Name / Signature) Walter Jenko	8/6/12

Site Operations & Infrastructure Evaluation		
Date: 8/6/12		Pit/Impoundment Name: Plum Creek South Fork
1	What is the type and frequency of company site inspections at the pit/impoundment? (routine or special inspection) (visual, walking) Weekly inspections, or after heavy rains	
2	What type of training or background does the inspector possess relative to pit/impoundment inspection? Doesn't know	
3	How many years of training does the inspector have in evaluating pits/impoundments? N/A	
4	Is there a standardized form/procedure used to inspect and record observations of the pit/impoundment inspection? Yes, made the inspection form one month ago	
5	Who developed the form and how is the information used to evaluate pit/impoundment safety? Walter Jenko	
6	Are there safety and emergency procedures for the pit/impoundment? Doesn't know	
7	Is there an Emergency Action Plan (EAP) for the pit/impoundment? Is the EAP posted at the site with contact numbers? Doesn't know	
8	Has the pit/impoundment inspector been trained on how to use the EAP? N/A	
9	Has the EAP been evaluated using a Table Top Review or other method? (If so, when?) N/A	
10	Does the company have a policy on pit/impoundment safety? Doesn't know	
11	How frequently does a Professional Engineer inspect the site? No PE inspecting the site	
12	Other comments: Oil/Diesel leak on access road to impoundment	

The following table shows the field observations from the site evaluation. The ranking column indicates the level of severity for each question, signified by a scale of one to four. A ranking of one specifies that the problem is very prevalent at the site and carries a high significance in regards to the structural integrity and safety of the pit or impoundment. A ranking of four indicates that the problem was not observed at the site. By summing the rankings for each question, a total score is obtained out of 76 total points. Using this point system, a percentage is assigned for each site, which is used as a comparison for the sites.

Plum Creek South Fork		**Existence**	**If YES then Evaluate Significance of Problem**			
		Yes/No/NA	Low < 33%	Moderate 33 - 66%	High > 66%	Ranking (1-4)
1	Are there any observed surface erosions, cracks, settlements, or scarps?	Yes	✓			3
2	Are there any slope movements or animal burrows?	No				4
3	Are there any depressions, sinkholes, or slides into the pit present?	No				4
4	Are there any signs of mine subsidence on or adjacent to the embankment?	No				4
5	Are there any observed trees, tall weeds, or other vegetation?	No				4
6	Are there any seeps, wet zones, or losses of soil?	Yes	✓			3
7	Are there any eddies/whirlpools or other signs of leakage or seeps present?	No				4
8	Are there any liner tears, bulges, holes, wind uplifts, or seam separations?	Yes		✓		2
9	Are there any areas where the liner is strained?	Yes	✓			3
10	Are there any areas where the liner has rock or debris on top of it?	Yes	✓			3
11	Is there any tear potential for the liner?	Yes	✓			3
12	Are there any deformations, cracks, or settlements around the anchor trench?	Yes	✓			3
13	Are there any signs of pipe abnormalities (gouges marks, leaks, cracks)?	Yes	✓			3
14	Are there any areas where the pipe is not properly supported?	Yes			✓	1
15	Are there any signs of pipes having significant sagging in line?	Yes			✓	1
16	Are there any signs of obstructions (trees, garbage, etc)?	Yes	✓			3
17	Are there any signs of water in ditch associated with pit?	Yes	✓			3
18	Are there any obstructions around the discharge outlet?	No				4
19	Are there any signs of downstream slope movement into ditch?	No				4

Total:	**59**	(Out of 76)
Percentage:	**77.6%**	



Plum Creek South Fork: Grain Size Distribution
U. S. Standard Sieve Size
4
20
40
60
100
140
200
Test 1
Test 2
Hydrometer Analysis
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10.000
1.000
0.100
0.010
0.001
Particle Size (mm)
Gravel
Fine
Sand
Coarse
Medium
Fine
Silt or Clay

Appendix P: Laboratory Soil Testing Procedures

Field Moisture Content (ASTM D2216)

Field moisture content is important for the analysis of the site soil conditions at the time of the evaluation, which may be useful in studying the phreatic surface. The procedure for determining the field moisture content followed ASTM D2216. Site soil samples were collected in soil jars that were sealed to ensure the moisture content remained constant until tested upon return from the field visit.

<u>Specified Equipment For This Soil Property Test:</u>

1. Drying oven
2. Balances
3. Specimen containers (with lids)
4. Heat resistant tongs

<u>Laboratory Soil Testing Procedure:</u>

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D2216 "Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass".

1. Determine the mass of a dry, clean moisture content container and record the number printed on the container and the mass of the container on a data sheet.

2. Place a representative sample of soil in the container. Weigh the container plus moist soil and record the mass on a data sheet.

3. Place the container and soil in an oven and allow the soil to dry overnight (at least 15 to 16 hours).

4. Determine the mass of the container and contents after the soil is dry, and record the mass on a data sheet.

Grain-Size Distribution and Hydrometer (ASTM D422)

Grain-size distribution is useful in estimating hydraulic conductivity and also in finding the engineering properties of soil. The ASTM method used for the grain-size distribution testing was ASTM D422. The grain-size distribution testing was performed by placing soil samples in the sieve shaker for five minutes. Table 13 gives the list of sieves used for the grain-size distribution throughout this study. The sieves were cleaned after each use. The sieve shaker used for performing the grain-size distribution testing is shown in Figure 26.

Sieve No.	Particle diameter (mm)
No. 4	4.76
No. 20	0.840
No. 40	0.425
No. 60	0.250
No. 100	0.150
No. 140	0.106
No. 200	0.075

Table 13: List of Sieves Used

Figure 26: Sieve Shaker

The uniformity of soil is defined using the uniformity coefficient (C_u) and the coefficient of curvature (C_c). C_u is defined as the ratio of D_{60} to D_{10}, where D_{60} is the particle diameter at which 60 percent of the soil weight is finer and D_{10} is the particle diameter at which 10 percent of the soil weight is finer. C_c is expressed in terms of D_{10}, D_{60} and D_{30}, where D_{30} is the particle diameter at which 30 percent of the soil weight is finer. The equations used to calculate C_u and C_c are shown below.

$$C_u = \frac{D_{60}}{D_{10}}$$

$$C_C = \frac{D_{30}^2}{(D_{10} * D_{60})}$$

The sieve analysis and particle diameters were used to classify the soil using the USCS classification methodology. Soil particles that passed the No. 200 sieve were used to perform the hydrometer testing as per the ASTM method. The hydrometer tests were conducted by making a blend of water, soil particles passing the No. 200 sieve, and the dispersing agent sodium hexametaphosphate. A calibrated hydrometer was used to measure the suspension of the soil particles in the blend at total elapsed times of 2, 5, 15, 30, 60, 250, and 1440 minutes. Two 1000 milliliter graduated cylinders were used for the test. After each reading, the hydrometer was kept in another 1000 milliliter graduated cylinder filled with water to clean the hydrometer between readings. The hydrometer testing apparatus is shown in Figure 27. Figure 28 shows hydrometer readings being careful observed and recorded.

Figure 27: Hydrometer Analysis

Figure 28: Hydrometer Readings

<u>Specified Equipment For These Soil Property Tests:</u>

1. Balances
2. Hard bristle brush
3. Various-sized round, stackable testing sieves (ASTM E 11 or AASHTO M 92)
4. Vibratory table
5. Two graduated cylinders (one liter)
6. Hydrometer
7. High-speed electric mixer with steel mixing cup
8. Deflocculating agent (sodium hexametaphosphate)
9. Thermometer
10. 600 mL glass beaker
11. Spatula
12. Squirt bottles
13. Distilled water supply
14. Chemical weighing spoon
15. Chemical weighing dish

Laboratory Soil Testing Procedure for Grain-Size Distribution:

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D422 "Standard Method for Particle-Size Analysis of Soils".

1. Weigh out a 500 g soil sample, oven-dried according to ASTM recommendations.
2. Record the mass of each clean sieve and the pan on a data sheet.
3. Place the soil sample in the uppermost sieve and secure with a lid.
4. Put the stack of sieves in the mechanical sieve shaker and shake for 5 minutes.
5. Remove the sieves from the shaker and set aside to allow dust to settle.
6. Remove each sieve from the stack, starting at the top.
7. Shake the first sieve over a sheet of paper until no particles fall onto the paper. Empty any soil particles on the paper into the next sieve.
8. Weigh the first sieve and record the mass of the sieve and soil retained on the data sheet.
9. Repeat Steps 7 and 8 for each sieve.

Laboratory Soil Testing Procedure for Hydrometer Analysis:

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D422 "Standard Method for Particle-Size Analysis of Soils".

1. Weigh out exactly 50 g of oven-dried soil in a 600 mL glass beaker.
2. Fill one 1-liter graduated cylinder with distilled water and place the hydrometer slowly inside.
3. Place the filled graduated cylinder and one empty 1-liter graduated cylinder on a stable counter in an area where the cylinders will not be shaken or moved for at least two hours.
4. Weigh out 2.5 g of sodium hexametaphosphate into a small dish.

5. Mix the soil with 250 mL of distilled water in a 500 mL glass beaker. Stir the slurry with a spatula and break the clumps of clay down into individual particles as much as possible.

6. Pour the slurry into a steel mixing cup and wash the remaining soil into the mixing cup.

7. Add the deflocculating agent (sodium hexametaphosphate).

8. Use distilled water to fill the mixing cup to two-thirds full.

9. Turn on the high-speed mixer and mix the soil slurry for one minute. Wash the suspension into the empty 1-liter graduated cylinder.

10. Add distilled water to fill the cylinder to the 1-liter mark and place a rubber stopper on the open end of the cylinder.

11. Cover the stopper with a hand and repeatedly turn the cylinder upside-down and right-side-up again until the suspension is thoroughly mixed.

12. Take hydrometer readings at total elapsed times of 2, 5, 15, 30, 60, 250, and 1440 minutes, and record the readings on a data sheet.

13. After each reading, remove the hydrometer from the cylinder and store in the graduated cylinder filled with clean water. Place a thermometer in the clean water to determine the temperature of the hydrometer.

Atterberg Limits (ASTM D4318)

Atterberg limits are the limits of water content used to define the soil behavior and classify the soil. Increasing the water content causes the soil to progress from a solid state, to a semi-solid state, to a plastic state, and finally to a liquid state. The limits that are used to define the soil behavior are the liquid limit (LL) and the plastic limit (PL). The liquid limit is defined as the water content at which the soil behaves as a liquid. The plastic limit is defined as the water content at which the soil crumbles when rolled into 1/8 inch diameter threads. The Plasticity Index (PI) is defined as the difference between the liquid limit and the plastic limit, and is useful in the classification of soil.

The ASTM D4318 method was used to determine the Atterberg Limits for this study. Specific water contents were taken to blend with the soil. The blend was placed in a liquid limit apparatus, shown in Figure 29, and a groove was made using a standard-width grooving tool. The cup was dropped until the groove closed, and the number of blows was counted. The water content at which the groove closes at 25 blows is defined as the liquid limit. The plastic limit was determined by rolling the soil into 1/8 inch diameter threads and measuring the water content at which the threads crumbled. The Plasticity Index was then calculated using the liquid limit and plastic limit values. This testing procedure is illustrated in Figure 30.

Figure 29: Liquid Limit Device (Casagrande Cup)

Figure 30: Atterberg Limits Testing

Specified Equipment For These Soil Property Tests:

1. Liquid limit device
2. Grooving tool
3. Moisture content containers
4. Glass or plastic plate
5. Soil mixing equipment (dish, spatula, and water bottle)
6. Balance

Laboratory Soil Testing Procedure for Liquid Limit:

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D4318 "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils".

1. Obtain a sample of air-dry, pulverized clay weighing 100 g.

2. Measure the height of the fall for the liquid limit device.

3. Place the air-dry soil in an evaporating dish and mix with 15 to 20 mL of distilled water, or until the soil is near the liquid limit.

4. Place the soil in the liquid limit device to a maximum thickness of 1 cm and smooth with a spatula.

5. Use a grooving tool to cut a groove into the soil.

6. Lift and drop the cup by turning the crank at a rate of about two drops per second until the groove closes along a distance of one-half inch.

7. Add soil and repeat process until the number of blows for closure is the same on two consecutive tests.

8. Record the number of blows on a data sheet.

9. Remove a slice of soil from the portion of soil that closed the groove together and place in a moisture content container to determine the water content.

10. Add more water to the soil as needed in order to perform the test three times with blow counts between five and 50.

Laboratory Soil Testing Procedure for Plastic Limit:

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D4318 "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils".

1. Mix 15 g of air-dry soil with water so that the soil is slightly wet of the estimated plastic limit.
2. Roll the soil into a thread with a diameter of one-eighth inch on a glass or plastic plate.
3. Break the thread into six or eight pieces.
4. Squeeze the pieces together into a uniform mass and reroll to a thread with one-eighth inch diameter.
5. Repeat Steps 2-4 until the soil can no longer be rolled into a thread.
6. Gather the portions of crumbled soil together and place in a moisture content container to determine the water content.

Specific Gravity (ASTM D854)

Specific gravity is defined as the ratio of the unit weight of a given material to the unit weight of distilled water at 4^{o}C. Specific gravity testing is performed to find the dry density, void ratio, and degree of saturation, and the results are also used in the hydrometer analysis calculations. The method used for the determination of specific gravity was ASTM D854 - Method A, in which a water pycnometer was used. The test was performed by weighing the pycnometer containing soil particles suspended in distilled water and taking the weight of equal volume of water in the same pycnometer. An air vacuum was applied for 2 hours during the test. The apparatus used for the specific gravity test is shown in Figure 31.

Figure 31: Specific Gravity

Specified Equipment For This Soil Property Test:

1. 250 ml volumetric flask
2. 500 ml volumetric flask
3. Thermometer
4. Balance
5. Vacuum hoses with rubber stoppers to fit on volumetric flasks
6. Small vibratory table
7. Medicine dropper

Laboratory Soil Testing Procedure:

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D854 "Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer".

1. Obtain 150 g of soil, 50 g of which is used to measure specific gravity while the remaining soil is used to determine water content.
2. Weigh a clean, dry volumetric flask and record on a data sheet.
3. Pour 50 g of soil into the flask.
4. Fill the flask two-thirds full with distilled water.
5. Place the vacuum hose with rubber stopper on the neck of the flask and open the valve to apply a vacuum to the soil-water mixture.
6. Fill the flask to the etch mark with distilled water, using the medicine dropper near the end.
7. Use a paper towel to dry the outside of the flask and the inside of the neck above the water level.
8. Weigh the flask plus soil and water and record the mass on a data sheet.
9. Place a thermometer inside the flask to determine the temperature of the mixture and record on a data sheet.
10. Empty the soil from the flask, and repeat Steps 6-9 using only distilled water.

Standard Proctor (ASTM D698)

In Marcellus Shale pits and impoundments, soil is compacted to a design density and used as structural fill. Due to the compaction, the flow of water (seepage) through soil reduces, and the material acquires strength which helps in the construction of the structure. During construction, compaction is performed by using rollers and dozers.

The objective of compaction testing was to determine the optimum moisture content and maximum dry density of the soil within a given compactive effort. Compaction testing was also used to determine the engineering properties of the soil such as hydraulic conductivity. Standard Proctor tests were used for the compaction testing, in accordance with Method A in ASTM D698. The equipment used for the compaction testing was a 4 inch diameter compaction mold with removable collar and base, a hammer, a mixer for blending the soil with water, and a jack to remove the compacted sample from the mold. The compaction mold and hammer are shown in Figure 32.

Figure 32: Compaction Mold and Hammer

Four samples from each site were prepared using different water contents. The soil samples were mixed with water and compacted in three layers with 25 blows per layer, in accordance with the ASTM method. After the compaction, the collar was removed, and the excess soil was trimmed to the surface of the mold. Figure 33 depicts the removal of the sample from the mold using a jack, leaving the compacted sample shown in Figure 34. After weighing each sample, discrete moisture contents were taken by cutting the sample into three equal layers and collecting a small amount of soil from the top, middle, and bottom layers. Using the results of the compaction testing, graphs of water content versus respective dry densities were developed, presenting the optimum moisture content and the maximum dry density of the sample.

Figure 33: Removal of Compacted Specimen from Mold Using Jack

Figure 34: Compacted Mold

Specified Equipment For This Soil Property Test:

1. Compaction mold
2. Compaction hammers
3. Soil mixer
4. Sharpened straight edge
5. Tools for breaking apart compacted samples (hammer, ice pick, etc.)
6. Extruder to remove samples from mold
7. Large scoop for handling soil
8. Balance
9. Oven
10. Moisture cans

Laboratory Soil Testing Procedure:

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D698 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort".

1. Weigh out 3,000 g of air-dried soil.
2. Weigh the mold (not including the weight of the collar).
3. Determine the amount of water to add to the soil sample in order to obtain a specific, or known, water content.
4. Place the soil in the mixer and slowly add water to bring the water content of the soil to the desired value.
5. Remove the soil from the mixer and compact into the mold using three equal lifts and twenty-five blows for each lift with the compaction hammer.
6. Remove the collar and trim the soil flush with the top of the mold using a sharpened straight edge.
7. Weigh the mold plus the soil and record on a data sheet.
8. Extrude the soil from the mold using the extruder.
9. Cut the sample into three equal layers and place representative portions of soil from each layer into a moisture content container to determine water content.

10. Break the sample into reasonably fine pieces and place back into the mixer, adding water to achieve the next desired compaction water content. Repeat the process as necessary.

Hydraulic Conductivity-Rigid Wall (ASTM D5856)

Hydraulic conductivity is a measure of the permeability of a soil and is useful in determining the flow of water through the soil. This soil property depends on several factors, including the grain-size distribution, void ratio, pore-size distribution, roughness of mineral particles, and degree of saturation. These factors vary between soil types, resulting in distinct hydraulic conductivity ranges for different soils.

Hydraulic conductivity testing was performed using the ASTM D5856 method. The objective of the hydraulic conductivity testing was to determine the permeability of water through a test specimen at the optimum and field moisture contents of the material at each site. Two samples were compacted to optimum and field moisture contents using the Standard Proctor procedure outlined above. Once compacted, the samples were connected to a head-water reservoir and a pressure board to push water through the samples at a hydraulic gradient of 100 pounds per square inch. Readings were taken at varying intervals depending on the sample, or until the readings stabilized. After the hydraulic conductivity readings reached equilibrium, the hydraulic conductivity was determined. Figure 35 depicts four samples undergoing hydraulic conductivity testing.

Figure 35: Hydraulic Conductivity Testing

Specified Equipment For This Soil Property Test:

1. Permeameter
2. Two porous stones
3. Two pieces of filter paper
4. Vacuum hoses
5. Membrane expander
6. O-rings
7. Compaction mold
8. Compaction hammers
9. Soil mixer
10. Sharpened straight edge
11. Tools for breaking apart compacted samples (hammer, ice pick, etc.)
12. Extruder to remove samples from mold
13. Large scoop for handling soil
14. Balance
15. Oven
16. Moisture cans

Laboratory Soil Testing Procedure:

The following section is based on ASTM standard D5856 "Standard Test Method for Measurement of Hydraulic Conductivity of Porous Material Using a Rigid-Wall, Compaction-Mold Permeameter".

1. Compact moist soil into a Standard Proctor mold following procedure outlined previously.
2. Record all physical properties of the soil sample on a data sheet.
3. Soak two porous stones and two pieces of filter paper in the permeating fluid until saturated.
4. Place one porous stone over the bottom plate of the permeameter cell and cover with filter paper.
5. Extrude the soil sample and place on top of the filter paper.
6. Place the remaining filter paper, porous stone, and top plate on top of the soil sample.
7. Place hydraulic grease around the outside of both top and bottom.
8. Place the membrane inside the membrane expander with at least two inches of excess at both ends.
9. Use a vacuum to expand the membrane.
10. Use the membrane expander to lower the membrane until the soil sample, top plate and bottom plate are encompassed.
11. Unclasp the vacuum line and allow the membrane to collapse around the sample.
12. Remove the membrane from the expander.
13. Fold the top and bottom of the membrane to remove any wrinkles.
14. Place two O-rings on one end of the membrane expander and place the membrane expander over the soil sample with the O-rings on the bottom of the expander.
15. Remove the O-rings so that the membrane is held tight against the top and bottom plates.
16. Secure the tail-water lines to the top plate.
17. Place the acrylic cover over the sample and secure with top cap.

18. Open the top valve to allow air to escape and fill the cell with water through the bottom valve.
19. Close both valves when water comes out the top.
20. Secure all lines from the pressure board to the cell.
21. Fill all three reservoirs with water, leaving at least two inches of air at the top of the reservoirs.
22. Set the cell water pressure to 10 psi, the head-water pressure to 8 psi, and the tail-water pressure to 6 psi.
23. Open the head-water valve that is connected to the head-water reservoir.
24. Open the head-water valve beside the first and allow the water to flow until all air bubbles are removed. Close both valves and repeat with the tail-water lines.
25. Open both the head-water and tail-water valves to allow the sample to saturate. Close both valves when air bubbles stop.
26. Drain the tail-water reservoir until there is only 1 cm of water.
27. Fill the head-water reservoir to 30 cm of water.
28. Measure the height of water in the head-water, tail-water, and cell-water reservoirs and record on a data sheet.
29. Set a time to start the test and turn both valves on at that time.
30. Record the height of water in the head-water, tail-water, and cell-water reservoirs as well as time of the readings and record on a data sheet.
31. Turn off both the head-water and tail-water valves when the head-water reservoir is nearly empty.
32. Take the last reading of the heights and the final time and record on a data sheet.
33. Disassemble the cell and take final moisture contents for the top, middle, and bottom layers of the sample.

Shear Strength (ASTM D3080/D3080M)

A major factor in the structural integrity of all geotechnical construction is the strength of the soil. Shear strength is a measure of the resistance of a soil to shearing stresses and is dependent upon the cohesion and internal friction between soil particles. The shear strength testing was performed on a GeoJac direct shear testing device. The testing followed the procedures outlined in ASTM D3080/D3080M. Once the hydraulic conductivity testing for a site was completed, three cylinders measuring 2.5 inches in diameter and 1 inch in height were cut from the top, middle, and bottom of each sample. Each test was performed at an optimum and field condition. The internal angle of friction (ϕ) was calculated using Mohr-Coulomb failure criterion concepts. The testing setup and equipment are shown in Figure 36.

Figure 36: Direct Shear Testing

<u>Specified Equipment For This Soil Property Test:</u>

1. Shear device
2. Shear box
3. Porous stones
4. Device for applying and measuring the normal force
5. Device for applying and measuring the horizontal force
6. Timer
7. Deformation devices

<u>Laboratory Soil Testing Procedure:</u>

The following section is referenced from the CE 351 Introductory Soil Mechanics Laboratory Manual, Department of Civil and Environmental Engineering, West Virginia University. This procedure is based on ASTM standard D3080/D3080M "Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions".

1. Assemble the shear box in the direct shear frame, placing porous stones on top and bottom.

2. Place the loading cap.

3. Attach and adjust the vertical displacement measurement device.

4. Obtain an initial reading for the vertical displacement device and a reading for the horizontal displacement device. Record the measurements on a data sheet.

5. Consolidate the soil sample under the appropriate force.

6. Measure the vertical deformation as a function of time and plot the time-settlement curve to determine the time to 50 percent consolidation.

7. Shear the soil sample and take readings of the horizontal displacement until the shear force peaks, remains constant, or results in a deformation of 10 percent of the original diameter of the sample.