Operation and Maintenance Plan
North Culvert and Pit Spring Passive Mine Water Treatment Systems

Morgan Run Watershed
Clearfield County, Pa

Prepared by: Hedin Environmental

For: Clearfield County Conservation District

October 2023

<u>Quick Start Guide</u> – Morgan Run North Culvert and Pit Spring DLB Passive Treatment Systems Operation and Maintenance

Introduction

This guide is meant to provide basic information as a guide to the inspection, operation and maintenance of the MR7 North Culvert and Pit Spring passive treatment systems in the Morgan Run watershed. More detailed information is included in the accompanying Operation and Maintenance Plan.

Location

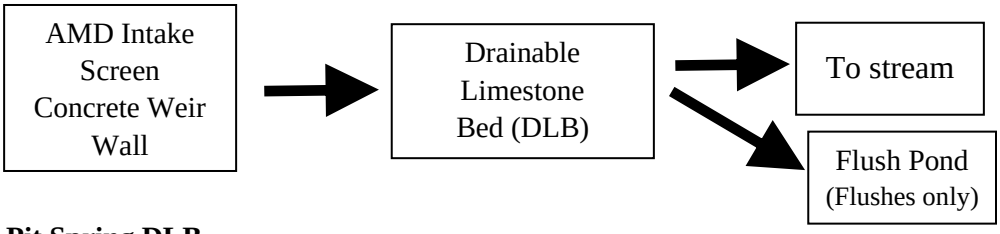
The treatment systems are located on private property in Decatur Township Clearfield County at the end of a gated private access road off of Sanborn Street, Osceola Mills, Pa. The geographic location of the systems is given in the following table.

System Name	Latitude	Longitude
North Culvert System	40.90692 **N**	-78.35858 W
Pit Spring System	40.90721 N	-78.35951 W

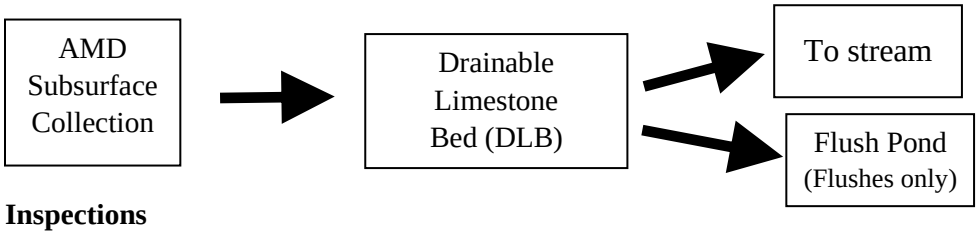
System basics

The site contains two drainable limestone beds (DLBs) that use limestone aggregate to neutralize acidity, raise pH and add alkalinity. Each DLB treats a separate source of AMD. The North Culvert DLB treats AMD captured from a drainage channel using a Coanda intake screen mounted on a concrete intake weir structure. The Pit Spring DLB treats AMD collected in a French drain located just south of the North Culvert DLB. Primary effluent from each system flows back to the drainage from which it was collected. The DLBs are automatically flushed by draining them empty once/week when independent solar-powered computer-controlled gate values are activated. Flush effluent is directed to a dedicated flush pond that serves both DLBs. A description and general flow schematic of each system follows.

North Culvert System



Pit Spring DLB



Inspections

Site inspections should be conducted at least quarterly and after significant precipitation events. A site inspection involves noting whether water is flowing through the system as intended and if there are maintenance needs to ensure proper system operation. Check for damage from rodents or vandals and

debris blocking pipes. Measure pH and flow. Water flowing through any emergency spillway is one indication of a problem that requires immediate investigation and resolution. The solar-powered, computer-controlled drainage system should be checked to assure that the battery is charged and that the gate valve is operational.

Sampling

Samples should be collected at least twice per year at the following locations: raw AMD into system and effluent from each DLB.

Contact Information

Project Management/Sponsor
Clearfield County Conservation District
contact: Kelly Williams

Treatment System Design
Hedin Environmental, 195 Castle Shannon Blvd, Pittsburgh PA 15228
Contact: Neil Wolfe, nwolfe@hedinenv.com, 570-295-0063
Contact: Ben Hedin, hedinb4031@gmail.com, 412-215-0239

Treatment System Construction
TP Contracting 402 Beck Road Loretto, Pa. 15940

Morgan Run North Culvert and Pit Spring DLB Passive Treatment System Operation and Maintenance Plan

Prepared by Hedin Environmental
For the Clearfield County Conservation District
October 2023

Introduction

This operation and maintenance plan is intended to provide the information necessary for successful operation of the North Culvert and Pit Spring passive treatment systems. The systems were designed by Hedin Environmental and constructed in 2023 using grants awarded to the Clearfield County Conservation District from PA DEP Growing Greener and Office of Surface Mining.

Safety

Personnel working on at the North Culvert and Pit Springs passive treatment systems should be aware of hazardous conditions and take appropriate precautions.

Project Background

Mining began in the Morgan Run watershed in the 19th century with the construction of underground mine workings in the Lower Kittanning coal seam and a clay mine that has extensive deep mine workings. Surface mining occurred in higher strata during the mid to late 20th century but much of the original deep mine workings are intact. Discharges of acidic mine water from the abandoned mines degrades aquatic life in Morgan Run. This project was undertaken to improve the water quality of Morgan Run through treatment of the North Culvert and Pit Spring discharges.

Passive Treatment Basics

The type of treatment system utilized is known as passive treatment. Passive treatment employs gravity, natural materials, and natural chemical and biological processes to remediate water polluted with acidity and metals. The North Culvert and Pit Spring passive treatment systems use limestone aggregate to add alkalinity to acidic waters followed by ponds to remove and retain metals. The acidic water dissolves the mineral calcite in the limestone which neutralizes acidity, raises pH and adds alkalinity. When the pH rises, dissolved metals in the mine water precipitate forming solids in the pore spaces of the limestone aggregate. Over time these solids accumulate and reduce the permeability of the aggregate and diminish the effectiveness of the treatment. Water in the limestone beds is drained out weekly and much of the accumulated metals flow out into a settling pond where they are retained. In this way, the accumulation of metals is managed and treatment effectiveness maintained.

The systems are designed to operate with minimal intervention and infrequent maintenance. Inevitably, the limestone will be consumed and the system will fill with metals solids necessitating major maintenance tasks. In order to assure that the system provides decades of good treatment, this operation and maintenance plan has been prepared to allow the caretakers to anticipate and identify maintenance needs and then implement maintenance work effectively.

Site Access

The treatment systems are located on properties owned by Dan Dixon and Steve Shennenberger in Decatur Township Clearfield County at the end of private gated access road off of Sanborn Street Osceola Mills Pa. Figure 1 shows the site location. The geographic location of the system is given in the following table.

System Name	Latitude	Longitude
North Culvert System	40.90692 **N**	-78.35858 W
Pit Spring System	40.90721 N	-78.35951 W

System Layout

Figure 2 shows the site layout. Two passive treatment systems were constructed to treat two separate AMD sources: North Culvert and Pit Spring. Each AMD source is captured and conveyed to a separate drainable limestone bed (DLB). Both DLBs flush to a common flush pond.

North Culvert AMD Collection

Design and Function

The North Culvert discharge was collected directly from small polluted drainage using Coanda Screen and concrete weir wall and inline water level control structure (WLCS). Water from the collection is controlled by a WLCS to permit design flow rate to enter the DLB .

Inspections

Inspection tasks:

1. Check screen for leaves, moss, iron solids and any other debris that might prevent flow.
2. Check for excessive corrosion of metal components

Maintenance

1. Adjust board height in WLCS (as needed)
    a. If too much or too little flow is entering the treatment system, adjust the height of the boards in the WLCS. Raise height to reduce flow and lower to increase flow. Flow can be fine-tuned by drilling holes in the boards or cutting them to the desired height.
2. Repair or replace corrosion-damaged parts

Pit Spring AMD Collection

Design and Function

The Pit Spring discharge was collected using a French drain consisting of non-calcareous aggregate and perforated pipe.

Inspections

Inspection tasks:

1. Check collection area for new seepages that could indicate incomplete collection of AMD.
2. Check overflow pipe for blockage.

Maintenance

1. No maintenance is required. Failure of the collection system can only be addressed through reconstruction of the collection system.

Pipelines

Design and Function

A pipeline conveys water from each AMD source to the treatment system and another pipeline conveys flush events from each DLB to the flush pond.

Inspections

Inspection tasks:

1. Check that water flows freely through the pipelines.

Maintenance

1. Remove obstructions from pipeline. The services of a professional pipe cleaning company may be required.

Drainable Limestone Beds

Design and Function

The North Culvert and Pit Spring discharges are each treated in a separate drainable limestone bed (DLB). A DLB is a pond filled with limestone aggregate. The basic design of both DLBs is the same with the only differences being the quantity and depth of limestone aggregate. As water flows through a DLB, acidity is neutralized by the calcite in the limestone, alkalinity is generated and metals are precipitated. Water entering the DLB is distributed along one edge of the limestone at the surface using an influent fountain that helps ensure that water flow through the limestone aggregate is as uniform as possible. Water leaves the DLB through a perforated pipe on the bottom parallel to the influent fountain but on the opposite end of the DLB.

As water is treated the metals precipitate and are deposited in the aggregate voids. This interferes with the uniform flow of water through the bed and also inhibits contact of the acidic water with the limestone surface. To avoid this problem and maintain permeability, the DLB must be drained empty on a regular basis so that a majority of the metals solids are flushed from the aggregate. The draining, which occurs on a weekly schedule is accomplished with a computer-controlled gate valve. When the DLB is draining it produces a high-solids effluent that flows to the flush pond where the solids settle. Between draining events, the limestone is flooded and water flows through continuously, producing an alkaline low-metal effluent directly to Morgan Run tributary. Perforated flush plumbing is located parallel to the influent fountain at toe of slope on inside bottom below the fountain.

Inspections

Inspection tasks:

1. Check the influent fountain. Water should enter the DLB through the perforations in the influent fountain not through the upturned elbow at the end of the fountain. Flow out of the upturned elbow indicates blockage of perforations in the fountain or excessive flow into the system.
2. Check for water level above the level of the limestone. Water should not be visible during normal operation. Under high flows, water may be visible but should not rise above the limestone and allow for flow over the stone rather than through it.
3. If the DLB effluent is cloudy or milky during normal flow (not during a flush event) then it is likely that aluminum has accumulated within the limestone that must be removed.
4. If the effluent of the DLB has pH below 6.0 under normal flow conditions, system monitoring should be increased to at least monthly. Two consecutive months of effluent pH between 5.5 and 6.0 indicates that minor maintenance actions should be taken to improve performance while plans

are made for more permanent solutions. Effluent pH below 5.5 indicates that major maintenance is required and should be implemented as quickly as possible.

5. Inspect WLCS to check for excessive corrosion of metal components
6. Observe bypass: measure or estimate flow rate

Maintenance

The bulk of the treatment occurs in the DLBs and as a result their maintenance is extremely important. Maintenance tasks are divided into minor and major categories. Minor maintenance tasks are tasks that can be typically performed with hand tools and generally do not involve replacement of treatment components. Minor maintenance should be considered a temporary measure to boost performance until major maintenance can be performed. Major maintenance tasks involve heavy equipment and replacement of treatment materials.

Minor maintenance of DLBs involves the following:

1. Temporarily increasing the frequency of flushing can address both the loss of permeability and declining effluent quality of the DLB. The SDS can be programmed to flush every day or every other day. Increased flushing frequency will temporarily reduce the quality of the effluent but it may improve permeability. Once permeability is restored flushing interval can be lengthened to improve effluent quality. This should be considered a temporary measure to boost performance until major maintenance can be performed.
2. Remove boards from the WLCS until the water level is below the top of the limestone.
3. Repair or replace corrosion-damaged parts

Major maintenance of DLBs involves the following:

Flushing of solids from the limestone is not 100% effective so mechanical removal of the solids will be required eventually. This is accomplished by mixing and rinsing the stone using an excavator and pumps. The goal of the cleaning is to remove solids from the limestone bed. Simply mixing the stone, and moving the solids to the bottom of the bed where the plumbing is located, is NOT sufficient. A procedure for mechanically cleaning the limestone that has been used effectively at other sites follows:

1. Mobilize an excavator to the site. An excavator with minimum 1 cubic yard bucket should be utilized. A smooth bucket (no teeth) is recommended to prevent damage.
2. Empty the flush pond using the flush pond SDS valve (from the screen with four arrows press and hold ESC+arrow up), closing the valve afterward.
3. Empty DLB by opening the SDS valves.
4. Excavate limestone to locate and uncover the perforated 16-inch outlet pipe on the bottom of the bed. Remove the end cap from the 16-inch outlet pipe (which is not glued).
5. Excavate a trench through the limestone (to the bottom of the bed) from the open end of the 16-inch outlet pipe to the upturned end of the influent fountain. The bottom of the DLB is sloped toward the 16-inch outlet pipe to help move solids out of the bed as the limestone is cleaned.
6. Pump water from the settling pond into the trench to carry solids out of the bed as limestone is cleaned. A 4” trash pump is sufficient but a 6” pump is preferred.
7. Clean limestone by dropping and mixing the stone in standing water. Impound water for washing by placing stone in the channel so that water backs up slightly. Alternatively, a stone box can be used as a wash basin if solids are carefully managed. Keep the stone box on dirty stone to avoid washing solids onto limestone that has already been cleaned.

8. Work from the influent toward the effluent being careful to keep clean and dirty stone separate. Occasionally solids will accumulate in the channel. These can easily be cleared by disturbing them with the excavator bucket. Denser solids may need to be shoveled out. Monitor the outlet of the flush pond to ensure that the effluent is clear. If solids begin to discharge from the flush pond, work should cease until the water in the settling pond clears then water can be released using the flush pond SDS to create storage before work resumes.
9. Replace the cap on the 12-inch outlet pipe and regrade stone to level. Additional limestone may be required to replace what has dissolved through treatment as well as make up for some settling.
10. Close the SDS valves and cleanup site as needed.
11. Methods for cleaning limestone using mechanical screen, water and pumps are being developed and will likely be preferred method when these systems are in need of limestone cleaning.

Water Level Control Structures and Smart Drainage System

Design and Function

The water level in the drainable limestone beds and flush pond is controlled by inline water level control structures (WLCS). The WLCSs are manufactured by Agri Drain Inc. (see Appendix for contact information) and consist of a PVC box with inlet and outlet pipes connected to its base and a series of boards that divide the interior of the box in half. Water backs up on one side of the boards in order to flow over and out the other side. Adding or removing boards raises or lowers the water level. These boards are either 5" or 7" in height permitting various combinations of board heights to be used to achieve the desired water level.

Each DLB has two WLCSs: one for primary flow and one for flush flow. Flush WLCSs are equipped with the Smart Drainage System (SDS). The SDS consists of an electrically actuated gate valve installed in the bottom board of the WLCS. The actuator is controlled by a computer and powered by a solar-charged battery. These components are mounted to a post next to the WLCS. Each DLB uses one control unit to actuate a pair of valves installed in parallel.

All of the SDS-equipped WLCSs have the boards installed to the maximum elevation to prevent discharge over the boards. The flush plumbing is installed very near the influent of the DLB so the flush WLCS should not be used as a primary discharge during normal operation.

The draining interval and duration can be programmed on the unit following the manufacturer's instructions. The units are programmed to drain each DLB once per week with flushing times staggered so that there is 3-4 days between flushes.

Inspections

The WLCSs should be inspected visually for signs of damage or degradation. Inspection of the SDS involves checking for proper function of the mechanism, power supply and controls.

1. Visually inspect for damage
2. Check battery voltage
3. Actuate valve to verify function. Do not completely open valve and close rapidly when the DLB is full. Stopping the large volume of water released by the valve will cause significant stress on the structure and could cause damage. Close the valve a few inches at a time with pauses in-between to allow the flow to slow gradually. Water draining from an empty or nearly empty DLB occurs at a much lower flow rate and can be closed rapidly without damage.

Maintenance

The WLCS require minimal maintenance but should be checked annually for proper function by doing the following:

1. Grease seals on boards
2. Replace worn or damaged parts

The SDS contains parts that degrade over time and must be periodically replaced. The major components and their replacement procedure are outlined below:

Solar Panels – Each unit is powered by a single 30 watt solar panel. The solar panels have a service life in excess of 20 years. The primary cause of failure is theft or vandalism. Replace solar panels with units having the same specifications as those shown on the back of the existing panels. Replacements may be purchased from any vendor or manufacturer.

Batteries – The batteries can be expected to last 3-5 years. Replace batteries when they fail to maintain charge level. Battery specifications are shown on the battery label. Replacements must be of similar dimensions as the original, so they fit within the enclosure. Replacements may be purchased from any vendor or manufacturer.

Actuators - The actuators typically last about 3 years. The actuators bolt in place and are easily removed. Replace actuators with units having the same specifications (stroke length, max force, voltage, etc.) Specifications are shown on the actuator body. Replacements may be purchased from any vendor or manufacturer.

Computer - The computer is a programmable logic controller. Service life is 10 or more years. Contact Agri Drain for replacement units.

Valve – The valve is a Valterra gate valve that has been bolted to a specially made WLCS board. To repair or replace the valve, the board and valve assembly can be removed like the WLCS boards, though with more effort required.

Flush Pond

Design and Function

Treatment of the mine water causes the formation of metals solids that are captured in ponds. The North Culvert and Pit Spring Systems contains one pond for this purpose. The flush pond only receives water discharged during draining events (flushes). This basin contains an internal aggregate baffle for the purpose of filtering metal solids as water passes from influent end to the effluent end of the flush pond.

Inspections

Inspection tasks:

1. Check for proper flow into and out of pond
2. Check for visible signs of damage to the berms or liners by erosion, vandalism or animals
3. Water level should be below the elevation of the emergency spillways. Check emergency spillways for signs of flow that would indicate recent high water events that should be investigated.
4. Note sludge accumulation.

Maintenance

Any obstruction to flow or damage to the berms or liners should be addressed promptly.

Sludge removal - Eventually the accumulation of solids (sludge) will reach a point that degrades the ability of the ponds to settle solids. When this occurs, it is necessary to remove the sludge. The sludge is non-hazardous and can be disposed of by burial on site (with landowner permission) or landfilled.

1. Prevent water from flushing to the pond.
    a. To prevent flow to the flush pond, disable the SDS controllers by unhooking the cable from the controller to the actuator.
2. Remove clear water from the pond to the stream.
    a. The settling pond can be decanted by siphoning or pumping. Siphoning allows for slow withdrawal of water setting upon the sludge that is to be pumped and will work throughout day and night without use of fuel. A section of filter sock and filter media upstream of the sock should be used to prevent solid particulates from the siphon/pump transfer to the stream.
3. Pump sludge into on-site disposal pit (if permitted) or into trucks for proper disposal off-site. This activity is best conducted by an experienced mine water treatment company.

System Inspections

A system inspection involves visual observations and simple water sampling. The entire process will require 1-2 hours and should occur quarterly. An inspection form is attached to this plan and component-specific descriptions and details are included in the following sub-sections. Use the "Notes" section to record any other relevant information about the site, such as signs of vandalism, sample numbers if lab samples are taken, or other information. This information should then be incorporated into a master spreadsheet containing water quality laboratory results that can be shared with others electronically and stored for historical purposes.

The following table provides key observations. If no problems are apparent, then the inspection is complete. The finding of "no problems" should be recorded and preserved in the project files and entered into the spreadsheet. If problems exist, then additional investigation should occur as discussed in the relevant section.

Sampling

Sampling locations are shown in Figure 3. During each inspection the flow rate and pH of water leaving each DLB should be measured. The DLBs are sampled at the two pipes discharging into small drainages to Morgan Run. If possible, flows should be measured using a bucket and stopwatch to produce gallons per minute. If the conditions are hazardous (e.g. icy slopes) or the flow too great, the flow rate can be estimated by measuring the depth of water over the boards in the primary water level control structures. Alkalinity is also a valuable field measurement but requires a titrating device. If this device is available, measure the alkalinity of the treated water.

At least twice a year, sampling for laboratory analyses should be conducted. The samples should be analyzed by a qualified laboratory for standard AMD parameters (pH, conductivity, alkalinity, acidity, Fe, Mn, Al, total suspended solids, and sulfate). The laboratory should provide bottles and reagents necessary to properly collect the samples.

Troubleshooting Guide

Problem	Potential Cause	Solution
No flow to North Culvert DLB	Intake clogged	Clean intake screen
Pit Spring collection area has new seepage	The collection system is leaking	Re-construct the AMD collection system.
No flow out of DLB	DLB is refilling following flush event	Check again on different day of week or under higher flow conditions
	Outlet pipe blocked	Check for obstruction of outlet pipe. Remove any obstruction.
DLB water level is above the top of the limestone	Boards in water level control structure not set at proper elevation.	Compare water level behind boards in water level control structure to water level in DLB. Adjust height of boards as necessary.
	Loss of permeability due to metals solids accumulation.	Remove board in effluent WLCS; Adjust SDS to increase frequency of flushing events; consider mixing or cleaning of limestone
Influent is not distributed across influent pipe	Holes are plugged or pipe is not level	Unplug holes; re-level the pipe, drill more holes in areas of dry holes
DLB performance (pH, alkalinity) declines over time	Change in raw AMD chemistry or flow rate	Review data to determine if the chemistry or flow of the discharge has changed. Consider treatment system modification if change is considered permanent.
	Limestone has been fouled by solids	Mix or clean limestone aggregate.
	Limestone is being consumed	Add more limestone to replace the limestone that has dissolved
Damage to pipes, berms, or structures	Muskrat or beaver activity is apparent in the system and is interfering with performance	Contact the Pa Game Commission or a local trapper and have animals removed.
	Vandalism	Repair damage, restrict access to site
Smart Drainage System not functioning	Low battery voltage	Test voltage of battery; replace if necessary. Check solar panel connection and orientation
	Equipment damage	Replace damaged parts
	Inconsistent charging	Check connections. Remove vegetation blocking solar panel, replace solar panel and charge controller
	Other problems	Contact Agri Drain
Vegetation	Vegetation blocking water flow or site access	Remove vegetation
	extensive woody vegetation	Remove vegetation

Passive Treatment System Inspection Form

Inspector _____ Date _____

Recent weather (wet, dry, cold, hot) _____

Table 1. Checklist for a Routine Inspection		**Y/N**	**Action**
Location	**What To Look For**		
AMD Collection	Is there water flowing in the channel below?		Y
Drainable Limestone Beds	Is the water level above the top of the limestone?		Y
	Is there evidence of vandalism to the Smart Drainage System?		Y
	Is the battery in the SDS charged?		N
	Is the effluent cloudy?		Y
	Is there excessive flow from the subsurface drains?		Y
Flush Pond	Is the water level below the emergency spillway?		N
	Is the sludge level below the level of the outlet pipe?		N
Animal Problems	Is there evidence of beaver or muskrat activity in the system?		Y
ATV Problems	Is there evidence of erosion or damage due to ATVs?		Y
Berms	Is there excessive growth of woody vegetation on the berms?		Y
	Are berms around the DLBs and flush pond competent?		N

Miscellaneous Observations: Detail any problems here

Flow and Water Sampling Information Data Collection Sheet

Inspector _____ Date _____

Recent weather (wet, dry, cold, hot) _____

North Culvert System

Location	Flow (gpm)	pH	Temp	Alkalinity	Notes
North Culvert Raw AMD				N/A	
North Culvert DLB Out					

Pit Spring System

Location	Flow (gpm)	pH	Temp (°C)	Alkalinity (mg/L)	Notes
Pit Spring Raw AMD				N/A	
PS DLB out					

Project Partners and Materials Suppliers Contact Information

Project Management/Sponsor
Clearfield County Conservation District
contact: Kelly Williams, 814-765-2629

Treatment System Design
Hedin Environmental, 195 Castle Shannon Blvd, Pittsburgh PA 15228
Contact: Neil Wolfe, nwolfe@hedinenv.com, 570-295-0063
Contact: Ben Hedin, hedinb4031@gmail.com, 412-215-0239

Treatment System Construction
TP Contracting 402 Beck Road Loretto, Pa. 15940

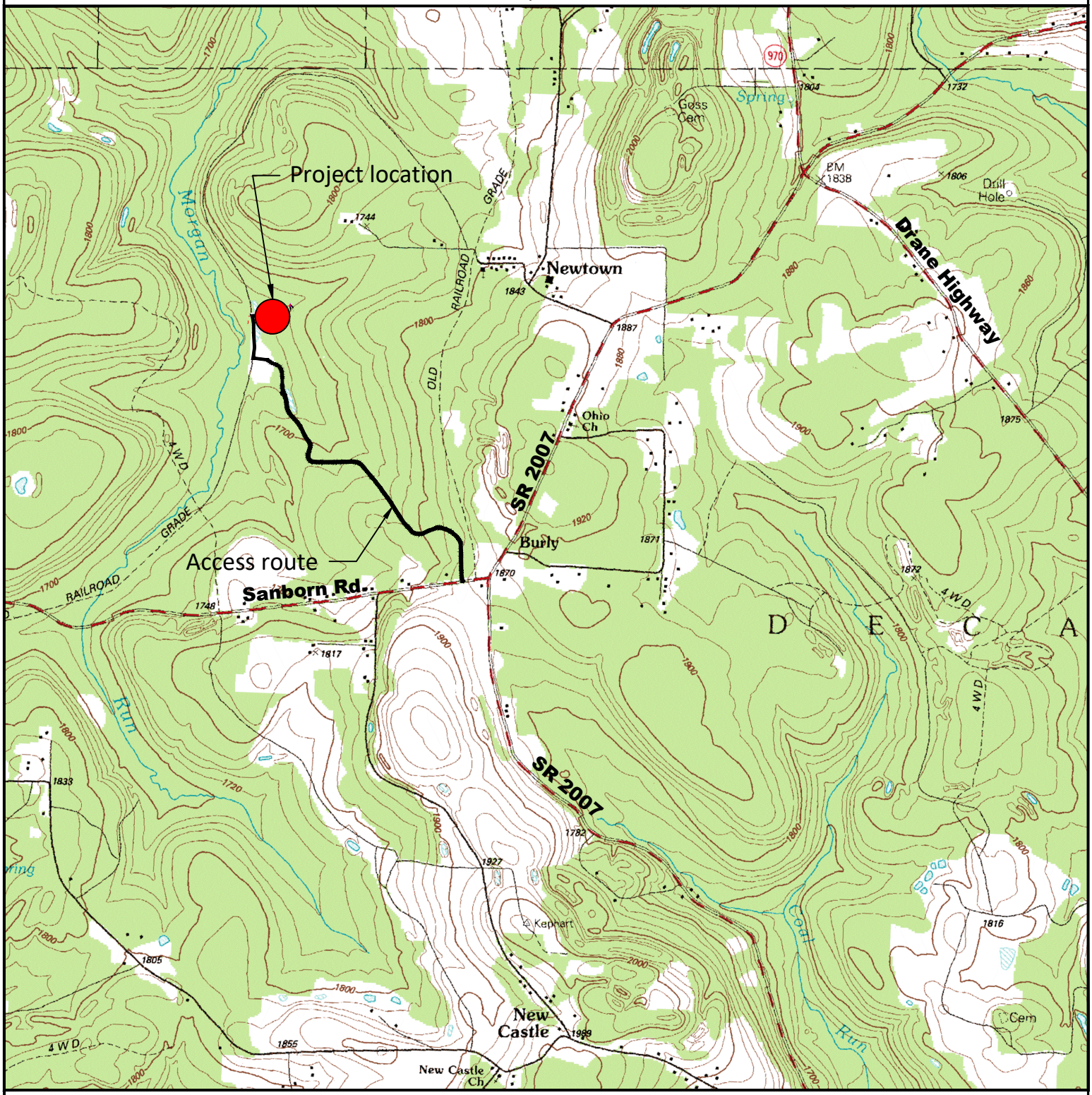
Water Level Control Structures and Smart Drainage Systems
Agri Drain Corporation, Adair, Iowa 50002
www.agridrain.com, 800-232-4742

Limestone Aggregate for Drainable Limestone Beds
Con-Stone, 5563 Penns Valley Rd, Aaronsburg, PA 16820
Contact: Jeff Confer, (814) 349-2400

Figure 1

Morgan Run MR-7
Passive Mine Water Treatment Project

Decatur Township, Clearfield County, PA
Clearfield County Conservation District



Wallaceton, PA USGS 7 1/2' quadrangle

Geographic coordinates: 40.9045°, -78.3583°

GRAPHIC SCALE

2,000 0 1,000 2,000

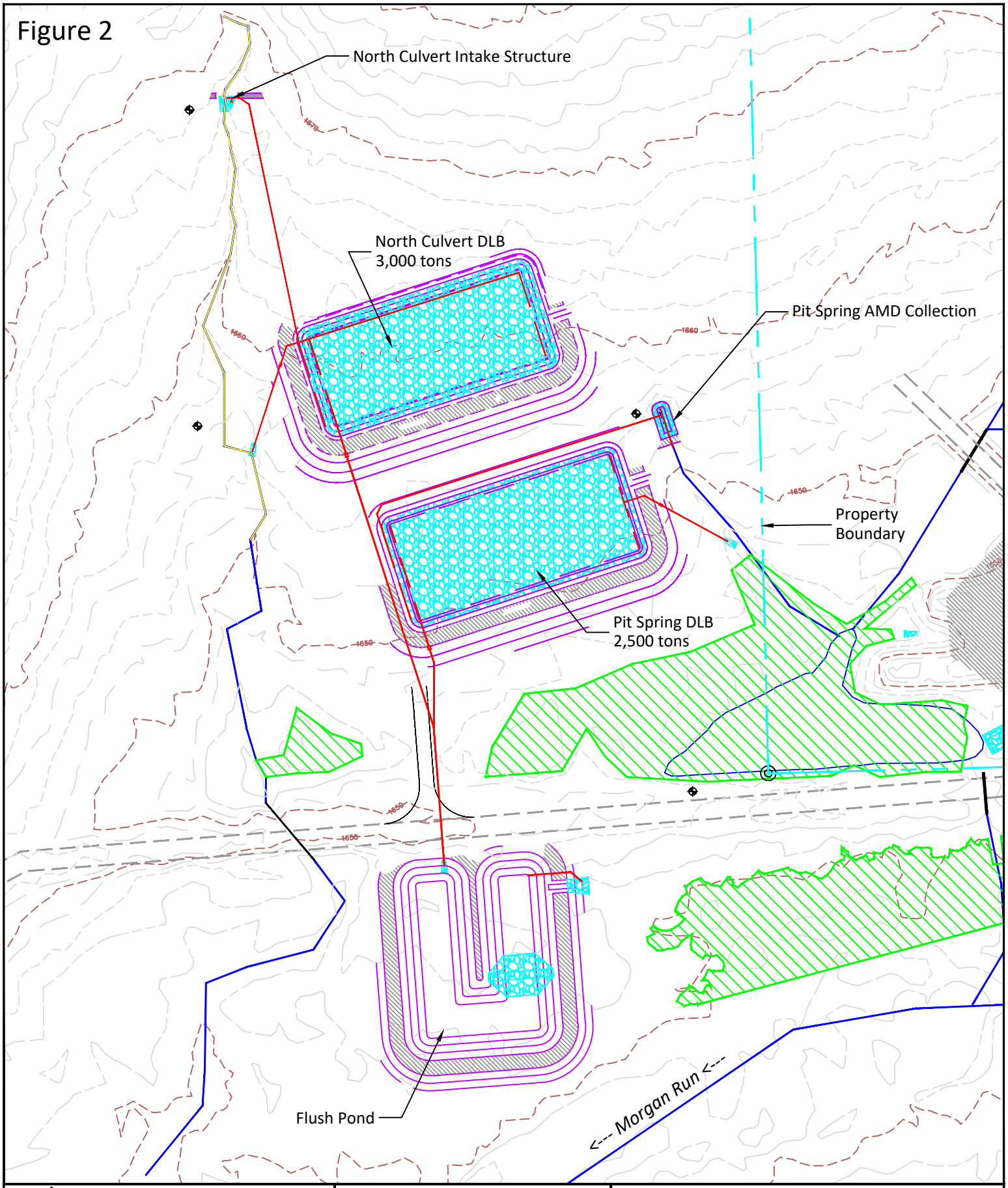
1 INCH = 2,000 FEET

HedinEnvironmental
195 Castle Shannon Blvd.
Pittsburgh, PA 15228
www.hedinenv.com

Site Location and Access Map

Municipality:	Date:	
Decatur Twp.	10/31/23	
COUNTY:	Drawn by:	Scale:
Clearfield	NAW	As shown

Figure 2



GRAPHIC SCALE

100 0 50 100

1 INCH = 100 FEET

C.I = 2'

HedinEnvironmental

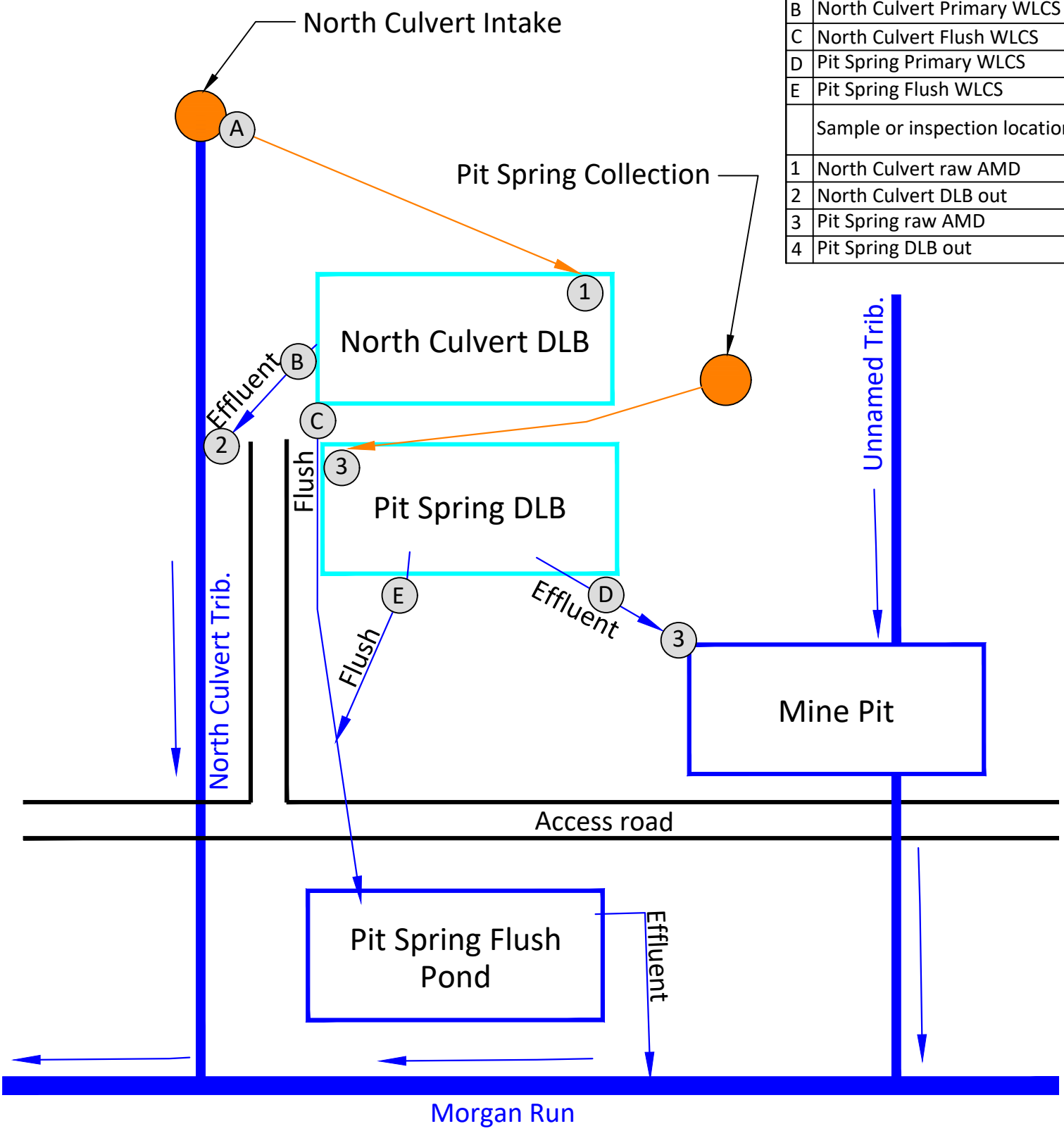
195 Castle Shannon Blvd.
Pittsburgh, PA 15228
www.hedinenv.com

North Culvert and Pit Spring Treatment System Site

Municipality:	Date:	
Decatur Twp.	10/31/23	
COUNTY:	Drawn by:	Scale:
Clearfield	NAW	As shown

Figure 3

	Water level control structures (WLCS)
A	Intake WLCS
B	North Culvert Primary WLCS
C	North Culvert Flush WLCS
D	Pit Spring Primary WLCS
E	Pit Spring Flush WLCS
	Sample or inspection location
1	North Culvert raw AMD
2	North Culvert DLB out
3	Pit Spring raw AMD
4	Pit Spring DLB out



NO SCALE

HedinEnvironmental
195 Castle Shannon Blvd.
Pittsburgh, PA 15228
www.hedinenv.com

North Culvert and Pit Spring Treatment System Flow Diagram

Municipality:	Date:	
Decatur Twp.	10/31/23	
COUNTY:	Drawn by:	Scale:
Clearfield	NAW	As shown