WATERSHED BASED PLAN FOR THE BEAVER CREEK WATERSHED, WEST VIRGINIA

Submitted to:

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List of Abbreviations

AMD	Acid Mine Drainage
AML	Abandoned Mine Land
AMLIS	Abandoned Mine Land Inventory System
BFS	Bond Forfeiture Site
BMP	Best Management Practice
DC&C	Davis Coal & Coke
WVDOT	West Virginia Department of Transportation
EPA	Environmental Protection Agency
FOB	Friends of Blackwater
HUC	Hydrologic Unit Code
LA	Load Allocation
LR	Load Reduction
MOS	Margin of Safety
NHD	National Hydrography Dataset
NMLRC	National Mine Land Reclamation Center
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Unit
OAMLR	Office of Abandoned Mine Lands and Reclamation
OLC	Oxic/Open Limestone Channel
OSMRE	Office of Surface Mining Reclamation and Enforcement
PAD	Project Area Description
RAP	Reducing and Alkalinity Producing System
RM	River Mile
SMCRA	Surface Mining Control and Reclamation Act
SWS	Subwatershed
TMDL	Total Maximum Daily Load
TIC	Terraced Iron Formations
USACE	United States Army Corp of Engineers
UNT	Unnamed Tributary
WBP	Watershed Based Plan
WLA	Wasteload Allocation
WVDEP	West Virginia Department of Environmental Protection
WVDNR	West Virginia Division of Natural Resources
WVGES	West Virginia Geological and Economic Survey
WVSCI	West Virginia Stream Condition Index
WVU	West Virginia University
WVU-NRAC	West Virginia University – Natural Resource Analysis Center

1. Introduction

This Watershed Based Plan (WBP) covers Beaver Creek located in West Virginia, from its headwaters along the Eastern Continental Divide to its mouth at the Town of Davis; including all tributaries (Figure 1). Beaver Creek, Hawkins Run – a principle tributary to Beaver Creek – and several unnamed tributaries are listed as impaired by the West Virginia Department of the Environment (WVDEP) for acid mine drainage (AMD) and acid deposition associated pollutants. Temperature and sediment impairments linked to stream channelization and erosion, reductions in canopy cover, unfettered recreational activity, and highway development have also been documented.

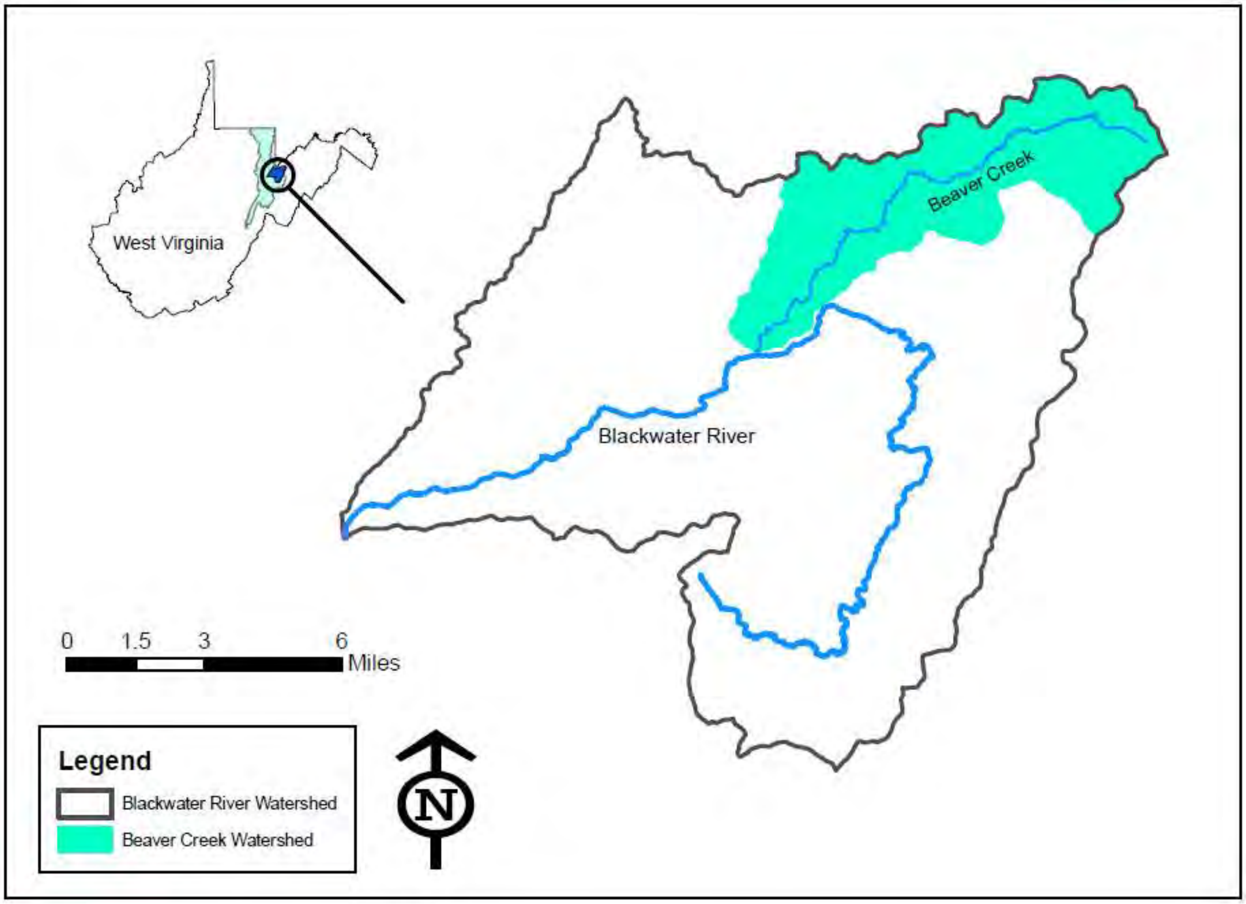


Figure 1. Beaver Creek watershed within the Blackwater River watershed.

This document provides guidance for agencies interested in implementing projects that target ecological restoration of the watershed. Funding for these projects will come principally from Environmental Protection Agency (EPA) Section 319, Office of Surface Mining, Reclamation and Enforcement (OSMRE), WVDEP, non-governmental organizations and donations from interested persons.

After providing background information on the natural and human history of the watershed, this WBP establishes a framework for recovery of the watershed by first identifying water quality targets (Section

2), describing the impairment sources (Section 3) and methods of remediation available(Section 4), and quantifying the extent of remediation needed to achieve water quality targets. This plan then discusses current remediation efforts (Section 6) and proposes new ones (Section 7); including design and cost estimates. In the remaining sections this WBP addresses technical and financial assistance availability (Section 8), discusses recovery assessment (Section 9) and monitoring (Section 10), documents the authoring organization's outreach and education program (Section 11), and proposes an implementation schedule (Section 12).

This WBP corresponds to the following Hydrologic Unit Codes (HUC): Cheat River – 0502004 (8-digit), Blackwater River – 0502000402 (10-digit), Middle Blackwater River – 050200040202 (12-digit).

1.1 Environmental Characteristics

Beaver Creek is a principle tributary of the Blackwater River, itself a tributary to the Cheat River whose waters ultimately flow to the Mississippi River Basin via the Monongahela and Ohio rivers. The Beaver Creek watershed drains an area of 23 square miles and is located entirely within Tucker County, West Virginia. The main channel flows approximately 15 miles from its headwaters at 4131 feet to its confluence with the Blackwater River at 2963 feet near the eastern edge of the town of Davis. The watershed is separated from the federally protected Canaan Valley wetland complex and the upper Blackwater River basin to the south by Brown Mountain.

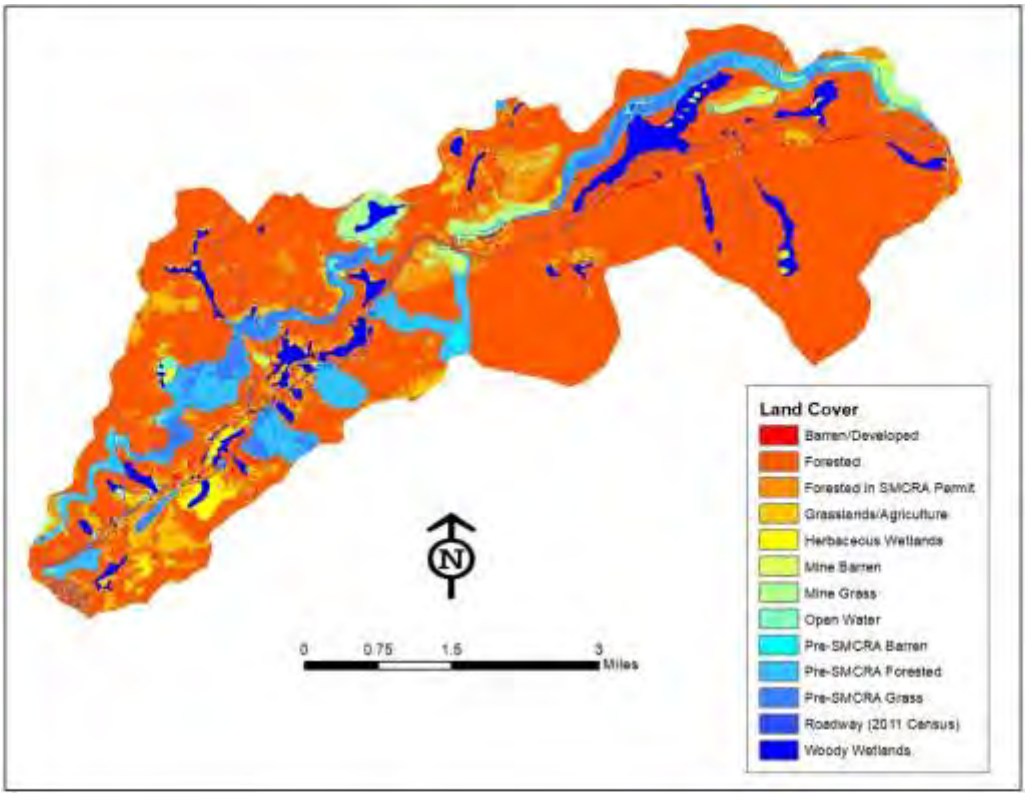


Figure 2. Land cover in the Beaver Creek watershed. Data source: WVU-NRAC, 2011.

Due in large part to the high elevation of the area, the flora and fauna of the Beaver Creek watershed are more similar to those found in Canada than to those in other areas at the same latitude. The West Virginia Division of Natural Resources (WVDNR) categorizes the watershed as part of the Allegheny Mountain Ecoregion Conservation Focus Area which is notable for supporting nearly all of the Red Spruce forests, most heath-grass barrens, the majority of high elevation Allegheny wetlands and a significant amount of coolwater stream habitat in the state of West Virginia (WDNR, 2015). This unique amalgam of wetlands, bogs and streams in turn serve as refugia for migratory birds and nearly endemic species of concern such as the Cheat Mountain Salamander (*Plethodon netting*) and the West Virginia Northern Flying Squirrel (*Glaucomys sabrinus fuscus*).

Over two-thirds of the watershed is forested with the remaining lands a mixture of grasslands, wetlands, water, barren mine lands, and roads. With the arrival of the Corridor H highway, the proportion of impervious roadway cover is certainly higher than documented in 2011 as shown in Figure 2. More than 15% of the watershed has been subject to mining activity at one time or another with the majority of those lands pre-dating the 1977 Surface Mining Control and Reclamation Act (SMCRA).

The majority of surface and near-surface rocks in the watershed are classified as part of the Conemaugh and Allegheny groups (Figure 3) which extend from the bottom of the Pittsburgh coal seam down to the top of the Upper Freeport coal seam, and from the top of the Upper Freeport coal to the top of the Homewood Sandstone, respectively (Viadero & Fortney, 2015). Of significance is the fact that Upper Freeport coal is known to contain high concentrations of pyritic material, with the associated drainage characterized by low pH and elevated levels of dissolved metals.

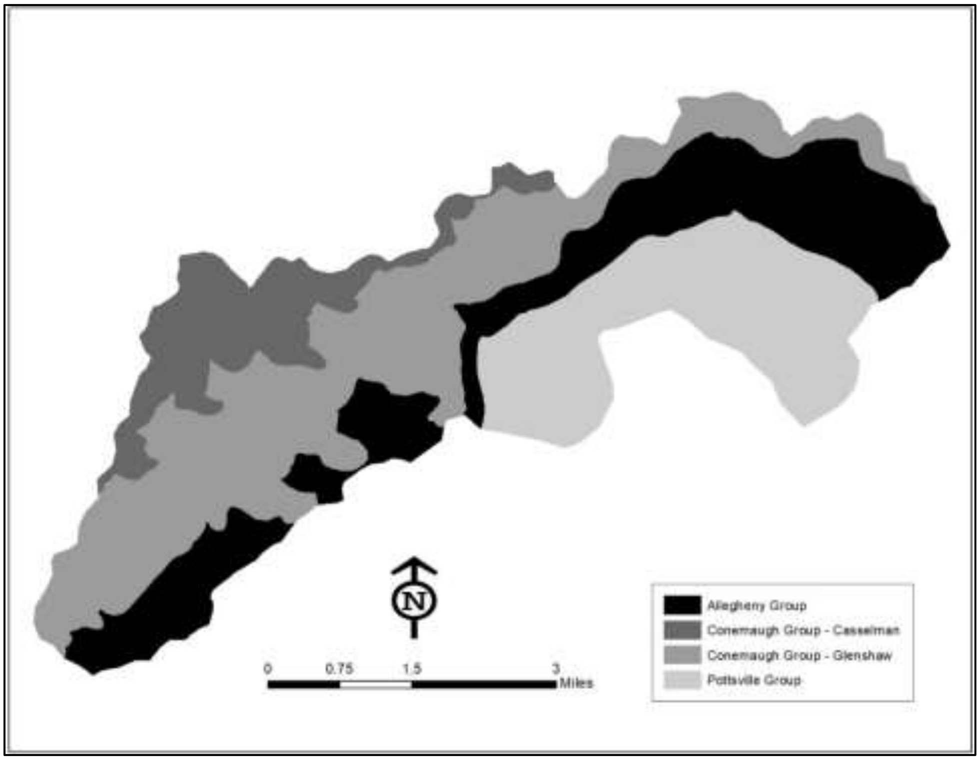


Figure 3. Geology in the Beaver Creek watershed. Data source: WVGES, 1999.

1.2 History and Economic Development

Wanting to establish a town along the junction of Beaver Creek and the Blackwater River, Henry Gassaway Davis extended his West Virginia Central & Pittsburgh Railway from Thomas to the future town of Davis in 1884. Rapid economic developed coincided with the arrival of the railroad and by 1889 the population of the town was 909 (Phillips, 2005). Now with the means to ship material to market, industrial interests were eager to capitalize on the area's abundant reserves of timber and coal.

Figure 4. Babcock lumber mill. Source: Western Maryland Historic Society

The first sawmill in Davis was started by Jacob Rumbarger in 1886. In 1891, the Beaver Creek Lumber Company began operation, and was one of the largest and finest plants of its kind in West Virginia. The company also established 22 miles of standard gauge railroad running northward along Beaver Creek which it used to haul all its timber. In 1907, the Babcock Lumber and Boom Company bought Thompson Lumber Company mill and began operation (Figure 4). This single mill was said to have manufactured more than 850 million board feet of lumber during its 17 years of operation, helping make Babcock the world's largest producer of hardwood lumber during the early 20th century (Grafton, 2012).

Operating principally out of the neighboring town of Thomas, Davis Coal and Coke (DC&C) began mining in 1882 in what was called the "Upper Potomac Coal Field" which included the Upper Freeport and Bakerstown coal seams. While the majority of mining took place in the adjacent North Fork watershed, the railroad extension to Davis allowed for extraction and transport of easily recoverable coal from the Beaver Creek watershed as well. DC&C dominated area coal production until its closure in 1950.

After swelling to a population of over 2500, Davis was on the decline by the late 1920's; all the trees had been cut and all the easy-to-reach coal had been mined. On October 6, 1942, the track into Davis was removed and the station torn down. However, only that portion of the track that entered into town was removed; the remainder was extended into the remaining coal fields along Beaver Creek. After 1950, strip mining took over in the region, and continues to this day. Production was far lower than in the early 20th century however, and by the 2000 census, the population of Davis had decreased to 624.

Tourism has emerged as a growing economic force in the 21st century. Local attractions such as the Monongahela National Forest, Blackwater Falls State Park, Canaan Valley Resort State Park and the Canaan Valley National Wildlife Refuge draw hundreds of thousands of outdoor recreationalists to the area each year. This in turn has attracted new residents to the town as well, and in 2010 the population of Davis increased to 660; the first increase in a hundred years. With the near completion of the Corridor H highway and the continued decrease in recoverable coal, tourism is likely to play an increasingly significant role in the area's economy for the foreseeable future.

2. Water Quality Goals

The Clean Water Act section 303(d) requires states to identify stream reaches that do not meet water quality standards. Numeric and narrative standards are set by federal and state regulators, and can vary depending on the designated use of the stream (Table 1). The entire length of Beaver Creek and multiple tributaries to it are identified as impaired because they fail to support one or more of these designated uses: maintenance and propagation of aquatic life (warm water fishery streams or trout waters), public water supply, and/or water contact recreation.

Table 1. West Virginia state water quality criteria for select parameters. Source: WVDEP, 2016.

PARAMETER	**AQUATIC LIFE**				**HUMAN HEALTH**	
	Warm Water Fishery		**Trout Waters**		**Public Water Supply**	**Contact Recreation**
	Acute[a]	**Chronic[b]**	**Acute[a]**	**Chronic[b]**		
Aluminum, dissolved (ug/L)	750[α]	750[α]	750[α]	87[α]	--	--
Iron, total (mg/L)	--	1.5	--	1.0	--	--
Manganese, total (mg/L)	--	--	--	--	1.0	--
pH	No values below 6.0 or above 9.0. Higher value due to photosynthetic activity… tolerated					
Biological Impairment	[N]o significant adverse impact to… biological components of aquatic ecosystems… allowed					
Turbidity	No point or non-point source to West Virginia's waters shall contribute a net load of suspended matter such that the turbidity exceeds 10 NTUs over background turbidity when the background is 50 NTUs or less, or have more than a 10% increase in turbidity (plus 10 NTU minimum) when the background turbidity is more than 50 NTUs					

[a] One-hour average concentration not to be exceed more than once every 3 years on the average.

[b] Four-day average concentration not to be exceeded more than once every 3 years on the average.

[α] For water with pH <6.5 or >9.0. Otherwise the acute and chronic standards are determined by the following equations, respectively: $Al = e^{(1.3695[\ln(\text{hardness})]+1.8268)}$ and $Al = e^{(1.3695[\ln(\text{hardness})]+0.9121)}$.

In 2011, WVDEP completed a total maximum daily load (TMDL) analysis for streams within the Cheat River basin, including several within the Beaver Creek watershed (Table 2). A TMDL is a quantitative assessment of the maximum amount of a given pollutant a stream can receive over a period of time and still meet water quality standards. TMDLs account for both point and nonpoint source pollution – also known as waste load allocation (WLA) and load allocation (LA), respectively – and include a margin of safety (MOS) to address the uncertainty in the calculation. A TMDL is expressed as:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

When the *true* load of a given pollutant exceeds the TMDL value for that pollutant in a segment of stream, then that segment can be considered impaired. TMDLs are a useful quantitative means of assessing the extent of restoration necessary to meet water quality standards.

The principle goal of this plan is to facilitate the implementation of restoration projects capable of improving water quality to such an extent that presently impaired stream reaches within the Beaver Creek watershed are capable of achieving their designated use.

Table 2. TMDLs developed for streams in the Beaver Creek Watershed. Source: WVDEP, 2011.

Stream Name	**Stream Code**	**Parameter**	**LA (lbs/day)**	**WLA (lbs/day)**	**MOS (lbs/day)**	**TMDL (lbs/day)**
Beaver Creek	WV-MC-124-K-23	Aluminum	21.77	17.20	2.05	41.02
		Iron	111.72	49.09	8.46	169.27
		Acidity$^{\delta}$	-626.80	N/A	-32.99	-659.79
Hawkins Run	WV-MC-124-K-23-C	Aluminum	1.96	N/A	0.10	2.07
		Acidity$^{\delta}$	-60.34	N/A	-3.18	-63.51
UNT/Beaver Creek RM 11.91	WV-MC-124-K-23-K	Acidity$^{\delta}$	-71.80	N/A	-3.78	-75.58
UNT/Beaver Creek RM 11.36	WV-MC-124-K-23-J	Aluminum	0.44	N/A	0.02	0.47
		Iron	5.26	0.67	0.31	6.24
		Acidity$^{\delta}$	-24.08	N/A	-1.27	-25.35

$^{\delta}$ Acidity load is calculated as lbs/day of CaCO3. Calcium carbonate is used as an equivalent due to its molecular weight of 100g/mol which allows for easier comparison across differing solutions.

3. Sources of Impairment

The main channel of Beaver Creek, one of its two named tributaries and three unnamed tributaries are listed on the West Virginia 303(d) list of impaired streams for biological, pH, iron and/or aluminum (Figure 5, Table 3).

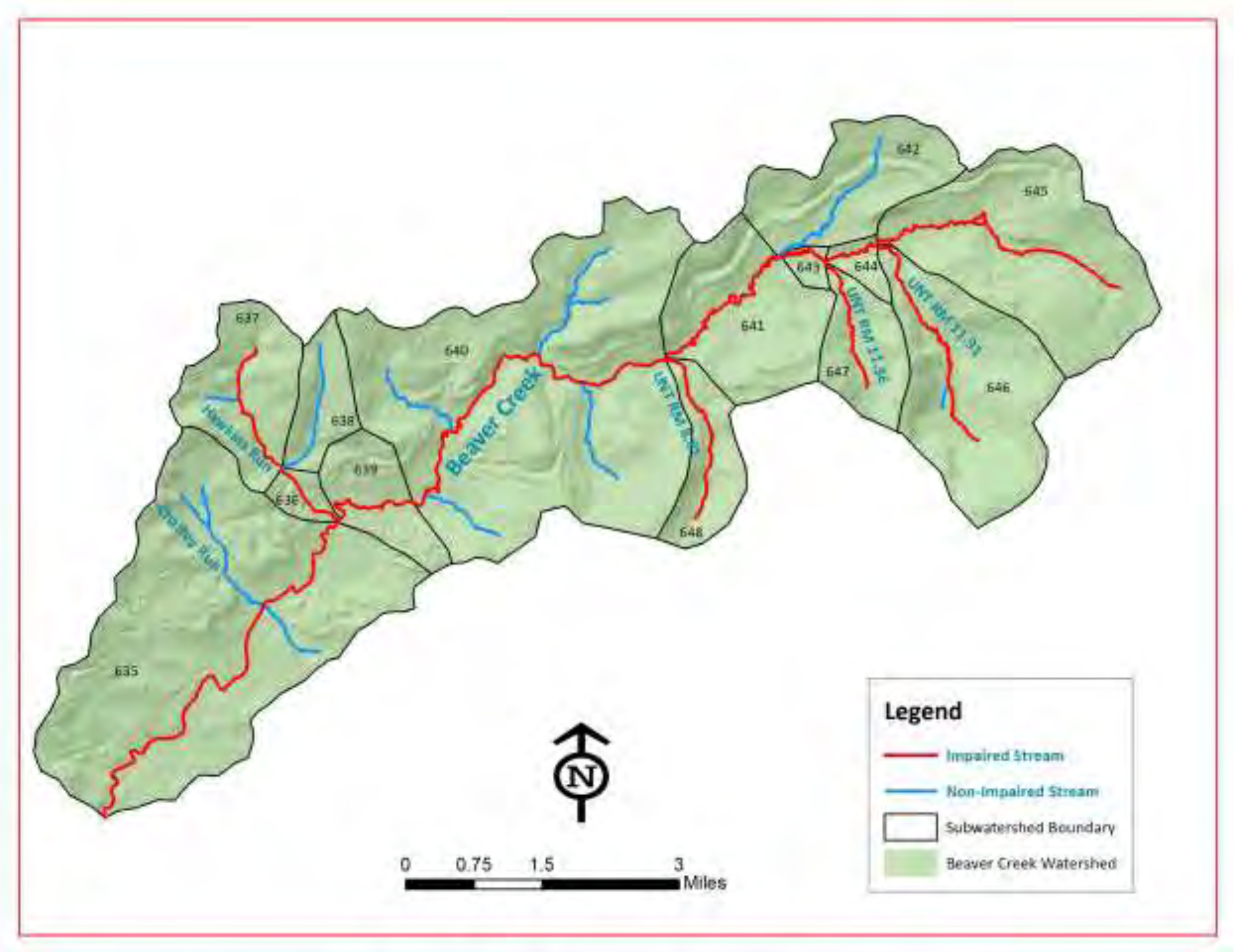


Figure 5. Impaired and non-impaired stream reaches and subwatershed boundaries in the Beaver Creek watershed.

Table 3. Impairment listing for stream reaches in the Beaver Creek watershed.

Stream	WV Stream Code	NHD Code	Length	pH	Fe	Al	Bio
Beaver Creek	WVMC-60-D-5	WV-MC-124-K-23	15	x	x	x	x_p
Hawkins Run	WVMC-60-D-5-C	WV-MC-124-K-23-C	2.1	x		x	
UNT/Beaver Creek RM 8.81	WVMC-60-D-5-E	WV-MC-124-K-23-H	1.7	x			
UNT/Beaver Creek RM 11.36	WVMC-60-D-5-G	WV-MC-124-K-23-J	1.3	x	x_t	x_t	
UNT/Beaver Creek RM 11.91	WVMC-60-D-5-H	WV-MC-124-K-23-K	2.1	x			x

$_p$ Indicates the impairment is for a portion of the waterways length

$_t$ Indicates the impairment is based on the more stringent *trout* waters standards

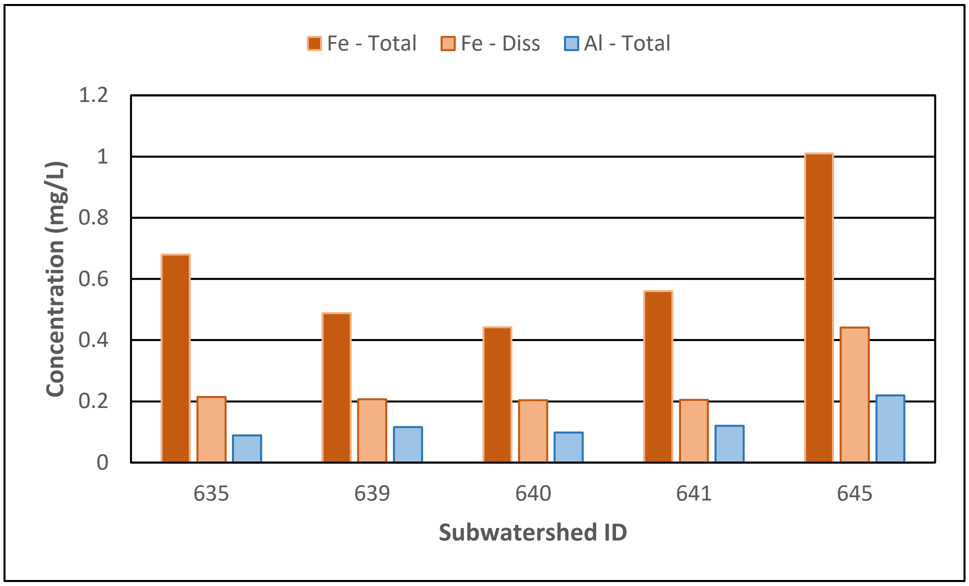


Figure 6. Median metals concentrations in Beaver Creek at SWS outlets. Data Source: FOB

According to the TMDL and 303(d) list, the main stem of Beaver Creek is impaired for metals toxicity along its entire length. The sources for metals impairment include both permitted point sources and nonpoint sources with the 2011 Cheat TMDL report attributing 68% of aluminum loading and 79% of iron loading to nonpoint sources. Nonpoint sources include AMD seeps discharging directly into the stream, alterations to terrestrial landscapes associated with increased sediment loading, and outflow from tributaries which themselves are receiving waters for AMD and landscape runoff. Analysis of the main stem indicates a fairly uniform and consistent presence of iron and aluminum (Figure 6) suggesting widespread distribution of these sources.

While AMD can result in pH impairment, this WBP also considers the additional source of acid deposition due to its potential to acidify waters. Similarly, temperature is discussed due to its negative impact on ecological function though metals toxicity and low pH contribute to biological impairment as well. Finally, the presence of the recently completed Corridor H highway has resulted in fragmentation of stream connectivity (Figure 7), but is not discussed further given no realistic means of addressing the issue and its limited impact.

Figure 7. Corridor H route through Beaver Creek watershed.

3.1 Permitted Point Sources

As of the beginning of 2018, there are seven point source permits authorized to discharge into Beaver Creek (Table 4). These entities include permitted sites under the National Pollution Discharge Elimination System (NPDES) and the Construction Storm Water permit programs. The NPDES permits set limits for the following pollutants: ammonia, aluminum, bacteria, flow, iron, manganese, selenium, total suspended solids and pH. For one facility, a total of four quarters have been in non-compliance over the last five years; excess levels of ammonia, bacteria and/or suspended solids were reported during these periods. One period of non-compliance for ammonia was reported for an additional facility as well. All other facilities have remained in compliance.

Table 4. Point source discharges in the Beaver Creek watershed.

Facility Name	Permit ID	Classification	Latitude	Longitude
Alpine / Dobbin Mine Complex	WV0005541	Mining	39.182500	-79.404722
A-34 Coal Preparation Plant	WV0060372	Mining	39.202222	-79.324722
E-mine	WV1018027	Mining	39.184435	-79.404451
Gatzmer Scalped Rock Disposal	WV1018094	Mining	39.190835	-79.380850
Rock Borrow Site	WVR106876	Construction	39.143935	-79.449452
Western Pocahontas Properties Waste Site 2	WVR106504	Construction	39.165635	-79.404451
	WVR106505			

3.2 Abandoned Mine Lands

The most severe nonpoint source pollution in the Beaver Creek watershed is AMD from abandoned mine lands (AMLs). AMLs are characterized as lands where mining was completed prior to passage of SMCRA in 1977 when it was common practice for mine operations to leave mined areas and refuse un-reclaimed. Under these conditions, sulfur-rich material such as pyrite and other iron sulfides found in mine refuse and adjacent geological formations react with air and water to form dissolved iron and sulfuric acid:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 2H^+$$

The resultant drainage is highly acidic and laden with dissolved metals – most commonly iron, aluminum and manganese – which in turn pollute streams and wetlands. Polluted water flows from a number of features; the largest flows are typically linked to underground mine portals or blowouts where water pressure has broken out the mine wall. There are no known discharges from underground mines in the Beaver Creek watershed. Rather, all AMD in the watershed emanates from acidic spoil and gob piles originating from surface mining activity.

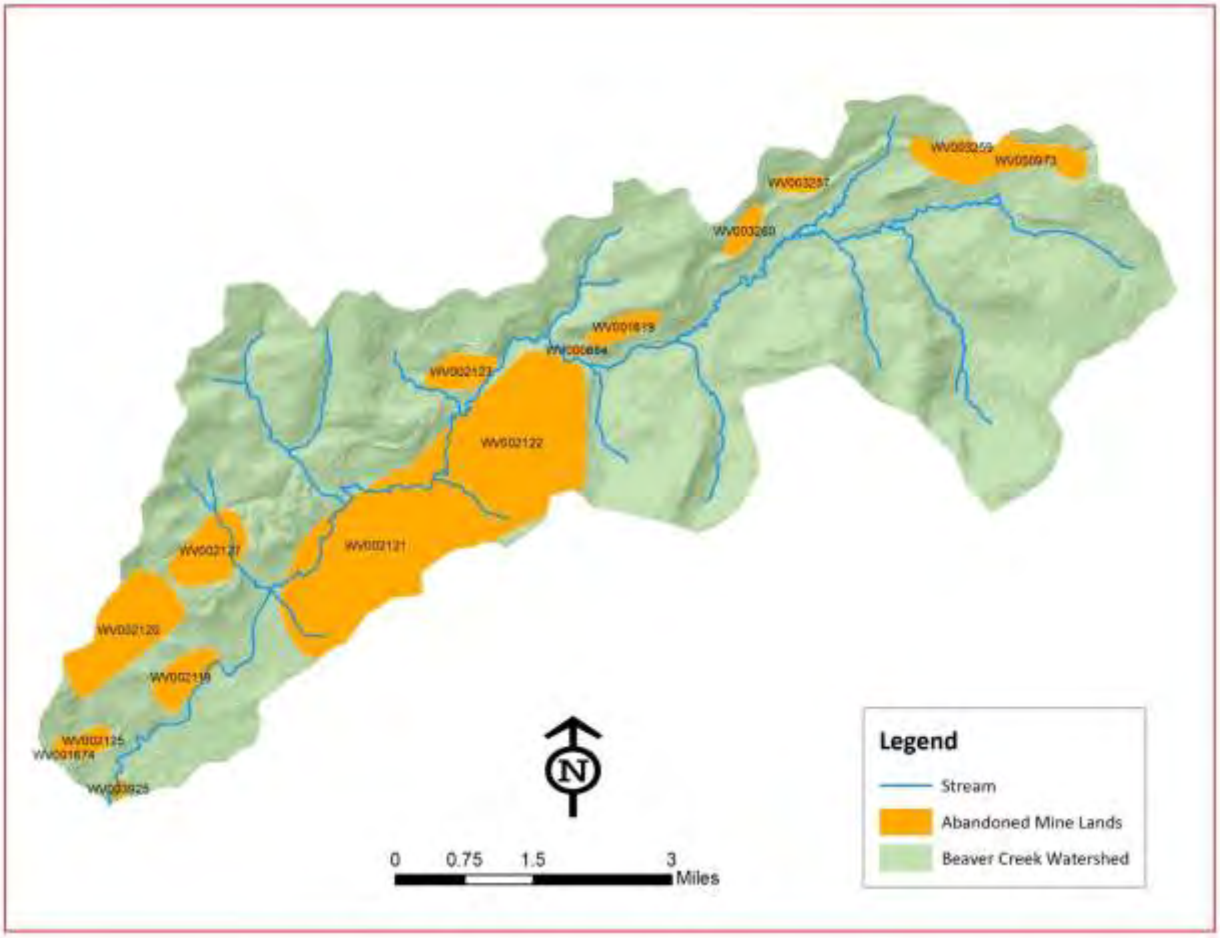


Figure 8. Abandoned mine lands in the Beaver Creek watershed.

There are currently 15 AMLs identified within the Beaver Creek watershed (Figure 8). Problem area descriptions (PADs) indicate that only one AML site is officially associated with AMD, but PADs do not necessarily include estimates of water flow and pollutant loads, nor does OSMRE mandate that water quality problems (Priority 2 and 3) be entered into the federal Abandoned Mine Land Inventory System (AMLIS); therefore, the list of AMLs with AMD may not be complete. The 2011 Cheat TMDL identified 5 AMD seeps discharging directly into the main stem and 1 discharging into Hawkins Run, while FOB monitoring identified an additional seep (Table 5). If future information indicates that an AML does, in fact, discharge AMD, this WBP will be updated as appropriate.

Though not necessarily associated with AMD, one AML site is of particular note given its unique water quality impact. Chaffey Run is not, itself, identified as impaired. It is, however, contributing to the impairment of the main stem due to the presence of a subsidence feature – AML site WV002127 – that diverts approximately 450 million gallons per year of surface water into the subterranean system. With the watershed largely unmined and forested, water draining into the feature is believed to be of good quality, thus qualitatively and quantitatively contributing to the impairment of Beaver Creek through its absence.

All AML sites presently believed to be associated with a nonpoint source water pollution issue are listed in Table 6.

Table 5. Identified AMD seeps in the Beaver Creek watershed.

Discharge ID	Receiving Stream	Subwatershed	Lat	Long
Seep 100-1	Beaver Creek	635	39.156389	-79.428103
Seep 100-2	Beaver Creek	635	39.157467	-79.426492
Seep 100-3	Beaver Creek	639	39.166028	-79.416550
Seep 100-4	Beaver Creek	639	39.166136	-79.416131
Seep 100-5	Hawkins Run	636	39.168444	-79.429417
Seep 200-1	Beaver Creek	640	39.182389	-79.390306
Seep DOM-1	Beaver Creek	640	39.173740	-79.403490

Table 6. AMLs known or believed to be associated with the formation and/or discharge of AMD.

PAD Name	PAD #	Status	Acreage	Lat	Long	Description
Beaver Creek Strip #1	WV002120	Unabated	358	39.153146	-79.454501	Highwall area containing subsidence pit features and believed to be the source of acidity loading to Lost Run.
Beaver Creek Strip #2	WV002121	Unabated	1115	39.158528	-79.416807	Large area covered by spoil and gob located to the southeast of the highway. AMD drains into SWS 639 and 635 above Chaffey Run. Contains Seep 100-1,2,3, & 4
Beaver Creek Strip #3	WV002122	Unabated	879	39.172349	-79.397698	Spoil and gob area immediately adjacent to WV002121. AMD drains into SWS 639 and 640. Contains Seep DOM-1 & 200-1.
Chaffey Run Strip	WV002127	Unabated	182	39.158197	-79.445186	Water pollution issue concerns the presence of a drainage feature capturing upstream waters and redirecting them into the subsurface. Final point of emergence uncertain but believed to be in the adjacent North Fork watershed.
Red Brush Strip Drainage	WV000973	Unabated	199	39.205778	-79.323719	Surface mining spoil area located to the north of and draining into the Beaver Creek headwaters (SWS 645).

3.3 Bond Forfeiture Sites

After the establishment of SMCRA, facilities were required to post a bond to ensure completion of reclamation requirements. When this bond is forfeited, WVDEP assumes reclamation responsibilities. Since 2009, WVDEP has been required to obtain a NPDES permit for discharges from forfeited sites. As such, these sites are now considered permitted point sources in TMDL development. The 2011 Cheat TMDL identifies one bond forfeiture site (BFS) in the Beaver Creek Watershed (Figure 9). Permit records indicate that it was indeed nearing forfeiture but was ultimately transferred, thereby eliminating the BFS LA listed in the 2011 TMDL report. The discharge outlet associated with this site is now part of NPDES permit WV0060372. Two additional potential BFSs not part of the 2011 TMDL have also been transferred; one site is associated with NPDES permit WV0091936 (now closed) and the other WV1018027.

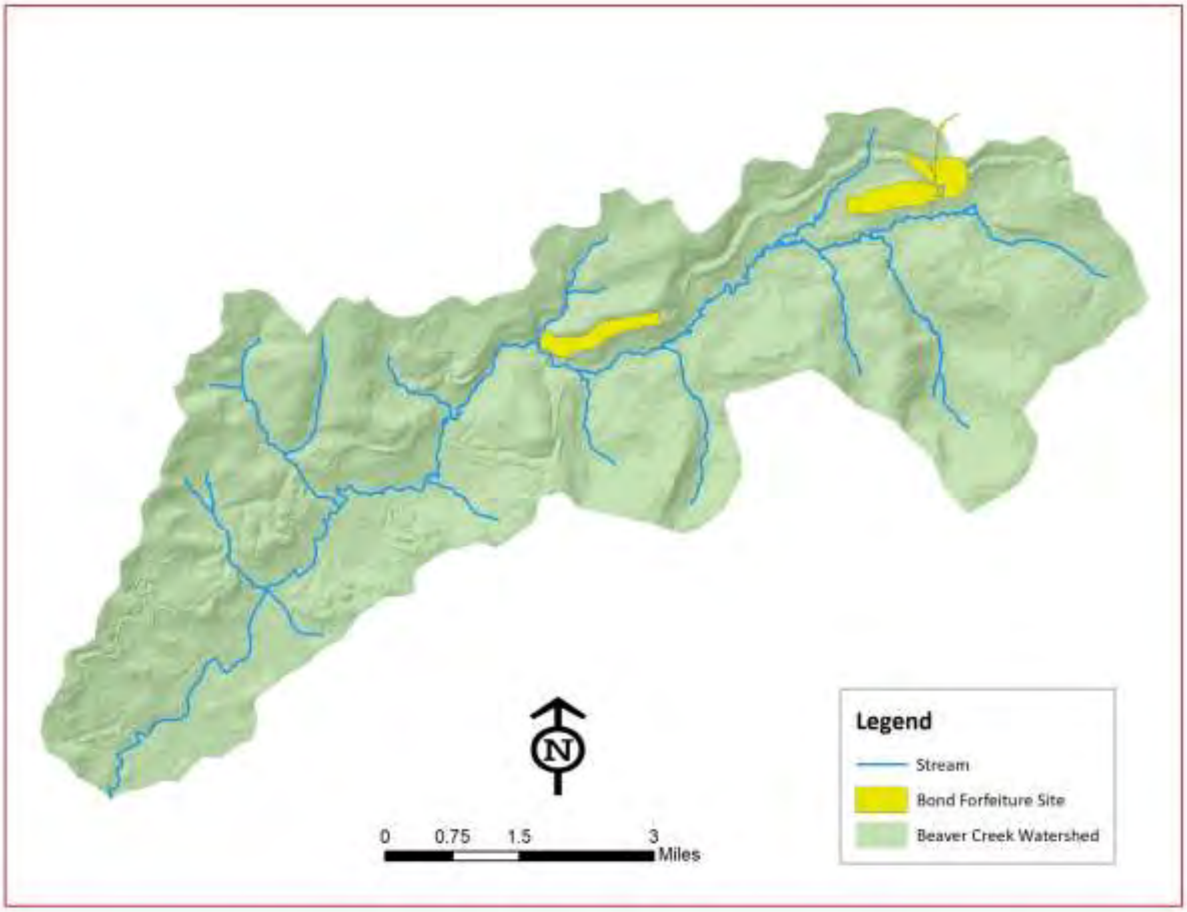


Figure 9. Location of bond forfeiture sites in the Beaver Creek watershed.

3.4 Sediment

Land disturbance can increase sediment loading to impaired waters. The control of sediment-introducing sources has been determined to be necessary to meet water quality criteria for total iron during high flow (WVDEP, 2011). For some impaired reaches, the Cheat TMDL attributes all of the nonpoint source metals toxicity to non-AML sediment sources.

Land disturbance sources of sediment pollution can include stormwater runoff from impervious surfaces such as roadways, poorly managed construction sites, and farming, timbering and mining operations. All of these land disturbances coupled with stream channel alteration exacerbate stream bank erosion which has been identified as a significant additional source of sediment in the watershed. While some portions of the watershed have a wooded riparian zone, emergent wetlands border much of the stream and are less resistant to weathering. Furthermore, analysis of available land cover data indicates that 4.7% of the entire riparian zone (defined in this case as 20 meters either side of the stream centerline) is characterized as grass covered or barren; land types even more erodible than wetlands.

3.5 Atmospheric and Terrestrial Acidification

Acid rain results from gases reacting with atmospheric water to form carbonic, sulfuric and nitric acids. While precipitation is naturally acidic due to the composition of the atmosphere, significant increases in acidity are attributed to the presence of sulfur dioxide and nitrogen oxides which enter the atmosphere primarily from the burning of fossil fuels; most notably at electric power generating plants. Given weather patterns, population distribution and the geographic location of power plants, the majority of acid deposition in the United States occurs in the east where it acidifies soils and waterways.

The acidification of soils and waterways can be further aided by natural conditions. While soils with high clay content and forested areas are typically capable of buffering against acid rain impacts, bog-wetland ecosystems – such as those present in the Beaver Creek watershed – are naturally acidic due to the vegetation present, the soil composition and the decomposition of organic matter. Furthermore, the Pottsville Sandstone geological formation found in the southern headwaters area of the Beaver Creek watershed is known to have very low buffering capacity.

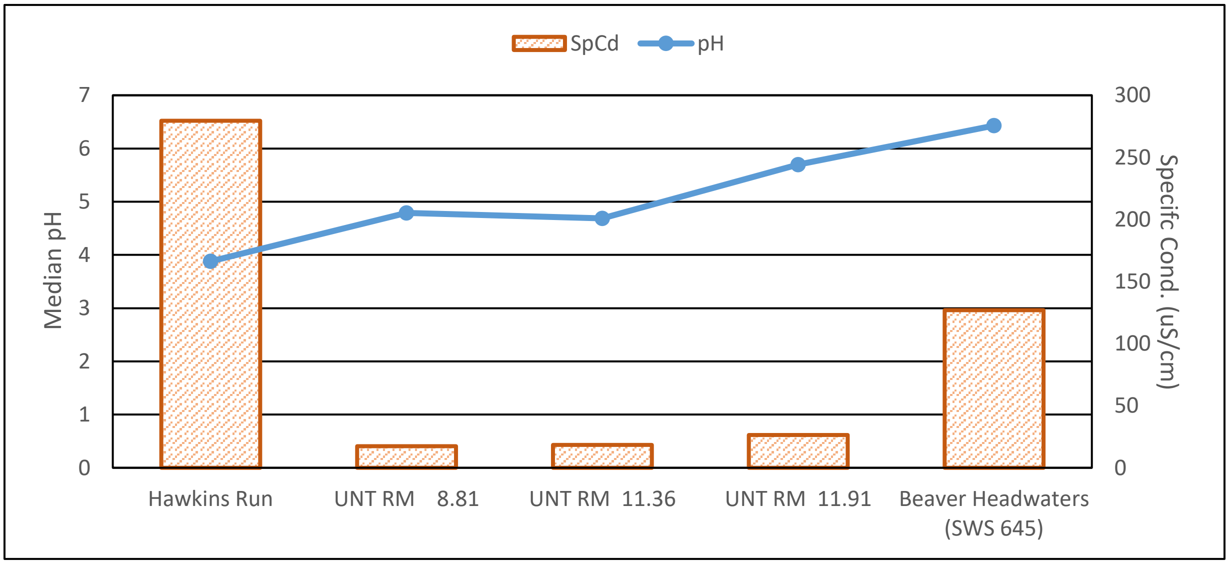


Figure 10. Median specific conductance and pH values for impaired tributary and headwater reaches.

Acid rain impacted waterways can be distinguished from AMD impacted waterways by the abundance of metals and sulfate. While both pollution sources can result in low pH levels, acid rain impacted waterways are associated with much lower concentrations of these analytes. Using specific conductivity as a surrogate for the presence these analytes, data indicate that the pH impaired tributaries in the upper portion of the watershed – unnamed tributaries (UNT) at river mile (RM) 8.81, UNT RM 11.36 and UNT RM 11.91 – are impaired due to acid rain, land disturbance and/or natural conditions (Figure 10).

3.6 Biological Impairment

Streams are listed for biological impairment based on the presence/absence of benthic macroinvertebrates. A West Virginia Stream Condition Index (WVSCI) survey score of less than 60.6 is indicative of biological impairment. Only the uppermost reach (RM 12.5 to source) of Beaver Creek and the UNT at RM 11.91 are listed as biologically impaired. Given the absence of human settlement within these areas, it is highly unlikely that bacteria – specifically Fecal Coliform species – are responsible for this impairment. Furthermore, the co-listing of pH impairment suggests biological impairment resulting from acidic conditions with acid deposition and/or sediment the likely source of low pH in the case of UNT RM 11.91, and AMD an additional potential source in the Beaver Creek headwaters. It is also possible that temperature is further contributing to this impairment.

Excessive temperature – or more specifically *heat* – seldom reaches such an extreme that it eliminates biological life. Instead, increases yield changes in community composition as most species thrive within a specific range of temperatures. This is notable in the case of Beaver Creek given its historic support of Brook Trout. Brook Trout are a cold water species and cannot be exposed to temperatures in excess of 25°C for extended periods as has been observed in Beaver Creek (Figure 11). Documented sources of excessive heat in Beaver Creek include reductions in shading as a result of riparian habitat degradation and increases in residence time as result of human and/or beaver activity. Long term climatic changes may yield elevated temperatures as well but this source is beyond the scope of this document.

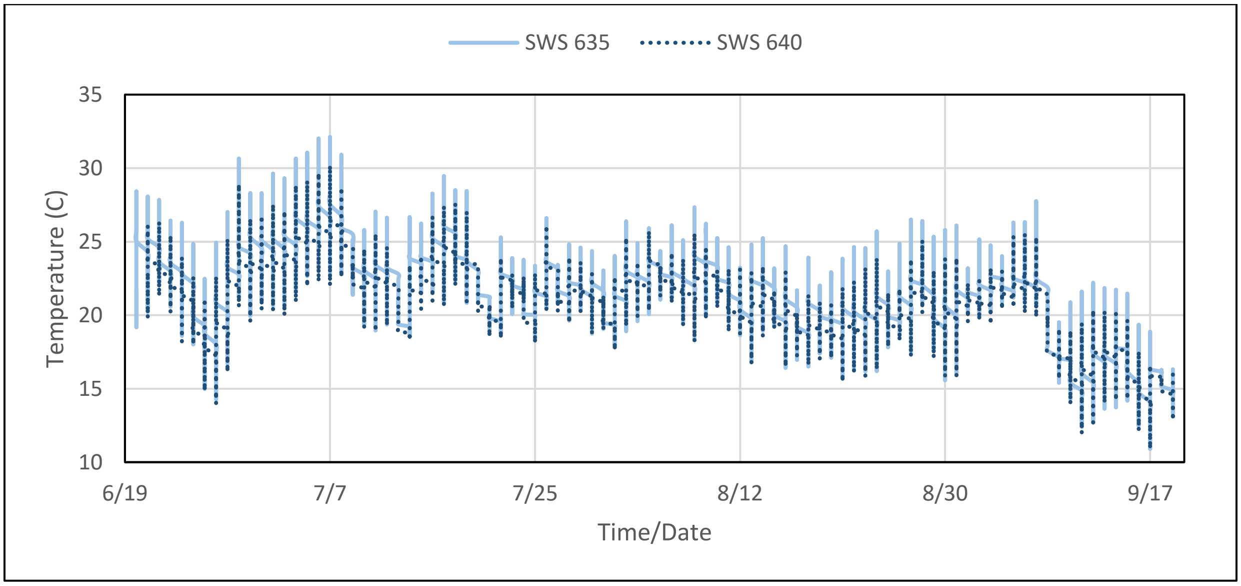


Figure 11. Hourly temperature data for main stem subwatershed outlets collected in 2012. Data source: WVDNR.

4. Nonpoint Source Management Methods

The following section identifies, characterizes and critiques various Best Management Practices (BMPs) for mitigating and controlling nonpoint sources of pollution impacting Beaver Creek.

4.1 AMD

Treatment of AMD has been broken into three strategies: land reclamation, passive treatment, and active treatment. The following lists provide details on the methods employed under each strategy. Numbers in parentheses refer to the potential load reduction associated with a given method/strategy. Load estimates assume proper design and implementation.

Land Reclamation

- Removing acid-forming material (100%): The removal of acid-forming material has the potential to eliminate acid loads originating on the surface. This is unlikely to be practical in the context of Beaver Creek due the lack of accessible materials concentrated in small areas; the cost of removing material would be orders of magnitude greater than sealing and isolating.
- Isolating acid-forming material from flow paths (50%): Infiltration of water in acid-forming material can be slowed by covering with a low-permeability material, such as clay, and covering that layer with vegetation. This is thought to eliminate a large proportion of AMD but it is difficult to estimate the exact efficacy. Interactions can be further minimized by separating the waste material from impermeable bedrock below with conductive materials such as coarse gravel. Water then flows beneath the spoil and is transported rapidly away, reducing the likelihood of the water table rising into the spoil. Whether intentional or by happenstance, the majority of AML acreage in Beaver Creek is presently vegetated making further or improved isolation limited.
- Surface water management: Rock-lined ditches and/or grouted channels can be used to greatly reduce residency of surface water on site, limiting infiltration into acid-forming material. Use of alkaline materials within such channels can provide additional acid neutralization as discussed below.

Passive Treatment

- Reducing and Alkalinity Producing Systems (RAPs) (25g acidity/m^2): Also known as successive alkalinity producing systems" and "vertical flow ponds". In these systems water encounters two or more treatment cells set in series. In the first, water passes through organic material reducing dissolved oxygen. In the resulting anoxic conditions, bacteria reduce sulfate to sulfur and all iron is reduced to ferrous iron. In the next cell, the anoxic solution comes in contact with limestone, neutralizing H^+ acidity. Additional alkalinity is generated, and since iron is in the ferrous form it does not armor the limestone. In the final step, water runs through an aeration and settling pond in which ferrous iron oxidizes and precipitates out of solution as ferric hydroxide, while the acidity produced during this process is neutralized by the accumulated alkalinity.
- Sulfate-reducing bioreactors (40 g acidity/m^2): These system are similar to RAPs in both composition and functionality with the primary difference being that organic matter is the

main reactant with limestone completely mixed with the organic matter. Respiring organic matter also provides CO_2, which accelerates dissolution of limestone and addition of alkalinity to the solution.

- Oxic (or Open) limestone channels (OLCs) (30%): Estimations of the efficacy of OLCs is active. OLCs have the advantage that continually moving water may erode any armoring from limestone. Furthermore, water should remove precipitates from OLCs so that they do not interfere with acid neutralization. With extremely acidic water containing iron as ferrous iron, terraced iron formations (TIFs) form. A TIF helps reduce iron concentrations as AMD flows over it and designers are experimenting with channel conditions that promote TIF formation and accelerate iron oxidation. The efficacy of OLCs may suffer due to channels being too short, the majority of limestone being located above the typical water level, and/or fluctuating water levels enhancing armoring.
- Limestone leachbeds (50%+): Limestone leachbeds are most effective when water has a pH of 3 or less, and when water retention times are short (~90 minutes). The low pH promotes rapid limestone dissolution, but the short retention time prevents armoring. Performance can be enhanced with the addition of siphons and/or valves that allow for the flushing of treated waters, thereby reducing armoring and promoting precipitate removal. This in turn allows for increased residence time and further alkaline generation.
- Steel slag leachbeds (addition of alkalinity): Steel slag leachbeds are not exposed to AMD. Instead, circumneutral feed water passes through these leachbeds to generate alkaline water. This water is then mixed with AMD to reduce its acidity drastically, though research has shown drastic decreases in alkalinity loading of over 75% as precipitate forms within the leachbeds (Goetz & Riefler, 2014).
- Compost wetlands: Constructed wetlands can serve multiple functions in AMD treatment. Wide areas of exposure to the atmosphere allow metals to oxidize and precipitate, while high residency time allows precipitates to fall out of suspension. Anaerobic zones in sediments allow for sulfate reduction, consuming acidity. The addition of limestone to the substrate provides an additional alkalinity source and helps maintain conditions that support sulfate reduction.

Active Treatment

- Doser (100%+): This method uses an automated mechanical system to mix one of a number of alkaline chemicals with AMD to raise pH, neutralize acidity, and precipitate metals. The mixed “slurry” is discharged downstream or aerated and passed through settling ponds to allow metal hydroxides to settle out as sludge. The alkaline chemical needs to be replenished as consumed with consumption rate highly dependent on flow and pollutant concentration.
- Limestone Sand Dumps (100%): Limestone sand is placed at the bank of a stream and periodically washed into the stream where the majority is dissolved in the water, thus increasing alkalinity and forcing the precipitation of metals. Some of the limestone sand becomes assimilated into the streambed adding longer term alkalinity. Periodic replenishment of the sand is needed as consumed.

4.2 Acid Deposition

The differentiating feature between AMD and acid rain derived acidity– outside of the terrestrial versus atmospheric nature of each – is the significantly reduced presence of metals. As such, mitigation of acid rain need not be concerned with the formation of precipitates, instead only needing to promote increased alkalinity loading. Since the potential origin point for sulfur dioxide and nitrogen oxides extend far beyond the boundaries of a watershed, the only means of addressing this source within Beaver Creek and its tributaries is by treating affected waterways. Any of the above proposed active and/or passive treatment systems designed to promote alkaline generation should be capable of remediating acid rain impacts with limestone sand dumps the favored method across the state at present. However, site selection can be critical given the highly diffuse nature of deposition and the potential impact of localized conditions (e.g. geology).

4.3. Sediment

Sediment mitigation strategies depend on the nature of the source and include the following:

- restoring eroded stream banks and stream sinuosity using natural stream design elements to reduce further erosion and hydrological alterations
- replanting riparian buffer zones with vegetation that provides bank stability
- removing dams and other flow impediment features that result in altered hydrology
- managing stormwater runoff from low permeability surfaces to limit sediment loading
- employing engineered BMPs specially designed to eliminate sediment impacts

Land surface derived sediment is best mitigated by converting land types with low groundwater infiltration rates – e.g. impervious surfaces and sloped grasslands – to more runoff resistant land types – e.g. forests. Additionally, BMPs designed to lessen peak discharge volumes and/or increase groundwater infiltration are frequently employed when conversion of land is not practical. Examples of such systems include retention ponds, swales and raingardens. Finally, streambank erosion sourced sediment is best mitigated through a combination of bank stabilization via the reestablishment of riparian corridors and the re-naturalization of altered stream channels.

4.4 Temperature

Temperature – or more accurately, heat – pollution remediation activities may be carried out at varying scales throughout the watershed due to its diffuse nature, but may target high priority areas. While there are a number of strategies used to reduce water temperature, the two strategies most applicable to the Beaver Creek watershed include increasing shading and reducing residence time. Increasing shading is accomplished through riparian restoration, specifically with plants capable of establishing a reasonably high and dense canopy which in turn prevent sunlight from reaching the water. Reducing residence time is accomplished by restoring natural streamflows impacted by the presence of features that prevent or delay the movement of water through a stream reach such as a dam or overwidened pool.

4.5 Biological Impairment

Once placed on the 303(d) list for biological impairment, a stressor identification process is completed to determine the cause(s) of impairment prior to TMDL development and establish a link between impairment and the possible source(s) of pollution. The following list of candidate causes has been developed by the WVDEP to help guide the stressor identification process:

- metal contamination (including metals contributed through soil erosion) causes toxicity;
- acidity (low pH) causes toxicity;
- basic (high, pH > 9) causes toxicity;
- increased ionic strength cause toxicity;
- organics enrichment (e.g. sewage discharges and agricultural runoff) cause habitat alterations;
- increased metals flocculation and deposition causes habitat alterations;
- increased total suspended solids/erosion and altered hydrology cause sedimentation and other habitat alterations;
- altered hydrology [and canopy loss] cause higher water temperature, resulting in direct impacts
- altered hydrology, nutrient enrichment, [higher water temperature], and increased biochemical oxygen demand cause reduced dissolved oxygen;
- algal growth causes food supply shift;
- high levels of ammonia causes toxicity (including toxicity increases due to algal growth); and
- chemical spills cause toxicity (WVDEP, 2014)

As Beaver Creek (from RM 12.5 to source) and UNT RM 11.92 were placed on the 303(d) list for biological impairment after development of the 2011 Cheat TMDL, the stressor identification process has not yet been completed. An updated TMDL is to be completed by 2024. From the WVDEP guidelines it is probable that AMD, acid deposition, altered hydrology, sedimentation and additional temperature sources contribute to the impairment. Given the co-listing of pH impairment for both reaches, it is probable that AMD and/or acid deposition are the principal causes, though the impact of sedimentation and temperature may be significant enough to reduce ecological function.

When the identified source(s) are addressed, the approaches to nonpoint source management should be consistent with this document. Those not addressed in this document should be managed in such a way to ensure that water quality standards are met.

5. Target Load Reductions

The 2011 TMDL for the Cheat River watershed set goals for pollutant reductions from nonpoint and point source activities that, once implemented, should improve water quality such that impaired stream segments meet standards and are removed from the 303(d) list. This plan focuses on meeting numeric water quality standards (pH, Al, Fe) with the belief that violation of narrative criteria (CNA biological impairment) will be eliminated as the stressor identification guidelines state that the reduction of aluminum and iron can be surrogate for metals toxicity, pH toxicity and sedimentation caused biological impairment. Furthermore, in scenarios where aluminum and iron impacts are insufficient to ameliorate biological impairment, additional non-metals derived acidity can further degrade ecological function. Once metal and acidity load reductions have been achieved, biological impairment will be revaluated.

The TMDL provides LAs for nonpoint source pollutants at the watershed and sub-watershed scale. In addition, TMDL targets are provided for identified AMD sources (e.g. seeps). WLA for point source discharges are not addressed in either the TMDL or this plan as they require regulatory authority to enforce a change in discharge. As such, load reduction calculations assume no reductions from point source discharges. Load reductions (LRs) are a quantitative assessment of the reduction in pollutant loading needed to achieve the target TMDL LA; calculated as:

LR = Pollutant Load – LA

5.1 Metals

Table 7. Target and baseline metal loads for seeps. Data from both the TMDL and FOB's monitoring is provided when available.

AMD ID	Metal	Target LA (lbs/yr)	Pollutant Loading (lbs/yr)		Reduction Necessary (%)	
			TMDL	*FOB*	*TMDL*	*FOB*
100-1	Aluminum	711	1180	2	39.7	0.0
	Iron	474	12316	403	96.2	0.0
100-2	Aluminum	635	3931	1671	83.8	62.0
	Iron	424	9466	3218	95.5	86.8
100-3	Aluminum	369	934	569	60.5	35.1
	Iron	246	1109	590	77.8	58.3
100-4	Aluminum	440	2668	8726	83.5	95.0
	Iron	293	3241	6657	91.0	95.6
100-5	Aluminum	105	3399	N/A	96.9	--
	Iron	13	13	N/A	0.0	--
200-1	Aluminum	12	12	10	0.0	0.0
	Iron	133	2184	2071	93.9	93.6
DOM-1	Aluminum	N/A	N/A	2729	--	--
	Iron	N/A	N/A	732	--	--

Metal LRs are calculated for identified AMD seeps (Table 7) and impaired streams (Table 8). When possible, calculations include data from both the 2011 TMDL model and FOB's monitoring program to provide a comprehensive list of reductions and to facilitate the comparison of results between data sources and methodologies. For completeness, loading rates for AMD sources absent from the TMDL but identified by FOB monitoring are listed; though no LR is calculated as no target LA is available.

Table 8. Target and baseline loads for metals impaired streams.

Stream Name	**Metal**	**Target LA (lbs/yr)**	**Pollutant Loading (lbs/yr)**		**Reduction Necessary (%)**	
			TMDL	*FOB*	*TMDL*	*FOB*
Beaver Creek	Aluminum	7947	20511	16365	61.3	51.4
	Iron	39950	101112	55345	60.5	27.8
Hawkins Run	Aluminum	717	4010	14449	82.1	95.0
UNT RM 11.36	Aluminum	162	162	629	0.0[α]	74.2
	Iron	1918	1994	892	3.8	0.0

[α] While no reduction is needed based on the target LA, the margin of safety component requires additional reductions to achieve the target TMDL.

Table 9. Target and baseline metals loading for each impaired subwatershed for each of three impairment sources: AMLs, Land Disturbance and Streambank Erosion. Only locations and parameters where reductions are needed are listed.

Stream Name	**SWS**	**Metal**	**Target LA (lbs/yr) / Pollutant Load (lbs/yr) / Reduction Necessary (%)**		
			AMLs	*Land Disturbance*	*Streambank Erosion*
Beaver Creek	635	Aluminum	1451/7750/81	--	--
		Iron	999/35792/97	380/3292/88	--
	639	Aluminum	808/3602/78	--	--
		Iron	539/4350/88	76/1741/96	--
	640	Aluminum	19/196/90	--	--
		Iron	140/3162/96	377/3935/90	581/2865/80
	641	Iron	--	1710/2096/18	384/1895/80
	643	Iron	--	--	309/1523/80
	644	Iron	--	18/100/82	243/1200/80
	645	Iron	--	133/955/86	--
Hawkins Run	636	Aluminum	105/3399/97	--	--
	637	Iron	--	107/478/78	--
UNT RM 8.81	648	Iron	--	1771/1903/7	55/529/90
UNT RM 11.36	647	Iron	--	13/89/86	--
UNT RM 11.91	646	Iron	--	100/284/65	--

Finally, the TMDL also provides metal LRs at the subwatershed (SWS) scale for each nonpoint source type as defined by the model (Table 9). In total, 41626, 11188 and 7692 pounds per year of iron linked to AMLs, land disturbances and streambank erosion, respectively, plus an additional 12564 pounds per year of aluminum from AMLs, need to be eliminated to achieve the metals TMDL.

5.2 Acidity

A net alkaline condition is necessary to maintain pH criteria. As such, sources of acidity loading need to be remediated to achieve this condition. While the free hydrogen ions associated with sulfuric, nitric and carbonic acids found in acid rain contribute directly to the acidification of a waterway, AMD acidity arises from both the hydrolysis of metals and the presence of free hydrogen ions. The acidity of this water can be calculated as follows (Hedin, 2006):

$$\text{Acid}^{calc} = 50*(2*\text{Fe}^{2+}/56 + 3*\text{Fe}^{3+}/56 + 3*\text{Al}/27 + 2*\text{Mn}/55 + 1000*10^{-pH})$$

where acidity is mg/L $CaCO_3$ and metals are mg/L. This acidity needs to be reduced at impaired streams and at major AML sources (Table 10) to achieve target pH levels. Furthermore, due to the complex interaction between dissolved metals and acidity, the model employed in the TMDL concluded that achievement of metals TMDL conditions would subsequently result in significant reductions in acidity as well; iron and aluminum are therefore considered an acid source in this regard. The 2011 TMDL establishes target net acidity/alkalinity loads at the SWS scale while identifying the reduction associated with each source of acid (Table 11).

Table 10. Acidity loading for impaired streams and identified seeps. Data source: FOB.

Stream Name / Seep ID	Acid^{calc} Loading (Tons/Year)
Beaver Creek α	N/A
Hawkins Run	73.0
UNT RM 8.81	4.4
UNT RM 11.36	3.8
UNT 11.91	8.0
Seep 100-1	0.3
Seep 100-2	20.5
Seep 100-3	2.7
Seep 100-4	23.0
Seep 100-5β	N/A
Seep 200-1	2.1
Seep DOM-1	15.7

α Acid loading for Beaver Creek has not been calculated due to the influence of current management efforts.
β This seep was not monitored by FOB.

Table 11. Baseline and target net acidity loads for each impaired SWS. Component reductions are provided for each source. Mass balancing can be accomplished by the following equation: LA - Target LA = Acid Rain + AML Seeps + Metals Reductions.

Stream Name	**SWS**	**LA Net Acidity Load (ton/yr)**	**Target LA Net Acidity Load (ton/yr)**	**Component Source Net Acidity Reductions (ton/yr)**		
				Acid Rain	*AML Seeps*	*Fe & Al Reductions*
Beaver Creek	635	57.4	-32.9	25.5	4.4	60.4
	639	15.7	-3.8	3.2	2.6	13.7
	640	26.2	-24.1	27.6	0.7	22.0
	641	2.6	-9.2	7.2	--	4.6
	643	-0.2	-0.7	0.5	--	--
	644	-1.0	-1.7	0.8	--	--
	645	28.4	-3.8	12.3	--	19.9
Hawkins Run	636	-0.5	-1.4	0.9	--	--
	637	-1.7	-7.0	5.3	--	--
UNT RM 8.81	648	-1.0	-4.2	3.2	--	--
UNT RM 11.36	647	-1.1	-4.4	3.3	--	--
UNT RM 11.91	646	-3.2	-13.1	9.9	--	--

6. Current Management Measures

A combination of intentional and unintentional factors are presently impacting nonpoint source metals and acidity loading throughout the Beaver Creek watershed. These include limestone sand additions administered by West Virginia Department of Natural Resources (WVDNR), the presence of the Corridor H highway, and acid deposition management strategies implemented far beyond the boundaries of the watershed. Each is discussed below in greater detail.

6.1 Limestone Sands

Figure 12. Locations of limestone sand dumps.

WVDNR began adding limestone sands to Beaver Creek tributaries and AMD seeps in March of 2018 with the intention of establishing a put-and-take warm water fishery. There are eight dump sites in total (Figure 12) with those waterways believed to be contributing most to the acidification of the main stem targeted. pH measurements taken above and below several of the dump sites show that the sands are increasing the pH of waters between 0.33 to 1.44 standard pH units. Furthermore, through June, indications are that, with the exception of a brief period at the end of March, the sands have been able to maintain a continuous pH of above 6 in the lower main stem (SWS 345), with additional monthly grab samples confirming that the same holds true at monitored main stem subwatershed outlets.

WVDNR has indicated that they intend to continue to maintain the dump sites and replenish sands as needed for an indefinite period of time. This is factored into the proposed management strategies presented in the next section of this document.

6.2 Corridor H

Though not consciously constructed with the intention of impacting the current state of the watershed, the Corridor H highway has influenced waters in varying ways. As such, it is discussed here in the context of a remediation project.

Multiple stormwater control failures were reported during the construction of the highway resulting in sediment releases. While the impact of these stormwater impacts can be argued to be limited to the period of construction, additional reports of AMD releases as a result of soils disturbance have also been noted. However, the use of limestone in the subsurface roadbed may also act as an alkaline source with the potential to provide a degree of remediation to both the AMD generated as a result of construction, and those metals and acidity sources already present on the landscape that drain through this material.

Figure 13. WVU highway study monitoring sites.

At the behest of The West Virginia Department of Transportation (WVDOT), West Virginia University (WVU) established a network of monitoring sites throughout the watershed to assess the impact of the highway on water quality (Figure 13). Data collection commenced two years prior to construction completion and is ongoing. A number of these sites are located on AMD seeps and impaired tributaries that cross through/under the highway allowing for upstream and downstream analysis of the highway's influence.

Data results vary widely (Figure 14). In general, UNT stream sites all showed a small decrease in net acidity despite small proportionate increases in iron and aluminum concentrations in the period before completion (note that "completion" is identified at the date on which the highway was open to traffic). In some ways this is in contrast to the period after completion in which reduction in net acidity is slightly greater, proportionate increases in aluminum concentrations are smaller, and iron concentrations are decreasing at 2 of the 3 UNT sites; by an average of 55 percent at one site. The scenario is quite a bit different at the lone monitored AMD site where downstream iron concentrations prior to completion were more than twice that of upstream, aluminum concentrations were lower, and acidity reductions exceeded 40 mg/L $CaCO_3$. In the period after construction however, the observed increases in iron and decreases in aluminum were both smaller, while the observed decrease in acidity was only 18 mg/L $CaCO_3$.

Broadly speaking, the overall trend is one of large increases in iron – and by extension, sediment – during construction as a result of land disturbance, with associated acidity impacts offset by the introduction of alkaline material. However, these trends appear to be diminishing over time. Given this, this document suggests that any presently observed impact of the highway in regards to metals or acidity should be considered irrelevant. Therefore, the impact of Corridor H has not been considered in the development of proposed remediation projects.

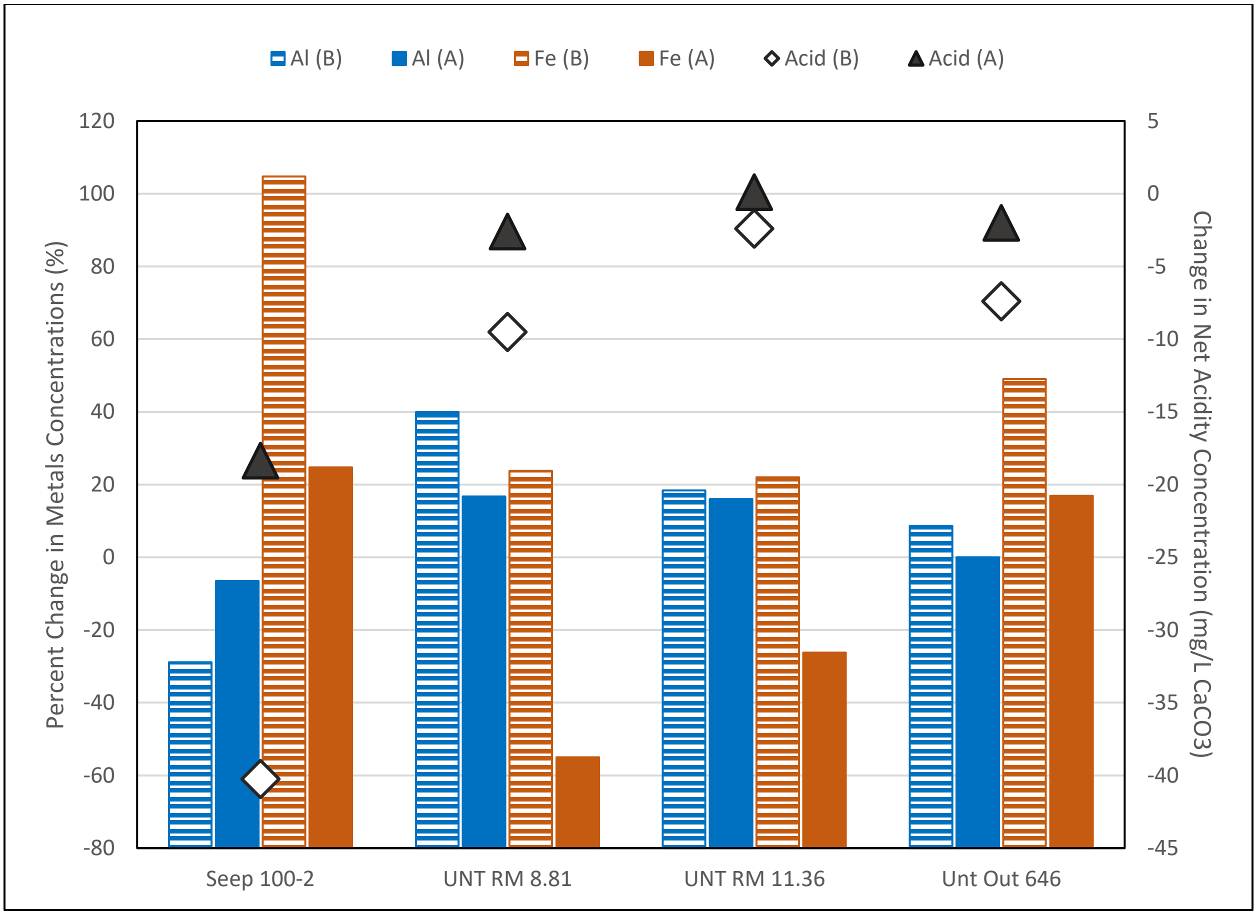


Figure 14. Trends for various analytes before (B) and after (A) completion of Corridor H. Data Source: WVU

6.3 Acid Deposition Trends

Multiple studies have linked declines in surface water sulfate and nitrate ions in the Appalachian region to declining sulfur and nitrogen emissions and deposition brought on by the 1990 Clean Air Act Amendments and subsequent NO_X control programs (Eshleman & Sabo, 2016; Kline *et al*, 2016). Although the regulatory status of the Clean Power Plan is uncertain, further declines in both direct deposition and terrestrial acidic leaching from legacy deposition can be expected through shifts in energy generation, technological advancements, consumption changes and other projected shifts. Therefore, impaired waterways within the Beaver Creek watershed whose impairment is principally due to acid rain are low priority targets long term; WVDNR's limestone sands program is currently providing short term remediation while trends outside of the watershed are likely to yield lasting benefits to these waters without localized expenditure of effort.

7. Proposed Best Management Measures

Due to the diffuse nature of impairment in the Beaver Creek watershed, treatment will require a mix of BMPs implemented over multiple phases. Ongoing monitoring is to continue through implementation of each phase as it is critical in assessing the performance of implemented BMPs and determining the necessity for additional management efforts. The current remediation programs/projects being implemented by AML and WVDNR are taken into account when determining areas of highest priority.

Phase I will target the principal sources of combined metals and acidity loading – principally AMD seeps – as identified by the TMDL and FOB's monitoring program. Phase II will principally target streambank stabilization and degraded landscapes in impaired subwatersheds while also reassessing the state of biological impairment. Phase III will target remaining impairment sources as identified through ongoing monitoring if water quality targets have not been met.

7.1.1 Phase I: AMD

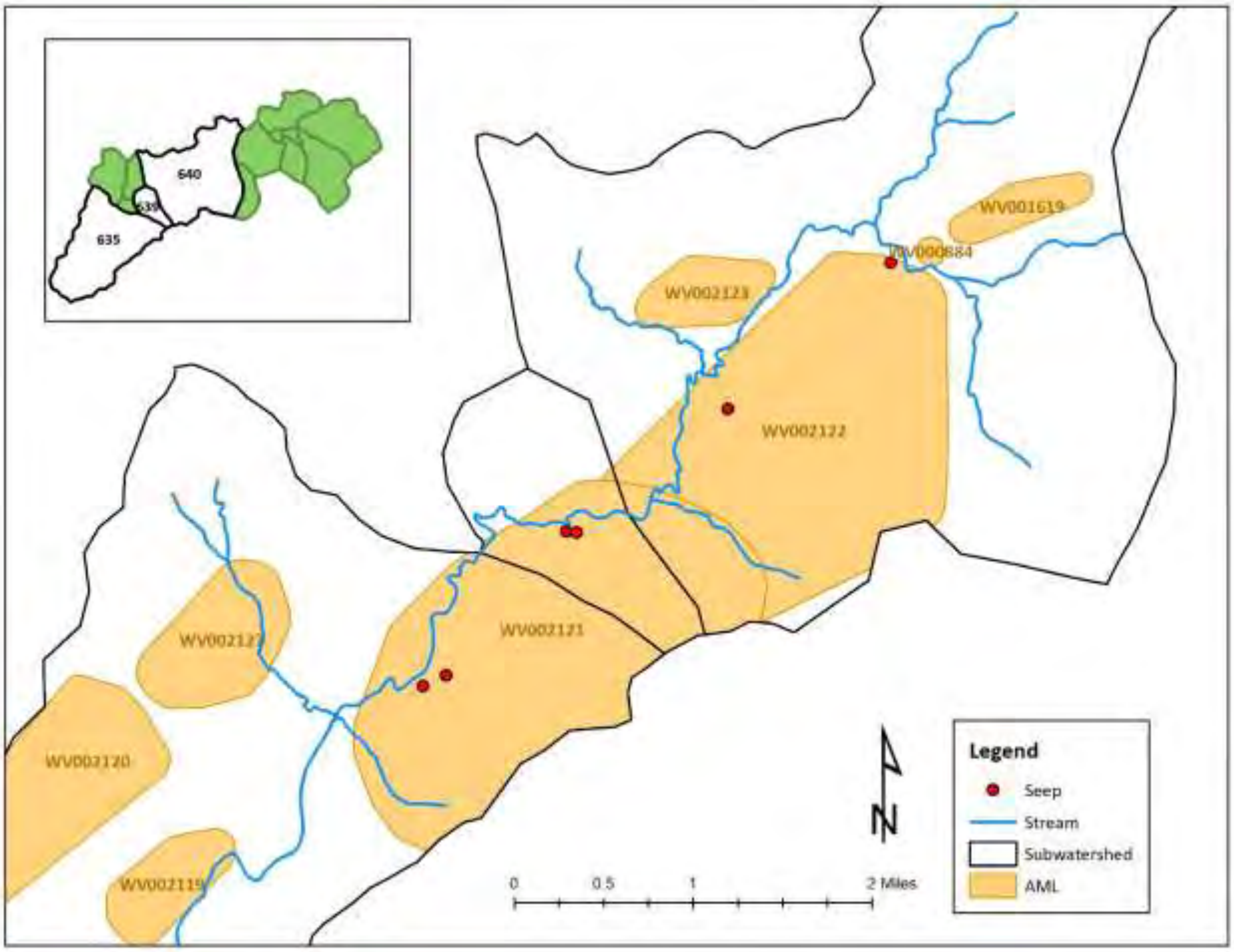


Figure 15. Map showing the location of seeps targeted for remediation in Phase I relative to the location of AMLs.

Adjacent AML sites WV002121 and WV002122 are the principle sources of AMD impacting Beaver Creek (Figure 15). The additional identified seep discharging into Hawkins Run needs further assessment during phase I given the widely divergent loading estimates between the TMDL and field data collected by FOB and Alliance Coal. Furthermore, while WVDNR limestone sand BMPs address acidity loading from AMLs, they do not effectively address metals precipitate generation and capture. As such, this plan recommends continued limestone sand applications in AMD seeps until an alternative BMP designed to capture and remove precipitates is implemented. It is further suggested that a temporary limestone sand dump is established at the Hawkins Run seep (Seep 100-5) upon installation of alternative BMPs at presently treated seeps.

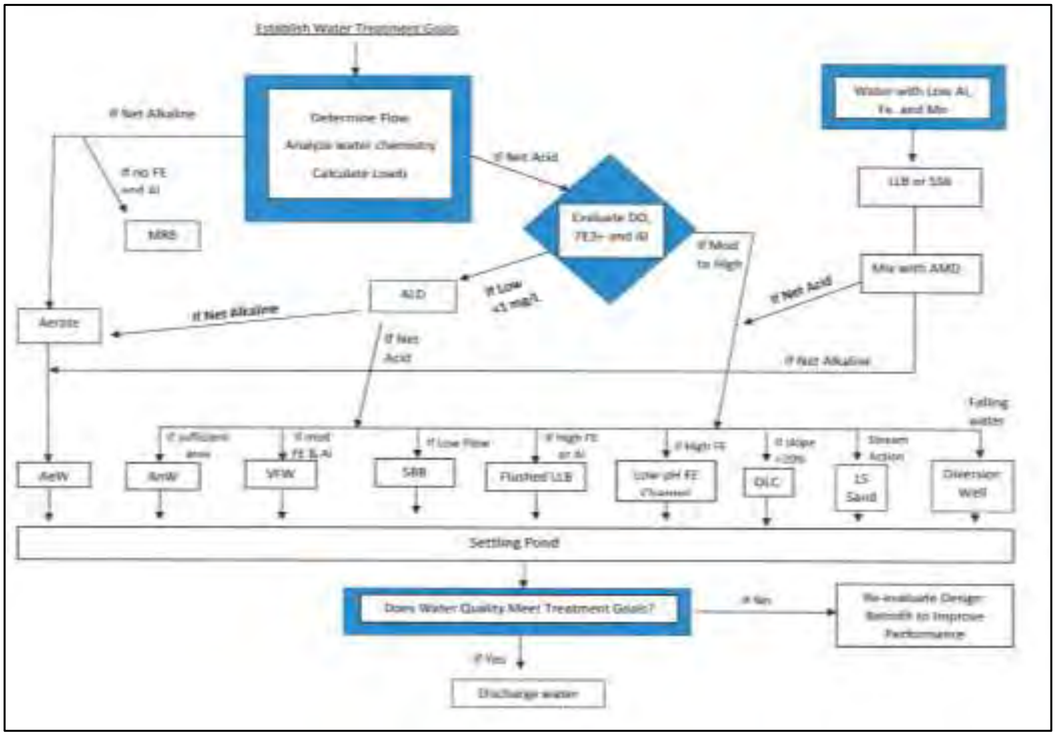


Figure 16. Flow chart for selecting a passive AMD treatment system based on water chemistry and flow. Source: Skousen et al, 2017.

System selection is based on several factors including: site geography, flow, construction costs, maintenance costs, and landowner considerations. Given the total acreage and current land cover, land reclamation is not practical. Instead each seep will have to be remediated individually with either a passive or active system. In general, passive systems are preferred over active. Passive treatment is appealing because it uses naturally occurring chemical processes that are self-sufficient and require little maintenance in comparison to active systems where continual chemical inputs are needed. Section 319 funds – the primary means of funding projects – are currently limited to funding capital costs, not operations and maintenance, limiting the feasibility of active systems for watershed groups with low capital.

Fortunately, flow and water chemistry indicate that passive systems will be applicable at all locations. The strategy for selecting the appropriate treatment system is presented Figure 16 with additional consultation from OMSRE, WVDEP and other watershed groups. OSMRE's AMDTreat computer program has been used to calculate sizing and cost requirements. A summary of proposed BMPs for each seep are presented below with additional detail in the Appendix section.

- *Seep 100-2*

Total Iron = 8.81 mg/L
Dissolved Iron = 8.08 mg/L
Dissolved Aluminum= 4.32 mg/L
pH = 2.90
Flow = 105.80 gpm
System Components: Open Limestone Channel
Limestone Leachbed
Settling Pond
Total Cost: $106,000

Description: Seep 100-2 receives diffuse AMD along nearly its entire length, is highly acidic, and contains moderate levels of iron and aluminum (and manganese). Project work areas are limited to a small open area located approximately 250 yards south of the highway where an access road crosses the stream channel, and to the channel itself. The envisioned treatment system consists of 1000 feet of open limestone channel constructed upstream of the access road crossing, and a limestone leachbed and settling pond located at the opening.

- *Seep 100-3 & 100-4*

Total Iron = 3.71 mg/L
Dissolved Iron = 2.86 gm/L
Dissolved Aluminum = 3.41 mg/L
pH = 4.21
Flow = 196.57 gpm
System Components: Limestone Leachbed
Settling Pond
Total Cost: $188,000 – $234,000

Description: Given that these seeps are within 100 yards of each other at the point where they flow under the railroad grade, it is possible to treat both sources with a single treatment system. Space is highly limited due to the close proximity of Beaver Creek, the abundance of wetlands and the lack of elevation. As a result, a 0.65 acre limestone leachbed system set within the footprint of the existing railroad bed and discharging into a settling pond is proposed. In may be necessary to discharge into an aerobic wetland rather than settling pond depending on wetland mitigation requirements, which would drive costs up.

- *Seep 200-1*

  Total Iron = 1.84 mg/L
  Dissolved Iron = 1.44 mg/L
  Dissolved Aluminum = Below Detection Limit
  pH = 6.17
  Flow = 231.83 gpm
  System Components: Aerobic Wetland
  Total Cost: $68,000

  Description: A pair of constructed wetlands are already in place at this seep. An additional aerobic wetland covering 1.19 acres is needed to remove the remaining metals and acidity with sufficient space available between the in-place wetlands and Beaver Creek.

- *Seep DOM-1*`

  Total Iron = 0.80 mg/L
  Dissolved Iron = 0.78 mg/L
  Dissolved Aluminum = 3.52 mg/L
  pH = 3.36
  Flow = 160.71 gpm
  System Components: Anoxic Limestone Drain
  Aerobic Wetland
  Total Cost: $33,000 - $72,000

  Description: Containing low metals concentrations and moderately acidic, the limiting factor in treatment of this seep is the terrain and available land area with the only space available lying between the highway and an upstream wetland complex. A 0.09 acre RAPS discharging into a 0.33 acre aerobic wetland is proposed, although it may be permissible to discharge from the RAPS directly into the culvert underlying the highway due to the presence of a large constructed wetland on the opposite side which would save roughly $35,000.

7.1.2 Phase I: Stream Restoration

For each main stem subwatershed reach, the TMDL attributes between 1% and 47% of iron loading and up to 100% of non-atmospheric deposition acidity loading to streambank erosion. This plan recommends initially focusing on those subwatersheds where streambank erosion is a proportional and quantitatively dominate driver of metals and acidity loading. Streambank stability is prioritized over land disturbances given its larger overall impact, lower degraded acreage, current active surface mining, lower estimated remediation cost, and simplicity of ownership status – the entire riparian corridor upstream of where Corridor H crosses Beaver Creek is now owned by the state of West Virginia.

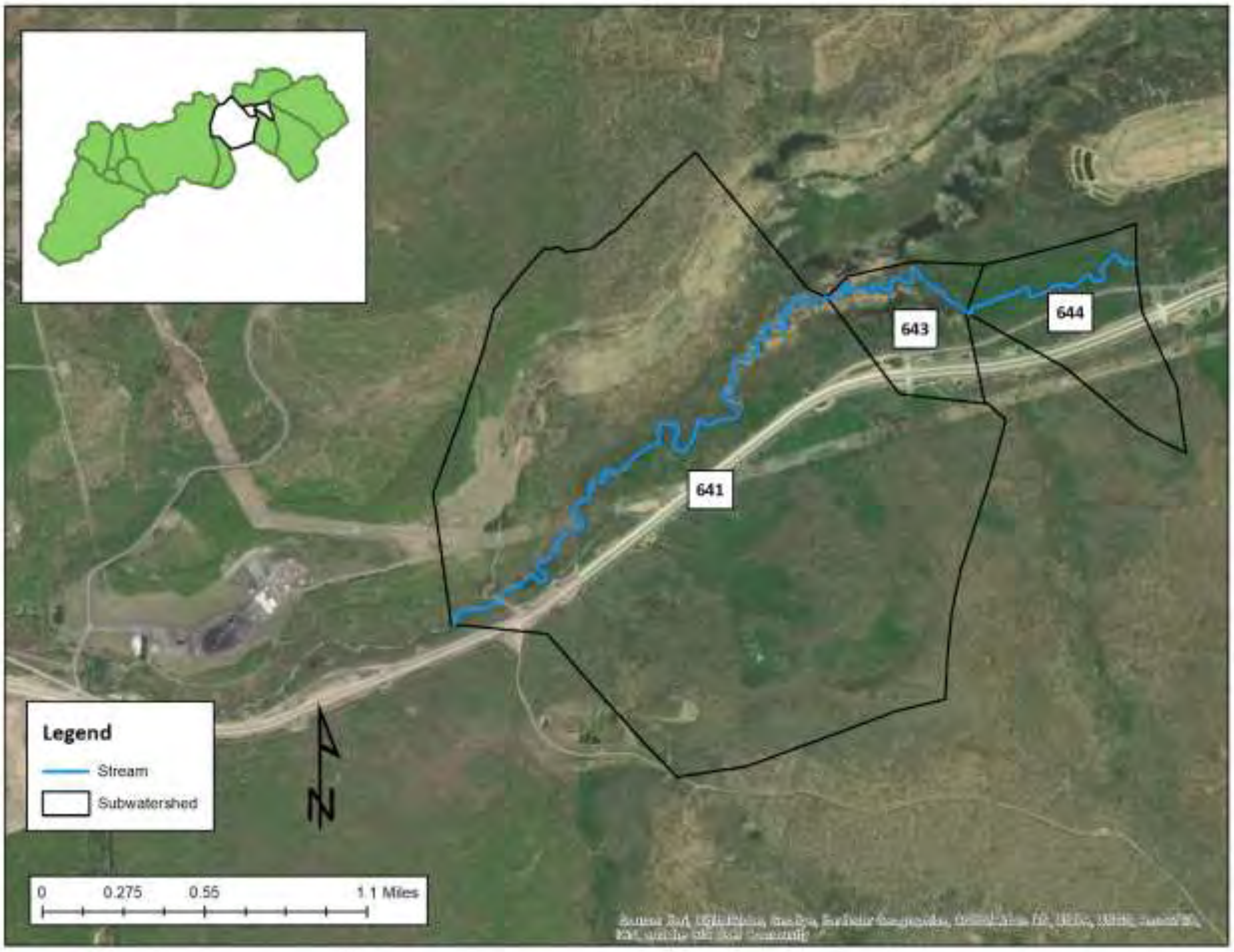


Figure 17. Aerial image of subwatersheds and stream channel targeted for streambank restoration in Phase I.

Under these criteria subwatershed 641, 643 and 644 reaches are targeted for phase I (Figure 17). While the less impacted headwaters have a wooded riparian zone, more erodible emergent wetlands border much of the stream in these areas. There are 3.94 river miles combined in these subwatersheds with an inexact amount of streambank in need of restoration; available land cover data lack sufficient resolution to make a detailed estimate. Once identified, bank and instream stabilization and habitat enhancement features consisting of a mix of woody debris and stumps, boulder and/or gravel material, and flood resistant vegetation will be implemented.

One particular problem site near the outlet of subwatershed 640 has previously been identified. A section of road and underlying 100 foot long culvert that once allowed access over Beaver Creek has been partially crushed. Above this section the stream is filling with fine sediment from the partial blockage while below, a pool wider than the width of the channel has been eroded. Restoration at this location would include removing the culvert, narrowing the channel at the overwidened pool below the culvert, enhancing in-stream habitat with woody debris, and establishing canopy species.

Stream restoration costs can vary widely from project to project depending on extent of existing degradation, materials used, availability of on-site material, site location, topography, access, land acquisition costs and in-kind support. A 2004 summary of 14 compensatory mitigation projects found an average cost of $59.20 per linear foot (Bonham & Stephenson, 2004) while a recent investigation of urban stream restoration projects lists a range of $500 to $1,200 per foot (Kenney *et al*, 2018). If the North Carolina Wetlands Restoration Program average cost of $106 per linear foot for rural restoration projects is used (DEQ, 2004), and it is assumed that 20% of the stream/streambank in SWS 640, 643 and 644 needs to be restored, then total restoration costs will be $441,000. An itemized price breakdown is provided in Table 12 for more detailed estimating when pursuing projects.

Table 12. Per unit costs for stream restoration materials. LF = linear feet, SF = square feet, SY = square yards, CY = cubic yards. Data source: DEQ, 2004.

	Costs	**Unit**	**Comments**
Bank Protection			
Tree revetments	$5-$25	LF	Higher cost if trees have to be obtained off site
Rootwad revetments	$200-$1700	Each	Higher cost if rootwads obtained off site
Stacked stone	$50/$90	Ton/CY	Quarry location is important factor in cost
Boulder revetments	$50/$90	Ton/CY	
Rock-Toe revetments	$75	LF	
Live crib wall	$11-$28	SF	
Interlocking jacks	$8-$15	LF	For 2'x2' units
Riprap Toe	$75	LF	
Bank Stabilization			
Natural fiber rolls	$10-$30	LF	Includes plants and stakes
Live soil lifts	$50	LF	Per LF of each 10" lift
Natural fiber matting	$3-$5	SY	
Live Fascines	$7-$22	LF	
Brush mattresses	$7-$12	SF	
Live stakes	$1-$4	Each	
Branch layering	$40-$50	SY	
Grade Control Structures			
Rock cross vanes	$90/$50	CY/Ton	
Rock W weirs	$90/$50	CY/Ton	
Rock vortex weirs	$90/$50	CY/Ton	
Step pools	$90/$50	CY/Ton	
Log drops and V log drops	$2000-$4000	Each	
Flow deflection / concentration			
Rock vanes	$90/$50	CY/Ton	
J Hook vanes	$90/$50	CY/Ton	
Wing deflectors	$90/$50	CY/Ton	
Log vanes	$300-$1200	Each	
Cut-off sills	$75	LF	

7.2.1 Phase II: Hawkins Run

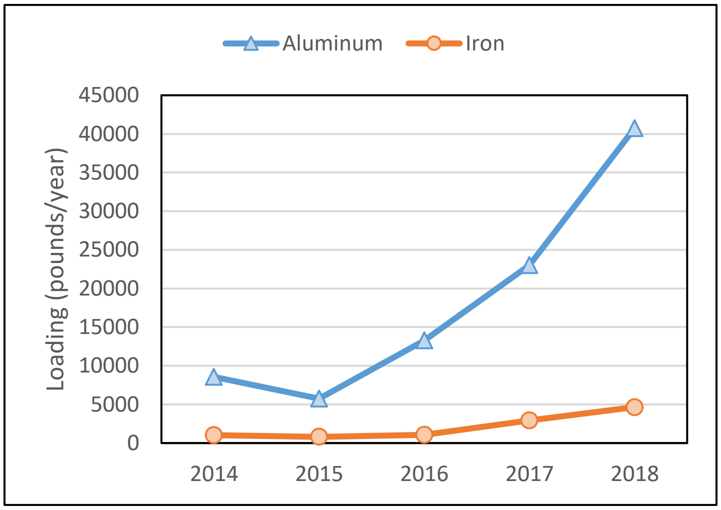


Figure 18. Annual mean loading for Seep 100-5. Data source: Alliance

Monthly data provided by Alliance Coal indicates a current (2018) average annual load from Hawkins Run of 40,740 lbs of aluminum requiring a 99.7% LR to achieve the target TMDL. This is significantly higher than the 4010 lbs/yr in aluminum listed in the TMDL which identifies no other source of aluminum other than Seep 100-5. Perhaps more troubling is the year over year increase in loading observed since 2015 (Figure 18). While the watershed has been host to strip mining in the past, there are no AML lands present nor active mining, therefore it is assumed that the discharge emanating from Seep 100-5 has worsened over time. If the current Alliance Coal data is used, a rudimentary treatment system composed of a single limestone leachbed and settling pond would cost $512,000 to design and construct. Monitoring conducted during Phase I will allow for design and construction in Phase II.

7.2.2 Phase II: Lost Run

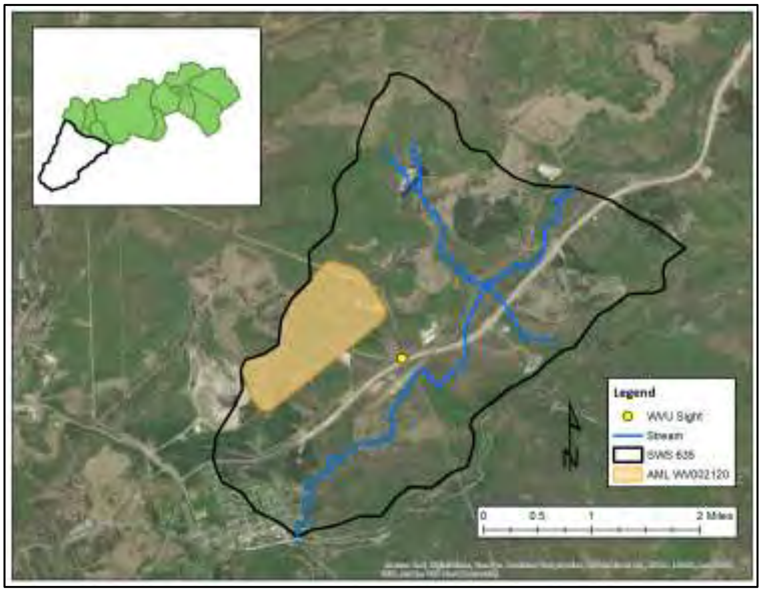


Figure 19. Lost Run sampling site and AMD source.

WVUs highway monitoring uncovered a previously unidentified supply of metals and acidity loading within the lower Beaver Creek subwatershed (SWS 635) in an area referred to on USFS maps as Lost Run. Data suggest an average annual load of 2759 lbs/yr of iron (aluminum data unavailable). This stream-wetland complex is believed to be impaired by AMD derived from the AML area located to the northwest of WVUs sampling sight (Figure 19), though this is currently uncorroborated. Treatment design and construction is too be completed in Phase II upon additional sight exploration and monitoring in Phase I.

7.2.3 Phase II: Unnamed Tributaries & Headwaters

All target metal load reductions in the Beaver Creek headwaters (SWS 645 reach), UNT RM 8.81, UNT RM 11.36 and UNT RM 11.91 will be achieved through land disturbance reclamation and, in the case of UNT RM 8.81, streambank erosion mitigation. The TMDL calls for a total of 125 acres of land reclamation plus a 90% reduction in streambank erosion for UNT RM 8.81. In the case of the UNT reaches, land reclamation targets may be under estimations as well as unachievable; roadways and a powerline right-of-way make up a significant portion of the disturbed lands (Figure 20) and the recent completion of Corridor H has only increased the amount of impervious roadway surface.

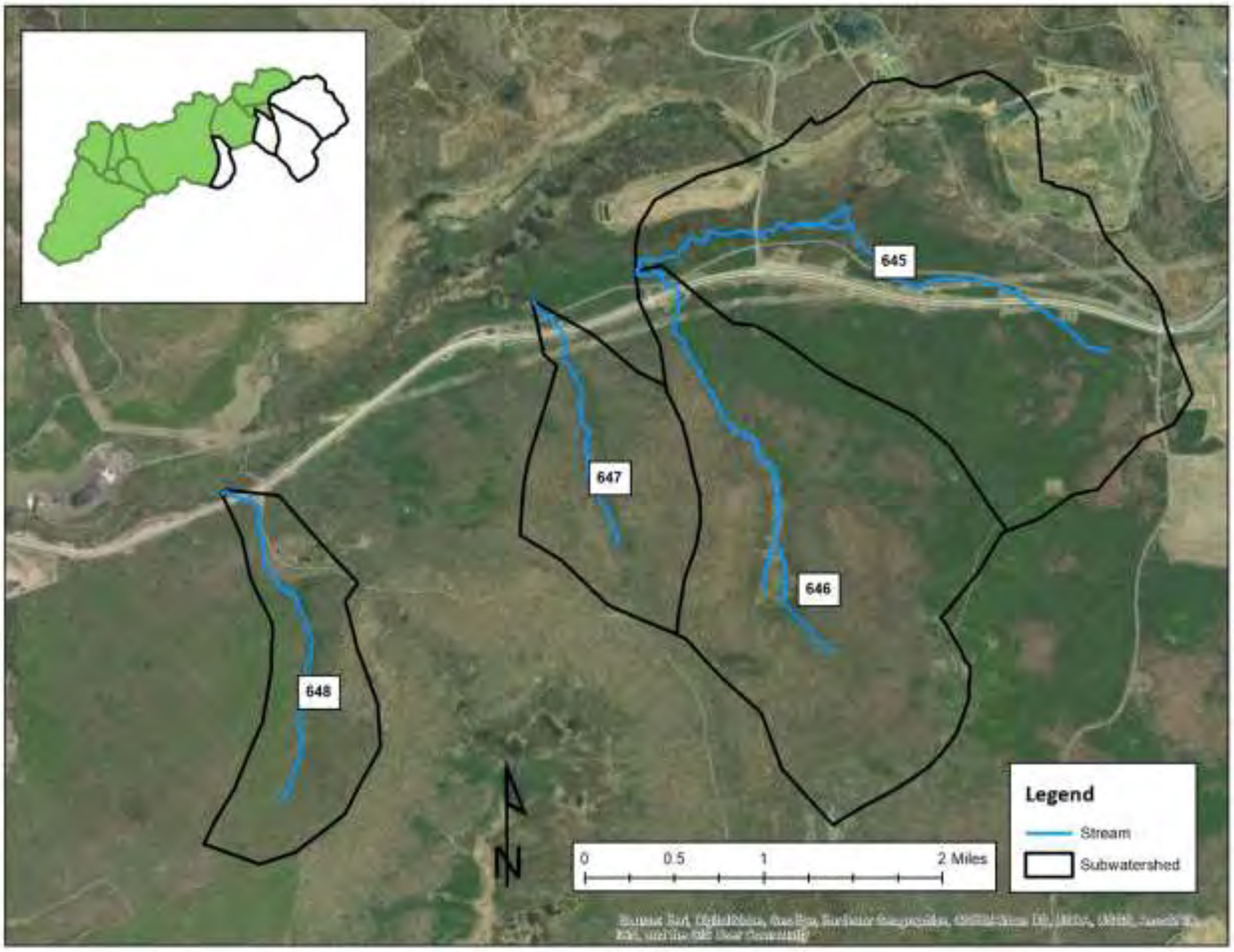


Figure 20. Aerial image of subwatersheds and stream reaches targeted for restoration in Phase II.

Metals remediation can be considered a low priority outside of the headwaters area given: 1) UNT RM 8.81 and UNT RM 11.91 are not metals impaired; 2) metals reductions are not expected to yield noticeable reductions in acidity for UNT reaches; and 3) metals impairment for UNT RM 11.36 may be a result of excessive natural leaching linked to acidic deposition. It is suggested that Phase II land disturbance BMPs target SWS 645. SWS 645 is home to active mining, therefore some land improvements can be expected upon completion of reclamation requirements. Further BMPs should focus on reestablishing riparian corridors where degraded, and reducing stormwater runoff from roadways.

Costs for reforestation of disturbed lands can vary widely depending on the terrain, species used and biodiversity complexity. Costs estimates range from $3,085 for monoculture plantations to $15,920 per hectare for more complex forests (Summer *et al*, 2015). While stormwater management retention ponds have been integrated into the construction of Corridor H, additional biofilter BMPs designed specifically to capture and retain metals may also be necessary if reforestation efforts are insufficient on their own. Bioswales are the preferred BMP in roadway runoff applications given low maintenance requirements and design flexibility. Cost estimates range from $5.50 to $24 per square foot (Environmental Services, 2006).

The TMDL attributes all measurable acidity loading in the impaired UNT reaches to acid deposition. As such, mitigation strategies should be selected accordingly in these areas. WVDNR is presently treating these waterways using limestone sands; an appropriate BMP strategy as metal precipitation formation, capture and removal is not a concern. Limestone sand additions are not expected to have to continue infinitum as further reductions in acid deposition are expected from regulatory mandates. Limestone sand application demands and costs are presented in Table 13.

Table 13. Limestone sand demands and annual costs for each watershed. Demands calculated according to the Clayton Formula. Per unit cost is $34.75 per ton. Cost source: OAMLR.

Stream ID	SWS	SWS Area (Hectares)	Median pH	Limestone Sands Needed (Tons)	Total Cost Annually
UNT RM 8.81	648	175.0	4.79	7.0	$243.25
UNT RM 11.36	647	183.2	4.69	7.3	$254.65
UNT RM 11.91	646	545.8	5.7	8.2	$284.49
Beaver Creek	645	663.8	6.43	6.6	$230.67

7.3 Phase III: Reevaluation and Further Improvements

Assuming continued independent reductions in acid deposition, improvements implemented during the first two phases are expected to yield sufficient reductions in metals and acidity loading to achieve target LAs. In Phase III, monitoring will be used to assess the validity of this claim and target any remaining sources of impairment. According to the TMDL, likely remaining sources would include streambank erosion in Hawkins Run, UNT RM 8.81 and the lower reaches of Beaver Creek, and land disturbances in tributary watersheds. Additional assessment of biological impairment is needed as well. It is expected that metals and acidity are driving this impairment, but the temperature stresses may be significant enough to sustain impairment. If so, additional stream channel and riparian corridor restoration will be necessary.

8. Technical and Financial Assistance

A combination of federal and state agencies, academic institutions, watershed organizations, consultants, and citizens will be involved in providing technical and financial assistance for Beaver Creek watershed projects.

8.1 Technical Assistance

Technical assistance is needed for the following tasks:

- Coordinating and applying for various funding sources;
- Collecting data from/on pollution sources in preparation for the design of remediation projects;
- Creating conceptual designs of remediation projects;
- Creating detailed engineering designs of remediation projects;
- Performing project management, including developing bid documents, project coordination and permitting, and tracking project progress; and
- Monitoring instream and source water quality following the installation or remediation projects to document their effectiveness.

Technical assistance providers include the following:

- *West Virginia Department of Environmental Protection*

  The WVDEP Division of Water and Waste Management monitors the water quality of the watershed through its Watershed Assessment Program and its pre-TMDL monitoring Program. This division also provides technical assistance for the use of BMPs, educates the public and land users on NPS issues, enforces water quality laws that affect nonpoint sources, and restores impaired watersheds through its Non-Point Source Program.

  WVDEP’s Office of Abandoned Mine Lands and Reclamation directs technical resources to watersheds impacted by the presence of AMLs. The office conducts extensive source monitoring of AMLs – as well as instream monitoring – before remediation systems are designed.

- *Office of Surface Mining, Reclamation and Enforcement*

  OSMRE provides technical assistance by sharing their knowledge and experience in designing and financing AML remediation projects; specifically with regards to using the OSMRE developed AMDTreat program.

- *West Virginia Division of Natural Resources*

  WVDNR works to preserve, protect and enhance the state's waterways through its fisheries management programs and Office of Land and Streams. Staff can provide expertise of habitat enhancement projects and are actively working in the Beaver Creek watershed.

- *West Virginia University*

  The National Mine Land Reclamation Center (NMLRC), housed at WVU, has experience providing conceptual site designs for reclamation projects and monitoring water quality produced by AMLs before and after project completion. NMLRC is dedicated to developing innovative AMD treatment technologies. Additional assistance may be provided by departments with expertise in fisheries and wildlife resources, mine land reclamation, and water quality improvement.

- *Natural Resource Conservation Service (NRCS)*

  NRCS delivers conservation technical assistance through its voluntary Conservation Technical Assistance Program with the goal helping land users implement sound natural resource management decisions on private, tribal and non-federal lands. Relevant areas of focus include implementing better land management technologies, protecting and improving water quality and quantity, and maintaining and improving wildlife and fish habitat.

- *Other Technical Assistance Providers*

  EPA staff with expertise in AMD and stream restoration from Region 3 and from headquarters may provide technical assistance. Local conservation districts may also be a repository of information and assistance.

8.2 Funding Sources

Several funding sources are available for nonpoint source remediation and for water quality monitoring, including:

- *Section 319 Funds*

  Clean Water Act Section 319 funds may be provided by EPA to WVDEP to be used for reclamation on nonpoint source pollution. This WBP is being authored so that these funds can be allocated to the Beaver Creek watershed. WVDEP sets priorities and administers the state Section 319 program.

- *The Abandoned Mine Land Trust Fund*

  Before enactment of SMCRA in 1977, coal mines generally did not manage acid-producing material to prevent AMD or treat the AMD that was produced. AMD presently emanating from these "pre-law" mines are treated as nonpoint sources under the Clean Water Act which established the AML Trust Fund. This fund, supported by a per-ton tax on mined coal, has been allocated to coal mining states for remediation projects but is set to expire in 2020.

  However, the AML Trust Fund has failed to address AMD at a rapid pace, largely due to prioritization of health and safety hazards ahead of water quality issues by WVDEP. Still, WVDEP has funded many AMD remediation projects, though these projects are typically not designed to meet stringent water quality goals like those in this WBP. Unless significantly more money were allocated to West Virginia's AML program and these funds were spent on water quality problems, the AML Trust Fund will not be sufficient to implement the AMD LRs addressed in this document.

- *10% AMD Set-Aside Fund*

  The 10% Set-Aside Program allows states to reserve up to 10% of their annual AML Trust Fund allocations as an endowment for use on water quality projects. While regular AML Trust Fund allocations can only be spent on capital costs, 10% AMD Set-Aside Fund allocations can be spent on operations and maintenance. These funds can only be allocated to watersheds once a Hydrologic Unit Plan is developed and approved by OSMRE.

- *Watershed Cooperative Agreement Program (WCAP)*

  Grants specifically for AMD remediation projects on AMLs are available through OSM's WCAP, which is part of the Appalachian Clean Streams Initiative. Grants of up to $100,000 are awarded to not-for-profit organizations that have developed cooperative agreements with other entities to reclaim AML sites (OSM, 2004). No match is technically required but funds are often used in conjunction with Section 319 funds.

- *Stream Partners Program*

  This program offers grants of up to $5,000 to watershed organizations in West Virginia. Grants can be used for a range of projects including small watershed assessments, water quality monitoring, public education, stream restoration and organizational support and development. FOB has received Stream Partners grants in the past and will continue to be pursued in the future to compliment nonpoint source research, education and reclamation in the Beaver Creek watershed.

- *Brownfields Grants*

  USEPA's Brownfield grants of up to $200 thousand are available through a competitive process; these grants can be applied to mine scarred lands. Competitive site assessment grants can be used for inventory, planning, quantification of environmental risks, and development of risk management or remedial action plans. Competitive remediation grants can then be used to carry out remediation tasks and projects.

- *Other Government Funding Sources*

  NRCS is funding AMD remediation in the Deckers Creek watershed in north-central West Virginia through a Public Law-566 watershed restoration project. USFWS, through its Wildlife & Sport Fish Restoration Program, offers grant opportunities to state and non-profit organization engaged in protecting and enhancing fish, wildlife and their habitats. U.S. Army Corp of Engineers (USACE) has funded an AMD study in the lower Cheat watershed and may be a potential funder for remediation projects in the future.

- *Private Foundation Grants*

  FOB has generated funding from private foundations to support a staff member responsible for interfacing with agencies and raising funds for AMD remediation. FOB will continue to seek addition private grants to sustain these essential services.

9. Milestones and Assessment

The success of projects will be determined according to the achievement of 3 objective milestones: chemical, biological and physical. The milestones follow the natural recovery of streams after disturbances have been lifted. The first milestone of stream recovery is the improvement of water chemistry to numeric water quality standards and TMDL targets. The second is the return of benthic macro invertebrates to the stream. The final milestone assesses the quality of the physical habitat.

Continuous improvement in assessment data over time will indicate achievement of interim objective and progress towards milestones. The following criteria will be used to measure progress towards these goals:

- *Chemical Assessment* – FOB will characterize water chemistry at locations above and below nonpoint sources of pollution. Treatment effects will be characterized by performing water sampling before and after construction. Water chemistry variables will include acidity, alkalinity, pH, specific conductance, sulfate, aluminum (dissolved), iron (total and dissolved), manganese (dissolved), and calcium (dissolved).

- *Biological Assessment* – Biological improvements will be assessed using the USEPA's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. Streams will then be scored according to WVSCI.

- *Habitat Assessment* – Physical habitat improvements will be tracked through time using the WVSCI's supplemental Habitat Characterization assessment. Physical habitat assessment characterizes the following parameters: substrate, embeddedness, sediment deposition, bank stability, riparian vegetation.

10. Monitoring

Instream monitoring is important for planning of reclamation priorities, essential for the design of realistic treatments, and a means of gauging the recovery of streams after remediation projects are implemented. Several agencies and organizations are now monitoring the Beaver Creek watershed and will continue to do so.

10.1 Friends of Blackwater

In anticipation of developing this WBP, FOB began monitoring in the Beaver Creek watershed in fall of 2016. Monitoring is conducted with the goal of understanding baseline conditions and fluctuations over time at the watershed-wide scale, though financial, temporal and capacity limitations prohibit monitoring at every subwatershed outlet and/or NPS.

Water quality data is collected at 16 sites (Figure 21) throughout the watershed though changes to locations may be needed as remediation projects are pursued. pH, conductivity and temperature data are collected on a monthly basis, with additional flow measurements and water samples collected on a quarterly basis. Samples are then sent to a laboratory for further analysis. Additional parameters analyzed include: alkalinity, acidity, iron, aluminum, manganese, calcium, and sulfate. Further detail on FOB's monitoring program can be found in the relevant Quality Assurance Project Plan.

Figure 21. FOB monitoring sites in the Beaver Creek watershed.

10.2 WVDEP Watershed Assessment Program

According the WVDEP's five-year watershed management framework cycle, the agency performs in-depth monitoring of the state's watersheds every five years. These monitoring data are helpful in assessing whether streams are improving or declining in quality. In addition to inorganic chemistry data, technicians collect benthic macroinvertebrate data to determine biological impairments and fecal coliform data to determine bacteria impairments. Technicians also perform sediment-related assessments. WVDEP use these data, plus data collected by other agencies and organizations, to make impairment decisions for the next 303(d) list.

10.3 WVDOT and WVU

In accordance with USACE guidelines, WVDOT is required to monitor the impact of Corridor H on the local watershed. WVU has been contracted to perform this task and will be monitoring main steam and tributary reaches throughout the watershed until 2022. Parameters measured are largely inorganics such at metals, nutrients and particulates. Additional organization have been contracted by WVDOT to monitor for oil and gas compounds associated with vehicular traffic and roadway runoff.

10.4 WVDNR

In conjunction with its limestone sands applications, WVDNR has deployed continuous monitoring equipment near the mouth of Beaver Creek that records temperature, pH and conductivity on an hourly basis. WVDNR staff also periodically conduct addition fish surveys with the next round of monitoring scheduled for 2019.

10.5 Corporations & Non-Profits

Mettiki and Vindex are currently active mines operating within the Beaver Creek watershed. In addition to routinely collected point source discharge data, these mines may also periodically collect data that may be used for non-point source pollution assessment. Locally based non-profits Canaan Valley Institute and the National Youth Science Foundation also periodically collect Beaver Creek water quality as part of their educational programs.

11. Outreach and Education

FOB has advocated for the protection of area watersheds for 18 years. In that time it has become apparent that protecting stream health requires more than a focus on water quality. FOB's outreach and educational initiatives are designed to engage the public in a variety of disciplines across local and regional scales in an effort to link human interests and values with genuine environmental needs.

- *Events* – FOB conducts annual litter clean-ups along Camp 70 Road, including the section of Beaver Creek near the confluence with the Blackwater, under the Adopt-A-Highway program. A previous history tour focused on the role of the timber industry in the Davis area included a stop near the Beaver Creek-Blackwater River confluence to explain how these waterways allowed mills and tanneries to operate. Other activities, such as winter film festivals or scenic tours, are not as specific to Beaver Creek but still bring general attention to the value of natural beauty and clean waterways. In the future, we intend to offer more tours and outings focused on the Beaver Creek watershed, and will develop those opportunities alongside the ongoing water quality improvement work.

- *Newsletters and other Publications* – FOB publishes quarterly newsletters that are e-mailed to nearly 5,000 digital subscribers, and mailed to roughly 1,000, with another 750 distributed through small businesses. The newsletter is also available on our website and announced on our Facebook page, which has nearly 3,600 followers. Each newsletter includes at least one page of watershed content, and in between quarterly newsletters we keep our members updated through blog posts on our website and Facebook updates.

- *Volunteers* – Volunteer programs include a hands on approach, such as water monitoring, watershed litter cleans ups under the Adopt-A-Highway program, trail maintenance to reduce erosion, history tours that lead people into the watershed, and water quality education. We also host education workshops and hold lectures on the industrial history of the area. Other initiatives include: tours of environmental treatment systems, film festivals, and more.

- *Youth education* – Friends of Blackwater has received a grant to install automated sensors in Beaver Creek. Students will be involved in all phases of that project – programming, installation, data collection and more. This project will both help improve the quality of data for Beaver Creek and provide students with hands-on lessons about technology and water quality.

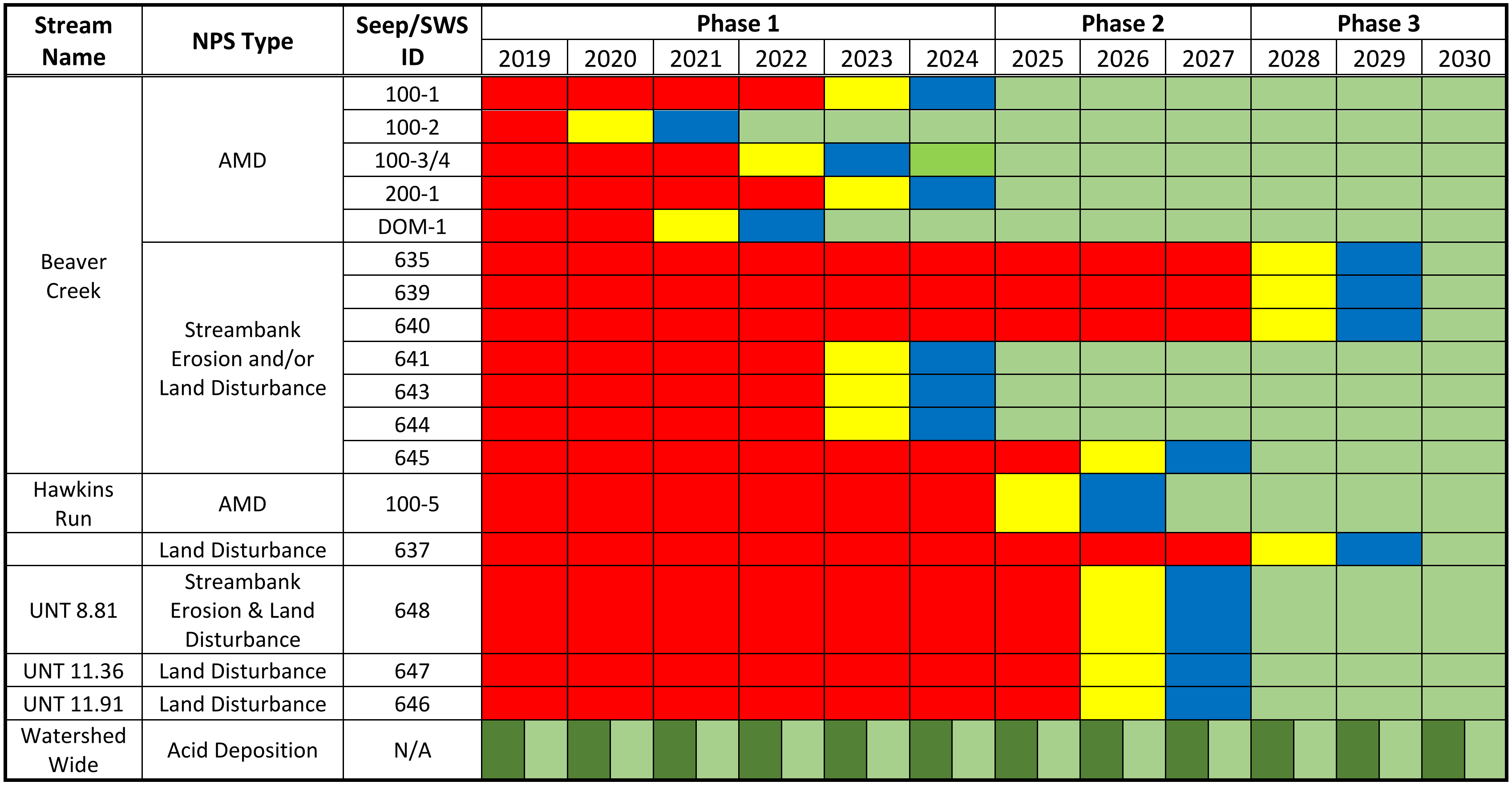
- *Website* – The Friends of Blackwater website – https://saveblackwater.org – includes a page devoted to watershed issues, as well as blog posts on water-related topics, event listings, and volunteer opportunities. The website was redesigned earlier this year to be more user-friendly and easier to manage, which has increased both visitor traffic and the frequency with which we can make updates.

- *Public outreach meetings, tabling and press* – Regular stakeholder meetings have been taking place throughout the process of writing the watershed-based plan in order to get input from state and federal agencies, local non-profits, businesses in the project area, and other stakeholders. We expect that these meetings will continue and possibly become more frequent as we begin to plan the actual remediation work. In addition, Friends of Blackwater will organize meetings geared towards the general public, in which representatives from FOB and the other involved organizations will present their plans for Beaver Creek. These meetings will initially focus on Davis, as the community closest to the waterway, but may expand to locations in Thomas and/or Canaan Valley in order to engage a wider audience. In the past, representatives of the Friends of Blackwater have conducted watershed tours to educate the public about the nonpoint source problems, so this would be an additional option for promoting local engagement. Friends of Blackwater's watershed work is presented at external events such as the Harpers Ferry Outdoor Festival, Cheat Fest, Leaf Peepers Festival in Davis and the Forest Festival in Elkins. We also attend and distribute information at Environment Day at the West Virginia Legislature. Press releases about these events and our work are sent to the local paper, the Parsons Advocate, and to the Elkins' Intermountain.

Since 2002, FOB's watershed outreach and education work has drawn financial and technical support from the Office of Surface Mining, West Virginia Department of Environmental Protection, Office of Abandoned Mine Lands and Reclamation, WV Division of Natural Resources, Friends of the Cheat, the Youth Science Foundation and the Tucker County Historical Society. Additional funding has been provided by the Appalachian Stewardship Foundation, West Virginia Humanities Council, Appalachian Community Fund, National Fish and Wildlife Foundation, the Oakland Foundation, Best Buy, Clif Bar, Patagonia, the North Face, and the Tucker Community Foundation.

12. Implementation Schedule

Table 14. Implementation schedule for Beaver Creek monitoring and restoration projects.



Stream Name	NPS Type	Seep/SWS ID	Phase 1						Phase 2			Phase 3		
			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Beaver Creek	AMD	100-1	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩
		100-2	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
		100-3/4	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟩
		200-1	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩
		DOM-1	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	Streambank Erosion and/or Land Disturbance	635	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩
		639	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩
		640	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩
		641	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩
		643	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩
		644	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩	🟩	🟩
		645	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩
Hawkins Run	AMD	100-5	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩	🟩
	Land Disturbance	637	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩
UNT 8.81	Streambank Erosion & Land Disturbance	648	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩
UNT 11.36	Land Disturbance	647	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩
UNT 11.91	Land Disturbance	646	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟦	🟩	🟩	🟩
Watershed Wide	Acid Deposition	N/A	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩	▩🟩

🟥 Pre-Monitoring & Planning	🟨 Engineering and Design Phase
🟩 Post-Monitoring & Assessment	🟦 Construction and Implementation
	▩ On-Going Active Treatment

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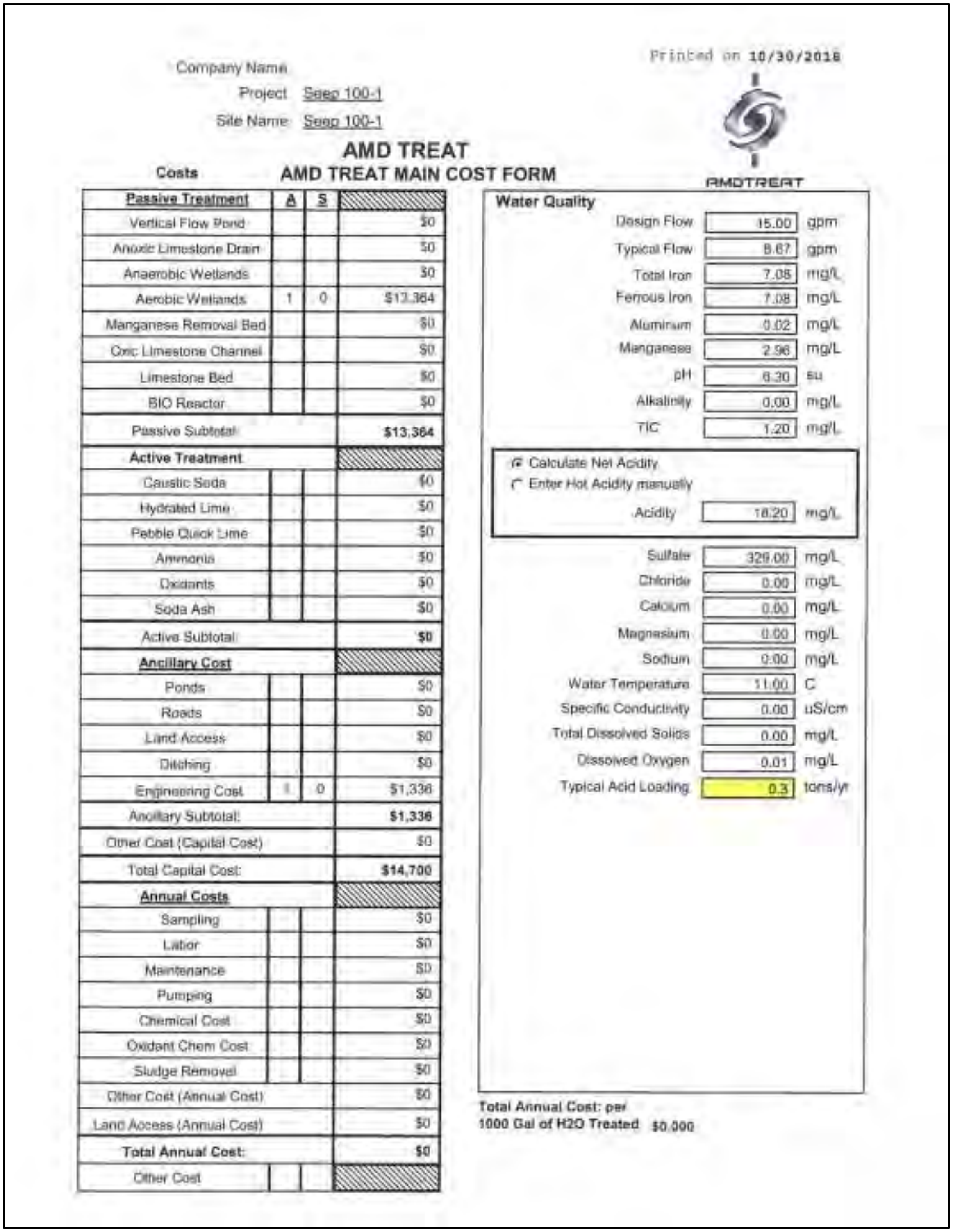
Appendix



Printed on 10/30/2018

Company Name
Project Seep 100-1
Site Name Seep 100-1

AMD TREAT
AMD TREAT MAIN COST FORM

AMDTREAT

Costs

Passive Treatment	**A**	**S**	
Vertical Flow Pond			$0
Anoxic Limestone Drain			$0
Anaerobic Wetlands			$0
Aerobic Wetlands	1	0	$13,364
Manganese Removal Bed			$0
Oxic Limestone Channel			$0
Limestone Bed			$0
BIO Reactor			$0
Passive Subtotal			**$13,364**
Active Treatment			
Caustic Soda			$0
Hydrated Lime			$0
Pebble Quick Lime			$0
Ammonia			$0
Oxidants			$0
Soda Ash			$0
Active Subtotal			**$0**
Ancillary Cost			
Ponds			$0
Roads			$0
Land Access			$0
Ditching			$0
Engineering Cost	1	0	$1,336
Ancillary Subtotal:			**$1,336**
Other Cost (Capital Cost)			$0
Total Capital Cost:			**$14,700**
Annual Costs			
Sampling			$0
Labor			$0
Maintenance			$0
Pumping			$0
Chemical Cost			$0
Oxidant Chem Cost			$0
Sludge Removal			$0
Other Cost (Annual Cost)			$0
Land Access (Annual Cost)			$0
Total Annual Cost:			**$0**
Other Cost			

Water Quality

Design Flow	15.00	gpm
Typical Flow	8.67	gpm
Total Iron	7.08	mg/L
Ferrous Iron	7.08	mg/L
Aluminum	0.02	mg/L
Manganese	2.96	mg/L
pH	6.30	su
Alkalinity	0.00	mg/L
TIC	1.20	mg/L

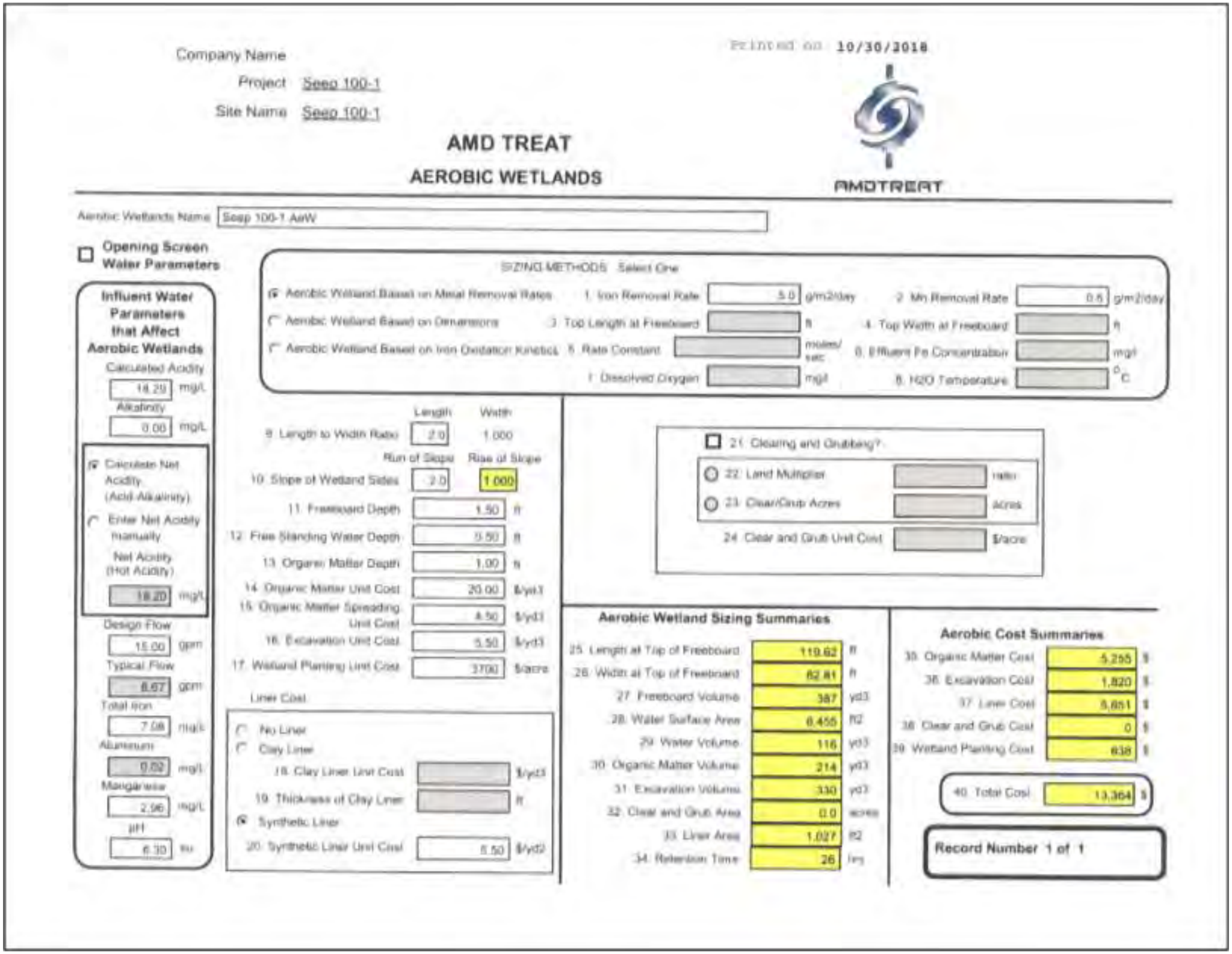
● Calculate Net Acidity
○ Enter Hot Acidity manually

Acidity	18.20	mg/L

Sulfate	329.00	mg/L
Chloride	0.00	mg/L
Calcium	0.00	mg/L
Magnesium	0.00	mg/L
Sodium	0.00	mg/L
Water Temperature	11.00	C
Specific Conductivity	0.00	uS/cm
Total Dissolved Solids	0.00	mg/L
Dissolved Oxygen	0.01	mg/L
Typical Acid Loading	0.3	tons/yr

**Total Annual Cost: per
1000 Gal of H2O Treated $0.000**

Figure 22. AMDTreat report on remediation system proposed for Seep 100-1.



Company Name

Project Seep 100-1

Site Name Seep 100-1

Printed on 10/30/2018

AMD TREAT

AEROBIC WETLANDS

Aerobic Wetlands Name: Seep 100-1 AeW

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect Aerobic Wetlands

Calculated Acidity: 18.29 mg/L

Alkalinity: 0.00 mg/L

● Calculate Net Acidity (Acid-Alkalinity)

○ Enter Net Acidity manually

Net Acidity (Hot Acidity): 18.20 mg/L

Design Flow: 15.00 gpm

Typical Flow: 8.67 gpm

Total Iron: 7.08 mg/L

Aluminum: 0.02 mg/L

Manganese: 2.96 mg/L

pH: 6.30 su

SIZING METHODS Select One

● Aerobic Wetland Based on Metal Removal Rates

1. Iron Removal Rate: 5.0 g/m2/day

2. Mn Removal Rate: 0.5 g/m2/day

○ Aerobic Wetland Based on Dimensions

3. Top Length at Freeboard: ft

4. Top Width at Freeboard: ft

○ Aerobic Wetland Based on Iron Oxidation Kinetics

5. Rate Constant: moles/sec

6. Effluent Fe Concentration: mg/l

7. Dissolved Oxygen: mg/l

8. H2O Temperature: °C

	Length	Width
9. Length to Width Ratio	2.0	1.000
	Run of Slope	Rise of Slope
10. Slope of Wetland Sides	2.0	1.000

11. Freeboard Depth: 1.50 ft

12. Free Standing Water Depth: 0.50 ft

13. Organic Matter Depth: 1.00 ft

14. Organic Matter Unit Cost: 20.00 $/yd3

15. Organic Matter Spreading Unit Cost: 4.50 $/yd3

16. Excavation Unit Cost: 5.50 $/yd3

17. Wetland Planting Unit Cost: 3700 $/acre

Liner Cost

○ No Liner

○ Clay Liner

18. Clay Liner Unit Cost: $/yd3

19. Thickness of Clay Liner: ft

● Synthetic Liner

20. Synthetic Liner Unit Cost: 5.50 $/yd2

☐ 21. Clearing and Grubbing?

○ 22. Land Multiplier: ratio

○ 23. Clear/Grub Acres: Acres

24. Clear and Grub Unit Cost: $/acre

Aerobic Wetland Sizing Summaries

25. Length at Top of Freeboard: 119.62 ft

26. Width at Top of Freeboard: 82.81 ft

27. Freeboard Volume: 387 yd3

28. Water Surface Area: 8,455 ft2

29. Water Volume: 116 yd3

30. Organic Matter Volume: 214 yd3

31. Excavation Volume: 330 yd3

32. Clear and Grub Area: 0.0 acres

33. Liner Area: 1,027 ft2

34. Retention Time: 26 hrs

Aerobic Cost Summaries

35. Organic Matter Cost: 5,255 $

36. Excavation Cost: 1,820 $

37. Liner Cost: 5,651 $

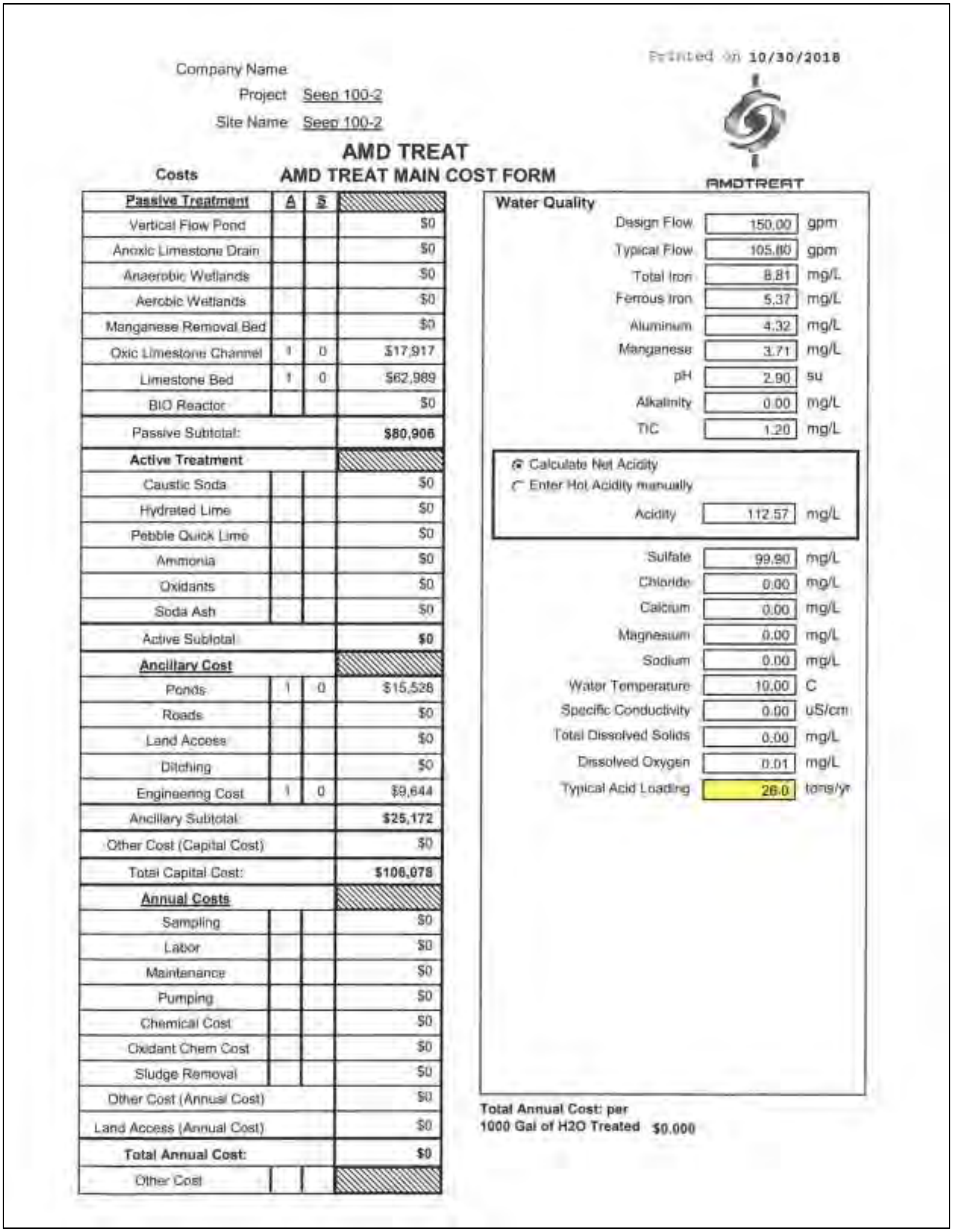
38. Clear and Grub Cost: 0 $

39. Wetland Planting Cost: 638 $

40. Total Cost: 13,364 $

Record Number 1 of 1

Figure 23. AMDTreat report on aerobic wetland for Seep 100-1.



Printed on 10/30/2018

Company Name
Project Seep 100-2
Site Name Seep 100-2

AMD TREAT

AMD TREAT MAIN COST FORM

AMDTREAT

Costs

Passive Treatment	A	S	
Vertical Flow Pond			$0
Anoxic Limestone Drain			$0
Anaerobic Wetlands			$0
Aerobic Wetlands			$0
Manganese Removal Bed			$0
Oxic Limestone Channel	1	0	$17,917
Limestone Bed	1	0	$62,989
BIO Reactor			$0
Passive Subtotal:			**$80,906**
Active Treatment			
Caustic Soda			$0
Hydrated Lime			$0
Pebble Quick Lime			$0
Ammonia			$0
Oxidants			$0
Soda Ash			$0
Active Subtotal			**$0**
Ancillary Cost			
Ponds	1	0	$15,528
Roads			$0
Land Access			$0
Ditching			$0
Engineering Cost	1	0	$9,644
Ancillary Subtotal			**$25,172**
Other Cost (Capital Cost)			$0
Total Capital Cost:			**$106,078**
Annual Costs			
Sampling			$0
Labor			$0
Maintenance			$0
Pumping			$0
Chemical Cost			$0
Oxidant Chem Cost			$0
Sludge Removal			$0
Other Cost (Annual Cost)			$0
Land Access (Annual Cost)			$0
Total Annual Cost:			**$0**
Other Cost			

Water Quality

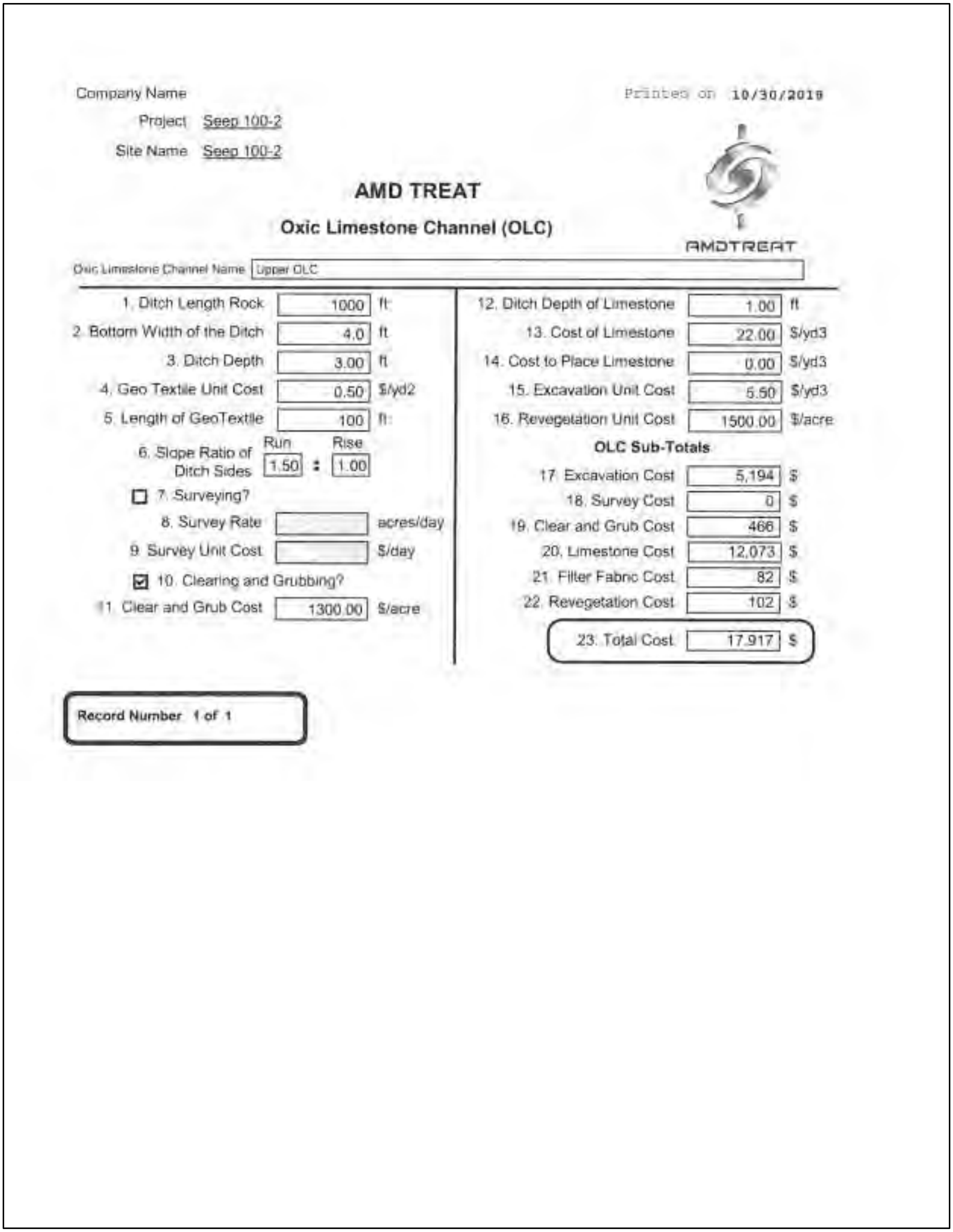
Design Flow	150.00	gpm
Typical Flow	105.80	gpm
Total Iron	8.81	mg/L
Ferrous Iron	5.37	mg/L
Aluminum	4.32	mg/L
Manganese	3.71	mg/L
pH	2.90	su
Alkalinity	0.00	mg/L
TIC	1.20	mg/L

● Calculate Net Acidity
○ Enter Hot Acidity manually

Acidity	112.57	mg/L
Sulfate	99.90	mg/L
Chloride	0.00	mg/L
Calcium	0.00	mg/L
Magnesium	0.00	mg/L
Sodium	0.00	mg/L
Water Temperature	10.00	C
Specific Conductivity	0.00	uS/cm
Total Dissolved Solids	0.00	mg/L
Dissolved Oxygen	0.01	mg/L
Typical Acid Loading	26.0	tons/yr

Total Annual Cost: per 1000 Gal of H2O Treated **$0.000**

Figure 24. AMDTreat report on remediation system proposed at Seep 100-2.



Company Name

Printed on 10/30/2019

Project Seep 100-2

Site Name Seep 100-2

AMD TREAT

Oxic Limestone Channel (OLC)

Oxic Limestone Channel Name: Upper OLC

1. Ditch Length Rock	1000	ft	12. Ditch Depth of Limestone	1.00	ft
2. Bottom Width of the Ditch	4.0	ft	13. Cost of Limestone	22.00	$/yd3
3. Ditch Depth	3.00	ft	14. Cost to Place Limestone	0.00	$/yd3
4. Geo Textile Unit Cost	0.50	$/yd2	15. Excavation Unit Cost	5.50	$/yd3
5. Length of GeoTextile	100	ft	16. Revegetation Unit Cost	1500.00	$/acre

6. Slope Ratio of Ditch Sides: Run 1.50 : Rise 1.00

☐ 7. Surveying?

8. Survey Rate ______ acres/day

9. Survey Unit Cost ______ $/day

☑ 10. Clearing and Grubbing?

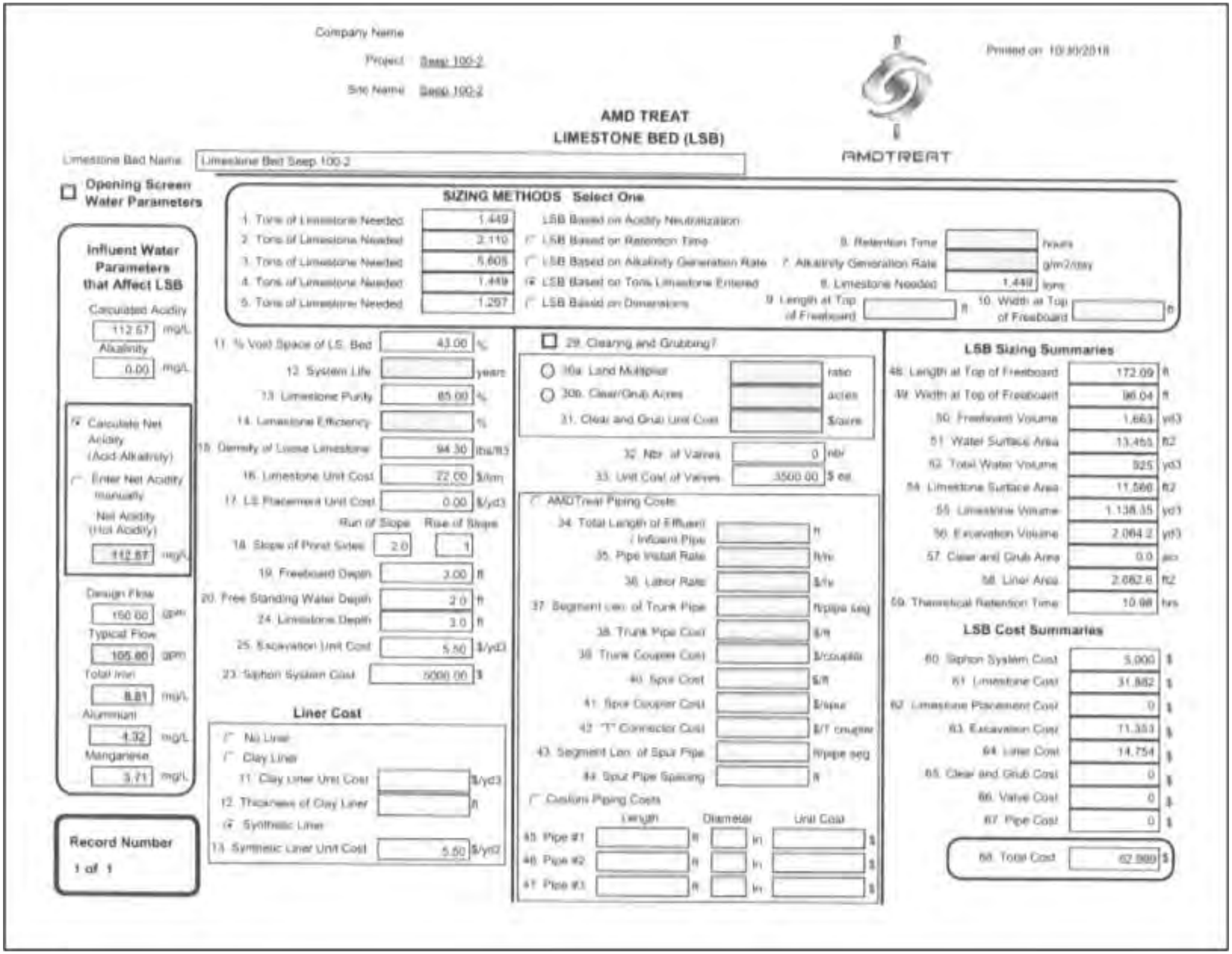
11. Clear and Grub Cost 1300.00 $/acre

OLC Sub-Totals

17. Excavation Cost	5,194	$
18. Survey Cost	0	$
19. Clear and Grub Cost	466	$
20. Limestone Cost	12,073	$
21. Filter Fabric Cost	82	$
22. Revegetation Cost	102	$
23. Total Cost	17,917	$

Record Number 1 of 1

Figure 25. AMDTreat report on open limestone channel components for Seep 100-2.



Company Name

Project: Seep 100-2

Site Name: Seep 100-2

Printed on: 10/30/2018

AMD TREAT

LIMESTONE BED (LSB)

AMDTREAT

Limestone Bed Name: Limestone Bed Seep 100-2

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect LSB

Calculated Acidity: 112.67 mg/L

Alkalinity: 0.00 mg/L

● Calculate Net Acidity (Acid-Alkalinity)

○ Enter Net Acidity manually

Net Acidity (Hot Acidity): 112.67 mg/L

Design Flow: 150.00 gpm

Typical Flow: 105.60 gpm

Total Iron: 8.81 mg/L

Aluminum: 4.32 mg/L

Manganese: 3.71 mg/L

Record Number

1 of 1

SIZING METHODS Select One

1. Tons of Limestone Needed	1,449	LSB Based on Acidity Neutralization
2. Tons of Limestone Needed	2,110	○ LSB Based on Retention Time
3. Tons of Limestone Needed	5,605	○ LSB Based on Alkalinity Generation Rate
4. Tons of Limestone Needed	1,449	● LSB Based on Tons Limestone Entered
5. Tons of Limestone Needed	1,257	○ LSB Based on Dimensions

6. Retention Time: ____ hours

7. Alkalinity Generation Rate: ____ g/m2/day

8. Limestone Needed: 1,449 tons

9. Length at Top of Freeboard: ____ ft

10. Width at Top of Freeboard: ____ ft

11. % Void Space of LS Bed: 43.00 %

12. System Life: ____ years

13. Limestone Purity: 85.00 %

14. Limestone Efficiency: ____ %

15. Density of Loose Limestone: 94.30 lbs/ft3

16. Limestone Unit Cost: 22.00 $/ton

17. LS Placement Unit Cost: 0.00 $/yd3

18. Slope of Pond Sides: Run of Slope 2.0, Rise of Slope 1

19. Freeboard Depth: 3.00 ft

20. Free Standing Water Depth: 2.0 ft

24. Limestone Depth: 3.0 ft

25. Excavation Unit Cost: 5.50 $/yd3

23. Siphon System Cost: 5000.00 $

Liner Cost

○ No Liner

○ Clay Liner

11. Clay Liner Unit Cost: ____ $/yd3

12. Thickness of Clay Liner: ____ ft

● Synthetic Liner

13. Synthetic Liner Unit Cost: 5.50 $/yd2

☐ 29. Clearing and Grubbing?

○ 30a. Land Multiplier: ____ ratio

○ 30b. Clear/Grub Acres: ____ acres

31. Clear and Grub Unit Cost: ____ $/acre

32. Nbr. of Valves: 0 nbr

33. Unit Cost of Valves: 3500.00 $ ea

○ AMDTreat Piping Costs

34. Total Length of Effluent / Influent Pipe: ____ ft

35. Pipe Install Rate: ____ ft/hr

36. Labor Rate: ____ $/hr

37. Segment Len. of Trunk Pipe: ____ ft/pipe seg

38. Trunk Pipe Cost: ____ $/ft

39. Trunk Coupler Cost: ____ $/coupler

40. Spur Cost: ____ $/ft

41. Spur Coupler Cost: ____ $/spur

42. "T" Connector Cost: ____ $/T coupler

43. Segment Len. of Spur Pipe: ____ ft/pipe seg

44. Spur Pipe Spacing: ____ ft

○ Custom Piping Costs

	Length	Diameter	Unit Cost
45. Pipe #1	ft	in	$
46. Pipe #2	ft	in	$
47. Pipe #3	ft	in	$

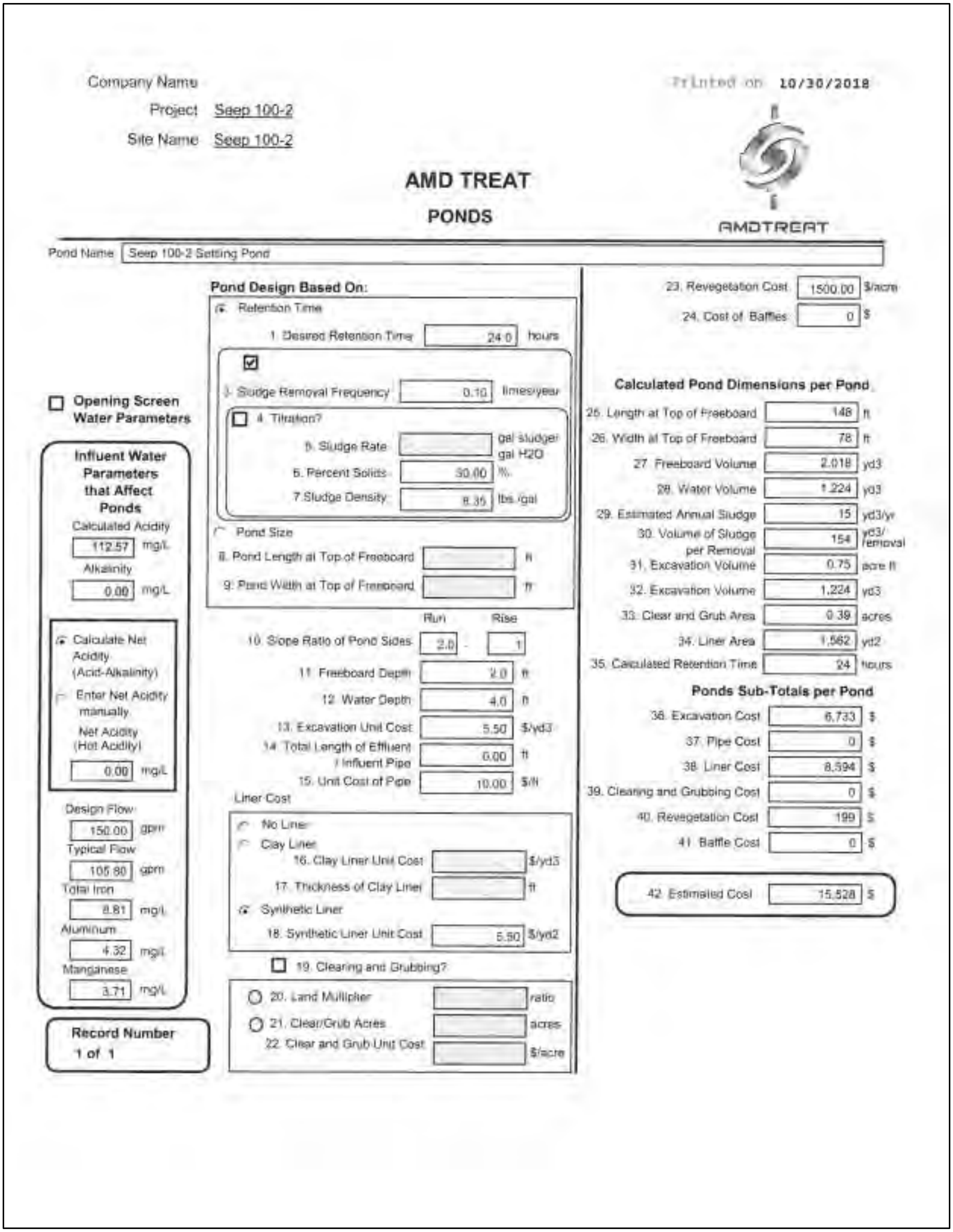
LSB Sizing Summaries

48. Length at Top of Freeboard	172.09	ft
49. Width at Top of Freeboard	86.04	ft
50. Freeboard Volume	1,663	yd3
51. Water Surface Area	13,455	ft2
52. Total Water Volume	925	yd3
54. Limestone Surface Area	11,566	ft2
55. Limestone Volume	1,138.35	yd3
56. Excavation Volume	2,064.2	yd3
57. Clear and Grub Area	0.0	acr
58. Liner Area	2,682.6	ft2
59. Theoretical Retention Time	10.98	hrs

LSB Cost Summaries

60. Siphon System Cost	5,000	$
61. Limestone Cost	31,882	$
62. Limestone Placement Cost	0	$
63. Excavation Cost	11,353	$
64. Liner Cost	14,754	$
65. Clear and Grub Cost	0	$
66. Valve Cost	0	$
67. Pipe Cost	0	$
68. Total Cost	62,989	$

Figure 26. AMDTreat report on limestone leachbed component for Seep 100-2.



Company Name

Project Seep 100-2

Site Name Seep 100-2

Printed on 10/30/2018

AMD TREAT

PONDS

Pond Name: Seep 100-2 Settling Pond

Pond Design Based On:

● Retention Time

1. Desired Retention Time: 24.0 hours

☑

3. Sludge Removal Frequency: 0.10 times/year

☐ 4. Titration?

5. Sludge Rate: gal sludge/gal H2O

6. Percent Solids: 30.00 %

7. Sludge Density: 8.35 lbs./gal

○ Pond Size

8. Pond Length at Top of Freeboard: ft

9. Pond Width at Top of Freeboard: ft

10. Slope Ratio of Pond Sides: Run 2.0 : Rise 1

11. Freeboard Depth: 2.0 ft

12. Water Depth: 4.0 ft

13. Excavation Unit Cost: 5.50 $/yd3

14. Total Length of Effluent / Influent Pipe: 0.00 ft

15. Unit Cost of Pipe: 10.00 $/ft

Liner Cost

○ No Liner

○ Clay Liner

16. Clay Liner Unit Cost: $/yd3

17. Thickness of Clay Liner: ft

● Synthetic Liner

18. Synthetic Liner Unit Cost: 5.50 $/yd2

☐ 19. Clearing and Grubbing?

○ 20. Land Multiplier: ratio

○ 21. Clear/Grub Acres: acres

22. Clear and Grub Unit Cost: $/acre

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect Ponds

Calculated Acidity: 112.57 mg/L

Alkalinity: 0.00 mg/L

● Calculate Net Acidity (Acid-Alkalinity)

○ Enter Net Acidity manually

Net Acidity (Hot Acidity): 0.00 mg/L

Design Flow: 150.00 gpm

Typical Flow: 105.80 gpm

Total Iron: 8.81 mg/L

Aluminum: 4.32 mg/L

Manganese: 3.71 mg/L

Record Number
1 of 1

23. Revegetation Cost: 1500.00 $/acre

24. Cost of Baffles: 0 $

Calculated Pond Dimensions per Pond

25. Length at Top of Freeboard: 148 ft

26. Width at Top of Freeboard: 78 ft

27. Freeboard Volume: 2,018 yd3

28. Water Volume: 1,224 yd3

29. Estimated Annual Sludge: 15 yd3/yr

30. Volume of Sludge per Removal: 154 yd3/removal

31. Excavation Volume: 0.75 acre ft

32. Excavation Volume: 1,224 yd3

33. Clear and Grub Area: 0.39 acres

34. Liner Area: 1,562 yd2

35. Calculated Retention Time: 24 hours

Ponds Sub-Totals per Pond

36. Excavation Cost: 6,733 $

37. Pipe Cost: 0 $

38. Liner Cost: 8,594 $

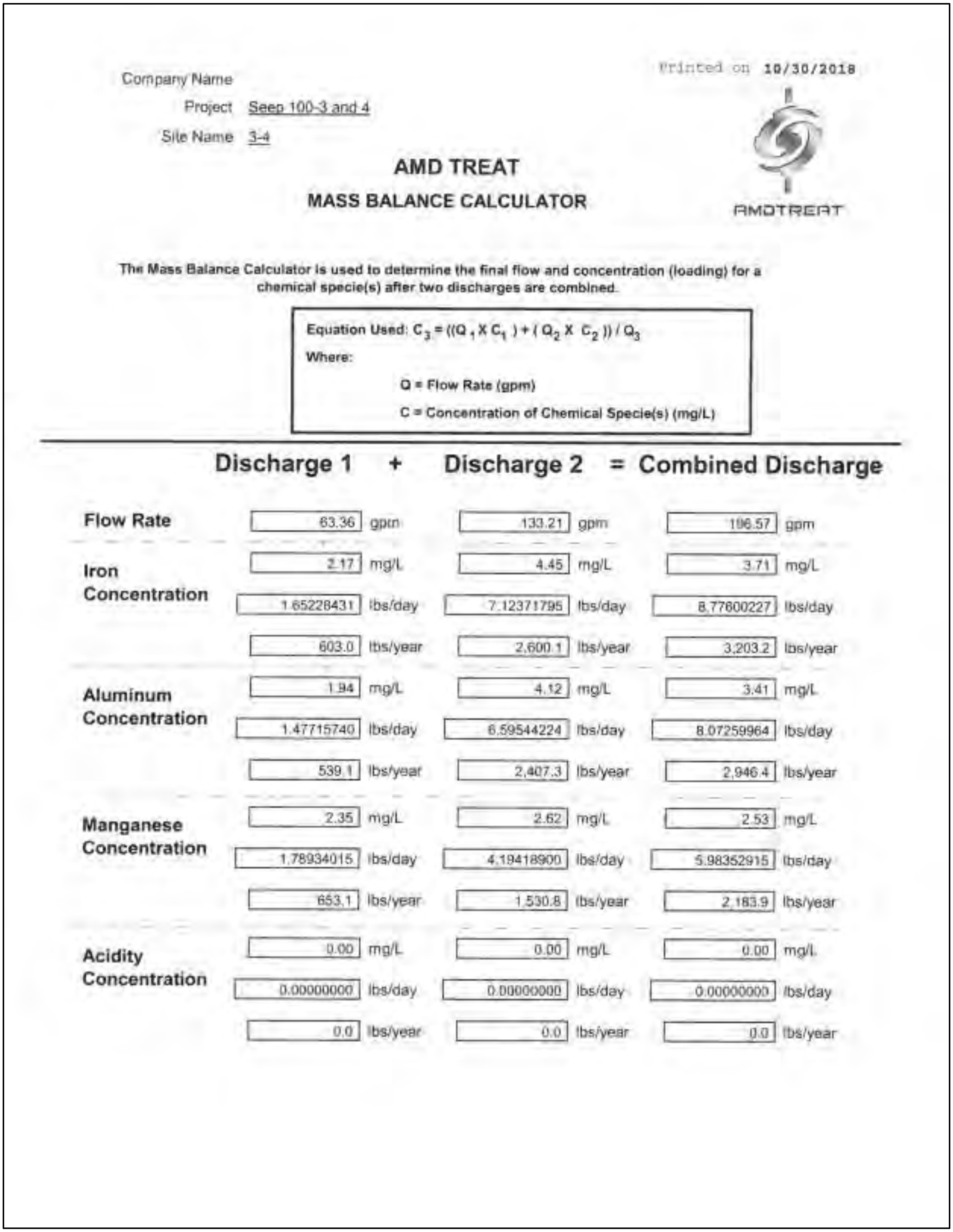
39. Clearing and Grubbing Cost: 0 $

40. Revegetation Cost: 199 $

41. Baffle Cost: 0 $

42. Estimated Cost: 15,528 $

Figure 27. AMDTreat report on settling pond component for Seep 100-2.



Printed on 10/30/2018

Company Name

Project Seep 100-3 and 4

Site Name 3-4

AMD TREAT

MASS BALANCE CALCULATOR

AMDTREAT

The Mass Balance Calculator is used to determine the final flow and concentration (loading) for a chemical specie(s) after two discharges are combined.

Equation Used: $C_3 = ((Q_1 X C_1) + (Q_2 X C_2)) / Q_3$

Where:

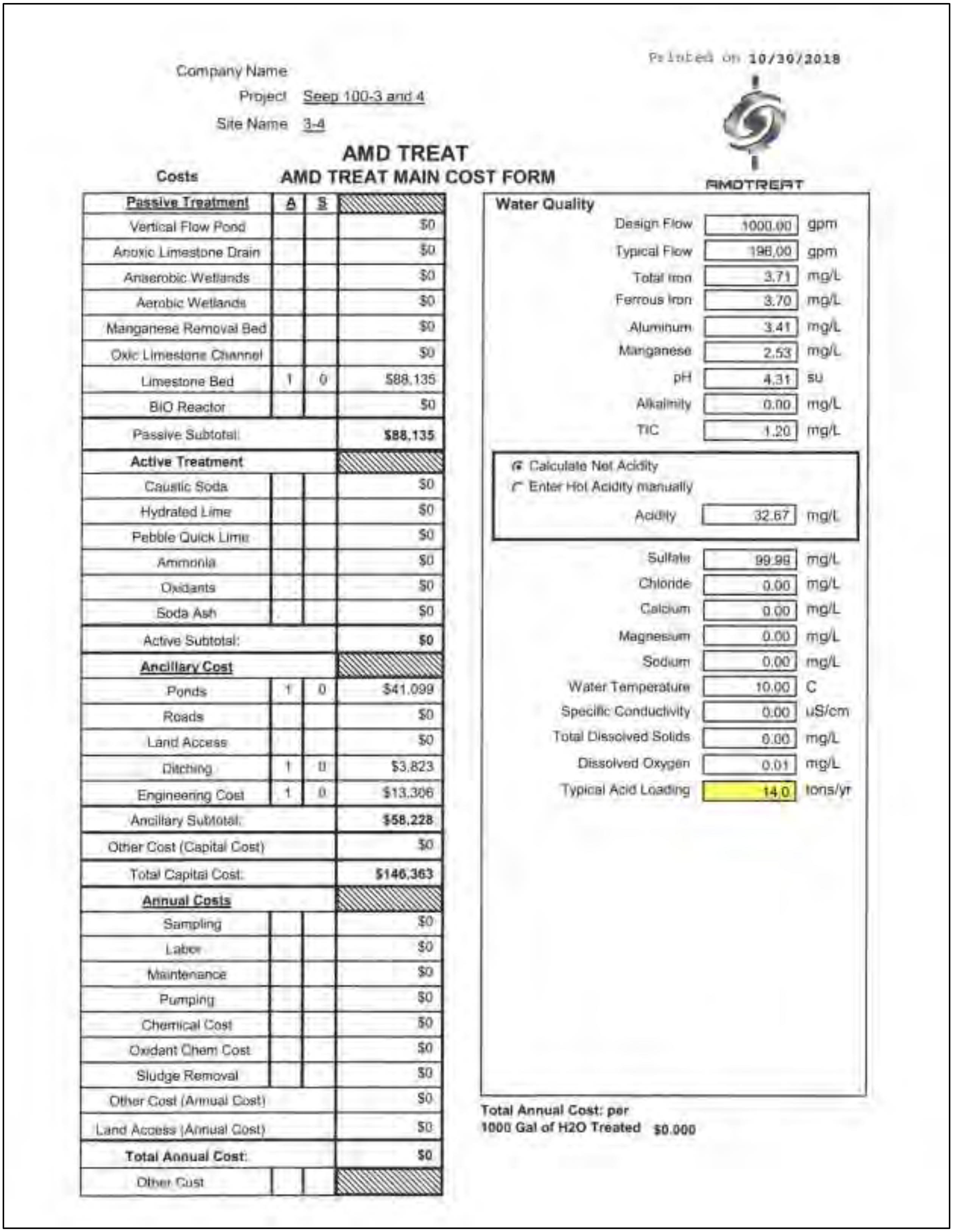
Q = Flow Rate (gpm)

C = Concentration of Chemical Specie(s) (mg/L)

Discharge 1 + Discharge 2 = Combined Discharge

	Discharge 1		Discharge 2		Combined Discharge	
Flow Rate	63.36	gpm	133.21	gpm	196.57	gpm
Iron Concentration	2.17	mg/L	4.45	mg/L	3.71	mg/L
	1.65228431	lbs/day	7.12371795	lbs/day	8.77600227	lbs/day
	603.0	lbs/year	2,600.1	lbs/year	3,203.2	lbs/year
Aluminum Concentration	1.94	mg/L	4.12	mg/L	3.41	mg/L
	1.47715740	lbs/day	6.59544224	lbs/day	8.07259964	lbs/day
	539.1	lbs/year	2,407.3	lbs/year	2,946.4	lbs/year
Manganese Concentration	2.35	mg/L	2.62	mg/L	2.53	mg/L
	1.78934015	lbs/day	4.19418900	lbs/day	5.98352915	lbs/day
	653.1	lbs/year	1,530.8	lbs/year	2,183.9	lbs/year
Acidity Concentration	0.00	mg/L	0.00	mg/L	0.00	mg/L
	0.00000000	lbs/day	0.00000000	lbs/day	0.00000000	lbs/day
	0.0	lbs/year	0.0	lbs/year	0.0	lbs/year

Figure 28. Mass balance report for treating Seep 100-3 and Seep 100-4 with one system.



Printed on **10/30/2018**

Company Name
Project Seep 100-3 and 4
Site Name 3-4

AMD TREAT
AMD TREAT MAIN COST FORM

AMDTREAT

Costs

Passive Treatment	**A**	**S**	▨
Vertical Flow Pond			$0
Anoxic Limestone Drain			$0
Anaerobic Wetlands			$0
Aerobic Wetlands			$0
Manganese Removal Bed			$0
Oxic Limestone Channel			$0
Limestone Bed	1	0	$88,135
BIO Reactor			$0
Passive Subtotal:			**$88,135**
Active Treatment			▨
Caustic Soda			$0
Hydrated Lime			$0
Pebble Quick Lime			$0
Ammonia			$0
Oxidants			$0
Soda Ash			$0
Active Subtotal:			**$0**
Ancillary Cost			▨
Ponds	1	0	$41,099
Roads			$0
Land Access			$0
Ditching	1	0	$3,823
Engineering Cost	1	0	$13,306
Ancillary Subtotal:			**$58,228**
Other Cost (Capital Cost)			$0
Total Capital Cost:			**$146,363**
Annual Costs			▨
Sampling			$0
Labor			$0
Maintenance			$0
Pumping			$0
Chemical Cost			$0
Oxidant Chem Cost			$0
Sludge Removal			$0
Other Cost (Annual Cost)			$0
Land Access (Annual Cost)			$0
Total Annual Cost:			**$0**
Other Cost			▨

Water Quality

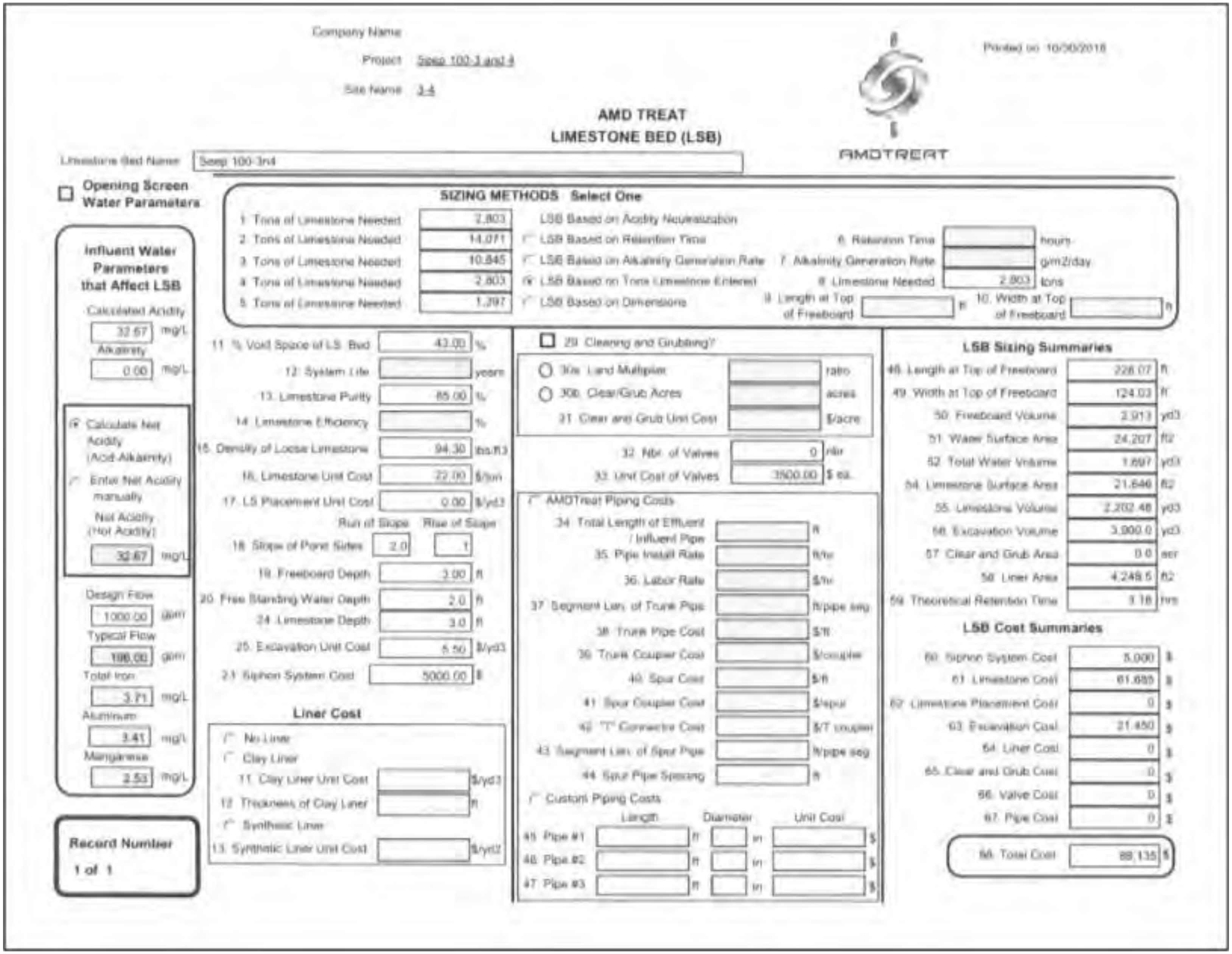
Design Flow	1000.00	gpm
Typical Flow	198.00	gpm
Total Iron	3.71	mg/L
Ferrous Iron	3.70	mg/L
Aluminum	3.41	mg/L
Manganese	2.53	mg/L
pH	4.31	su
Alkalinity	0.00	mg/L
TIC	1.20	mg/L

● Calculate Net Acidity
○ Enter Hot Acidity manually

Acidity	32.67	mg/L
Sulfate	99.98	mg/L
Chloride	0.00	mg/L
Calcium	0.00	mg/L
Magnesium	0.00	mg/L
Sodium	0.00	mg/L
Water Temperature	10.00	C
Specific Conductivity	0.00	uS/cm
Total Dissolved Solids	0.00	mg/L
Dissolved Oxygen	0.01	mg/L
Typical Acid Loading	14.0	tons/yr

Total Annual Cost: per
1000 Gal of H2O Treated **$0.000**

Figure 29. AMDTreat report on treatment system proposed for Seeps 100-3 & 100-4.



Company Name

Project Seep 100-3 and 4

Site Name 3-4

Printed on 10/30/2018

AMD TREAT

LIMESTONE BED (LSB)

Limestone Bed Name: Seep 100-3n4

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect LSB

Calculated Acidity: 32.67 mg/L

Alkalinity: 0.00 mg/L

● Calculate Net Acidity (Acid-Alkalinity)

○ Enter Net Acidity manually

Net Acidity (Hot Acidity): 32.67 mg/L

Design Flow: 1000.00 gpm

Typical Flow: 198.00 gpm

Total Iron: 3.71 mg/L

Aluminum: 3.41 mg/L

Manganese: 2.53 mg/L

Record Number

1 of 1

SIZING METHODS Select One

1 Tons of Limestone Needed	2,803		LSB Based on Acidity Neutralization
2 Tons of Limestone Needed	14,071	○	LSB Based on Retention Time
3 Tons of Limestone Needed	10,845	○	LSB Based on Alkalinity Generation Rate
4 Tons of Limestone Needed	2,803	●	LSB Based on Tons Limestone Entered
5 Tons of Limestone Needed	1,397	○	LSB Based on Dimensions

6. Retention Time: hours

7. Alkalinity Generation Rate: g/m2/day

8. Limestone Needed: 2,803 tons

9. Length at Top of Freeboard: ft

10. Width at Top of Freeboard: ft

11. % Void Space of LS Bed	43.00	%
12. System Life		years
13. Limestone Purity	85.00	%
14. Limestone Efficiency		%
15. Density of Loose Limestone	94.30	lbs/ft3
16. Limestone Unit Cost	22.00	$/ton
17. LS Placement Unit Cost	0.00	$/yd3
18. Slope of Pond Sides	Run of Slope 2.0	Rise of Slope 1
19. Freeboard Depth	3.00	ft
20. Free Standing Water Depth	2.0	ft
24. Limestone Depth	3.0	ft
25. Excavation Unit Cost	5.50	$/yd3
21 Siphon System Cost	5000.00	$

Liner Cost

○ No Liner

○ Clay Liner

11. Clay Liner Unit Cost: $/yd3

12. Thickness of Clay Liner: ft

○ Synthetic Liner

13. Synthetic Liner Unit Cost: $/yd2

☐ 29. Clearing and Grubbing?

○ 30a. Land Multiplier: ratio

○ 30b. Clear/Grub Acres: acres

31. Clear and Grub Unit Cost: $/acre

32. Nbr. of Valves: 0 nbr

33. Unit Cost of Valves: 3500.00 $ ea.

○ AMDTreat Piping Costs

34. Total Length of Effluent / Influent Pipe: ft

35. Pipe Install Rate: ft/hr

36. Labor Rate: $/hr

37. Segment Len. of Trunk Pipe: ft/pipe seg

38. Trunk Pipe Cost: $/ft

39. Trunk Coupler Cost: $/coupler

40. Spur Cost: $/ft

41. Spur Coupler Cost: $/spur

42. "T" Connector Cost: $/T coupler

43. Segment Len. of Spur Pipe: ft/pipe seg

44. Spur Pipe Spacing: ft

○ Custom Piping Costs

	Length		Diameter		Unit Cost	
45. Pipe #1		ft		in		$
46. Pipe #2		ft		in		$
47. Pipe #3		ft		in		$

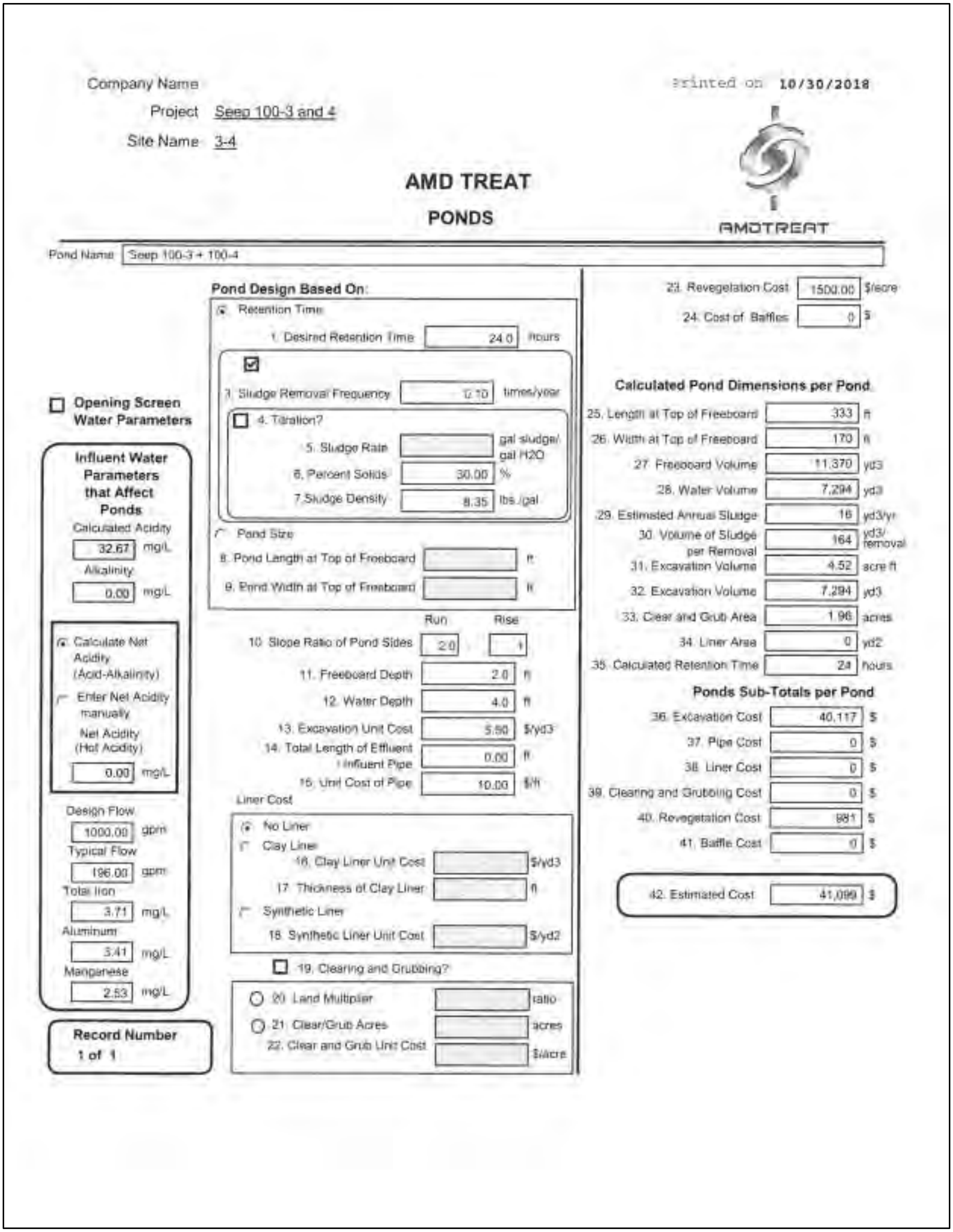
LSB Sizing Summaries

48. Length at Top of Freeboard	228.07	ft
49. Width at Top of Freeboard	124.03	ft
50. Freeboard Volume	2,913	yd3
51. Water Surface Area	24,207	ft2
52. Total Water Volume	1,897	yd3
54. Limestone Surface Area	21,646	ft2
55. Limestone Volume	2,202.48	yd3
56. Excavation Volume	3,900.0	yd3
57. Clear and Grub Area	0.0	acr
58. Liner Area	4,248.5	ft2
59. Theoretical Retention Time	3.18	hrs

LSB Cost Summaries

60. Siphon System Cost	5,000	$
61. Limestone Cost	61,685	$
62. Limestone Placement Cost	0	$
63. Excavation Cost	21,450	$
64. Liner Cost	0	$
65. Clear and Grub Cost	0	$
66. Valve Cost	0	$
67. Pipe Cost	0	$
68. Total Cost	88,135	$

Figure 30. AMDTreat report on limestone leach bed component for Seep 100-3/100-4.



Company Name

Project Seep 100-3 and 4

Site Name 3-4

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AMD TREAT

PONDS

Pond Name Seep 100-3 + 100-4

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect Ponds

Calculated Acidity 32.67 mg/L

Alkalinity 0.00 mg/L

● Calculate Net Acidity (Acid-Alkalinity)

○ Enter Net Acidity manually

Net Acidity (Hot Acidity) 0.00 mg/L

Design Flow 1000.00 gpm

Typical Flow 196.00 gpm

Total Iron 3.71 mg/L

Aluminum 3.41 mg/L

Manganese 2.53 mg/L

Record Number
1 of 1

Pond Design Based On:

● Retention Time

1. Desired Retention Time 24.0 hours

☑

3. Sludge Removal Frequency 0.10 times/year

☐ 4. Titration?

5. Sludge Rate gal sludge/gal H2O

6. Percent Solids 30.00 %

7. Sludge Density 8.35 lbs./gal

○ Pond Size

8. Pond Length at Top of Freeboard ft

9. Pond Width at Top of Freeboard ft

10. Slope Ratio of Pond Sides Run 2.0 Rise 1

11. Freeboard Depth 2.0 ft

12. Water Depth 4.0 ft

13. Excavation Unit Cost 5.50 $/yd3

14. Total Length of Effluent / Influent Pipe 0.00 ft

15. Unit Cost of Pipe 10.00 $/ft

Liner Cost

● No Liner

○ Clay Liner

16. Clay Liner Unit Cost $/yd3

17. Thickness of Clay Liner ft

○ Synthetic Liner

18. Synthetic Liner Unit Cost $/yd2

☐ 19. Clearing and Grubbing?

○ 20. Land Multiplier ratio

○ 21. Clear/Grub Acres acres

22. Clear and Grub Unit Cost $/acre

23. Revegetation Cost 1500.00 $/acre

24. Cost of Baffles 0 $

Calculated Pond Dimensions per Pond

25. Length at Top of Freeboard 333 ft

26. Width at Top of Freeboard 170 ft

27. Freeboard Volume 11,370 yd3

28. Water Volume 7,294 yd3

29. Estimated Annual Sludge 16 yd3/yr

30. Volume of Sludge per Removal 164 yd3/removal

31. Excavation Volume 4.52 acre ft

32. Excavation Volume 7,294 yd3

33. Clear and Grub Area 1.96 acres

34. Liner Area 0 yd2

35. Calculated Retention Time 24 hours

Ponds Sub-Totals per Pond

36. Excavation Cost 40,117 $

37. Pipe Cost 0 $

38. Liner Cost 0 $

39. Clearing and Grubbing Cost 0 $

40. Revegetation Cost 981 $

41. Baffle Cost 0 $

42. Estimated Cost 41,099 $

Figure 31. AMDTreat report on settling pond component for Seep 100-3/4.

Company Name

Printed on 10/30/2018

Project Seep 100-3 and 4

Site Name 3-4

AMD TREAT

DITCHING

Ditching Name Ditching Estimate Seep 100-3n4

1. Ditch Length Rock 75 ft
2. Ditch Length Grass 75 ft
3. Bottom Width of Ditch 4.0 ft
4. Ditch Depth 3.00 ft
5. Geo Textile Unit Cost 3.00 $/yd2
6. Length of Geo Textile 75 ft
7. Slope Ratio of Ditch Sides Run 2.00 : Rise 1.00

☐ 8. Surveying?

9. Survey Rate acres/day
10. Survey Unit Cost $/day

☑ 11. Clearing and Grubbing?

12. Clear and Grub Cost 1300.00 $/acre

Record Number 1 of 1

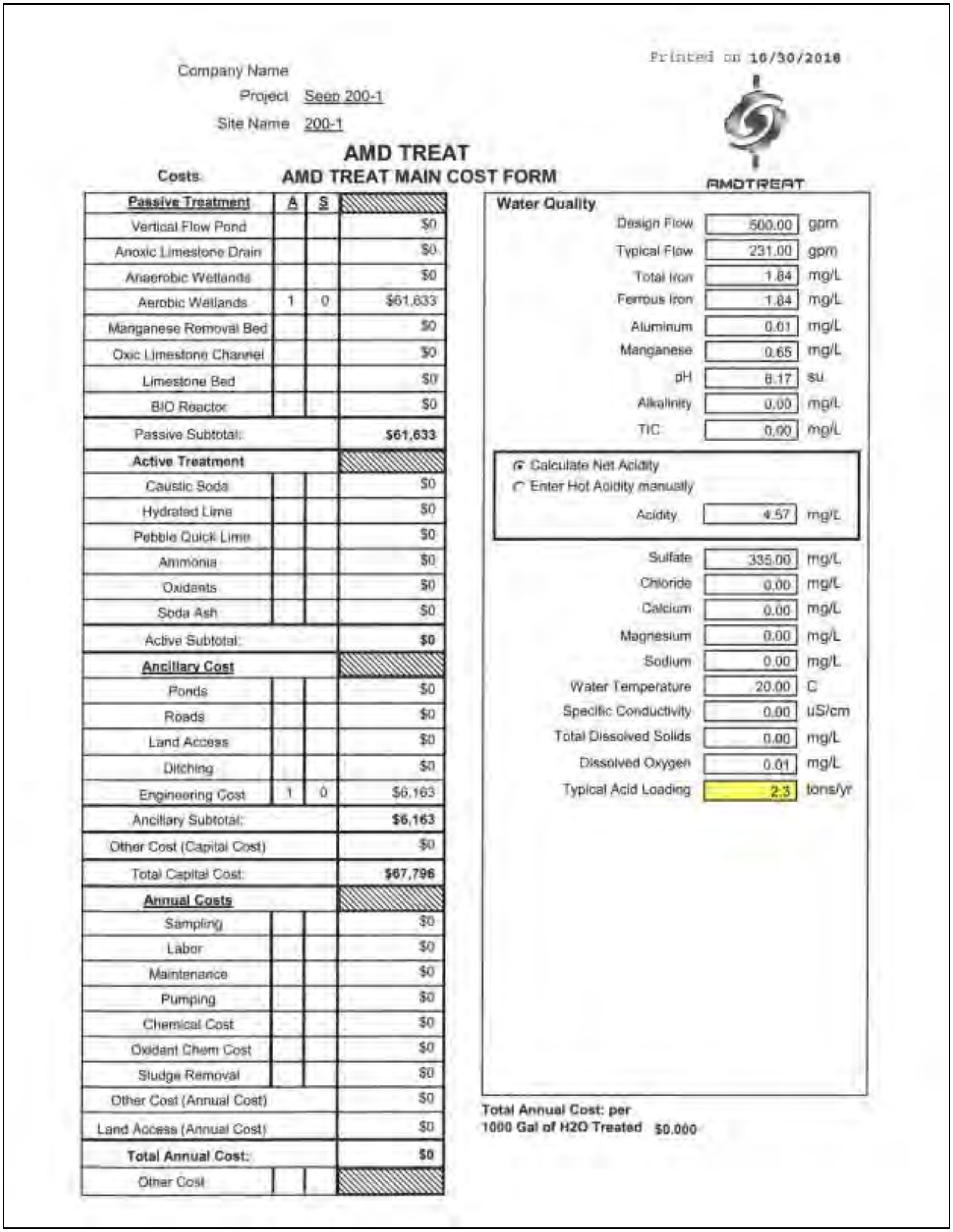
13. Ditch Depth of Rock 1.50 ft
14. Cost of Ditch Surface Rock 20.00 $/yd3
15. Cost to Place Rock 12.00 $/yd3
16. Excavation Unit Cost 5.50 $/yd3
17. Length of Silt Fence 0.00 ft
18. Unit Cost of Silt Fence 1.15 $/ft
19. Revegetation Unit Cost 1500.00 $/acre

Ditching Sub-Totals

20. Excavation Cost 917 $
21. Survey Cost 0 $
22. Clear and Grub Cost 86 $
23. Aggregate Cost 2,322 $
24. Filter Fabric Cost 435 $
25. Silt Fence Cost 0 $
26. Revegetation Cost 63 $

27. Total Cost 3,823 $

Figure 32. AMDTreat report on ditching costs for Seep 100-3/4.



Printed on **10/30/2018**

Company Name
Project Seep 200-1
Site Name 200-1

AMD TREAT

Costs **AMD TREAT MAIN COST FORM**

AMDTREAT

Passive Treatment	**A**	**S**	▨
Vertical Flow Pond			$0
Anoxic Limestone Drain			$0
Anaerobic Wetlands			$0
Aerobic Wetlands	1	0	$61,633
Manganese Removal Bed			$0
Oxic Limestone Channel			$0
Limestone Bed			$0
BIO Reactor			$0
Passive Subtotal:			**$61,633**
Active Treatment			▨
Caustic Soda			$0
Hydrated Lime			$0
Pebble Quick Lime			$0
Ammonia			$0
Oxidants			$0
Soda Ash			$0
Active Subtotal:			**$0**
Ancillary Cost			▨
Ponds			$0
Roads			$0
Land Access			$0
Ditching			$0
Engineering Cost	1	0	$6,163
Ancillary Subtotal:			**$6,163**
Other Cost (Capital Cost)			$0
Total Capital Cost:			**$67,796**
Annual Costs			▨
Sampling			$0
Labor			$0
Maintenance			$0
Pumping			$0
Chemical Cost			$0
Oxidant Chem Cost			$0
Sludge Removal			$0
Other Cost (Annual Cost)			$0
Land Access (Annual Cost)			$0
Total Annual Cost:			**$0**
Other Cost			▨

Water Quality

Design Flow	500.00	gpm
Typical Flow	231.00	gpm
Total Iron	1.84	mg/L
Ferrous Iron	1.84	mg/L
Aluminum	0.01	mg/L
Manganese	0.65	mg/L
pH	6.17	su
Alkalinity	0.00	mg/L
TIC	0.00	mg/L

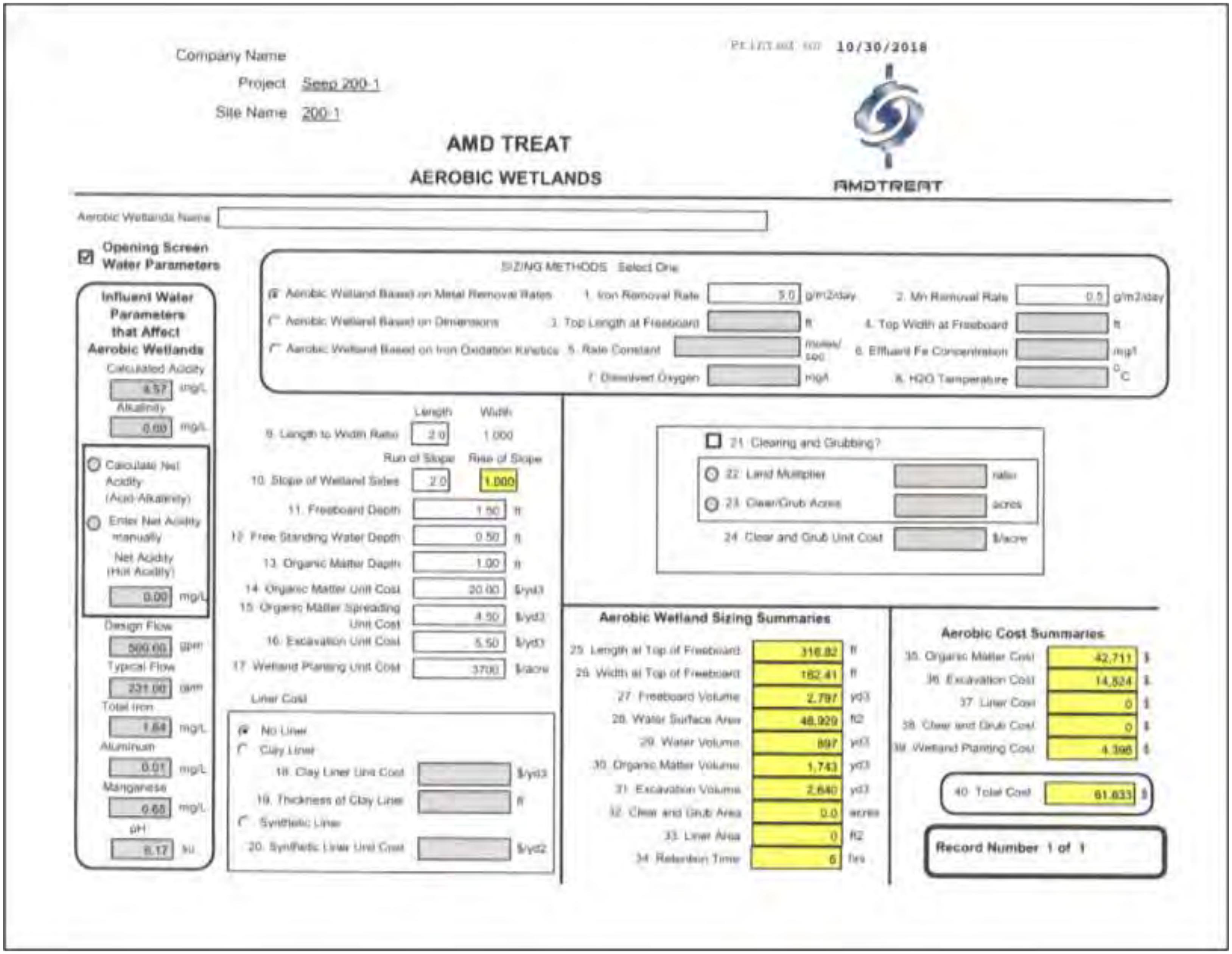
● Calculate Net Acidity
○ Enter Hot Acidity manually

Acidity	4.57	mg/L

Sulfate	335.00	mg/L
Chloride	0.00	mg/L
Calcium	0.00	mg/L
Magnesium	0.00	mg/L
Sodium	0.00	mg/L
Water Temperature	20.00	C
Specific Conductivity	0.00	uS/cm
Total Dissolved Solids	0.00	mg/L
Dissolved Oxygen	0.01	mg/L
Typical Acid Loading	2.3	tons/yr

Total Annual Cost: per
1000 Gal of H2O Treated **$0.000**

Figure 33. AMDTreat report on treatment system proposed for Seep 200-1.



Company Name
Project Seep 200-1
Site Name 200-1

Printed on 10/30/2018

AMD TREAT

AEROBIC WETLANDS

Aerobic Wetlands Name

☑ **Opening Screen Water Parameters**

Influent Water Parameters that Affect Aerobic Wetlands

Calculated Acidity	4.57	mg/L
Alkalinity	0.00	mg/L
○ Calculate Net Acidity (Acid-Alkalinity)		
○ Enter Net Acidity manually		
Net Acidity (Hot Acidity)	0.00	mg/L
Design Flow	500.00	gpm
Typical Flow	231.00	gpm
Total Iron	1.84	mg/L
Aluminum	0.01	mg/L
Manganese	0.65	mg/L
pH	6.17	su

SIZING METHODS Select One

● Aerobic Wetland Based on Metal Removal Rates
○ Aerobic Wetland Based on Dimensions
○ Aerobic Wetland Based on Iron Oxidation Kinetics

1. Iron Removal Rate	5.0	g/m2/day	2. Mn Removal Rate	0.5	g/m2/day
3. Top Length at Freeboard		ft	4. Top Width at Freeboard		ft
5. Rate Constant		moles/sec	6. Effluent Fe Concentration		mg/l
7. Dissolved Oxygen		mg/l	8. H2O Temperature		°C

	Length	Width	
9. Length to Width Ratio	2.0	1.000	
	Run of Slope	Rise of Slope	
10. Slope of Wetland Sides	2.0	1.000	
11. Freeboard Depth	1.50		ft
12. Free Standing Water Depth	0.50		ft
13. Organic Matter Depth	1.00		ft
14. Organic Matter Unit Cost	20.00		$/yd3
15. Organic Matter Spreading Unit Cost	4.50		$/yd3
16. Excavation Unit Cost	5.50		$/yd3
17. Wetland Planting Unit Cost	3700		$/acre

Liner Cost

● No Liner
○ Clay Liner

18. Clay Liner Unit Cost		$/yd3
19. Thickness of Clay Liner		ft

○ Synthetic Liner

20. Synthetic Liner Unit Cost		$/yd2

☐ 21. Clearing and Grubbing?

○ 22. Land Multiplier		ratio
○ 23. Clear/Grub Acres		acres
24. Clear and Grub Unit Cost		$/acre

Aerobic Wetland Sizing Summaries

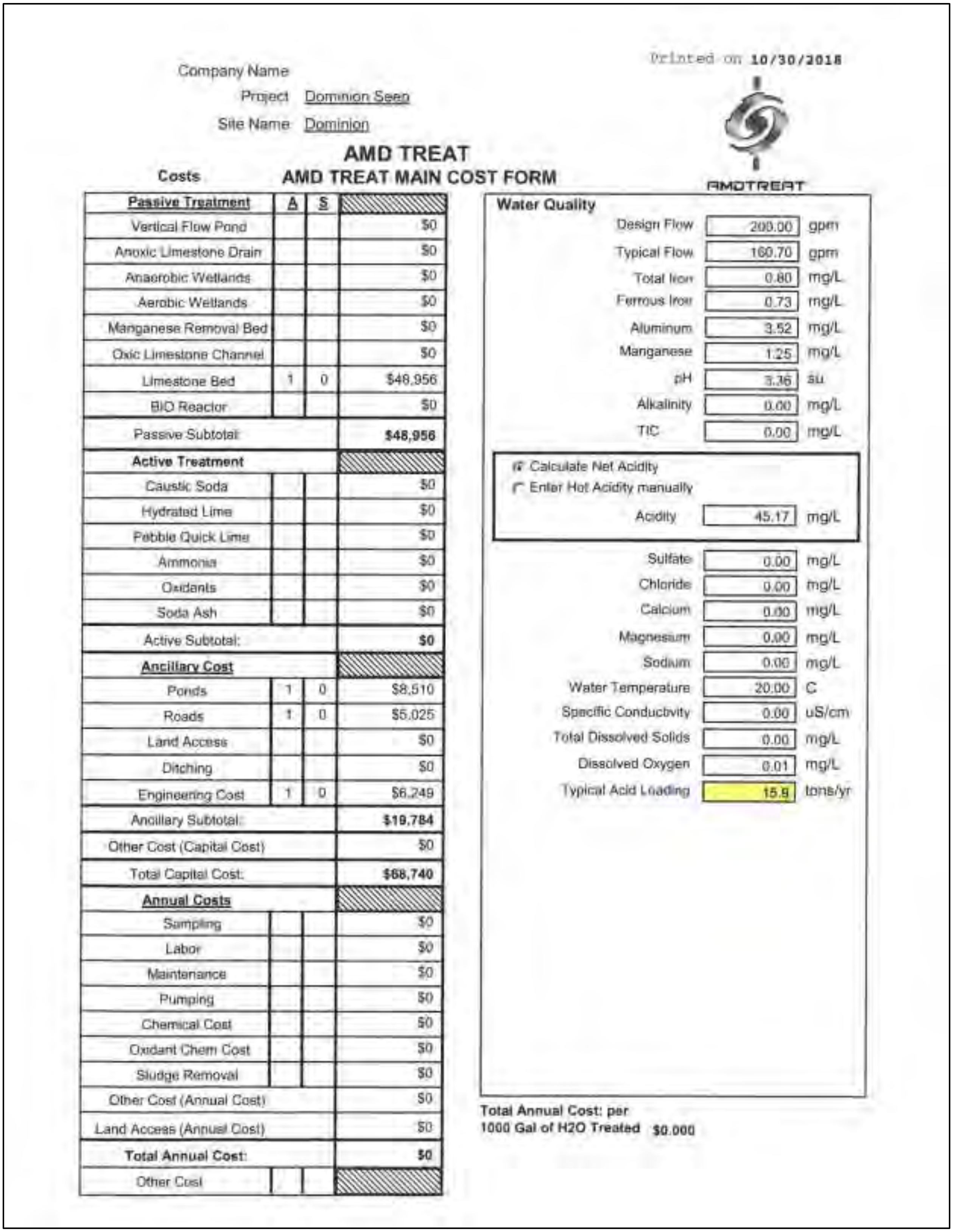
25. Length at Top of Freeboard	316.82	ft
26. Width at Top of Freeboard	162.41	ft
27. Freeboard Volume	2,797	yd3
28. Water Surface Area	48,929	ft2
29. Water Volume	897	yd3
30. Organic Matter Volume	1,743	yd3
31. Excavation Volume	2,640	yd3
32. Clear and Grub Area	0.0	acres
33. Liner Area	0	ft2
34. Retention Time	6	hrs

Aerobic Cost Summaries

35. Organic Matter Cost	42,711	$
36. Excavation Cost	14,824	$
37. Liner Cost	0	$
38. Clear and Grub Cost	0	$
39. Wetland Planting Cost	4,398	$
40. Total Cost	61,933	$

Record Number 1 of 1

Figure 34. AMDTreat report on aerobic wetland component for Seep 200-1.



Printed on 10/30/2018

Company Name
Project Dominion Seep
Site Name Dominion

AMD TREAT

AMD TREAT MAIN COST FORM

Costs

Passive Treatment	**A**	**S**	▨
Vertical Flow Pond			$0
Anoxic Limestone Drain			$0
Anaerobic Wetlands			$0
Aerobic Wetlands			$0
Manganese Removal Bed			$0
Oxic Limestone Channel			$0
Limestone Bed	1	0	$48,956
BIO Reactor			$0
Passive Subtotal:			**$48,956**
Active Treatment			▨
Caustic Soda			$0
Hydrated Lime			$0
Pebble Quick Lime			$0
Ammonia			$0
Oxidants			$0
Soda Ash			$0
Active Subtotal:			**$0**
Ancillary Cost			▨
Ponds	1	0	$8,510
Roads	1	0	$5,025
Land Access			$0
Ditching			$0
Engineering Cost	1	0	$6,249
Ancillary Subtotal:			**$19,784**
Other Cost (Capital Cost)			$0
Total Capital Cost:			**$68,740**
Annual Costs			▨
Sampling			$0
Labor			$0
Maintenance			$0
Pumping			$0
Chemical Cost			$0
Oxidant Chem Cost			$0
Sludge Removal			$0
Other Cost (Annual Cost)			$0
Land Access (Annual Cost)			$0
Total Annual Cost:			**$0**
Other Cost			▨

Water Quality

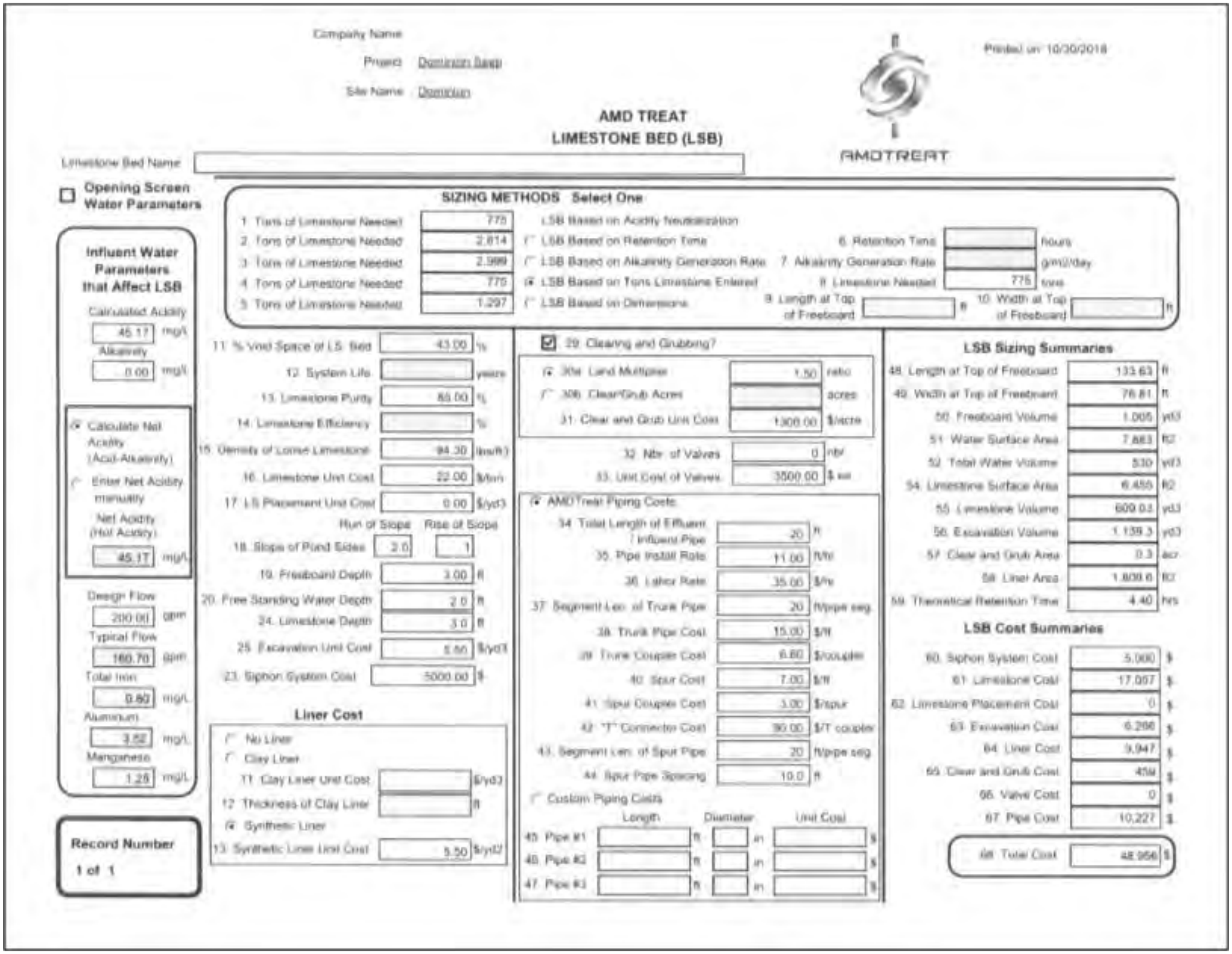
Design Flow	200.00	gpm
Typical Flow	160.70	gpm
Total Iron	0.80	mg/L
Ferrous Iron	0.73	mg/L
Aluminum	3.52	mg/L
Manganese	1.25	mg/L
pH	3.36	su
Alkalinity	0.00	mg/L
TIC	0.00	mg/L

● Calculate Net Acidity
○ Enter Hot Acidity manually

Acidity	45.17	mg/L
Sulfate	0.00	mg/L
Chloride	0.00	mg/L
Calcium	0.00	mg/L
Magnesium	0.00	mg/L
Sodium	0.00	mg/L
Water Temperature	20.00	C
Specific Conductivity	0.00	uS/cm
Total Dissolved Solids	0.00	mg/L
Dissolved Oxygen	0.01	mg/L
Typical Acid Loading	15.9	tons/yr

Total Annual Cost: per 1000 Gal of H2O Treated **$0.000**

Figure 35. AMDTreat report on treatment system proposed for Seep DOM-1.



Company Name
Project Dominion Seep
Site Name Dominion

AMD TREAT
LIMESTONE BED (LSB)

Printed on 10/30/2018

Limestone Bed Name

☐ Opening Screen Water Parameters

Influent Water Parameters that Affect LSB

Calculated Acidity 45.17 mg/l
Alkalinity 0.00 mg/l

● Calculate Net Acidity (Acid-Alkalinity)
○ Enter Net Acidity manually
Net Acidity (Hot Acidity) 45.17 mg/L

Design Flow 200.00 gpm
Typical Flow 160.70 gpm
Total Iron 0.80 mg/L
Aluminum 3.52 mg/L
Manganese 1.26 mg/L

Record Number
1 of 1

SIZING METHODS Select One

1 Tons of Limestone Needed 775 LSB Based on Acidity Neutralization
2 Tons of Limestone Needed 2,814 ○ LSB Based on Retention Time
3 Tons of Limestone Needed 2,989 ○ LSB Based on Alkalinity Generation Rate
4 Tons of Limestone Needed 775 ● LSB Based on Tons Limestone Entered
5 Tons of Limestone Needed 1,297 ○ LSB Based on Dimensions

6. Retention Time hours
7. Alkalinity Generation Rate g/m2/day
8. Limestone Needed 775 tons
9. Length at Top of Freeboard ft
10. Width at Top of Freeboard ft

11. % Void Space of LS Bed 43.00 %
12. System Life years
13. Limestone Purity 85.00 %
14. Limestone Efficiency %
15. Density of Loose Limestone 94.30 (lbs/ft3)
16. Limestone Unit Cost 22.00 $/ton
17. LS Placement Unit Cost 0.00 $/yd3
18. Slope of Pond Sides: Run of Slope 2.0, Rise of Slope 1
19. Freeboard Depth 3.00 ft
20. Free Standing Water Depth 2.0 ft
24. Limestone Depth 3.0 ft
25. Excavation Unit Cost 5.50 $/yd3
23. Siphon System Cost 5000.00 $

Liner Cost

○ No Liner
○ Clay Liner
11. Clay Liner Unit Cost $/yd3
12. Thickness of Clay Liner ft
● Synthetic Liner
13. Synthetic Liner Unit Cost 5.50 $/yd2

☑ 29. Clearing and Grubbing?
● 30a. Land Multiplier 1.50 ratio
○ 30b. Clear/Grub Acres acres
31. Clear and Grub Unit Cost 1300.00 $/acre

32. Nbr. of Valves 0 nbr
33. Unit Cost of Valves 3500.00 $ ea

● AMDTreat Piping Costs
34. Total Length of Effluent / Influent Pipe 20 ft
35. Pipe Install Rate 11.00 ft/hr
36. Labor Rate 35.00 $/hr
37. Segment Len. of Trunk Pipe 20 ft/pipe seg
38. Trunk Pipe Cost 15.00 $/ft
39. Trunk Coupler Cost 6.80 $/coupler
40. Spur Cost 7.00 $/ft
41. Spur Coupler Cost 3.00 $/spur
42. "T" Connector Cost 30.00 $/T coupler
43. Segment Len. of Spur Pipe 20 ft/pipe seg
44. Spur Pipe Spacing 10.0 ft

○ Custom Piping Costs

	Length		Diameter		Unit Cost	
45. Pipe #1		ft		in		$
46. Pipe #2		ft		in		$
47. Pipe #3		ft		in		$

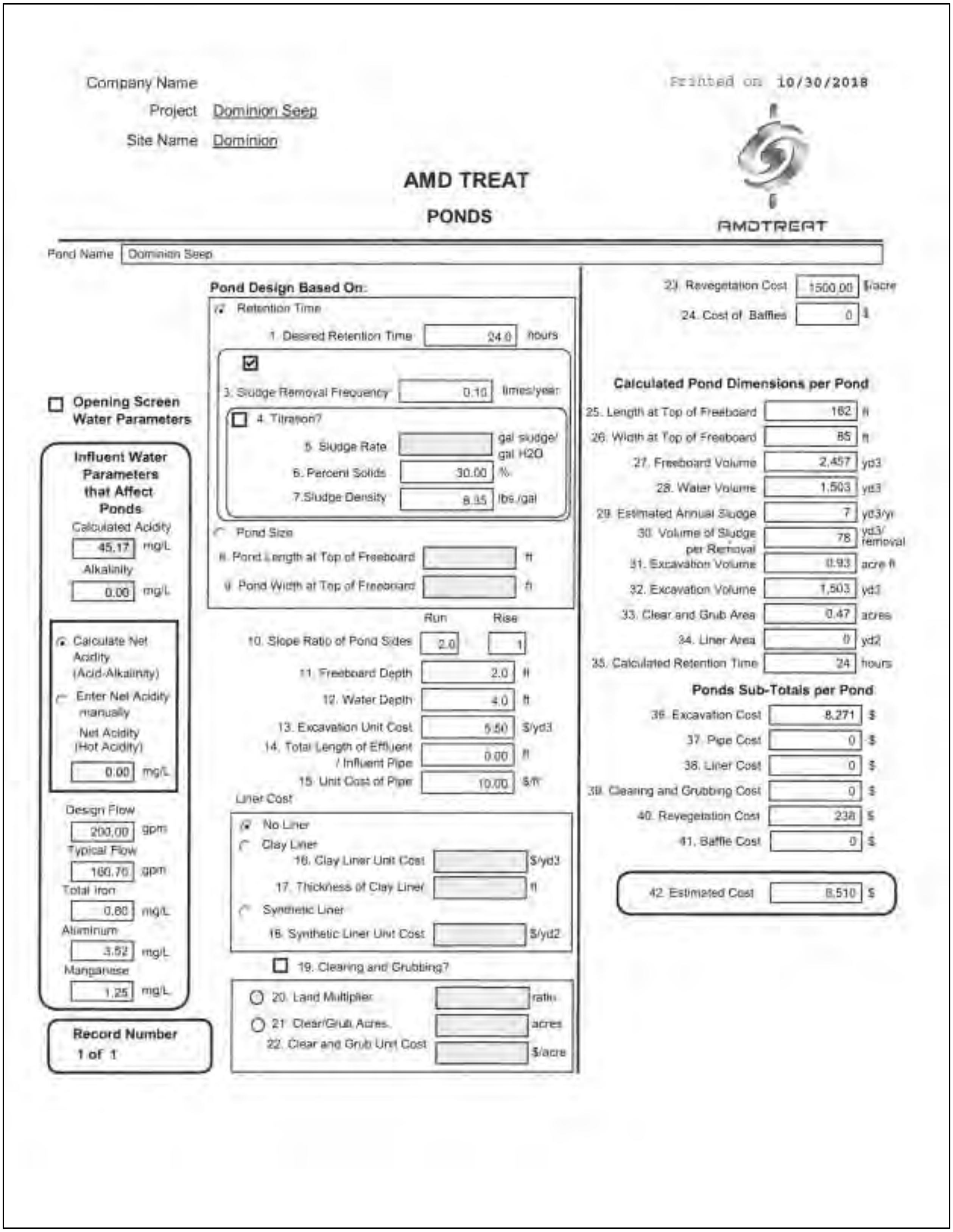
LSB Sizing Summaries

48. Length at Top of Freeboard 133.63 ft
49. Width at Top of Freeboard 76.81 ft
50. Freeboard Volume 1,005 yd3
51. Water Surface Area 7,883 ft2
52. Total Water Volume 530 yd3
54. Limestone Surface Area 6,455 ft2
55. Limestone Volume 609.03 yd3
56. Excavation Volume 1,139.3 yd3
57. Clear and Grub Area 0.3 acr
58. Liner Area 1,808.6 ft2
59. Theoretical Retention Time 4.40 hrs

LSB Cost Summaries

60. Siphon System Cost 5,000 $
61. Limestone Cost 17,057 $
62. Limestone Placement Cost 0 $
63. Excavation Cost 6,266 $
64. Liner Cost 9,947 $
65. Clear and Grub Cost 459 $
66. Valve Cost 0 $
67. Pipe Cost 10,227 $
68. Total Cost 48,956 $

Figure 36. AMDTreat report on limestone leachbed for Seep DOM-1.



Company Name

Project Dominion Seep

Site Name Dominion

Printed on 10/30/2018

AMDTREAT

AMD TREAT

PONDS

Pond Name Dominion Seep

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect Ponds

Calculated Acidity 45.17 mg/L

Alkalinity 0.00 mg/L

● Calculate Net Acidity (Acid-Alkalinity)

○ Enter Net Acidity manually

Net Acidity (Hot Acidity) 0.00 mg/L

Design Flow 200.00 gpm

Typical Flow 160.76 gpm

Total Iron 0.80 mg/L

Aluminum 3.52 mg/L

Manganese 1.25 mg/L

Record Number
1 of 1

Pond Design Based On:

● Retention Time

1. Desired Retention Time 24.0 hours

☑

3. Sludge Removal Frequency 0.10 times/year

☐ 4. Titration?

5. Sludge Rate gal sludge/ gal H2O

6. Percent Solids 30.00 %

7.Sludge Density 8.35 lbs./gal

○ Pond Size

8. Pond Length at Top of Freeboard ft

9. Pond Width at Top of Freeboard ft

10. Slope Ratio of Pond Sides Run 2.0 Rise 1

11. Freeboard Depth 2.0 ft

12. Water Depth 4.0 ft

13. Excavation Unit Cost 5.50 $/yd3

14. Total Length of Effluent / Influent Pipe 0.00 ft

15. Unit Cost of Pipe 10.00 $/ft

Liner Cost

● No Liner

○ Clay Liner

16. Clay Liner Unit Cost $/yd3

17. Thickness of Clay Liner ft

○ Synthetic Liner

18. Synthetic Liner Unit Cost $/yd2

☐ 19. Clearing and Grubbing?

○ 20. Land Multiplier ratio

○ 21. Clear/Grub Acres acres

22. Clear and Grub Unit Cost $/acre

23. Revegetation Cost 1500.00 $/acre

24. Cost of Baffles 0 $

Calculated Pond Dimensions per Pond

25. Length at Top of Freeboard 182 ft

26. Width at Top of Freeboard 85 ft

27. Freeboard Volume 2,457 yd3

28. Water Volume 1,503 yd3

29. Estimated Annual Sludge 7 yd3/yr

30. Volume of Sludge per Removal 78 yd3/ removal

31. Excavation Volume 0.93 acre ft

32. Excavation Volume 1,503 yd3

33. Clear and Grub Area 0.47 acres

34. Liner Area 0 yd2

35. Calculated Retention Time 24 hours

Ponds Sub-Totals per Pond

36. Excavation Cost 8,271 $

37. Pipe Cost 0 $

38. Liner Cost 0 $

39. Clearing and Grubbing Cost 0 $

40. Revegetation Cost 238 $

41. Baffle Cost 0 $

42. Estimated Cost 8,510 $

Figure 37. AMDTreat report on settling pond component for Seep DOM-1.