Design Report

Acid Mine Drainage Abatement

AMD 26(2768) 101.2
Cucumber Run
Swatara Township, Fayette County

Commonwealth of Pennsylvania
Department of Environmental Resources

Bureau of Abandoned Mine Reclamation

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Background

The objective of this project is to improve the water quality of the North Branch of Cucumber Run by reducing the pollution load from several acid mine drainage discharges. The mine discharges emanate from abandoned drift mines on the hillsides to both the north and south of the North Branch of Cucumber Run. An attempt was made to hydraulically seal the mines in the 1970s. Although some water was impounded by the seals, discharges continued to occur near the drift openings. Several new discharges that were not previously documented also developed apparently as a result of the impounded water.

In1989, three separate wetlands treatment systems were constructed to provide treatment of the mine drainage. These are designated as Wetlands #1, #2 and #3 on the site plan.

For the purposes of this report, the discharges in the project area have been broken down into five separate discharge areas described as follows:

- Discharge #1: This discharge is the combination of several large seeps that flow to existing wetland #1. The flow from discharge #1 is considerably larger than that from the other discharges.

- Discharge #2: This is the combination of three discharges that flow to existing wetland #2. The sources of these discharges are diffuse and much of the area surrounding the discharges is usually wet. The combined flow from these discharges is typically less than 5 gpm.

- Discharge #3: This is the combination of two small discharges that flow to existing wetland #2. The combined flow from these discharges is typically less than 5 gpm.

- Discharge #4: This is the combination of at least three discharges that occur on the reclaimed strip mine bench to the north of Cucumber Run. The strip mine was backfilled with clay as part of the mine sealing project. There are two manholes in the vicinity of the discharge which apparently contain valves that were provided to allow for draining of the mine pool created by the seals.

- Discharge #5: This discharge occurs directly into the bottom of the stream bed of Cucumber Run. Although it is not possible to measure the volume of this discharge, its effects on Cucumber Run are evidenced by a gradual discoloration of the stream and a degradation in water quality in the vicinity of the discharge. The origin of this discharge is unknown. This discharge was not documented in reports prepared prior to the mine sealing project. The origin of some of the discharge may be from Discharge #4 which partially disappears into the ground between the toe of the strip mine and the stream bank.

Design Overview:

As described in the proposal for this project, the acid mine drainage abatement is intended to be provided by the construction of several anoxic limestone drains (ALDs) and making improvements to the wetlands where necessary.

The ALDs will be constructed between the discharges and the existing wetlands. The purpose of the ALDs is to increase the pH and alkalinity of the water entering the wetlands. The pH of the various discharges entering the wetlands ranges from 3.0 to 4.5. Research that has occurred in the time since the wetlands were constructed indicates that constructed wetlands are much more effective at higher pH values. This is primarily due to the fact that the rate of iron oxidation and subsequent precipitation is much greater at higher pH values.

It is proposed that the mine water from ALDs at discharges #1, #2 and #3 be discharged to wetlands #1, #2 and #3, respectively. It is further proposed that the effluent from the ALD at discharge #4 be discharged to wetland #1. This is being recommended due to the space limitations in the vicinity of discharge #4 and the fact there is considerable coal refuse in the vicinity of the discharges which would be an undesirable material for the base of a wetland. The ALD for discharge #4 would drain into the western end of wetland #1. This part of the wetland currently receives very little if any flow because of the location of the wetland effluent pipes which promote short circuiting around the western portion of the wetland. Because the flow from discharge #4 is relatively small (<10 gpm) it is anticipated that there is sufficient wetland space available to allow for oxidation and precipitation of iron in the wetland following the ALD.

Design Considerations

This section of the report describes the various considerations used to develop the design features of the ALDs.

Water Quality Considerations: It is undesirable to retain calcium sulfate (gypsum), iron, manganese or aluminum in an ALD. Precipitation of these metals within the ALD may armor limestone and/or decrease the permeability of the system.

Calcium sulfate: Based on information provided by Hedin, et al., gypsum saturation should not be a problem with sulfate concentrations less than 2,000 mg/L. A review of water quality data provided by the Department indicates that sulfate concentrations at all four discharges are well below 2000 mg/L and for this reason, gypsum precipitation should not be a problem.

Aluminum: Aluminum hydroxide will precipitate at a pH of 4.5 and higher. All four discharges have aluminum concentrations above background levels. The highest levels are found in the discharge #1 and in discharge #4. The levels in the discharge #1 range between 2.2 mg/L and 27 mg/L, with an average of 17 mg/L. This is higher than the average of 7.4 mg/L as reported in the RFP for discharge #1. It appears that the highest levels were measured after the RFP had been issued. At any rate, these aluminum levels will result in some aluminum hydroxide precipitation in the ALD for discharge #1. Watzlaf, et al. described the failure of an ALD that had an influent aluminum concentration of 21 mg/l. The ALD failed, apparently due to precipitation of aluminum hydroxides within the ALD. To reduce the risk of failure we are recommending that relatively large diameter limestone be used in the initial stage of ALDs #1 and #4.

Iron: It is desirable that iron be in the ferrous (reduced) form to prevent precipitation of ferric hydroxide in the ALDs. Hedin et al. has reported that ferrous iron is not significantly retained unless ferrous iron exceeds 650 mg/L, at which point precipitation of ferrous carbonate may occur. Because the total iron is well below this value, ferrous iron precipitation is not a concern. Ferric iron precipitation is, however, of much greater concern. The following table shows the average ferrous and total iron concentrations of the various discharges based on data provided by the Department in the RFP and in a report dated February 13, 1995:

Discharge #	Average Ferrous Iron (mg/L)	Average Total Iron (mg/L)
1	164	158
2	74	88
3	0.6	7.2
4	116	131

The concentration of ferric iron is obtained by subtracting the ferrous iron value from the total iron. In the case of discharge #1, this results in a negative value, which is attributed to analytical error or interference on two samples for which the ferrous iron exceeded the total iron. The remainder of the samples indicate that discharge #1 is low in ferric iron. All of the discharges contain some ferric iron. Even though the percentage of ferric iron in discharges 1,2 and 4 is small, there is sufficient ferric iron available to cause some precipitation of ferric hydroxide and subsequent coating of the limestone in the ALDs. Thus selection of stone size and gradation must be such that sufficient void space is provided to prevent failure of the ALDs. It is also possible that actual ferric iron concentrations at the seep are lower than at the sample location due to exposure to the atmosphere between seep and sample point. The ALDs should be constructed such that the entire seep area is sheltered from the atmosphere.

Manganese: The average manganese concentration in all of the discharges is less than 5 mg/L. Generally, significant manganese precipitation will not occur until a pH of 8.0 is reached. Because of the high acidity of the discharges it is not anticipated that pH values anywhere close to 8.0 will be achieved.

Mass of Limestone: An enclosed spreadsheet shows the calculations used to size the ALDs. The calculations are based on a paper prepared by Hedin et al. The calculations to determine the mass of limestone required are based on flow, limestone bulk density, detention time, bulk void volume, predicted alkalinity in the effluent, calcium carbonate content of the limestone and design life of the ALD. The following describes the basis for the various values used to calculate limestone quantity.

Detention time: Data presented in several papers indicate that to produce a maximum concentration of alkalinity, retention time of mine water must be at least approximately 15 hours.

Limestone density and void volume: A limestone bulk density of 100 pounds per cubic foot was assumed for the calculations. It was further assumed that the void volume of the limestone is approximately 50%.

Alkalinity generated: Based on alkalinity concentrations measured at several ALDs, Naim et al. reported an upper limit of alkalinity that can be generated of 300 to 400 mg/L as $CaCO_3$. Hayden et al reported alkalinities of 150 to 175 mg/L from ALDs treating a 530 gpm discharge. Yednock measured alkalinities exceeding 250 mg/L from an ALD.

Based on this information a predicted alkalinity of 250 mg/L was used to size the ALDs.

Design life: A design life of 20 years was used to size the ALDs. This design life is based on information provided in the RFP.

Limestone calcium carbonate concentration: The literature seems to indicate that calcium carbonate concentration is not critical assuming that the limestone is at least 70% $CaCO_3$. Faulkner et al. reviewed the performance of 19 ALDs at 5 sites in West Virginia and found that the grade of limestone, which varied between 70 to 90% calcium carbonate equivalent, did not appear to be critical to limestone dissolution rates and alkalinity generation. Yednock measured alkalinities exceeding 250 mg/L from ALDs with a 78% $CaCO_3$ concentration. Watzlaf measured the alkalinity generated from six limestones and one dolomite in a laboratory bench test. The six limestones tested dissolved much faster than the single dolomite tested. Within the limestone category, however, no correlation was found between the calcium content of the rock and the generation of alkalinity. Note that all limestones tested had a $CaCO_3$ content of least 90%, except for one limestone, which had a $CaCO_3$ content of 82% and had a slightly lower alkalinity. The most significant factor that influenced the generation of alkalinity in the experiments was the mine water. The most significant factor may be the partial pressure of CO_2 in the water.

Thus, the CaCO3 content does not appear to be critical to the overall performance of the ALD. However, the lower the CaCO3 content the greater the mass of limestone required. Based on our discussions with limestone suppliers, limestone with a CaCO3 content of 80% is available in Bedford County which is probably the closest location that can provide high CaCO3 limestone. To provide higher CaCO3 content limestone would involve shipping the limestone a considerably longer distance. For this reason, a CaCO3 content of 80% has been used to size the ALDs. A higher CaCO3 content could be used but the cost of the limestone would apparently be greater.

Based on the sizing calculations, there should be sufficient space available to provide ALDs of adequate size.

ALD Design Features

Limestone size: The literature indicates that limestone particle size is probably not critical to the performance of the ALDs. Data from sites in West Virginia indicate that AASHTO #57 (1.5 inch to #8 mesh) is commonly used. Faulkner et al. indicate that larger limestone particle size (3-10 inches) increases hydraulic conductivity and may reduce the potential of plugging. However, large limestone particle size has less surface area for water contact and alkalinity generation.

Nairn et al. report effective treatment provided by an ALD constructed of R-4 riprap (1 to 6 in.).

The U.S. Bureau of Mines publication indicates that "most effective systems have used number 3 or 4 (baseball-size) limestone" and that some systems constructed with limestone fines and small gravel have failed, apparently because of plugging problems.

An enclosed appendix shows standard gradations for limestone.

It is our opinion that the even under ideal conditions (low aluminum, ferric iron and D.O.) some scaling of the limestone will occur. The smaller the diameter of the limestone, the higher the ratio of limestone surface area to limestone mass and the greater the utilization of the limestone. This fact has to be weighed against the fact that the larger diameter limestone will provide more pore space because of the more irregular shapes.

Based on this discussion it is recommended that either NCSA R-3 (2-6 inches) or AASHTO #1 (3/4 to 4 inches) be used. In the longer ALDs, R-3 could be used in the upstream portions and AASHTO #1 in the downstream portions.

Limestone Availability: Based on our conversation with the DER mining inspector for Fayette County, high calcium carbonate limestone is not available in Fayette County. Although the Loylhanna Limestone is mined in several places in the county, the limestone is very high in silica and has a CaCO3 content of less than 75%. To date, mine operators constructing ALDs in the county have purchased limestone from Bedford County.

Based on our discussions with New Enterprise Stone and Lime, limestone provided from Bedford County quarries typically has CaCO3 contents of 80 to 85%. The costs of the various limestones are as follows:

AASHTO #1, 3, 57, 67:	$12.00 delivered $6.00 quarry
NCSA R3, R4:	$13.00 delivered $7.00 quarry

Oxygen barrier: The ALD must be sealed such that inputs of oxygen are minimized. There are three potential sources of oxygen: dissolved oxygen (D.O.) in the mine water, D.O. in fresh water that infiltrates into the ALD and atmospheric oxygen. There is no way to control D.O. in the mine water. But, provisions are recommended to prevent fresh water from entering the ALD. This is a significant issue at ALD #1. where it was observed that considerable runoff can enter the discharge channel from several locations. To minimize this it is recommended that a diversion ditch be constructed on the hill to the northeast of the discharge to prevent several fresh water springs from entering the ALD. Additionally, diversion ditches should be constructed on both sides of the ALD to prevent storm water runoff from entering the ALD.

Fresh water infiltration does not appear to be an issue for the ALDs at discharges 2,3 and 4.

To prevent atmospheric oxygen entry into the ALDs it is recommended that each ALD be covered with a plastic liner directly above the ALD and then with at least two feet of low permeability soil above the liner.

Polyethylene liner material is locally available in 4 and 6 mil thicknesses. It is recommended that a double layer (2 sheets) of 6 mil thick polyethylene be used to cover the limestone. The polyethylene comes in rolls with dimensions of either 10 feet by 100 feet or 20 feet by 200 feet.

It is recommended that the top and sides of the ALDs be covered. Since most of the seeps occur over diffuse areas and there is no significant infiltration of fresh groundwater into any the ALD areas, the lining of the bottoms of the ALDs is not recommended. However, in portions of the ALDs below the seeps, if significant unsuitable material (rocks, gravel) is encountered, it is recommended that this unsuitable material be replaced with one foot of clay to prevent mine water from short-circuiting below the ALDs.

Observation well: Because the ALDs will cover the origin of the mine water seeps it will be impossible to evaluate the performance of the ALDs by direct comparison of the influent and effluent unless monitoring wells are provided. It is proposed to construct one monitoring well near the start of ALD #1. No monitoring wells are proposed for the other discharges because of the difficulty and expense of constructing the wells through the ALDs and because the flow rates (and ALDs) are much smaller in volume.

The observation well will be constructed of 3-inch schedule 80 PVC pipe perforated through the limestone with an outer 4-inch cast iron pipe and threaded cap at the surface.

ALD Dimensions: Based on the various publications sited in this report, ALD dimensions are not a critical design feature. Many different configurations of limestone beds have been used successfully. According to the USBM publication, ALDs of 30 to 60 feet width have been constructed and have worked effectively. For this project, we propose to design the dimensions to suit the site configurations at the various ALDs.

Details of Specific ALDs

ALD #1: This drain will treat several seeps at discharge #1. The dimensions of the ALD will vary based on space availability from widest near the source to narrowest at the discharge.

The ALD will be covered with a two sheets of 6 mil polyethylene and a minimum of 2.5 feet of impervious soil. An important consideration is that the entire seepage area is covered to ensure that none of the seepage is exposed to air prior to flowing into the ALD.

To promote inundation of the limestone it is proposed to construct two clay barriers within the ALD. Because of the slope of the ALD, mine water will tend to flow along the floor of the ALD. The purpose of the barriers is to force some water to flow near the top. The use of these barriers is recommended for the lower (downstream) part of the ALD only. The use of barriers near the source is not recommended because the reduced cross sectional area at the barriers would be likely spots for failure due to plugging and most scaling is expected to occur in the upstream portion of the ALD.

A concrete endwall with a 12-inch drain pipe is proposed for the downstream end of the ALD. The endwall will prevent erosion of the impervious soil above the ALD and reduce the air exposure to the limestone at the end of the ALD.

Just downstream of the ALD, we propose to construct a weir to allow for monitoring of the flow through the ALD. The weir will consist of a concrete wall with an aluminum plate with a 90 degree V-notch.

Ditches will be constructed on both sides of the ALD to intercept stormwater runoff. The drainage area on the left side of the ALD is very small and very little runoff is anticipated. This ditch, therefore, will be designed with only a small cross-sectional area. The ditch on the right side of the ALD will intercept runoff from an existing ditch which receives some runoff from the ridge to the north. Because the ridge is heavily forested, the runoff coefficient is low.

Design calculations for the right (west) ditch are enclosed. The maximum depth of water in the ditch is estimated to be 0.61 feet but as a measure of safety, riprap is being provided to a depth of 1.5 feet on the section below the existing ditch. Based on the calculations it is proposed to use R4 riprap to line this ditch.

Because there is significant aluminum in the discharges, it is recommended that R-3 limestone be used in the upstream portions of the ALD and AASHTO #1 in the downstream portions under the assumption that most aluminum will precipitate near the source.

The sizing calculation indicates that approximately 25,700 cu. ft. of limestone is required. In accordance with the proposed design, approximately 31,600 cu. ft. is provided. Although this exceeds the calculated required volume, having extra volume will be beneficial because of the loss of alkalinity generating capacity caused by the high aluminum concentration in this ALD.

ALDs #2A, #2B and #2C: ALDs 2A, 2B and 2C will treat three seeps at discharge #2.

Because of there is not much elevation drop between the discharges and the existing wetland, the ALDs will be designed to be wide but shallow. Although it would be possible to build the ALDs deeper and have the water ascend into the wetland at the discharge via hydrostatic pressure, the concern is that the hydrostatic pressure may cause the mine water to short circuit above the limestone.

Sketches of the typical cross section for ALDs 2A, 2B and 2C is enclosed. A detail of the terminus, which will consist of clay barrier and pipe is also provided. The cross-sectional area of all the ALDs is 6.5 feet width by 4 feet depth.

The sizing calculation indicates that approximately 5,100 cu. ft. of limestone is required. In accordance with this design approximately 5,200 cu. ft. is provided.

ALD #3: This ALD will treat discharge #3. The ALD will cross through two seeps and discharge to the first cell of wetland #3. A third seep, which is shown to the east of these two seeps on the drawing provided by the Department was not present during our field investigation and no treatment is proposed for this seep.

ALD #3 will have the same dimensions (6.5 feet width by 4 feet depth) as that for ALDs 2A, 2B and 2C. The main limitation at this discharge is the lack of sufficient distance between the seeps and existing wetland to meet the calculated volume requirement of 5,100 cu. ft. The actual limestone provided is 2,600 cu. ft.. Although this is less than the calculated required amount, the 10 gpm flow used to size the ALD is probably very conservative. During our field investigation the flow appeared to be less than 2.0 gpm. Also, this wetland visually appeared to remove most iron from the seep even without the ALD. Based on these observations, therefore, we are suggesting that the design volume of limestone is adequate.

ALDs #4A, #4B and #4C: These ALDs treat discharge #4. There are three seeps at this discharge. As discussed previously, it is proposed that the effluent from the ALDs at discharge #4 be discharged to wetland #1. This is being recommended due to the space limitations in the vicinity of discharge #4 and that fact there is considerable coal refuse in the vicinity of the discharges which would be an undesirable material for the base of a wetland. The additional alkalinity provided by these ALDs should help the performance of wetland #1.

ALDs 4B and 4C will drain into 4A which will convey the mine water to wetland #1 via the existing haulroad. The proposed cross-sectional area for these ALDs is 4 feet by 4 feet. Using the estimated length of these ALDs of 650 feet, the total volume provided is 10,400 cu. ft. Although this exceeds the calculated required volume, it will be beneficial to have extra limestone because some will be rendered ineffective by aluminum precipitation.

The top of the ALD along the existing haulroad will be designed such that the ALD will not prohibit the use of the haulroad in the future if necessary. This will be accomplished by keeping the top of the impervious soil layer flush with the haulroad surface.

Wetland Improvements

Wetland #1: Rather severe short circuiting is currently occurring in this wetland. Most of the water follows a route near the middle of the wetland. Some portions of the wetland are nearly dry, including much of the westernmost cell of the wetland which receives little if any flow.

Recommended work for this wetland is to provide some "baffles" in the wetland to encourage more even flow distribution,

Wetland #2: This wetland appears to be in good condition. Water depths are relatively uniform and only minor short circuiting is occurring. For this reason, no work is recommended for this wetland.

Wetland #3: This wetland is in very good condition. No short circuiting was observed. During our visit a large number of frogs were observed in the wetland. For these reasons, no improvements are recommended for this wetland.

References:

Faulkner, et al., Treatment of Acid Mine Drainage by Passive Treatment Systems, International Land Reclamation and Mine Drainage Conference, Pittsburgh, PA. April, 1994

Hedin, et al., The Effects of Anoxic Limestone Drains on Mine Water Chemistry, International Land Reclamation and Mine Drainage Conference, Pittsburgh, PA. April, 1994.

Hayden, et al., Performance of the Howe Bridge Passive Treatment System, International Land Reclamation and Mine Drainage Conference, Pittsburgh, PA. April, 1994

Hayden, et al., Performance of the Morrison Passive Treatment System, International Land Reclamation and Mine Drainage Conference, Pittsburgh, PA. April, 1994

Nairn, et al., Generation of Alkalinity in an Anoxic Limestone Drain, Proceedings of the 9th Annual National Meeting of the American Society for Surface Mining and Reclamation, June, 1992

USBM Information Circular 9389, *Passive Treatment of Acid Mine Drainage*, 1994

Watzlaf, et al., A Method for Predicting the Alkalinity Generated by Anoxic Limestone Drains, Proceedings, 14th Annual West Virginia Surface Mine Drainage Task Force Symposium, April, 1993

Watzlaf, et al., The Performance of the Jennings Environmental Center Limestone Drain, International Land Reclamation and Mine Drainage Conference, Pittsburgh, PA. April, 1994.

Yednock, Construction and Performance of Anoxic Limestone Drains Installed to Treat Acid Mine Drainage on Abandoned Mine Lands in West Virginia, International Land Reclamation and Mine Drainage Conference, Pittsburgh, PA. April, 1994

Appendix A

ALD Sizing Calculations

Appendix A: ALD Worksheet

Calculation of Limestone Required:

Equation:

$$M = \frac{Q*d*t}{V} + \frac{Q*C*T}{x}$$ (from Hedin, et al., 1994)

Where

M= Mass of limestone (tons)
Q= Flow rate (gpm)
d= Bulk density of limestone
t= Detention time (hours)
V= Bulk void volume
C= Predicted Alkalinity Concentration (mg/L as $CaCO_3$)
T= Design life (years)
x= Calcium carbonate content of limestone

1) Discharge #1 (Discharge to Wetland #1):

Q= 50 gpm
d= 100 lbs./ft3
t= 15 hours
V= 0.5
C= 250 mg/l as $CaCO_3$
T= 20 years
x= 0.8 $CaCO_3$

Mass = 1285 tons of $CaCO_3$ req'd **Volume = 25,700 ft3**

2) Discharge #2 (Discharge to Wetland #2):

Q= 10 gpm
d= 100 lbs./ft3
t= 15 hours
V= 0.5
C= 250 mg/l as $CaCO_3$
T= 20 years
x= 0.8 $CaCO_3$

Mass = 257 tons of $CaCO_3$ req'd **Volume = 5,100 ft3**

Appendix A: ALD Worksheet

3) **Discharge #3 (Discharge to Wetland #3):**

Q=	10 gpm
d=	100 lbs./ft3
t=	15 hours
V=	0.5
C=	250 mg/l as CaCO3
T=	20 years
x=	0.8 CaCO3

Mass = 257 tons of CaCO3 req'd   Volume = 5,100 ft3

4) **Discharge #4 (Bench seep):**

Q=	10 gpm
d=	100 lbs./ft3
t=	15 hours
V=	0.5
C=	250 mg/l as CaCO3
T=	20 years
x=	0.8 CaCO3

Mass = 257 tons of CaCO3 req'd   Volume = 5,100 ft3

Appendix B

Calculation of Limestone Provided

Appendix B: Calculation of Limestone Provided:

ALD #1 - Limestone Volume Calculations (as designed):

Section		ALD Length	ALD Depth	ALD Avg. Width	Volume (ft3)	
0	20	20	5	40	4000	
20	50	30	5	52.5	7875	
50	90	40	4	50	8000	
90	130	40	4	28.5	4560	
130	180	50	4	18	3600	
180	222	42	4	10	1680	
222	252	30	4	5.5	660	
252	300	48	4	5	960	
300	315	15	4	5	300	
				Total	**31635**	**ft3**

ALD #2A,B,C - Limestone Volume Calculations (as designed):

Section		ALD Length	ALD Depth	ALD Avg. Width	Volume (ft3)	
2A		75	4	6.5	1950	
2B		60	4	6.5	1560	
2C		65	4	6.5	1690	
				Total	**5200**	**ft3**

ALD #3 - Limestone Volume Calculations (as designed):

Section		ALD Length	ALD Depth	ALD Avg. Width	Volume (ft3)	
3		100	4	6.5	2600	
				Total	**2600**	**ft3**

ALD #4A,B,C - Limestone Volume Calculations (as designed):

Section		ALD Length	ALD Depth	ALD Avg. Width	Volume (ft3)	
4A		520	4	4	8320	
4B		80	4	4	1280	
4C		50	4	4	800	
				Total	**10400**	**ft3**

Appendix C

Standard Limestone Gradations

2. **Size and Gradation.**

	Percent Passing (Square Openings)					
Class, Size No. (NCSA)	**R-8****	**R-7****	**R-6**	**R-5**	**R-4**	**R-3**
Rock Size (Inches)						
42	100*					
30		100*				
24	15-50		100*			
18		15-50		100*		
15	0-15					
12		0-15	15-50		100*	
9				15-50		
6			0-15		15-50	100*
4				0-15		
3					0-15	15-50
2						0-15
Nominal Placement Thickness (inches)	48	36	30	24	18	12

*Maximum Allowable Rock Size.
**Use Class 2, Type A Geotextile

Provide two samples of rock, at least 5 tons each or each one-half the total project quantity, whichever is smaller. Provide one sample in place at the construction site and provide the other sample at the quarry. The construction site sample may be incorporated into the work. These samples will be used as a reference for judging the size and gradation of the rock supplied and placed. Certify as to gradation, as specified in Section 106.03(b)3.

(b) Geotextiles. Class 2, For the type required. Section 735

850.3 CONSTRUCTION — As shown on the Standard Drawings and as follows:

Prepare the area required for placing the geotextile and rock.

This preparation may include, but not be limited to excavating, removing unsuitable material, backfilling, placing embankment, and clearing and grubbing, as specified in Section 201.3. Place the geotextiles, as specified in Section 212.3(c).

Carefully place the rock on the geotextiles to produce an even distribution of pieces, with a minimum of voids and without tearing the geotextile. Place the full-course thickness in one operation in a manner to prevent segregation and to avoid displacement of the underlying material. Placing of rock in layers, by dumping into chutes, or by similar methods likely to cause segregation or geotextile damage will not be permitted. Rearrange individual rocks, if necessary, to insure uniform distribution.

850.4 MEASUREMENT AND PAYMENT —

(a) Rock Lining. Square Yard

(b) Excavation. Cubic Yard
For the class indicated.

TABLE C
SIZE AND GRADING REQUIREMENTS FOR COARSE AGGREGATES
(Based on Laboratory Sieve Tests, Square Openings)

AASHTO NUMBER	TOTAL PERCENT PASSING													
	4"	3½"	2½"	2"	1½"	1"	¾"	½"	⅜"	#4	#8	#16	#100	*** #200
1	100	90-100	25-60		0-15		0-5							
3			100	90-100	35-70	0-15		0-5						
5					100	90-100	20-55	0-10	0-5					
57					100	95-100		25-60		0-10	0-5			
67						100	90-100		20-55	0-10	0-5			
7							100	90-100	40-70	0-15	0-5			
8								100	85-100	10-30	0-10	0-5		
10									100	85-100			10-30	
2A**				100			52-100		36-70	24-50	16-38*	10-30		0-10
OGS**				100			52-100		36-65	8-40		0-12		0-5

* Applies only for bituminous mixtures

**PaDOT Number

*** For #200, see Table "D"

Note A: A combination of No. 7 and No. 5 may be substituted for No. 57, provided that not more than 50% nor less than 30% of the combination is No. 7 size.

Note B: Provide No. OGS material that has a minimum average coefficient of uniformity of 4.0. The average coefficient of uniformity is defined as the average of the sublots within each lot. Determine the coefficient of uniformity in accordance with PTM No. 149 each time the gradation is determined. Individual samples may not have a coefficient of uniformity less than 3.5. If the coefficient of uniformity of any sample falls below 3.5, reject the lot. The coefficient of uniformity is not to be used in the multiple deficiency formula.

4. Material Finer Than the No. 200 Sieve. Determine the loss by washing, in accordance with PTM No. 100 and as shown on Table D.

This test is not required for aggregate processed through a mechanical dryer for use in bituminous concrete; however, the aggregate is to be clean and free of any fines which would adversely affect the coating of the aggregate with bituminous material.

TABLE D
MATERIAL PASSING THE NO. 200 SIEVE —
(Based on Laboratory Sieve Tests, Square Openings)

SECTION	SPECIFICATION	% MAXIMUM
350	Subbase (No. 2A)	10
350	Subbase (No. OGS)	5
430	Bit. Wear. Crse. FB-2	2
431	Bit. Bind. Crse. FB-2	2
439	Bit. Wear. Crse. FB-1	2
440	Bit. Bind. Crse. FB-1	2
441	Bit. Bind. Crse. CP-2	2.0
450	Bit. Bind. Crse. DP-1	2.0
470	Bit. Seal Coat	1.0
471	Bit. Seal Coat w/Precoat. Aggr.	2.0
480	Bit. Surf. Treatment	1.0
704	Cement Concrete	1
—	All other uses	2

5. Crushed Fragments. PTM No. 621

6. Compact Unit Weight. PTM No. 609, for slag.

7. Deleterious Shale. The percentage of weight by four cycles of wetting and drying will be determined in accordance with PTM No. 519. Confirmation will be made by the MTD, using petrographic analysis.

8. Friable Particles. AASHTO-T112, by percentage of weight.

9. Coal or Coke. Determine the percentage of weight by visual identification and hand separation. confirmation will be made by the MTD, using petrographic analysis, when required.

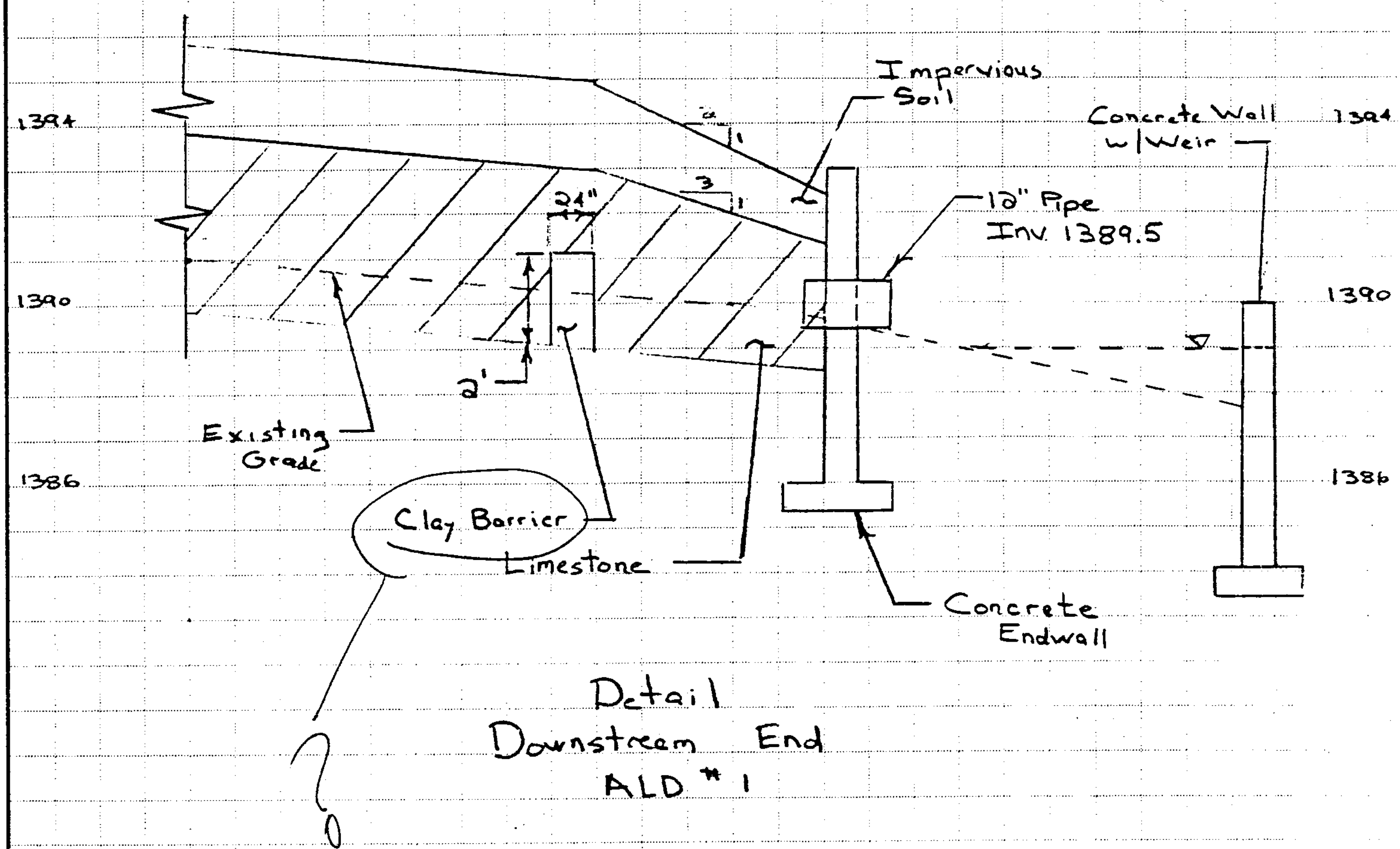
10. Glassy Particles. Determine the percentage of weight by visual identification and hand separation. Pieces of slag containing more than 50% glass will be considered glassy particles. The maximum allowable amount for use in cement concrete is 4%, 10% for other uses.

Appendix D

Design Sketches

CET ENGINEERING SERVICES
1240 North Mountain Road
HARRISBURG, PENNSYLVANIA 17112
(717) 541-0622
FAX (717) 541-8004

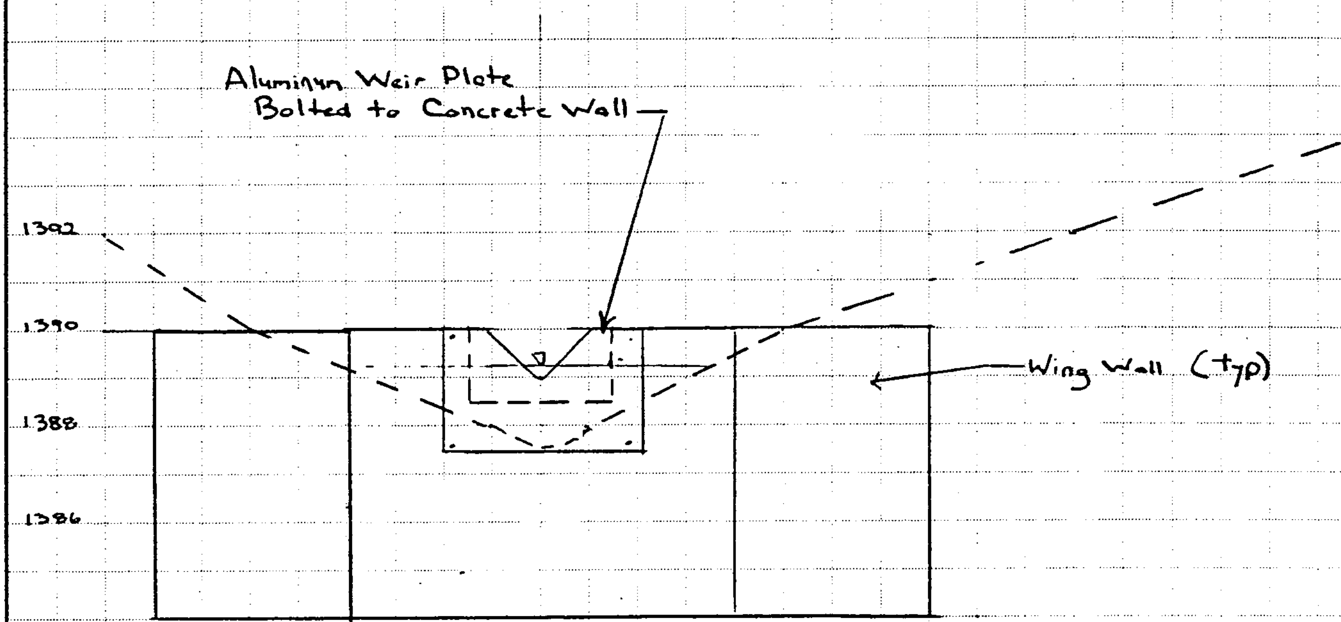
JOB: AMD 26(2768) 101.2 - Cucumber Run
SHEET NO.: 1 OF: 1
CALCULATED BY: PJL DATE: 4/11/95
CHECKED BY: DATE:
SCALE:



Detail
Downstream End
ALD #1

CET ENGINEERING SERVICES
1240 North Mountain Road
HARRISBURG, PENNSYLVANIA 17112
(717) 541-0622
FAX (717) 541-8004

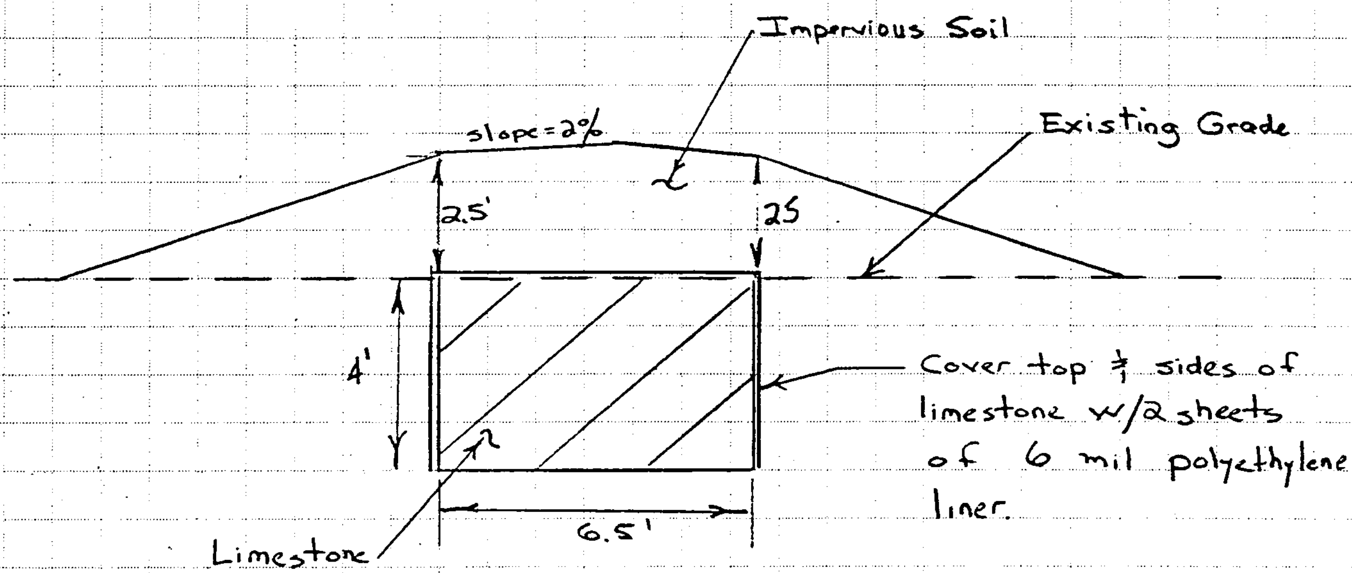
JOB AMD 26(2768) 101.2 - Cucumber Run
SHEET NO. 1 OF 1
CALCULATED BY PJL DATE 4/11/95
CHECKED BY ______ DATE ______
SCALE 1" = 4'



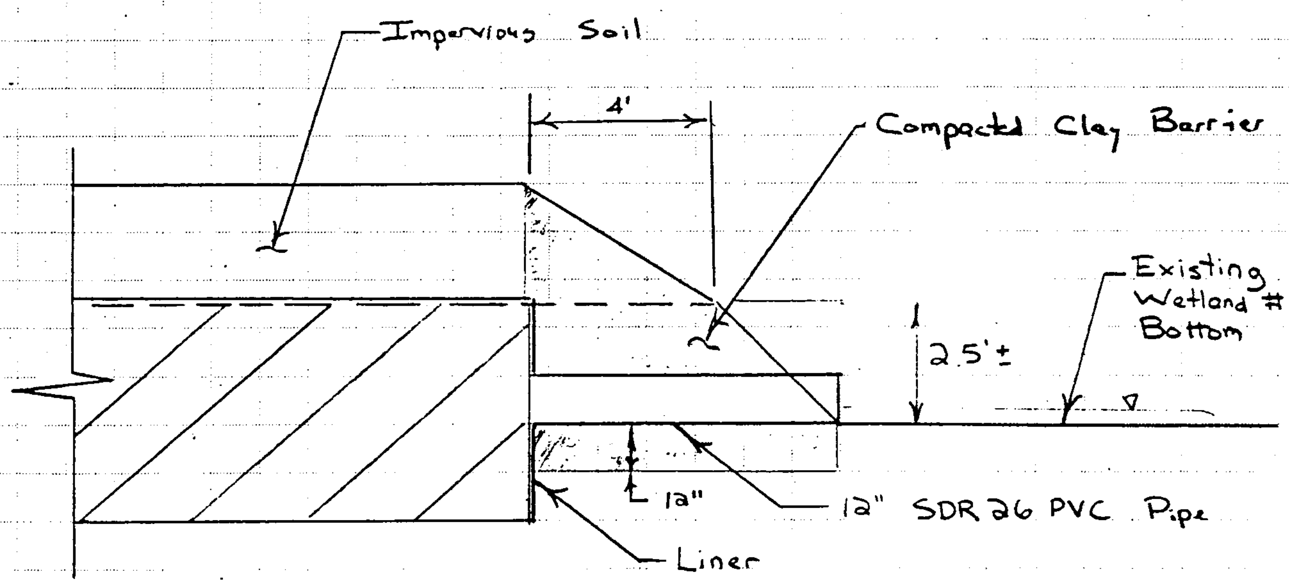
Detail: Concrete Wall w/ Aluminum Weir

CET ENGINEERING SERVICES
1240 North Mountain Road
HARRISBURG, PENNSYLVANIA 17112
(717) 541-0622
FAX (717) 541-8004

JOB AMD 26(2768) 1012 - Cucumber Ru
SHEET NO. 1 OF 1
CALCULATED BY PJL DATE 4/11/95
CHECKED BY ______ DATE ______
SCALE 1" = 4'



Section
ALDs #2A, 2B, 2C, 3A
1" = 4'



Detail
Terminus - ALDs #2A, 2B, 2C, 3A

1" = 4'

CET ENGINEERING SERVICES
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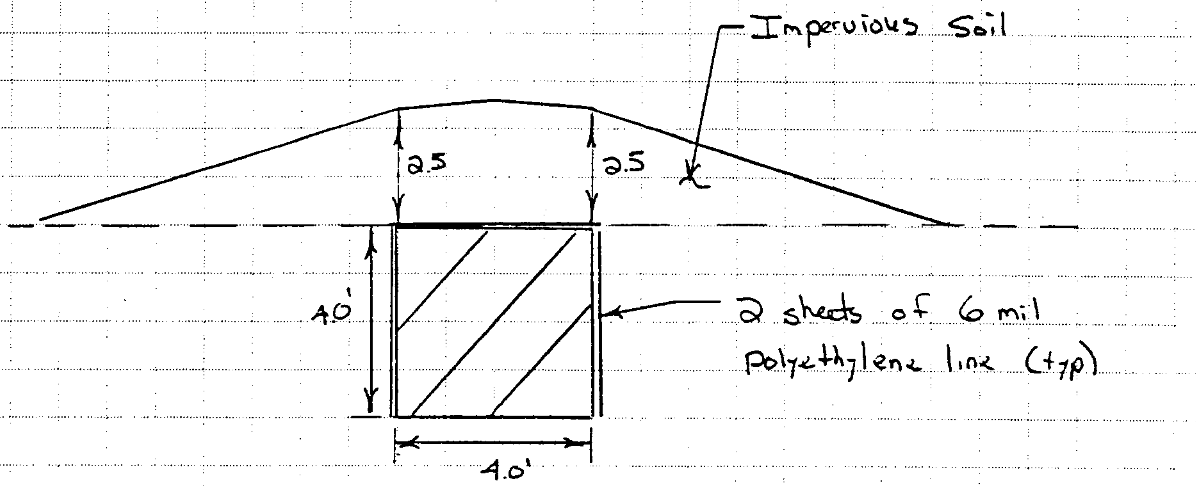
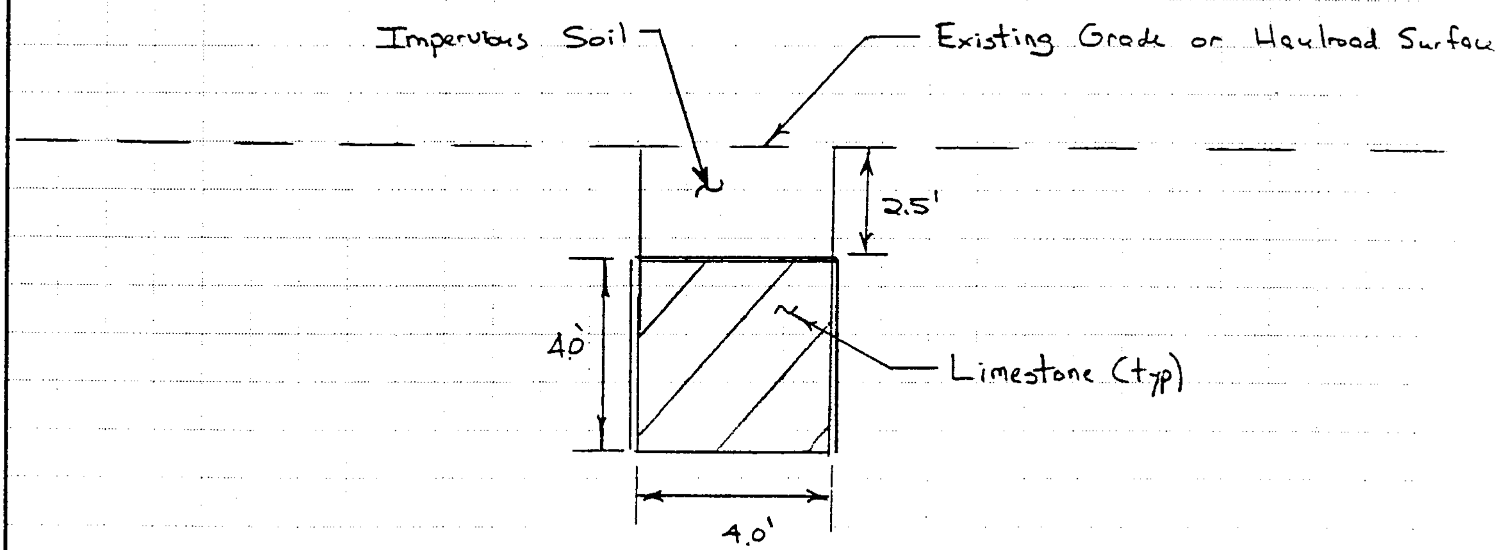
(717) 541-0622
FAX (717) 541-8004

JOB AMD 26(2768) 101.2 - Cucumber
SHEET NO. 1 OF 1
CALCULATED BY PJL DATE 4/11/95
CHECKED BY ______ DATE ______
SCALE 1" = 4'



Section
ALDs 4A, 4B & 4C - In Vicinity of Seepage Areas



Section
ALDs 4A, 4B & 4C - In Vicinity of Bench & Haulroad

Appendix E

Stormwater Runoff Calculations and Ditch Sizing Calculation

(ALD#1 - Right Ditch)

CET ENGINEERING SERVICES
1240 North Mountain Road
HARRISBURG, PENNSYLVANIA 17112
(717) 541-0622
FAX (717) 541-8004

JOB AMD 26(7768)101.2 – Runoff Cal.
SHEET NO. 1 OF 2
CALCULATED BY PJL DATE 4/8/9
CHECKED BY ______ DATE ______
SCALE ______

Calculation of Peak Stormwater Runoff for Ditch to the West side of ALD #1 (Designed for 25 yr. rtn. storm)

Use Rational Formula, where $Q = CIA$

where C = runoff factor = 0.15 (heavy woods, brush, boulders)
I = rate of rainfall for Tc (inches/hour)
A = drainage area = 9.4 Ac. (see map)

Time of concentration = woods + channel

Woodland slope = $\frac{1780 - 1460}{1100}$ = 30%

Woodland length = 1100 feet.
Woodland velocity = 3.5 ft/sec (est - PA Dot Publ)
Woodland Tc = 1100 / 3.5 ft/sec = 314 sec

Riprap channel (A) flat area

length = 400'
slope = $\frac{1460 - 1451}{400}$ = 2%

velocity = 1.5 fps (est from graph)
tc = 400 / 1.5 = 266 sec

(B) Steep area

length = 140'
slope = $\frac{1450 - 1403}{140}$ = 33%

Velocity = 6 fps - (est. from graph)
Tc = 140 / 6 = 23 sec.

∴ Total Tc = 314 s + 266 s + 23 s = 603 sec = 10 min.

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(717) 541-0622
FAX (717) 541-8004

JOB: AMD 26(2768) 101.2 - Runoff Calc.
SHEET NO. 2 OF 2
CALCULATED BY: P-L DATE: 4/8/95
CHECKED BY: DATE:
SCALE:

ALD #1 west ditch stormwater runoff calc (cont'd)

Rate of rainfall = I = 5.2 inches/hour, (for 25 yr storm)

∴ Runoff = Q = C I A

= 0.15 × 5.2 in/hr × 9.5 A

= 7.4 cfs

Determine Max Water Depth in channel:

Given min channel slope = 2%, riprap lined channel (n = 0.035), depth = 0.61'

(see attached chart)

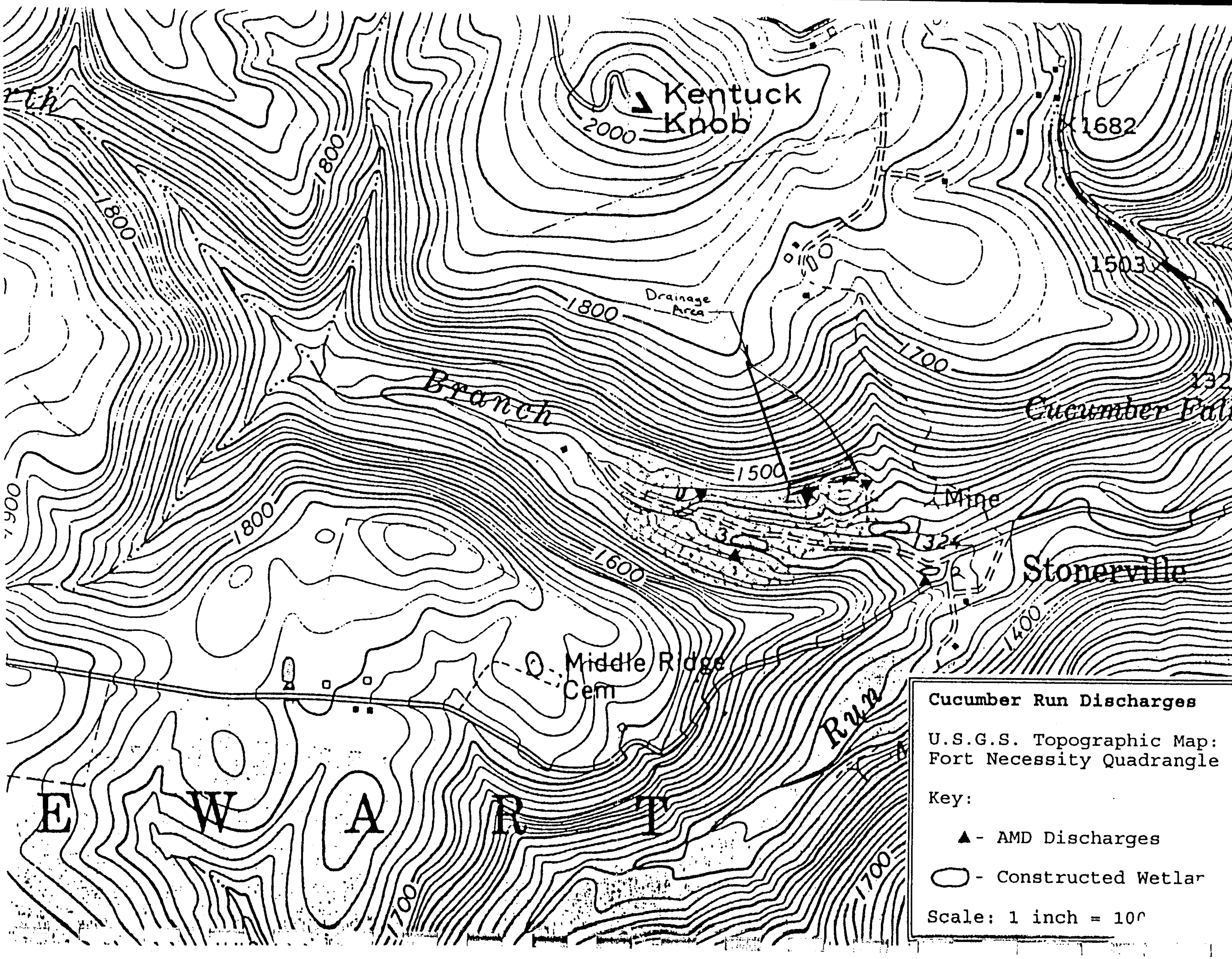
Determine Max water velocity in channel:

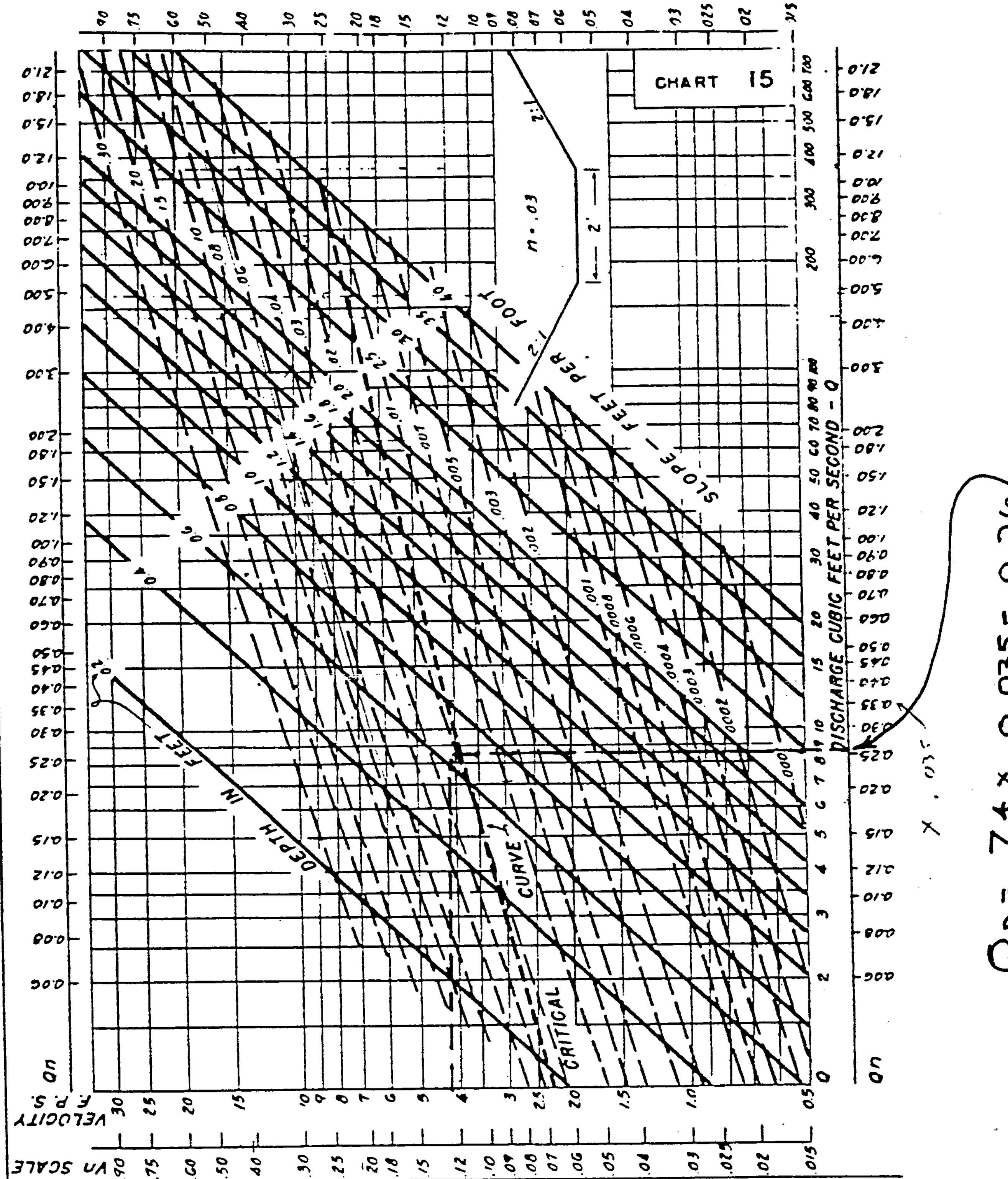
Given max. channel slope, compute velocity & riprap size

Max slope occurs at downstream end of ditch,
S = 8/40 = 0.2

From enclosed graph @ Q = 7.4, n = 0.035 V = 9.0 fps

∴ use NCSA R-4 riprap in accordance w/ enclosed table.


Kentuck Knob
2000
1682
1800
1503
Drainage Area
1700
1325
Cucumber Falls
Branch
1500
Mine
1900
1800
1600
Stonerville
1400
Middle Ridge Cem
Run
E W A R T
1700
Cucumber Run Discharges
U.S.G.S. Topographic Map: Fort Necessity Quadrangle
Key:
▲ - AMD Discharges
- Constructed Wetlar
Scale: 1 inch = 10



CHANNEL CHART
2:1 b = 2 FT.

RAINFALL INTENSITY - DURATION - FREQUENCY CURVES

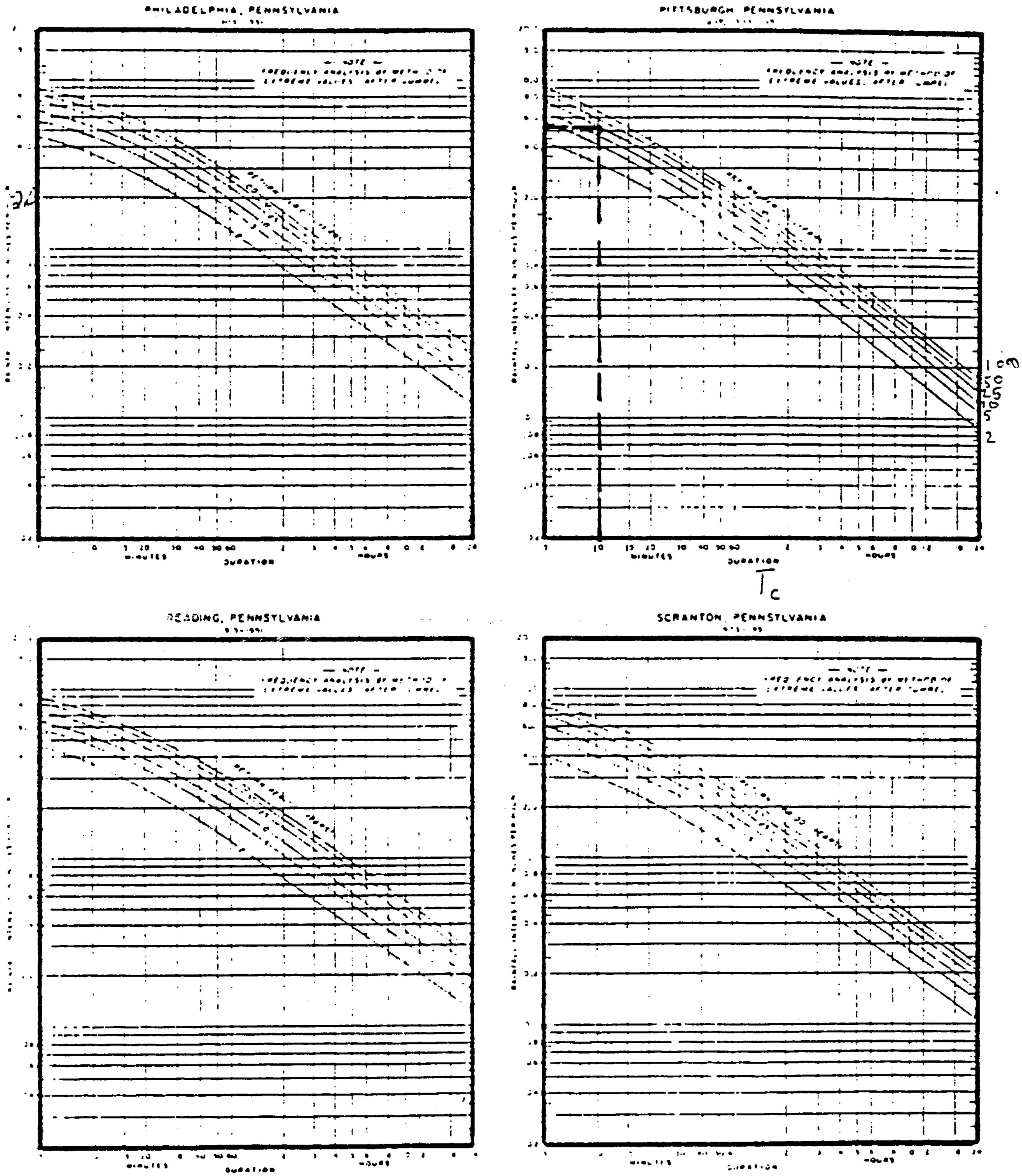


FIGURE 2.10.12 I

SUGGESTED SIZES

Depending on the factors involved in the final decision and crushed stone products generally available, the following is offered:

Table 3

Flow Velocity (ft./sec.)	GRADED RIPRAP STONE NCSA No.	Size Inches (sq. openings) Max.	Avg.	Min.	Filter Stone NCSA No.
4.5	R-2	3	1½	1	FS-1
6.5	R-3	6	3	2	FS-2
9.0	R-4	12	6	3	FS-2

Note: See Appendix for more complete information on riprap sizes and filter stone requirements.

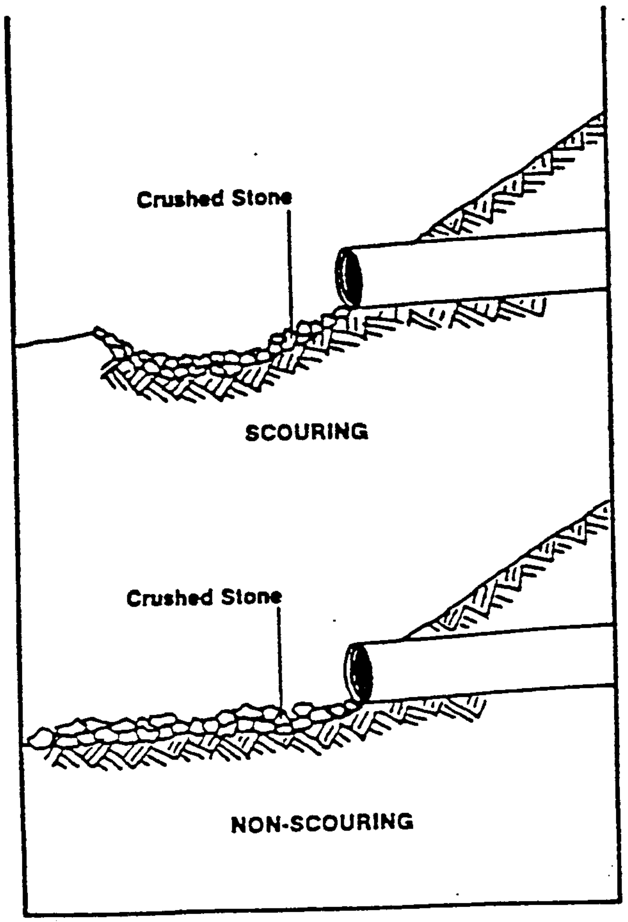
Pipe Outlets (Riprap Basins)

PROBLEMS/CONDITIONS

The concentration of water being discharged from any pipe creates an almost automatic erosion problem. If the erosion tendency is not controlled, the lower end of the pipe may be undercut and this may lead to more severe problems within the embankment and/or surrounding area. Soil washed away by erosion at a pipe outlet can contribute greatly to siltation problems elsewhere.

FACTORS IN THE SOLUTION

The flow rate, culvert size, and tail water depth are important considerations. As shown in the sketches below, the riprap basin at pipe outlets can be either the Scouring or Non-Scouring type. When the Scouring Type (i.e. making allowances for some scour) is used, the design more effectively dissipates the energy in the flowing water and as a result, the size of stone required can be reduced. A stone filter layer is generally not required as long as some siltation between the stone pieces is anticipated.



Appendix F

Water Quality Data

AMPLE ANALYSES

ACID MINE DRAINAGE PROJECT SITE

PROJECT NO. AMD 26(2768)101.1

ucumber Run

ntry Discharge to Wetland #1

Report Date: February 13, 1995

Sample Date	Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
03/25/94		4.2	0.0		350.0	340.0	60.2	60.2	0.8	2.2	126.0
04/28/94		4.5	0.0		354.0	366.0	52.7	52.7	0.9	1.7	122.0
06/02/94		4.3	0.0		756.0	738.0	145.0	136.0	2.4	14.9	338.0
06/29/94		4.2	0.0		876.0	792.0	151.0	151.0	2.6	17.2	430.0
07/14/94		4.0	0.0		1164.0	1210.0	219.0	215.0	3.5	26.8	634.0
07/21/94		4.0	0.0		1110.0	1210.0	209.0	209.0	3.3	26.5	604.0
07/28/94		4.1	0.0		1270.0	1540.0	226.0	270.0	3.4	24.7	636.0
08/11/94		3.6	0.0	240.0	936.0	1040.0	201.0	220.0	3.4	22.2	526.0

Report Date: February 13, 1995

NUMERICAL AVERAGES

Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
	4.11	0.0	240.0	852.0	904.5	158.0	164.2	2.5	17.0	427.0

SAMPLE ANALYSES
ACID MINE DRAINAGE PROJECT SITE
PROJECT NO. AMD 26(2768)101.1
Cucumber Run
Seep near entry discharge, to Wetland #1

Report Date: February 13, 1995

Sample Date	Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
03/23/94		4.5	0.6		146.0	143.0	20.4	20.2	1.9	0.7	66.0
04/28/94		3.7	0.0	12.8	234.0	233.0	38.0	38.0	3.3	1.4	98.0
06/02/94		3.8	0.0	58.0	588.0	558.0	121.0	121.0	6.0	6.8	256.0
06.29/94		7.2	30.0		50.0	39.0	0.4	0.0	0.1	0.3	0.0
07/14/94		6.8	28.0		54.0	34.0	0.4	0.0	0.2	0.3	0.0
07/21/94		3.5	0.0	508.0	1060.0	1160.0	211.0	211.0	7.8	23.0	604.0
07/28/94		3.6	0.0	150.0	1090.0	1010.0	245.0	270.0	7.9	28.6	680.0
08/11/94		3.3	0.0	270.0	1160.0	1290.0	243.0	243.0	7.0	30.1	794.0

Report Date: February 13, 1995

NUMERICAL AVERAGES

Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
	4.55	7.3	199.8	547.8	558.4	109.9	112.9	4.3	11.4	312.3

SAMPLE ANALYSES

Report Date: February 13, 1995

ACID MINE DRAINAGE PROJECT SITE

PROJECT NO. AMD 26(2768)101.1

Cucumber Run

Inflow to wetland #3

Sample Date	Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
03/23/94		3.2	0.0		200.0	191.0	2.8	0.3	2.1	3.3	78.0
04/28/94		3.2	0.0	36.0	232.0	211.0	6.0	0.3	3.8	2.7	78.0
06/02/94		3.2	0.0	40.0	250.0	250.0	7.6	0.6	4.4	3.1	78.0
06/29/94		3.1	0.0	50.0	254.0	268.0	6.5	1.1	3.5	2.7	88.0
07/14/94		3.1	0.0	54.0	264.0	264.0	7.2	0.4	4.4	2.7	110.0
07/21/94		3.2	0.0	56.0	288.0	282.0	8.7	0.7	4.4	3.1	92.0
07/28/94		3.2	0.0	52.0	292.0	288.0	8.7	0.7	4.6	3.2	104.0
08/11/94		3.1	0.0	62.0	316.0	356.0	10.0	0.8	4.7	3.2	118.0

Report Date: February 13, 1995

NUMERICAL AVERAGES

Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
	3.16	0.0	50.0	262.0	263.8	7.2	0.6	4.0	3.0	93.3

SAMPLE ANALYSES

ACID MINE DRAINAGE PROJECT SITE

PROJECT NO. AMD 26(2768)101.1

Cucumber Run

Seep on bench above Wetland #1

Report Date: February 13, 1995

Sample Date	Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
03/23/94		4.3	0.0	48.0	178.0	177.0	34.4	34.4	1.5	2.1	94.0
04/28/94		4.3	0.0		214.0	197.0	43.7	43.7	2.6	2.8	108.0
06/02/94		4.0	0.0		720.0	672.0	167.0	164.0	6.5	22.8	406.0
06/29/94		3.4	0.0	24.0	97.0	88.0	5.3	1.4	0.9	4.8	62.0
07/14/94	0										
07/21/94		3.5	0.0	242.0	1330.0	1240.0	262.0	262.0	6.3	50.2	880.0
07/28/94		2.8	0.0	438.0	1140.0	1250.0	228.0	197.0	7.3	55.1	950.0
08/11/94		2.6	0.0	624.0	1130.0	1170.0	180.0	110.0	6.9	50.6	1102.0

Report Date: February 13, 1995

NUMERICAL AVERAGES

Flow (GPM)	pH	TAlk (mg/l)	PH4 (mg/l)	THard (mg/l)	SO4 (mg/l)	Fe (mg/l)	Fe+2 (mg/l)	Mn (mg/l)	Al (mg/l)	TAcid (mg/l)
	3.56	0.0	229.3	687.0	684.9	131.5	116.1	4.6	26.9	514.6