Full-Scale Toe Drain Test
Many Farms Dam

DSO-99-05

Materials Engineering and Research Laboratory

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Executive Summary

Full-scale laboratory testing was conducted on the proposed toe drain design for Many Farms Dam. The toe drain design calls for 10-inch single-wall corrugated high-density polyethylene (HDPE) drain pipe with 1/16-inch wide slotted perforations, covered with a knitted geotextile sock, and backfilled with a fine sand envelope. The geotextile sock has an apparent opening size (AOS) of #30 sieve (0.6 mm), and is placed on the pipe at the factory. The 1/16-inch slotted perforations are intended to clog with sand particles if the geotextile sock should tear. However, the slot width could potentially double if the drain pipe elongates significantly during installation.

Test Results.—The test was conducted for 13 days, and the outflow quickly stabilized at 7.3 gallons per minute (gpm) per foot (see figure 1). The envelope loss was stabilizing at about 1,000 grams per linear foot, which was higher than expected, but believed acceptable. This loss equates to a calculated thickness loss of 0.087 inches around the pipe circumference. After testing, the pipe was carefully exhumed, and a coarser natural soil filter had formed adjacent to the geotextile sock, measuring ½ to 1 inch thick. Because of the loss of 1,000 grams of sand envelope per foot of toe drain, a coarser more broadly graded envelope material has been proposed.

Cost Savings.—Traditional two-stage filters use a gravel envelope surrounded by a sand filter, and require extensive bench-cut (open-cut) excavation. Use of the geotextile sock in lieu of the gravel envelope allows construction with trenching equipment, which can offer significant cost savings.

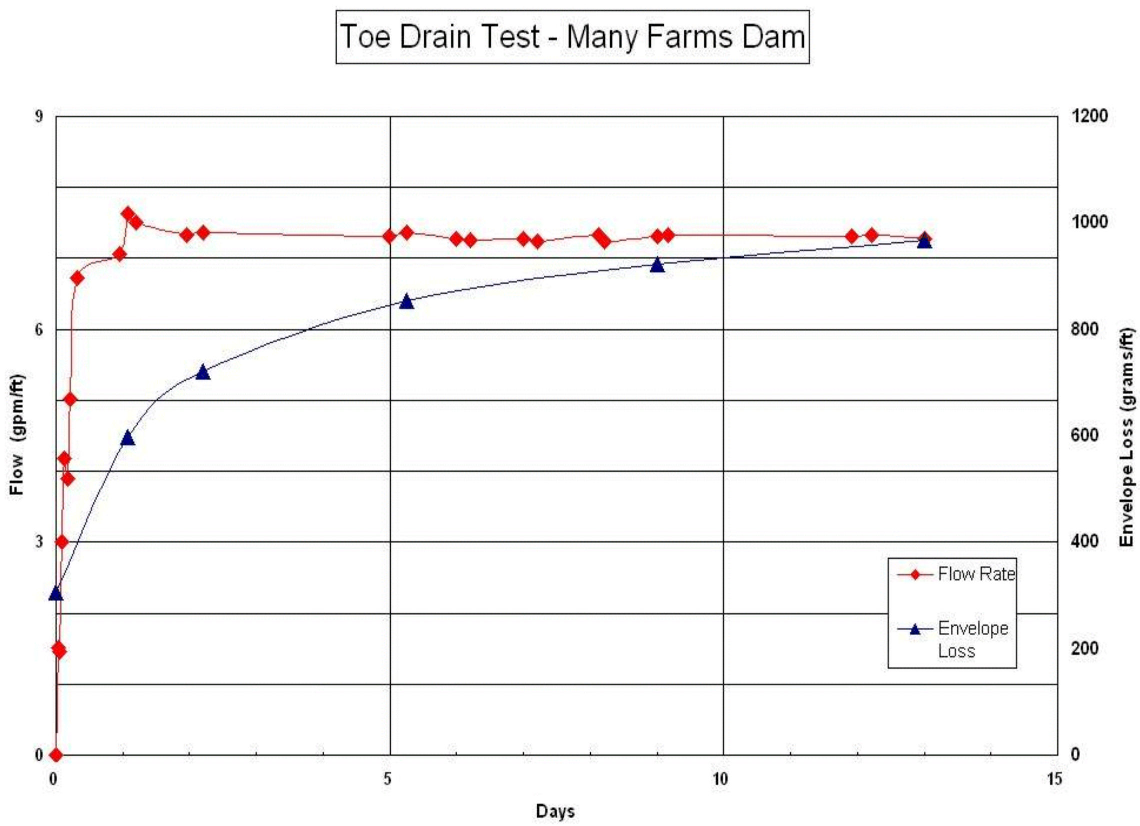


Figure 1.—Test results - toe drain with geotextile sock for Many Farms Dam.

Geotextile.—The knitted geotextile sock used in this study is the only geotextile that is pre-installed on the pipe at the factory. The knitted sock is only available with AOS of #30, which limits design options. Other geotextile products (such as monofilament woven) would have to be attached to the pipe in the field, but are available in a wide range of AOS.

Introduction

This report describes the full-scale laboratory testing (pipe box testing) of the proposed toe drain design for Many Farms Dam. The test apparatus is shown in figure 2. The toe drain design calls for 10-inch single-wall corrugated HDPE drain pipe with 1/16-inch slotted perforations, covered with a knitted geotextile sock, and backfilled with a fine sand envelope. The geotextile sock has an AOS = #30 sieve (0.6 mm), and is placed onto the pipe at the factory. This configuration allows installation of the toe drain with trenching equipment, eliminating the need for extensive bench-cut excavation. The sand envelope gradation (figure 3) is designed to filter the fine grained (silty) native soils (including some dispersive clays) . Previous work (Swihart, 1999) showed that the same geotextile sock used with a slightly coarser sand from Lake Alice Dam could simultaneously improve flow rates by factors of 3 to 12, and improve retention of sand envelope by factors of 4 to 17.

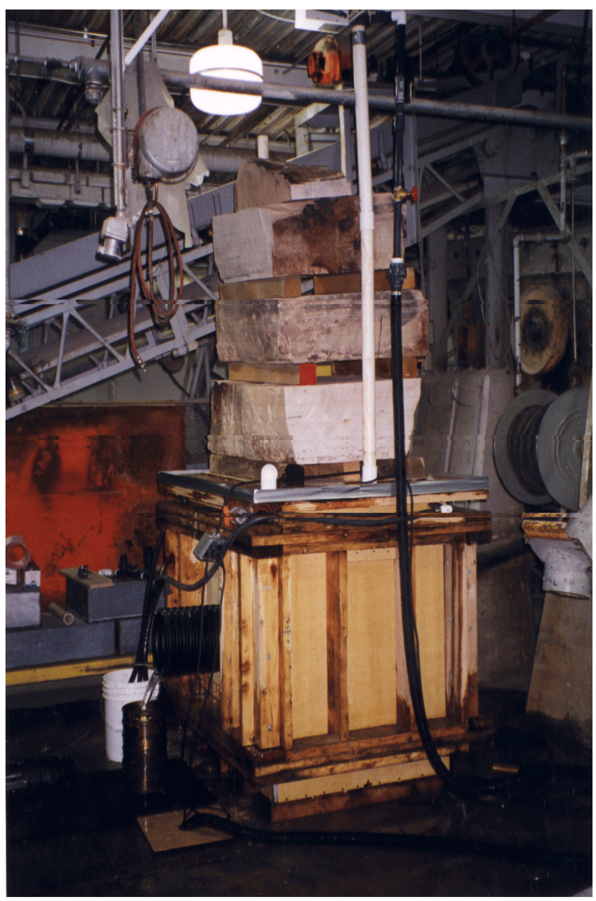
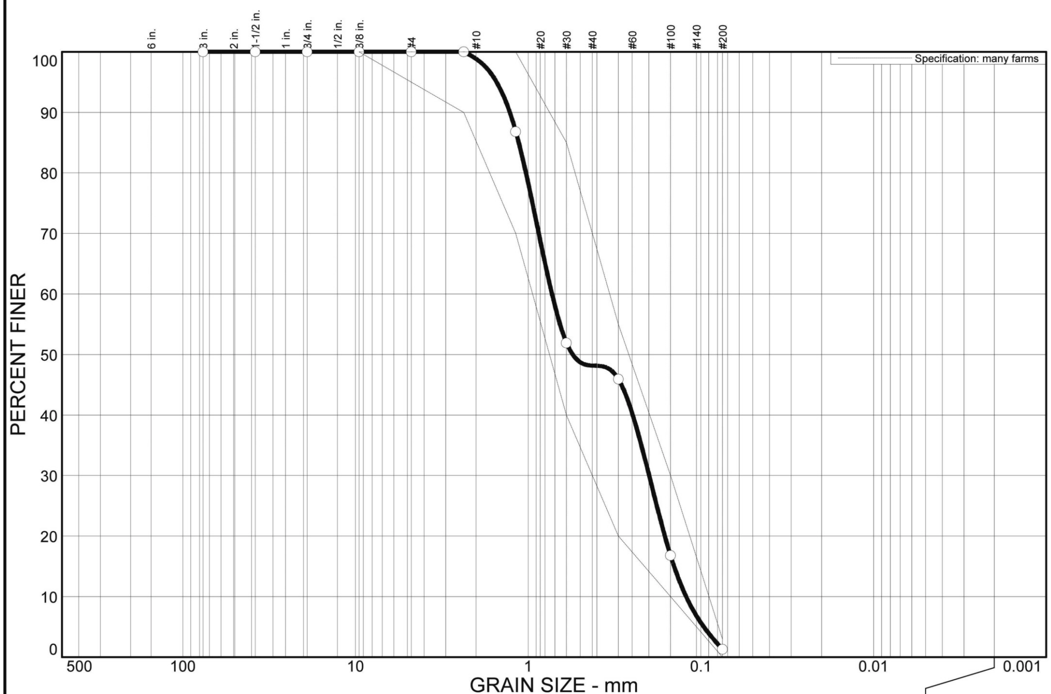


Figure 2.—Pipe box test apparatus.

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.2	50.7	46.8	1.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0	100.0 - 100.0	
#4	100.0	95.0 - 100.0	
#8	100.0	90.0 - 100.0	
#16	86.8	70.0 - 100.0	
#30	51.9	40.0 - 85.0	
#50	45.9	20.0 - 55.0	
#100	16.8	10.0 - 30.0	
#200	1.3	0.0 - 3.0	

* many farms

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.14 D_{60}= 0.729 D_{50}= 0.553
D_{30}= 0.199 D_{15}= 0.143 D_{10}= 0.122
C_u= 5.98 C_c= 0.45

Classification

USCS= SP AASHTO=

Remarks

Average of A-1, A-2, B-1, B-2

Sample No.: 62H - Average **Source of Sample:** Filter Box **Date:** 6-15-99
Location: Purchased **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure**

Figure 3.—Gradation of laboratory test sand for Many Farms Dam.

Test Set-up.—For the laboratory test, a 10-inch diameter dual-wall corrugated HDPE drain pipe with 5/64-inch slots was used. The slots are 1 inch long with 4 slots per corrugation. Open area is 3 square inches per linear foot. The geotextile sock is a knitted polyester (AOS = #30) provided by the pipe manufacturer. The laboratory sand was purchased commercially. As shown in figure 3, the test sand meets the specification limits, but doesn't contain any particles coarser than #16 sieve and is somewhat gap graded at the #50 sieve. The sand was placed in 6-inch lifts and compacted by flooding with a fire hose at 20 gpm.

Test Results.—The inflow rate was slowly ramped-up over a 24-hr period, until the box began to overflow. The inflow was then held constant, and the test was conducted at a constant head of 2.5 feet above the pipe invert for the 13-day test duration. The outflow was continuously sieved to determine the quantity and size of particles washed through the geotextile sock. The test results are shown in figure 4. The outflow stabilized after 2 to 3 days at 7.3 gpm per foot. The envelope loss was rather high initially, but was stabilizing at a total loss of about 1,000 grams per linear foot. The sieve analysis (table 1) shows that the loss was predominantly in the #100 and #200 particle sizes, and that the percentage of #100 particles was decreasing as a natural soil filter developed around the geotextile.

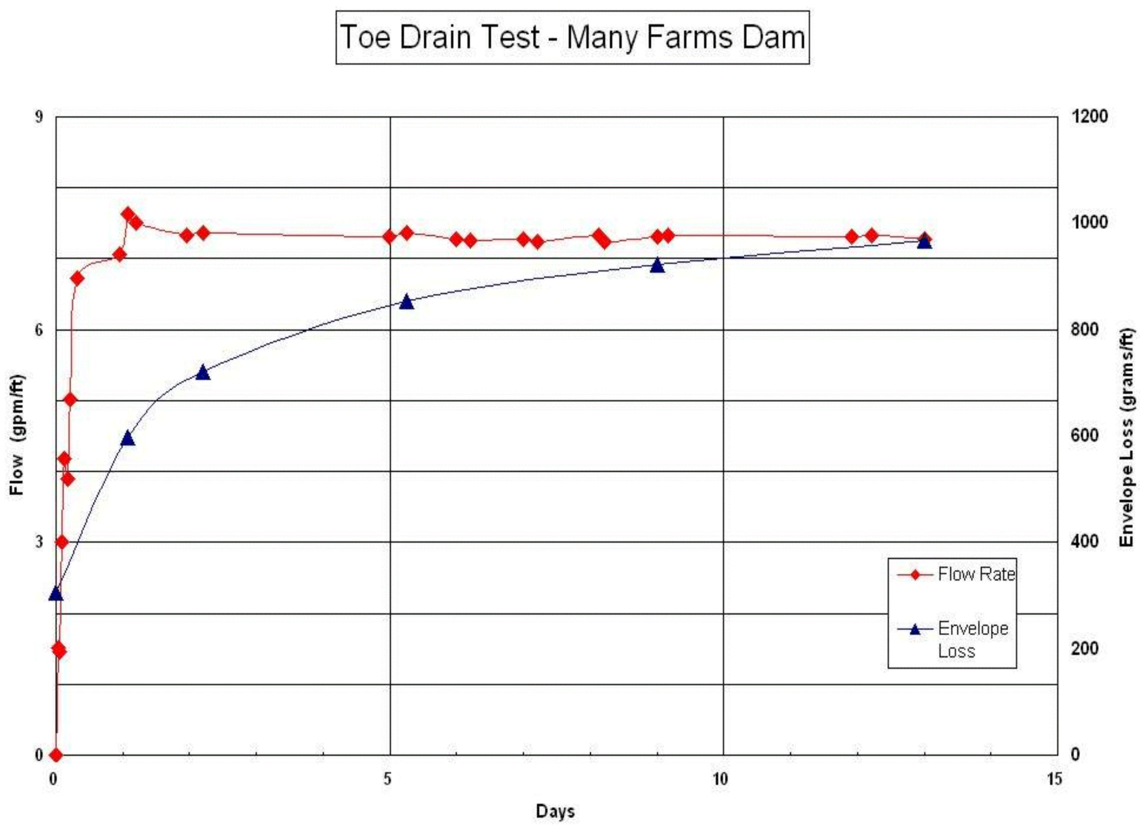


Figure 4.—Test results - toe drain with geotextile sock for Many Farms Dam.

Table 1.—Sieve analysis of envelope material washing through the geotextile sock

Sample	Pan (%)*	#200 (%)	#100 (%)	#50 (%)	#30 (%)	#16 (%)	Weight (g/ft)
Sluicing	---	10.6	87.6	1.7	0.1	0.0	306
Day 1	---	14.3	80.5	5.1	0.1	0.0	293
Day 2	---	27.0	66.0	7.0	0.0	0.0	122
Day 3-5	---	23.0	73.0	4.0	0.0	0.0	133
Day 6-9	---	38.8	56.0	5.1	0.1	0.0	68
Day 10-13	---	38.5	55.2	6.3	0.0	0.0	45

* Pan-size particles (minus #200) were not collected.

Exhumation of Pipe.—After testing, the pipe was carefully exhumed to check for the formation of a natural soil filter around the geotextile. The examination showed an area of coarser sand directly against the geotextile where finer particles had washed through the geotextile, leaving the coarser particles behind. These coarser particles then served as a natural soil filter, preventing the loss of additional fine particles. This natural soil filter was about 1 inch thick directly below the pipe invert, but appeared much thinner (less than ½ inch) around the rest of the pipe. Seven samples were collected from around the pipe for gradation analysis. Four samples were in direct contact with the geotextile (crown, springline, haunch, and invert). Three samples were taken at various depths (½, 1, and 1½ inches) below the pipe invert. The results are shown in table 2, along with the gradation of the surrounding sand . The coarser sand directly around the pipe had larger particle sizes (mm) than the finer surrounding sand for all particle fractions (D_{10} through D_{85}). The gradations for the individual specimens from each location are plotted in appendix A.

Table 2.—Gradation analysis of envelope material exhumed from around toe drain

Location	D_{10} (mm)	D_{15} (mm)	D_{30} (mm)	D_{50} (mm)	D_{60} (mm)	D_{85} (mm)
Crown	0.159	0.183	0.291	0.748	0.851	1.12
Springline	0.161	0.192	0.294	0.760	0.870	1.26
Haunch	0.153	0.186	0.292	0.754	0.859	1.22
Invert	0.145	0.167	0.240	0.702	0.824	1.23
½ inch below Invert	0.141	0.174	0.282	0.750	0.860	1.25
1 inch below Invert	0.144	0.174	0.262	0.706	0.819	1.19
1½ inch below Invert	0.132	0.152	0.206	0.545	0.716	1.08
Surrounding Sand	0.122	0.143	0.199	0.553	0.729	1.14

Discussion

Slotted Perforations.—If the geotextile sock should tear during installation, the toe drain could fill completely with sand envelope washing through the pipe perforations. To prevent this possibility, 1/16-inch slotted perforations were selected, based on Reclamation's retention criteria (Perforation Size ≤ ½D_{85}). Based on previous testing (Swihart, 1998), the 1/16-inch slotted perforations should either retain the sand envelope or plug with sand particles.

Pipe Stretch.—During installation, single-wall drain pipe can stretch up to 5 percent. For pipe with slotted perforations, the stretch occurs mostly in the slotted perforations, and slot width might increase by up to 0.05 inch. Therefore, pipe with 1/16-inch slotted perforations might have (approximately) 1/8-inch slotted perforations after installation. This increased slot width caused by pipe stretch should be considered during design.

Sand Envelope Loss.—The sand envelope loss was about 1,000 grams per linear foot of toe drain. Based on an 11½-inch pipe outside diameter (OD) and a sand density of 100 pounds per cubic foot (pcf), the calculated thickness of sand envelope lost from around the entire pipe circumference was 0.087 inches. The calculation is shown in appendix B. This thickness loss is quite small compared to the minimum envelope thickness of 3 inches, and compared to the 1-inch thickness of the natural soil filter that developed. This loss of fine particles has little to no effect on the volume of the natural soil filter, and is not considered detrimental to performance.

Geotextile AOS.—The required AOS for the geotextile to adequately retain the sand envelope was calculated by several methods, as shown in table 3. These calculations were based on the actual gradation of the laboratory sand. Most of the calculations indicate that the knitted geotextile sock with AOS of #30 sieve (O_{95} = 0.6 mm) should function adequately. The Federal Highway Administration (FHWA) calculation showing only marginal performance is based on dynamic flow, suggesting that compaction methods other than wet sluicing could improve retention. The actual calculations are shown in appendix C.

Table 3.—Calculation of minimum AOS (O_{95}) for retention of sand envelope

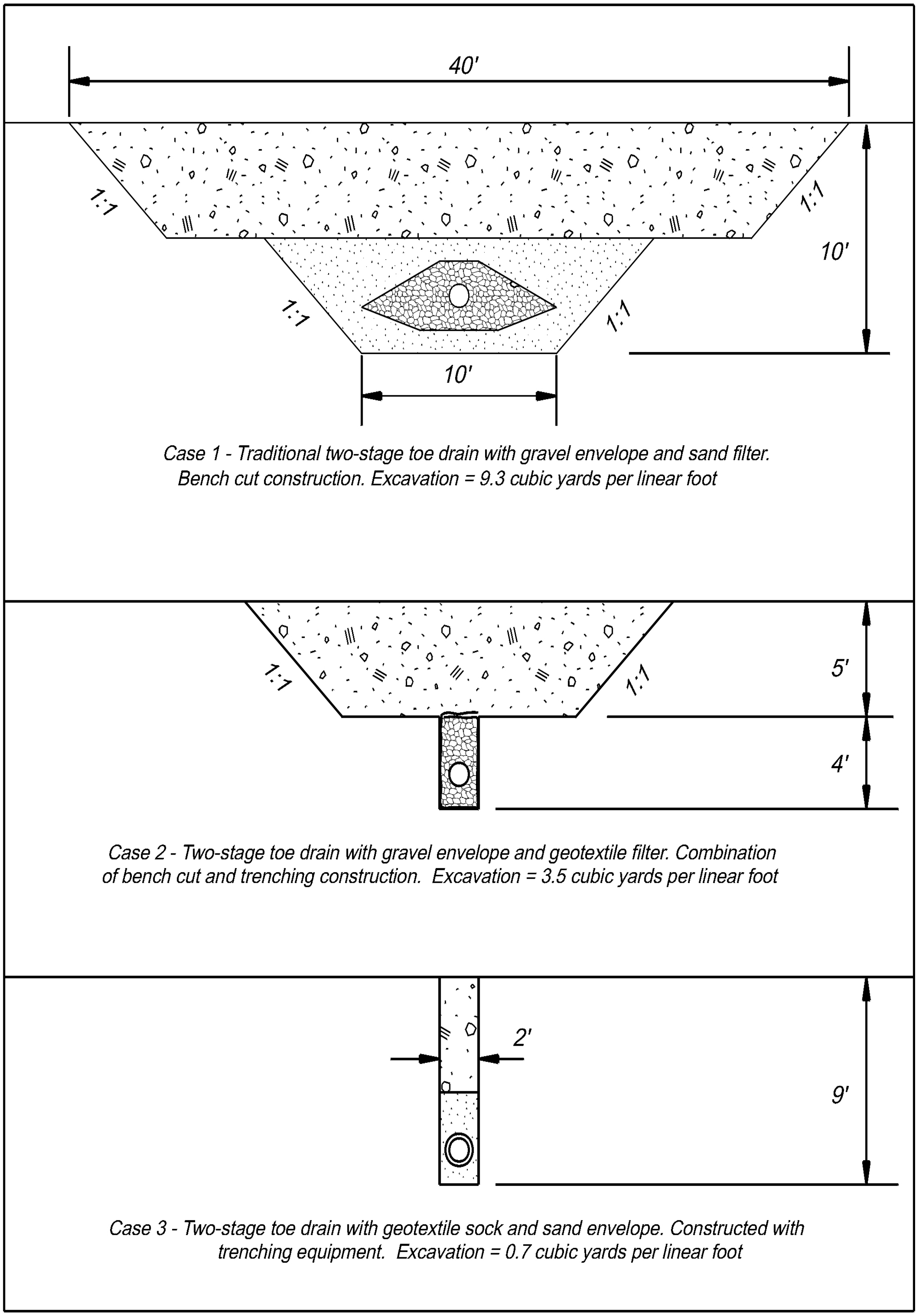
Method	Formula	Calculated Value (mm)	Suitability of #30 Geotextile (0.6 mm)
Giroud, 1982	$O_{95} < 13.5\ d_{50} / C_U$	1.25	Acceptable
Luettich et al., 1992	$O_{95} < 13.5\ d'_{50} / C'_U$	1.3	Acceptable
FHWA, 1985 (steady flow)	$O_{95} < 8\ d_{85} / C_U$	1.53	Acceptable
FHWA, 1985 (dynamic flow)	$O_{95} < 0.5\ d_{85}$	0.57	Marginal

Field Construction

Cost Savings.—Use of the geotextile sock allows construction with trenching equipment (figure 5) which offers significant cost savings over other construction methods on large jobs where the mobilization costs are justified. Three alternative construction techniques are shown in figure 6. Case 1 is a traditional two-stage filter requiring extensive bench-cut excavation. Case 2 uses a combination of bench-cut and trenching construction, which allows traditional placement of the geotextile around the gravel envelope. Finally, case 3 shows a geotextile sock pre-installed directly on the toe drain pipe, acting as one stage of the two-stage filter. This method allows exclusive use of trenching equipment.

Geotextile.—The knitted geotextile sock used in this study is the only geotextile that is pre-installed on the pipe at the factory. The knitted sock is only available with AOS of #30, which limits design options; however, additional products with tighter AOS are reportedly being developed. Other types of geotextiles (such as monofilament woven) could also be used as a pipe sock directly around the toe drain. These other geotextiles would have to be attached to the pipe in the field, but would increase design flexibility.

Figure 5.—Installation of drain pipe (without geotextile sock) using wheel trencher equipment.



Case 1 - Traditional two-stage toe drain with gravel envelope and sand filter. Bench cut construction. Excavation = 9.3 cubic yards per linear foot

Case 2 - Two-stage toe drain with gravel envelope and geotextile filter. Combination of bench cut and trenching construction. Excavation = 3.5 cubic yards per linear foot

Case 3 - Two-stage toe drain with geotextile sock and sand envelope. Constructed with trenching equipment. Excavation = 0.7 cubic yards per linear foot

Figure 6.—Techniques for toe drain construction.

Conclusions

1. The outflow was stable at 7.3 gpm per foot of pipe, which is almost 100 times the anticipated accretion rate of 0.08 gpm per foot.

2. After 13 days, the total loss of sand envelope had stabilized at about 1,000 grams per foot of pipe, which equates to a calculated soil loss of 0.087 inches around the pipe. This loss is higher than initially expected, but not considered detrimental to performance. The actual loss in the field would probably be less at the lower flow rates expected at Many Farms Dam (0.08 gpm per foot).

3. Pipe exhumation showed that a natural soil filter had developed against the geotextile sock. This natural soil filter was about 1 inch thick below the pipe invert, but much thinner (less than ½ inch thick) around the rest of the pipe perimeter. The difference in these thicknesses suggest that the invert area was the principle flow path between the slotted screen and the drain pipe.

4. Soil retention calculations indicate that the geotextile sock (AOS = #30 sieve) is acceptable for steady flow, but only marginal for dynamic flows. Therefore, dry compaction (without sluicing) might significantly improve retention of the sand envelope.

5. Use of the geotextile sock allows for toe drain construction with trenching equipment at significant cost savings over traditional two-stage filters requiring extensive bench-cut excavation.

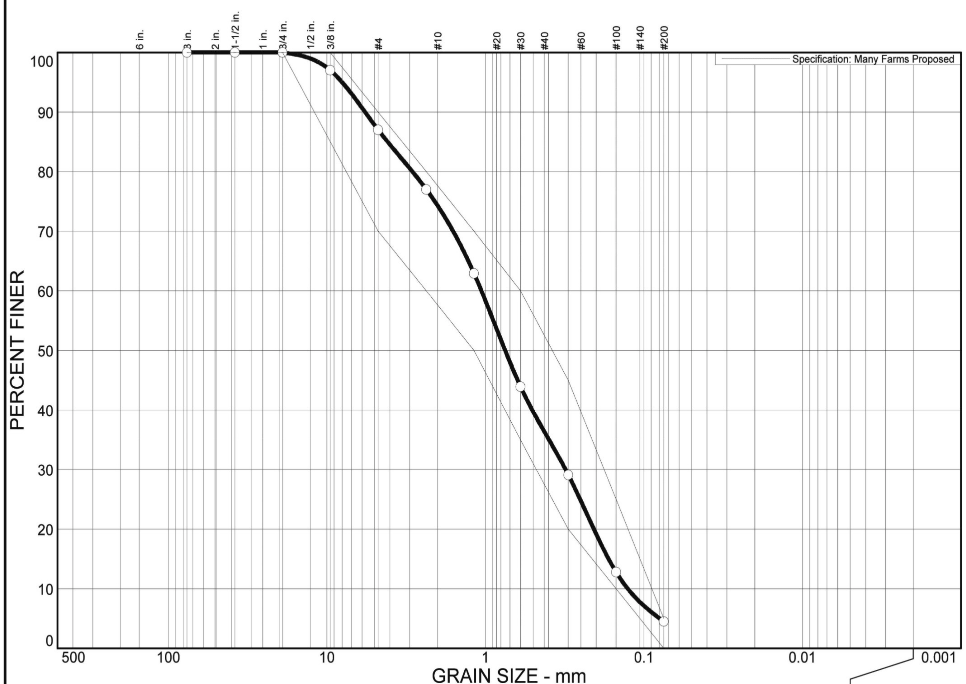
6. The knitted geotextile sock used in this study is the only geotextile pre-installed on the pipe at the factory. The knitted sock is only available with AOS of #30 which limits design options. Other geotextile products (such as monofilament woven) would have to be attached to the pipe in the field, but are available in a wide range of AOS, which would increase design flexibility.

7. Future Testing - Because the loss of nearly 1,000 grams of envelope per foot of toe drain was higher than desired, a coarser envelope has been proposed for Many Farms Dam (table 4). Materials are on-hand for manufacturing sand to meet the proposed specification as shown in figure 7.

Table 4.—Proposed specifications for sand envelope around toe drain at Many Farms Dam

Sieve Size	Original Specification (% finer)	Proposed Specification (% finer)
0.75	100	100
0.375	100	85-100
#4	95-100	70-90
#8	90-100	60-80
#16	70-100	50-70
#30	40-85	35-60
#50	20-55	20-45
#100	10-30	10-25
#200	0-3	0-5

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	13.0	12.7	37.9	31.9	4.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0	100 - 100	
1.5 in.	100.0	100 - 100	
.75 in.	100.0	100 - 100	
.375 in.	97.0	85 - 100	
#4	87.0	70 - 90	
#8	77.0	60 - 80	
#16	62.9	50 - 70	
#30	43.9	35 - 60	
#50	29.1	20 - 45	
#100	12.8	10 - 25	
#200	4.5	0 - 5	

* Many Farms Proposed

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.14 D_{60}= 1.06 D_{50}= 0.752
D_{30}= 0.312 D_{15}= 0.167 D_{10}= 0.127
C_u= 8.38 C_c= 0.73

Classification

USCS= SP AASHTO=

Remarks

Sample No.: 3 **Source of Sample:** Filter Box **Date:** 6-23-99
Location: Proposed **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure**

Figure 7.—Proposed Many Farms specification limits, and proposed gradation for laboratory test sand.

References

Federal Highway Administration, Christopher, B.R. and Holtz R.D., *Geotextile Engineering Manual*, Report No. FHWA-TS-86/203, Federal Highway Administration, Washington, DC, March 1985.

Giroud, J.P., "Filter Criteria for Geotextiles," *Proceedings of 2nd International conference on Geotextiles*, Las Vegas, Nevada, Volume 1, pp. 103-109, August 1982.

Luettich, S.M., Giroud, J.P., and Bachus, R.C., "Geotextile Filter Design Guide" *Journal of Geotextiles and Geomembranes*, Volume 11, No. 4-6, pp. 19-34, 1992.

Swihart, J. J., "Laboratory Pipe Box Testing to Simulate Toe Drain Performance," *Filtration and Drainage in Geotechnical/Geoenvironmental Engineering*, ASCE, Boston, Massachusetts, pp. 137-150, October 1998.

Swihart, J. J., "Full-Scale Laboratory Testing of a Toe Drain with a Geotextile Sock," *Symposium on Testing and Performance of Geosynthetics in Subsurface Drainage*, ASTM STP, Seattle, Washington, June 1999.

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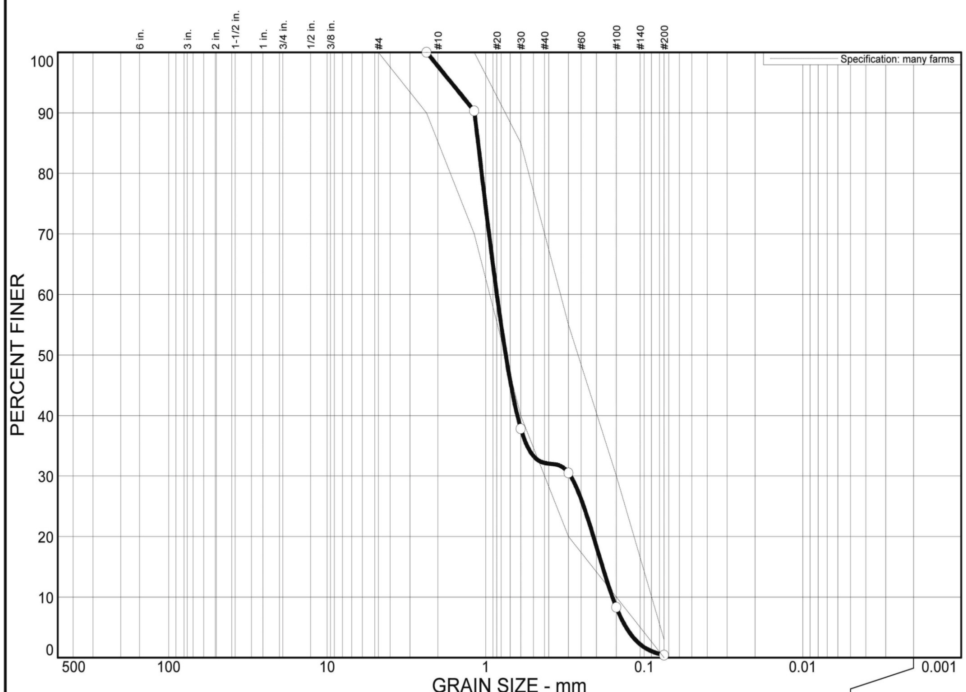
APPENDIX A

Sieve Analysis of Envelope Material
Exhumed Around Toe Drain
with Geotextile Sock

Samples were taken from the following locations:

1. Pipe Crown
2. Pipe Springline
3. Pipe Haunch
4. Pipe Invert
5. ½ inch below Invert
6. 1 inch below Invert
7. 1½ inches below Invert
8. Surrounding Area - Original Gradation

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	2.3	65.5	31.8	0.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0	90.0 - 100.0	
#16	90.3	70.0 - 100.0	
#30	37.8	40.0 - 85.0	X
#50	30.5	20.0 - 55.0	
#100	8.3	10.0 - 30.0	X
#200	0.4	0.0 - 3.0	

* many farms

Soil Description

Poorly graded sand

Atterberg Limits

PL= n/a LL= n/a PI= n/a

Coefficients

D_{85}= 1.12 D_{60}= 0.851 D_{50}= 0.748
D_{30}= 0.291 D_{15}= 0.183 D_{10}= 0.159
C_u= 5.36 C_c= 0.63

Classification

USCS= SP AASHTO=

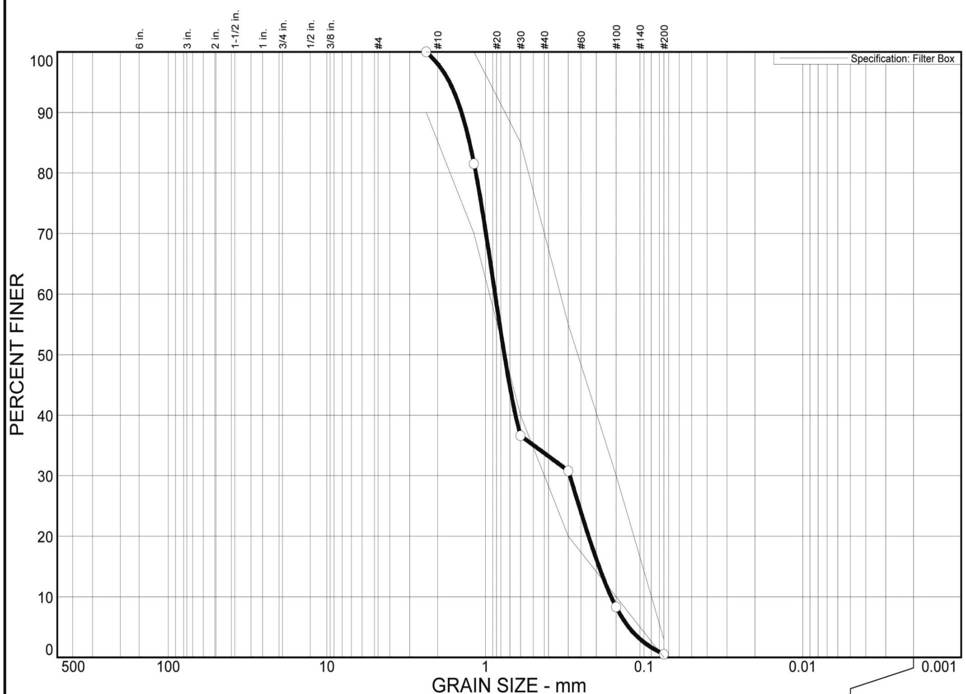
Remarks

Sample No.: Filter Box **Source of Sample:** Filter Box **Date:** 6/30/99
Location: crown **Elev./Depth:**

BUREAU OF RECLAMATION	**Project:** Filter Box **Feature:** **Project No:** **Figure**

Figure A1.—Gradation of sand from pipe crown.

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	2.0	64.3	33.2	0.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0	90.00 - 100.0	
#16	81.5	70.0 - 100.0	
#30	36.6	40.0 - 85.0	X
#50	30.8	20.0 - 55.0	
#100	8.3	10.0 - 30.0	X
#200	0.5	0.0 - 3.00	

* Filter Box

Soil Description

Atterberg Limits

PL= n/a LL= n/a PI= n/a

Coefficients

D_{85}= 1.26 D_{60}= 0.870 D_{50}= 0.760
D_{30}= 0.294 D_{15}= 0.192 D_{10}= 0.161
C_u= 5.40 C_c= 0.61

Classification

USCS= SP AASHTO=

Remarks

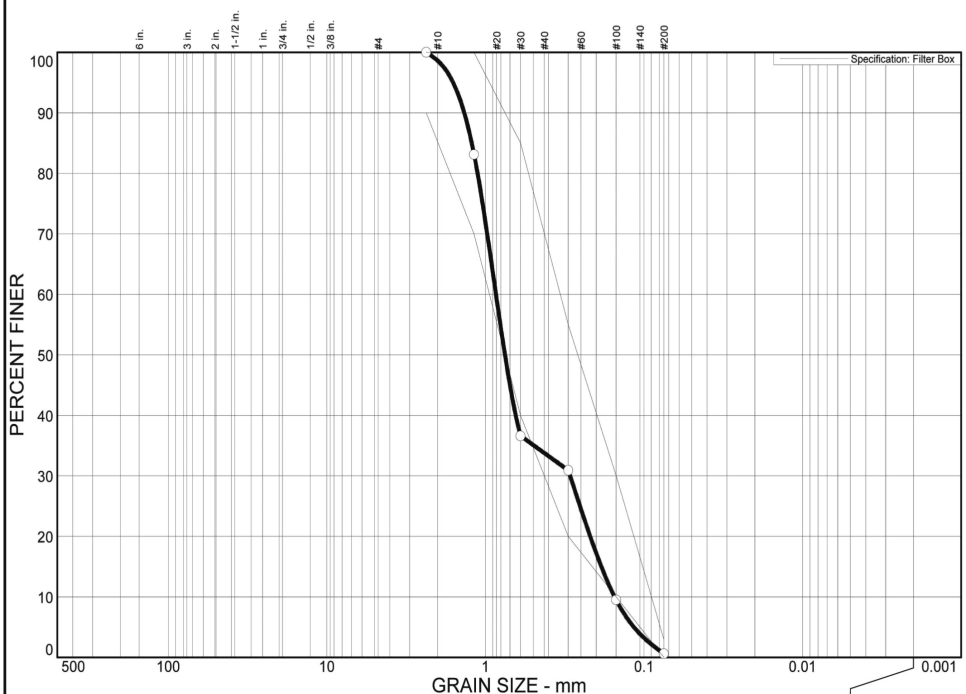
Sample No.: Filter Box A **Source of Sample:** Filter Box **Date:** 6/30/99
Location: Spring Line **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure**

Figure A2.—Gradation of sand from pipe springline.

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.4	64.8	33.2	0.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0	90.00 - 100.0	
#16	83.1	70.0 - 100.0	
#30	36.6	40.0 - 85.0	X
#50	30.9	20.0 - 55.0	
#100	9.5	10.0 - 30.0	X
#200	0.6	0.0 - 3.00	

* Filter Box

Soil Description

Atterberg Limits

PL= n/a LL= n/a PI= n/a

Coefficients

D_{85}= 1.22 D_{60}= 0.859 D_{50}= 0.754
D_{30}= 0.292 D_{15}= 0.186 D_{10}= 0.153
C_u= 5.60 C_c= 0.65

Classification

USCS= SP AASHTO=

Remarks

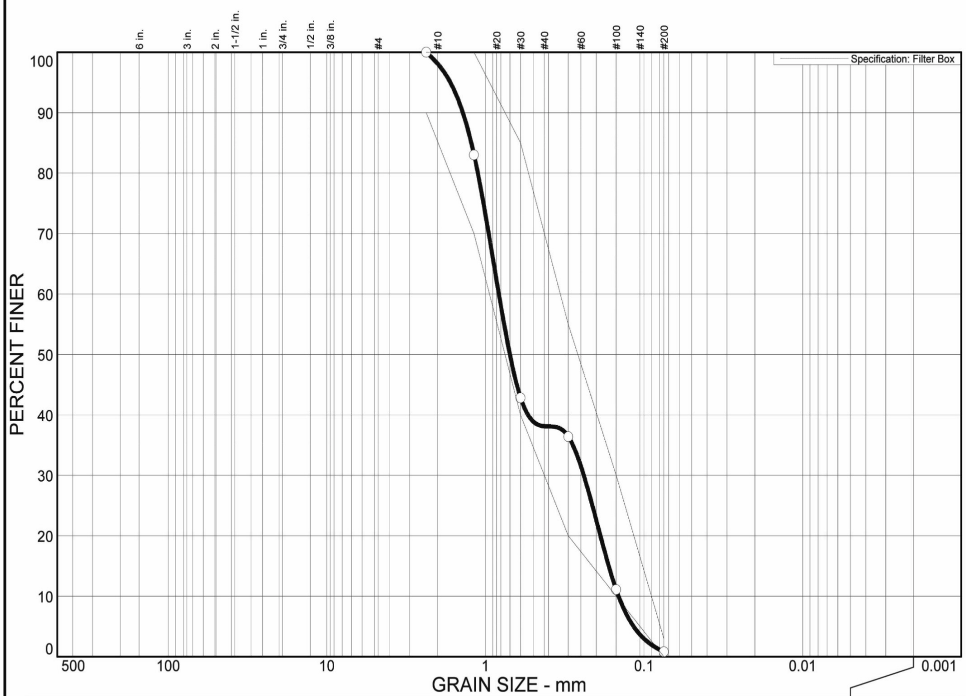
Sample No.: Filter Box B **Source of Sample:** Filter Box **Date:** 6/30/99
Location: Below Spring Line **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure** 6

Figure A3.—Gradation of sand from below springline (pipe haunch).

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.9	60.0	37.3	0.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0	90.00 - 100.0	
#16	83.0	70.0 - 100.0	
#30	42.8	40.0 - 85.0	
#50	36.4	20.0 - 55.0	
#100	11.1	10.0 - 30.0	
#200	0.8	0.0 - 3.00	

* Filter Box

Soil Description

Atterberg Limits

PL= n/a LL= n/a PI= n/a

Coefficients

D_{85}= 1.23 D_{60}= 0.824 D_{50}= 0.702
D_{30}= 0.240 D_{15}= 0.167 D_{10}= 0.145
C_u= 5.69 C_c= 0.48

Classification

USCS= SP AASHTO=

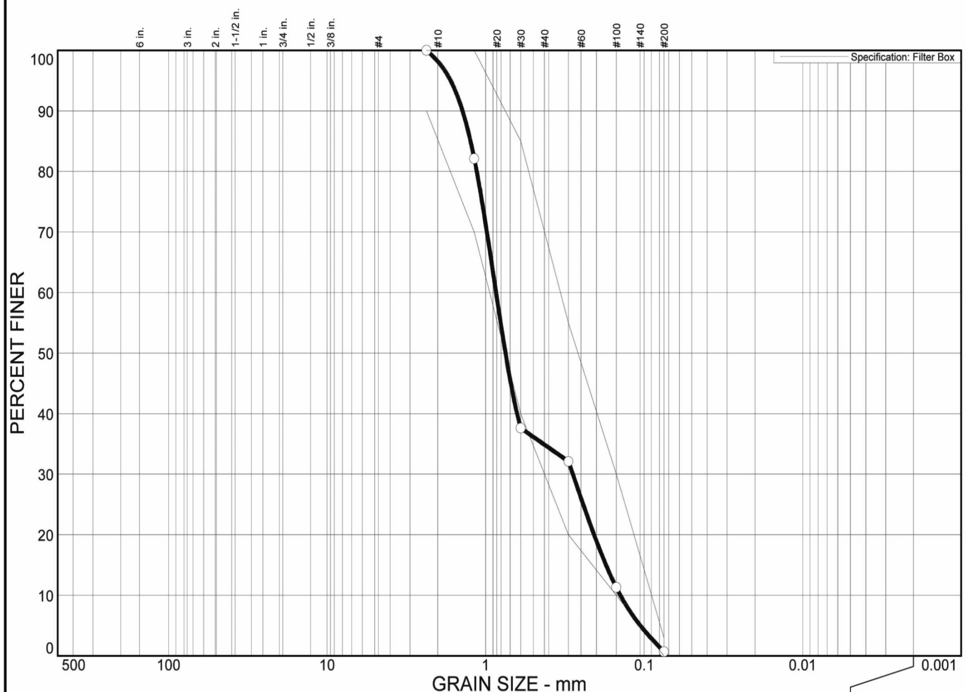
Remarks

Sample No.: C, Filter Box **Source of Sample:** Filter Box **Date:** 6/30/99
Location: Invert **Elev./Depth:**

BUREAU OF RECLAMATION	**Project:** Filter Box **Feature:** **Project No:** **Figure**

Figure A4.—Gradation of sand from pipe invert.

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.9	63.3	34.1	0.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0	90.00 - 100.0	
#16	82.1	70.0 - 100.0	
#30	37.6	40.0 - 85.0	X
#50	32.1	20.0 - 55.0	
#100	11.3	10.0 - 30.0	
#200	0.7	0.0 - 3.00	

Soil Description

Atterberg Limits

PL= n/a LL= n/a PI= n/a

Coefficients

D_{85}= 1.25 D_{60}= 0.860 D_{50}= 0.750
D_{30}= 0.282 D_{15}= 0.174 D_{10}= 0.141
C_u= 6.09 C_c= 0.65

Classification

USCS= SP AASHTO=

Remarks

* Filter Box

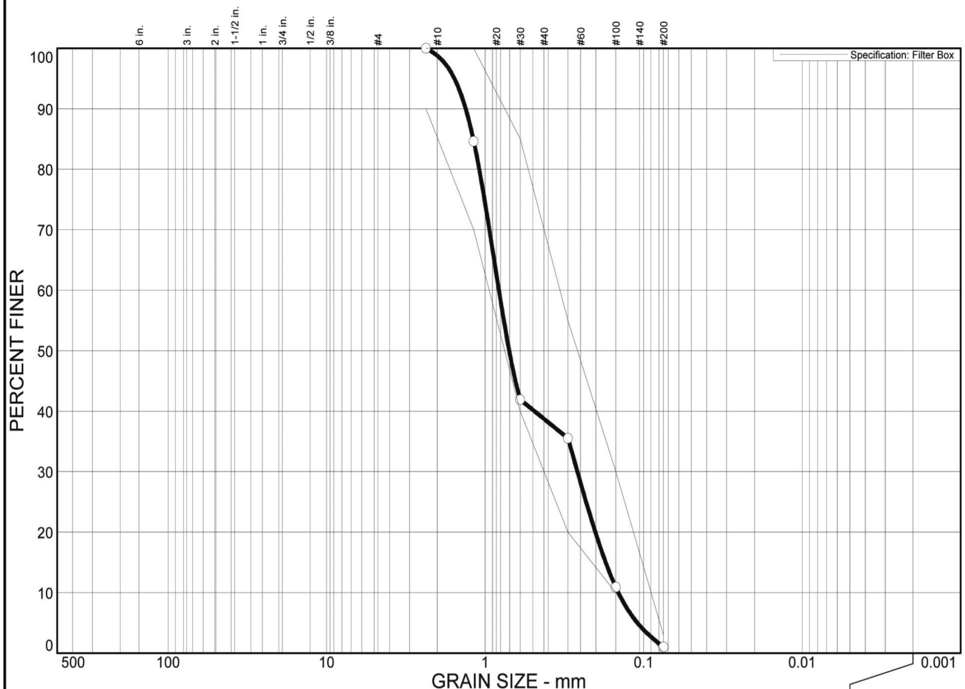
Sample No.: D,Filter Box **Source of Sample:** Filter Box **Date:** 6/30/99
Location: 1/2" Below Invert **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure**

Figure A5.—Gradation of sand ½ inch below pipe invert.

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.3	60.0	37.7	1.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0	90.00 - 100.0	
#16	84.6	70.0 - 100.0	
#30	41.9	40.0 - 85.0	
#50	35.5	20.0 - 55.0	
#100	10.9	10.0 - 30.0	
#200	1.0	0.0 - 3.00	

* Filter Box

Soil Description

Atterberg Limits

PL= n/a LL= n/a PI= n/a

Coefficients

D_{85}= 1.19 D_{60}= 0.819 D_{50}= 0.706
D_{30}= 0.262 D_{15}= 0.174 D_{10}= 0.144
C_u= 5.67 C_c= 0.58

Classification

USCS= SP AASHTO=

Remarks

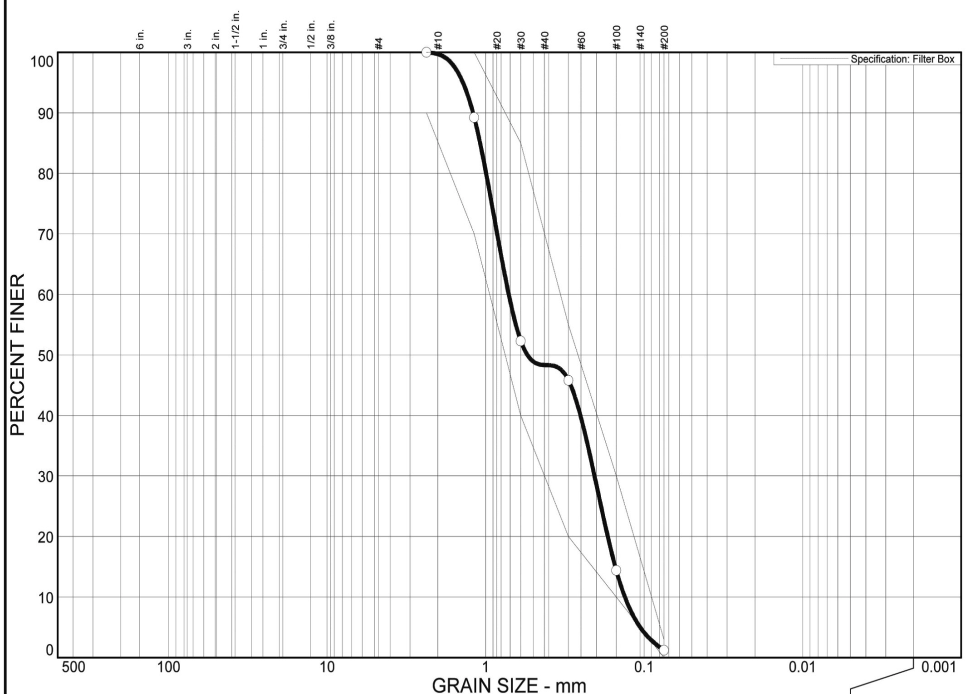
Sample No.: E, Filter Box **Source of Sample:** Filter Box **Date:** 6/30/99
Location: 1" Below Invert **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure**

Figure A6.—Gradation of sand 1 inch below pipe invert.

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.3	51.4	47.1	1.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0	90.00 - 100.0	
#16	89.2	70.0 - 100.0	
#30	52.3	40.0 - 85.0	
#50	45.8	20.0 - 55.0	
#100	14.4	10.0 - 30.0	
#200	1.2	0.0 - 3.00	

* Filter Box

Soil Description

Atterberg Limits

PL= n/a LL= n/a PI= n/a

Coefficients

D_{85}= 1.08 D_{60}= 0.716 D_{50}= 0.545
D_{30}= 0.206 D_{15}= 0.152 D_{10}= 0.132
C_u= 5.41 C_c= 0.45

Classification

USCS= SP AASHTO=

Remarks

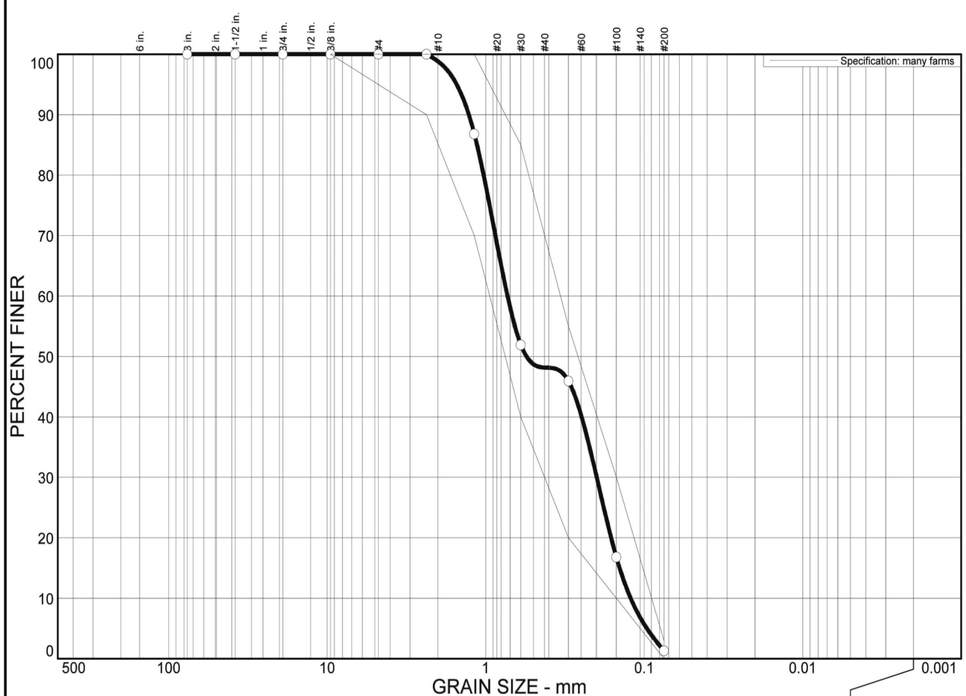
Sample No.: F, Filter Box **Source of Sample:** Filter Box **Date:** 6/30/99
Location: 1 1/2" Below Invert **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure**

Figure A7.—Gradation of sand 1 ½ inch below pipe invert.

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.2	50.7	46.8	1.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1.5 in.	100.0		
.75 in.	100.0		
.375 in.	100.0	100.0 - 100.0	
#4	100.0	95.0 - 100.0	
#8	100.0	90.0 - 100.0	
#16	86.8	70.0 - 100.0	
#30	51.9	40.0 - 85.0	
#50	45.9	20.0 - 55.0	
#100	16.8	10.0 - 30.0	
#200	1.3	0.0 - 3.0	

* many farms

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.14 D_{60}= 0.729 D_{50}= 0.553
D_{30}= 0.199 D_{15}= 0.143 D_{10}= 0.122
C_u= 5.98 C_c= 0.45

Classification

USCS= SP AASHTO=

Remarks

Average of A-1, A-2, B-1, B-2

Sample No.: 62H - Average **Source of Sample:** Filter Box **Date:** 6-15-99
Location: Purchased **Elev./Depth:**

BUREAU OF RECLAMATION

Project: Filter Box
Feature:
Project No: **Figure**

Figure A8.—Gradation of surrounding sand - orignial gradation.

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APPENDIX B

Thickness Loss Calculation for Sand Envelope

Loss = 1000 grams per linear foot = 2.2 lbf per linear foot

Sand density = 100 lbf/ft^3

1 ft^3 = 12 in x 12 in x 12 in = 1728 in^3

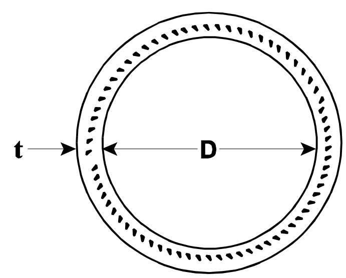
Loss = $\frac{\text{2.2 lbf/lin ft}}{\text{100 lbf/ft}^3}$ = 0.022ft^3/lin ft = 38.0 in^3/lin ft

Loss = 38.0 in^3/lin ft = 3.17 in^3/linear inch = 3.17 in^2

Loss = Area = 3.17 in^2

D = pipe OD = 11.5 inches

A = Area = 3.17 in^2 = C t



C = Circumference = π D = 36.1 inches

t = thickness

t = A/C = 3.17 in^2/36.1 in = 0.087 inches

<u>Thickness Loss = 0.087 inches</u>

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APPENDIX C

Geotextile AOS Calculation for Soil Retention ($AOS = O_{95}$)

AOS Calculation (Giroud)

$C_U = 5.96$ ($C_U > 3.0$)
$d_{50} = 0.553$ mm

Soil Density

Loose	$O_{95} <$	$\frac{9\ d_{50}}{C_u}$	=	$\frac{(9)(0.553)}{5.96}$	=	0.835 mm
Medium	$O_{95} <$	$\frac{13.5\ d_{50}}{C_u}$	=	$\frac{(13.5)(0.553)}{5.96}$	=	1.25 mm ←
Dense	$O_{95} <$	$\frac{18\ d_{50}}{C_u}$	=	$\frac{(18)(0.553)}{5.96}$	=	1.67 mm

AOS Calculation (Luettich) - modified Giroud using only the finer portion of gradation curve

$C_C = 0.45$ ($C_C < 1.0$)

d'_{xx} values from straight-line through d_{10} and d_{30}
$d'_0 = 0.096$ mm
$d'_{50} = 0.33$ mm
$d'_{100} = 1.2$ mm

$C'_u = (d'_{100} / d'_0)^{½} = 3.53$

Soil Density

Loose	$O_{95} <$	$\frac{9\ d'_{50}}{C'_u}$	=	$\frac{(9)(0.33)}{3.53}$	=	0.84 mm
Medium	$O_{95} <$	$\frac{13.5\ d'_{50}}{C'_u}$	=	$\frac{(13.5)(0.33)}{3.53}$	=	1.3 mm ←
Dense	$O_{95} <$	$\frac{18\ d'_{50}}{C'_u}$	=	$\frac{(18)(0.33)}{3.53}$	=	1.7 mm

AOS Calculation (FHWA)

C_U = 5.96 ($8 > C_U > 4$)
d_{85} = 1.14 mm

Steady Flow

$$O_{95} < \frac{8\ d_{85}}{C_u} = \frac{(8)(1.14)}{5.96} = 1.53 \longleftarrow$$

Dynamic Flow

$$O_{95} < 0.5\ d_{85} = (0.5)(1.14) = 0.57 \text{ mm} \longleftarrow$$