SD93-12-F

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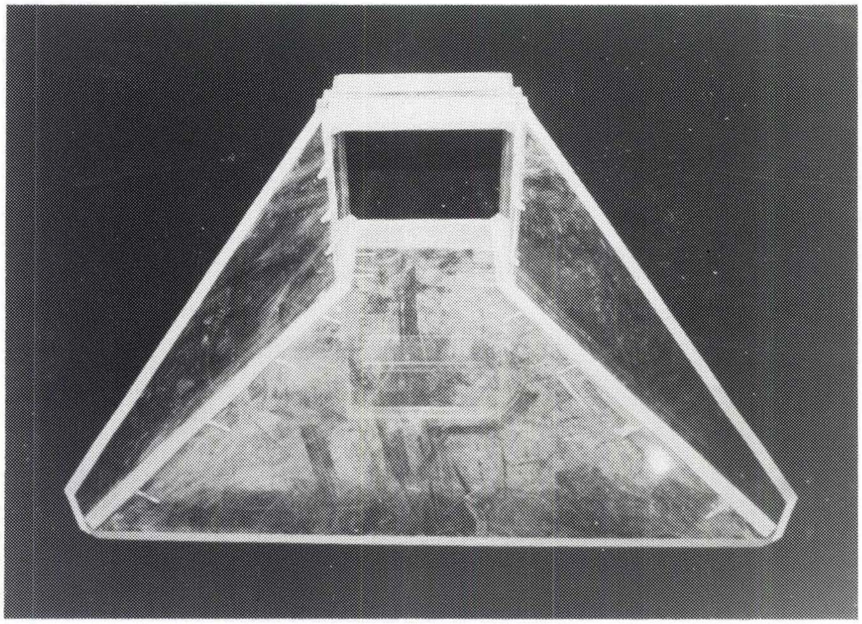

Determination of Single Barrel Box Culvert Inlet Loss Coefficients

Study SD93-12
Final Report

Prepared by
GKY and Associates
5411-E Backlick Road
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February, 1996

DISCLAIMER

ACKNOWLEDGEMENTS

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16. Abstract

Each year, the South Dakota Department of Transportation builds a number of box culverts through its highway construction program. In the past, cast-in-place box culverts were used exclusively, but use of precast box culverts is becoming a viable option. With cast-in-place box culverts, beveled inlet edges and 30° flared wingwalls are used at the inlet because that is usually the most efficient inlet shape. When precast box culverts are used, the inlet ends available from the South Dakota precast industry are mitered end with 0° flared wingwalls which have a standard four inch (regardless of barrel size) beveled edge along the bottom of the top edge of the inlet opening and along the top inside edge of the wingwalls. Current design methods, such as computer program HY8, do not provide for this mitered inlet option because, to our knowledge, model testing has not been conducted for this configuration.

The Turner-Fairbank Highway Research Center agreed to determine inlet loss coefficients for certain inlet types used by SDDOT. The initial models were built and hydraulics testing performed as a graduate research fellowship project. Unfortunately, the models were not properly constructed and did not conform to the plans. As a result, the inlet loss coefficients determined by testing were not valid. After the research panel pointed this out, the research center agreed to accurately reconstruct the models and perform the tests again. The Research Center contracted with GKY & Associates, Inc., who took over the study and completed it in four months.

During retesting, Richard Phillips, SDDOT Hydraulics Engineer, inspected a representative number of the new models and found them to accurately represent the box culvert inlets submitted for testing. The results indicate that the use of 30° flared wing walls, as on cast-in-place inlets, is slightly more hydraulically efficient than straight wing walls with beveled edges, as on precast culverts.

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1. PROBLEM STATEMENT

Each year, the South Dakota Department of Transportation builds a number of box culverts through its highway construction program. In the past, cast-in-place box culverts were used exclusively, but use of precast box culverts is becoming a viable option. The cast-in-place box culverts feature a beveled top edge and 30-degree flared wingwalls. A sketch of the cast-in-place culvert is shown in figure 1. The precast box culverts that are available from the South Dakota precast industry have wingwalls with a 0-degree flare (basically extensions of the culvert sides) and are mitered at a slope of 2:1. The precast inlets also come with a standard 4-in (regardless of barrel size) beveled edge along the bottom of the top edge of the inlet opening and along the top inside edges of the wingwalls. The precast sections follow the Minnesota Department of Transportation standards that are also used by a number of other state departments of transportation. Schematics of three precast inlet sizes, including a 6 ft x 6 ft, 8 ft x 8 ft, and a 12 ft x 12 ft box culvert, are shown in figures 2, 3, and 4.

Currently, design coefficients for the precast inlet configurations described above are not available due to a lack of model testing. To aid the South Dakota Department of Transportation in comparing the performance, and therefore cost-effectiveness, of the precast versus cast-in-place culvert inlets, culvert model experiments were undertaken at the Federal Highway's Turner-Fairbank Highway Research Center located in McLean, Virginia.

2. EXPERIMENTAL SETUP

All tests were conducted in an apparatus designed and built specifically for testing model culverts. The basic components of the apparatus, as shown in figure 5, consisted of a headbox connected by a model culvert barrel to a tailbox. All of the components, the dimensions of which are shown in figure 5, were constructed of 3/4-in plywood.

Water entered the headbox in a direction perpendicular to the centerline of the culvert barrel. Towards the rear of the headbox between the inflow pipe and the culvert inlet, a weir was installed to produce a uniform flow field across the cross-section of the headbox. After passing over the weir, the water flowed under a sheet of plywood tied loosely to the sides of the headbox. The plywood, which was free to float on the surface of the water, acted as a wave suppressor. Water then entered the culvert inlet.

After passing through the culvert barrel, water flowed into the tailbox where it was routed into a sump. The tailbox had an adjustable tailgate that allowed a backwater to be created for the model runs investigating culverts operating under outlet control conditions.

Water depths in the culvert system were measured through ports in the plywood floor that were hydraulically connected via 1/8-in Tygon tubing to a pressure transducer. A valve manifold enabled each port to be isolated and the water depth measured via a commercially available data gathering/analysis software package. The transducer was calibrated daily prior to the conduct of experiments.

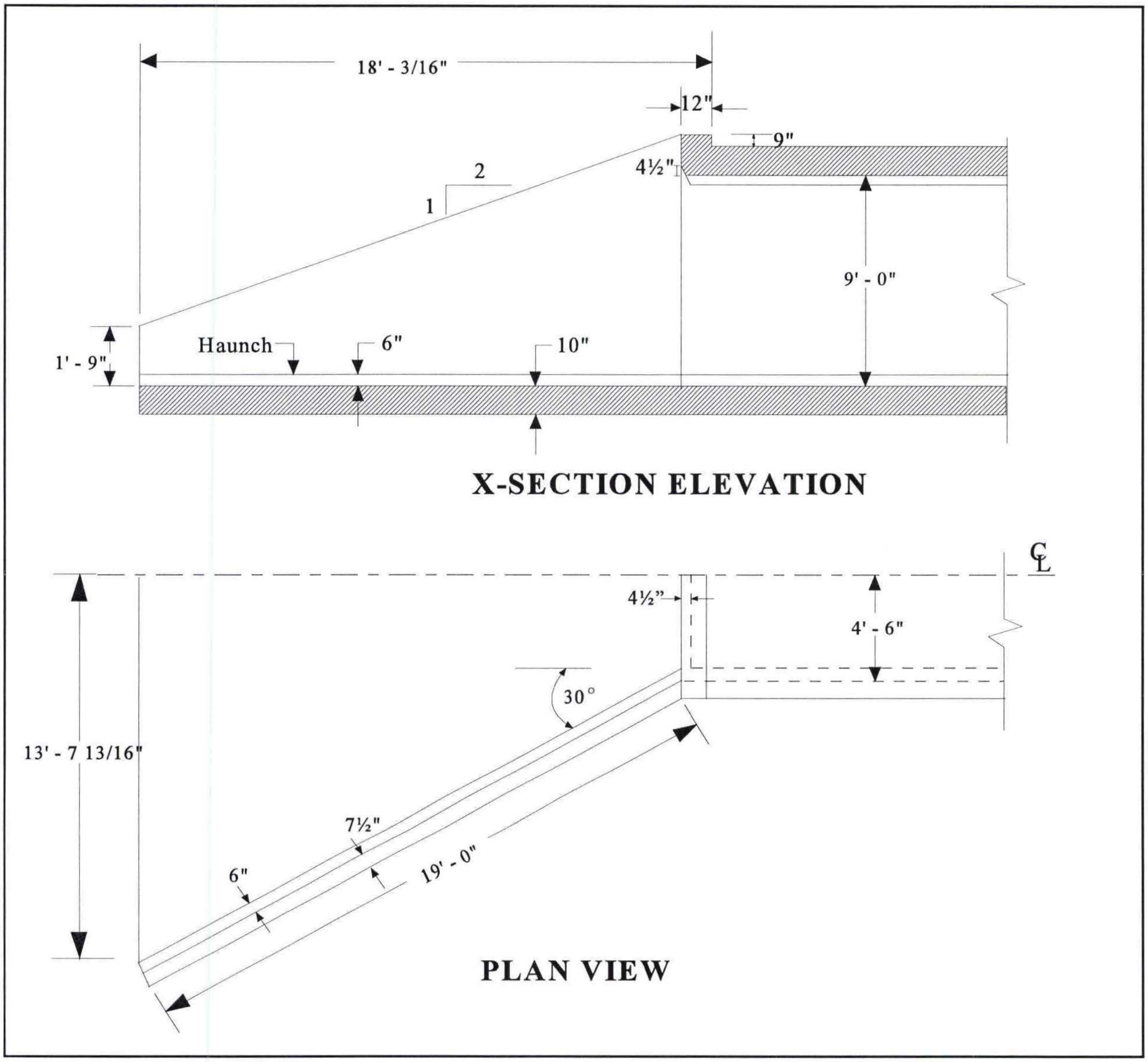

Figure 1. Sketch of South Dakota cast-in-place culvert inlet, 30° wingwall flare (tested by culvert model 3).

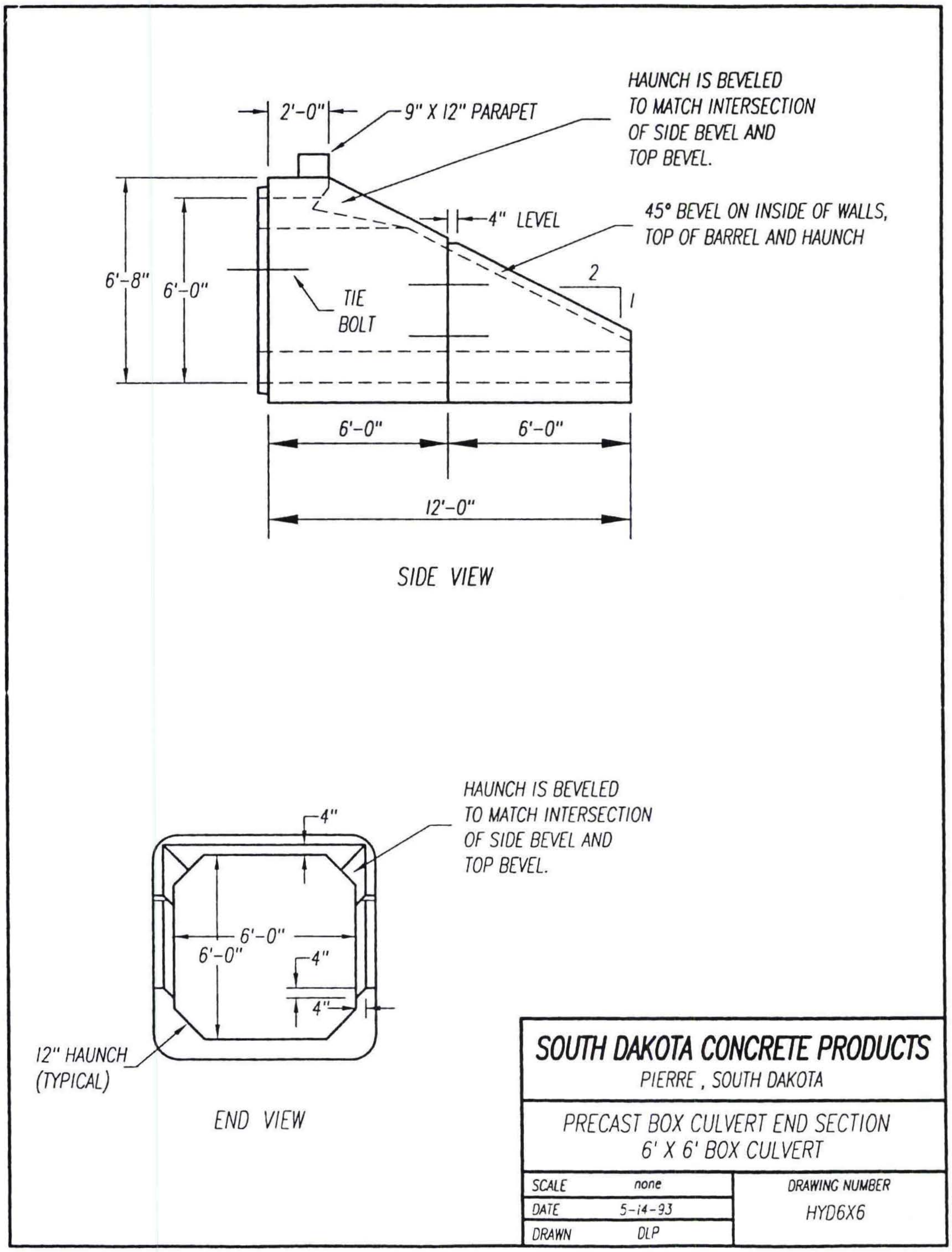

Figure 2. Schematic of the South Dakota precast culvert end section, 6 ft x 6 ft box (tested by culvert model 5).

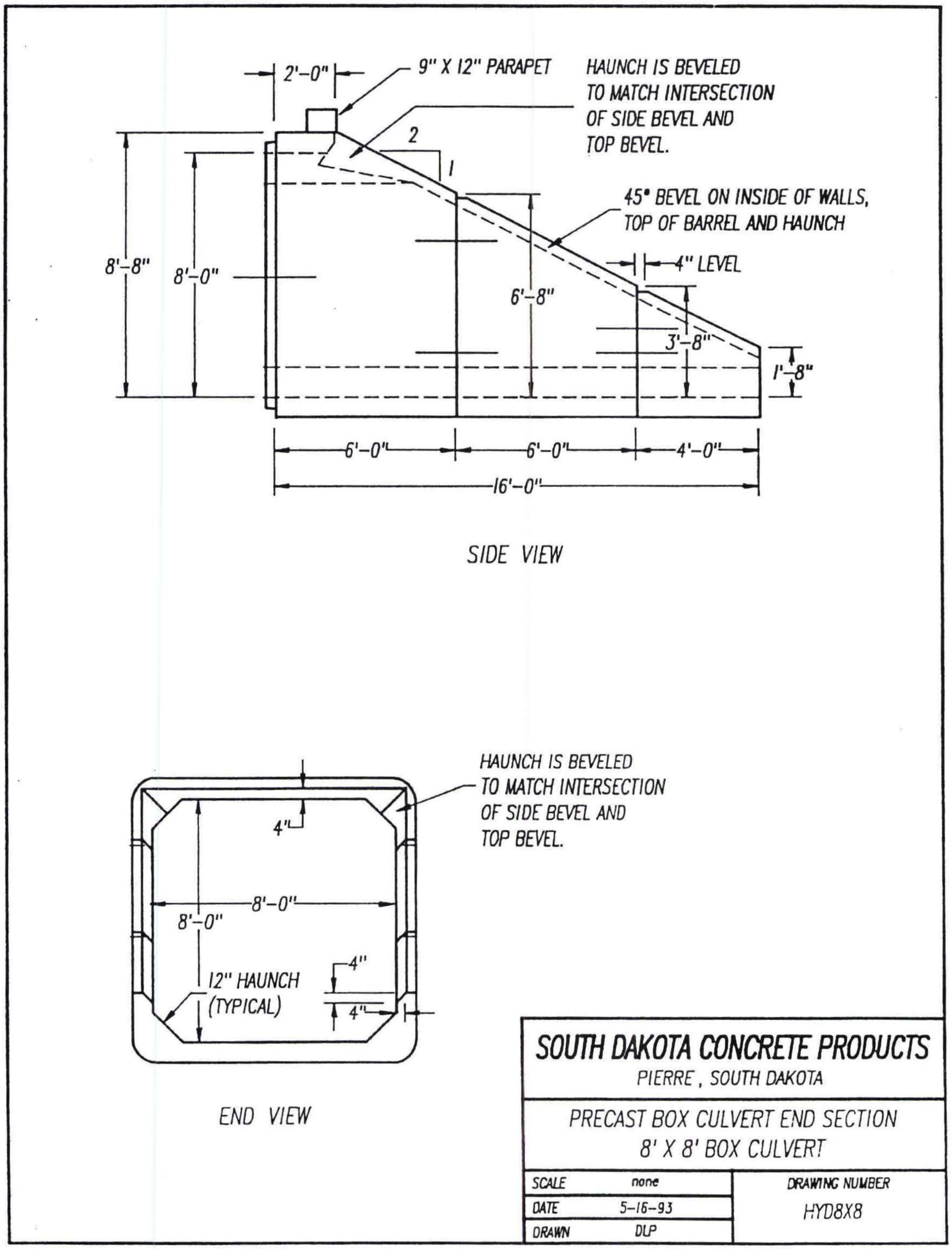

Figure 3. Schematic of the South Dakota precast culvert end section, 8 ft x 8 ft box.

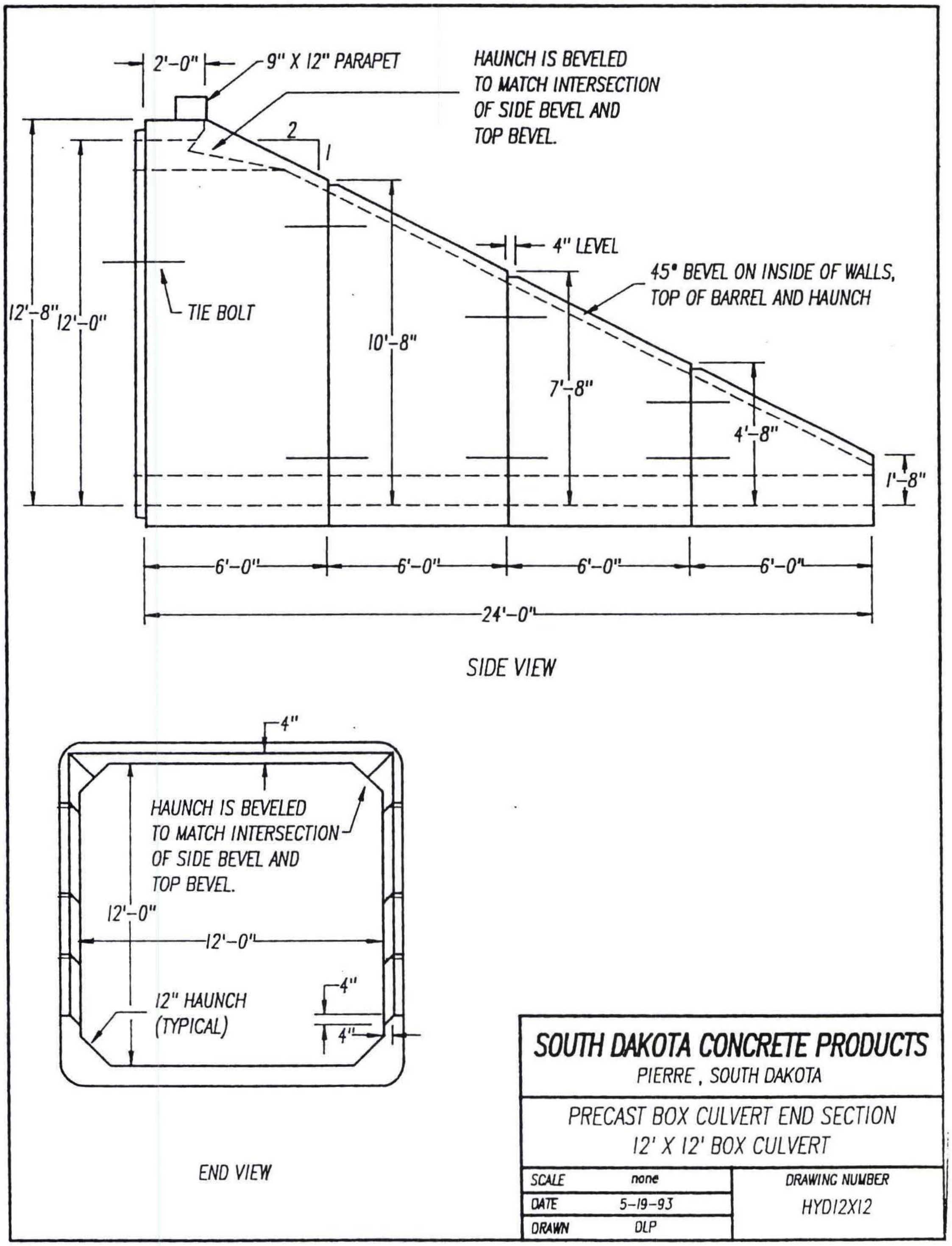

Figure 4. Schematic of the South Dakota precast culvert end section, 12 ft x 12 ft box (tested by culvert model 6).

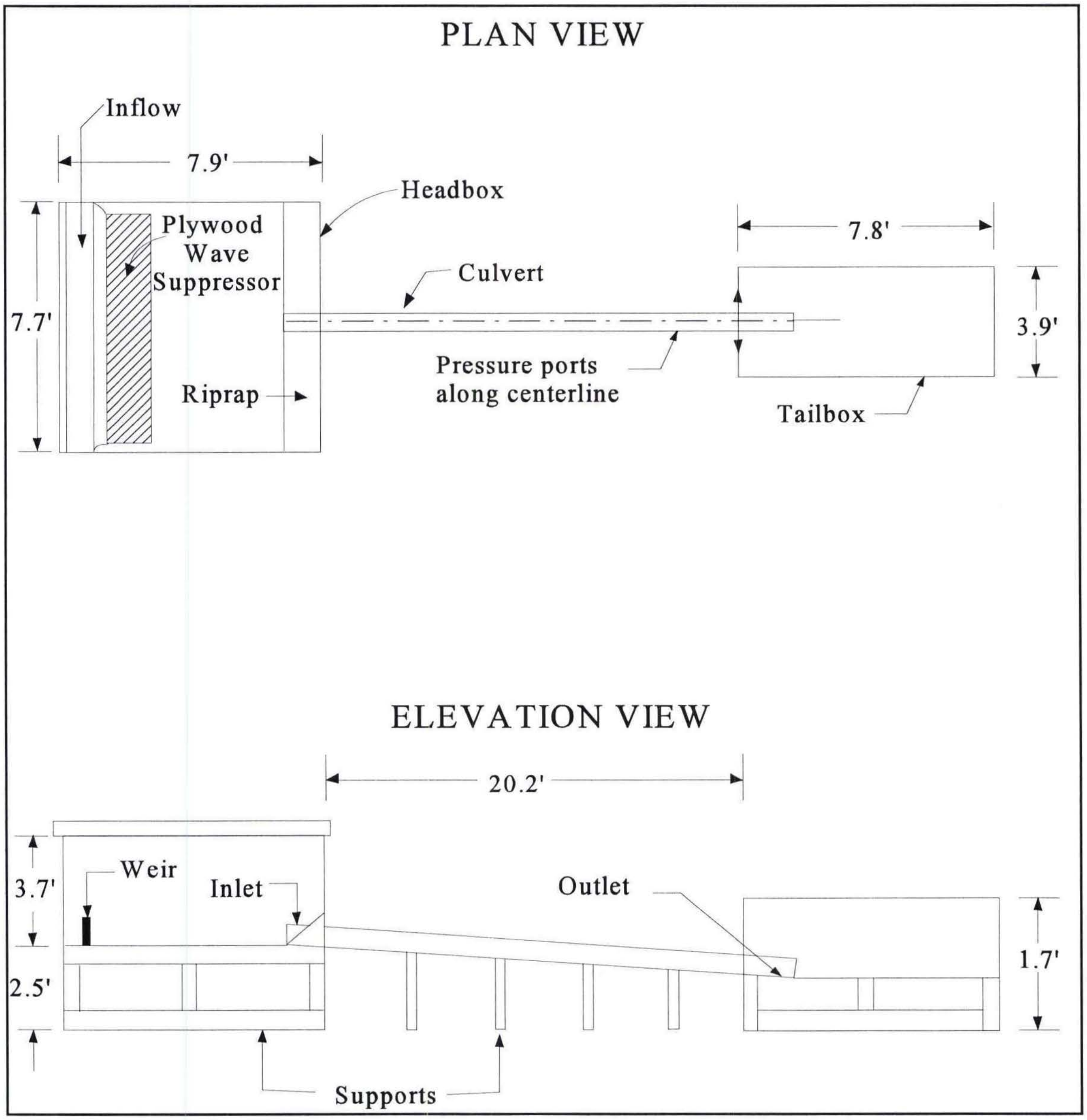

Figure 5. Sketch of experimental set-up.

Model inlets, which were constructed of either 1/2 or 3/4-in acrylic, were attached to an extension of the culvert barrel that protruded through the wall of the headbox. The sides of the model inlets were backfilled with gravel.

3. MODEL RUNS

A test matrix was developed, in coordination with South Dakota Department of Transportation personnel, to investigate the effect of the following:

- Wingwall flare.
- Constant bevel height, regardless of culvert size.
- Wingwall miter slope.
- Parapets.
- Culvert barrel slope.

Table 1 details the culvert models tested in this study. Culvert model dimensions were developed from the dimensions shown in figures 1 through 4 with the appropriate scaling factor (as shown in table 1) applied. Photos of each of the culvert models (including models 1,2,3,5, and 6) are shown in figures 6 through 10, respectively. Note that culvert model 5 is shown installed in the headbox and that model 4, which is not shown, is simply culvert model 5 without the parapet. Each culvert was tested under both inlet and outlet control conditions.

4. DATA ANALYSIS

<u>Inlet Control</u>

Design coefficients were developed by performing regressions of experimental data. For inlet control, unsubmerged conditions, design coefficients K and M were developed using Form 2 of the inlet control design equations (Normann, 1985) for each of the culvert models:

$$FORM\ 2 \qquad \frac{HW}{D} = K\left[\frac{Q}{AD^{0.5}}\right]^{M}$$

Where:

HW	=	headwater, ft.
D	=	culvert barrel rise, ft.
A	=	cross-sectional area of culvert barrel, ft^2.
Q	=	flow, ft^3/s.
K,M	=	design coefficients.

Table 1. Model run test matrix.

Culvert Model	Description	Model Culvert Parameters: Edge Type	Wingwall Flare	Wingwall Miter	Rise, D (ft)	Barrel Slope (ft/ft)	Wall Thickness (ft)	Bevel Height (ft)	Model Scale
1	Rectangular;benchmark run; compares to HDS-5 Chart 8/3, 6 ft x 6 ft	Square	0°	2:1	0.5625	0.03	0.0625	NA	1:10.67
2	Rectangular, 6 ft x 6 ft	Square	0°	3:1	0.5625	0.03	0.0625	NA	1:10.67
3	Rectangular with haunches and parapet; South Dakota cast-in-place model, 9 ft x 9 ft	Top edge beveled	30°	2:1	0.6042	0.03, 0.0175	0.0417	0.0250	1:15
4	Rectangular with haunches; South Dakota precast model of 6 ft x 6 ft box w/o parapet	Wingwall and top edge beveled	0°	2:1	0.5625	0.03	0.0625	0.0313	1:10.67
5	Rectangular with haunches and parapet; South Dakota precast model of 6 ft x 6 ft box	Wingwall and top edge beveled	0°	2:1	0.5625	0.03, 0.0175	0.0625	0.0313	1:10.67
6	Rectangular with haunches; South Dakota precast model of 12 ft x 12 ft box w/o parapet	Wingwall and top edge beveled	0°	2:1	0.75	0.03	0.0417	0.0208	1:16

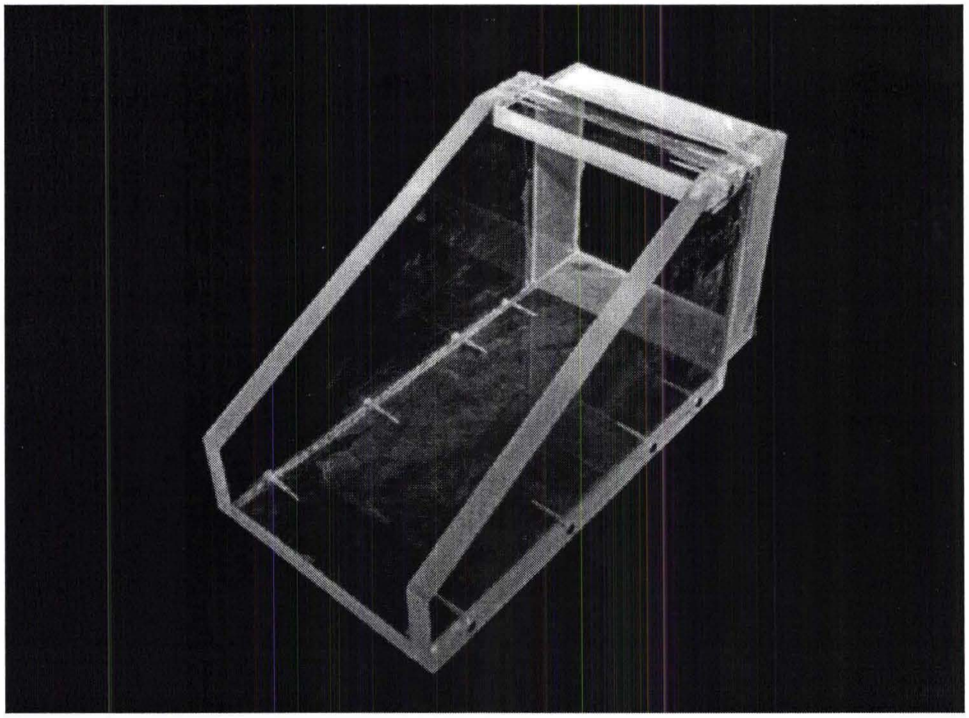

Figure 6. Culvert model 1, HDS-5 chart 8, scale 3.

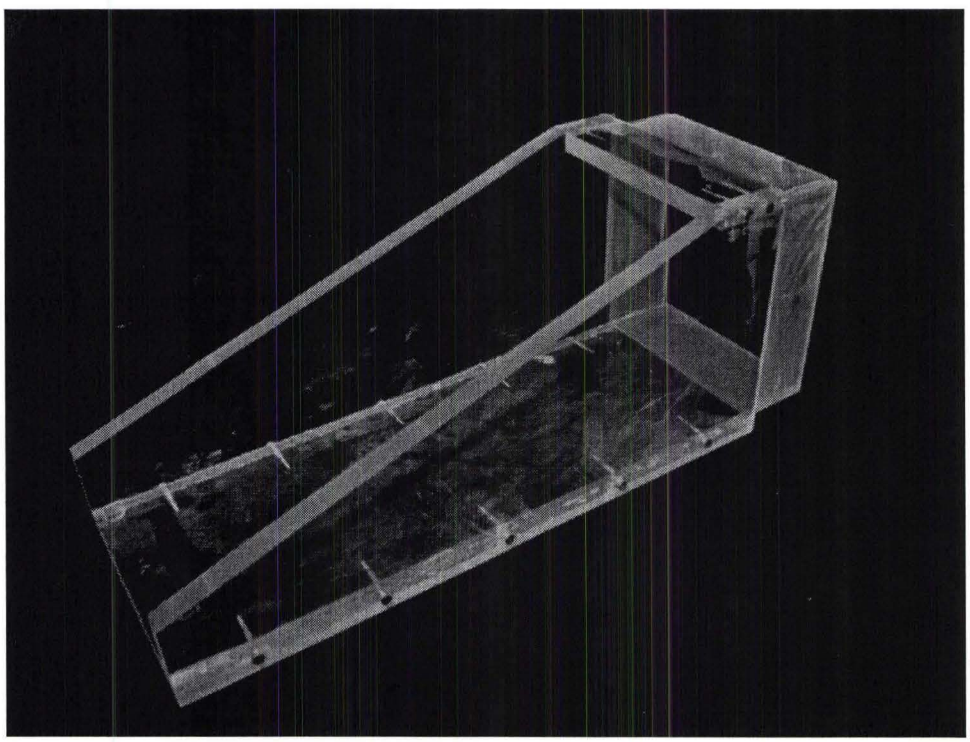

Figure 7. Culvert model 2, 3:1 wingwall miter.

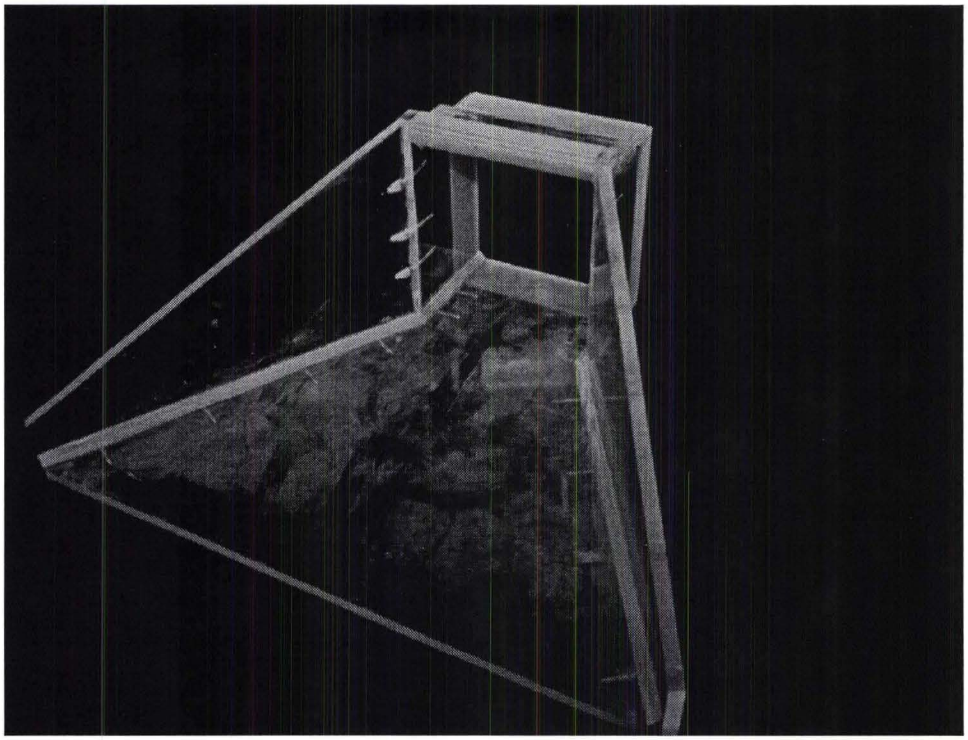

Figure 8. Culvert model 3, cast-in-place, 30-degree wingwall flare.

Figure 9. Culvert model 5, 6 ft x 6 ft precast, 0-degree wingwall flare.

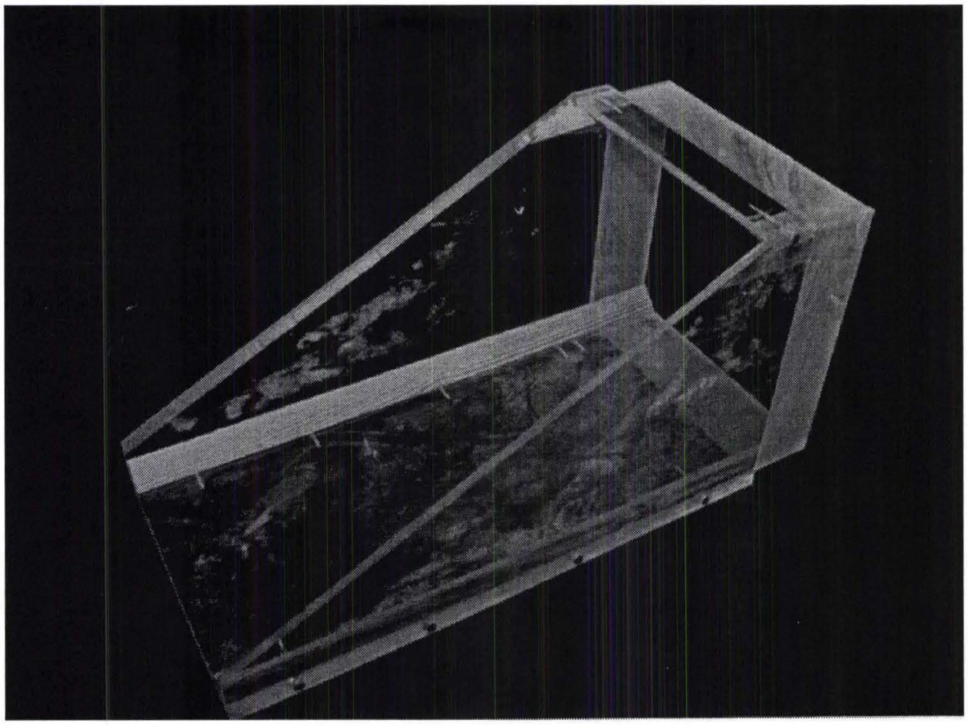

Figure 10. Culvert model 6, 12 ft x 12 ft precast, 0-degree wingwall flare.

For culvert model 1, design coefficients (K and M) were also developed using Form 1 of the culvert inlet design equations (Normann, 1985) to allow for a direct comparison to HDS-5:

$$FORM\ 1 \qquad \frac{HW}{D} = \frac{H_c}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^M + 0.7S$$

Where:

H_c	=	specific head at critical depth, ft.
S	=	slope, ft/ft.
0.7	=	slope correction factor for mitered wingwalls.

For inlet control under submerged conditions, design coefficients c and Y were determined using Form 3 of the inlet control design equations (Normann, 1985) for each of the culvert models tested:

$$FORM\ 3 \qquad \frac{HW}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^2 + Y + 0.7S$$

Where:

c,Y	=	design coefficients.

Outlet Control

The entrance loss coefficient under outlet control, K_e, was calculated for each culvert model using the following equation:

$$H_e = K_e \left[\frac{V^2}{2g} \right]$$

Where:

H_e	=	entrance loss, ft.
V	=	velocity, ft/s.
g	=	gravity, ft/s^2.
K_e	=	entrance loss coefficient.

5. RESULTS

A summary of the design coefficients developed for each of the model runs is presented in table 2. Where appropriate, design coefficients for a similar configuration in HDS-5 are included. Spreadsheets of the data analysis for each of the listed runs is presented in Appendix A.

Plots of the regression lines developed from the experimental data for each of the runs presented in table 2 are shown in figures 11a through 11p. Included on the plots are the individual data points as well as the line representing the region over which the regression coefficients were developed. Plots of the design curves for culvert model 1 vs HDS-5 are presented in figures 12a and 12b. Figures 13a through 16b were developed to compare the effects of various experimental parameters, including:

- Wingwall miter.
- Constant bevel.
- Culvert barrel slope.
- Inlet configuration (wingwall flare, wingwall miter, and parapets).

6. DISCUSSION

Inlet Control

A comparison between the experimental results and HDS-5 for culvert model 1 is shown in figures 12a and 12b for unsubmerged and submerged conditions, respectively. Experimental results compare fairly well with HDS-5, given the uncertainty in the exact configuration of the HDS-5 model. Experimental results predict a lower (less than 10 percent) HW/D ratio than HDS-5 for both submerged and unsubmerged conditions.

Table 2. Summary of culvert inlet design coefficients.

Culvert Model	Run No.	Figure No.	Inlet Control										Outlet Control	
			Unsubmerged						Submerged					
			Form 1				Form 2		Laboratory		HDS - 5		Laboratory	HDS -5
			Laboratory		HDS - 5		Laboratory							
			K	M	K	M	K	M	c	Y	c	Y	K_e	K_e
1	39	11a,b; 12a,b; 13a,b; 16a,b	0.009	1.5432	0.061	0.75	0.4767	0.7252	0.0435	0.6152	0.0423	0.82		
	5												0.68	0.7
2	40	11c,d; 13a,b; 16a,b					0.4850	0.6699	0.0407	0.6311				
	20												0.59	
3	33	11e,f; 15a,b; 16a,b					0.3896	0.7940	0.0331	0.6337				
	32*	11g,h; 15a,b					0.4299	0.7332	0.0312	0.7288				
	21												0.25	0.2
4	34	11i,j; 14a,b; 16a,b					0.4792	0.6753	0.0432	0.5671				
	6												0.43	
5	43	11k,l; 15a,b; 16a,b					0.4026	0.7875	0.0384	0.5853				
	12*	11m,n; 15a,b					0.4889	0.6815	0.0343	0.7571				
	14												0.40	
6	42	11o,p; 14a,b					0.4368	0.7384	0.0506	0.5343				
	26												0.64	

* Barrel slope = 0.0175; all other runs slope = 0.03

Figures 13a and b depict the effect of wingwall miter. For unsubmerged conditions (figure 13a), the miter slope appears to have no effect. Under submerged conditions (figure 13b), the 3:1 miter appears to be slightly more efficient at the higher HW/D ratios.

Figures 14a and 14b depict the effect of the constant bevel height (in terms of the bevel height to culvert rise ratio, B/D) regardless of culvert size. The plot of unsubmerged conditions (figure 14a) suggests that the B/D ratio has little effect. For submerged conditions (figure 14b), however, the higher B/D ratio results in a lower HW/D ratio (approximately 11 percent at the upper end of the experimental flow range). For a constant bevel, therefore, the smaller culvert appears to be more efficient.

The effect of the culvert barrel slope is depicted in figures 15a and b. The data suggest that under unsubmerged conditions, the slope has a small effect (figure 15a) with the higher slope being more efficient. Figure 15b depicts submerged conditions and shows that the slope has less of an effect than under unsubmerged conditions but that the higher slope is slightly more efficient.

The last set of figures, 16a and 16b, present the effects of various experimental parameters, including the parapet, wingwall miter, and wingwall flare. For unsubmerged conditions (figure 16a), the data suggest that the configuration does not have a large effect on headwater, with the exception of wingwall flare. The data suggest the model of the cast-in-place, 30-degree flared wingwall inlet (model 3) is approximately 8 percent more efficient, over the experimental range, than the model of the 6 ft x 6 ft precast, 0-degree flared inlet (model 5).

For submerged conditions (figure 16b), results similar to the unsubmerged conditions were observed. The data suggest the following:

- culverts with a parapet are slightly more efficient than those without a parapet;
- 3:1 wingwall miter is slightly more efficient than the 2:1 wingwall miter;
- and the most efficient configuration tested appears to be the cast-in-place, 30-degree flared wingwall inlet (model 3). Data from this experiment show a predicted HW/D ratio that is approximately 10 percent lower than the 6 ft x 6 ft precast, 0-degree flared inlet (model 5) under submerged flow conditions.

Outlet Control

Entrance loss coefficients, K_e, were computed for culvert models 1 and 3 under outlet control conditions. For culvert model 1, an experimental K_e of 0.68 was computed, compared to a value of 0.7 presented in HDS-5 (table 12, page 179). For culvert model 3, an experimental K_e of 0.25 compares with the HDS-5 value of 0.2.

The K_e values computed for culvert models 5 and 6 were 0.40 and 0.65, respectively. As with the inlet control runs, the data suggest that the lower the B/D ratio the less efficient the culvert. The K_e for the 12 ft x 12 ft culvert (model 6) approaches that of a square edge.

The computed K_e for culvert model 4 of 0.43 (compared to a K_e of 0.40 for model 5) suggests that the parapet may be slightly beneficial in passing flow under outlet control conditions.

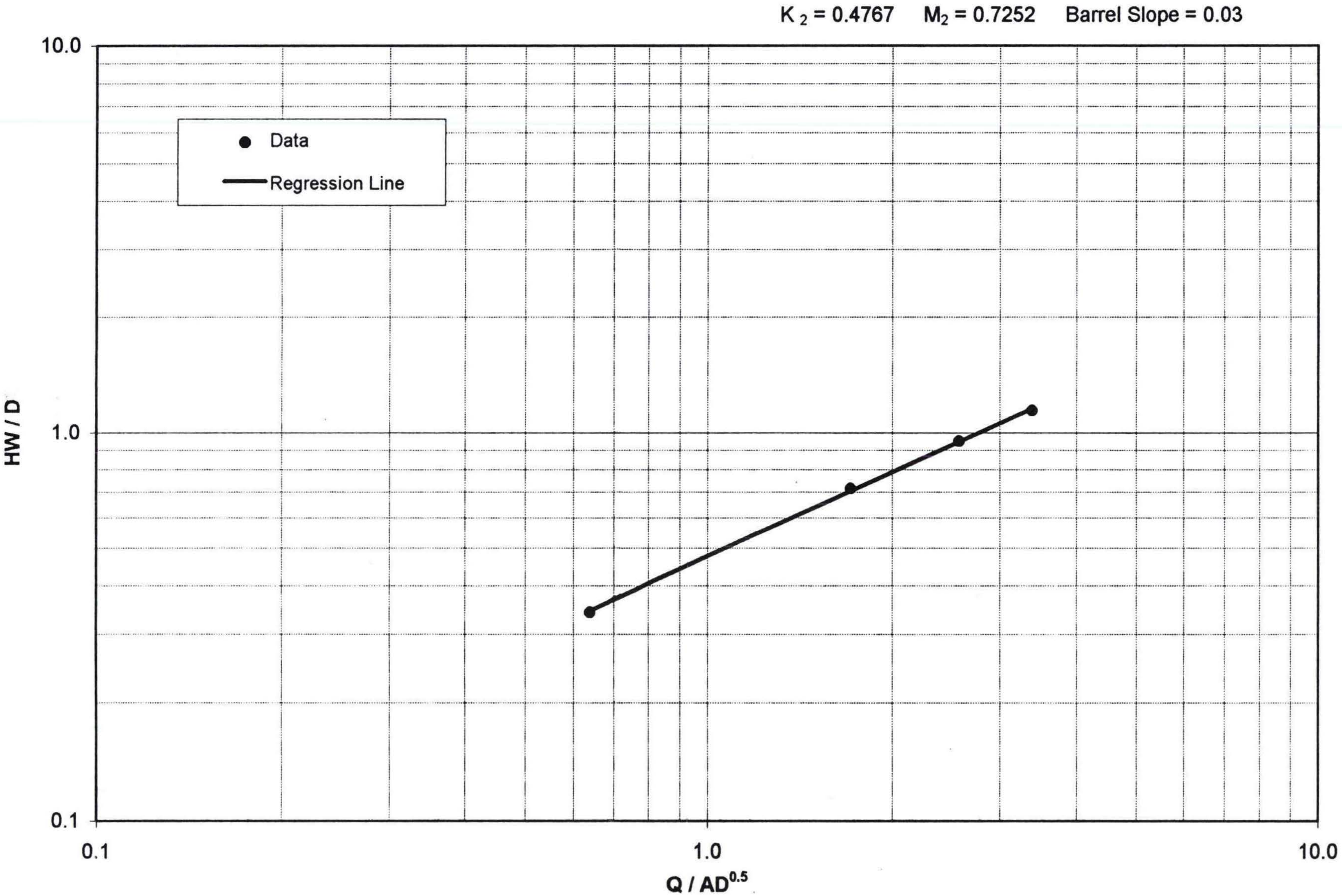

Figure 11a. Regression line vs. data, unsubmerged conditions, culvert model 1, run 39.

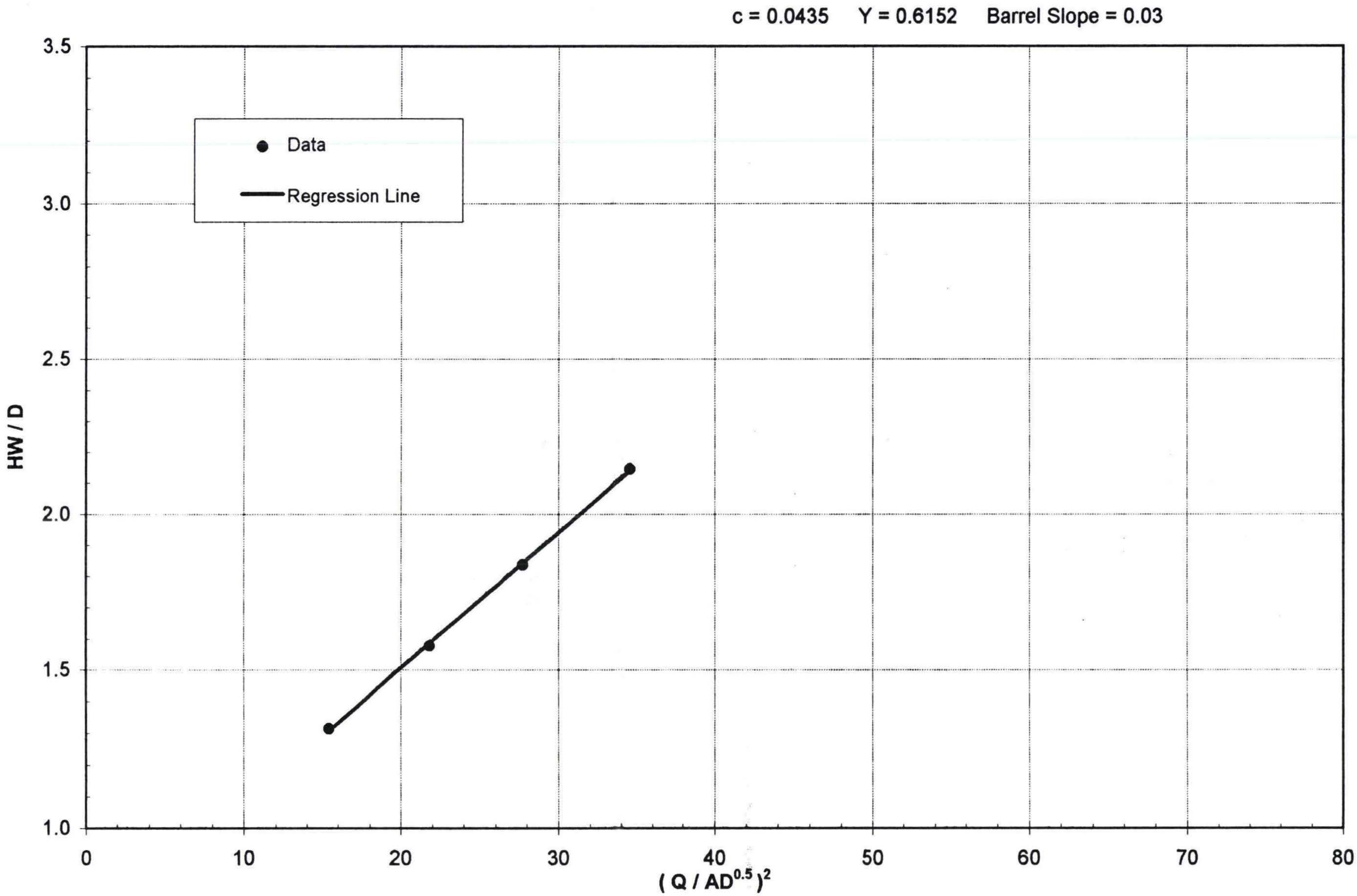

Figure 11b. Regression line vs. data, submerged conditions, culvert model 1, run 39.

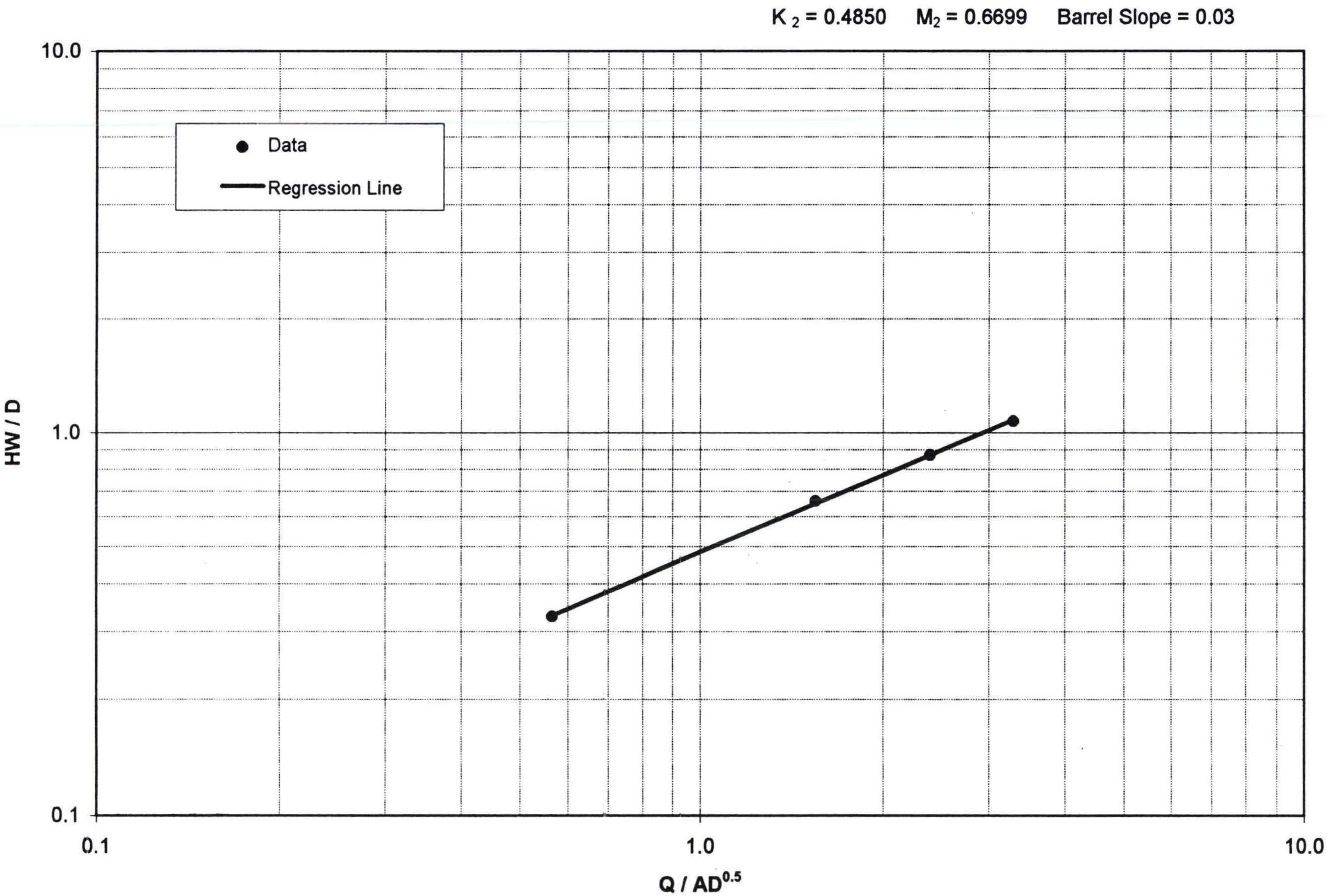

Figure 11c. Regression line vs. data, unsubmerged conditions, culvert model 2, run 40.

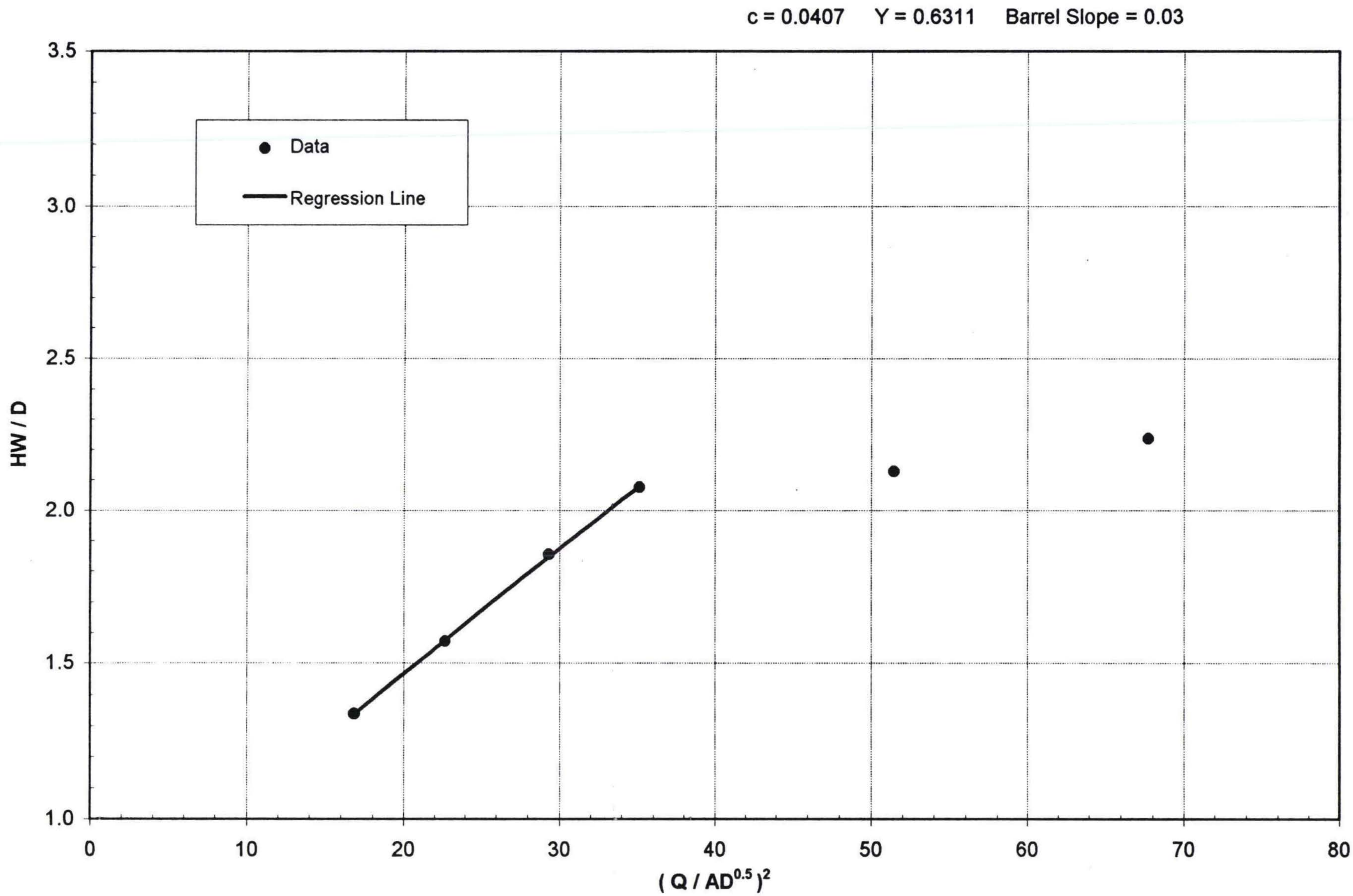

Figure 11d. Regression line vs. data, submerged conditions, culvert model 2, run 40.

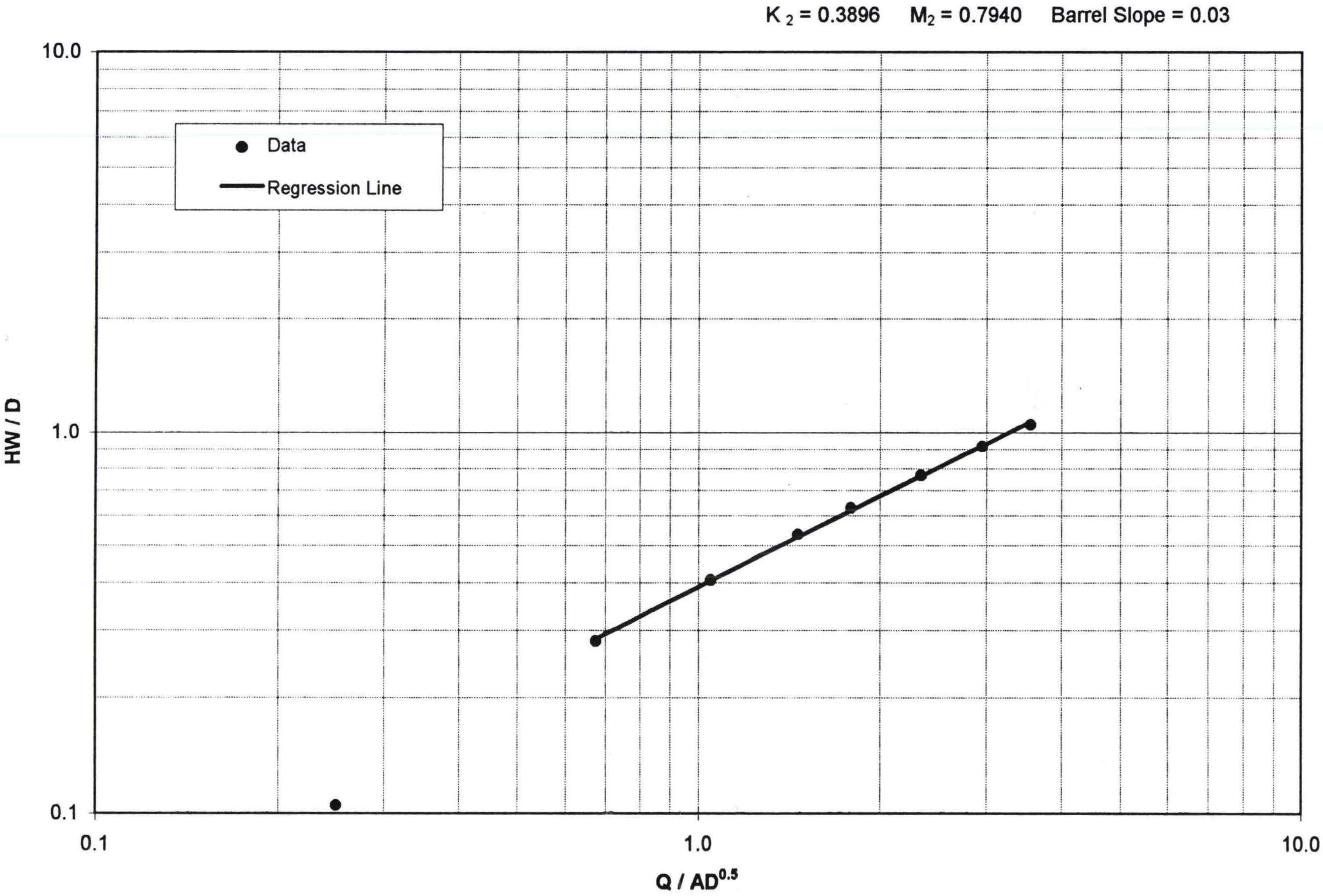

Figure 11e. Regression line vs. data, unsubmerged conditions, culvert model 3, run 33.

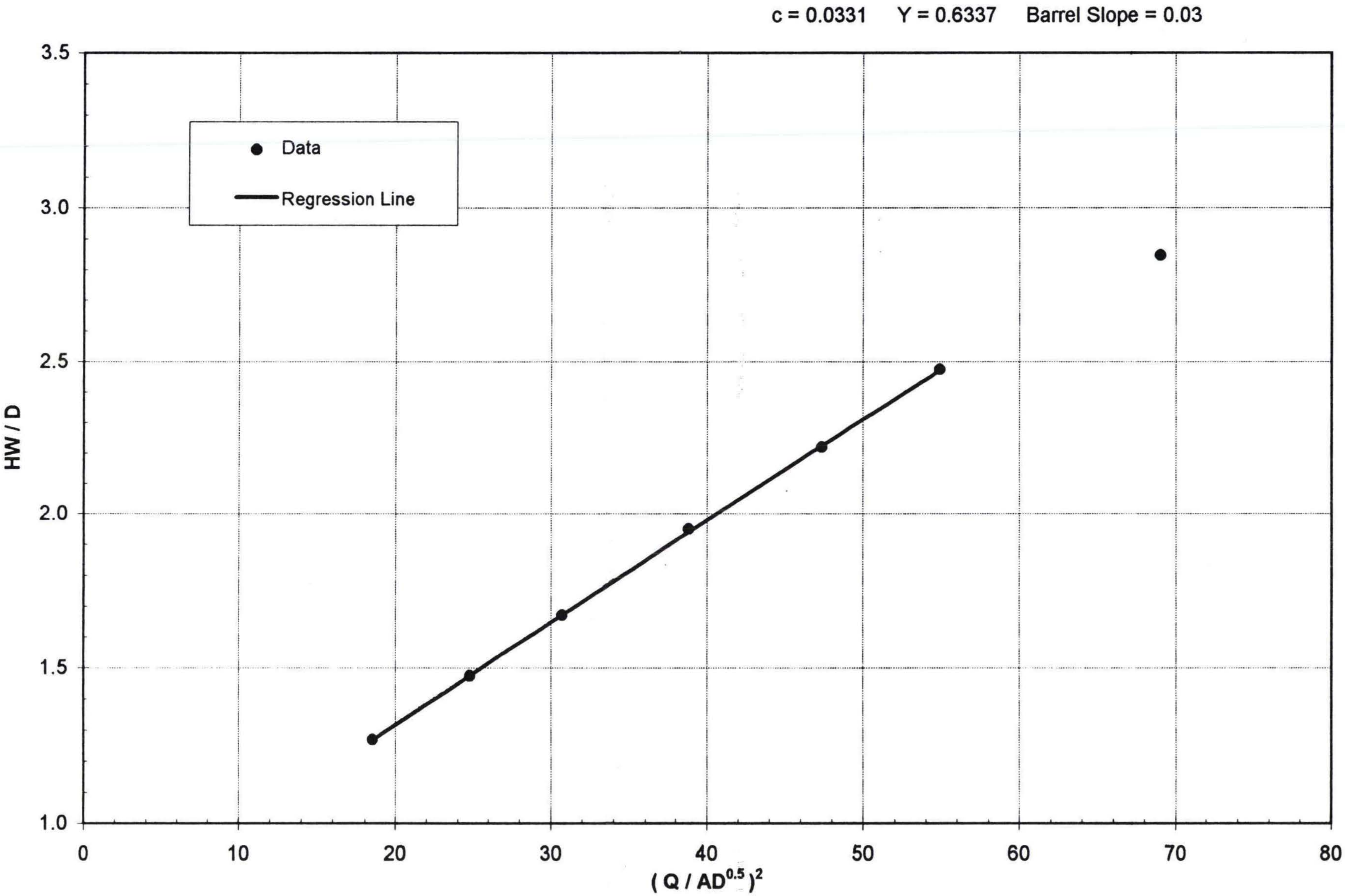

Figure 11f. Regression line vs. data, submerged conditions, culvert model 3, run 33.

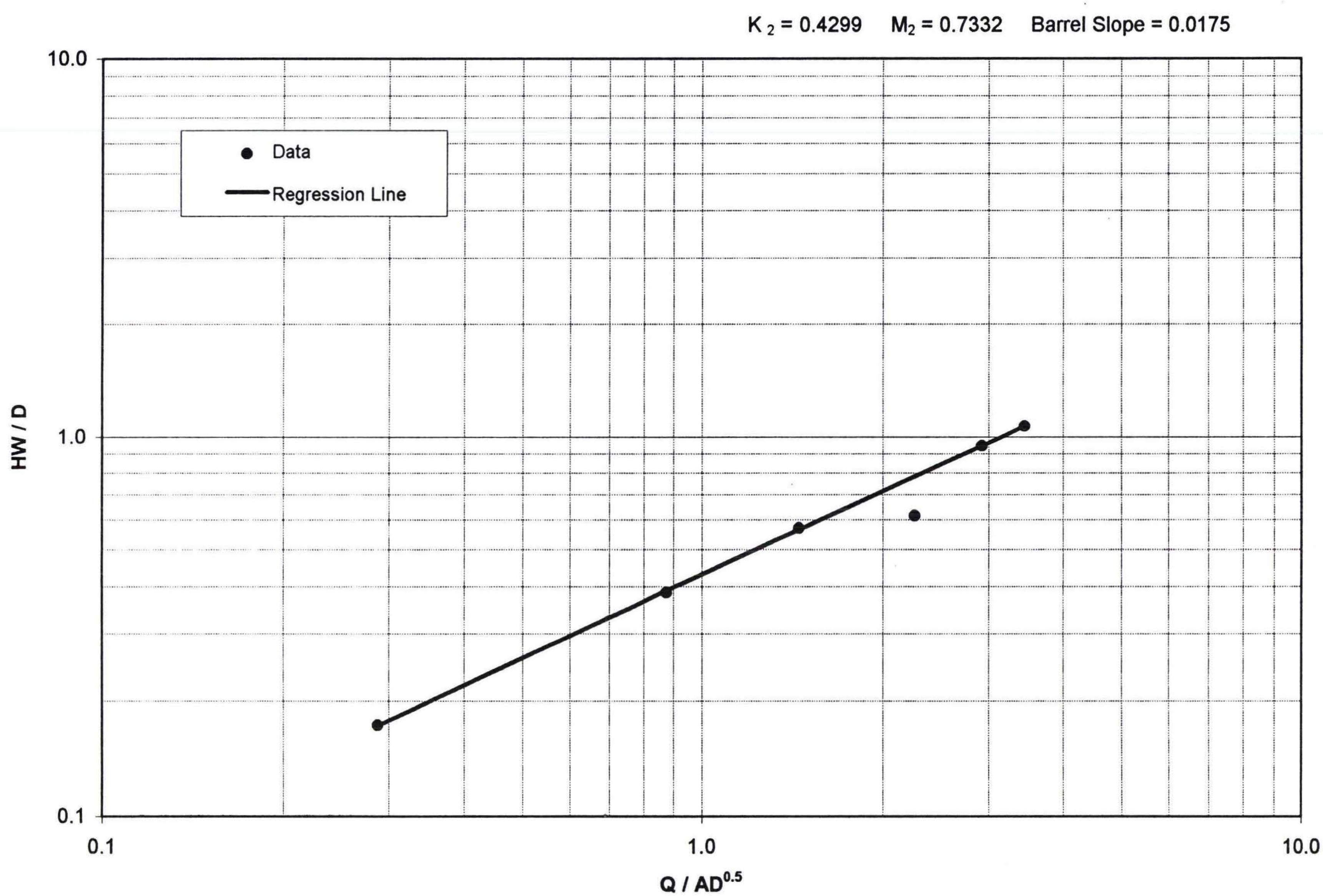

Figure 11g. Regression line vs. data, unsubmerged conditions, culvert model 3, run 32.

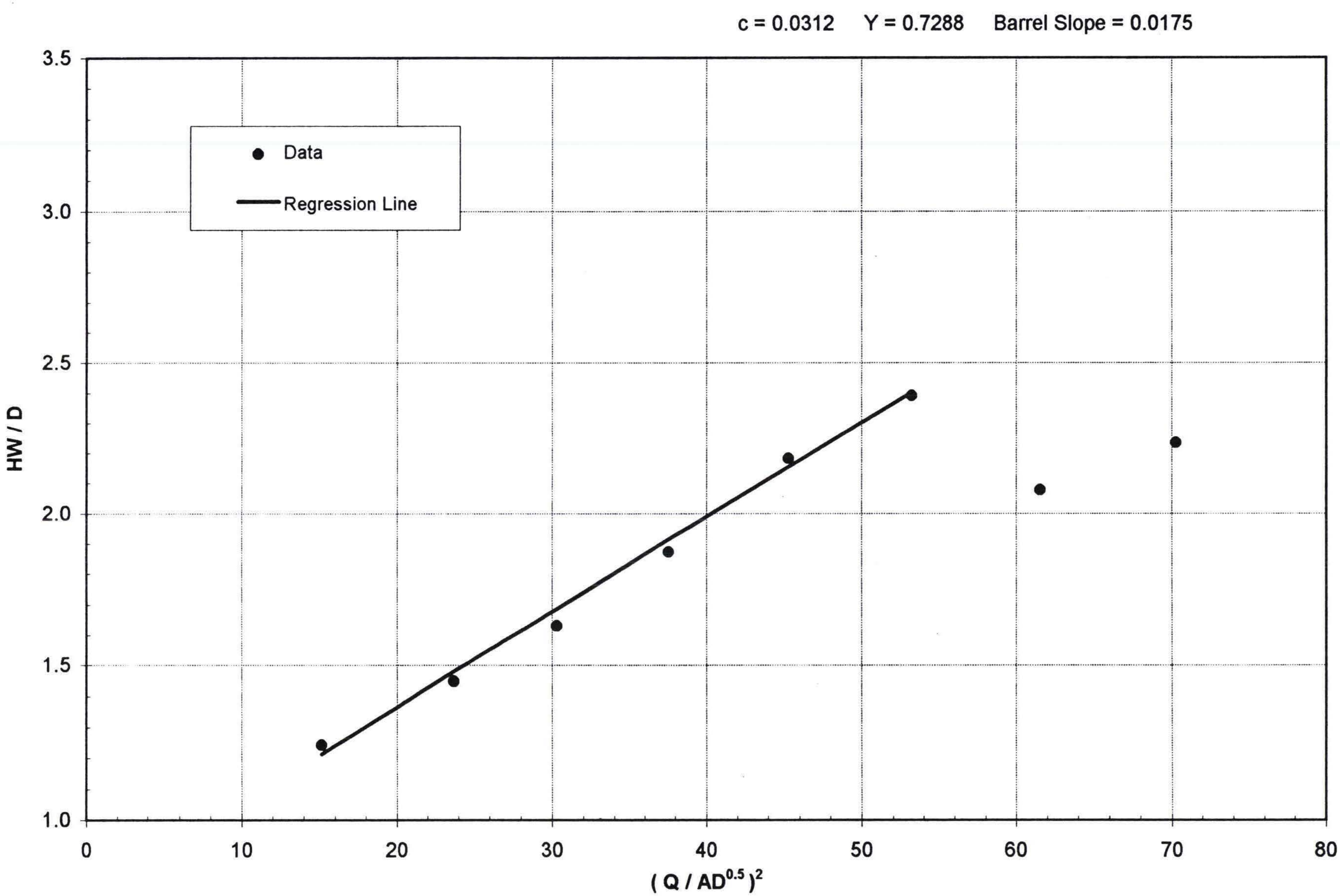

Figure 11h. Regression line vs. data, submerged conditions, culvert model 3, run 32.

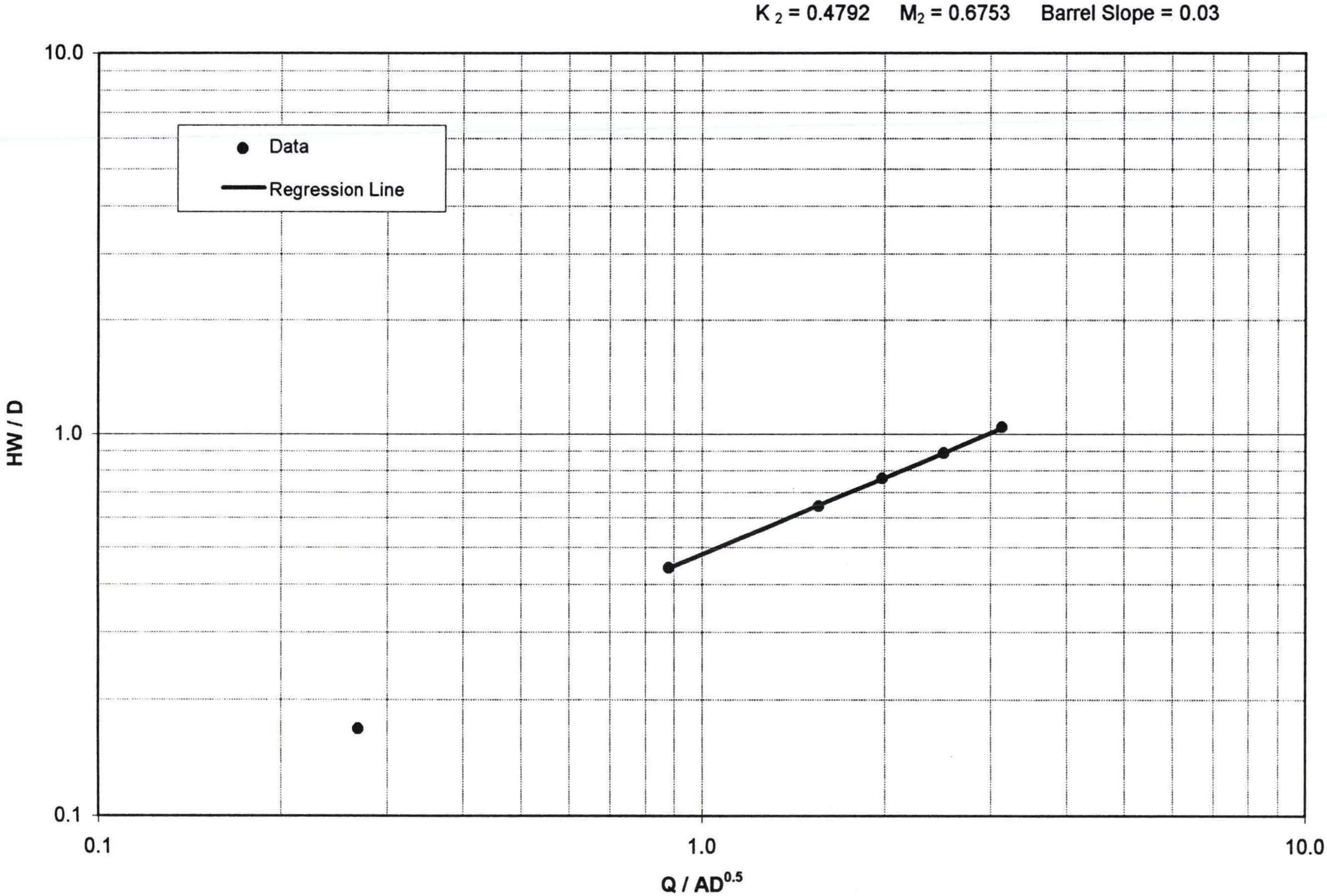

Figure 11i. Regression line vs. data, unsubmerged conditions, culvert model 4, run 34.

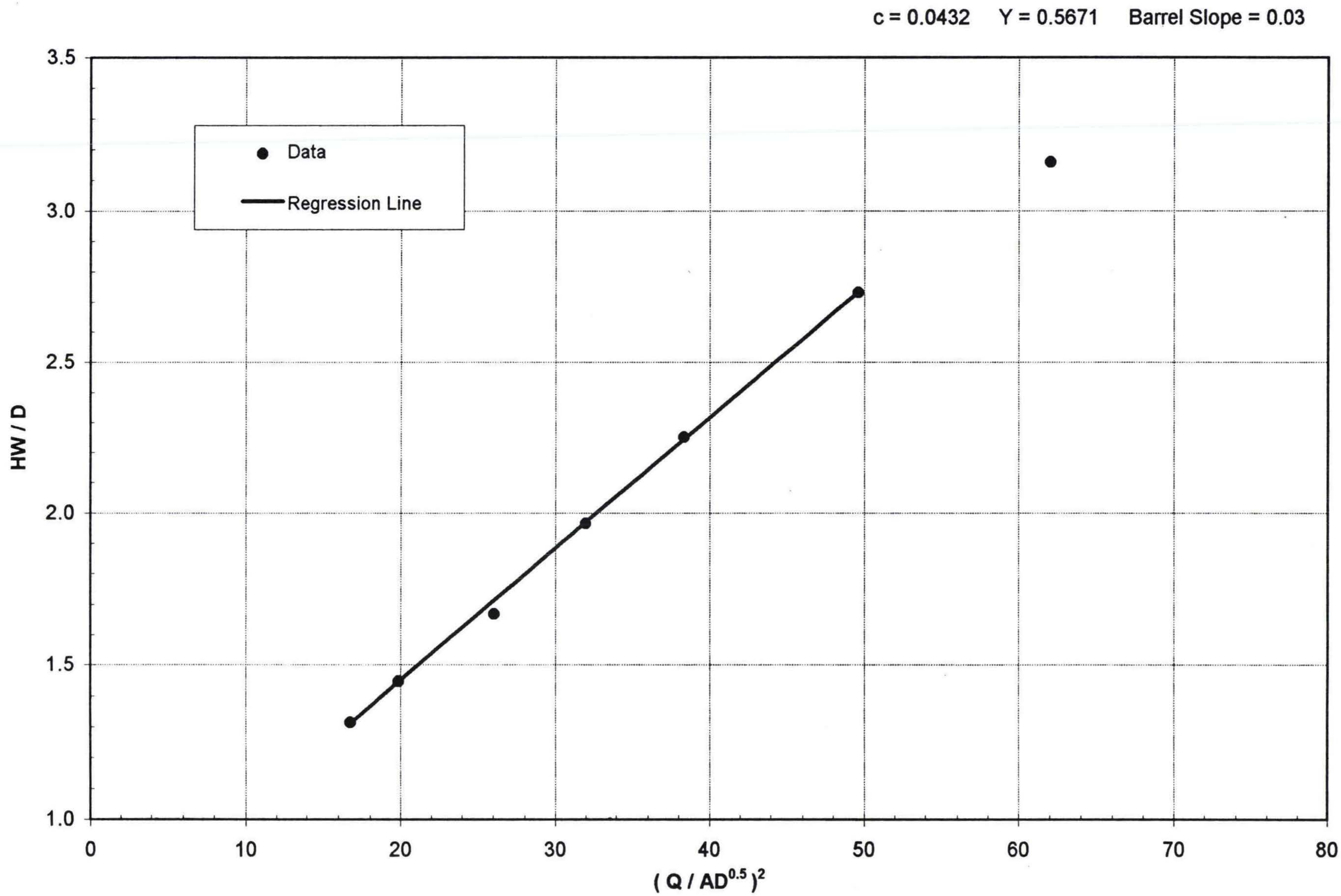

Figure 11j. Regression line vs. data, submerged conditions, culvert model 4, run 34.

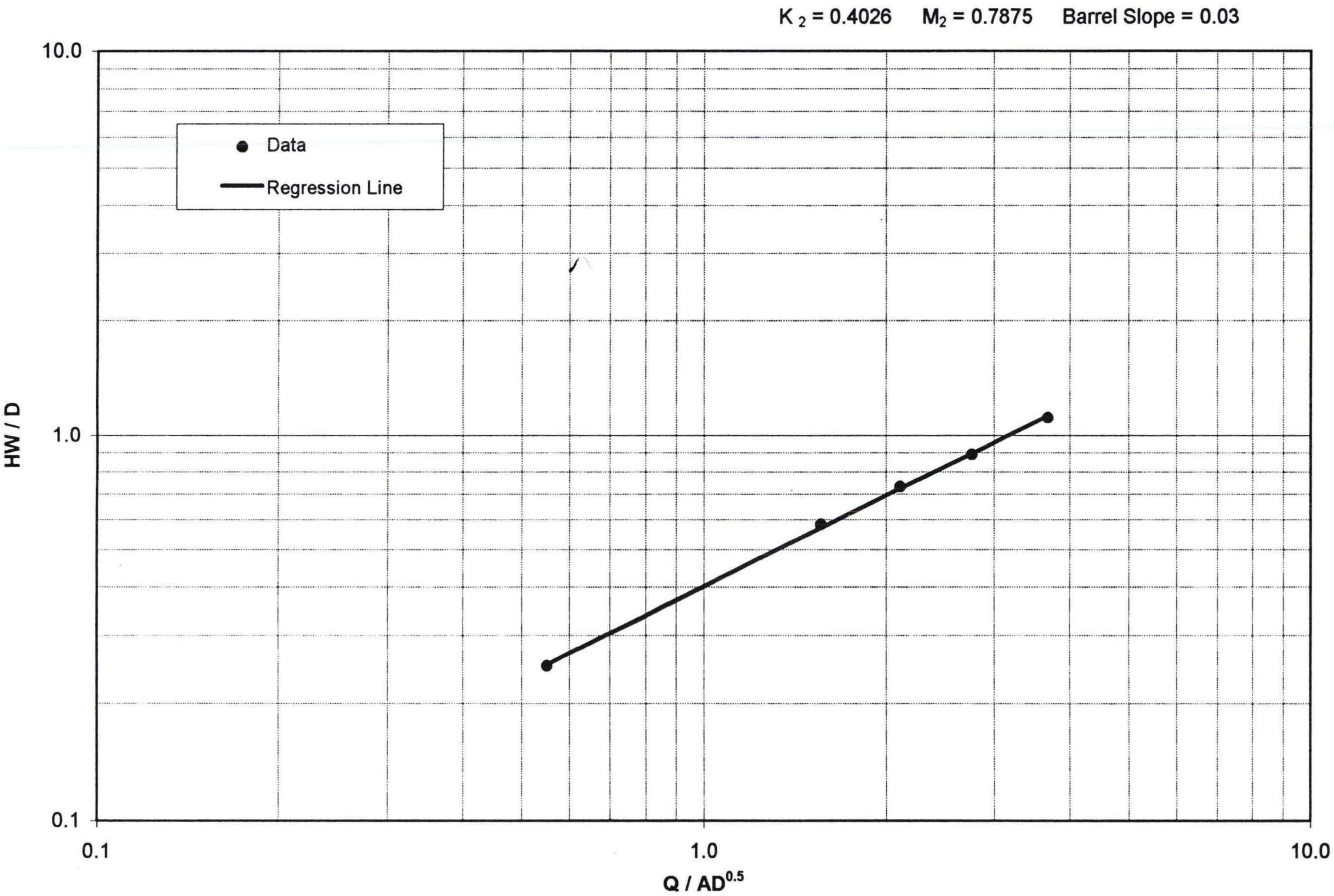

Figure 11k. Regression line vs. data, unsubmerged conditions, culvert model 5, run 43.

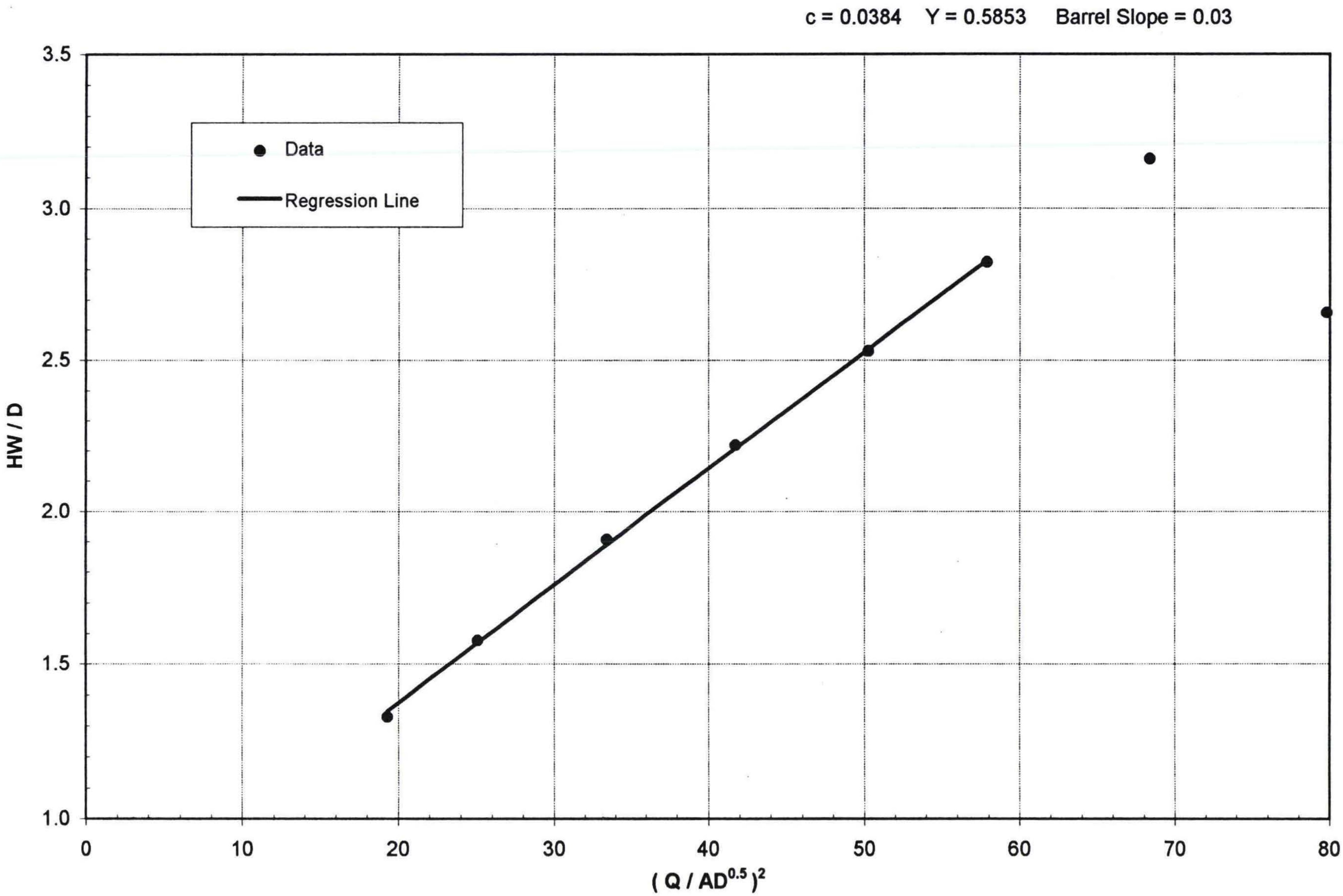

Figure 11l. Regression line vs. data, submerged conditions, culvert model 5, run 43.

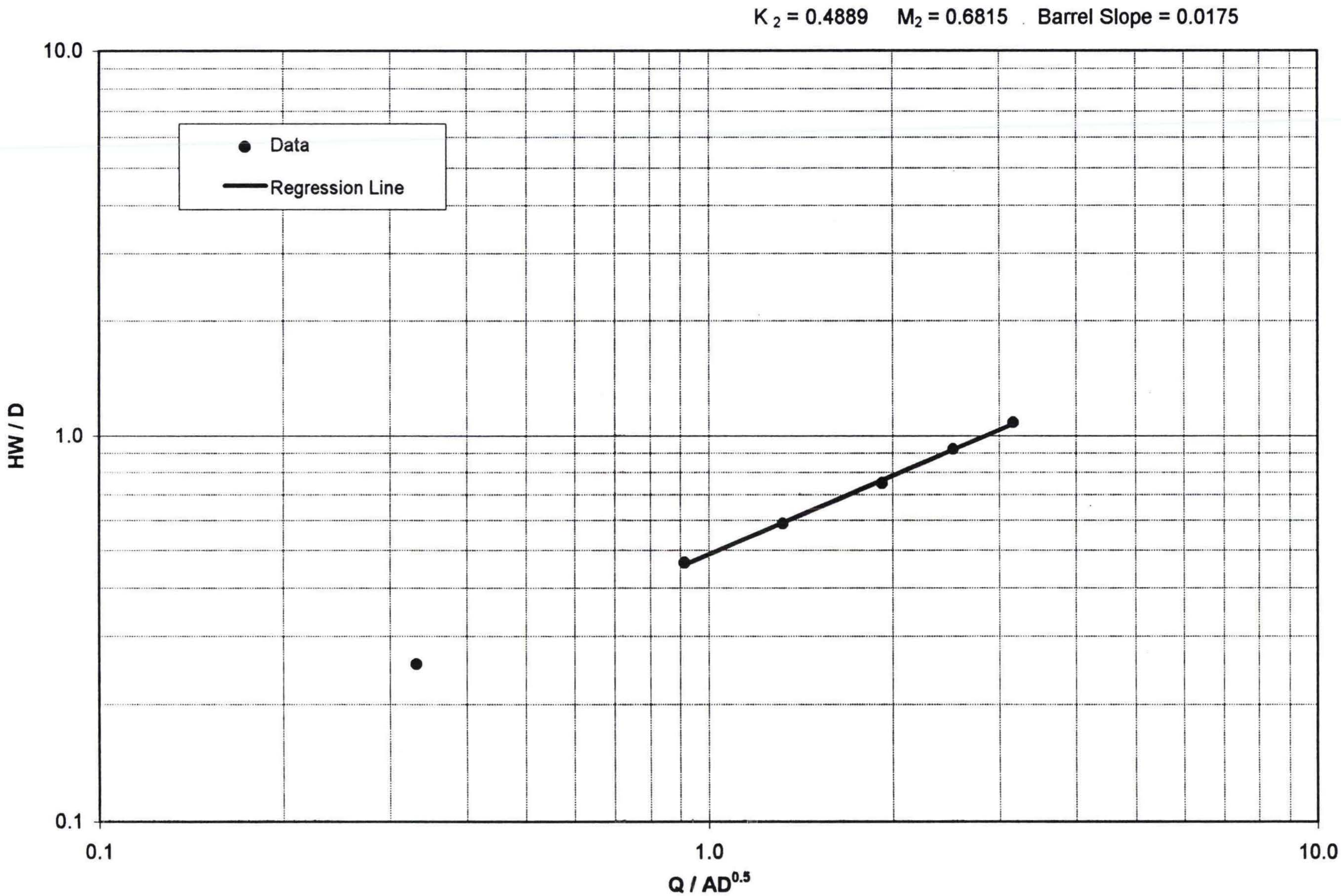

Figure 11m. Regression line vs. data, unsubmerged conditions, culvert model 5, run 12.

c = 0.0343   Y = 0.7571   Barrel Slope = 0.0175

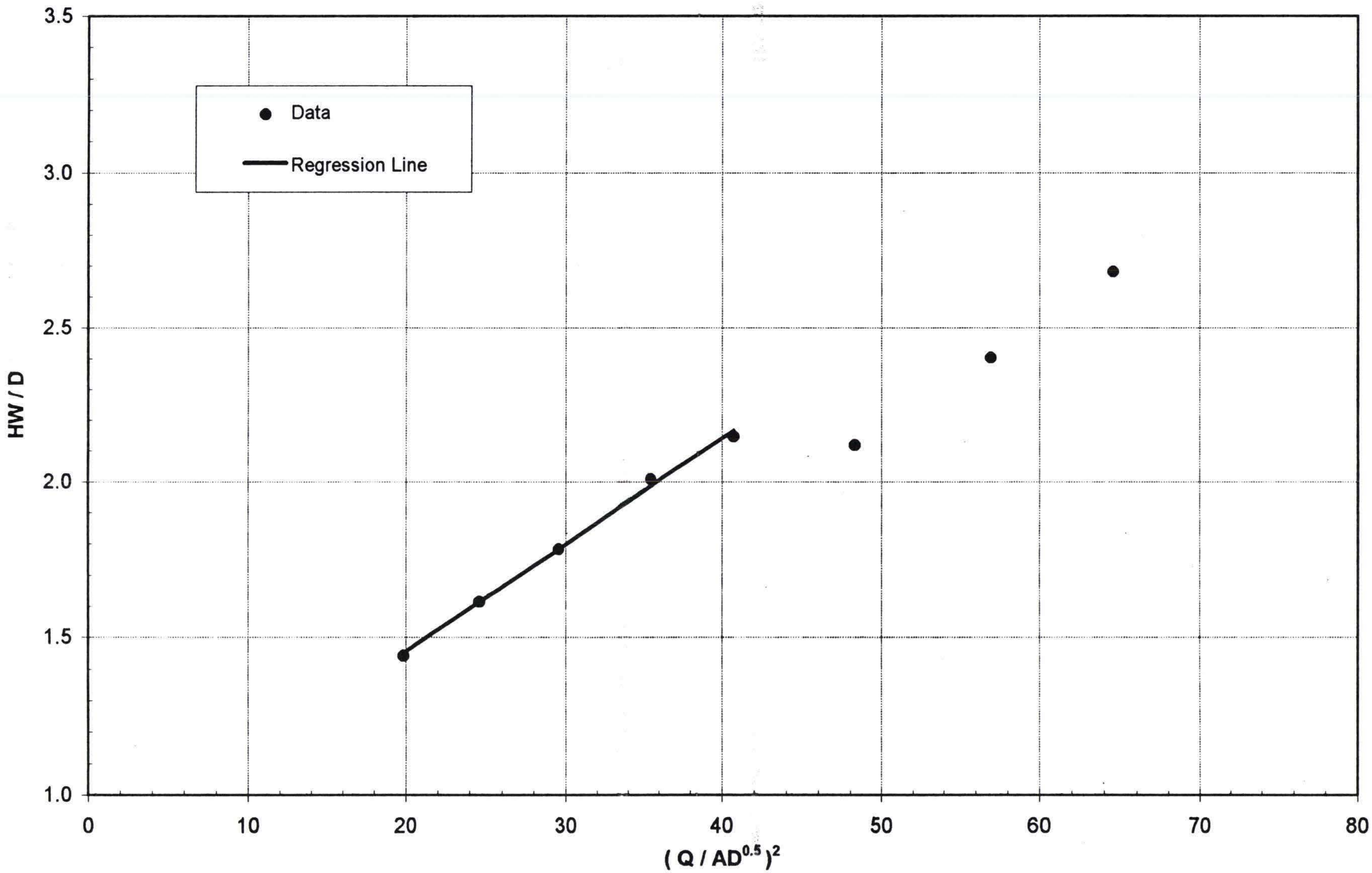

Figure 11n. Regression line vs. data submerged conditions, culvert model 5, run 12:

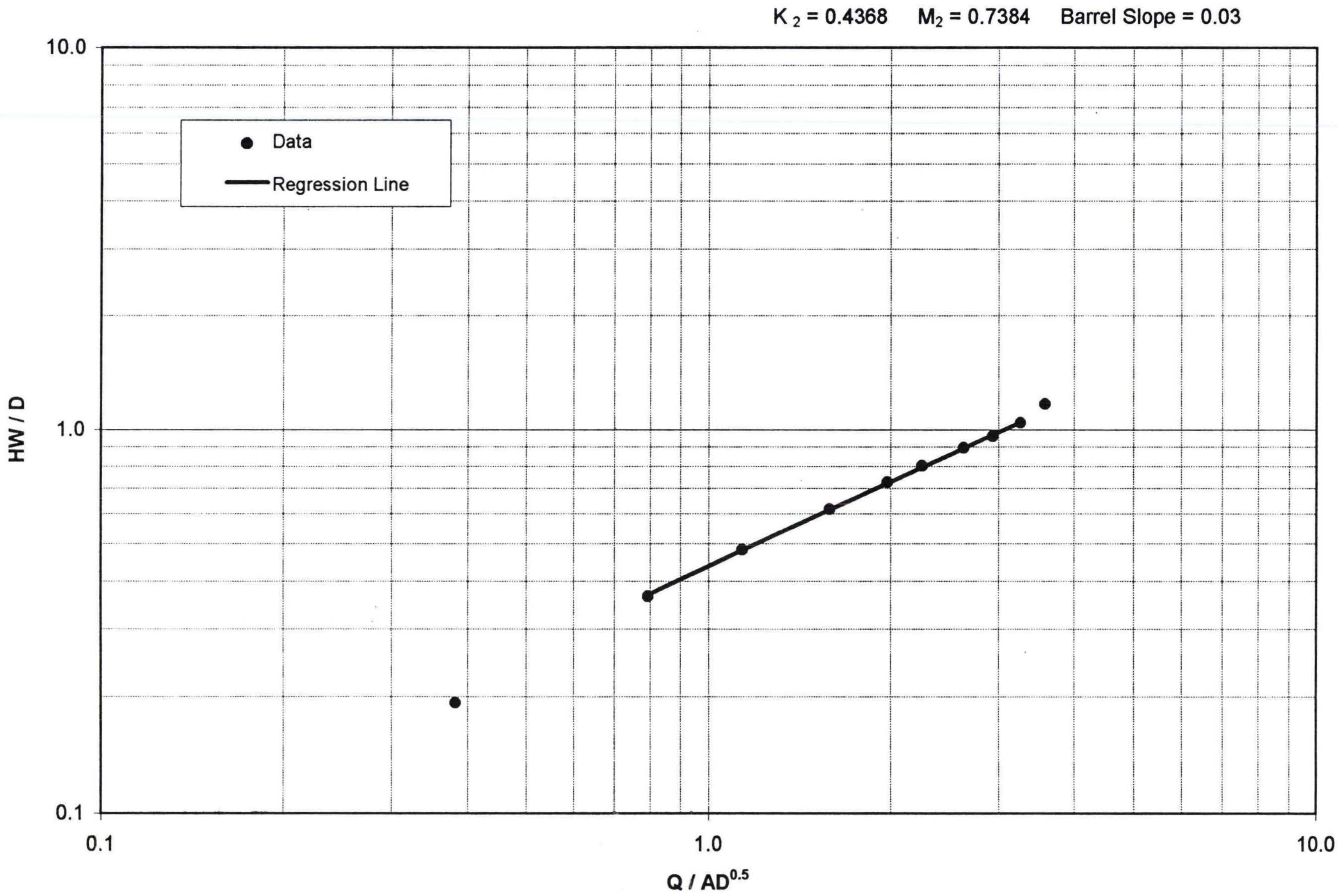

Figure 11o. Regression line vs. data, unsubmerged conditions, culvert model 6, run 42.

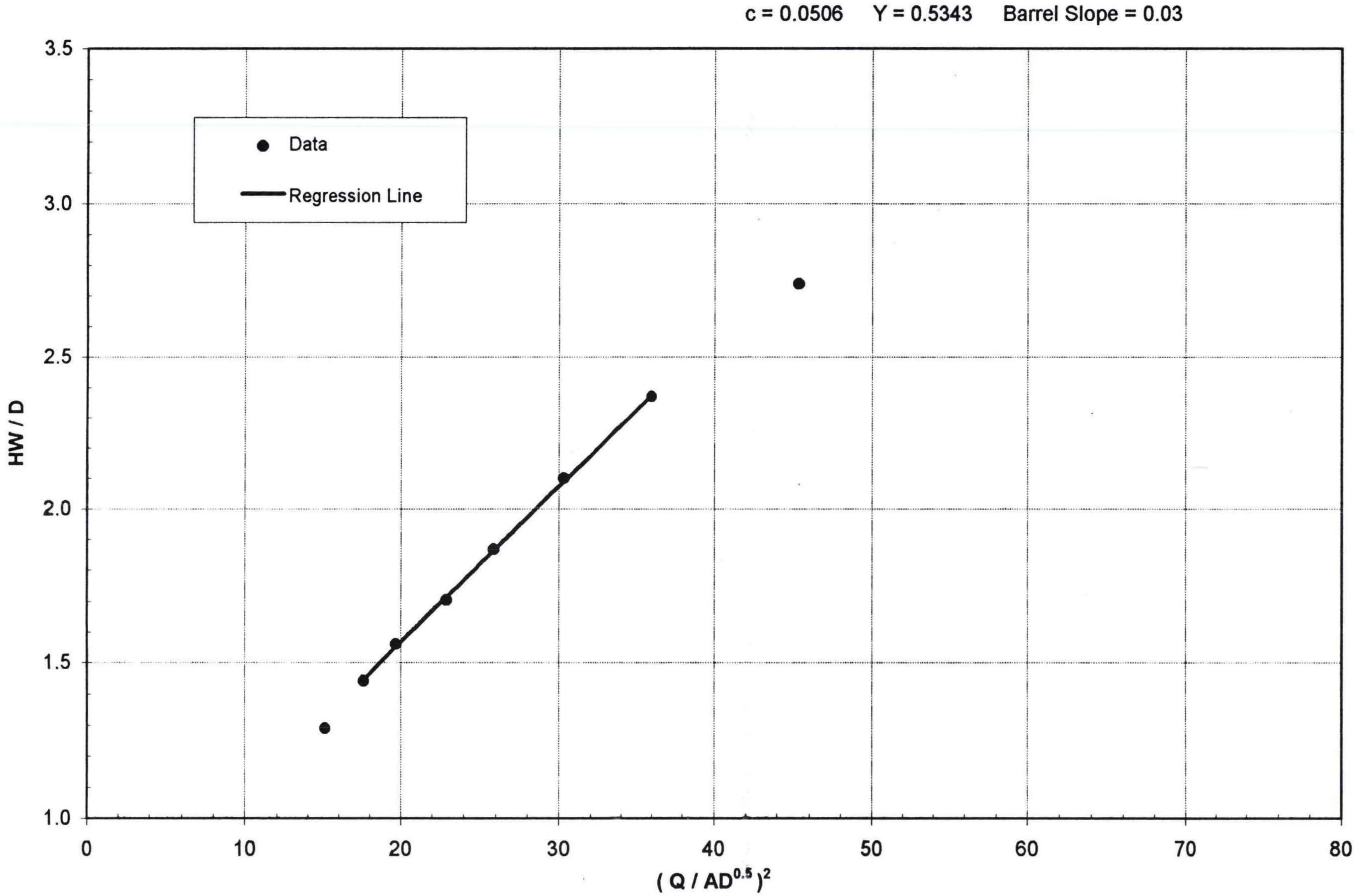

Figure 11p. Regression line vs. data, submerged conditions, culvert model 6, run 42.

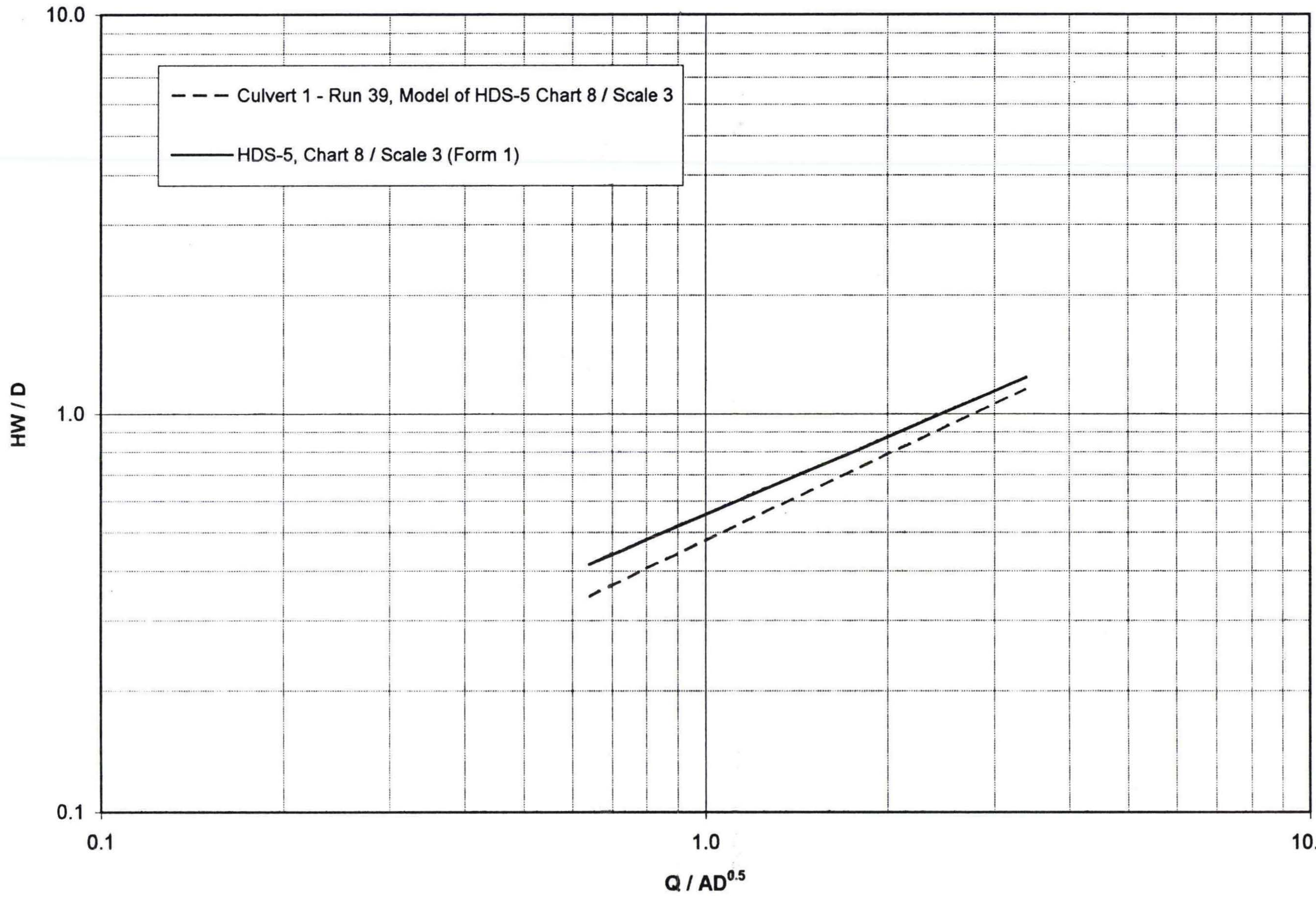

Figure 12a. Benchmark test, unsubmerged conditions

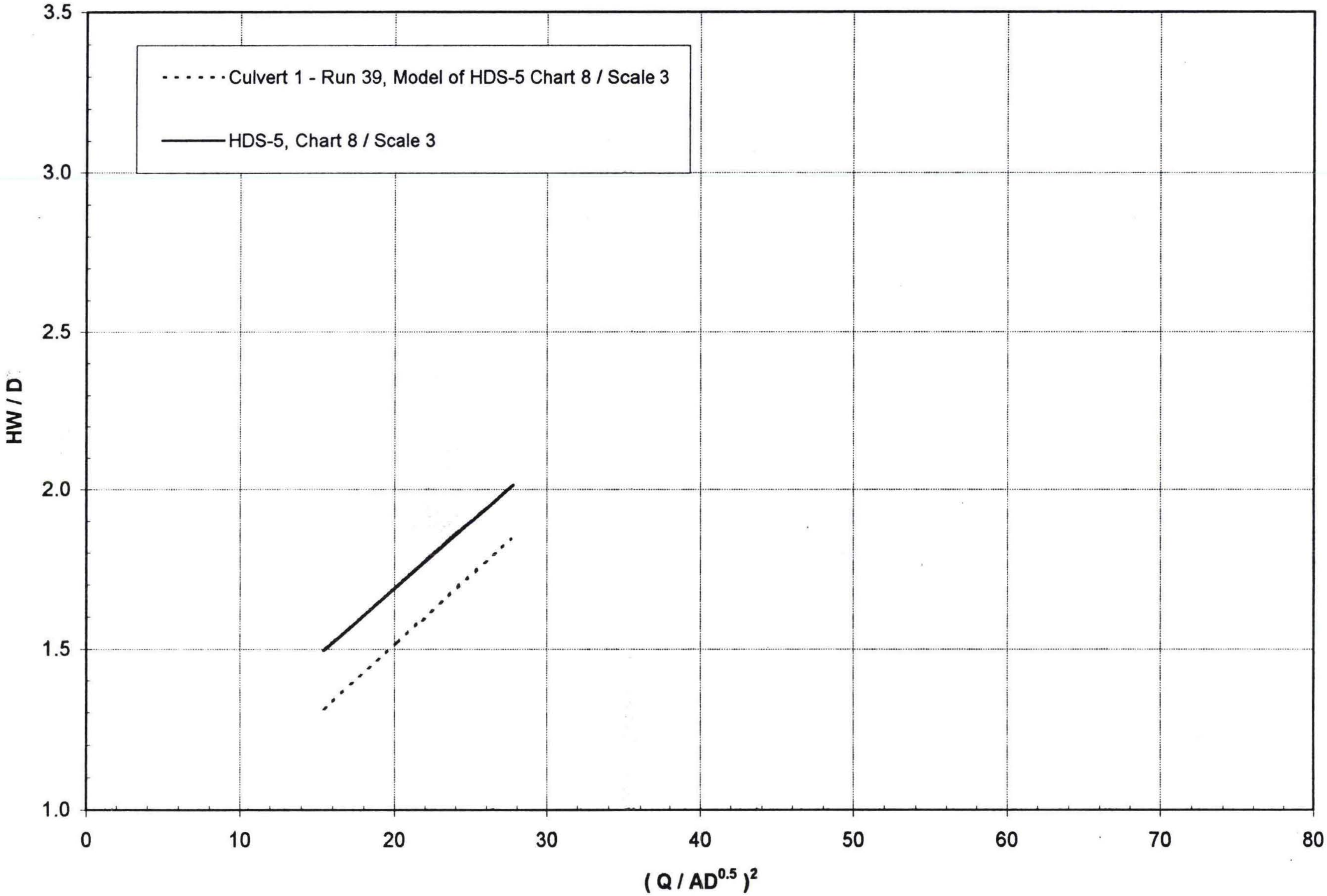

Figure 12b. Benchmark test, submerged conditions

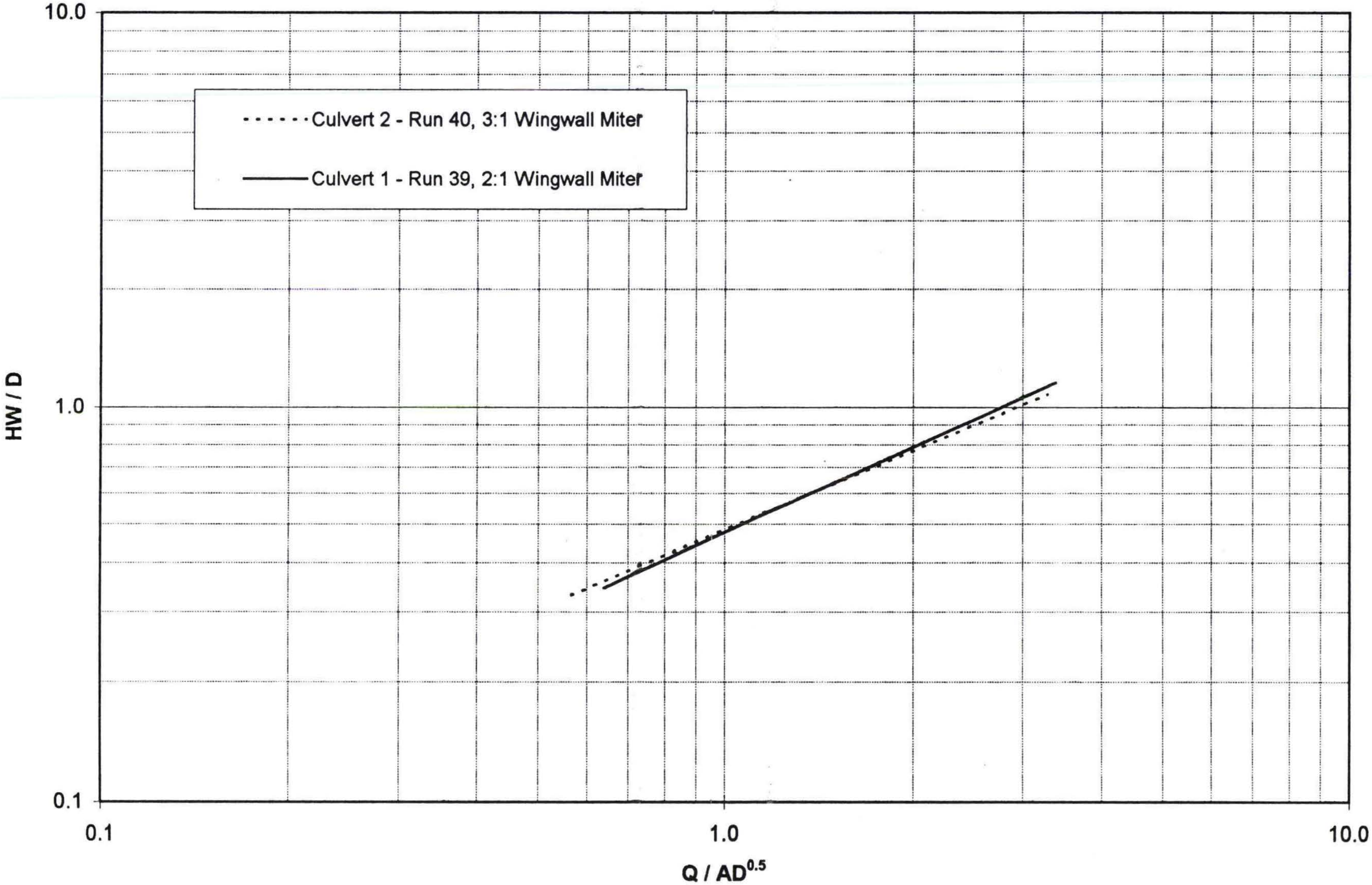

Figure 13a. Effect of wingwall miter, unsubmerged conditions.

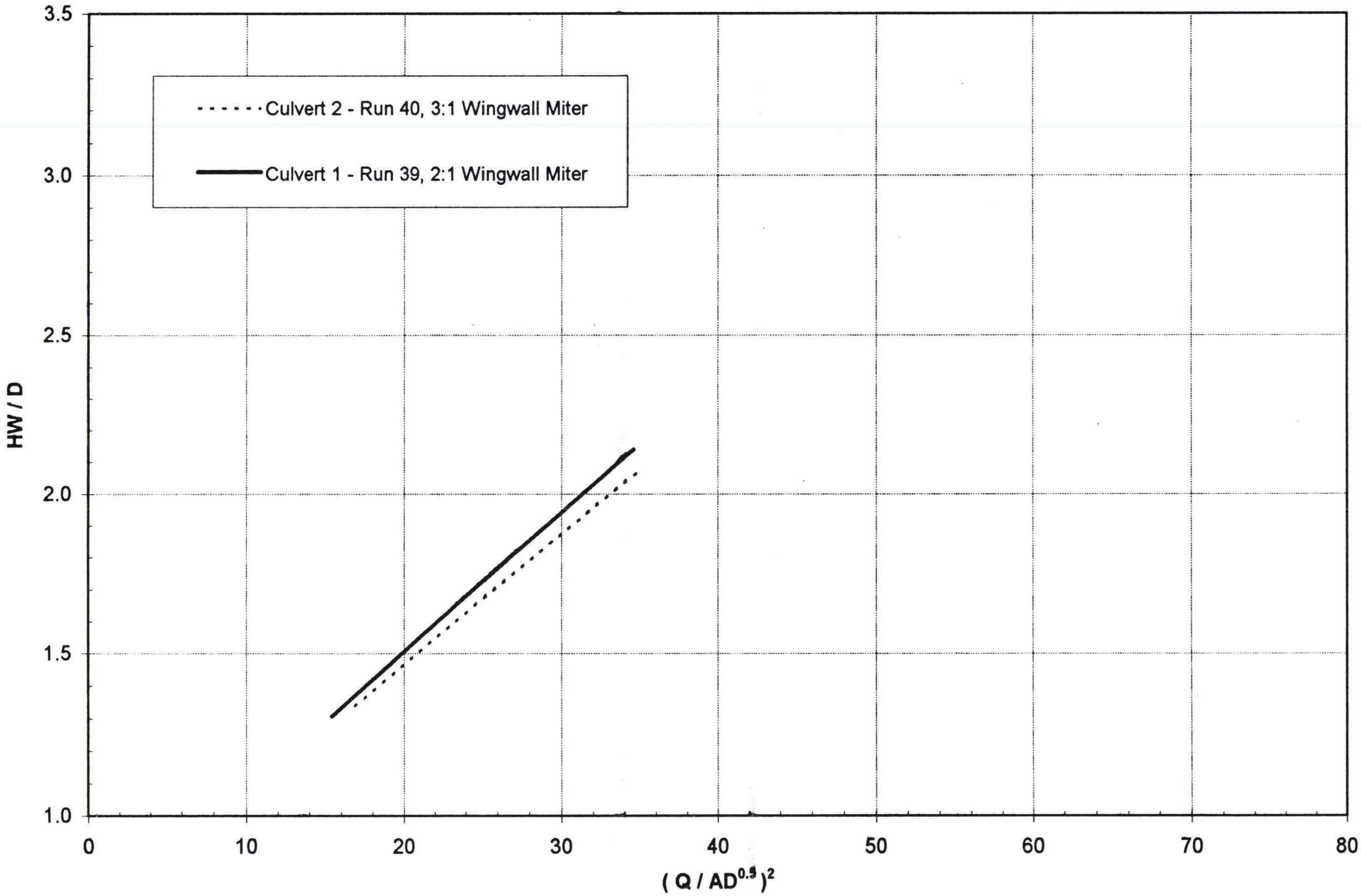

Figure 13b. Effect of wingwall miter, submerged conditions.

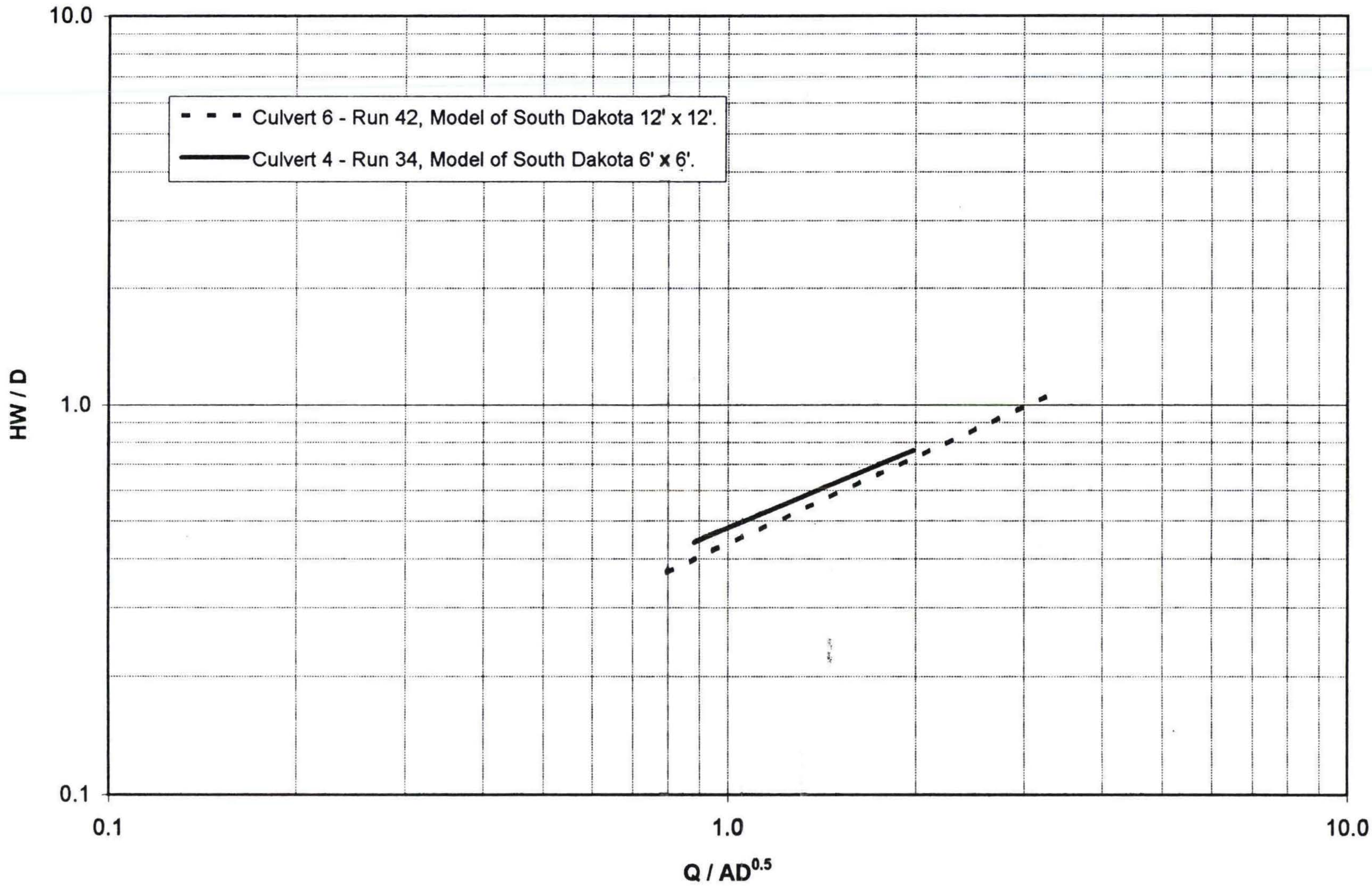

Figure 14a: Effect of constant bevel, unsubmerged conditions.

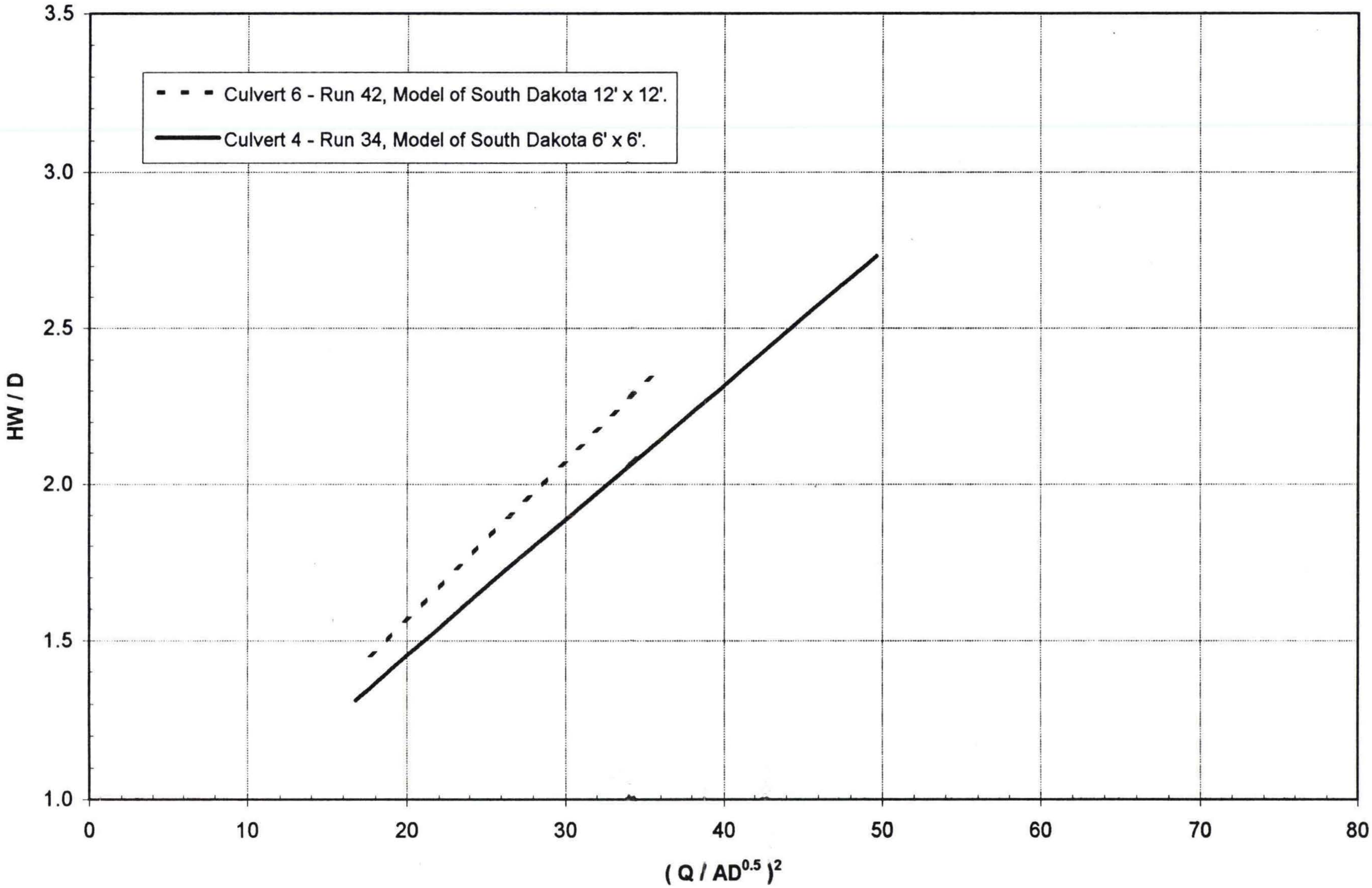

Figure 14b. Effect of constant bevel, submerged conditions.

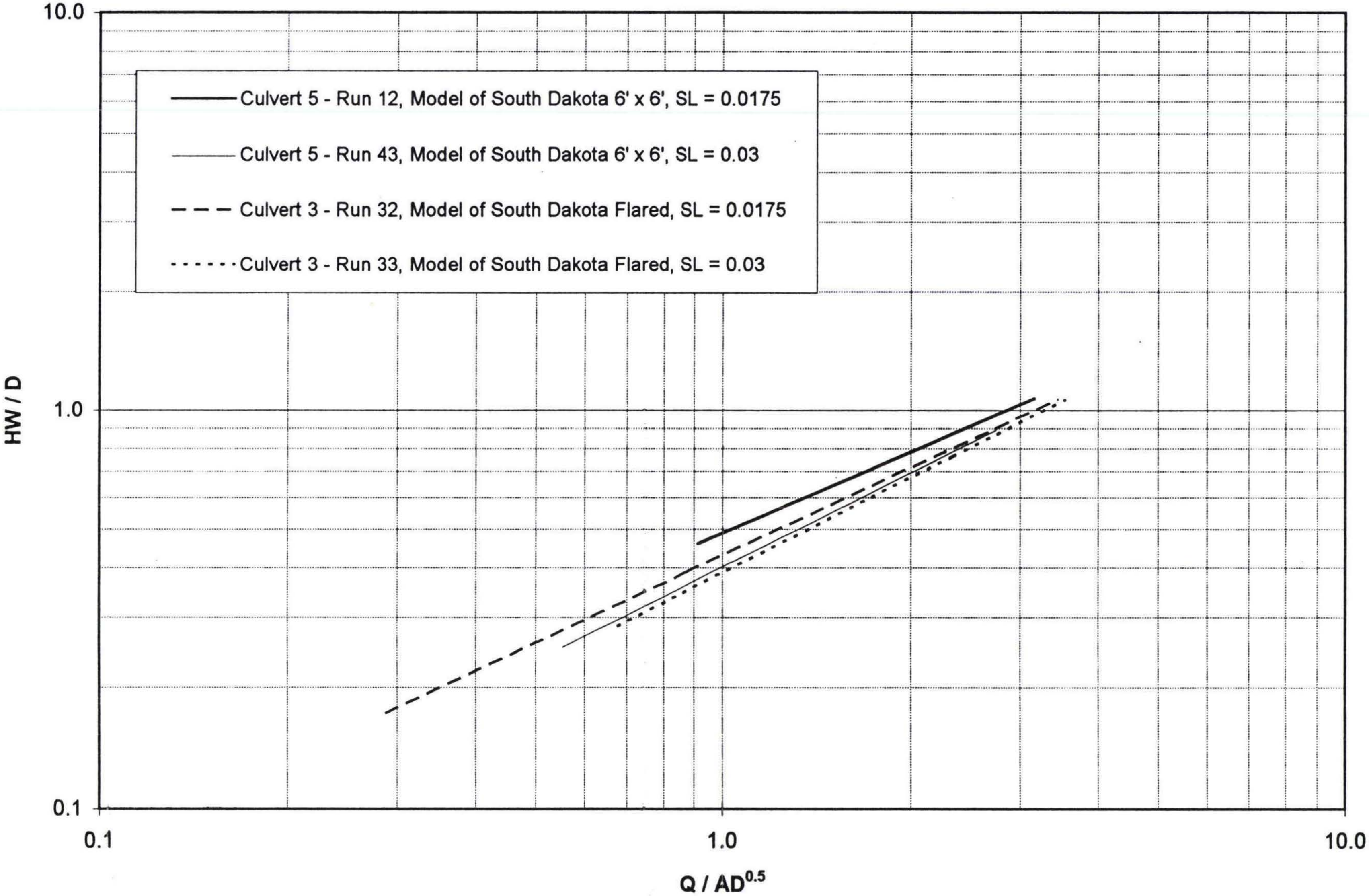

Figure 15a. Effect of barrel slope, unsubmerged conditions.

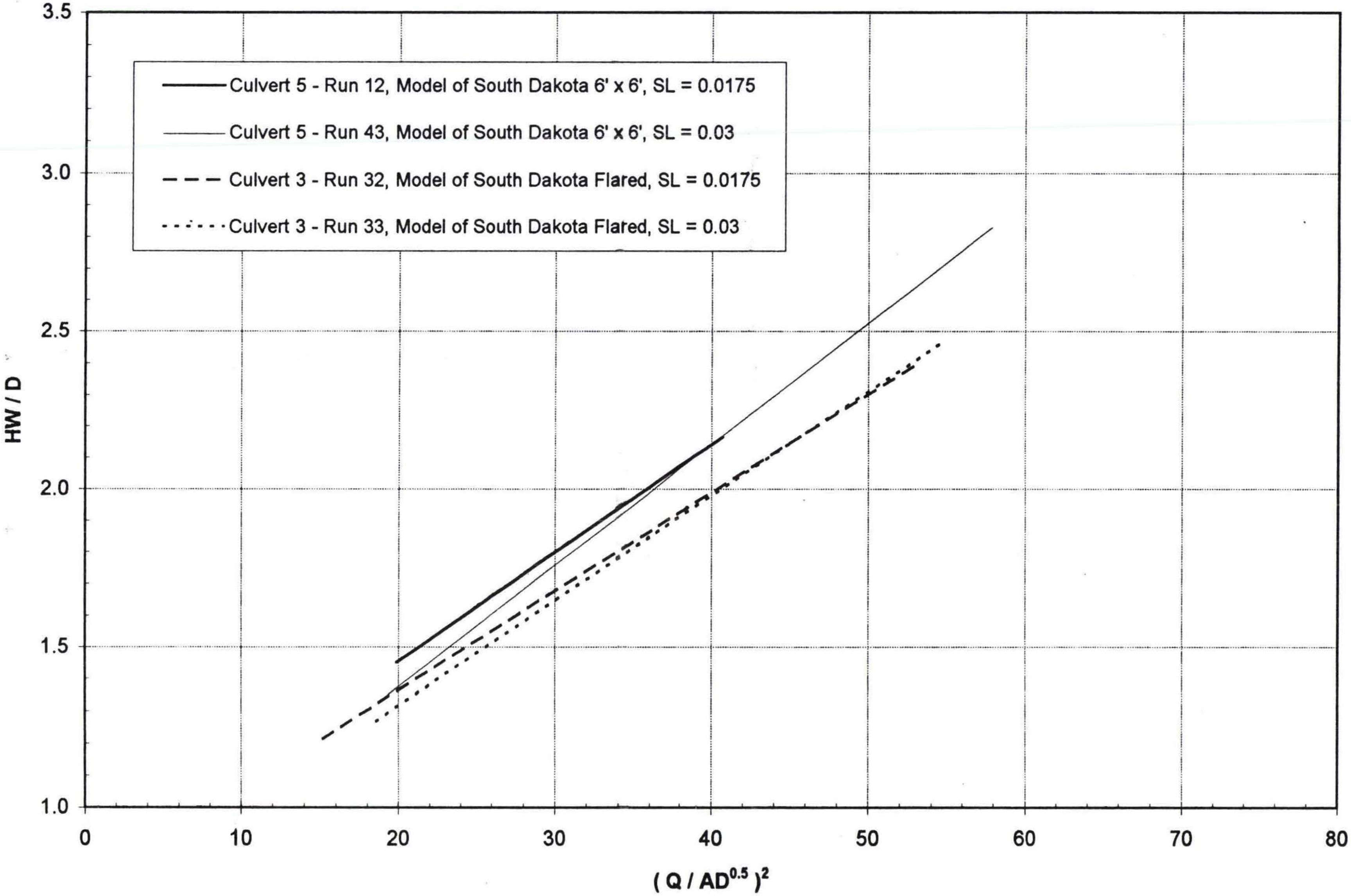

Figure 15b. Effect of barrel slope, submerged data.

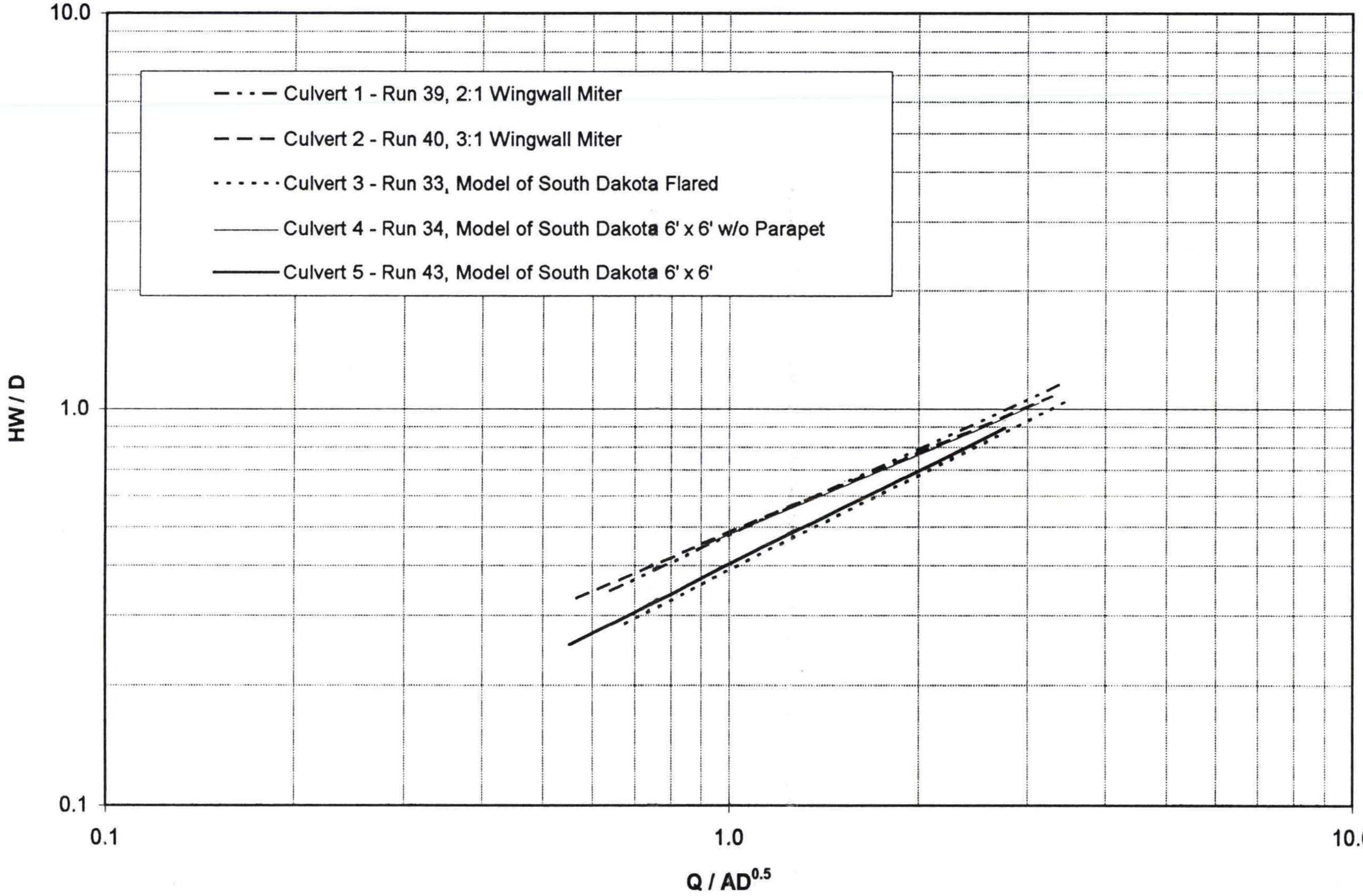

Figure 16a. Effect of configuration, unsubmerged conditions.

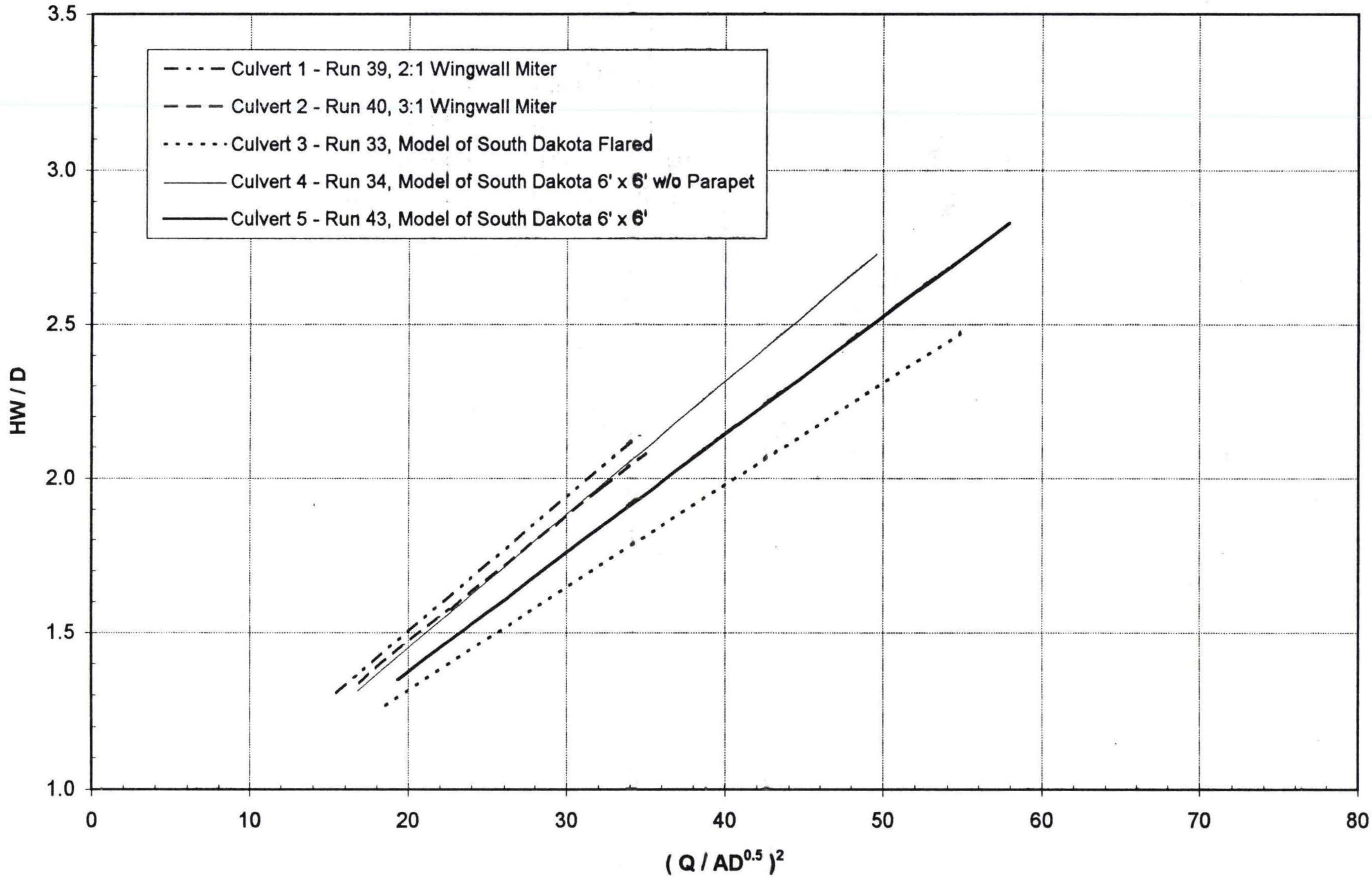

Figure 16b. Effect of configurations, submerged data.

REFERENCES

1. Normann, Jerome M., et al., *Hydraulic Design of Highway Culverts*, FHWA Hydraulic Design Series No. 5, FHWA-1P-85-15, Washington, DC, September 1985.

Date: 2/7/96
Run#: 39
Data Collected By: ERU
Inlet Description: Square Edge - 2/1

Barrel Slope: 3.0 percent
Barrel Type: Square Barrel
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.3164 ft^2
Culvert Height: 6.75 inches
Culvert Width: 6.75 inches

Unsubmerged Inlet Control Design Constants

Form (1)
K = 0.0090
M = 1.5432

Form (2)
K = 0.4767
M = 0.7252

Submerged Inlet Control Design Constants

c = 0.0435
Y = 0.6152

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

											Unsubmerged				Submerged	
											Form 1 Data		Form 2 Data			
											Y	X	Y	X	Y	X
Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	H_c (ft)	$Q/(AD^{0.5})$	H_w/D	H_c/D	$H_w/D-H_c/D-0.7S$	$\ln(H_w/D-H_c/D-0.7S)$	$\ln(Q/(AD^{0.5}))$	$\ln(H_w/D)$	$\ln(Q/(AD^{0.5}))$	$H_w/D-0.7S$	$(Q/(AD^{0.5}))^2$
0	0.0000	0.5625	0.0000	0.31640	0.0300	0.0000	0.0000	0.0000	0.0000	-0.02100						
1	0.1926	0.5625	0.1519	0.31640	0.0300	0.1969	0.6399	0.3424	0.3501	-0.02875	#NUM!	-0.44641	-1.07185	-0.44641		
2	0.4026	0.5625	0.4061	0.31640	0.0300	0.3795	1.7114	0.7157	0.6746	0.02007	-3.90832	0.53732	-0.33455	0.53732		
3	0.5337	0.5625	0.6109	0.31640	0.0300	0.4982	2.5746	0.9488	0.8857	0.04215	-3.16644	0.94568	-0.05254	0.94568		
4	0.6426	0.5625	0.8052	0.31640	0.0300	0.5989	3.3931	1.1425	1.0646	0.05684	-2.86753	1.22174	0.13319	1.22174		
5	0.7396	0.5625	0.9323	0.31640	0.0300		3.9288	1.3148							1.29381	15.43562
6	0.8870	0.5625	1.1089	0.31640	0.0300		4.6729	1.5768							1.55584	21.83612
7	1.0334	0.5625	1.2501	0.31640	0.0300		5.2682	1.8371							1.81612	27.75382
8	1.2064	0.5625	1.3949	0.31640	0.0300		5.8783	2.1446							2.12365	34.55496

Date: 2/9/96
Run#: 40
Data Collected By: ERU
Inlet Description: Square Edge - 3/1

Barrel Slope: 3.0 percent
Barrel Type: Square Barrel
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.3164 ft^2
Culvert Height: 6.75 inches
Culvert Width: 6.75 inches

Unsubmerged Inlet Control Design Constants

Form (2)
K = 0.4850
M = 0.6699

Submerged Inlet Control Design Constants

c = 0.0407
Y = 0.6311

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

								Unsubmerged Form 2 Data		Submerged	
								Y	X	Y	X
Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	$Q/(AD^{0.5})$	H_w/D	$\ln(H_w/D)$	$\ln(Q/(AD^{0.5}))$	$H_w/D-0.7S$	$(Q/(AD^{0.5}))^2$
0	0.0000	0.5625	0.0000	0.3164	0.0300	0.00000	0.00000				
1	0.1850	0.5625	0.1342	0.3164	0.0300	0.56551	0.32881	-1.11227	-0.57002		
2	0.3714	0.5625	0.3673	0.3164	0.0300	1.54772	0.66025	-0.41514	0.43678		
3	0.4894	0.5625	0.5686	0.3164	0.0300	2.39598	0.87008	-0.13917	0.87379		
4	0.6024	0.5625	0.7840	0.3164	0.0300	3.30378	1.07087	0.06847	1.19507		
5	0.7530	0.5625	0.9747	0.3164	0.0300	4.10740	1.33873			1.31773	16.87075
6	0.8842	0.5625	1.1301	0.3164	0.0300	4.76220	1.57189			1.55089	22.67859
7	1.0431	0.5625	1.2855	0.3164	0.0300	5.41701	1.85448			1.83348	29.34398
8	1.1677	0.5625	1.4055	0.3164	0.0300	5.92299	2.07597			2.05497	35.08184
9	1.1975	0.5625	1.7022	0.3164	0.0300	7.17307	2.12890			2.10790	51.45295
10	1.2574	0.5625	1.9529	0.3164	0.0300	8.22969	2.23535			2.21435	67.72772
11	1.5653	0.5625	2.1542	0.3164	0.0300	9.07795	2.78274			2.76174	82.40923
12	1.8811	0.5625	2.3626	0.3164	0.0300	9.95598	3.34412			3.32312	99.12162

Date: 1/29/96
Run#: 33
Data Collected By: ERU
Inlet Description: South Dakota Flared

Barrel Slope: 3.0 percent
Barrel Type: Square Barrel with Haunches
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.36306 ft^2
Culvert Height: 7.25 inches
Culvert Width: 7.25 inches

Unsubmerged Inlet Control Design Constants

Form (2)
K = 0.3896
M = 0.7940

Submerged Inlet Control Design Constants

c = 0.0331
Y = 0.6337

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

								Unsubmerged Form 2 Data		Submerged	
								Y	X	Y	X
Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	$Q/(AD^{0.5})$	H_w/D	$\ln(H_w/D)$	$\ln(Q/(AD^{0.5}))$	$H_w/D-0.7S$	$(Q/(AD^{0.5}))^2$
0	0.0000	0.6042	0.0000	0.36306	0.0300	0.00000	0.00000				
1	0.0634	0.6042	0.0706	0.36306	0.0300	0.25028	0.10494	-2.25435	-1.38517		
2	0.1695	0.6042	0.1907	0.36306	0.0300	0.67576	0.28061	-1.27078	-0.39192		
3	0.2456	0.6042	0.2966	0.36306	0.0300	1.05118	0.40646	-0.90026	0.04992		
4	0.3236	0.6042	0.4132	0.36306	0.0300	1.46415	0.53557	-0.62443	0.38127		
5	0.3791	0.6042	0.5050	0.36306	0.0300	1.78951	0.62748	-0.46605	0.58194		
6	0.4639	0.6042	0.6604	0.36306	0.0300	2.34013	0.76785	-0.26416	0.85021		
7	0.5543	0.6042	0.8334	0.36306	0.0300	2.95332	0.91746	-0.08615	1.08293		
8	0.6338	0.6042	1.0029	0.36306	0.0300	3.55400	1.04901	0.04785	1.26807		
9	0.7673	0.6042	1.2148	0.36306	0.0300	4.30484	1.27002			1.24902	18.53169
10	0.8901	0.6042	1.4055	0.36306	0.0300	4.98061	1.47326			1.45226	24.80643
11	1.0098	0.6042	1.5644	0.36306	0.0300	5.54374	1.67133			1.65033	30.73304
12	1.1786	0.6042	1.7587	0.36306	0.0300	6.23201	1.95086			1.92986	38.83799
13	1.3406	0.6042	1.9423	0.36306	0.0300	6.88275	2.21884			2.19784	47.37219
14	1.4948	0.6042	2.0906	0.36306	0.0300	7.40834	2.47407			2.45307	54.88346
15	1.7198	0.6042	2.3449	0.36306	0.0300	8.30935	2.84659			2.82559	69.04532

Date: 1/25/96
Run#: 32
Data Collected By: ERU
Inlet Description: South Dakota Flared

Barrel Slope: 1.75 percent
Barrel Type: Square Barrel with Haunches
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.36306 ft^2
Culvert Height: 7.25 inches
Culvert Width: 7.25 inches

Unsubmerged Inlet Control Design Constants

Form (2)
K = 0.4299
M = 0.7332

Submerged Inlet Control Design Constants

c = 0.0312
Y = 0.7288

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	$Q/(AD^{0.5})$	H_w/D	Unsubmerged Form 2 Data Y: $\ln(H_w/D)$	Unsubmerged Form 2 Data X: $\ln(Q/(AD^{0.5}))$	Submerged Y: $H_w/D-0.7S$	Submerged X: $(Q/(AD^{0.5}))^2$
0	0.0000	0.6042	0.0000	0.36306	0.0175	0.00000	0.00000				
1	0.1046	0.6042	0.0812	0.36306	0.0175	0.28782	0.17309	-1.75393	-1.24541		
2	0.2331	0.6042	0.2472	0.36306	0.0175	0.87599	0.38583	-0.95237	-0.13241		
3	0.3442	0.6042	0.4097	0.36306	0.0175	1.45163	0.56964	-0.56274	0.37269		
4	0.3716	0.6042	0.6392	0.36306	0.0175	2.26505	0.61512	-0.48593	0.81760		
5	0.5714	0.6042	0.8264	0.36306	0.0175	2.92830	0.94570	-0.05583	1.07442		
6	0.6439	0.6042	0.9747	0.36306	0.0175	3.45389	1.06584	0.06377	1.23950		
7	0.7585	0.6042	1.0983	0.36306	0.0175	3.89188	1.25550			1.24325	15.14673
8	0.8825	0.6042	1.3737	0.36306	0.0175	4.86798	1.46063			1.44838	23.69721
9	0.9926	0.6042	1.5538	0.36306	0.0175	5.50620	1.64295			1.63070	30.31820
10	1.1391	0.6042	1.7304	0.36306	0.0175	6.13190	1.88542			1.87317	37.60021
11	1.3255	0.6042	1.8999	0.36306	0.0175	6.73258	2.19386			2.18161	45.32759
12	1.4523	0.6042	2.0588	0.36306	0.0175	7.29571	2.40388			2.39163	53.22739
13	1.2624	0.6042	2.2142	0.36306	0.0175	7.84633	2.08946			2.07721	61.56490
14	1.3570	0.6042	2.3661	0.36306	0.0175	8.38444	2.24613			2.23388	70.29876
15	1.5217	0.6042	2.5886	0.36306	0.0175	9.17282	2.51873			2.50648	84.14068

Date: 1/30/96
Run#: 34
Data Collected By: ERU
Inlet Description: South Dakota

Barrel Slope: 3.0 percent
Barrel Type: Square Barrel with Haunches
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.29883 ft^2
Culvert Height: 6.75 inches
Culvert Width: 6.75 inches

Unsubmerged Inlet Control Design Constants

Form (2)
K = 0.4792
M = 0.6753

Submerged Inlet Control Design Constants

c = 0.0432
Y = 0.5671

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

								Unsubmerged Form 2 Data		Submerged	
								Y	X	Y	X
Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	$Q/(AD^{0.5})$	H_w/D	$\ln(H_w/D)$	$\ln(Q/(AD^{0.5}))$	$H_w/D-0.7S$	$(Q/(AD^{0.5}))^2$
0	0.0000	0.5625	0.0000	0.29883	0.0300	0.00000	0.00000				
1	0.0946	0.5625	0.0600	0.29883	0.0300	0.26787	0.16812	-1.78305	-1.31726		
2	0.2485	0.5625	0.1978	0.29883	0.0300	0.88239	0.44182	-0.81685	-0.12513		
3	0.3616	0.5625	0.3496	0.29883	0.0300	1.55993	0.64290	-0.44177	0.44464		
4	0.4290	0.5625	0.4450	0.29883	0.0300	1.98537	0.76261	-0.27100	0.68580		
5	0.4999	0.5625	0.5615	0.29883	0.0300	2.50534	0.88874	-0.11795	0.91843		
6	0.5854	0.5625	0.7028	0.29883	0.0300	3.13562	1.04068	0.03988	1.14283		
7	0.6506	0.5625	0.8264	0.29883	0.0300	3.68711	1.15661				
8	0.7397	0.5625	0.9182	0.29883	0.0300	4.09679	1.31511			1.29411	16.78369
9	0.8134	0.5625	0.9994	0.29883	0.0300	4.45920	1.44605			1.42505	19.88445
10	0.9383	0.5625	1.1442	0.29883	0.0300	5.10523	1.66812			1.64712	26.06338
11	1.1052	0.5625	1.2678	0.29883	0.0300	5.65672	1.96471			1.94371	31.99850
12	1.2664	0.5625	1.3879	0.29883	0.0300	6.19246	2.25139			2.23039	38.34651
13	1.5355	0.5625	1.5786	0.29883	0.0300	7.04333	2.72980			2.70880	49.60846
14	1.7773	0.5625	1.7657	0.29883	0.0300	7.87844	3.15967			3.13867	62.06986
15	2.0033	0.5625	1.9317	0.29883	0.0300	8.61902	3.56139			3.54039	74.28744

Date: 2/14/96
Run#: 43
Data Collected By: ERU
Inlet Description: South Dakota with Parapet

Barrel Slope: 3.00%
Barrel Type: Square Barrel with Haunches
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.29883 ft^2
Culvert Height: 6.75 inches
Culvert Width: 6.75 inches

Unsubmerged Inlet Control Design Constants

Form (2)
K = 0.4026
M = 0.7875

Submerged Inlet Control Design Constants

c = 0.0384
Y = 0.5853

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

								Unsubmerged Form 2 Data		Submerged	
								Y	X	Y	X
Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	$Q/(AD^{0.5})$	H_w/D	$\ln(H_w/D)$	$\ln(Q/(AD^{0.5}))$	$H_w/D-0.7S$	$(Q/(AD^{0.5}))^2$
0	0.0000	0.5625	0.0000	0.29883	0.0300	0.00000	0.00000				
1	0.1402	0.5625	0.1236	0.29883	0.0300	0.55149	0.24920	-1.38951	-0.59513		
2	0.3276	0.5625	0.3496	0.29883	0.0300	1.55993	0.58239	-0.54062	0.44464		
3	0.4124	0.5625	0.4732	0.29883	0.0300	2.11142	0.73316	-0.31039	0.74736		
4	0.5002	0.5625	0.6180	0.29883	0.0300	2.75745	0.88918	-0.11746	1.01431		
5	0.6246	0.5625	0.8264	0.29883	0.0300	3.68711	1.11038	0.10470	1.30484		
6	0.7477	0.5625	0.9853	0.29883	0.0300	4.39617	1.32925			1.30825	19.32632
7	0.8871	0.5625	1.1230	0.29883	0.0300	5.01069	1.57699			1.55599	25.10701
8	1.0723	0.5625	1.2961	0.29883	0.0300	5.78278	1.90639			1.88539	33.44051
9	1.2478	0.5625	1.4479	0.29883	0.0300	6.46032	2.21829			2.19729	41.73577
10	1.4225	0.5625	1.5892	0.29883	0.0300	7.09060	2.52887			2.50787	50.27658
11	1.5879	0.5625	1.7057	0.29883	0.0300	7.61058	2.82298			2.80198	57.92086
12	1.7776	0.5625	1.8540	0.29883	0.0300	8.27236	3.16025			3.13925	68.43202
13	1.4935	0.5625	2.0023	0.29883	0.0300	8.93415	2.65515			2.63415	79.81911
14	1.8697	0.5625	2.2743	0.29883	0.0300	10.14743	3.32386			3.30286	102.97042
15	2.1458	0.5625	2.5250	0.29883	0.0300	11.26617	3.81481			3.79381	126.92665

Date: 10/31/95
Run#: 12
Data Collected By: ELW
Inlet Description: South Dakota with Parapet

Barrel Slope: 1.75 percent
Barrel Type: Square Barrel with Haunches
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.29883 ft^2
Culvert Height: 6.75 inches
Culvert Width: 6.75 inches

Unsubmerged Inlet Control Design Constants

Form (2)
K = 0.4889
M = 0.6815

Submerged Inlet Control Design Constants

c = 0.0343
Y = 0.7571

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

								Unsubmerged Form 2 Data		Submerged	
								Y	X	Y	X
Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	$Q/(AD^{0.5})$	H_w/D	$\ln(H_w/D)$	$\ln(Q/(AD^{0.5}))$	$H_w/D-0.7S$	$(Q/(AD^{0.5}))^2$
0	0.0000	0.5625	0.0000	0.29883	0.0175	0.00000	0.00000				
1	0.1425	0.5625	0.0742	0.29883	0.0175	0.33089	0.25328	-1.37326	-1.10596		
2	0.2612	0.5625	0.2048	0.29883	0.0175	0.91390	0.46442	-0.76696	-0.09003		
3	0.3309	0.5625	0.2966	0.29883	0.0175	1.32358	0.58822	-0.53066	0.28034		
4	0.4226	0.5625	0.4308	0.29883	0.0175	1.92234	0.75124	-0.28603	0.65354		
5	0.5183	0.5625	0.5650	0.29883	0.0175	2.52110	0.92141	-0.08185	0.92470		
6	0.6083	0.5625	0.7098	0.29883	0.0175	3.16713	1.08151	0.07836	1.15283		
7	0.6931	0.5625	0.8440	0.29883	0.0175	3.76590	1.23214				
8	0.8114	0.5625	0.9994	0.29883	0.0175	4.45920	1.44240			1.43015	19.88445
9	0.9084	0.5625	1.1124	0.29883	0.0175	4.96342	1.61490			1.60265	24.63553
10	1.0030	0.5625	1.2184	0.29883	0.0175	5.43613	1.78303			1.77078	29.55146
11	1.1293	0.5625	1.3349	0.29883	0.0175	5.95610	2.00773			1.99548	35.47516
12	1.2069	0.5625	1.4302	0.29883	0.0175	6.38154	2.14567			2.13342	40.72403
13	1.1922	0.5625	1.5574	0.29883	0.0175	6.94879	2.11942			2.10717	48.28563
14	1.3515	0.5625	1.6916	0.29883	0.0175	7.54755	2.40260			2.39035	56.96548
15	1.5070	0.5625	1.8011	0.29883	0.0175	8.03601	2.67906			2.66681	64.57748
16	1.7571	0.5625	1.9988	0.29883	0.0175	8.91840	3.12365			3.11140	79.53780
17	2.0450	0.5625	2.2072	0.29883	0.0175	9.84805	3.63561			3.62336	96.98415
18	2.2083	0.5625	2.4579	0.29883	0.0175	10.96679	3.92593			3.91368	120.27053

Date: 2/12/95
Run#: 42
Data Collected By: ERU
Inlet Description: South Dakota - 9.0"

Barrel Slope: 3.0 percent
Barrel Type: Square Barrel with Haunches
Barrel Length: 20 feet
Barrel Cross Sectional Area: 0.55469 ft^2
Culvert Height: 9.0 inches
Culvert Width: 9.0 inches

Unsubmerged Inlet Control Design Constants

Form (2)
K = 0.4368
M = 0.7384

Submerged Inlet Control Design Constants

c = 0.0506
Y = 0.5343

Definitions:

H_w = Headwater depth above inlet control section invert, ft
D = Interior height of culvert barrel, ft
H_c = Specific head at critical depth ($d_c + V_c^2/2g$), ft
Q = Discharge, ft^3/s
A = Full cross sectional area of culvert barrel, ft^2
S = Culvert barrel slope, ft/ft
K,M,c,Y = Constants

								Unsubmerged Form 2 Data		Submerged	
								Y	X	Y	X
Reading Number	H_w (ft)	D (ft)	Q (ft^3/s)	A (ft^2)	S (ft/ft)	$Q/(AD^{0.5})$	H_w/D	$\ln(H_w/D)$	$\ln(Q/(AD^{0.5}))$	$H_w/D-0.7S$	$(Q/(AD^{0.5}))^2$
0	0.0000	0.7500	0.0000	0.55469	0.0300	0.00000	0.00000				
1	0.1446	0.7500	0.1836	0.55469	0.0300	0.38228	0.19280	-1.64608	-0.96161		
2	0.2743	0.7500	0.3814	0.55469	0.0300	0.79396	0.36570	-1.00593	-0.23072		
3	0.3620	0.7500	0.5474	0.55469	0.0300	1.13948	0.48261	-0.72854	0.13057		
4	0.4624	0.7500	0.7628	0.55469	0.0300	1.58792	0.61658	-0.48357	0.46242		
5	0.5444	0.7500	0.9500	0.55469	0.0300	1.97755	0.72583	-0.32044	0.68186		
6	0.6022	0.7500	1.0842	0.55469	0.0300	2.25690	0.80293	-0.21949	0.81399		
7	0.6706	0.7500	1.2643	0.55469	0.0300	2.63183	0.89414	-0.11189	0.96768		
8	0.7196	0.7500	1.4126	0.55469	0.0300	2.94059	0.95943	-0.04142	1.07861		
9	0.7817	0.7500	1.5680	0.55469	0.0300	3.26406	1.04232	0.04145	1.18297		
10	0.8761	0.7500	1.7234	0.55469	0.0300	3.58752	1.16809	0.15537	1.27746		
11	0.9674	0.7500	1.8681	0.55469	0.0300	3.88893	1.28981			1.26881	15.12380
12	1.0815	0.7500	2.0165	0.55469	0.0300	4.19770	1.44204			1.42104	17.62065
13	1.1713	0.7500	2.1330	0.55469	0.0300	4.44029	1.56168			1.54068	19.71622
14	1.2787	0.7500	2.2990	0.55469	0.0300	4.78581	1.70494			1.68394	22.90402
15	1.4002	0.7500	2.4438	0.55469	0.0300	5.08723	1.86691			1.84591	25.87986
16	1.5758	0.7500	2.6451	0.55469	0.0300	5.50626	2.10105			2.08005	30.31889
17	1.7774	0.7500	2.8817	0.55469	0.0300	5.99881	2.36986			2.34886	35.98571
18	2.0542	0.7500	3.2348	0.55469	0.0300	6.73396	2.73895			2.71795	45.34618

Date: 10/17/95
Run#: 5
Data Collected By: ELW
Inlet Description: Square Edge w/o parapet - 2:1

Barrel Slope: 0.50%
Barrel Type: Square
Barrel Length: 20ft = 6.096m
Barrel Cross Sectional Area: 0.31641 ft^2
Culvert Height: 171.45 mm = 6.75"
Culvert Width: 171.45 mm = 6.75"

Reading #	Headbox EGL	Projected EGL	He	Ke = $2g/V^2$*He
1*	1.0378	1.0412	-0.0034	-1.3670
2	1.1366	1.1202	0.0165	0.5921
3	1.2528	1.2137	0.0391	0.6306
4	1.3378	1.2912	0.0466	0.4801
5	1.4610	1.3748	0.0862	0.6592
6	1.5634	1.4508	0.1126	0.6732
7	1.7506	1.5811	0.1695	0.7537
8	1.9177	1.6973	0.2204	0.7769
9	2.0868	1.8209	0.2659	0.7719
10	2.2904	1.9741	0.3163	0.7595
11	2.4802	2.1103	0.3698	0.7587
12	2.7632	2.3360	0.4273	0.7094

Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)
1	0.1271	0.00251	1	1.0407		
			2	1.0413		
			3	1.0253		
			4	1.0440		
			5	1.0381	2.00	1.0406
			6	1.0384	4.00	1.0409
			7	1.0384	6.00	1.0409
			8	1.0377	7.67	1.0402
			9	1.0374	10.00	1.0399
			10	1.0371	12.00	1.0396
			11	1.0367	14.00	1.0393
			12	1.0361	15.67	1.0386
			13	1.0367	18.00	1.0393
3	0.6321	0.0620	1	1.2546		
			2	1.2595		
			3	1.2421		
			4	1.2549		
			5	1.1490	2.00	1.2109
			6	1.1437	4.00	1.2057
			7	1.1365	6.00	1.1985
			8	1.1280	7.67	1.1899
			9	1.1230	10.00	1.1850
			10	1.1211	12.00	1.1830
			11	1.1122	14.00	1.1742
			12	1.1122	15.67	1.1742
			13	1.1093	18.00	1.1712
5	0.9182	0.1308	1	1.4633		
			2	1.4656		
			3	1.4495		
			4	1.4656		
			5	1.2365	2.00	1.3673
			6	1.2234	4.00	1.3542
			7	1.2162	6.00	1.3470
			8	1.1962	7.67	1.3270
			9	1.1778	10.00	1.3086
			10	1.1785	12.00	1.3092
			11	1.1617	14.00	1.2925
			12	1.1617	15.67	1.2925
			13	1.1493	18.00	1.2800
7	1.2042	0.2249	1	1.7556		
			2	1.7546		
			3	1.7379		
			4	1.7543		
			5	1.3412	2.00	1.5661
			6	1.3192	4.00	1.5441
			7	1.3031	6.00	1.5281
			8	1.2700	7.67	1.4949
			9	1.2467	10.00	1.4716
			10	1.2316	12.00	1.4565
			11	1.2070	14.00	1.4319
			12	1.2018	15.67	1.4267
			13	1.1870	18.00	1.4119
9	1.4903	0.3445	1	2.0915		
			2	2.0919		
			3	2.0705		
			4	2.0932		
			5	1.4544	2.00	1.7989
			6	1.4259	4.00	1.7703
			7	1.3963	6.00	1.7408
			8	1.3465	7.67	1.6909
			9	1.3091	10.00	1.6535
			10	1.2943	12.00	1.6388
			11	1.2579	14.00	1.6023
			12	1.2480	15.67	1.5925
			13	1.2254	18.00	1.5699
11	1.7728	0.4875	1	2.4823		
			2	2.4846		
			3	2.4669		
			4	2.4869		
			5	1.5971	2.00	2.0846
			6	1.5387	4.00	2.0262
			7	1.5013	6.00	1.9888
			8	1.4344	7.67	1.9218
			9	1.3862	10.00	1.8736
			10	1.3579	12.00	1.8454
			11	1.2959	14.00	1.7834
			12	1.2943	15.67	1.7817
			13	1.2510	18.00	1.7384

Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)
2	0.4238	0.02785	1	1.1411		
			2	1.1404		
			3	1.1230		
			4	1.1421		
			5	1.0896	2.00	1.1174
			6	1.0879	4.00	1.1158
			7	1.0863	6.00	1.1141
			8	1.0830	7.67	1.1109
			9	1.0774	10.00	1.1053
			10	1.0771	12.00	1.1050
			11	1.0732	14.00	1.1010
			12	1.0741	15.67	1.1020
			13	1.0709	18.00	1.0987
4	0.7910	0.0971	1	1.3415		
			2	1.3428		
			3	1.3258		
			4	1.3409		
			5	1.1890	2.00	1.2860
			6	1.1795	4.00	1.2765
			7	1.1706	6.00	1.2677
			8	1.1591	7.67	1.2562
			9	1.1467	10.00	1.2437
			10	1.1437	12.00	1.2408
			11	1.1312	14.00	1.2283
			12	1.1329	15.67	1.2299
			13	1.1237	18.00	1.2207
6	1.0383	0.1672	1	1.5673		
			2	1.5705		
			3	1.5512		
			4	1.5646		
			5	1.2733	2.00	1.4405
			6	1.2582	4.00	1.4254
			7	1.2421	6.00	1.4093
			8	1.2283	7.67	1.3955
			9	1.2064	10.00	1.3736
			10	1.1972	12.00	1.3644
			11	1.1765	14.00	1.3437
			12	1.1801	15.67	1.3473
			13	1.1631	18.00	1.3303
8	1.3526	0.2837	1	1.9222		
			2	1.9226		
			3	1.9032		
			4	1.9229		
			5	1.3917	2.00	1.6755
			6	1.3727	4.00	1.6564
			7	1.3524	6.00	1.6361
			8	1.2986	7.67	1.5823
			9	1.2753	10.00	1.5590
			10	1.2664	12.00	1.5501
			11	1.2290	14.00	1.5127
			12	1.2178	15.67	1.5016
			13	1.2051	18.00	1.4888
10	1.6386	0.4164	1	2.2890		
			2	2.2972		
			3	2.2782		
			4	2.2972		
			5	1.5279	2.00	1.9443
			6	1.4951	4.00	1.9115
			7	1.4524	6.00	1.8689
			8	1.3894	7.67	1.8059
			9	1.3510	10.00	1.7675
			10	1.3225	12.00	1.7390
			11	1.2756	14.00	1.6920
			12	1.2710	15.67	1.6874
			13	1.2323	18.00	1.6487
12	1.9706	0.6023	1	2.7644		
			2	2.7723		
			3	2.7487		
			4	2.7674		
			5	1.6929	2.00	2.2952
			6	1.6375	4.00	2.2397
			7	1.5915	6.00	2.1938
			8	1.5049	7.67	2.1072
			9	1.4334	10.00	2.0357
			10	1.3967	12.00	1.9989
			11	1.3238	14.00	1.9261
			12	1.3304	15.67	1.9327
			13	1.2779	18.00	1.8802

Date:	10/19/95	
Run#:	6	
Data Collected By:	ELW	
Inlet Description:	South Dakota w/o parapet- 2:1	
Barrel Slope:	0.50%	
Barrel Type:	Square	
Barrel Length:	20ft = 6.096m	
Barrel Cross Sectional Area:		0.29883 ft^2
Culvert Height:	171.45 mm = 6.75"	
Culvert Width:	171.45 mm = 6.75"	

Reading #	Headbox EGL	Projected EGL	He
1*	1.0317	1.0440	-0.0123
2*	1.1197	1.1224	-0.0028
3*	1.2183	1.2221	-0.0039
4	1.3433	1.3104	0.0328
5	1.4444	1.3943	0.0501
6	1.5758	1.5087	0.0671
7	1.6807	1.5951	0.0856
8	1.8173	1.6867	0.1307
9	1.9240	1.7560	0.1680
10	2.0353	1.8462	0.1890
11	2.1275	1.9246	0.2029
12	2.3221	2.0689	0.2532
13	2.4883	2.2212	0.2670
14	2.6997	2.4023	0.2974

Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)	Reading #			Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)
1	0.1766	0.00542	1	1.0443			2	0.3955	0.02720	1	1.1299		
			2	1.0446						2	1.1332		
			3	0.9918						3	1.0823		
			4	1.0459						4	1.1332		
			5	1.0377	2.00	1.0432				5	1.0925	2.00	1.1197
			6	1.0371	4.00	1.0425				6	1.0909	4.00	1.1181
			7	1.0374	6.00	1.0428				7	1.0906	6.00	1.1178
			8	1.0381	7.67	1.0435				8	1.0863	7.67	1.1135
			9	1.0364	10.00	1.0418				9	1.0820	10.00	1.1092
			10	1.0351	12.00	1.0405				10	1.0810	12.00	1.1082
			11	1.0344	14.00	1.0399				11	1.0787	14.00	1.1059
			12	1.0344	15.67	1.0399				12	1.0774	15.67	1.1046
			13	1.0348	18.00	1.0402				13	1.0758	18.00	1.1030
3	0.6321	0.0695	1	1.2274			4	0.7663	0.1021	1	1.3547		
			2	1.2329						2	1.3553		
			3	1.1831						3	1.3071		
			4	1.2297						4	1.3560		
			5	1.1496	2.00	1.2191				5	1.2031	2.00	1.3052
			6	1.1417	4.00	1.2112				6	1.1916	4.00	1.2937
			7	1.1381	6.00	1.2076				7	1.1864	6.00	1.2885
			8	1.1299	7.67	1.1994				8	1.1722	7.67	1.2744
			9	1.1237	10.00	1.1932				9	1.1585	10.00	1.2606
			10	1.1184	12.00	1.1879				10	1.1611	12.00	1.2632
			11	1.1138	14.00	1.1833				11	1.1480	14.00	1.2501
			12	1.1112	15.67	1.1807				12	1.1447	15.67	1.2468
			13	1.1073	18.00	1.1768				13	1.1352	18.00	1.2373
5	0.9182	0.1466	1	1.4573			6	1.0665	0.1978	1	1.5879		
			2	1.4580						2	1.5879		
			3	1.4081						3	1.5374		
			4	1.4541						4	1.5899		
			5	1.2398	2.00	1.3864				5	1.2972	2.00	1.4950
			6	1.2326	4.00	1.3792				6	1.2851	4.00	1.4829
			7	1.2162	6.00	1.3628				7	1.2654	6.00	1.4632
			8	1.2011	7.67	1.3477				8	1.2448	7.67	1.4425
			9	1.1841	10.00	1.3307				9	1.2205	10.00	1.4183
			10	1.1834	12.00	1.3300				10	1.2106	12.00	1.4084
			11	1.1657	14.00	1.3123				11	1.1877	14.00	1.3854
			12	1.1709	15.67	1.3175				12	1.1883	15.67	1.3861
			13	1.1555	18.00	1.3021				13	1.1759	18.00	1.3736
7	1.1724	0.2390	1	1.6923			8	1.2819	0.2858	1	1.8284		
			2	1.6913						2	1.8304		
			3	1.6440						3	1.7805		
			4	1.6952						4	1.8301		
			5	1.3428	2.00	1.5819				5	1.3757	2.00	1.6614
			6	1.3202	4.00	1.5592				6	1.3507	4.00	1.6365
			7	1.3045	6.00	1.5435				7	1.3366	6.00	1.6224
			8	1.2657	7.67	1.5048				8	1.2972	7.67	1.5830
			9	1.2438	10.00	1.4828				9	1.2717	10.00	1.5574
			10	1.2339	12.00	1.4730				10	1.2549	12.00	1.5407
			11	1.2096	14.00	1.4487				11	1.2287	14.00	1.5144
			12	1.2011	15.67	1.4401				12	1.2169	15.67	1.5026
			13	1.1883	18.00	1.4274				13	1.1719	18.00	1.4577
9	1.3631	0.3231	1	1.9370			10	1.4585	0.3699	1	2.0502		
			2	1.9367						2	2.0509		
			3	1.8862						3	1.9918		
			4	1.9364						4	2.0482		
			5	1.4117	2.00	1.7349				5	1.4495	2.00	1.8194
			6	1.3898	4.00	1.7129				6	1.4278	4.00	1.7977
			7	1.3688	6.00	1.6919				7	1.4032	6.00	1.7731
			8	1.3219	7.67	1.6450				8	1.3507	7.67	1.7206
			9	1.2913	10.00	1.6144				9	1.3146	10.00	1.6845
			10	1.2753	12.00	1.5984				10	1.2907	12.00	1.6606
			11	1.2457	14.00	1.5688				11	1.2543	14.00	1.6242
			12	1.2428	15.67	1.5659				12	1.2569	15.67	1.6268
			13	1.2169	18.00	1.5400				13	1.2297	18.00	1.5996
11	1.5327	0.4085	1	2.1411			12	1.6774	0.4893	1	2.3350		
			2	2.1421						2	2.3369		
			3	2.0843						3	2.2785		
			4	2.1427						4	2.3379		
			5	1.4925	2.00	1.9009				5	1.5469	2.00	2.0362
			6	1.4564	4.00	1.8648				6	1.5194	4.00	2.0086
			7	1.4324	6.00	1.8409				7	1.4780	6.00	1.9673
			8	1.3740	7.67	1.7825				8	1.4140	7.67	1.9033
			9	1.3337	10.00	1.7421				9	1.3678	10.00	1.8571
			10	1.3117	12.00	1.7201				10	1.3432	12.00	1.8325
			11	1.2720	14.00	1.6804				11	1.3009	14.00	1.7901
			12	1.2772	15.67	1.6857				12	1.2976	15.67	1.7869
			13	1.2349	18.00	1.6434				13	1.2533	18.00	1.7426

Date:	11/2/95	
Run#:	14	
Data Collected By:	ELW	
Inlet Description:	South Dakota w parapet- 2:1	
Barrel Slope:	0.50%	
Barrel Type:	Square	
Barrel Length:	20ft = 6.096m	
Barrel Cross Sectional Area:		0.29883 ft^2
Culvert Height:	171.45 mm = 6.75"	
Culvert Width:	171.45 mm = 6.75"	

Reading #	Headbox EGL	Projected EGL	He	Ke = $2g/V^2*He$
1*	1.1301	1.1290	0.0011	0.1820
2	1.1973	1.1913	0.0060	0.2658
3	1.2648	1.2519	0.0129	0.3031
4	1.3717	1.3442	0.0275	0.3372
5	1.4746	1.4332	0.0414	0.3398
6	1.5863	1.5281	0.0581	0.3494
7	1.6800	1.6039	0.0761	0.3676
8	1.7881	1.6905	0.0975	0.3914
9	1.5304	1.2737	0.2567	0.8741
10	2.0268	1.8846	0.1422	0.4099
11	2.1293	1.9704	0.1589	0.4057
12	2.3067	2.1243	0.1824	0.3840
13	2.4881	2.2715	0.2166	0.3900
14	2.7644	2.5215	0.2429	0.3521

Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)
1	0.1872	0.00609	1	1.1286		
			2	1.1289		
			3	1.1319		
			4	1.1309		
			5	1.1227	2.00	1.1288
			6	1.1227	4.00	1.1288
			7	1.1214	6.00	1.1275
			8	1.1204	7.67	1.1265
			9	1.1184	10.00	1.1245
			10	1.1207	12.00	1.1268
			11	1.1184	14.00	1.1245
			12	1.1198	15.67	1.1258
			13	1.1188	18.00	1.1249
2	0.3602	0.02256	1	1.1982		
			2	1.1972		
			3	1.1982		
			4	1.1959		
			5	1.1667	2.00	1.1892
			6	1.1637	4.00	1.1863
			7	1.1624	6.00	1.1850
			8	1.1611	7.67	1.1837
			9	1.1562	10.00	1.1787
			10	1.1555	12.00	1.1781
			11	1.1503	14.00	1.1728
			12	1.1529	15.67	1.1754
			13	1.1483	18.00	1.1709
3	0.4944	0.0425	1	1.2635		
			2	1.2621		
			3	1.2661		
			4	1.2674		
			5	1.2067	2.00	1.2492
			6	1.2005	4.00	1.2430
			7	1.1955	6.00	1.2380
			8	1.1909	7.67	1.2334
			9	1.1854	10.00	1.2279
			10	1.1837	12.00	1.2262
			11	1.1719	14.00	1.2144
			12	1.1755	15.67	1.2180
			13	1.1713	18.00	1.2138
4	0.6851	0.0816	1	1.3675		
			2	1.3743		
			3	1.3753		
			4	1.3698		
			5	1.2572	2.00	1.3388
			6	1.2480	4.00	1.3296
			7	1.2428	6.00	1.3244
			8	1.2306	7.67	1.3123
			9	1.2221	10.00	1.3037
			10	1.2198	12.00	1.3014
			11	1.1985	14.00	1.2801
			12	1.2064	15.67	1.2880
			13	1.2008	18.00	1.2824
5	0.8370	0.1218	1	1.4734		
			2	1.4741		
			3	1.4754		
			4	1.4754		
			5	1.3035	2.00	1.4253
			6	1.2910	4.00	1.4128
			7	1.2808	6.00	1.4026
			8	1.2684	7.67	1.3902
			9	1.2552	10.00	1.3771
			10	1.2503	12.00	1.3721
			11	1.2198	14.00	1.3416
			12	1.2339	15.67	1.3557
			13	1.2221	18.00	1.3439
6	0.9782	0.1664	1	1.5840		
			2	1.5869		
			3	1.5879		
			4	1.5863		
			5	1.3533	2.00	1.5197
			6	1.3337	4.00	1.5001
			7	1.3225	6.00	1.4889
			8	1.3002	7.67	1.4666
			9	1.2828	10.00	1.4492
			10	1.2792	12.00	1.4456
			11	1.2382	14.00	1.4046
			12	1.2536	15.67	1.4200
			13	1.2444	18.00	1.4108
7	1.0912	0.2071	1	1.6808		
			2	1.6775		
			3	1.6791		
			4	1.6827		
			5	1.3911	2.00	1.5981
			6	1.3691	4.00	1.5762
			7	1.3533	6.00	1.5604
			8	1.3264	7.67	1.5335
			9	1.3074	10.00	1.5145
			10	1.2999	12.00	1.5069
			11	1.2759	14.00	1.4830
			12	1.2730	15.67	1.4800
			13	1.2736	18.00	1.4807
8	1.1972	0.2492	1	1.7838		
			2	1.7884		
			3	1.7900		
			4	1.7900		
			5	1.4259	2.00	1.6751
			6	1.4052	4.00	1.6544
			7	1.3868	6.00	1.6360
			8	1.3579	7.67	1.6072
			9	1.3268	10.00	1.5760
			10	1.3153	12.00	1.5645
			11	1.2949	14.00	1.5442
			12	1.2917	15.67	1.5409
			13	1.2671	18.00	1.5163
9	1.2996	0.2937	1	1.9022		
			2	1.4055		
			3	1.4068		
			4	1.4072		
			5	0.9767	2.00	1.2704
			6	0.9596	4.00	1.2533
			7	0.9455	6.00	1.2392
			8	0.9144	7.67	1.2080
			9	0.9006	10.00	1.1943
			10	0.9006	12.00	1.1943
			11	0.8750	14.00	1.1687
			12	0.8809	15.67	1.1746
			13	0.8770	18.00	1.1706
10	1.4126	0.3470	1	2.0269		
			2	2.0266		
			3	2.0259		
			4	2.0279		
			5	1.5177	2.00	1.8647
			6	1.4862	4.00	1.8332
			7	1.4606	6.00	1.8076
			8	1.4167	7.67	1.7636
			9	1.3780	10.00	1.7249
			10	1.3678	12.00	1.7148
			11	1.3278	14.00	1.6747
			12	1.3212	15.67	1.6682
			13	1.2972	18.00	1.6442
11	1.5009	0.3917	1	2.1247		
			2	2.1286		
			3	2.1319		
			4	2.1319		
			5	1.5614	2.00	1.9531
			6	1.5194	4.00	1.9111
			7	1.4898	6.00	1.8815
			8	1.4393	7.67	1.8310
			9	1.3983	10.00	1.7900
			10	1.3878	12.00	1.7795
			11	1.3448	14.00	1.7365
			12	1.3379	15.67	1.7296
			13	1.3077	18.00	1.6994
12	1.6527	0.4750	1	2.2995		
			2	2.3061		
			3	2.3094		
			4	2.3117		
			5	1.6217	2.00	2.0967
			6	1.5820	4.00	2.0570
			7	1.5417	6.00	2.0166
			8	1.4843	7.67	1.9592
			9	1.4370	10.00	1.9120
			10	1.4160	12.00	1.8910
			11	1.3537	14.00	1.8286
			12	1.3527	15.67	1.8277
			13	1.3274	18.00	1.8024

Date:	11/15/95
Run#:	20
Data Collected By:	ELW
Inlet Description:	Square Edge - 3:1
Barrel Slope:	0.50%
Barrel Type:	Square
Barrel Length:	20ft = 6.096m
Barrel Cross Sectional Area:	0.3164 ft^2
Culvert Height:	171.45 mm = 6.75"
Culvert Width:	171.45 mm = 6.75"

Reading #	Headbox EGL	Projected EGL	He	$Ke = 2g/V^2{*}He$
1	1.0193	1.0160	0.0033	0.3985
2	1.1007	1.0887	0.0121	0.4327
3	1.2002	1.1695	0.0307	0.5125
4	1.2771	1.2293	0.0479	0.5891
5	1.3899	1.3211	0.0688	0.5645
6	1.5084	1.4138	0.0946	0.5697
7	1.6106	1.4902	0.1203	0.5890
8	1.7146	1.5646	0.1501	0.6157
9	1.8088	1.6276	0.1812	0.6626
10	1.9324	1.7125	0.2200	0.6932
11	2.0637	1.8186	0.2451	0.6606
12	2.1932	1.9065	0.2867	0.6738
13	2.3600	2.0283	0.3317	0.6750
14	2.5296	2.1633	0.3663	0.6519

Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)	Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)
1	0.2295	0.00817	1	1.0177			2	0.4238	0.02786	1	1.0997		
			2	1.0184						2	1.0991		
			3	1.0197						3	1.1030		
			4	1.0213						4	1.1010		
			5	1.0085	2.00	1.0167				5	1.0587	2.00	1.0866
			6	1.0052	4.00	1.0134				6	1.0558	4.00	1.0836
			7	1.0056	6.00	1.0138				7	1.0538	6.00	1.0817
			8	1.0052	7.67	1.0134				8	1.0479	7.67	1.0758
			9	1.0026	10.00	1.0108				9	1.0463	10.00	1.0741
			10	1.0020	12.00	1.0101				10	1.0449	12.00	1.0728
			11	1.0030	14.00	1.0111				11	1.0387	14.00	1.0666
			12	1.0016	15.67	1.0098				12	1.0384	15.67	1.0662
			13	1.0016	18.00	1.0098				13	1.0384	18.00	1.0662
3	0.6215	0.0599	1	1.1972			4	0.7240	0.0813	1	1.2749		
			2	1.2034						2	1.2766		
			3	1.2031						3	1.2792		
			4	1.1972						4	1.2779		
			5	1.1066	2.00	1.1665				5	1.1460	2.00	1.2273
			6	1.1001	4.00	1.1600				6	1.1368	4.00	1.2181
			7	1.0961	6.00	1.1560				7	1.1286	6.00	1.2099
			8	1.0892	7.67	1.1492				8	1.1211	7.67	1.2024
			9	1.0840	10.00	1.1439				9	1.1122	10.00	1.1935
			10	1.0833	12.00	1.1433				10	1.1099	12.00	1.1912
			11	1.0748	14.00	1.1347				11	1.1027	14.00	1.1840
			12	1.0745	15.67	1.1344				12	1.1017	15.67	1.1830
			13	1.0679	18.00	1.1278				13	1.0955	18.00	1.1768
5	0.8864	0.1219	1	1.3901			6	1.0347	0.1661	1	1.5075		
			2	1.3891						2	1.5082		
			3	1.3911						3	1.5098		
			4	1.3894						4	1.5082		
			5	1.1923	2.00	1.3141				5	1.2356	2.00	1.4016
			6	1.1831	4.00	1.3049				6	1.2254	4.00	1.3915
			7	1.1726	6.00	1.2944				7	1.2149	6.00	1.3810
			8	1.1611	7.67	1.2830				8	1.1903	7.67	1.3564
			9	1.1450	10.00	1.2669				9	1.1791	10.00	1.3452
			10	1.1450	12.00	1.2669				10	1.1699	12.00	1.3360
			11	1.1293	14.00	1.2511				11	1.1496	14.00	1.3157
			12	1.1283	15.67	1.2502				12	1.1522	15.67	1.3183
			13	1.1198	18.00	1.2416				13	1.1352	18.00	1.3012
7	1.1477	0.2043	1	1.6089			8	1.2537	0.2438	1	1.7126		
			2	1.6096						2	1.7123		
			3	1.6112						3	1.7142		
			4	1.6125						4	1.7195		
			5	1.2795	2.00	1.4839				5	1.3123	2.00	1.5561
			6	1.2549	4.00	1.4592				6	1.2887	4.00	1.5325
			7	1.2415	6.00	1.4458				7	1.2651	6.00	1.5089
			8	1.2218	7.67	1.4261				8	1.2451	7.67	1.4889
			9	1.1988	10.00	1.4031				9	1.2198	10.00	1.4636
			10	1.1880	12.00	1.3923				10	1.2100	12.00	1.4538
			11	1.1667	14.00	1.3710				11	1.1841	14.00	1.4278
			12	1.1699	15.67	1.3743				12	1.1814	15.67	1.4252
			13	1.1572	18.00	1.3615				13	1.1719	18.00	1.4157
9	1.3278	0.2735	1	1.8068			10	1.4302	0.3173	1	1.9321		
			2	1.8061						2	1.9318		
			3	1.8114						3	1.9344		
			4	1.8110						4	1.9314		
			5	1.3379	2.00	1.6114				5	1.3770	2.00	1.6943
			6	1.3182	4.00	1.5917				6	1.3501	4.00	1.6674
			7	1.2989	6.00	1.5724				7	1.3258	6.00	1.6431
			8	1.2631	7.67	1.5366				8	1.2936	7.67	1.6109
			9	1.2395	10.00	1.5130				9	1.2618	10.00	1.5791
			10	1.2241	12.00	1.4976				10	1.2461	12.00	1.5634
			11	1.1985	14.00	1.4720				11	1.2116	14.00	1.5289
			12	1.1965	15.67	1.4700				12	1.2073	15.67	1.5246
			13	1.1775	18.00	1.4510				13	1.1867	18.00	1.5040
11	1.5468	0.3711	1	2.0591			12	1.6563	0.4255	1	2.1886		
			2	2.0630						2	2.1969		
			3	2.0653						3	2.1952		
			4	2.0676						4	2.1923		
			5	1.4206	2.00	1.7917				5	1.4501	2.00	1.8756
			6	1.4029	4.00	1.7740				6	1.4298	4.00	1.8553
			7	1.3717	6.00	1.7428				7	1.3947	6.00	1.8202
			8	1.3327	7.67	1.7038				8	1.3560	7.67	1.7815
			9	1.2946	10.00	1.6657				9	1.3077	10.00	1.7332
			10	1.2785	12.00	1.6497				10	1.2887	12.00	1.7142
			11	1.2392	14.00	1.6103				11	1.2385	14.00	1.6640
			12	1.2329	15.67	1.6040				12	1.2418	15.67	1.6673
			13	1.2133	18.00	1.5844				13	1.2169	18.00	1.6424

Date:	11/21/95	
Run#:	21	
Data Collected By:	ELW	
Inlet Description:	South Dakota Flare - 2:1	
Barrel Slope:	0.50%	
Barrel Type:	Square	
Barrel Length:	20ft = 6.096m	
Barrel Cross Sectional Area:		0.36306 ft²
Culvert Height:	171.45 mm = 6.75"	
Culvert Width:	171.45 mm = 6.75"	

Reading #	Headbox EGL	Projected EGL	He	Ke = $2g/V^2 \cdot He$
1*	0.9310	0.9313	-0.0003	-0.0789
2*	1.0244	1.0216	0.0027	0.0998
3	1.1274	1.1153	0.0121	0.1901
4	1.2178	1.1944	0.0234	0.2394
5	1.3140	1.2862	0.0278	0.1943
6	1.4019	1.3644	0.0375	0.2027
7	1.4914	1.4263	0.0651	0.2810
8	1.5969	1.5267	0.0701	0.2535
9	1.7151	1.6255	0.0896	0.2795
10	1.8126	1.7046	0.1080	0.2929
11	1.9274	1.8027	0.1247	0.2943
12	2.0878	1.9451	0.1427	0.2820
13	2.1926	2.0231	0.1695	0.3060
14	2.3591	2.1703	0.1888	0.2959

Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)	Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)
1	0.1730	0.00353	1	0.9301			2	0.4803	0.02717	1	1.0249		
			2	0.9308						2	1.0230		
			3	0.9321						3	1.0246		
			4	0.9311						4	1.0249		
			5	0.9281	2.00	0.9317				5	0.9931	2.00	1.0203
			6	0.9259	4.00	0.9294				6	0.9895	4.00	1.0167
			7	0.9262	6.00	0.9297				7	0.9872	6.00	1.0144
			8	0.9265	7.67	0.9300				8	0.9849	7.67	1.0121
			9	0.9255	10.00	0.9291				9	0.9826	10.00	1.0098
			10	0.9245	12.00	0.9281				10	0.9803	12.00	1.0075
			11	0.9245	14.00	0.9281				11	0.9777	14.00	1.0049
			12	0.9236	15.67	0.9271				12	0.9760	15.67	1.0032
			13	0.9242	18.00	0.9277				13	0.9741	18.00	1.0013
3	0.7345	0.0636	1	1.1217			4	0.9111	0.0978	1	1.2149		
			2	1.1302						2	1.2198		
			3	1.1312						3	1.2238		
			4	1.1263						4	1.2126		
			5	1.0489	2.00	1.1124				5	1.0915	2.00	1.1893
			6	1.0430	4.00	1.1065				6	1.0827	4.00	1.1805
			7	1.0397	6.00	1.1033				7	1.0774	6.00	1.1752
			8	1.0279	7.67	1.0914				8	1.0623	7.67	1.1601
			9	1.0285	10.00	1.0921				9	1.0587	10.00	1.1565
			10	1.0246	12.00	1.0882				10	1.0541	12.00	1.1519
			11	1.0187	14.00	1.0823				11	1.0469	14.00	1.1447
			12	1.0151	15.67	1.0787				12	1.0390	15.67	1.1368
			13	1.0115	18.00	1.0750				13	1.0335	18.00	1.1313
5	1.1018	0.1430	1	1.3123			6	1.2537	0.1852	1	1.3986		
			2	1.3150						2	1.4035		
			3	1.3150						3	1.4039		
			4	1.3136						4	1.4016		
			5	1.1335	2.00	1.2765				5	1.1683	2.00	1.3535
			6	1.1237	4.00	1.2667				6	1.1526	4.00	1.3377
			7	1.1184	6.00	1.2615				7	1.1503	6.00	1.3354
			8	1.0948	7.67	1.2378				8	1.1161	7.67	1.3013
			9	1.0899	10.00	1.2329				9	1.1142	10.00	1.2993
			10	1.0837	12.00	1.2267				10	1.1043	12.00	1.2895
			11	1.0755	14.00	1.2185				11	1.0971	14.00	1.2823
			12	1.0620	15.67	1.2050				12	1.0781	15.67	1.2632
			13	1.0515	18.00	1.1945				13	1.0630	18.00	1.2481
7	1.4020	0.2316	1	1.4931			8	1.5327	0.2767	1	1.5958		
			2	1.4911						2	1.5968		
			3	1.4911						3	1.5978		
			4	1.4902						4	1.5971		
			5	1.2001	2.00	1.4317				5	1.2379	2.00	1.5146
			6	1.1847	4.00	1.4163				6	1.2165	4.00	1.4933
			7	1.1768	6.00	1.4084				7	1.2064	6.00	1.4831
			8	1.1394	7.67	1.3710				8	1.1572	7.67	1.4339
			9	1.1362	10.00	1.3677				9	1.1640	10.00	1.4408
			10	1.1257	12.00	1.3572				10	1.1493	12.00	1.4260
			11	1.1165	14.00	1.3480				11	1.1444	14.00	1.4211
			12	1.0984	15.67	1.3300				12	1.1112	15.67	1.3879
			13	1.1572	18.00	1.3887				13	1.0906	18.00	1.3673
9	1.6492	0.3204	1	1.7165			10	1.7693	0.3688	1	1.8100		
			2	1.7129						2	1.8104		
			3	1.7136						3	1.8130		
			4	1.7172						4	1.8169		
			5	1.2861	2.00	1.6065				5	1.3225	2.00	1.6913
			6	1.2631	4.00	1.5835				6	1.2828	4.00	1.6516
			7	1.2510	6.00	1.5714				7	1.2815	6.00	1.6503
			8	1.1923	7.67	1.5127				8	1.2129	7.67	1.5817
			9	1.1926	10.00	1.5130				9	1.2037	10.00	1.5725
			10	1.1716	12.00	1.4920				10	1.1867	12.00	1.5554
			11	1.1588	14.00	1.4792				11	1.1759	14.00	1.5446
			12	1.1184	15.67	1.4388				12	1.1450	15.67	1.5138
			13	1.1096	18.00	1.4300				13	1.1194	18.00	1.4882
11	1.8964	0.4237	1	1.9265			12	2.0730	0.5062	1	2.0876		
			2	1.9291						2	2.0869		
			3	1.9259						3	2.0873		
			4	1.9281						4	2.0896		
			5	1.3606	2.00	1.7842				5	1.4196	2.00	1.9258
			6	1.3264	4.00	1.7501				6	1.3671	4.00	1.8734
			7	1.3120	6.00	1.7357				7	1.3642	6.00	1.8704
			8	1.2283	7.67	1.6520				8	1.2615	7.67	1.7677
			9	1.2336	10.00	1.6573				9	1.2569	10.00	1.7631
			10	1.2133	12.00	1.6369				10	1.2336	12.00	1.7398
			11	1.1998	14.00	1.6235				11	1.2185	14.00	1.7247
			12	1.1627	15.67	1.5864				12	1.1788	15.67	1.6850
			13	1.1237	18.00	1.5473				13	1.1322	18.00	1.6384

Date:	12/5/95		Reading #	Headbox EGL	Projected EGL	He	$Ke = 2g/V^2 * He$
Run#:	26		1*	1.1508	1.1494	0.0014	1.7260
Data Collected By:	ELW		2*	1.2302	1.2284	0.0019	0.1751
Inlet Description:	South Dakota Flare - 12x12		3*	1.3021	1.3031	-0.0010	-0.0341
Barrel Slope:	0.50%		4	1.3980	1.3806	0.0173	0.3103
Barrel Type:	Square		5	1.4899	1.4531	0.0368	0.4338
Barrel Length:	20ft = 6.096m		6	1.5790	1.5279	0.0511	0.4347
Barrel Cross Sectional Area:		0.55469 ft^2	7	1.6696	1.5920	0.0776	0.5288
Culvert Height:	171.45 mm = 6.75"		8	1.7795	1.6522	0.1274	0.7204
Culvert Width:	171.45 mm = 6.75"		9	1.8834	1.7173	0.1661	0.7843
			10	1.9803	1.7823	0.1980	0.8028
			11	2.0955	1.8531	0.2424	0.8478
			12	2.2734	1.9824	0.2910	0.8197
			13	2.4779	2.1493	0.3287	0.7748
			14	2.6520	2.2859	0.3660	0.7277

Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)	Reading #	Q (ft^3/s)	$V^2/2g$ (ft)	Port #	HGL (ft)	Horizontal Distance (ft)	Measured EGL $HGL+V^2/2g$ (ft)
1	0.1271	0.00082	1	1.1503			2	0.4591	0.01064	1	1.2280		
			2	1.1499						2	1.2306		
			3	1.1519						3	1.2320		
			4	1.1512						4	1.2303		
			5	1.1486	2.00	1.1494				5	1.2162	2.00	1.2268
			6	1.1490	4.00	1.1498				6	1.2172	4.00	1.2278
			7	1.1493	6.00	1.1501				7	1.2159	6.00	1.2265
			8	1.1486	7.67	1.1494				8	1.2142	7.67	1.2249
			9	1.1486	10.00	1.1494				9	1.2133	10.00	1.2239
			10	1.1480	12.00	1.1488				10	1.2100	12.00	1.2206
			11	1.1496	14.00	1.1504				11	1.2123	14.00	1.2229
			12	1.1493	15.67	1.1501				12	1.2106	15.67	1.2213
			13	1.1493	18.00	1.1501				13	1.2110	18.00	1.2216
3	0.7593	0.0291	1	1.3100			4	1.0524	0.0559	1	1.3976		
			2	1.3117						2	1.3967		
			3	1.3143						3	1.3999		
			4	1.3143						4	1.3963		
			5	1.2723	2.00	1.3014				5	1.3176	2.00	1.3735
			6	1.2710	4.00	1.3001				6	1.3205	4.00	1.3764
			7	1.2671	6.00	1.2962				7	1.3173	6.00	1.3732
			8	1.2680	7.67	1.2971				8	1.3153	7.67	1.3712
			9	1.2644	10.00	1.2935				9	1.3136	10.00	1.3695
			10	1.2621	12.00	1.2912				10	1.3064	12.00	1.3623
			11	1.2608	14.00	1.2899				11	1.3045	14.00	1.3604
			12	1.2592	15.67	1.2883				12	1.3012	15.67	1.3571
			13	1.2582	18.00	1.2873				13	1.2979	18.00	1.3538
5	1.2960	0.0848	1	1.4869			6	1.5256	0.1175	1	1.5801		
			2	1.4908						2	1.5771		
			3	1.4948						3	1.5833		
			4	1.4872						4	1.5755		
			5	1.3586	2.00	1.4434				5	1.3973	2.00	1.5148
			6	1.3655	4.00	1.4503				6	1.4003	4.00	1.5177
			7	1.3530	6.00	1.4378				7	1.3894	6.00	1.5069
			8	1.3517	7.67	1.4365				8	1.3937	7.67	1.5112
			9	1.3510	10.00	1.4358				9	1.3871	10.00	1.5046
			10	1.3438	12.00	1.4286				10	1.3704	12.00	1.4879
			11	1.3383	14.00	1.4230				11	1.3665	14.00	1.4839
			12	1.3317	15.67	1.4165				12	1.3563	15.67	1.4738
			13	1.3287	18.00	1.4135				13	1.3547	18.00	1.4721
7	1.7057	0.1468	1	1.6752			8	1.8717	0.1768	1	1.7723		
			2	1.6693						2	1.7772		
			3	1.6598						3	1.7848		
			4	1.6742						4	1.7838		
			5	1.4301	2.00	1.5769				5	1.4547	2.00	1.6315
			6	1.4344	4.00	1.5812				6	1.4593	4.00	1.6361
			7	1.4186	6.00	1.5655				7	1.4475	6.00	1.6243
			8	1.4111	7.67	1.5579				8	1.4432	7.67	1.6200
			9	1.4203	10.00	1.5671				9	1.4360	10.00	1.6128
			10	1.4035	12.00	1.5504				10	1.4163	12.00	1.5931
			11	1.3963	14.00	1.5432				11	1.4111	14.00	1.5879
			12	1.3799	15.67	1.5268				12	1.3980	15.67	1.5748
			13	1.3691	18.00	1.5159				13	1.3822	18.00	1.5590
9	2.0483	0.2117	1	1.8766			10	2.2107	0.2466	1	1.9764		
			2	1.8842						2	1.9770		
			3	1.8878						3	1.9833		
			4	1.8848						4	1.9846		
			5	1.4816	2.00	1.6934				5	1.5118	2.00	1.7585
			6	1.4892	4.00	1.7009				6	1.5200	4.00	1.7667
			7	1.4718	6.00	1.6835				7	1.4944	6.00	1.7411
			8	1.4724	7.67	1.6842				8	1.4931	7.67	1.7398
			9	1.4610	10.00	1.6727				9	1.4852	10.00	1.7319
			10	1.4446	12.00	1.6563				10	1.4646	12.00	1.7112
			11	1.4350	14.00	1.6468				11	1.4613	14.00	1.7079
			12	1.4245	15.67	1.6363				12	1.4308	15.67	1.6774
			13	1.3983	18.00	1.6100				13	1.4229	18.00	1.6695
11	2.3802	0.2859	1	2.1030			12	2.6521	0.3550	1	2.2717		
			2	2.1030						2	2.2730		
			3	2.0928						3	2.2743		
			4	2.0830						4	2.2746		
			5	1.5364	2.00	1.8223				5	1.5846	2.00	1.9396
			6	1.5492	4.00	1.8351				6	1.6148	4.00	1.9698
			7	1.5233	6.00	1.8092				7	1.5699	6.00	1.9249
			8	1.5292	7.67	1.8151				8	1.5659	7.67	1.9209
			9	1.5066	10.00	1.7925				9	1.5666	10.00	1.9216
			10	1.4987	12.00	1.7846				10	1.5423	12.00	1.8973
			11	1.4865	14.00	1.7725				11	1.5233	14.00	1.8783
			12	1.4623	15.67	1.7482				12	1.4865	15.67	1.8415
			13	1.4354	18.00	1.7213				13	1.4672	18.00	1.8222