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REATA PASS WASH CHANNEL HYDRAULIC MODEL

DATA REPORT

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by

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Prepared for
Stantech Consulting Inc.
7776 Pointe Parkway W., Suite 290
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October 1997

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October 2, 1997

Mr. Scot Schlund
Stantech Consulting Inc.
7776 Pointe Parkway W. Suite 290
Phoenix, AZ 85044

RE: Pima Road 3 Basins Project
No. 28900051

Dear Mr. Schlund,

In accordance with my discussion with George Sabol on 25 September, 1997, I have enclosed five (5) copies of a draft of the data report for the Pima Road 3 Basins Project. Any comments or suggestions would be greatly appreciated. Upon receipt of your comments, a final copy of the report will be prepared, bound and sent. If you have any questions please contact me at (970) 491-8394. I look forward to hearing from you.

Sincerely,

Christopher I. Thornton
Research Associate
Colorado State University
Fort Collins, CO 80523

INTRODUCTION

The City of Scottsdale, Arizona has elected to improve the Desert Greenbelt Reata Pass Wash channel to provide flood protection the its confluency. The proposed flood control channel, starts at Pinnacle Peak Road and extends south for approximately 5,610 feet. Designed to convey flow in a supercritical condition, the channel will be comprised of a series of two (2) and three (3) foot drop structures, and at a slope of 1.8 percent. A discharge of 11,760 cubic feet per second (cfs) was determined as a 100 year design discharge. Stantech Consulting Inc., through cooperation with the City of Scottsdale, contracted with Colorado State University to construct and operate a scale model of a segment of the Reata Pass Wash channel to test the feasibility of the proposed in-channel structures. Figure 1 presents a schematic of the segment of the channel to be modeled.

A physical model of a segment of the Reata Pass Wash channel was constructed at the Hydraulics Laboratory, Engineering Research Center, Colorado State University. The modeled segment extended from station 221+20 to 232+00, as shown in Figure 1. Operation and construction of the modeled channel (135 feet in length) was conducted on a unit width basis. As such, 64 feet of channel width, measured equilaterally from the center line of the channel, were modeled in the laboratory. Discharges of 20, 50, 75 and 100 percent of the design discharge were conveyed through the model. The design discharge expressed on a unit width basis is 147 cfs per foot. Velocity and water surface elevations were collected at nine (9) cross sections along the length of the model. Collected data were reduced and tabulated for interpretation and analysis. The following sections describe the construction and operation of the physical model. Collected data are presented in both tabular and graphical form.

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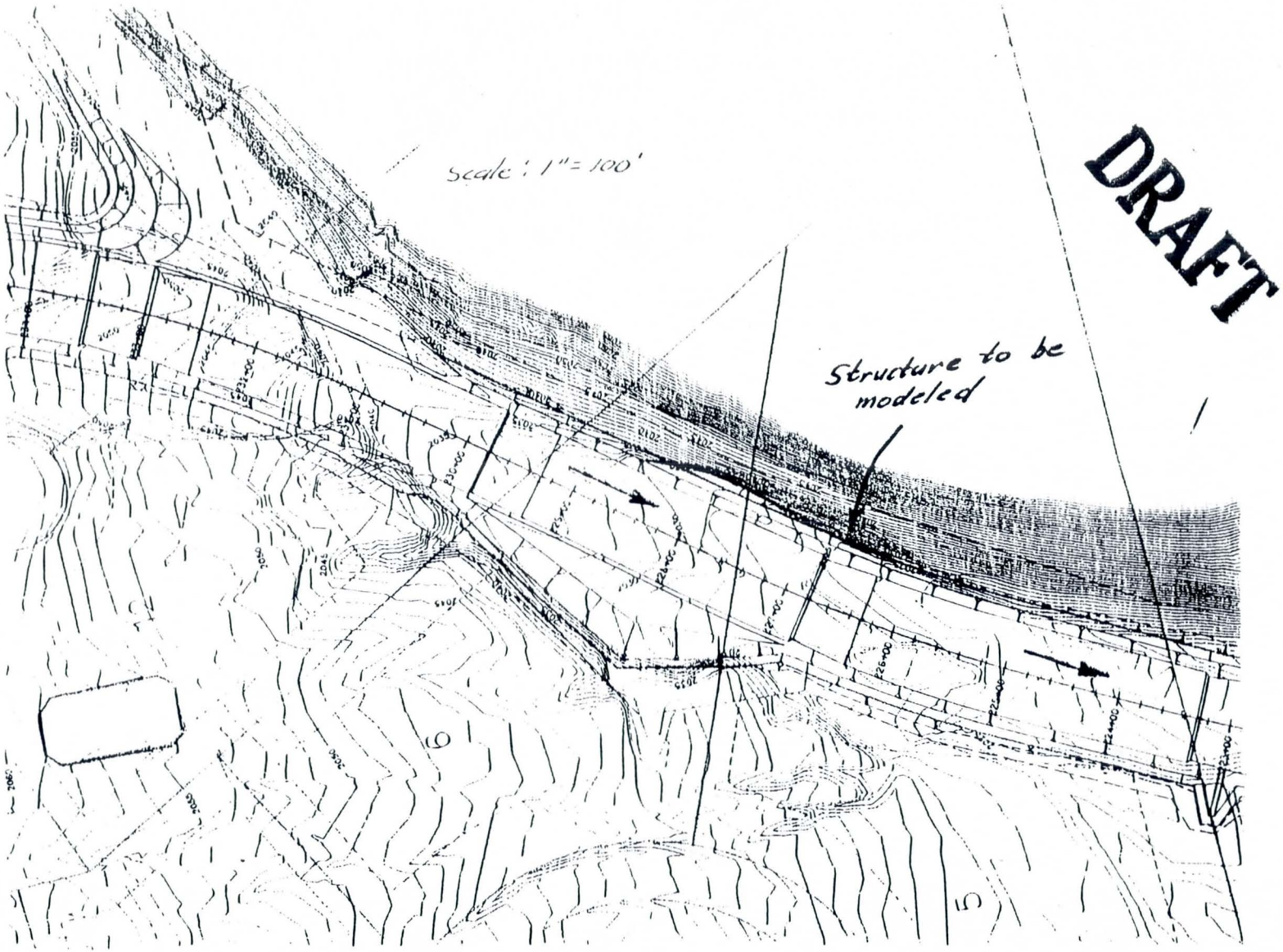

Figure 1. Modeled Segment of Reata Pass Wash Channel

TEST FACILITY AND TEST PROGRAM

A physical model of a typical segment of Reata Pass Wash channel was constructed to provide the Stantech Consulting Inc. Project Team a physical scaled version of the proposed channel to visualize operational aspects of the channel and the proposed drop structures. The results of the study will enable Stantech Consultants Inc. to evaluate flow characteristics in the channel over a range of unit discharges, and also evaluate the energy dissipation across the proposed drop structures.

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Test Facility

The testing facility consisted of a flume, the model and the data acquisition instrumentation. A recirculating flume, 200 feet in length and eight (8) feet wide was used for the experimental program. Water was supplied to the flume from a sump via two (2) 125 horsepower pumps capable of operating separately or in parallel to achieve a desired discharge. The flume has a maximum capacity of 110 cubic feet per second and can be adjusted from a horizontal bed to a slope of approximately 2.5 percent. A motorized cart traversed the flume and served as a platform for mounting data acquisition instrumentation and photography equipment. Figure 2 presents a schematic of the flume and test area.

A 1:8 undistorted Froude scale model was constructed. Table 1 presents the model to prototype ratios for the scale model. Prototype station 226+80 was designated by Stantech Consultants Inc. as the proposed drop structure to be studied. Therefore the model was constructed incorporating one drop structure upstream and one drop structure downstream of station 226+80 as configured in the Reata Pass Wash channel master plan. Modeling extended from prototype station 221+20 to station 232+00. Three drop structures were incorporated into the model to ensure entrance and exit conditions to the

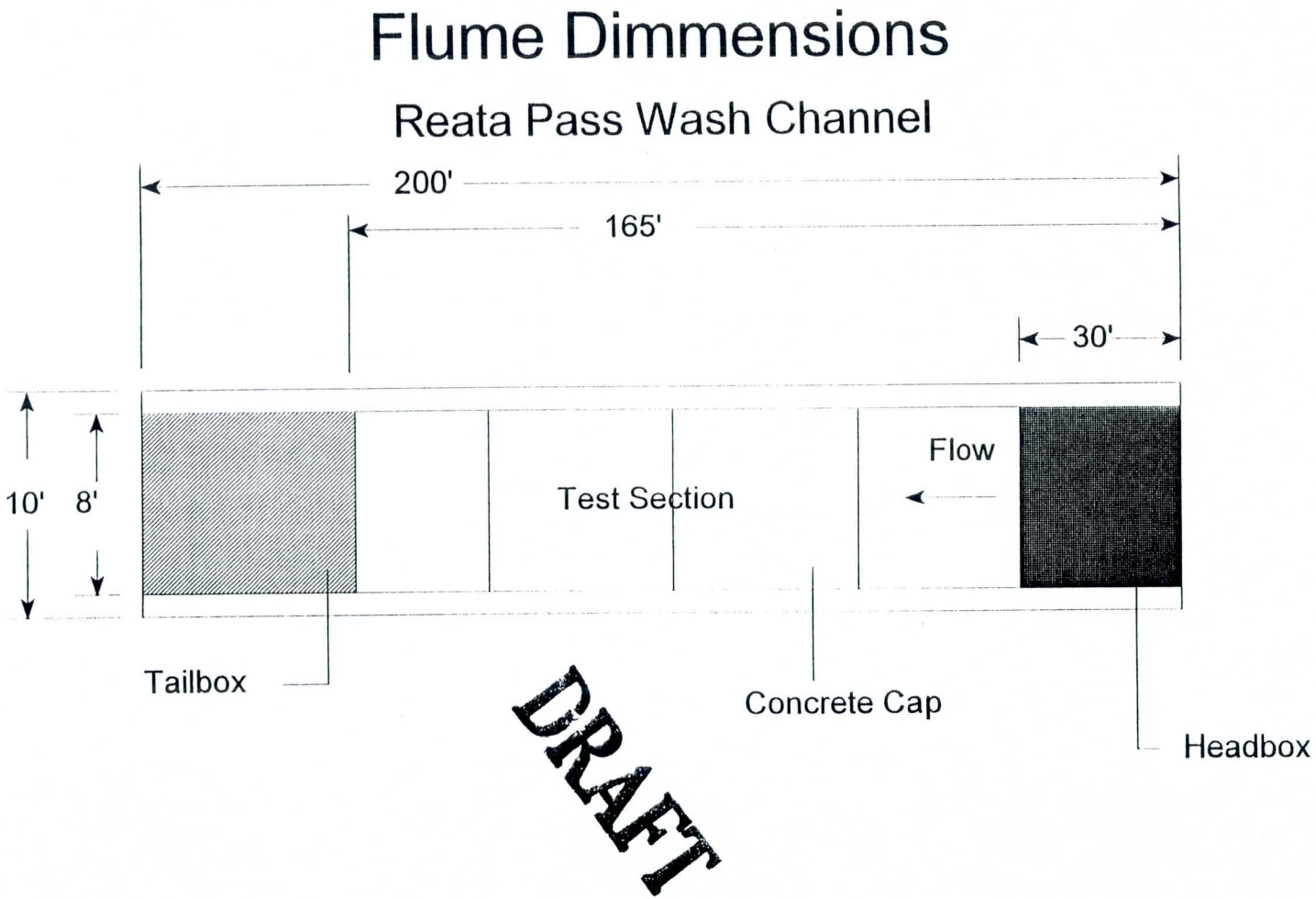

Figure 2. Schematic of Flume

drop structure at station 226+80 would simulate the prototype conditions.

Table 1. Model to Prototype Relations for Reata Pass Wash Channel

Variable	Relation	Scaling Factor
Length	L_r	1:8
Discharge	$Q_r = L_r^{5/2}$	1:182
Velocity	$V_r = L_r^{1/2}$	1:2.828
Area	$A_r = L_r^2$	1:64
Roughness	$n_r = L_r^{1/6}$	1:1.414

Construction of the model began with placing and contouring pea gravel in the flume to reproduce the prototype channel geometry condition. A layer of grout, approximately three (3) inches thick, was applied on top of the pea gravel. The surface of the grout was textured to achieve a desired roughness. Drop structures were constructed of plywood and covered with a sheet of steel. Quarter inch gravel was adhered to the surface of the steel to model the texture of the material comprising the prototype drop structures. Once the concrete cap had cured, the flume was tilted to a bed slope of 1.8 percent. Figure 3 displays schematic plan and profile views of the modeled reach of Reata Pass Wash channel.

Instrumentation used to monitor each flow included a calibrated orifice plate, a Rosemount® pressure transducer, a Marsh McBirney® magnetic 1-D flow meter, a point gage, video camera and a 35-mm camera. Each of the two conveyance lines utilized an orifice plate, accurate to ± 3 percent, to monitor the discharge to the flume. One (1) Rosemount® pressure transducer was utilized to monitor seven (7) of the nine data collection locations. Taps were installed in the left side (looking downstream) of the flume and piezometer tubes routed through a valve box and into the transducer. The transducer

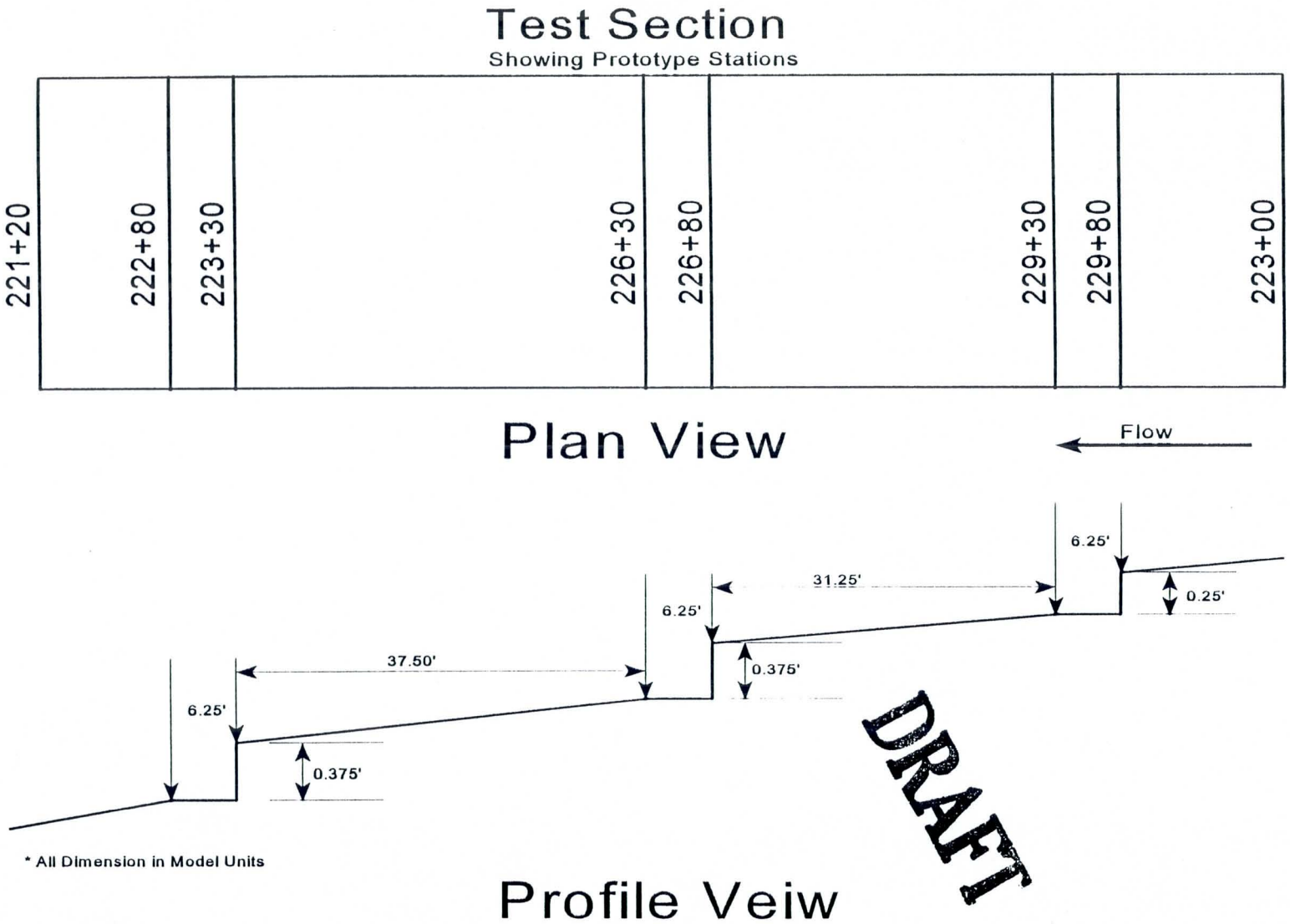

Figure 3. Plan and Profile View of Model

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was calibrated for zero (0) to fifty (50) inches of water. Depth information was output from the transducer in the form of voltage measurements and recorded on a data acquisition computer. Voltages were converted to flow depths by means of the calibration equation and recorded. Data collected from the pressure transducer has been stored on disk. Figure 4 presents the calibration data and voltage to depth conversion equation for the Rosemount® pressure transducer.

A Marsh McBirney® magnetic flow meter, accurate to ± 2 percent of the reading, was used to measure point flow velocities at each of the data collection sections. Point velocities were recorded along with average channel velocity determined by continuity.

Water surface elevations were determined along the longitudinal center line of the flume with a point gage accurate to ± 0.001 feet. The point gage was attached to a motorized cart capable of being positioned over each of the data collection sections outlined in Table 3. In addition, point gage measurements were taken along the left wall of the flume directly above the taps to verify pressure transducer measurements. Using the point gage measurements as a check, it was determined that the pressure transducer readings were accurate, on an average, to ± 4.7 percent.

Test Program

Four flows were conveyed through the model as designated by the Stantech Consultants Inc.. Unit discharges in the model were 1.62, 3.23, 4.85, 6.47 cfs per foot width, corresponding to 25, 50, 75, and 100 percent of the design discharge respectively. Table 2 presents the prototype and scaled discharges evaluated in the model.

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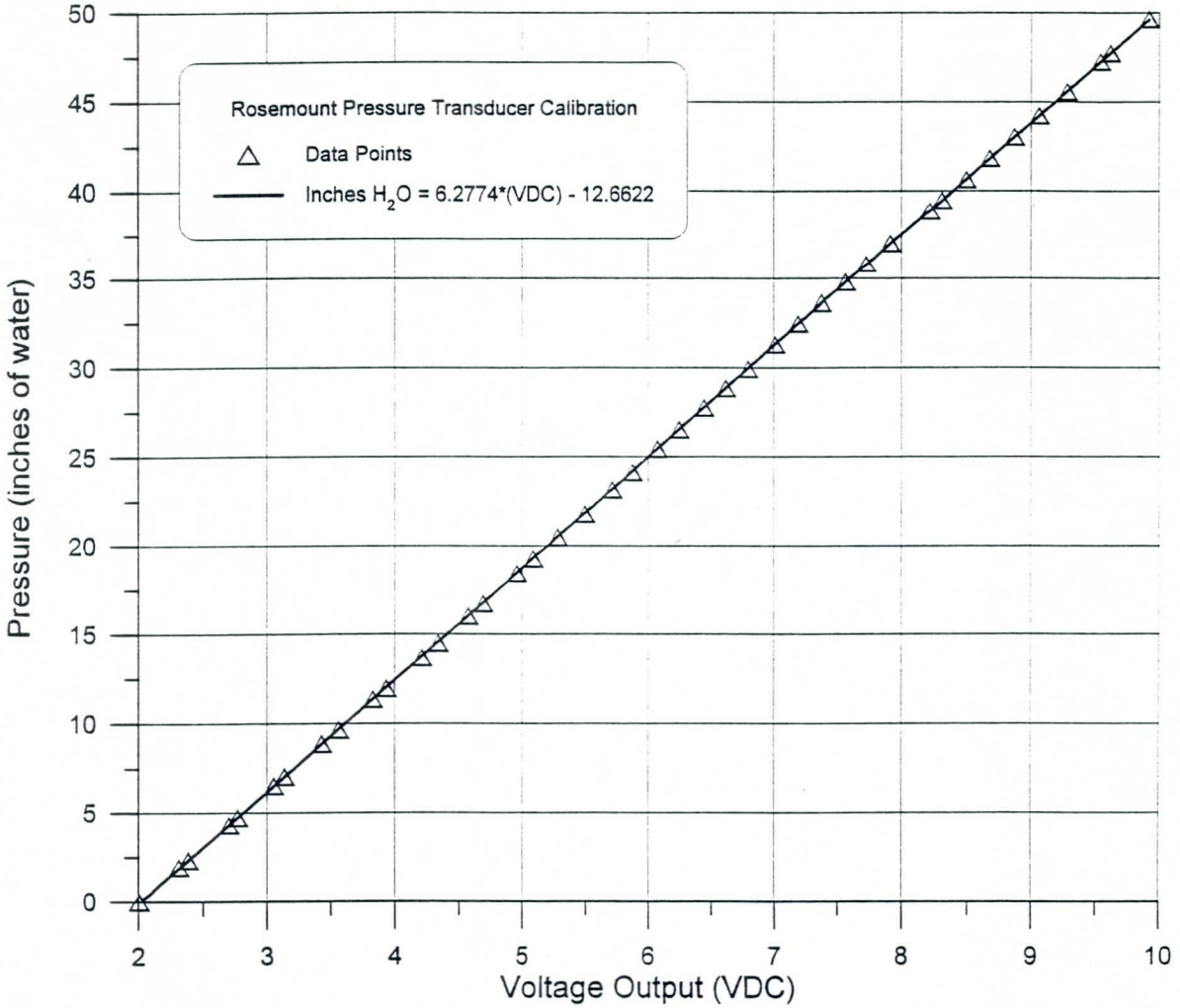

Figure 4. Calibration Data for Pressure Transducer

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Table 2. Prototype and Scaled Unit Discharges for the Reed Pass Wash Channel

Flow Number	Percent of Design Discharge (%)	Prototype Unit Discharge (cfs/ft)	Model Unit Discharge (cfs/ft)
1	25	36.75	1.62
2	50	73.50	3.23
3	75	110.25	4.85
4	100	147.00	6.47

Nine (9) sections were designated for data collection. Data were collected at each station and included water surface elevation and point velocities. Velocity measurements were collected along the longitudinal center line of the flume while water surface elevations were determined along the center line and at the left wall. When the depth of flow was sufficient, greater than 0.4 feet, velocities were collected at 20, 60 and 80 percent of the flow depth. At flow depths less than 0.4 feet, point velocity measurements were obtained at 20 and 60 percent of the flow depth. In both cases, measurement locations were measured from the water surface. Table 3 indicates the location of the nine (9) data collection locations in the test reach. Figure 5 schematically portrays the data collection locations.

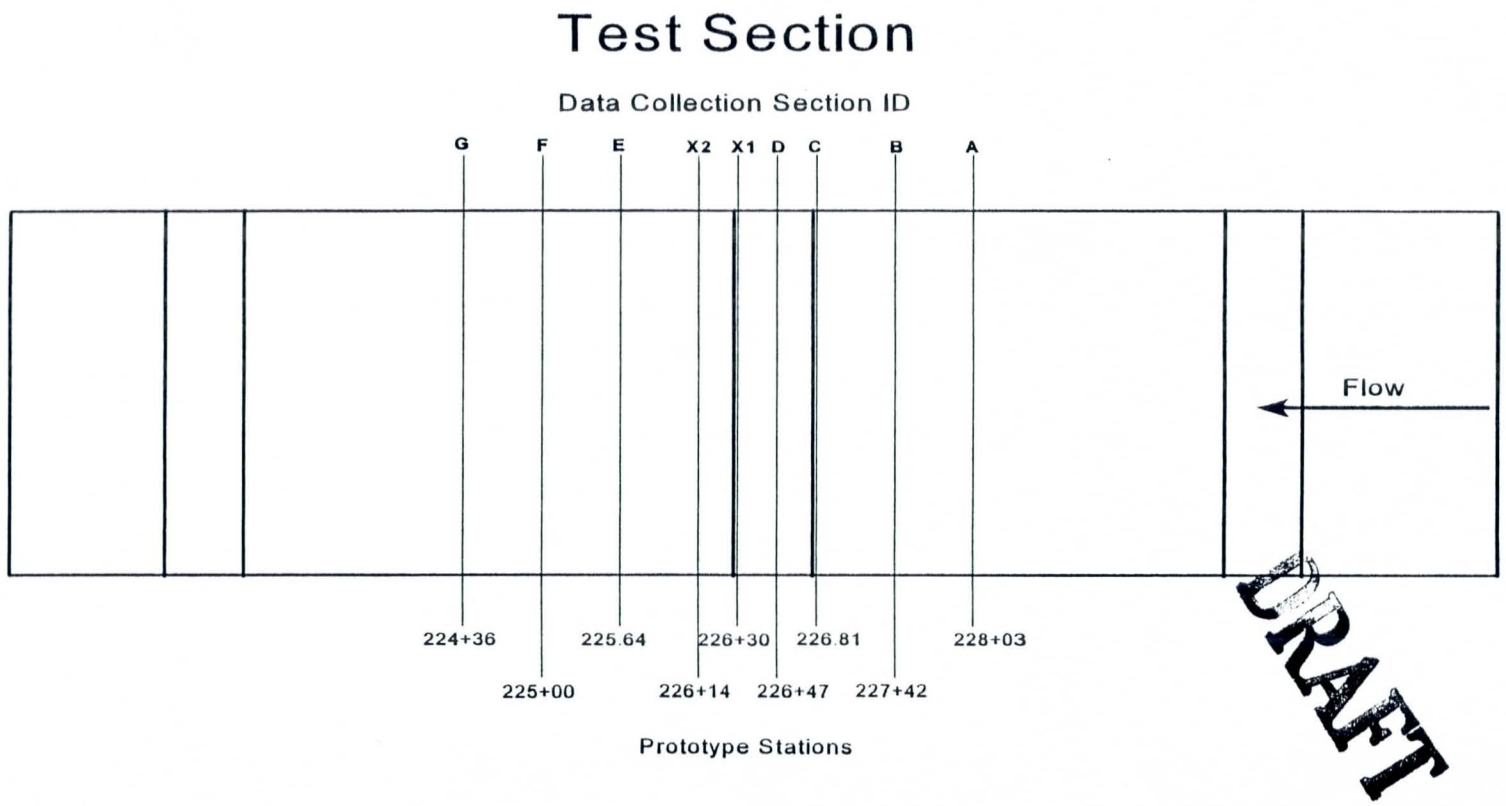

Figure 5. Data Collection Section Locations

Table 3. Identification of Data Collection Locations

Section Identification	Model Location (ft)	Prototype Location (ft)	Transducer Hookup
A	73.4	228+03	YES
B	80.95	227+42	YES
C	88.68	226+81	YES
D	92.9	226+47	YES
X1	95	226+30	NO
X2	97	226+14	NO
E	103.28	225+64	YES
F	111.3	225+00	YES
G	119.27	224+36	YES

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Shake Down Test

Prior to the beginning of record testing, a shake down test was conducted. The purpose of the shake down test was to determine the roughness of the channel, fine tune the instrumentation, and develop a testing procedure. Analysis of the shake down test indicated that the Manning's n of the channel was 0.0174, approximately 3.3 percent lower than the target value of 0.018. Upon discussion with representatives of Stantech Consultants Inc., it was determined that a n value of 0.0174 was within tolerable limits.

Test Procedure

The four discharges in the test series were run in sequence. The test procedure for each discharge is summarized as follows.

The pipe network was charged and the head box of the flume slowly filled. Flow was conveyed through the channel and the desired discharge was established. Video

cameras were started and continued to operate throughout the sequence of discharges. The pressure transducer was activated and all piezometer lines bled to remove trapped air. Once the flow was set and stabilized, the motorized cart was positioned at data collection section A (see Figure 5) and spot velocities were measured. Point gage readings were then obtained along the centerline of the flume and directly above the pressure transducer tap. Piezometer lines corresponding to the current location were opened and the pressure transducer allowed to stabilize. Transducer readings were then recorded for a period of twenty seconds using the data acquisition unit. The cart was then positioned at the next station (moving downstream) and the procedure repeated. Upon completion of data collection at all nine (9) stations, still photos were taken and overall flow characteristics recorded on video tape. The discharge was increased and the process outlined above repeated.

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RESULTS

All collected data have been tabulated and are presented in Tables 4 through 7 for unit discharges of 25, 50, 75, and 100 percent of the design discharge, respectively. Tabulated data include; data collection section (1), flume station (2), prototype location (3), bed elevation (4), flow depth as determined by the point gage (5), water surface elevation (6), transducer reading (7), difference in transducer and point gage reading (8), bed elevation at the transducer tap (9), water depth above transducer tap as determined by the point gage (10), water surface elevation above the transducer tap (11), spot velocities measured with the Marsh McBirney® (12), average flow velocity as calculated through continuity utilizing the point gage measurements (13), average flow velocity as calculated

Table 4. Results of 25 Percent of Design Discharge Flow

(1) SECTION	(2) STATION	(3) LOCATION	(4) BED	(5) DEPTH	(6) W.S	(7) X-DUCER	(8) DIFF	(9) X-D BED	(10) X-D DEPTH	(11) X-D WS	(12) VEOCITY (ft/s)		(13) V avg	(14) V X-D	(15) EGL
											20	5.79			
A	73.4	228+03	96.12	0.287	96.407	96.396	-0.011	96.12	0.31	96.43	60	5.17	5.66	0.00	96.90
											80				
											20	5.80			
B	80.95	227+42	95.98	0.309	96.289	96.251	-0.038	95.97	0.31	96.28	60	5.70	5.26	0.00	96.72
											80				
											20	5.65			
C	88.68	226+81	95.8	0.301	96.101	96.066	-0.035	95.81	0.3	96.11	60	5.13	5.40	0.00	96.55
											80				
											20	6.70			
D	92.9	226+47	95.43	0.293	95.723	95.697	-0.026	95.44	0.31	95.75	60	6.45	5.55	0.00	96.20
											80				
											20	6.10			
X1	95	226+30	95.43	0.303	95.733	***	***	95.46	0.27	95.73	60	5.65	5.36	***	96.18
											80				
											20	6.15			
X2	97	226.14	95.41	0.29	95.7	***	***	95.43	0.33	95.76	60	5.60	5.60	***	96.19
											80				
											20	5.65			
E	103.28	225+64	95.34	0.33	95.67	95.603	-0.067	95.33	0.25	95.58	60	5.05	4.92	0.00	96.05
											80				
											20	5.70			
F	111.3	225+00	95.2	0.325	95.525	95.534	0.009	95.21	0.33	95.54	60	5.40	5.00	0.00	95.91
											80				
											20	5.50			
G	119.27	224+36	95.08	0.313	95.393	95.401	0.008	95.07	0.32	95.39	60	4.95	5.19	0.00	95.81
											80				

(1) Data Cross Section
(2) Flume Station of Cross Section
(3) Prototype Location of Cross Section
(4) Bed Elevation of Cross Section
(5) Water Depth at Cross Section
(6) Water Surface Elevation in Center of Flume (measured with a point gage)
(7) Water Surface Elevation Along Side of Flume (recorded from a pressure transducer)
(8) Difference in Pressure Transducer and Point Gage Water Surface Elevation
(9) Bed Elevation at Pressure Transducer
(10) Water Depth at Pressure Transducer Location (along side of flume, measured with a point gage)
(11) Water Surface Elevation Along Side of Flume at Pressure Transducer (measured with a point gage)
(12) Point Velocity (measured with a Marsh Mcbirney)
(13) Average Velocity (computed using continuity and point gage)
(14) Average Velocity (computed using continuity and pressure transducer)
(15) Energy Grade Line Elevation (computed from columns (5) and (12))

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Table 5. Results of 50 Percent of Design Discharge Flow

(1) SECTION	(2) STATION	(3) LOCATION	(4) BED	(5) DEPTH	(6) W.S	(7) X-DUCER	(8) DIFF	(9) X-D BED	(10) X-D DEPTH	(11) X-D WS	(12) VEOCITY (ft/s)		(13) V_avg	(14) V X-D	(15) EGL
A	73.4	228+03	96.12	0.48	96.6	96.54	-0.06	96.12	0.47	96.59	20	7.30			
											60	6.70	6.77	0.00	97.31
											80	5.90			
B	80.95	227+42	95.98	0.5	96.48	96.432	-0.048	95.97	0.49	96.46	20	7.55			
											60	6.90	6.50	0.00	97.14
											80	5.60			
C	88.68	226+81	95.8	0.45	96.25	96.195	-0.055	95.81	0.47	96.28	20	7.70			
											60	7.00	7.22	0.00	97.06
											80	6.50			
D	92.9	226+47	95.43	0.45	95.88	95.902	0.022	95.44	0.51	95.95	20	8.30			
											60	8.00	7.22	0.00	96.69
											80	7.20			
X1	95	226+30	95.43	0.46	95.89	***	***	95.46	0.41	95.87	20	6.90			
											60	7.90	7.07	***	96.67
											80	6.95			
X2	97	226.14	95.41	0.44	95.85	***	***	95.43	0.46	95.89	20	7.90			
											60	6.90	7.39	***	96.70
											80	6.00			
E	103.28	225+64	95.34	0.46	95.8	95.753	-0.047	95.33	0.43	95.76	20	7.40			
											60	6.90	7.07	0.00	96.58
											80	6.10			
F	111.3	225+00	95.2	0.49	95.69	95.689	-0.001	95.21	0.49	95.7	20	7.30			
											60	7.10	6.63	0.00	96.37
											80	6.70			
G	119.27	224+36	95.08	0.49	95.57	95.563	-0.007	95.07	0.5	95.57	20	7.30			
											60	7.30	6.63	0.00	96.25
											80	6.50			

(1) Data Cross Section
(2) Flume Station of Cross Section
(3) Prototype Location of Cross Section
(4) Bed Elevation of Cross Section
(5) Water Depth at Cross Section
(6) Water Surface Elevation in Center of Flume (measured with a point gage)
(7) Water Surface Elevation Along Side of Flume (recorded from a pressure transducer)
(8) Difference in Pressure Transducer and Point Gage Water Surface Elevation
(9) Bed Elevation at Pressure Transducer
(10) Water Depth at Pressure Transducer Location (along side of flume, measured with a point gage)
(11) Water Surface Elevation Along Side of Flume at Pressure Transducer (measured with a point gage)
(12) Point Velocity (measured with a Marsh Mcbirney)
(13) Average Velocity (computed using continuity and point gage)
(14) Average Velocity (computed using continuity and pressure transducer)
(15) Energy Grade Line Elevation (computed from columns (5) and (12))

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Table 6. Results of 75 Percent of Design Discharge Flow

(1) SECTION	(2) STATION	(3) LOCATION	(4) BED	(5) DEPTH	(6) W.S	(7) X-DUCER	(8) DIFF	(9) X-D BED	(10) X-D DEPTH	(11) X-D WS	(12) VEOCITY (ft/s)		(13) V avg	(14) V X-D	(15) EGL
A	73.4	228+03	96.12	0.62	96.74	96.694	-0.046	96.12	0.62	96.74	20	8.50	7.86	0.00	97.70
											60	7.50			
											80	7.10			
B	80.95	227+42	95.98	0.64	96.62	96.593	-0.027	95.97	0.65	96.62	20	8.50	7.62	0.00	97.52
											60	7.60			
											80	7.20			
C	88.68	226+81	95.8	0.6	96.4	96.286	-0.114	95.81	0.62	96.43	20	8.60	8.13	0.00	97.43
											60	8.00			
											80	7.00			
D	92.9	226+47	95.43	0.58	96.01	96.041	0.031	95.44	0.68	96.12	20	9.30	8.41	0.00	97.11
											60	8.80			
											80	7.30			
X1	95	226+30	95.43	0.61	96.04	***	***	95.46	0.57	96.03	20	9.30	7.99	***	97.03
											60	9.00			
											80	7.30			
X2	97	226.14	95.41	0.59	96	***	***	95.43	0.55	95.98	20	9.50	8.26	***	97.06
											60	8.40			
											80	7.40			
E	103.28	225+64	95.34	0.64	95.98	95.884	-0.096	95.33	0.56	95.89	20	9.30	7.62	0.00	96.88
											60	8.20			
											80	7.00			
F	111.3	225+00	95.2	0.66	95.86	95.828	-0.032	95.21	0.63	95.84	20	8.80	7.39	0.00	96.71
											60	8.50			
											80	7.40			
G	119.27	224+36	95.08	0.63	95.71	95.713	0.003	95.07	0.64	95.71	20	9.40	7.74	0.00	96.64
											60	8.30			
											80	7.40			

(1) Data Cross Section
(2) Flume Station of Cross Section
(3) Prototype Location of Cross Section
(4) Bed Elevation of Cross Section
(5) Water Depth at Cross Section
(6) Water Surface Elevation in Center of Flume (measured with a point gage)
(7) Water Surface Elevation Along Side of Flume (recorded from a pressure transducer)
(8) Difference in Pressure Transducer and Point Gage Water Surface Elevation
(9) Bed Elevation at Pressure Transducer
(10) Water Depth at Pressure Transducer Location (along side of flume, measured with a point gage)
(11) Water Surface Elevation Along Side of Flume at Pressure Transducer (measured with a point gage)
(12) Point Velocity (measured with a Marsh Mcbirney)
(13) Average Velocity (computed using continuity and point gage)
(14) Average Velocity (computed using continuity and pressure transducer)
(15) Energy Grade Line Elevation (computed from columns (5) and (12))

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Table 7. Results of 100 Percent of Design Discharge Flow

(1) SECTION	(2) STATION	(3) LOCATION	(4) BED	(5) DEPTH	(6) W.S	(7) X-DUCER	(8) DIFF	(9) X-D BED	(10) X-D DEPTH	(11) X-D WS	(12) VELOCITY (ft/s)		(13) V_avg	(14) V X-D	(15) EGL
	45	230+58	96.75	0.87	97.62	***	***	***	***	***	***	***	7.47	***	98.49
	51	229+84	96.63	0.8	97.43	***	***	***	***	***	***	***	8.13	***	98.46
	57.5	229+30	96.38	0.79	97.17	***	***	***	***	***	***	***	8.23	***	98.22
											20	9.75			
A	73.4	228+03	96.12	0.75	96.87	96.806	-0.064	96.12	0.72	96.84	60	8.85	8.67	0.00	98.04
											80	7.45			
											20	9.80			
B	80.95	227+42	95.98	0.74	96.72	96.714	-0.006	95.97	0.75	96.72	60	8.80	8.78	0.00	97.92
											80	7.50			
											20	10.15			
C	88.68	226+81	95.8	0.7	96.5	96.344	-0.156	95.81	0.7	96.51	60	8.90	9.29	0.00	97.84
											80	7.75			
											20	11.50			
D	92.9	226+47	95.43	0.68	96.11	96.139	0.029	95.44	0.75	96.19	60	10.05	9.56	0.00	97.53
											80	8.65			
											20	10.60			
X1	95	226+30	95.43	0.69	96.12	***	***	95.46	0.64	96.1	60	9.65	9.42	***	97.50
											80	7.65			
											20	10.55			
X2	97	226.14	95.41	0.7	96.11	***	***	95.43	0.65	96.08	60	9.60	9.29	***	97.45
											80	8.45			
											20	10.75			
E	103.28	225+64	95.34	0.72	96.06	95.977	-0.083	95.33	0.64	95.97	60	9.20	9.03	0.00	97.33
											80	8.15			
											20	10.35			
F	111.3	225+00	95.2	0.76	95.96	95.94	-0.02	95.21	0.65	95.86	60	8.10	8.55	0.00	97.10
											80	7.75			
											20	10.25			
G	119.27	224+36	95.08	0.74	95.82	95.804	-0.016	95.07	0.73	95.8	60	9.05	8.78	0.00	97.02
											80	7.85			
	132.2	223+32	94.80	0.70	95.50	***	***	***	***	***	***	***	9.29	***	96.84
	139	222+80	94.45	0.69	95.14	***	***	***	***	***	***	***	9.42	***	96.52
	149.5	221+96	94.20	0.70	94.90	***	***	***	***	***	***	***	9.29	***	96.24

(1) Data Cross Section
(2) Flume Station of Cross Section
(3) Prototype Location of Cross Section
(4) Bed Elevation of Cross Section
(5) Water Depth at Cross Section
(6) Water Surface Elevation in Center of Flume (measured with a point gage)
(7) Water Surface Elevation Along Side of Flume (recorded from a pressure transducer)
(8) Difference in Pressure Transducer and Point Gage Water Surface Elevation
(9) Bed Elevation at Pressure Transducer
(10) Water Depth at Pressure Transducer Location (along side of flume, measured with a point gage)
(11) Water Surface Elevation Along Side of Flume at Pressure Transducer (measured with a point gage)
(12) Point Velocity (measured with a Marsh Mcbirney)
(13) Average Velocity (computed using continuity and point gage)
(14) Average Velocity (computed using continuity and pressure transducer)
(15) Energy Grade Line Elevation (computed from columns (5) and (12))

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through continuity utilizing the pressure transducer measurements (14), and the elevation of the energy grade line utilizing continuity and point gage readings.

Six (6) additional water surface elevation measurements were obtained during the design storm discharge (6.47 cfs/ft), as shown in Table 7. Measurements were collected with the point gage along the longitudinal center line of the flume. These measurements were used to extend the elevation of the energy grade line 28 feet upstream of section A and 30 feet downstream of section G. Table 7 includes the numerical data collected at the additional sections.

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Graphical representations were compiled of each flow condition as presented in Figures 6 through 9 corresponding to unit discharges of 25, 50, 75, and 100 percent of the design discharge, respectively. Each plot displays the invert elevation, water surface elevation and elevation of the energy grade line for the respective flow condition. Figure 10, incorporating the extended data collected during the design discharge flow, displays the invert elevation water surface elevation and elevation of the energy grade line across all three modeled drop structures.

OBSERVATIONS

Observations made during testing and resulting from data compilation are as follows:

- Supercritical flow was observed throughout the entire length of the modeled channel. Froude numbers ranged from 1.41 to 2.04.

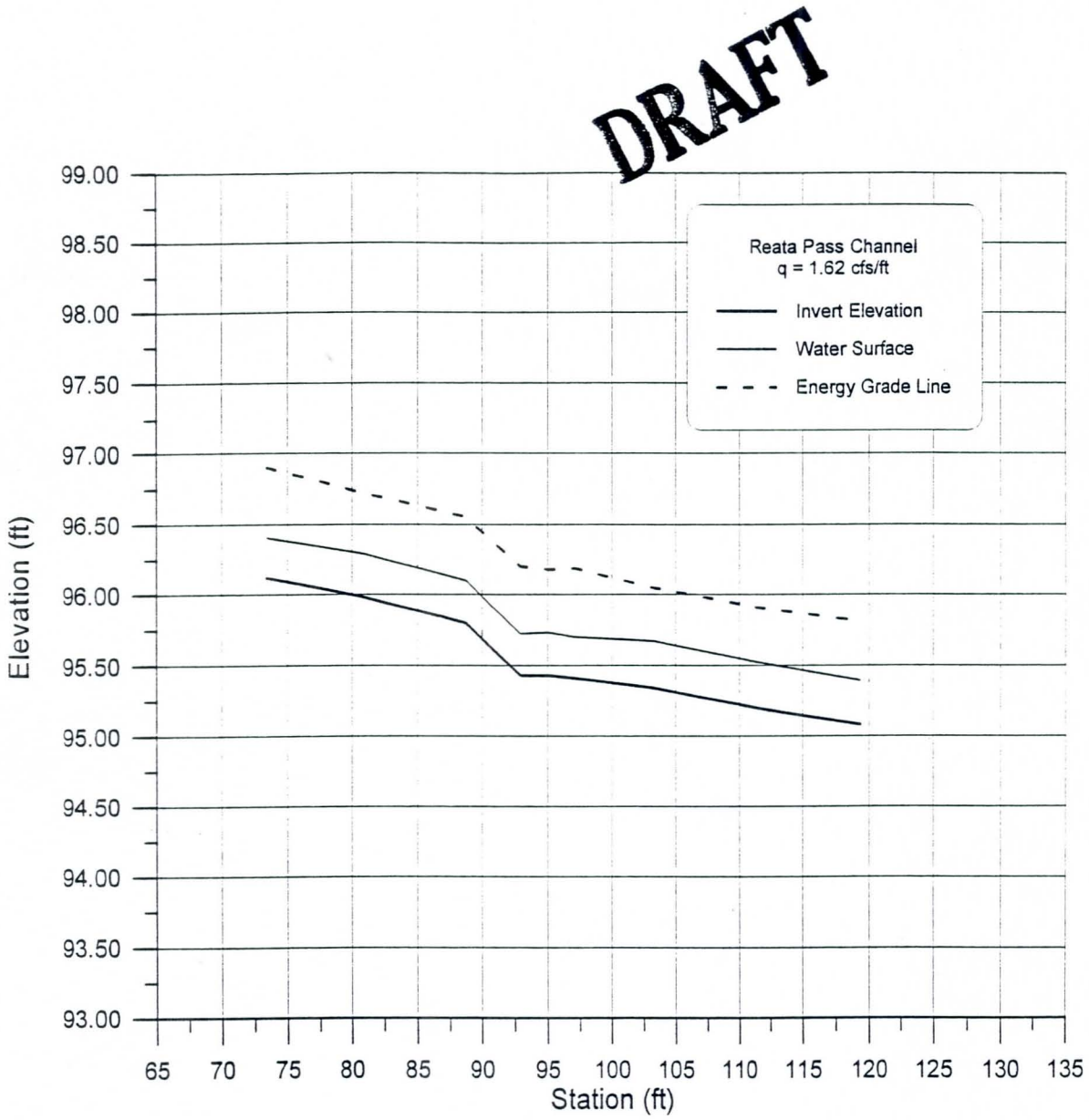

Figure 6. 25 Percent of Design Discharge

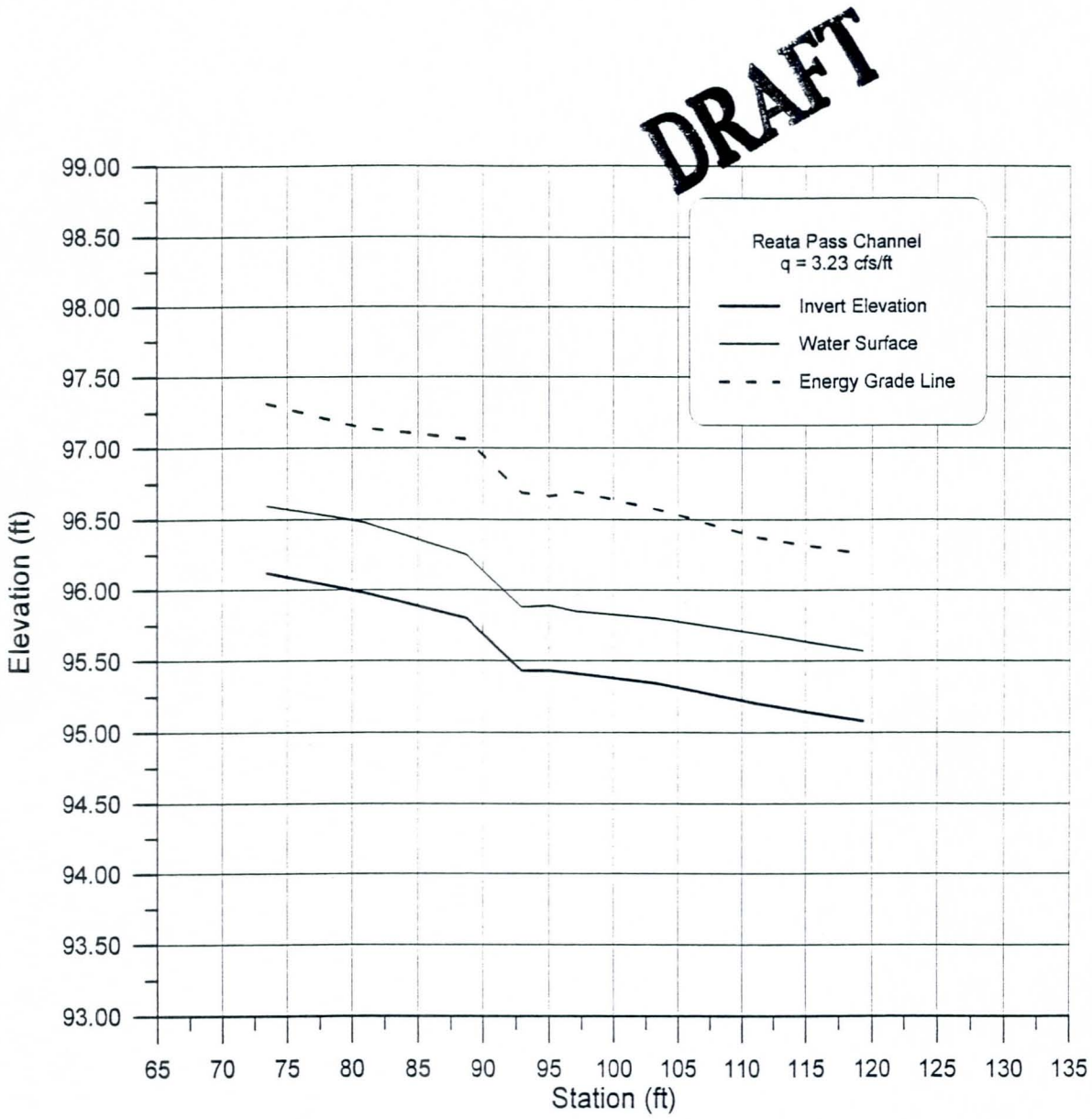

Figure 7. 50 Percent of Design Discharge

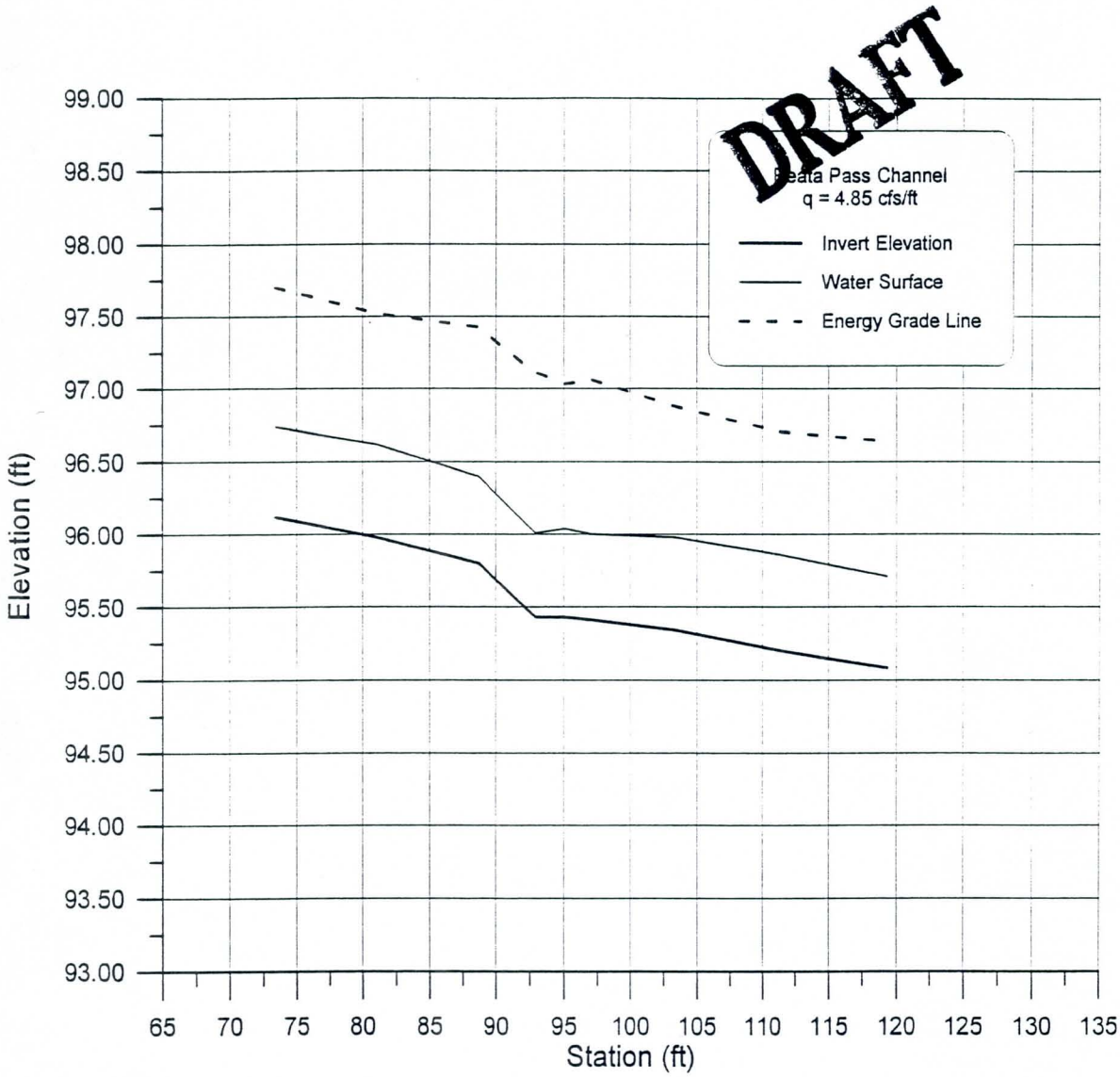

Figure 8. 75 Percent of Design Discharge

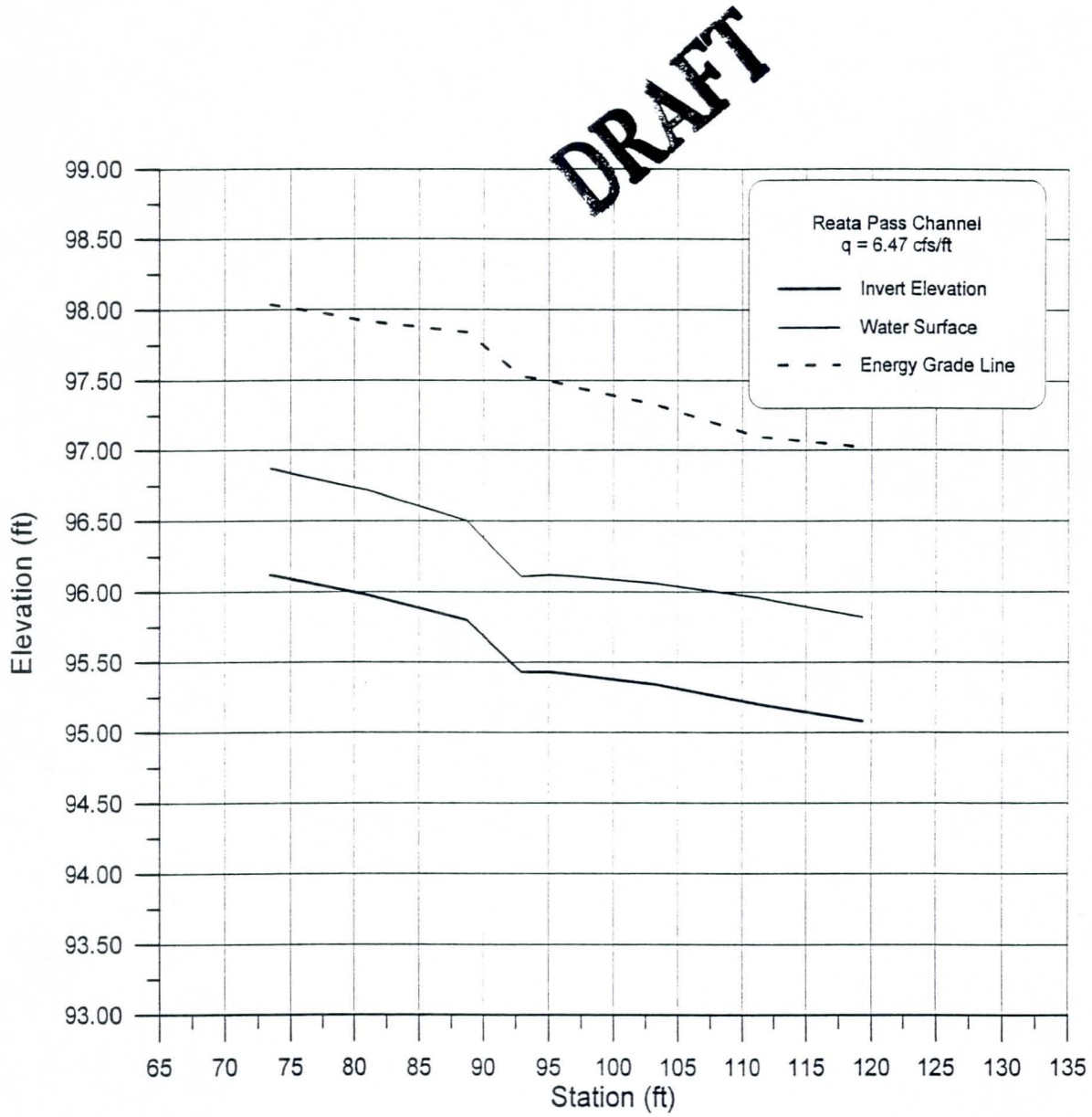

Figure 9. 100 Percent of Design Discharge

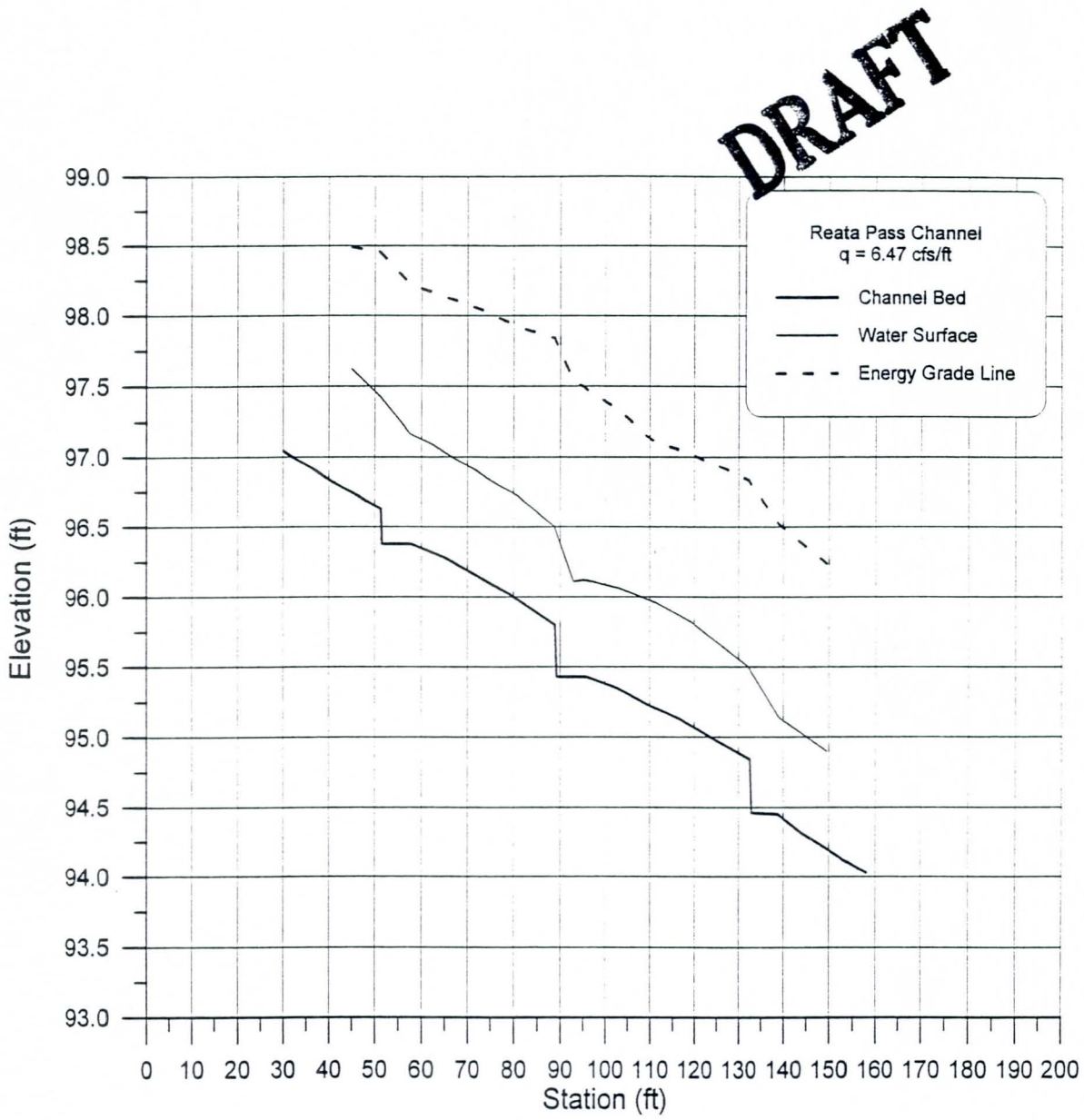

Figure 10. Plot of Energy Grade Line Across Three Drops

- At a unit discharge of ≤ 25 percent of the design discharge, a roller was observed in the stilling basin immediately downstream of the drop structure. Flow higher than 25 percent of the design discharge did not exhibit this phenomenon.
- Due to supercritical flow conditions in the modeled reach, hydraulic control was established just downstream of the first modeled drop structure (station 229+80).
- Energy dissipation through the drop structure and stilling basin appeared to decrease as the unit discharge increased.
- On average, spot velocities were approximately 13 percent higher than the average velocity (computed through continuity) at a specified cross section for the design discharge.
- Observation of the modeled drop structure indicated the water surface recovered downstream of the structure.
- Observation of water surface recovery indicated the length of the stilling basin apron may need to be reevaluated.

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SUMMARY

A 1:8 scale model was constructed of a 1080 foot portion of the proposed Reata Pass Wash Channel at the Hydraulics Laboratory of Colorado State University. Operation of the model was on a unit width basis. Four flows were conveyed through the model corresponding to 25, 50, 75, and 100 percent of the design discharge (147 cfs per foot). Hydraulic data collected included; invert elevation, water surface elevation, point velocities and average velocities. In addition, each flow was documented with video and still photography.

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REFERENCES

George V. Sabol Consulting Engineers, Inc., Desert Greenbelt Project Pima Road Channel Recommended Design Concept and Construction Cost Estimate, Final Draft, December 16, 1996.