[redacted]

AGUA FRIA RIVER

SEDIMENT TRANSPORT STUDY

FINAL REPORT

DEPARTMENT OF CIVIL ENGINEERING

College of Engineering and Applied Sciences
Arizona State University
Tempe, Arizona 85287-5306

AGUA FRIA RIVER

SEDIMENT TRANSPORT STUDY

FINAL REPORT

Conducted for: Flood Control District
Maricopa County
Phoenix, Arizona

Conducted by: Civil Engineering Department
Arizona State University
Tempe, Arizona

Civil Engineering Department
Arizona State University
January 21, 1992

TABLE OF CONTENTS

No.	Title	Page
	Title Page	i
	Table of Contents	ii
I	INTRODUCTION	1
	1.1 Purpose of Study	1
	1.2 Authority for Study	1
	1.3 Coordination and Acknowledgment	1
II	WATERSHED DESCRIPTION	3
	2.1 Scope of the Study	3
	2.2 Physical Characteristics	3
	2.2.1 River Geometry	3
	2.2.2 Sediment Characteristics	6
	2.2.3 Hydrology	9
	2.2.3.1 Flood Hydrographs	9
	2.2.3.2 Flood Frequency	9
	2.2.3.3 Stage-Discharge Rating Data	10
	2.3 Structural Features	10
	2.3.1 Existing Waddell Dam	11
	2.3.2 New Waddell Dam	11
III	PREVIOUS STUDIES AND SCOPE OF CURRENT STUDY	14
	3.1 Previous Studies and Reports	14
	3.1.1 Hydraulic and Geomorphic Analysis of the Agua Fria River	14
	3.1.2 Application of HEC-6 to Ephemeral Rivers of Arizona	14
	3.1.3 Agua Fria Sedimentation Study to Determine the Effects of Gravel Mining Below Lower Buckeye Road	15
	3.1.4 Hydrology for the Evaluation of Flood Reduction by New Waddell Dam *[From Agua Fria River Below New Waddell Dam to the New River Confluence]*	15
	3.1.5 Flood Insurance Study: Agua Fria River, Maricopa County, Arizona	16
	3.1.6 Effects of In-Stream Mining on Channel Stability, *Executive Summary*	16
	3.2 Scope of Work for the Present Study	17
	3.2.1 Training	18
	3.2.2 Collection and Review of Available Data	18
	3.2.3 Data Verification and Acquisition	19
	3.2.4 Sediment Transport Evaluation	19

3.2.5 Coordination 20
3.2.6 Preparation of Final Report 20

IV CALIBRATION ANALYSIS 22

4.2 Location of River Reach 22
4.2 Modeling Data 22
4.2.1 Geometric and Hydraulic Data 22
4.2.2 Hydrologic Data 32
4.2.3 Sediment Data 35
4.3 Determination of Inflowing Sediment 36
4.3.1 Data Requirements 36
4.3.2 Procedures in the Determination of Inflowing Sediments 37
4.3.3 Inflowing Sediment Loads 38
4.4 Selection of Sediment Transport Function 39
4.4.1 Selection Process 39
4.4.2 Simulated Results 41
4.5 Sensitivity Analysis 50
4.5.1 Manning's Coefficient (n) 51
4.5.2 Inflowing Sediment Load and Sediment Gradation Data 54

V MODELING DESCRIPTIONS 57

5.1 Model I 57
5.1.1 Modeling Description 57
5.1.2 Geometric Data 57
5.1.3 Sediment Data 57
5.1.4 Hydrologic Data 58
5.2 Model II 59
5.2.1 Modeling Description 59
5.2.2 Description of Mining Sites Along the Agua Fria River 59
5.2.2.1 Site A 59
5.2.2.2 Site B 66
5.2.2.3 Site C 73
5.2.3.4 Site D 84
5.2.3.5 Site E 91
5.2.3.6 Site F 100
5.2.3.7 Site G 106
5.2.3.8 Site H 113
5.3 Model III 127
5.3.1 Modeling Description 127
5.3.2 Rationale of Channelization 127
5.3.3 Location of Improvement Channels 127
5.3.3.1 Improvement Channel-I 128
5.3.3.2 Improvement Channel-II 137

VI RESULTS AND ANALYSIS 142

6.1 Calibration Analysis 142

6.2 Inflowing Sediment Load for the Modeling of the Agua Fria River 142
6.3 Modeling Results 143
6.3.1 Model I Results 143
6.3.2 Model II Results 146
6.3.3 Model III Results 150
6.3.3.1 Improvement Channel-I 150
6.3.3.2 Improvement Channel-II 150
6.4 Comparison of the Results with other Studies 154

VI I CONCLUSIONS AND RECOMMENDATIONS 156

7.1 Calibration Study 156
7.2 Previous Sedimentation Modeling for Agua Fria River 156
7.3 Sensitivity Analysis 157
7.4 Model I 157
7.5 Model II 158
7.6 Model III 159

VIII REFERENCES 160

APPENDICES 163

Appendix A - River Geometry and Hydraulic Data 164

A.1 Hydraulic Data 165
A.1.1 Hydraulic Data for the Selected Station (Model I) 165
A.1.2 Hydraulic Data for Additional Stations Considered for Mining Sites (Model II) 167
A.2 Plots of Cross-Sections 168

Appendix B - Sediment Data 234

B.1 Gradation Curves of Collected Sediment Samples 235
B.2 Inflowing Sediment Load for the Calibration Study 272

Appendix C - Hydrologic Data 278

C.1 Stage-Discharge Rating Data 279
C.2 Hydrographs 283
C.3 Peak Discharges at Various Locations Along the Agua Fria River Under New Waddell Dam Condition 285

Appendix D - HEC-6 Input File for Model I 286

INTRODUCTION

1.1 Purpose of Study

The project is aimed at developing sediment transport models capable of simulating the long-term stream bed profile behavior of the Agua Fria River using the U.S. Army Corps of Engineer's HEC-6 code. Long-term aggradation or degradation under the post-New Waddell Dam conditions are evaluated considering the existing, on-going, and proposed developments along and around the river vicinity. Results of the study would be used as a basis for the development of regulatory management practices for the Agua Fria River floodplain under the post-New Waddell Dam scenarios. The various models to be developed are described as follows:

Model I — Development of a model to evaluate the sediment transport under the existing condition with New Waddell Dam and the Arizona Canal Diversion Channel (ACDC) built;

Model II — Development of a future condition model using the existing condition model (Model I) to reflect the ultimate sand and gravel mining as permitted today;

Model III — Development of a future condition model by adding 1000-foot wide channel improvement along the Agua Fria River (wherever applicable) to Model II in order to evaluate the effect of mining sites on the proposed channel;

1.2 Authority for Study

There has always been a great need in the recent years to have a working model capable to predict the aggradation and degradation processes along the Agua Fria River for the purpose of assessing the long-term impacts of sedimentation. In this way, measures to provide good and workable floodplain management practices around the vicinity could be developed both in the sediment management and hydraulic standpoints. The recognition of this need by the Flood Control District of Maricopa County has apparently led to the conception of this modeling study.

In August, 1991, the Flood Control District of Maricopa County has commissioned the Department of Civil Engineering, Arizona State University (ASU) to study the sedimentation processes along the Agua Fria River with considerations on a number of development scenarios along the river. The sedimentation study employed the use of the HEC-6 code developed by the **U.S. Army Corps of Engineers (1991).**

1.3 Coordination and Acknowledgments

Efforts to gather and consolidate information vital to the conduct of the project were pursued. As soon as the work was started in October, 1991, a two-day trip was organized by the Flood Control District of Maricopa County to conduct a field and familiarization survey of the entire 34-mile river reach. This field survey was made

starting from Gila River Confluence to the Waddell Dam which impounds the Lake Pleasant. Also, regular meetings were held either at the Flood Control District office or at the Civil Engineering Department at A.S.U. for gathering and verifying information, updating and evaluating work progresses, training, and hands-on sessions held mainly to upgrade the quality of the project output.

The works put forward by Besian Khatiblou in the initial-phase of the project in order to provide a smooth start of the research has been exemplary. The engineers and technical personnel from the Maricopa County Flood Control District, (MCFCD) [John Svechovsky, Tim Murphy, Joon Hoong Kim, Jan Opstein, and Carol Davis] who participated in training sessions, had given the much-needed momentum. They provided some insightful comments during training sessions which opened opportunities for a deeper understanding of the HEC-6 code and widened the perspective needed on the modeling consideration for the Agua Fria River.

The untiring collaborative efforts made by Tim Murphy, who took over the management of the project from Besian Khatiblou, were extraordinary in many respects. The assistance he provided in all the stages of the project works are very much appreciated. Kofi Awumah, who recently joined the team, has been an active participant in validating the works accomplished and has contributed significantly during the review process of the calibration works.

The helpful insights and the physical contributions provided by some students in the Civil Engineering Department, ASU - specially in the collection, and laboratory analysis of sediment samples - are appreciated. The modeling runs made by Hasan Mushtaq and Tom Shedden during the calibration and selection work of sediment transport functions form a vital contribution to the project. Also, the critical reviews on the calibration works provided by Hasan Mushtaq are recognized.The help provided by David Boggs, who assisted in the project for a while on the hydrologic analysis, plotting of gradation curves, data collection, and reviews of previous works on Agua Fria River has greatly lighten the work load.The services rendered by the Civil Engineering Department for the smooth arrangements of various work and service requests are extraordinary in all respects.

Each work contributed above have played a significant role in the successful completion of the project.

II WATERSHED DESCRIPTION

2.1 Scope of the Study

The modeling work covers the entire 34-mile reach of the Agua Fria River, which extends from the Gila Confluence to the south (designated as Mile 0.00) to the existing Waddell Dam to the north (designated as Mile 33.30). The existing dam will be breached, however, when the New Waddell Dam is completed. The watershed area of the river is estimated at about 2,340 mi^2 **(U.S. Army Corps of Engineers, 1968).**

2.2 Physical Characteristics

The Agua Fria River, which flows intermittently, begins in the Prescott National Forest within the Yavapai County but the flows are temporarily stored at the Waddell Dam [Mile 33.3] which impounds Lake Pleasant before they are eventually released. The river meanders southwardly until it joins the Gila River downstream.

2.2.1 River Geometry

The channel geometry of the whole 34-mile river reach could be physically described using the 450 cross-sections developed by **Jerry R. Jones & Assoc., Inc. (1989).** Each cross-section information is comprised of paired coordinates of ground elevation and distance that run laterally from the left floodplain (or overbank) then cross the main channel and terminates at the end of right floodplain. Considering the capability of the most recent version of HEC-6 code, 96 stations were selected to define the cross-section geometry and physical characteristics of the river. **Table 2.1** lists the selected stations that were used based on the following criteria:

(1) *The extensive coverage of sampling observation points;*
(2) *Maintenance of a fairly reasonable reach length in between stations:*
   (i) *About six to ten times of the channel width for stations other than those at bridge locations [see* **Table 2.2** *for the bridge locations along the river];*
   (ii) *About one to five times the river width at bridges;*
(3) *Consistency of the current data with those data obtained in the previous years;*
(4) *The plots of the cross-sections which aids in judging the condition of the data;*
(5) *Stations that may be running under supercritical or critical conditions.*
(6) *Stations where sediment data are available; and,*
(7) *Stations where particular locations of interest are studied.*

Table 2.1- The selected stations for the Agua Fria River

No.	Mile No.	Criteria Used	Approximate Location/Descriptions
1	0.160		Most downstream station
2	0.440	1	
3	0.730	1	
4	1.330	6,7	Broadway Road
5	1.710	1,6	About 0.5 mile south of Lower Buckeye Road
6	2.020	1	
7	2.600	6,7	Lower Buckeye Road
8	2.800	7	
9	3.270	6	About 0.5 mile south of Buckeye Road
10	3.400	5,7	
11	3.430	2	
12	3.729	2	
13	3.734	7	Buckeye Road Bridge, East bank levee starts
14	3.757	2	
15	3.767	7	South Pacific Railroad Bridge
16	4.094	5	
17	4.270	1,6	About 0.5 mile south of Van Buren Road
18	4.700	2	
19	4.754	6,7	Van Buren Road Bridge
20	4.790	5	
21	5.150	5	
22	5.290	6,7	Interstate 10 Bridge
23	5.380	2	
24	5.689	1,6,7	McDowell Road Bridge
25	5.750	6	
26	5.900	6	
27	6.430	6	About 0.50 mile south of Thomas Road
28	6.890	5	
29	6.990	6	
30	7.490	6	About 0.5 mile south of Indian School Road
31	8.000	7	Indian School Road Bridge
32	8.100	7	East bank levee ends
33	8.210	1	
34	9.130	6,7	Camelback Road Bridge
35	9.900	5,1	
36	10.530		
37	10.720	6	About 0.5 mile south of Glendale Avenue
38	11.010	1,2	
39	11.340	6,7	Glendale Avenue Bridge
40	11.520	5	
41	11.800	6	About 0.50 mile north of Glendale Avenue
42	12.380	5,6	Northern Avenue
43	13.330	6,7	
44	13.810	2	
45	14.380	6	Peoria Avenue
46	14.850	5	
47	14.940	6	About 0.5 mile north of Peoria Avenue
48	15.320	1	

Table 2.1- The selected stations for the Agua Fria River (continued..)

No.	Mile No.	Criteria Used	Approximate Location/Descriptions
49	15.510	5	Cactus Road
50	15.980	6	About 0.5 mile north of Cactus Road
51	16.420	7	Grand Avenue Bridge
52	16.446	7	
53	16.450	6	San Fe Railroad Bridge
54	16.910	5	
55	17.380	1,2	
56	17.760	6	Greenway Road
57	18.240	5	
58	18.920	6,7	Bell Road Bridge
59	19.440	6	
60	19.890	6	
61	20.450	6	
62	20.920	2	
63	21.010	7	
64	21.420	1	
65	21.760	5,6	
66	22.320	6	
67	22.790	6	
68	23.350	6	Pinnacle Peak
69	23.890	6	About 0.50 mile south of Happy Valley Road
70	24.350	6	Happy Valley Road
71	24.540	5	
72	24.900	6	About 0.5 mile south of Jomax Road
73	25.370	7	
74	25.590	2	Jomax Road
75	25.860	5	
76	26.290	6	About 0.5 mile north of Jomax Road
77	26.730	5,6	
78	27.030	5	
79	27.680	6	Dixileta Drive
80	28.120	6	About 0.5 mile north of Dixileta Drive
81	28.670	6	Lone Mountain (About 1.0 mile south of CAP Canal)
82	29.040	6	About 0.5 mile south of CAP Canal
83	29.540	7a	
84	29.610	5,7	Beardsley Canal Flume
85	29.800	6	CAP Canal
86	30.070	5	
87	30.260	6	About 0.5 mile north of CAP Canal
88	30.820	6	
89	31.390	6	About 0.5 mile north of Carefree Road
90	31.860	6	Cloud Road
91	32.430	6	About 0.5 mile south of Highway 74
92	32.860	5	
93	32.984	5,6,7	Highway 74 Bridge
94	32.998	5	
95	33.410	2	
96	33.820		Most Downstream Station

Table 2.2 - Bridge locations along the Agua Fria River

No.	Bridge Location	Approximate Mile Designation
1	Buckeye Road	Mile 3.734
2	South Pacific Railroad	Mile 3.767
3	Van Buren Road	Mile 4.754
4	Interstate 10 (I-10)	Mile 5.300
5	McDowell Road	Mile 5.689
6	Indian School Road	Mile 8.000
7	Camelback Road	Mile 9.130
8	Glendale Avenue	Mile 11.340
9	Olive Road	Mile 13.330
10	Grand Avenue	Mile 16.420
11	Santa Fe Railroad	Mile 16.450
12	Bell Road	Mile 18.920
13	Beardsley Canal Flume	Mile 29.611
14	Highway 74	Mile 32.984

2.2.2 Sediment Characteristics

Typical to alluvial rivers or streams, the characteristic description of the sediments at the Agua Fria River is generally coarser at the upstream river end and finer at the downstream end. This general description could be attributed to the movement of sediments in the form of wash-loads and finer aggregates that are transported downstream during flood events. Normally, sediment data are presented in size distribution plots called gradation curves. The sediment information compiled for the Agua Fria River are listed in **Table 2.3** and their respective gradation curves are presented in **Appendix B.**

Table 2.3- Sediment information for the Agua Fria River

No.	Mile No.	Date Collected	Depth/Other Descriptions	Source/Reference
(1)	0.0947	02-25-83	4"to 6"	SLA (1983)
		03-02-83	12" to 15"	SLA (1983)
	0.0947*		4" to 15"	ASU (1992)
(2)	0.92	02-22-92	0 to 3'	ASU (1992)
(3)	1.33	02-22-92	0 to 3'	ASU (1992)
(4)	1.71	02-22-92	0 to 3'	ASU (1992)
(5)	2.60	02-22-92	0 to 3'	ASU (1992)
(6)	3.27	02-22-92	0 to 3'	ASU (1992)
(7)	3.851	04-11-83	2'	SLA (1983)
	3.851	04-08-83	3' to 10'	SLA (1983)
	3.851	04-09-83	11'	SLA (1983)
	3.851*		2' to 11'	ASU (1992)
(8)	3.946	03-02-83	12" to 15"	SLA (1983)
	3.946*			ASU (1992)
(9)	4.30	03-22-92	0 to 3'	ASU (1992)
(10)	4.754/4.759		9.5' to 11' (2 samples)	SHB (1984)
			14.5' to 16'	SHB (1984)
			24.5' to 26'	SHB (1984)
			39' to 49'	SHB (1984)
	4.757*		9.5' to 49'	ASU (1992)
(11)	5.29	02-22-92	0 to 3'	ASU (1992)
(12)	5.69		44' to 35'	SHB (1982)
(13)	5.75		19.5' to 21'	SHB (1982)
(14)	5.878	04-09-83	2' to 7'	SLA (1983)
(15)	6.43	02-08-92	0 to 3'	ASU (1992)
(16)	6.97/6.99	04-11-83	0 to 10"	SLA (1983)
	6.97/6.99	04-12-83	6'	SLA (1983)
	6.97/6.99	04-11-83	8'	SLA (1983)
	6.98*		0 to 8'	ASU (1992)
(17)	7.49	02-08-92	0 to 3'	ASU (1992)
(18)	7.96/8.01		0 to 18'	SHB (1980)
			14' to 20'	SHB (1980)
			19 1/2' to 21	SHB (1980)
	8.00*		0 to 21'	ASU (1992)
(19)	8.34		2' to 4'	SHB (1991)
			14' to16'	SHB (1991)
			34' to 36'	SHB (1991)
	8.34*		2' to 36'	ASU (1992)
(20)	8.54		3' to 5'	SHB (1991)
			13' to 15'	SHB (1991)
			14' to 16'	SHB (1991)
			24' to 26'	SHB (1991)
			30' to 32'	SHB (1991)
	8.54*		3' to 32'	ASU (1992)
(21)	8.64	02-08-92	0 to 3'	ASU (1992)
(22)	8.73		2' to 4' (2 locations)	SHB (1991)
			12' to 14'	SHB (1991)
			14' to 16'	SHB (1991)
			18' to 20'	SHB (1991)
	8.73*		2' to 20'	ASU (1992)

Table 2.3 - Sediment information for the Agua Fria River (continued...)

No.	Mile No.	Date Collected	Depth/Other Descriptions	Source/Reference
(23)	8.83		2' to 4'	SHB (1991)
			23' to 25'	SHB (1991)
	8.83*		2' to 25'	ASU (1992)
(24)	8.93		3' to 5'	SHB (1991)
			34' to 36'	SHB (1991)
	8.93*		3' to 36'	ASU (1992)
(25)	9.02		12' to 14'	SHB (1991)
			28' to 30'	SHB (1991)
	9.02*		12' to 30'	ASU (1992)
(26)	9.13/9.135	07-17-91	1' to 2'	ABC (1991)
	9.13*			ASU (1992)
(27)	9.25		3' to 5'	SHB (1991)
			18' to 20'	SHB (1991)
	9.25*		3' to 20'	ASU (1992)
(28)	9.47	02-28-83	12" to 15"	SLA (1983)
	9.47*		12" to 15"	ASU (1992)
(29)	9.625	04-09-83	3'	SLA (1983)
	9.625*			ASU (1992)
(30)	10.34	04-19-83	0 to 3'	SLA (1983)
	10.34	04-19-83	0 to 5'	SLA (1983)
	10.34*		0 to 5'	ASU (1992)
(31)	10.72	02-08-92	0 to 3'	ASU (1992)
(32)	11.34	02-08-92	0 to 3'	ASU (1992)
(33)	11.80	02-08-92	0 to 3'	ASU (1992)
(34)	12.38	02-08-92	0 to 3'	ASU (1992)
(35)	12.84	02-08-92	0 to 3'	ASU (1992)
(36)	13.31/13.33		14.5' to 16.0'	SHB (1984)
			26' to 27.5'	SHB (1984)
			29' to 39'	SHB (1984)
			30' to 35'	SHB (1984)
	13.32*		14.5' to 39'	ASU (1992)
(37)	13.90	01-18-92	0 to 3'	ASU (1992)
(38)	14.38	01-18-92	0 to 3'	ASU (1992)
(39)	14.94	01-18-92	0 to 3'	ASU (1992)
(40)	15.98	01-18-92	0 to 3'	ASU (1992)
(41)	16.46	02-08-92	0 to 3'	ASU (1992)
(42)	17.09	02-08-92	0 to 3'	ASU (1992)
(43)	17.76	01-18-92	0 to 3'	ASU (1992)
(44)	18.42	01-18-92	0 to 3'	ASU (1992)
(45)	18.90/18.94	11-00-76	5' to 21'	SHB (1980)
	18.92*			ASU (1992)
(46)	19.44	01-18-92	0 to 3'	ASU (1992)
(47)	19.89	01-18-92	0 to 3'	ASU (1992)
(48)	20.45	01-20-92	0 to 3'	ASU (1992)
(49)	20.83	01-20-92	0 to 3'	ASU (1992)
(50)	21.68	06-08-91	0" to 15" (5 Samples)	Ryan (1991)
	21.68*			ASU (1992)
(51)	21.76	06-08-91	0" to 15" (5 Samples)	Ryan (1991)
	21.76*			ASU (1992)

Table 2.3 - Sediment information for the Agua Fria River (continued...)

No.	Mile No.	Date Collected	Depth/Other Descriptions	Source/Reference
(52)	22.32	01-20-92	0 to 3'	ASU (1992)
(53)	22.79	01-20-92	0 to 3'	ASU (1992)
(54)	23.35	01-25-92	0 to 3'	ASU (1992)
(55)	23.89	01-25-92	0 to 3'	ASU (1992)
(56)	24.35	01-25-92	0 to 3'	ASU (1992)
(57)	24.90	01-25-92	0 to 3'	ASU (1992)
(58)	25.37	01-25-92	0 to 3'	ASU (1992)
(59)	25.86	01-25-92	0 to 3'	ASU (1992)
(60)	26.29	01-25-92	0 to 1 1/2'	ASU (1992)
(61)	26.55	01-25-92	0 to 3'	ASU (1992)
(62)	26.73	01-25-92	0 to 3'	ASU (1992)
(63)	27.30	01-25-92	0 to 3'	ASU (1992)
(64)	27.58	01-25-92	0 to 3'	ASU (1992)
(65)	27.68	02-01-92	0 to 3'	ASU (1992)
(66)	28.12	05-30-86	0' to 6"	UM (1986)
	28.12	05-30-86	6' to 12'	UM (1986)
	28.12	05-30-86	12' to 15'	UM (1986)
	28.12*		0' to 15'	ASU (1992)
(67)	28.21	02-01-92	0 to 3'	ASU (1992)
(68)	28.67	02-08-92	0 to 3'	ASU (1992)
(69)	29.04	02-22-92	0 to 3'	ASU (1992)
(70)	29.80	02-01-92	0 to 4"	ASU (1992)
(71)	30.26	02-01-92	0 to 3'	ASU (1992)
(72)	30.82	02-01-92	0 to 3'	ASU (1992)
(73)	31.29	02-01-92	0 to 3'	ASU (1992)
(74)	31.86	02-01-92	0 to 3'	ASU (1992)
(75)	32.43	02-01-92	0 to 3'	ASU (1992)
(76)	32.98	02-08-92	0 to 4"	ASU (1992)

2.2.3 Hydrology

2.2.3.1 Flood Hydrographs - The 100-year hydrographs for the Agua Fria River at the confluence with the New River (Mile 9.87) were developed by **Water Resources Associates, Inc. (1986)**. Also the same study provided a 100-year hydrograph for the Arizona Canal Diversion Channel (ACDC) at the New River which is the major tributary of the Agua Fria river.

2.2.3.2 Flood Frequency - A flood insurance study made for the Agua Fria River was conducted in 1988 of which a flood frequency curve was presented **[Jerry R. Jones & Associates, Inc., 1989]**. The peak discharge-flood frequency relationships were provided by the U.S. Army Corps of Engineers (COE). The summary of discharges for 10- 25-, 50-, 100-, and 500-year discharges at various locations along the 34-mile river is tabulated in **Table 2.4.**

Table 2.4 - Design Flood Discharge at the Agua Fria River [Waddell Dam to Gila River for Existing Conditions]

Location Along the Agua Fria River	Peak Discharge (cfs) 10-yr	25-yr	50-yr	100-yr	500-yr
Inflow - Waddell Dam	60,000	90,000	110,000	135,000	190,000
Outflow-Waddell Dam [Mile 33.25]	60,000	90,000	110,000	135,000	182,000
Bell Road [Mile 18.91]	37,000	60,000	87,000	115,000	182,000
U/S New River Confluence [Mile 9.90]	30,000	48,000	66,000	90,000	177,000
D/S New River Confluence [Mile 9.81]	32,000	50,000	69,000	95,000	184,000
Camelback Road [Mile 9.375]	31,000	50,000	69,000	95,000	184,000
Indian School Road [Mile 8.03]	30,000	49,000	69,000	94,000	183,000
McDowell Road [Mile 6.34]	29,000	48,000	68,000	91,000	182,000
I-10 Freeway [Mile 5.39]	29,000	48,000	68,000	91,000	181,000
Avondale	28,000	47,000	67,000	90,000	179,000
Gila River Confluence [Mile 0.00]	27,000	47,000	67,000	89,000	179,000

[Source: U.S. Army Corps of Engineers, 1981]

2.2.3.3 **Stage-Discharge Rating Data** - Due to insufficiency of field data to relate water surface elevation with discharge at the most downstream control point of the river, a rating curve was generated using the slope-area method. **Appendix C** lists the stage-discharge rating data at the most downstream stations (i.e., stations 0.16, 0.25, 0.35, 0.44, and 0.54) determined from the use of the method. A number of energy gradients, S_e, were used to show that at some distance upstream [from the most downstream station 0.16], the water surface elevation converges [see **Tables C.1.2 - C.1.7**]. In addition, even when critical depths are assumed at the most downstream station [i.e. station 0.16], the same convergence behavior is expected at some distance upstream [see **Table C.1.1**]. These results of the analysis explain that only the reach below this station point, where the convergence occurs, will the sedimentation processes be inaccurately predicted.

Based on the evaluation of the most downstream station [i.e. Station 0.16] where the energy slope is small, a gradient slope, Se, of 0.001 is assumed [see **Fig. C.1.2**]. **Fig. 2.1** shows the rating curve with a fitted relation expressed as,

$$WSE = 912.92 + 2.5237x10^{-4}Q - 2.8335x10^{-9}Q^2 + 1.2925x10^{-14}Q^3$$

where WSE is the water surface elevation, ft, and, Q is the flood discharge, cfs.

2.3 Structural Features

The discharges that currently flow through the Agua Fria River originates mostly from the existing Waddell Dam which impounds Lake Pleasant. Currently, the existing dam regulates the flows for downstream use. In 1993, however, the New Waddell Dam which is being constructed at about one-fourth of a mile downstream of the existing dam, will regulate most of these discharges that serve downstream demands as well as those discharges that pass through the Agua Fria River.

2.3.1 Existing Waddell Dam

The existing dam impounds about 157,600 ac-ft of water at Lake Pleasant. Completed in 1927, the dam was built initially for water supply. About two-thirds of the Agua Fria watershed is controlled by the dam. The physical data of the existing Waddell Dam are provided in Table 2.5.

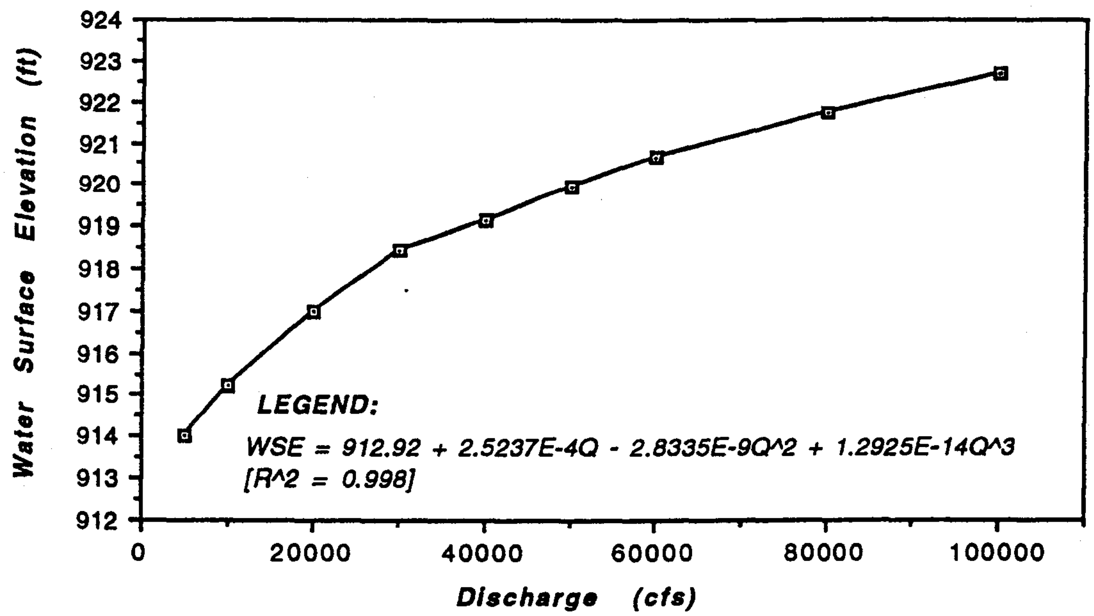

Fig. 2.1 - Rating curve at Station 0.16 obtained from slope-area method.

Table 2.5 - Physical Data of the Existing Waddell Dam

Item	Description
Type of Dam	Concrete Multiple Arch
Height	176 feet
Crest Length	2,160 feet
Maximum Storage Capacity	157,600 acre-feet
Surface Area at Maximum Storage Capacity	3,760 acres

2.3.2 The New Waddell Dam

Due to the large spills over the existing Waddell Dam during the 1978-, 1979-, and 1980-floods, the dam was redesigned to accomodate larger flows and thus serve the purpose of flood control, in addition to the original purpose of water supply. Such consideration has led to the construction of the New Waddell Dam which is situated about one-fourth of a mile downstream of the existing dam. The dam capacity has increased to 891,000 ac-ft with maximum release in the magnitude of 25,000 cfs. The advantages of building the New Waddell Dam are provided as follows:

(i) trap more sediments due to larger storage and increased detention time for the sediments in the reservoir;
(ii) the flood discharge will be significantly reduced;
(iii) reduction on downstream sediment transport due to controlled and more regulated releases; and,
(iv) the 100-year flood peak at Camelback Road could be reduced from 95,000 cfs to 47,000 cfs.

In short, the New Waddell Dam will have the greatest impact from among the developments upstream of the Agua Fria River on controlling future flood peaks and subsequently, the channel morphology response. The relevant physical data of the New Waddell Dam are provided in **Table 2.6**

Table 2.6 - Physical Data of the New Waddell Dam

Item		Description
A.	**Dam**	
	Type	*Rockfill Embankment*
	Height	*440 feet (300 feet above streambed)*
	Crest Elevation	*1,730 feet*
	Crest Length	*4,700 feet*
B.	**Spillway**	
	Type	*Ungated, free-overflow*
	Crest Length	*1,000 feet*
	Crest Elevation	*1,706.5 feet*
C.	**Reservoir**	
	Maximum Storage Capacity [Including Flood Space]	*902,100 acre-feet*
	Elevation at Maximum Storage Capacity	*1,706.5 feet*
	Surface Area at Maximum Storage Capacity	*10,340 acres*
	Conservation Storage Capacity	*816,000 acre-feet*
	(i) CAP Water	*658,400 acre-feet*
	(ii) MWD Replacement	*157,600 acre-feet*
	Minimum Pool	*40,500 acre-feet*
	Elevation at Maximum Conservation Storage	*1,702 feet*
	Surface Area at Maximum Conservation Storage	*9,970 acres*
D.	**Pumping-Generating Plant**	
	Number of Units	*8*
	Pump capacity	*3,000 cfs*
	Power Generation (Maximum)	*45 megawatts*
	Maximum Lift	*192 feet*
E.	**Waddell Canal**	
	Length	*4.9 Miles*
	Typical Cross-Section	*24 -foot bottom width, 82.5 to 88.5 feet wide at top of lining, lining height of 19.5 to 21.5 feet.*
	Lining Thickness	*4 inches*
	Capacity	*3000 cfs*

Note: CAP - Central Arizona Project; MWD - Maricopa Water District

III SEDIMENT TRANSPORT ANALYSIS

3.1 Previous Studies and Reports

3.1.1 Hydraulic and Geomorphic Analysis of the Agua Fria River [by Simons, Li, & Assoc., Inc., May 1983]

This study covers only the portion of the Agua Fria between the confluence of the New River and the confluence with the Gila River - some nine (9) river miles. A qualitative and engineering geomorphic analysis are presented, along with the results provided by QUASED - the sediment routing developed by **Simons, Li and Associates, Inc. [SLA]** in 1981. HEC-2 simulation was performed for the 100-year flood event. Stream reaches of aggradation and degradation are noted. Cross-sectional comparisons between 1973 and 1981 data were made. Recommendations for flood control projects were presented. Appended in the report are gradation data curves for sediments collected at 19 locations in the river and analyzed by Desert Earth Engineering.

3.1.2 Application of HEC-6 to Ephemeral Rivers of Arizona [by Dust, D. W., Bowers, M. T., and Ruff, P. F., January 1986]

The report details three case studies where the HEC-6 model was applied to Arizona streams: (i) the Agua Fria River between Jomax Road and Bell Road; (ii) the Salt River; and (iii) Rillito Creek. The report is intended as an aid to users of HEC-6 on Arizona ephemeral rivers, presenting some useful computer programs and strategies for collection and input of data, and in the calibration of model results against actual data using a program called STAP. For the Agua Fria, three sets of HEC-6 hydrologic inputs were used: (i) 1964-79 data; (ii) 1964-83 data; and, (iii) 1979-1983 data. Some particularly useful observations for the Agua Fria include the designation of ineffective flow areas and hydraulic weighting factors in the HEC-6 input, and methodologies for estimating Manning's "n" for the main channel and overbanks. Inflowing sediment loads were generated using a dummy reach for five (5) different HEC-6 options for sediment load transport. The inflow hydrograph to the study reach was a release of record from Waddell Dam. The report presents some useful information on HEC-6 computational stability when selecting discrete flow duration times at various flow rates. Stability tests were performed for Q = 4,000 cfs, 20,000 cfs, and 60,000 cfs. Absence of a rating curve at the downstream end of the study reach was compensated for by using HEC-6 default critical depth option to satisfy the downstream water surface elevation boundary requirements. The HEC-6 model results are inconclusive, but the "rigid bank" assumption for HEC-6 is indicated as a source of the discrepancies in actual and modeled stream cross-sectional geometries.

3.1.3 Agua Fria River Sedimentation Study to Determine Effects of Gravel Mining Below Lower Buckeye Road [by Water Resources Associates, Inc., May 1986]

This report was prepared for Development Engineering, the operator for two sand and gravel mining companies - the Allied Sand & Rock and West Sand & Rock. These two companies are proposing a large sand and gravel extraction operation in the Agua Fria River bed between Miles 1.0 and 2.5, just above the confluence with the Gila River. The companies plan to excavate a 40-foot deep pit, approximately 3,000 feet in width cross the river for a length of 8,000 feet. The study attempts to quantify changes in flood elevations and channel geometry likely to occur as a result of the proposed excavations. The report is intended to support the application of these mining companies to secure a permit from the Flood Control District of the Maricopa County (FCDMC) to operate the sand and gravel mines. The study area includes only 3.5 miles of the Agua Fria River, immediately upstream from the confluence with the Gila River. The data used by Water Resources Assoc., Inc. for the said study were the 1981-cross section data, the 100-year flood of 94,000 cfs, and a 10,000 cfs flow for channel slope-equilibrium analysis. The hydrograph for the 100-year flood (Waddell Dam spill) and a 29,000 cfs spill from the Arizona Canal Diversion Canal (ACDC) were prepared by the U.S. Army Corps of Engineers. A summary of sediment grain size distribution analyzed by **Force & Vann, Inc.**, is presented, although location of samples is unspecified. A HEC-2 backwater analysis was performed, and aerial photographs of stream channel location in 1936, 1975, late 1970's, and late 1980's along with 1957 USGS topographic quadrangles were used. The study attempted to quantify (i) local scour (using Armor Control, Neil, and Shen methods); (ii) regional scour (using the equilibrium-slope method with the Meyer-Peter-Muller bedload function and the Einstein integration for the suspended bedload); and (iii) head-cut migration at the upstream and downstream cuts (40-foot deep @ 10% slope).

The consultant predicts a 1,500-foot upstream headcut migration to a depth of 40 feet, and additional secondary regional and local scour upstream which threaten several structures. Downstream of the proposed excavation, headcut migration is predicted to extend only 340 feet, and to a depth of 5.5 feet. The consultants recommend armor, riprap and/or staircasing of the 40-ft faces, and maintenance of 200-foot wide buffers laterally to minimize chances of damage due to erosion.

3.1.4 Hydrology for the Evaluation of Flood Reduction by New Waddell Dam, Agua Fria River Below New Waddell Dam to the New River Confluence [by U.S. Army Corps of Engineers - Los Angeles District, September 1988]

This report analyzes the hydrology of the inflow to the New Waddell Dam reservoir and presents a "balanced" hydrograph routing through the reservoir. The outflow from the dam is evaluated under three potential operation schemes: (i) Joint use [in which seasonal flood control space is provided between 1694 ft and 1702 ft, with full-time flood control space above elevation 1702 ft.]; (ii) No joint use [consisting of full-time water supply until elevation 1702 ft., and dedicated flood control from 1702 to 1706.5 ft.]; and (iii) Full-time water supply [providing no flood control protection at all].

Discharge-frequency relationships are presented at four (4) locations between the dam and Agua Fria's confluence with the New River. They are: (1) below Waddell Dam; (2) at Bell Road; (3) at Grand Avenue; and, (4) above New River confluence. With the Waddell Dam, the 100-year flood peak will be reduced from 135,00 cfs (without the dam) to 10,000 cfs. Even with operation without flood control (full-time water supply), the 500-year flood release from Waddell to the Agua Fria River goes from 182,000 cfs (without the dam) to less than 70,000 cfs. Reservoir operations with storage reduces the 500-year peaks from 50,000 cfs (with the dam) to 30,000. The U.S. Army Corps of Engineers used a rainfall-runoff model to add local inflows to the discharge from Waddell Dam for hydrologic routing up to the confluence with the New River. The portion of the Agua Fria River between the New River confluence and the confluence with the Gila River is not studied.

3.1.5 Flood Insurance Study (FIS): Agua Fria River, Maricopa County, Arizona [by Jerry R. Jones & Assoc., Inc., January 1989]

This report is the restudy of the 1988 Flood Insurance Study maps done by FEMA necessitated by modifications and construction in the floodplain. FEMA's Flood Insurance Study stopped at Jomax Road, whereas this study goes all the way down to the confluence with the Gila River. The study considers "Pre-Waddell Dam" hydrology, but incorporates new bridges constructed along the river and soil-cement levees constructed between Indian School and Broadway Roads. The restudy delineates the 100-year floodplain under the changed conditions since the 1988 FEMA maps to allow establishment of actuarial rates for flood insurance. The report presents 10, 50, 100, and 500-year flood discharges at Old Waddell Dam, at 7 downstream locations on the Agua Fria River. The report is most useful for the HEC-2 analysis, which produced in excess of 450 cross-sections of the river. The report contains references to other studies which may be useful to the current effort:

(i) U.S. Army Corps of Engineers, Los Angeles District, (1968), "Floodplain Information Study, Agua Fria River, Maricopa County, Arizona," Los Angeles, California.
(ii) U.S. Department of HUD, FIA, (1979), "Flood Insurance Study, Maricopa County, Arizona,", Washington, D.C., May 1979;
(iii) USGS, "Flood of February 1980 along the Agua Fria River, Maricopa County, Arizona," WRI Open File Rep. 80-767, Tucson, June 1980;
(iv) Simons, Li & Assoc., Inc., (1984), "Agua Fria Side-Drainage Analysis," Tucson, November 1984; and,
(v) Simons, Li & Assoc., Inc., (1985), "Agua Fria Control Project, Analysis of Side-Drainage Requirements, Buckeye Road to 1,500 feet South of Interstate 10,"Tucson, January 1985.

3.1.6 Effects of In-Stream Mining on Channel Stability, *Executive Summary* [by Simons, Li & Assoc., Inc., June 1989]

This report addresses the issues of sand and gravel extraction in general and is applicable to desert alluvial streams, including: regulatory practices, structural hazards, economic value, social and environmental factors, statewide classification of streams in

Arizona, review of study methodologies, mitigative measures, engineering parameters, long and short-term procedures, river response simulation procedures, case studies, justification for regulations on the industry, implementation plans, and needs for additional monitoring and data collection. The report provides a detailed description of the aggregate extraction activities in the Agua Fria River. Seven (7) "clusters" of mining are inventoried in the Agua Fria River between Buckeye Road and Camelback Road; and, additional five (5) "clusters" are located between the confluence of the New River and the confluence with the Gila River. Some basic data of volumes excavated and aggradation/ degradation measurements are presented for these reaches of the Agua Fria River.

A study was made in 1985 to develop strategies on the development of general input data and calibration of HEC-6 for ephemeral rivers in Arizona **[Dust, et al., 1986]**. The work also aimed at identifying potential limits on the capability of HEC-6 for such rivers.The study reach chosen for the Agua Fria River spanned to about 6.52 miles located about seven (7) miles downstream of Waddell Dam which impounds Lake Pleasant. The north and south boundaries of the river reach exactly coincided with Jomax Road (Mile 26.60) and Bell Road (Mile 20.08), respectively, and consisted of 29 cross-sections. Due to the substantially inaccurate geometric data used, the results of the application of the HEC-6 Model to the Agua Fria River are inconclusive. The results suggested that the "rigid bank" assumption is a limiting factor in the application of HEC-6 to braided ephemeral rivers in Arizona.

Another study for the Agua Fria River was made to assess the hydraulic and geomorphic conditions and evaluate some proposed flood control projects along the study reach. The study reach was defined from the river's confluence with the New River (Mile 9.70) to Gila River (Mile 0.0). The entire effort was geared to provide baseline information on hydraulic and sediment transport characteristics of the Agua Fria for future flood control projects **[Simons, Li and Associates, Inc., 1983]**. Three levels of analysis were made: (i) qualitative geomorphic analysis; (ii) engineering geomorphic analysis; and, (iii) mathematical model simulation.

For the mathematical model simulation, the channel response of the Agua Fria River was made through QUASED **(Simons, Li and Assoc., Inc., 1981)** using the 1978-, 1979-, and 1980-floods. The 1973 cross-sections of the river obtained from the U.S. Army Corps of Engineers were used to simulate the pre-flood conditions while the 1981-cross-sections derived from 1981 topographic maps were used to approximate the post-flood conditions. The study concluded that QUASED satisfactorily predicted the aggradation and degradation trends for the 1978, 1979, and 1980 floods, and thus would give reasonable sedimentation predictions for the 100-year flood.

3.2 Scope of Work for the Present Study

The project is aimed at developing sediment transport models using the HEC-6 code to simulate the long-term stream bed profile response of the Agua Fria River based on different development scenarios. The sedimentation modeling covers the whole reach of the Agua Fria River which comprised of approximately 34 miles. The study reach has its upstream boundary located in the diversion outlet south of the New Waddell Dam and its downstream boundary at the Gila River confluence. Associated with the modeling works being developed for the Agua Fria River, training personnel from the Maricopa County Flood Control District would be made with highlights on the development of sediment models that reflect the existing and future conditions along the river. The stage-by-stage incorporation of the development projects along the river forms the basis of the modeling effort which when evaluated help identify and locate problem areas in the river. These problem areas are associated with the extent of degradation and aggradation encountered as by-product of the development projects considered. The components of the work scope are provided as follows:

(i) training
(ii) collection and review of available data;
(iii) data verification, acquisition, and validation;
(iv) sediment transport evaluation;
(v) coordination; and,
(vi) preparation of final products.

3.2.1 Training - The Civil Engineering Department offers the expertise to train Maricopa County Flood Control District personnel in the modeling:

(i) to simulate stream bed profile behavior;
(ii) to identify potential degradation/aggradation of stream beds;
(iii) to assess the natural dynamics of the river system;
(iv) to analyze the impacts of gravel mining; and,
(v) to identify flood risks due to sediment transport.

The training includes the review of data coding, selection of pertinent data and information, and debugging process.

3.2.2 Collection and Review of Available Data - Data collection includes the following information,

(i) geometric data - stream geometry from flood plain studies, aerial and ground photos, surveys and past sediment studies;
(ii) hydrologic and hydraulic data - historic flood, peak discharges from flood insurance studies for Agua Fria River, peak discharges for post-New Waddell Dam, rainfall data, and water surface profiles from HEC-2 runs of the Agua Fria River flood insurance study **(Jerry R. Jones & Assoc., Inc., 1989).**
(iii) sediment data - sediment gradation data, dredging and mining frequency, quantities and locations, and review of past sediment reports;
(iv) site reconnaisance information - project site survey to observe the overall river and appropriate tributaries that aids in calculating sediment transport quantities; photographic documentation of sediment characteristics, inspection of flood control or drainage structures;
(v) field reconnaisance report that summarizes the site survey including photographs to document field sediment information. This report shall be included in the final report as an Appendix.

3.2.3 Data Verification and Acquisition

(i) collection of additional data required for the development of HEC-6 models. Data acquisition includes: geotechnical analysis; collection of sediment samples; and sieve analysis.

(ii) verification and validation of available geometric and sediment data, etc.

3.2.4 Sediment Transport Evaluation

(i) development of three (3) HEC-6 multi-profile models each for peak discharges of Q = 18,500 cfs, 32,000 cfs, 54,000 cfs, and 85,000 cfs which represent the 50-, 100-, 200-, and 500-year return period flood peaks of the post-New Waddell Dam. The development scenarios for these three (3) models are provided as follows:

Model I	Development of a model to evaluate the sediment transport under the existing condition with New Waddell Dam and the Arizona Canal Diversion Channel (ACDC) built;
Model II	Development of a future condition model using the existing condition model (Model I) to reflect the ultimate sand and gravel mining as permitted today;
Model III	Development of a future condition model by adding 1000-foot wide channel improvement along the Agua Fria River (wherever applicable) to Model II in order to evaluate the effect of mining sites on the proposed channel;

(ii) evaluation of the ten (10) sediment transport functions currently available in the most recent version of HEC-6 code; the functions will be tested to evaluate their validity for the Agua Fria River. In addition, sensitivity analyses of the various input parameters for the sediment transport functions, including Manning's roughness coefficient, will be performed.

(ii) development of all HEC-6 models from the available Agua Fria River HEC-2 model **(Jerry R. Jones & Assoc., Inc., 1989)** to calculate surface profiles, sediment transport capacity at each section, volume of material scoured or deposited between cross-sections, associated change in bed surface elevation, and the modification of cross-section geometry to appropriately reflect the scenarios considered and under each event;

(iv) preparation of a narrative report describing the modeling procedure, and assumptions made based upon the sediment availability of the river system.

(v) comparison of the previous sediment studies within the study area and the results obtained by the HEC-6 model. Major differences will be addressed which will ultimately be discussed in the final report;

(vi) presentation of working maps and models during the course of the sediment transport modeling analysis for review by District staff at coordination meetings;

(vii) preparation of cross-section plots using a pen-plotter. The cross-sections will show water surface profiles, limits of movable bed, surface gradation for transport theory, gradation for scour calculations, and model invert. These plots in addition to the working maps, HEC-6 output, and HEC-6 inputs/outputs on diskettes are to be available at all reviews.

(viii) evaluation and analysis of the results of each modeling effort will be done separately; documentation of these results will be made separately and comparatively in the final report;

(ix) extent of the applicability of the study should be explained in the final report.

(x) final sediment transport maps will be based on the Agua Fria River floodplain maps;

(xi) tabulations which indicate the points of gradation, volume, depth, change of velocities, water surface elevations, and invert profiles will be presented in the final report.

3.2.5 Coordination - In addition to the weekly training session, regular coordination meetings shall be held to discuss work progress. Milestone coordination meetings shall be held at the completion of any major task. Prior to finalizing the sediment transport analysis, maps, reports, cross-section plots, HEC-6 output hard copies, and HEC-6 input/output files on diskettes shall be submitted to the Flood Control District for review and approval.

3.2.6 Preparation of Final Report - The following final products shall be considered for submission in the final stage of work:

(i) Mapping

- Three (3) complete sets of contour maps showing degradation/ aggradation associated with each of the cross-sections for the 50- and 100- peak discharge events on (24"X36") reproducible mylars and four sets of blueline copies. Final maps should show the cross-section locations, the points of gradation, total volumes, and depths, existing thalweg profile with two runs plotted for both 50- and 100-year peak discharge events;

- Three (3) complete sets of mylars for foldout (11"X17") and three (3) sets of blueline copies as used in the report;

- Three (3) complete sets of (8 1/2" X11") penplotter cross-sections as described in section **3.2.4 (vii)** above.

(ii) Two hardcopies of the HEC-6 printouts and a copy of the HEC-6 model input/output on diskettes compatible with an IBM-AT personal computer;

(iii) Six (6) copies of the final report addressing all comments of the Flood Control District during the review process.

IV CALIBRATION ANALYSIS

The calibration analysis is made as a preliminary study prior to the sedimentation modeling proper of the entire Agua Fria River. This is essential to generate and define basic information essential to the development of sedimentation models for the river.

The Agua Fria River is being studied for the purpose of developing sedimentation models that could predict the long-term aggradation and degradation along its 34-mile long channel. HEC-6, a computer sedimentation code developed by the **U.S. Army Corps of Engineers (1991)** will be used to achieve the purpose. HEC-6 is a simulation model of particular use in analyzing scour and deposition by modeling the interaction between the water-sediment mixture, material sediment forming the streambed, and the hydraulics of flow. The objective of achieving a realistic prediction of long-term sedimentation in the river, however, requires a number of essential considerations:

(i) the assumptions associated with the development of HEC-6 code are, likewise, adopted for the modeling of the river;
(ii) the generation of inflowing sediment if field data are not available;
(iii) the selection of sediment transport function that closely describes the transport dynamics of sediment movement in the river; and,
(iv) sensitivity analysis of the hydraulic parameters used.

4.1 Location of the River Reach

The study reach is located in Central Arizona, approximately 10 miles northwest of Phoenix. The north and south boundaries of the study reach are coincident with Jomax Road and Bell Road, respectively [see **Fig. 4.1**]. Within the set limits, the intermittent Agua Fria River is characterized by a wide flood plain in which braided channels meander through a relatively low relief and sparsely vegetated desert plain. Flow in the Agua Fria is controlled by flood gates in Waddell Dam which impounds Lake Pleasant. This reservoir is located approximately seven miles north of the upstream limit of the study reach.

4.2 Modeling Data

4.2.1 Geometric and Hydraulic Data

(i) <u>Cross-Section Data -</u> The geometric data of 1979 for the study reach is used as the original data for the simulation study. The data was based on the floodplain delineation map drawn by **Yost and Gardner Engineers (1979)** covering the reach from Bell Road to Jomax Road which is about 7.4 miles long. The map has a contour interval of 4.0 feet and a scale of 1:400. There are 39 cross-sections defined for the entire study reach and they are designated accordingly by their mileage number (see **Table 4.1**). As shown, adjustment on the mileage numbering has to be made to be consistent with the mileage numbering system that was used by the **Jerry R. Jones & Assoc., Inc.** in the 1989 flood insurance study of the Agua Fria River [**Jerry R. Jones &**

Associates, Inc., 1989]. Cross-section plots of 1979- and 1989-data for surveyed stations that are located closed to one another are shown in Figs. 4.2 (a) - (f). All the plots shown reveal that the flood event that occurred in February 13-22, 1980, has generally, lowered the channel bed elevation.

(ii) Channel Section Boundaries - The river channel comprises three sections: left overbank (LOB), main channel, and right overbank (ROB). The significance of defining these section boundaries is to differentiate the main channel from the bank channels. **Table 4.1** defines the station boundaries that divide the left overbank, main channel, and right overbank sections.

(iii) Thalweg Elevations - The thalweg elevation data obtained from various locations along the study reach in 1979 [**Yost and Gardner Engineers, 1979**] and in 1989 [**Jerry Jones Associates, Inc., 1989**] are plotted in **Figs. 4.3 (a, b, and c)**. It is obvious from the figures that the bed changes along the channel from 1979 to 1989 are predominantly scouring.

(iv) Roughness Coefficients - The roughness coefficient data along the study reach were derived from the NH card of the **HEC-2** input data file used by the **Yost and Gardner Engineers (1979)** in the floodplain study of the Agua Fria River in 1979.

Since the NH card provides the relationship between the lateral segments of the river cross-section and roughness coefficient 'n', a computer program was developed to determine the representative 'n' values for the left overbank (LOB), main channel, and the right overbank (ROB) to be used in the calibration study. The representative roughness coefficients at various sections of the study reach are tabulated in **Table 4.2** and further plotted in **Fig. 4.4**

(v) Energy Loss Coefficients Due to Channel Contraction and Expansion - The loss coefficients attributable to the expansion and contraction of the river channel are respectively, 0.1 and 0.3.

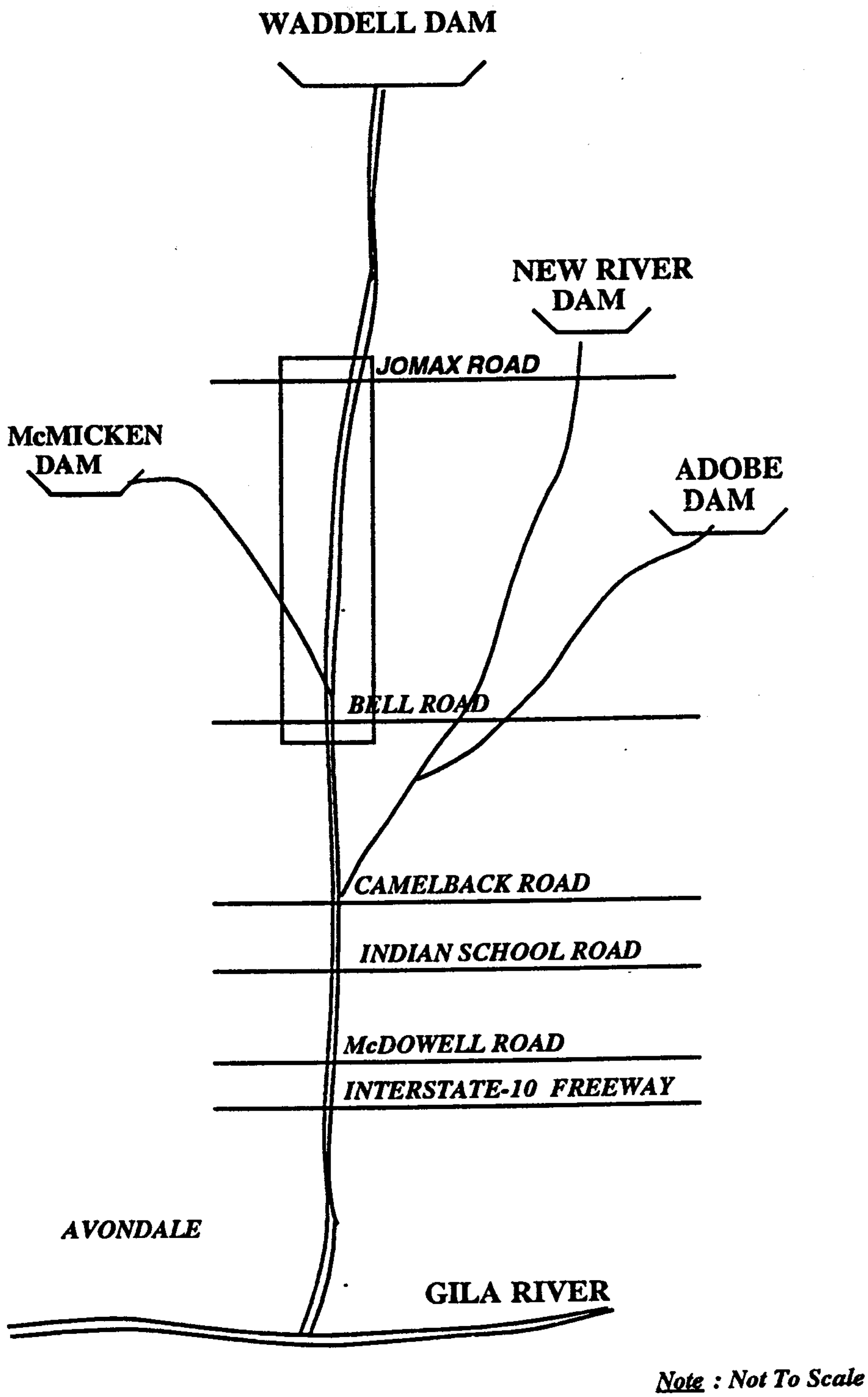

Fig. 4.1 - River sketch of the Agua Fria River showing the location of the river reach.

Table 4.1 - Cross-sections covering the study reach from Bell Road to Jomax Road with the section boundaries.

Location	No.	Mileage Number	Adjusted Number	Section Boundaries LOB-Main	Section Boundaries Main-ROB
Bell Road	1	19.585	18.900	9770.00	10374.00
	2	19.620	18.940	8125.60	10352.70
	3	19.800	19.170	8584.10	10407.50
	4	20.000	19.350	7613.00	10077.50
	5	20.200	19.540	7397.30	10094.80
	6	20.400	19.720	7377.70	10594.90
	7	20.600	19.890	7975.10	10793.70
	8	20.800	20.080	8538.50	11071.70
	9	21.000	20.270	8252.40	11164.60
	10	21.200	20.450	7422.00	10304.00
	11	21.400	20.640	6482.60	10100.90
	12	21.600	20.830	7798.90	10284.10
	13	21.800	21.090	7997.20	10566.10
	14	22.000	21.240	8592.30	10201.40
	15	22.200	21.420	9030.20	10135.40
	16	22.280	21.590	9329.00	10276.70
	17	22.460	21.680	9514.50	10421.20
	18	22.600	21.760	9595.90	10818.10
	19	22.800	21.850	9752.50	11849.20
	20	23.000	22.130	9917.80	12406.60
	21	23.200	22.320	9550.40	12458.20
	22	23.400	22.600	9875.80	13445.90
	23	23.600	22.790	9929.10	13612.90
	24	23.850	22.980	9886.50	13112.70
	25	24.050	23.160	9945.60	13159.90
	26	24.250	23.350	9846.00	13075.40
	27	24.450	23.620	9882.50	12844.60
	28	24.650	23.800	9368.50	11313.10
	29	24.900	23.980	9094.80	11500.20
	30	25.100	24.170	9337.50	10940.00
	31	25.300	24.350	9599.40	10765.40
	32	25.450	24.450	9608.70	10908.40
	33	25.650	24.630	9731.80	10982.90
	34	25.900	24.900	9615.30	11329.60
	35	26.100	25.090	9850.30	10501.70
	36	26.300	25.370	9684.10	10554.90
	37	26.450	25.530	9724.70	10277.70
Jomax Road	38	26.600	25.590	9660.90	10744.80
	39	26.900	25.790	9535.40	10937.50

Source: HEC-2 Input Data File, Yost and Gardner Engineers, 1979.

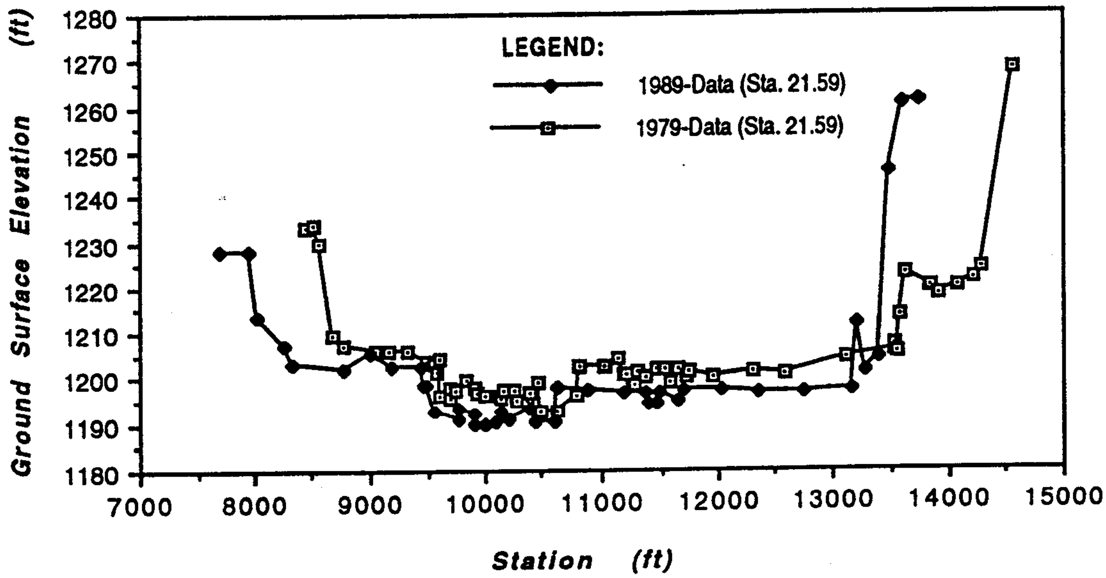

Fig.4.2 (a) - Cross-section plot of 1979- and 1989-data for Station 21.76

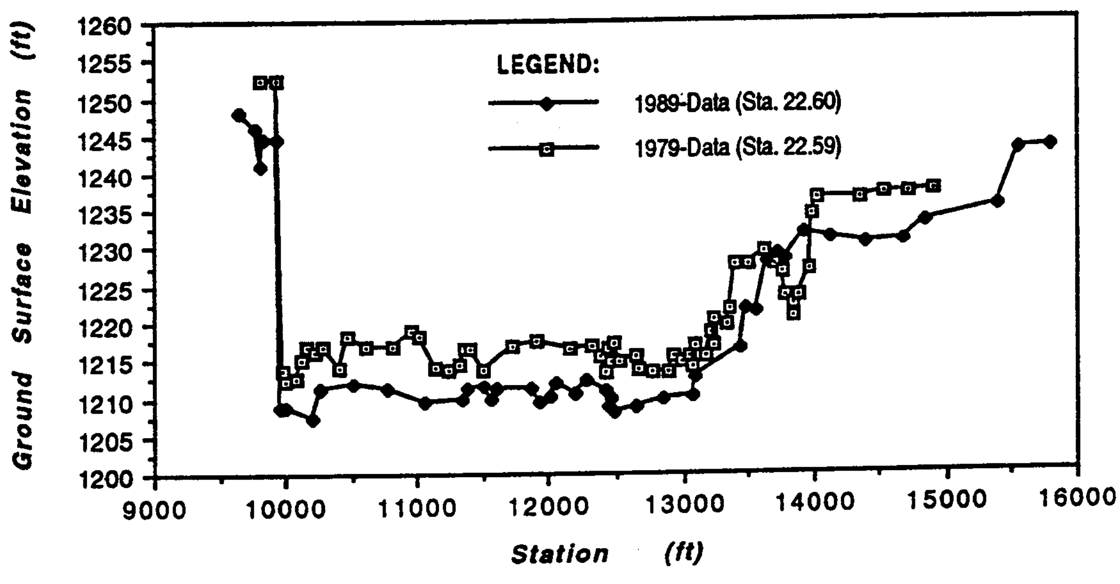

Fig.4.2 (b) - Cross-section plot of 1979- and 1989-data for Station 22.79

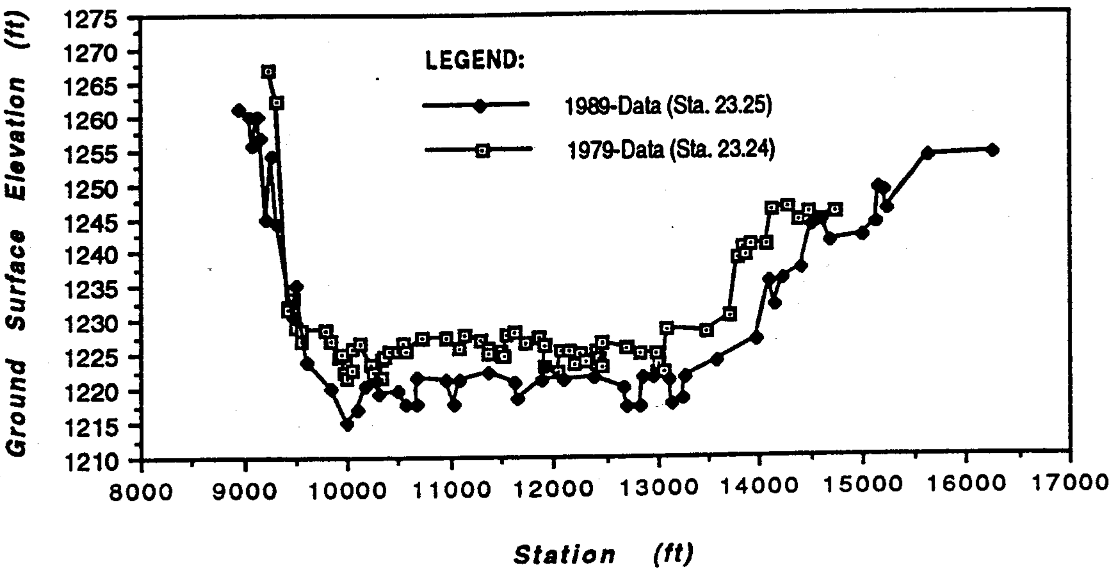

Fig. 4.2 (c) - Cross-section plot of 1979- and 1989-data for Station 23.35

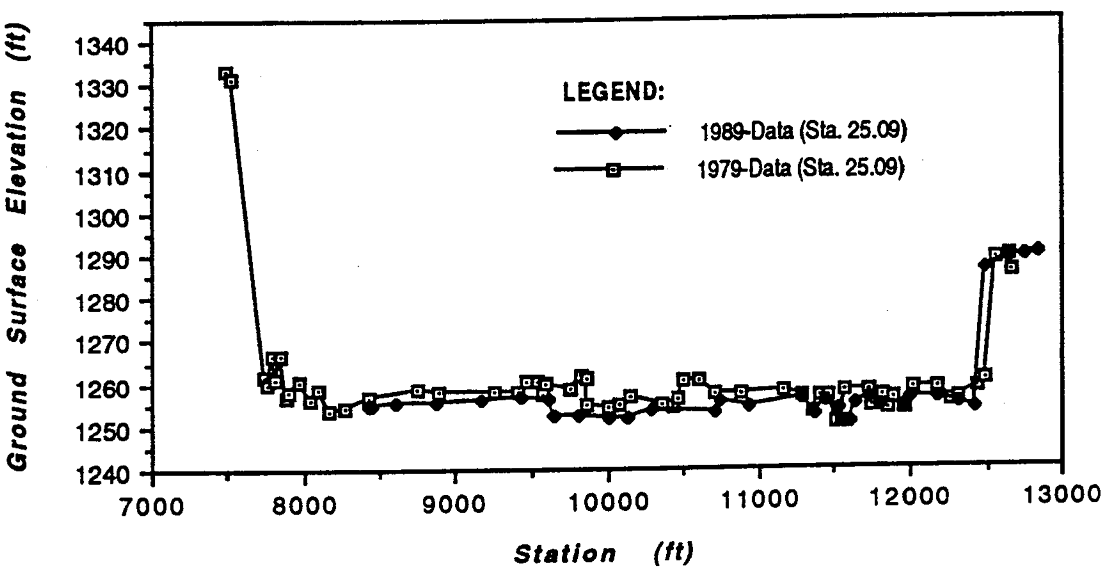

Fig 4.2 (d) - Cross-section plot of 1979- and 1989-data for Station 25.09

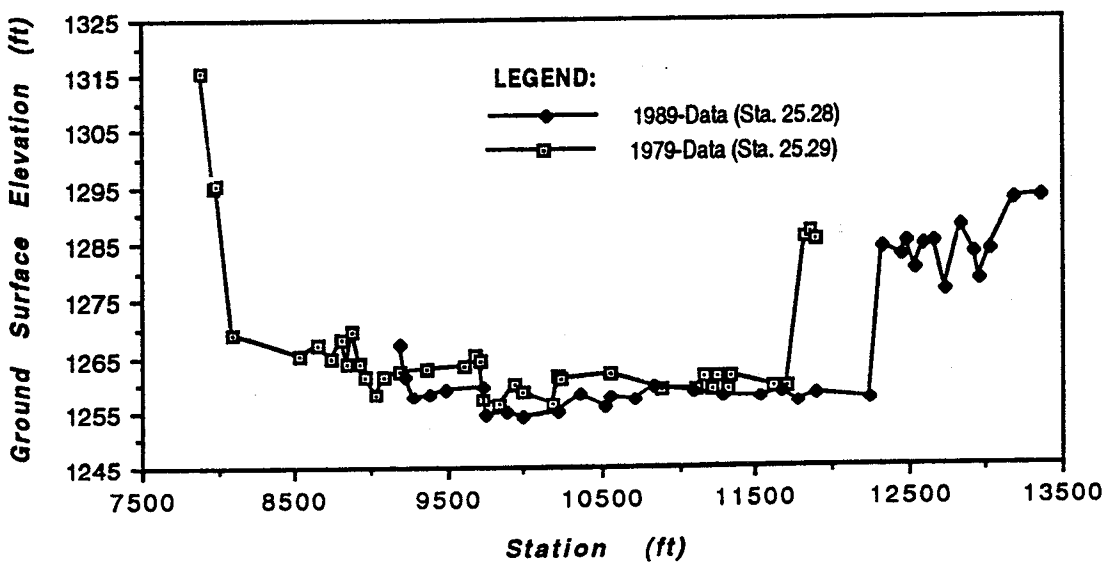

Fig.4.2 (e) - Cross-section plot of 1979- and 1989-data for Station 25.37

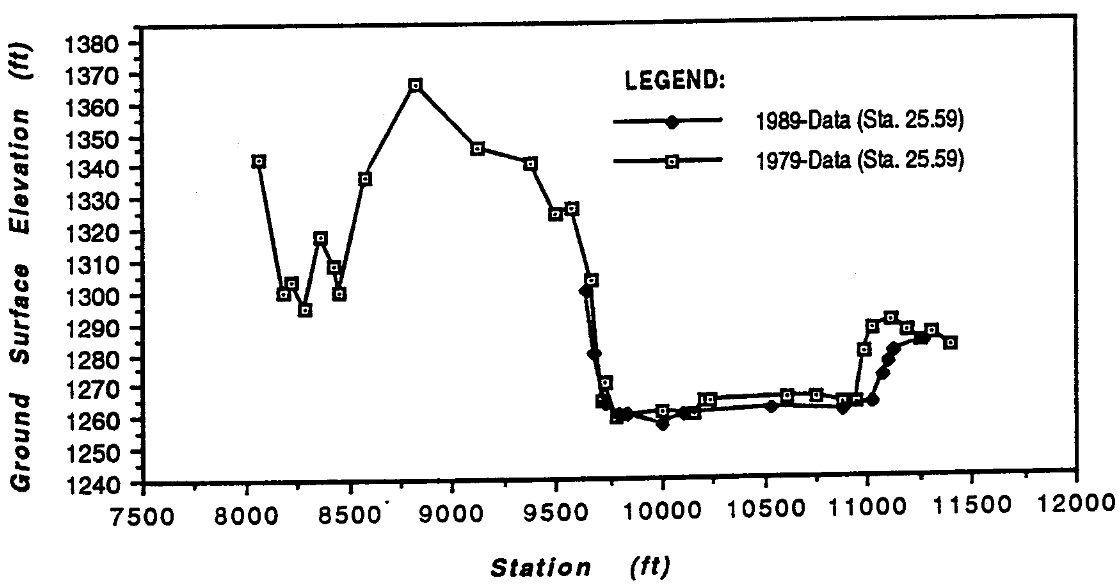

Fig.4.2 (f) - Cross-section plot of 1979- and 1989-data for Station 25.59.

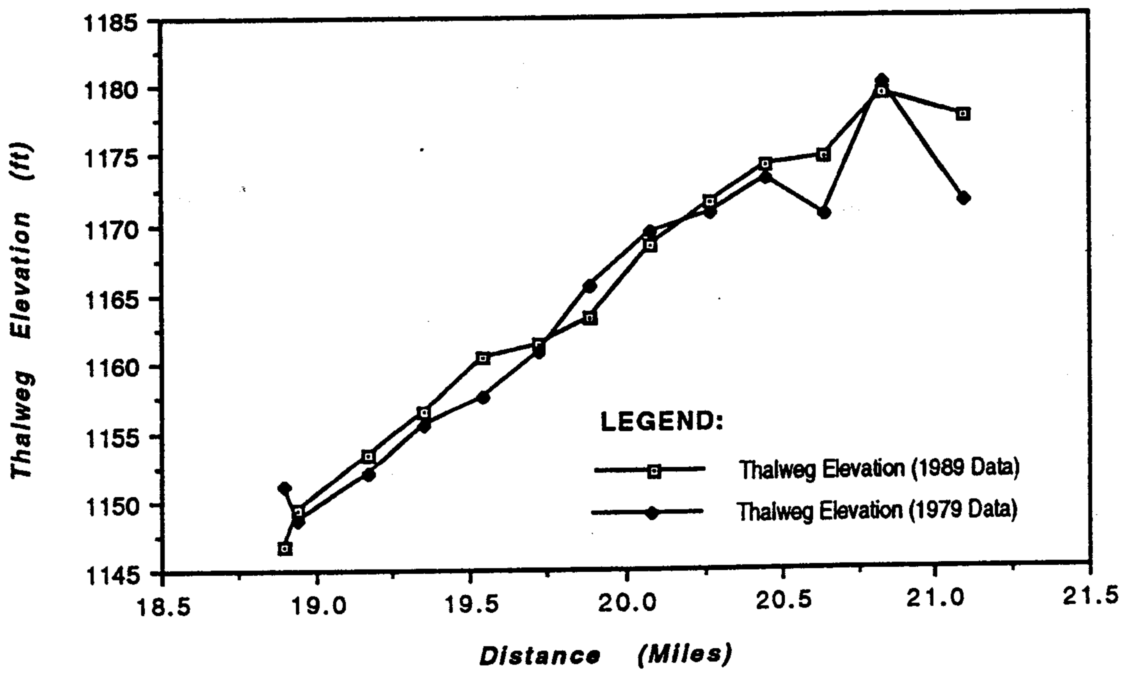

Fig. 4.3 (a) - Thalweg elevations, 1979- and 1989-data [First segment]

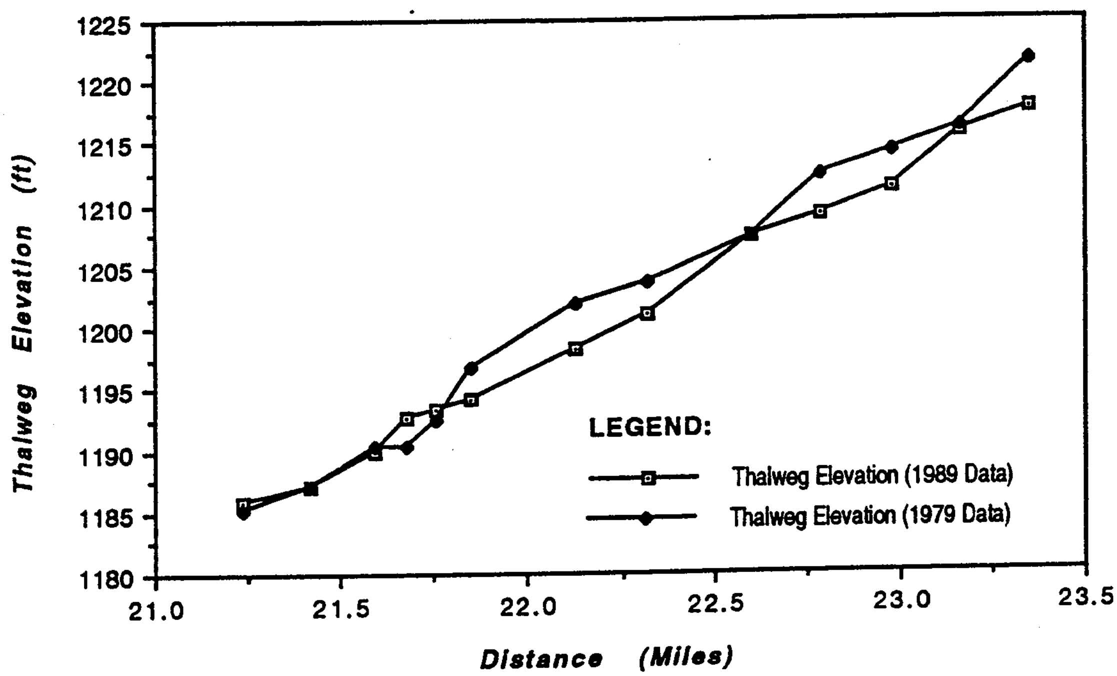

Fig. 4.3 (b) - Thalweg elevations, 1979- and 1989-data [Second segment]

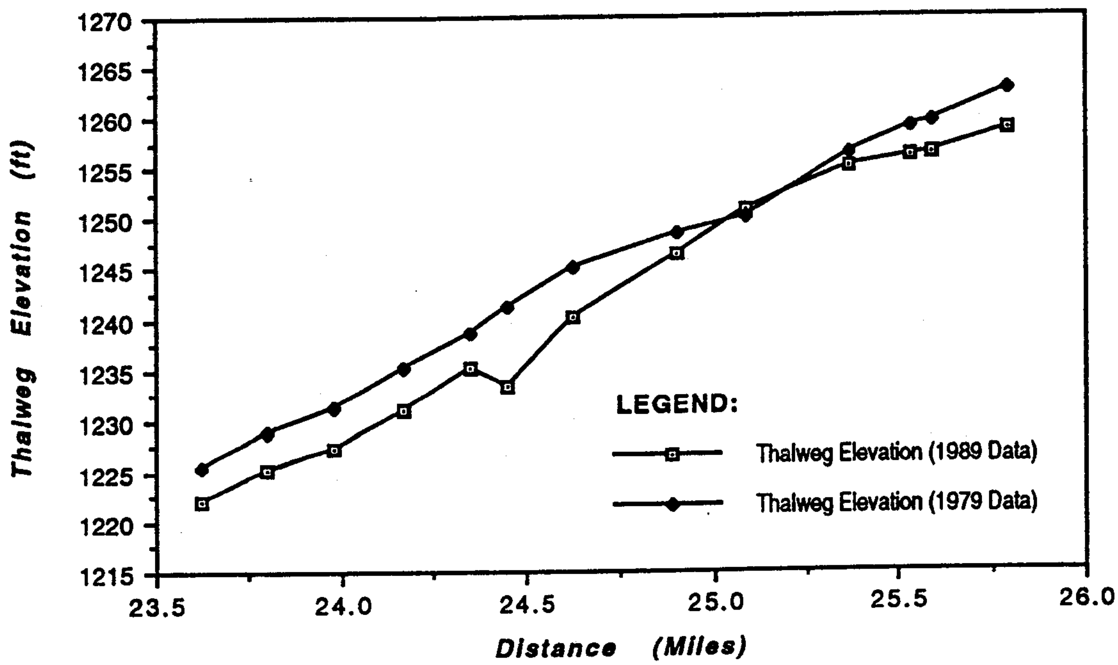

Fig. 4.3 (c) - Thalweg elevations, 1979- and 1989-data [Third segment]

Table 4.2 - Roughness coefficients derived from the NH card of 1979 data

Location	No.	Mileage No.	Left Overbank	Channel	Right Overbank
Bell Road	1	18.900	0.0400	0.0240	0.0397
	2	18.940	0.0400	0.0312	0.0250
	3	19.170	0.0394	0.0467	0.0250
	4	19.350	0.0400	0.0517	0.0250
	5	19.540	0.0400	0.0492	0.0250
	6	19.720	0.0400	0.0351	0.0600
	7	19.890	0.0400	0.0378	0.0600
	8	20.080	0.0404	0.0388	0.0400
	9	20.270	0.0404	0.0380	0.0350
	10	20.450	0.0405	0.0403	0.0350
	11	20.640	0.0403	0.0395	0.0350
	12	20.830	0.0406	0.0399	0.0500
	13	21.090	0.0406	0.0340	0.0800
	14	21.240	0.0412	0.0349	0.0800
	15	21.420	0.0396	0.0305	0.0732
	16	21.590	0.0299	0.0252	0.0762
	17	21.680	0.0498	0.0263	0.0576
	18	21.760	0.0500	0.0262	0.0525
	19	21.850	0.0500	0.0351	0.0495
	20	22.130	0.0250	0.0314	0.0500
	21	22.320	0.0250	0.0394	0.0500
	22	22.600	0.0250	0.0366	0.0500
	23	22.790	0.0250	0.0359	0.0500
	24	22.980	0.0250	0.0423	0.0500
	25	23.160	0.0400	0.0368	0.0500
	26	23.350	0.0400	0.0382	0.0500
	27	23.620	0.0500	0.0372	0.0500
	28	23.800	0.0500	0.0304	0.0478
	29	23.980	0.0500	0.0336	0.0500
	30	24.170	0.0744	0.0322	0.0250
	31	24.350	0.0728	0.0267	0.0250
	32	24.450	0.0729	0.0274	0.0250
	33	24.630	0.0708	0.0272	0.0500
	34	24.900	0.0500	0.0506	0.0500
	35	25.090	0.0500	0.0250	0.0625
	36	25.370	0.0500	0.0315	0.0670
	37	25.530	0.0500	0.0259	0.0800
Jomax Road	38	25.590	0.0250	0.0365	0.0800
	39	25.790	0.0250	0.0250	0.0800

Note: Derived from NH Card of the HEC-2 Input File [Yost and Gardner Engineers (1979)]

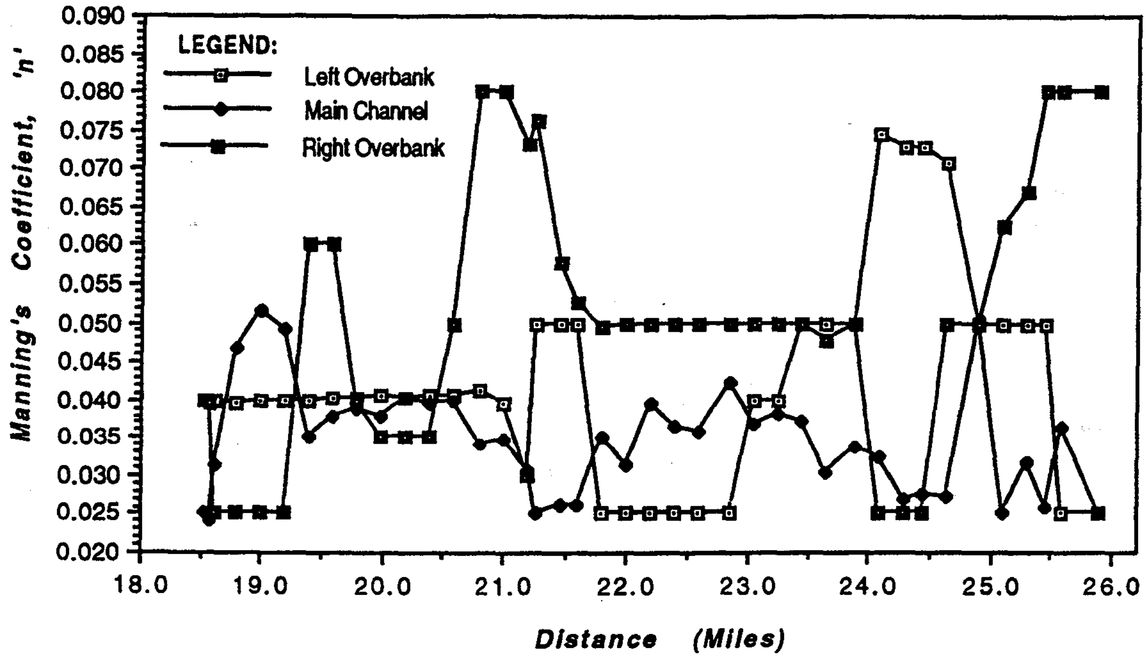

Fig. 4.4 - Roughness coefficients at various locations of the study reach

4.2.2 Hydrologic Data

(i) Flood Data - Only one flood event had occurred between December 21, 1979 and January 29, 1989 - the respective dates when the delineation maps of the Agua Fria River were made. That flood event was the reservoir releases made at the Waddell Dam in February 13-22, 1980, a period of about 8.79 days. The release hydrograph is shown in **Fig. 4.5 (a).** The discretized hydrographs for the said flood event are shown in **Figs. 4.5 (b).**

(ii) Discharge Rating Data - The discharge rating data at Bell Road is taken from the 1983 study of the same reach. The basis of this 1983 study is the 1979 data of the Agua Fria River - particularly the reach between Bell Road and Jomax Road [**Dust, Bowers, and Ruff, 1986**]. The rating data used in the 1983 study is shown in **Table 4.3** for Mile 19.00 whose derivation is based on critical depth analysis.

Since there are observed discrepancies between the GR data used by **Dust et al, (1986)** and the data used by **Yost & Gardner Engineers (1979)** in the study of the Agua Fria River, it was attempted to determine the rating data at the most downstream reach using the slope-area method [**Hoggan, 1989**]. This was done essentially to provide a more realistic input for the calibration study and for the purpose of comparison. To derive the rating curve for the most downstream section (Mile No. 18.90) at Bell Road using the slope-area method, an estimate of the starting water surface elevation must be specified.

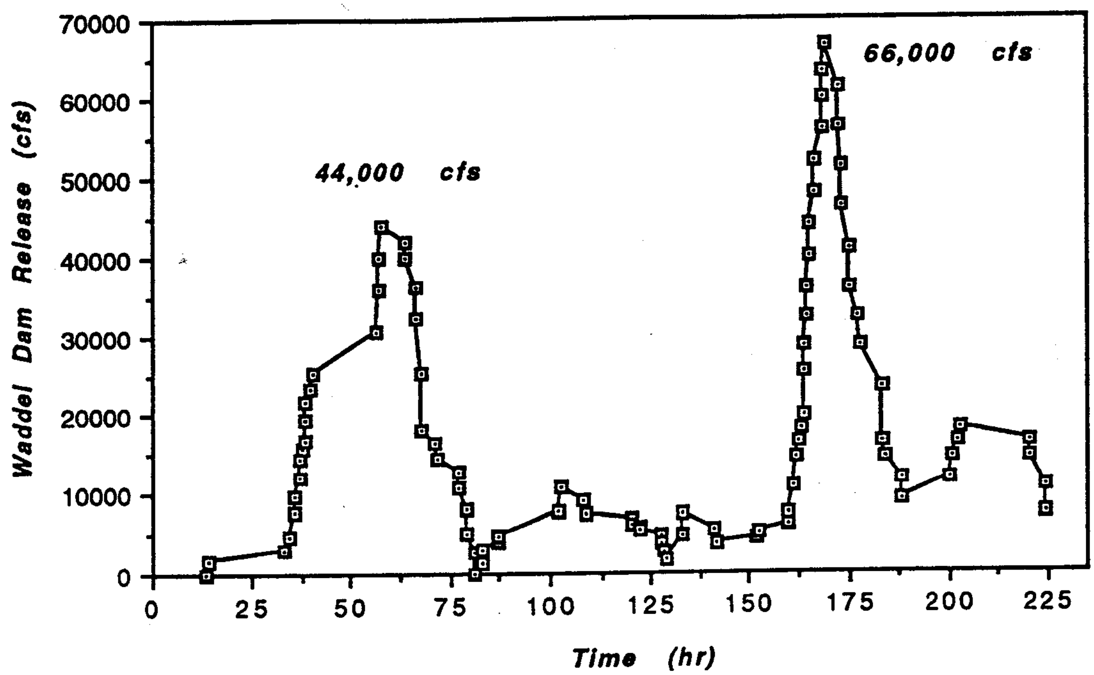

Fig. 4.5 (a) - Release hydrograph from the Waddell Dam [February 13-22, 1980]

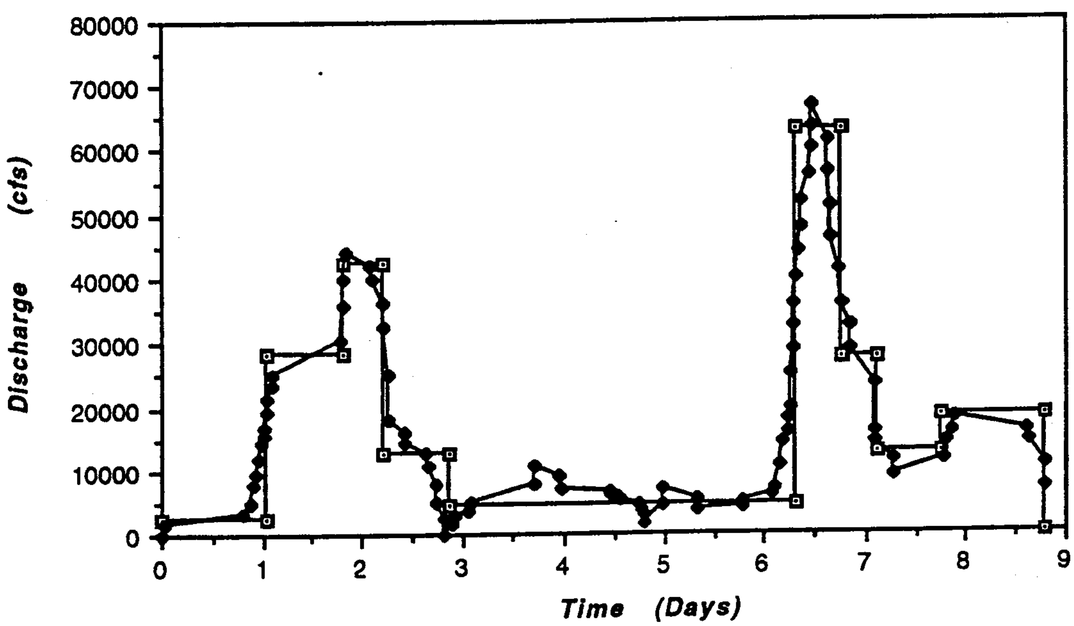

Fig. 4.5 (b) - Discretized hydrograph of Feb. 13-22, 1980 releases [Number of time steps, N = 9]

Assuming that the flow is uniform, the procedure computes a discharge for these initial conditions and compares this computed discharge with the given discharge. If there is a significant difference, the estimated elevation is adjusted and the discharges computed again. This procedure is repeated until the computed discharge and the given discharge are within a one-percent (1%) difference. The elevation, thus computed, is used as the starting water surface elevation [Hoggan, 1989]. The results of employing this method is shown in **Table 4.4.** The rating data used by **Dust, et al., (1986)** and the rating data derived.using the slope-area method are plotted in **Fig. 4.5.**

Table 4.3 - Rating data at Section 19.00

N	Discharge (cfs)	Water Surface Elev. (ft)
1	4000.00	1146.80
2	22000.00	1150.56
3	40000.00	1155.40
4	58000.00	1156.16
5	70000.00	1157.00

<u>Note</u>: **From Dust, Bowers and Ruff (1986).**
$WSE = 1145.3 + 3.2038 \times 10^{-4}Q - 2.2010 \times 10^{-9}Q^2$

Table 4.4 - Rating data at Section 18.900

N	Discharge (cfs)	Water Surface Elev. (ft)
1	2,000.00	1152.10
2	7,000.00	1153.77
3	12,000.00	1154.93
4	17,000.00	1155.86
5	22,000.00	1156.59
6	27,000.00	1157.15
7	32,000.00	1157.57
8	37,000.00	1157.87
9	42,000.00	1158.11
10	47,000.00	1158.29
11	52,000.00	1158.46
12	57,000.00	1158.64
13	62,000.00	1158.87
14	67,000.00	1159.18
15	72,000.00	1159.59

<u>Note:</u> These values were generated using the 1979-data and slope-area method.
$WSE = 1151.7 + 3.36911 \times 10^{-4}Q - 6.1161 \times 10^{-9}Q^2 + 4.11097 \times 10^{-14}Q^3$

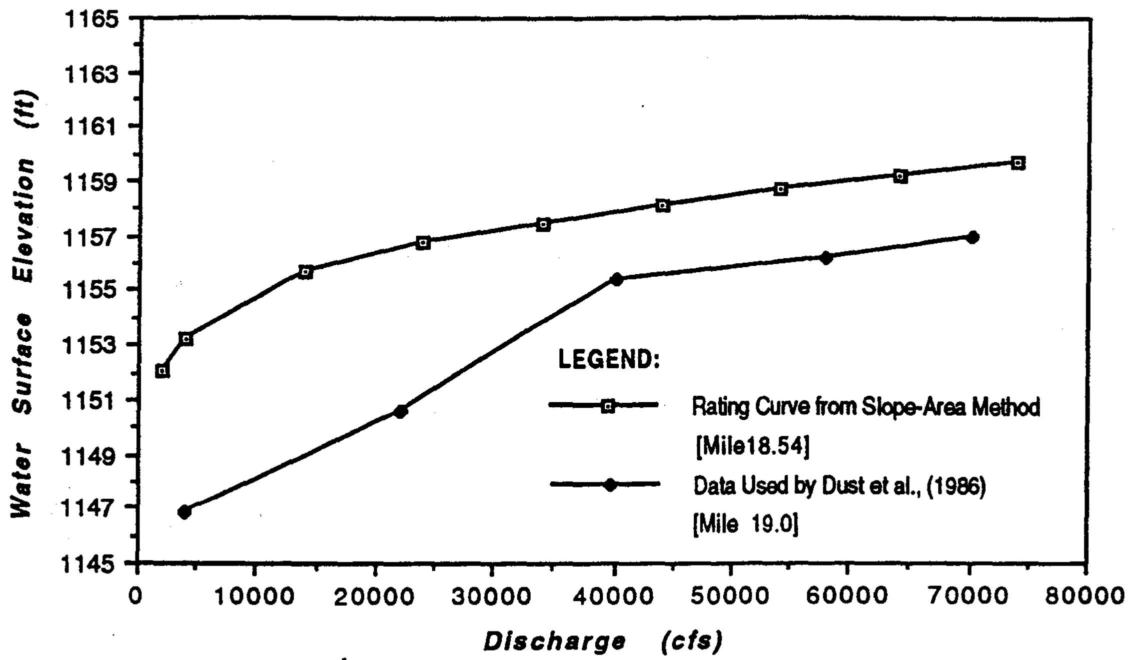

Fig. 4.6 - Rating curves for the most downstream section of the study reach.

4.2.3 Sediment Data

The gradation data for the sediments along the study reach were obtained from the works of **Dust et. al, (1986).** There were three gradation types of sediments presented of which only two will be presented in this report. They are classified as: (i) *Type-1* data which is composed predominantly of sands with less than 6% gravel; and, (ii) *Type-2* data which is described by a more uniform gradation with about 35% gravel. These sediment data are presented in **Table 4.5** and their corresponding gradation curves are shown in **Fig. 4.7.**

Table 4.5 - Sediment data [Dust et al., 1986]

Classification	Size Range (mm)	Percentage (%) Type-1	Percentage (%) Type-2
VFS	0.062- 0.125	3.500	0.200
FS	0.125- 0.250	4.500	0.400
MS	0.250- 0.500	26.000	11.400
CS	0.500- 1.000	41.000	19.000
VCS	1.000- 2.000	15.000	19.500
VFG	2.000- 4.000	5.500	12.000
FG	4.000- 8.000	2.167	9.000
MG	8.000- 16.000	2.333	9.200
CG	16.000- 32.000	0.000	10.300
VCG	32.000- 64.000	0.000	9.000

Note: VFS - very fine sand, FS - fine sand, MS - medium sand, CS - coarse sand, VCS - very coarse sand, VFG - very fine gravel, FG - fine gravel, MG - medium gravel, CG - coarse gravel, VCG - very coarse gravel.

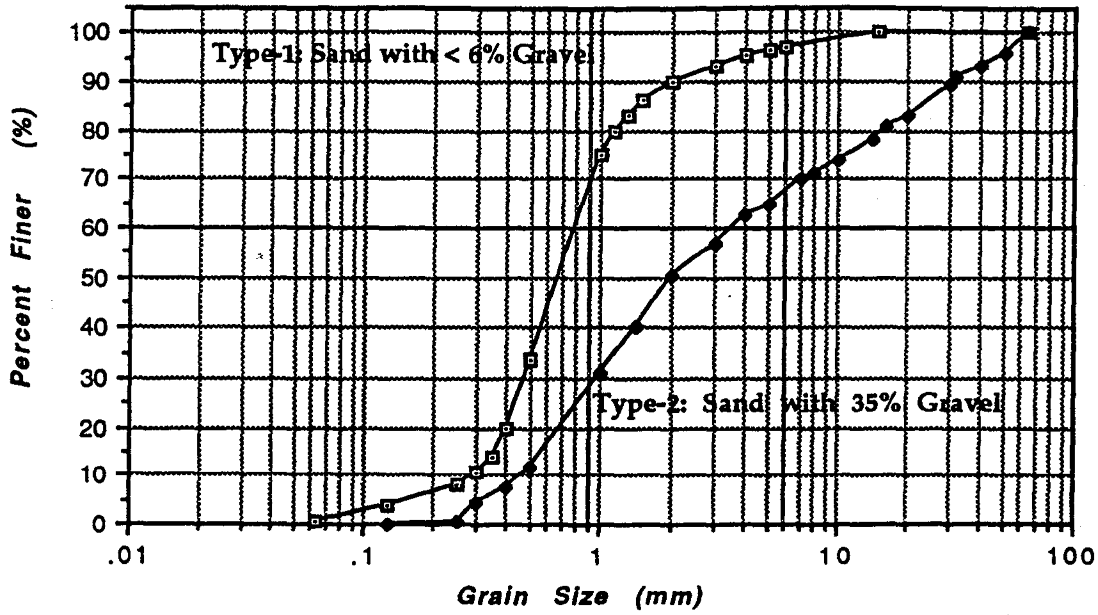

Fig.4.7 - Gradation curves for the sediments collected at the study reach
(Dust et. al, 1986)

4.3 Determination of Inflowing Sediment

Since the inflowing sediment data are important in running HEC-6, proper considerations have to be made in their determination. Dust et al., (1986) has given a comprehensive outline on how inflowing sediment data can be generated.

4.3.1 Data Requirements

(i) A complete set of geometric data - This geometric data can be for the entire study reach or just the 'upstream dummy reach'. It has been observed that either of these sets of geometric data can be used to generate satisfactory inflowing sediment data. However, it is more efficient to use the 'dummy reach' geometric data.

(ii) A complete set of sediment data - The L-cards are initially set to zero.

(iii) Hydrologic data - Three or more sets of hydrologic data are needed which include the lower and upper limits of discharge (e.g. the low-flow, bank-full flow, or the high-flow] in the river. In addition, the total duration of each of these sets of hydrologic data must be long enough to allow, *"equilibrium transport rates"* to be computed. However, the individual time steps within the hydrologic data sets must be short enough to preserve 'computational stability'.

4.3.2 Procedures in the Determination of Inflowing Sediment

Given the above input data for **HEC-6**, the L-card data (i.e. the inflowing sediment data and the percentage of each sediment size) can be generated in the following manner,

Step (1). Execute **HEC-6** separately for the three sets of hydrologic data. The calculated sediment loads, for each reach increment and grain size, are listed in "*____C" level output. If the "dummy reach" is used, select a reach increment located near the middle of the dummy reach and use the corresponding calculated transport rates as L-card value for the next set of **HEC-6** executions. Similarly, select a reach increment that best resembles the river upstream of the study reach and use the calculated transport rates as L-card values for the next set of **HEC-6** executions, if the entire study reach is used.

Step (2). Repeat *Step (1)* until the calculated sediment discharges converge to the 'equilibrium' discharge for each grain size.

Step (3) *Steps (1)* and *(2)* need to be repeated for each transport relationship considered in the study.

The importance of the L-card data can be reduced by adding several "dummy-sections" to the upstream end of the geometric data. These dummy sections/reaches can be copies of the upstream-most cross-sections where the elevations and reach lengths of the duplicated cross-sections are adjusted to maintain the bed-slope. Dummy sections can also be the actual cross-sections upstream of the river study reach.

After the inflowing sediments are obtained for each sediment transport function, they are used in the model as upstream boundary conditions in simulating the sediment transport processes in the river. Using the flood events, the extent of degradation and aggradation in the study reach could be simulated. These simulated results from the model could be compared with the actual physical data. The sediment transport function that gives very good agreement with the actual physical data will be selected as the most appropriate transport function to model the transport processes in the river.

4.3.3 Inflowing Sediment Loads

Ten (10) sediment transport functions have been evaluated in the determination of the inflowing sediment load associated with the four (4) flows considered (i.e., 4,000, 20,000, 45,000 and 67,000 cfs). Using the *Type-2* sediment data (see Table **4.5** and **Fig. 4.6**) throughout the 39 sections of the study reach, the generated inflowing sediment loads are listed in the ***Appendix B*** [see **Tables B.2-1** to **B.2-10**] which also list down the amount of load for each grain size considered. The summary of these generated inflowing sediment load corresponding to the four (4) discharge rates are listed in **Table 4.6.** As could be observed, a flow discharge of 4,000 cfs could generate a sediment load of about 11,301.1 tons/day using the Toffaleti formula or 38,274 tons/day using the Madden's modification (1963) formula. The grain sizes in abbreviated form in the ***Appendix A*** (i.e., VFS - very fine sand; FS - fine sand; MS -

medium sand; CS - coarse sand; and VCS - very coarse sand, etc.) refer only to the sand and gravel size aggregates, as classified by the **U.S. Army Corps of Engineers [1991]**, for HEC-6 code. Further, **Figs. 4.8 (a) & (b)** show the relationship (in semi-log plot) between the discharge rate (Q) and the generated inflowing sediment load (Gs) for the different sediment transport functions. These inflowing sediment loads are used as boundary input data for the most upstream section of the study reach.

Table 4.2 - Summary table of the Q-Gs [discharge-inflowing sediment load] relationship.

MTC No.	Sediment Transport Function	Discharge (cfs) Q = 4000	Q = 20000	Q = 45000	Q=60000
0,1	Toffaleti	11301.1	90264.2	145083.0	156146.0
3	Madden's (1963)	38274.0	278592.0	——	2200540.0
4	Yang's streampower	13900.2	110223.3	350663.1	604913.3
5	Duboys	61850.2	325068.1	704987.8	1058847.5
7	Ackers and White	16700.7	103099.7	318772.6	560082.5
8	Colby	4032.8	27873.2	66773.6	95300.3
9	Toffaleti/Schoklitsch	15642.6	115699.0	204395.7	245111.6
10	Meyer-Peter and Muller	10900.6	65493.9	175053.0	271187.9
12	Toffaleti/Meyer-Peter & Muller	21794.4	154974.0	319006.3	426247.1
13	Madden's (1985)	16351.0	88347.0	——	274768.0

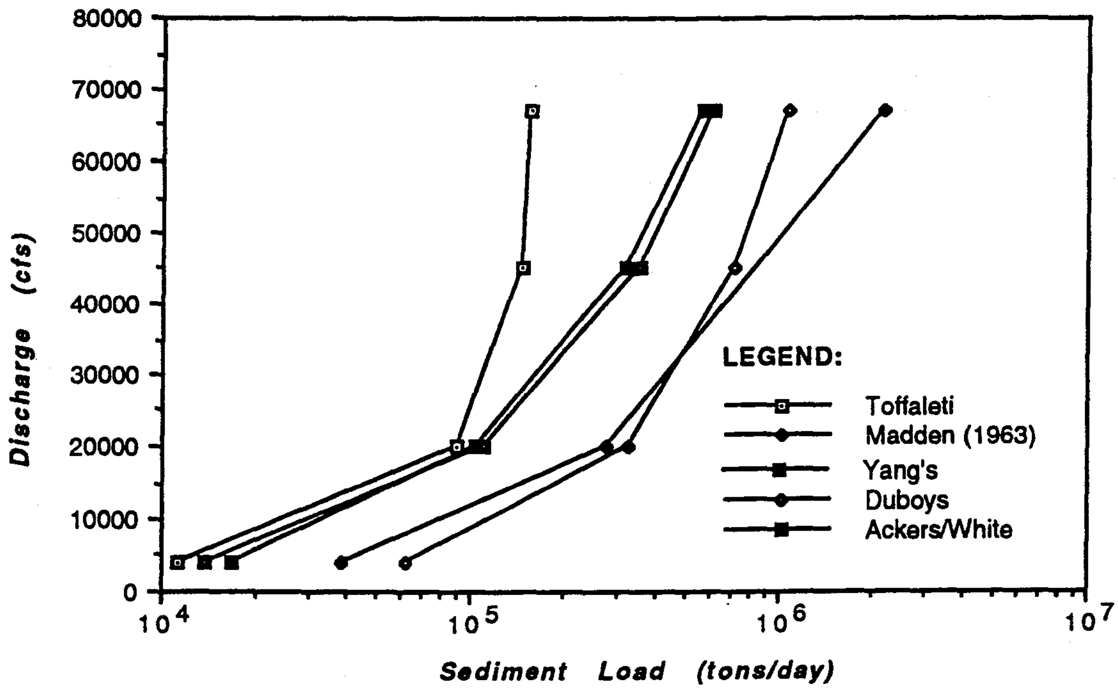

Fig.4.8 (a) - Plot of discharge (Q) and inflowing sediment load (G_s) relationship for five sediment transport function.

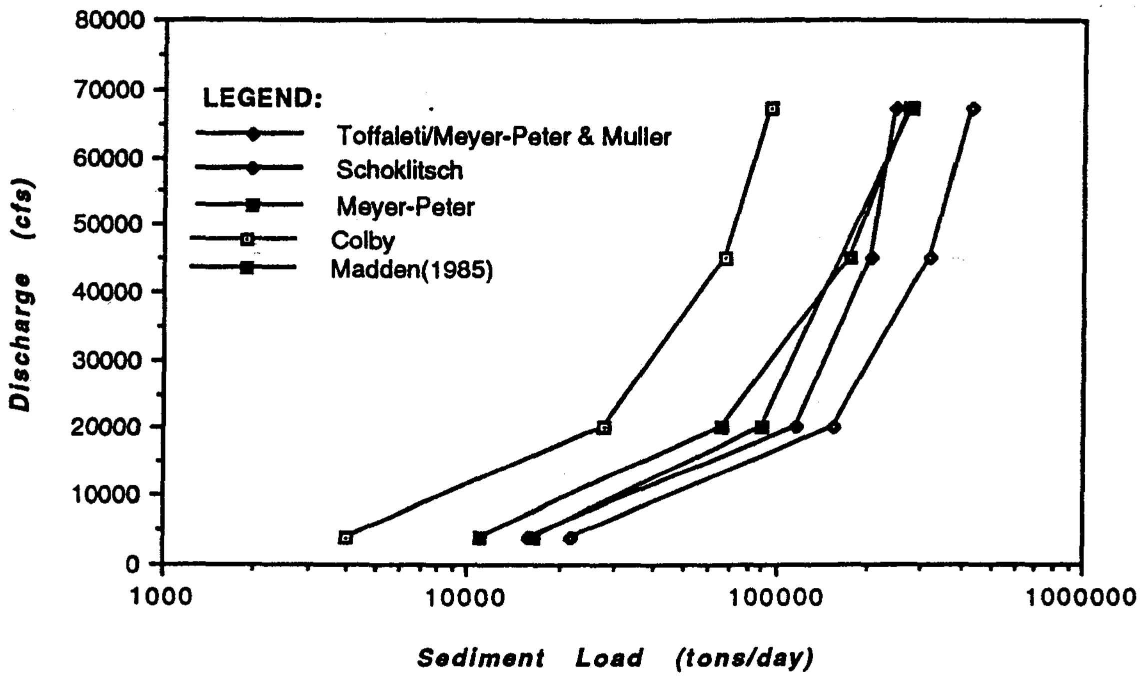

Fig.4.8 (b) - Plot of discharge (Q) and inflowing sediment load (G_S) relationship for five sediment transport function.

4.4. Selection of Sediment Transport Function

4.4.1 Selection Process

As presented earlier, the current version of the HEC-6 code offers ten (10) sediment transport functions for users to choose from. These functions (see **Table 4.7**) are used in the evaluation of the most appropriate sediment transport function for the sedimentation modeling of the Agua Fria River.

Table 4.7 - Sediment transport function options for HEC-6

MTC No.	Transport Function
0,1	Toffaleti
3	Madden's (1963) modifications of Laursen's formula (1958)
4	Yang's streampower function
5	Duboys
7	Ackers and White
8	Colby
9	Toffaleti and Schoklitsch
10	Meyer-Peter and Muller
12	Toffaleti and Meyer-Peter & Muller
13	Madden's (1985) modification of Laursen's formula (1958)

The selection process for the sediment transport function for the sedimentation modeling of the Agua Fria River can be briefly summarized as follows:

(i) *Select a river reach of considerable length having good information on the following:*

(a) *Geometric Data - A topographical information before and after a flood event or series of flood events along the study reach. This is to assume that the flood or flood events play a very vital role in affecting major morphological changes in the river.*

(b) *Sediment Data - Gradation data information for the sediments collected prior to the first flood events.*

(c) *Hydrologic Data - All flood data that had passed the river reach before the next topographical mapping is made.*

(ii) *Create a HEC-6 input data file comprising of: (a) geometric data drawn from the first topographical mapping; (b) hydrologic data consisting of all flood events; and (c) sediment data comprising of the gradation data.*

(iii) *Run HEC-6 computer model using the different sediment transport formulas.*

(iv) *Compare the simulated thalweg elevations drawn from the HEC-6 run results with the observed thalweg elevation data [observed from the topographic map].*

(v) *Select the sediment transport function that results in acceptable agreement with the observed thalweg elevations. If visual comparison, among the sediment transport functions, is difficult, a statistical evaluation of the total deviation and total squares of the deviation between the observed (i.e. 1989-thalweg elevation data) and simulated data will be considered. Statistically, the most appropriate transport function can be evaluated based on any of the following two criteria:*

Criterion 1: Minimum Sum of the Deviation

$$\text{Minimum DEV} = \sum_{i=1}^{N} \left| YOBS_i - YSIM_i \right|$$

Criterion 2: Minimum Sum of Squares of the Deviation

$$\text{Minimum SSQ} = \sum_{i=1}^{N} \left| YOBS_i - YSIM_i \right|^2$$

Where:

DEV = absolute sum of the deviation;
SSQ = sum of squares of the deviation;
$YOBS_i$ = observed thalweg-elevation at station i;

$YSIM_i$	= simulated thalweg elevation at station i;
N	= number of stations along the study reach.
i	= station index number; $1 \le i \le N$.

4.4.2 Simulated Results

The simulation results involving the 10 sediment transport functions have been plotted for visual evaluation. The whole study reach, however, was divided into three segments in order to have a more distinctive evaluation of the results. These three segments can be defined as:

(i)	*First segment*	*- downstream sub-reach*	*[Mile 18.90 - Mile 21.09]*
(ii)	*Second segment*	*- middle sub-reach*	*[Mile 21.24 - Mile 23.75]*
(iii)	*Third segment*	*- upstream sub-reach*	*[Mile 23.62 - Mile 25.79]*

For each segment, the simulated results from sediment transport functions are plotted against the 1989-thalweg elevation data in order to assess the most appropriate sediment transport function (see **Figs. 4-8** to **4.10**). The selection process using this approach is very difficult because in most cases the plots generated are close to one another; or in, some instances, the performance of some functions may be poor at some stations but may be compensated at other segments in the river reach.

Figs. 4.8 (a), (b), and **(c)** show the plot of the simulated results using Toffaleti, Madden (1963) and Yang's streampower formulas. Here, Madden's (1963) modification of Laursen's formula provides the best behavior among the three sediment transport formulas. Yang's streampower formula, however, behaves very closely with Madden's (1963) formula; in fact, it even outperforms the latter.

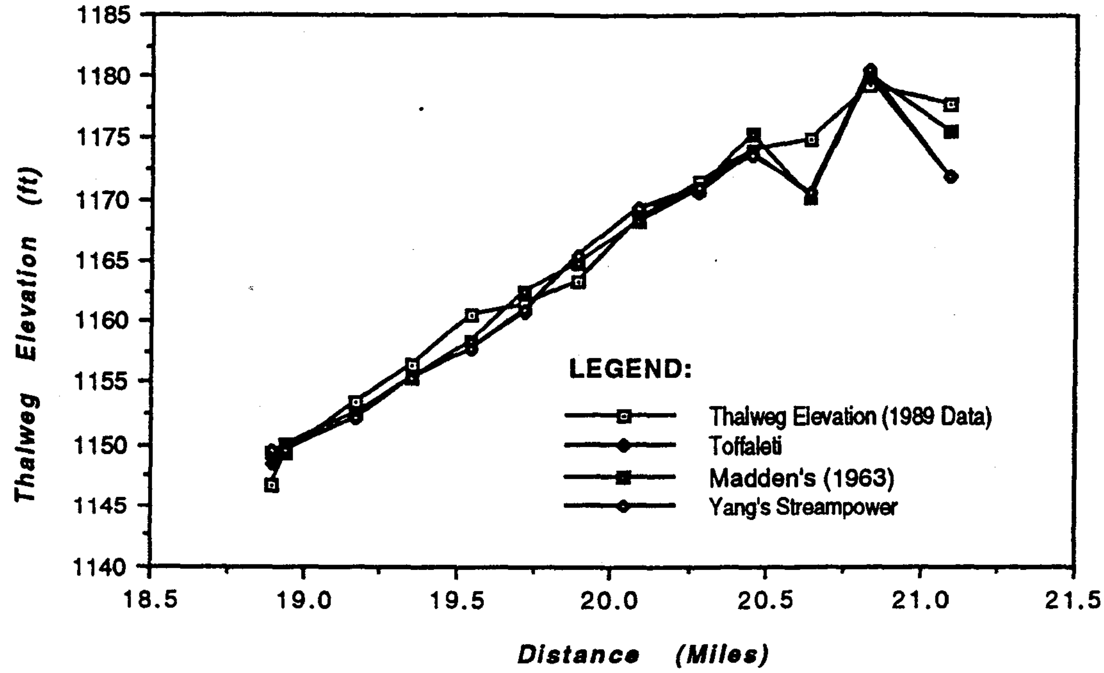

Fig. 4.8 (a) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [First segment].

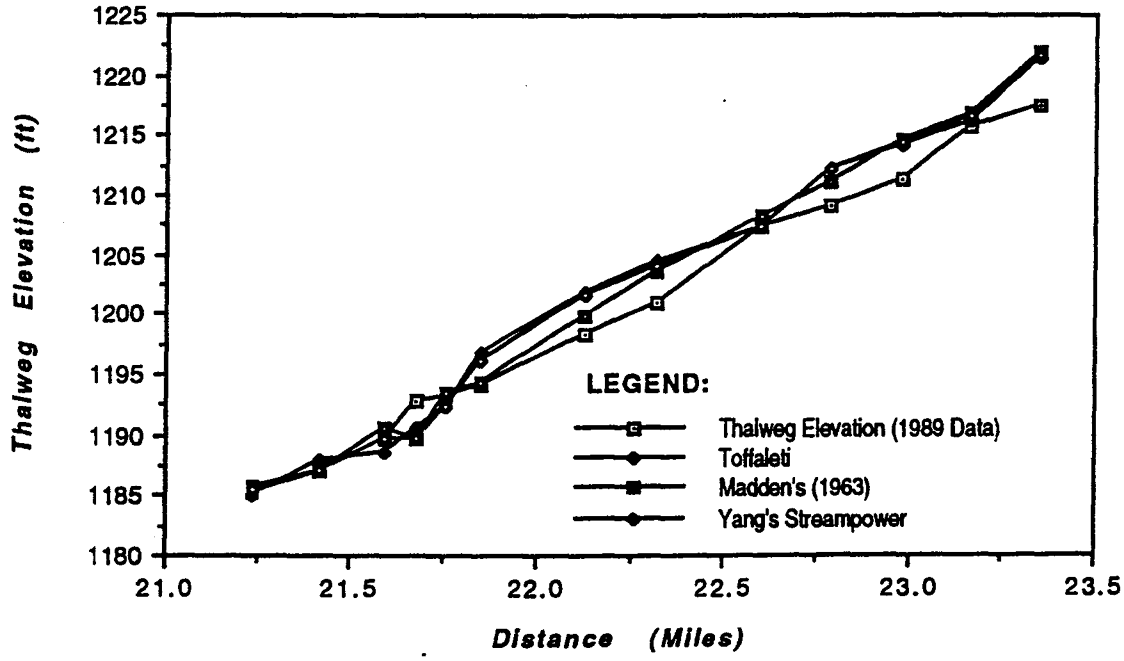

Fig. 4.8 (b) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [Second segment]

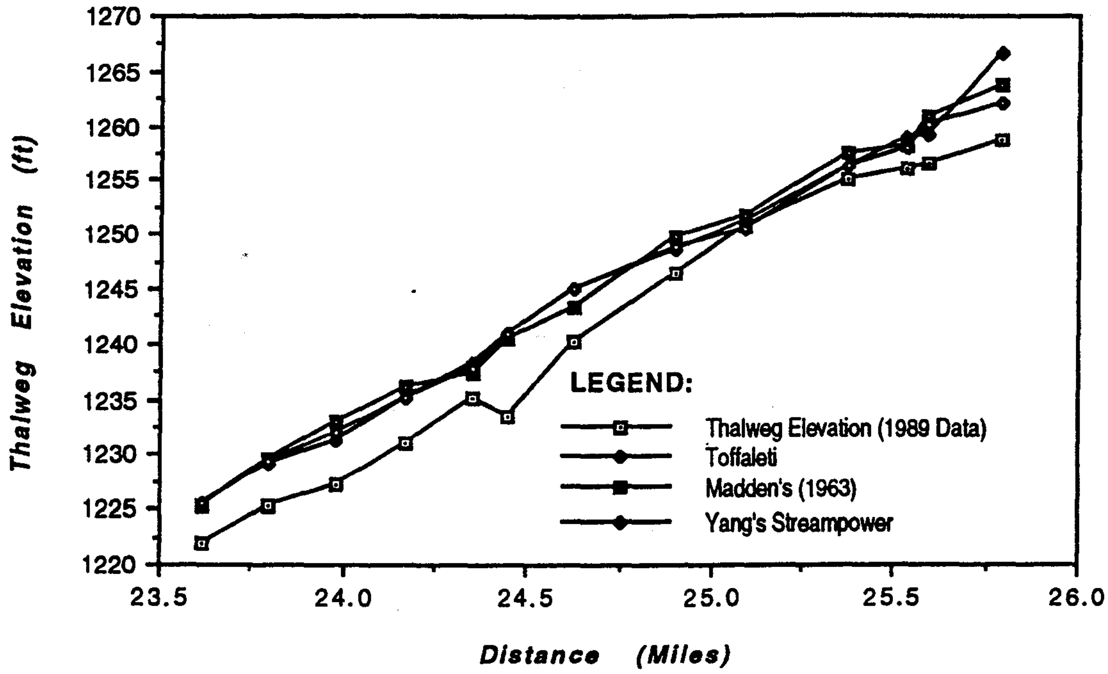

Fig. 4.8 (c) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [Third segment]

Figs. 4.9(a), (b) and (c) show the plot of the simulated results using Duboys, Ackers and White, and Colby formulas. Evaluation of the plots against the 1989-data thalweg elevation data shows superiority of Duboys over the other two functions.

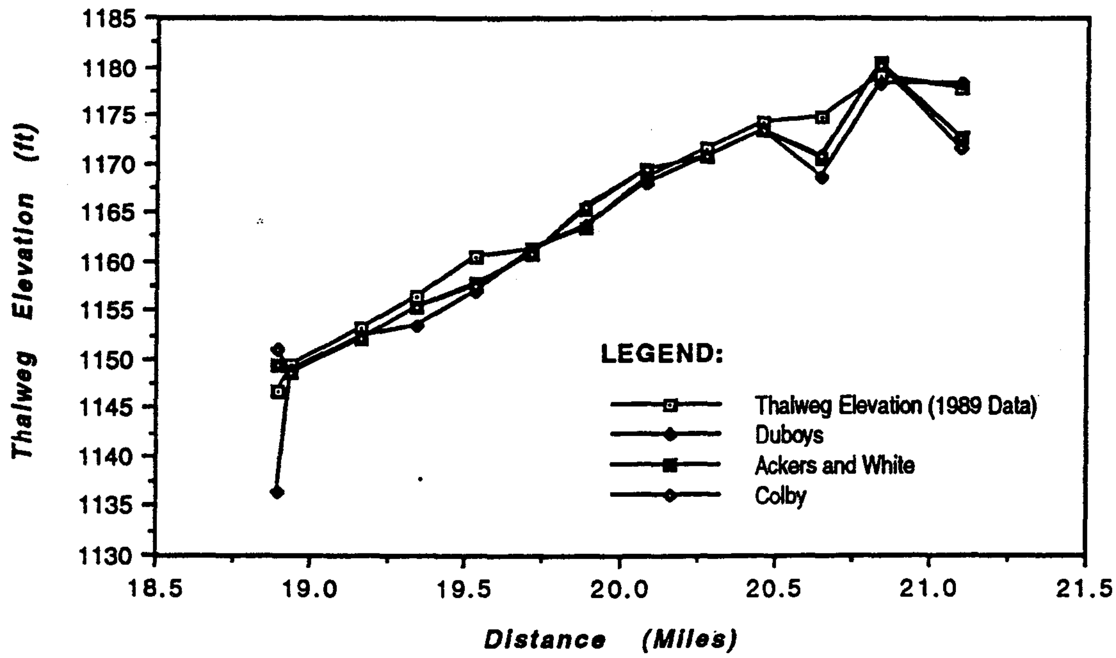

Fig. 4.9 (a) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [First segment]

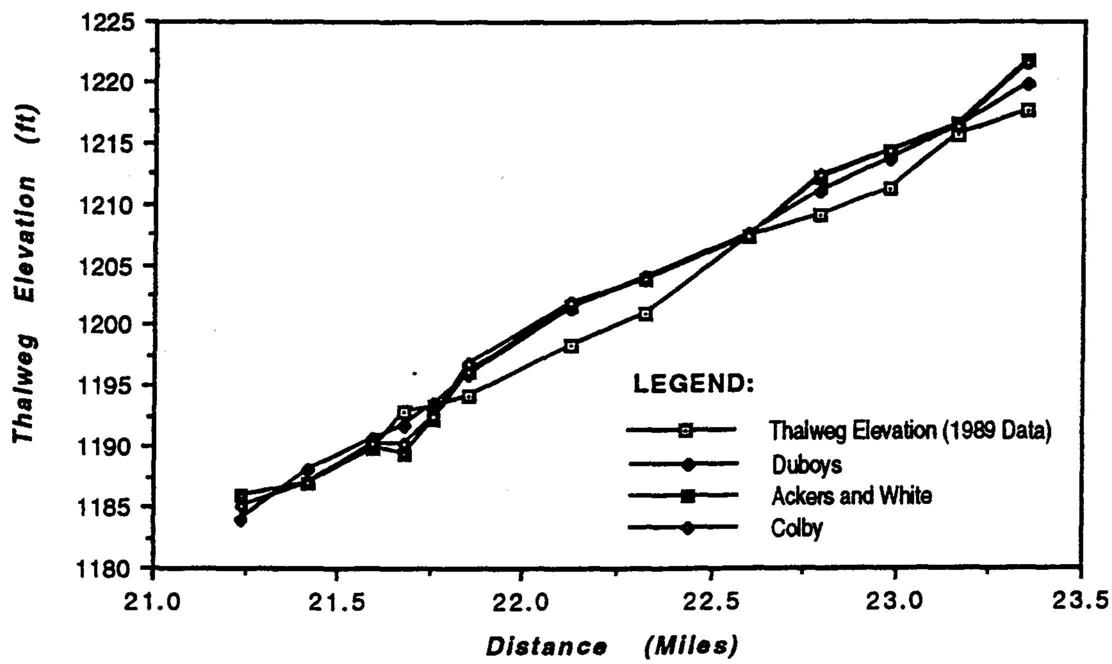

Fig. 4.9 (b) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [Second segment]

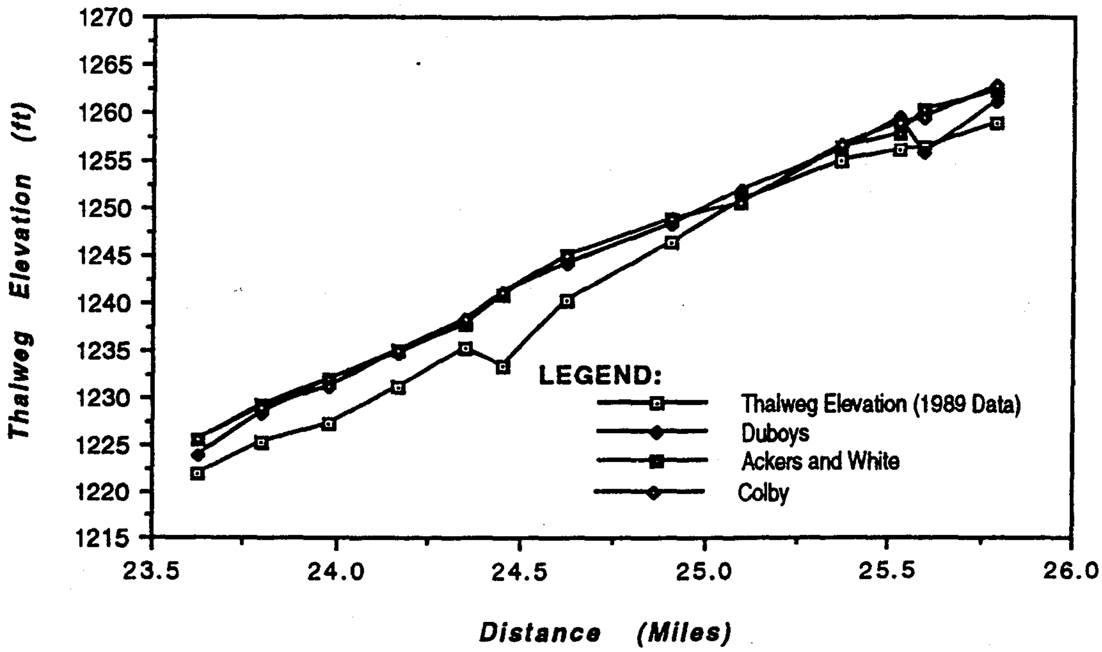

Fig. 4.9 (c) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [Third segment]

Figs. 4.10 (a), (b), and (c) show the plot of the simulated results using Toffaleti & Schoklitsch, Meyer-Peter & Muller, Toffaleti/Meyer-Peter and Muller, and the Madden's (1985) formulas. Analytical comparison using the two criteria in the selection process provided a quantitative basis. Table 4.8 (a) shows the evaluated values of the two criteria for the ten (10) sediment transport functions analyzed. Duboys formula exhibited the best performance under criterion I but performed very poorly under criterion II. The combined functions of Toffaleti and Schoklitsch provided good performance for both criteria which indicates that in addition to the fact that it has the capability to describe very closely the complex sediment transport dynamics along the river reach, it also exhibited consistency. Tables 4.8 (b) and (c) list the station-by-station results generated by the ten (10) sediment transport functions in the analysis.

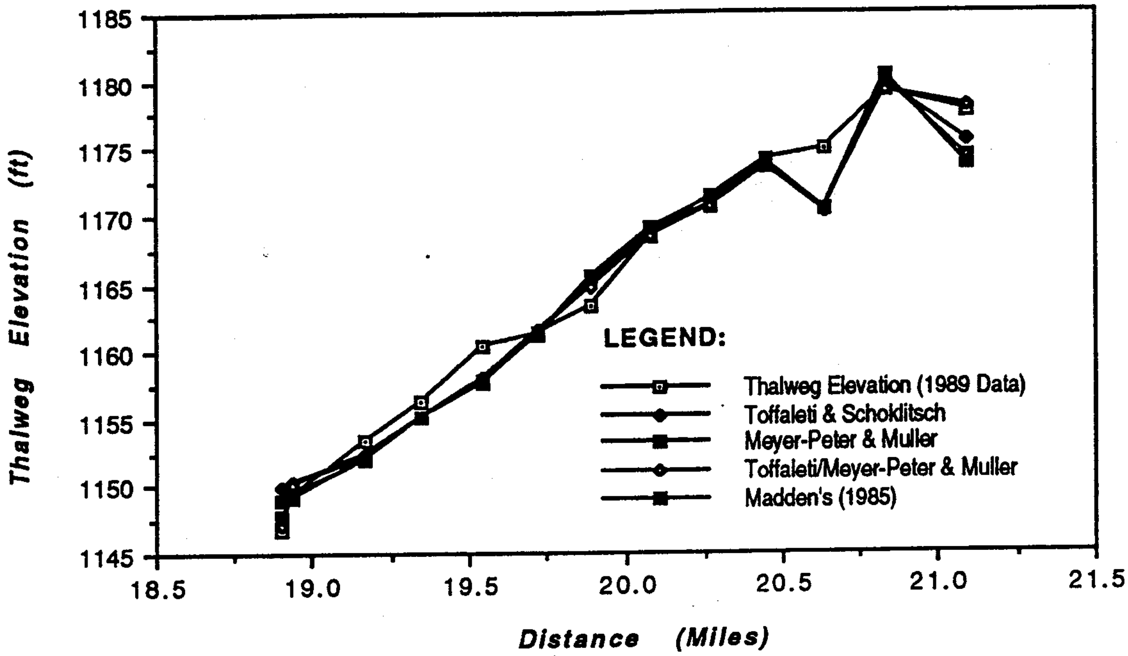

Fig. 4.10 (a) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [First segment]

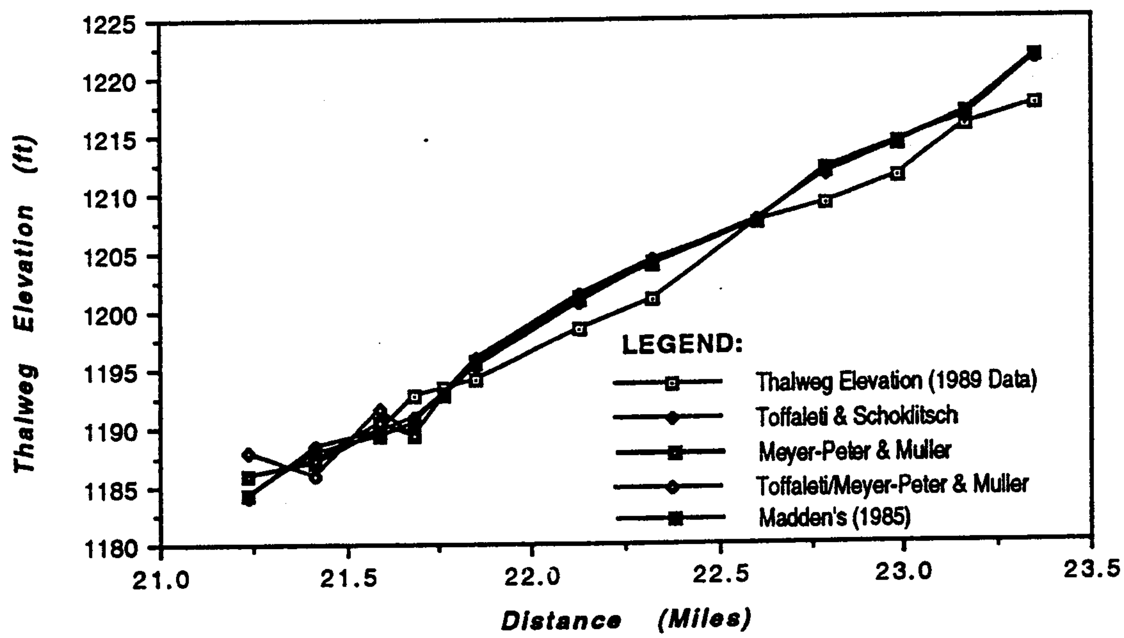

Fig. 4.10 (b) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [Second segment]

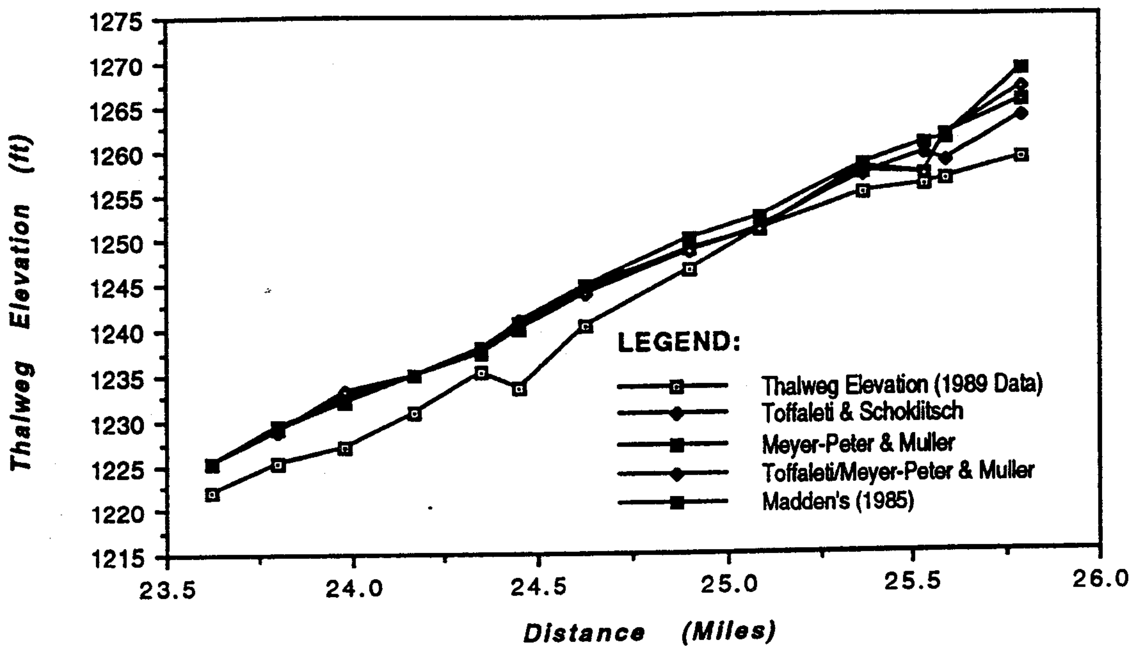

Fig. 4.10(c) - Plot of simulation results from three sediment transport formulas against the 1989-thalweg data [Third segment]

Table 4.8(a) - Evaluated values of the two criteria in the selection process

MTC No.	Sediment Transport Function	Sum of Deviation	Sum of Squares of Deviations
0,1	Toffaleti	96.06	372.61
3	Madden (1963)	88.61	317.49
4	Yang's Streampower	92.04	339.36
5	Duboys	86.86	364.31
7	Ackers and White	91.34	327.28
8	Colby	95.83	352.35
9	Toffaleti and Schoklitsch	87.20	299.79**
10	Meyer-Peter and Muller	88.04	324.29
12	Toffaleti and Meyer-Peter & Muller	88.42	337.68
13	Madden (1985)	102.28	439.28

Note: ** Toffaleti and Schoklitsch formula provided the most appropriate predictor for the transport dynamics of sediments at the study reach.

Table 4.8 (b) - Simulated results of the ten sediment transport functions

Station Number	Observed 1989-Data	Thalweg Elevation (ft) MTC=1	MTC=3	MTC=4	MTC=5	MTC=7
25.790	1258.80	1266.53	1263.87	1262.17	1261.21	1262.10
25.590	1256.50	1259.07	1260.77	1260.07	1255.93	1260.17
25.530	1256.00	1258.83	1258.26	1258.04	1259.41	1257.72
25.370	1255.00	1256.37	1257.40	1256.32	1256.22	1256.44
25.090	1250.80	1251.23	1251.70	1250.49	1251.87	1250.55
24.900	1246.50	1248.50	1249.74	1248.85	1248.38	1248.99
24.630	1240.20	1244.90	1243.27	1244.89	1244.23	1244.91
24.450	1233.40	1240.96	1240.42	1240.87	1241.01	1240.76
24.350	1235.20	1238.34	1237.29	1237.88	1237.77	1237.88
24.170	1231.00	1235.04	1236.03	1235.13	1234.75	1235.09
23.980	1227.20	1231.31	1232.95	1232.04	1231.84	1231.89
23.800	1225.20	1229.06	1229.59	1229.29	1228.46	1229.26
23.620	1222.00	1225.42	1225.30	1225.57	1224.02	1225.55
23.350	1217.60	1221.50	1221.95	1221.67	1219.82	1221.70
23.160	1215.70	1216.22	1216.81	1216.54	1216.16	1216.44
22.980	1211.30	1214.20	1214.58	1214.44	1213.74	1214.32
22.790	1209.10	1212.17	1211.07	1212.18	1210.94	1212.16
22.600	1207.40	1207.28	1208.32	1207.36	1207.63	1207.31
22.320	1201.00	1204.45	1203.67	1204.06	1203.98	1203.88
22.130	1198.40	1201.73	1199.87	1201.71	1201.31	1201.65
21.850	1194.20	1196.72	1194.33	1196.01	1196.00	1196.14
21.760	1193.30	1192.41	1193.43	1192.31	1193.59	1192.30
21.680	1192.80	1190.50	1189.71	1189.67	1191.76	1189.48
21.590	1189.80	1188.58	1190.61	1189.73	1190.78	1189.95
21.420	1187.00	1187.99	1187.15	1187.06	1188.00	1187.07
21.240	1185.80	1185.03	1185.40	1185.47	1183.86	1185.94
21.090	1177.60	1171.90	1175.43	1171.80	1178.27	1172.50
20.830	1179.20	1179.92	1180.06	1180.51	1178.27	1180.29
20.640	1174.80	1170.44	1170.25	1170.52	1168.62	1170.49
20.450	1174.10	1173.85	1175.40	1173.62	1173.43	1173.34
20.270	1171.40	1170.68	1170.79	1171.11	1170.63	1170.82
20.080	1168.50	1169.26	1168.20	1169.27	1167.93	1169.23
19.890	1163.30	1165.45	1164.75	1165.44	1163.67	1165.41
19.720	1161.40	1160.77	1162.29	1160.86	1161.28	1160.87
19.540	1160.40	1157.62	1158.22	1157.71	1156.99	1157.71
19.350	1156.40	1155.31	1155.22	1155.27	1153.37	1155.33
19.170	1153.30	1152.10	1152.48	1152.04	1152.38	1152.04
18.940	1149.30	1149.58	1149.86	1149.44	1148.87	1148.69
18.900	1146.70	1148.38	1149.17	1149.55	1136.48	1149.43
Sum of Deviation		96.06	88.61	92.04	86.86	91.34
Sum of Squares of Deviation		372.61	317.49	339.36	364.31	327.28

Where: MTC = 1, Toffaleti; MTC = 3, Madden's (1963); MTC = 4, Yang's Streampower function; MTC = 5 Duboys; and MTC = 7, Ackers and White.

Table 4.8 (c) - Simulated results of the ten sediment transport functions

Station Number	Observed 1989-Data	Thalweg Elevation (ft)				
		MTC=8	MTC=9	MTC=10	MTC=12	MTC=13
25.790	1258.80	1262.68	1263.44	1265.20	1266.64	1268.95
25.590	1256.50	1259.55	1258.51	1261.50	1261.56	1261.29
25.530	1256.00	1259.02	1259.51	1257.14	1257.09	1260.61
25.370	1255.00	1256.55	1256.92	1257.31	1258.03	1258.22
25.090	1250.80	1250.42	1251.24	1250.82	1250.80	1252.43
24.900	1246.50	1248.90	1248.57	1248.91	1248.61	1249.91
24.630	1240.20	1245.02	1244.77	1244.42	1243.93	1244.84
24.450	1233.40	1241.02	1240.77	1240.05	1239.89	1240.70
24.350	1235.20	1238.42	1237.35	1237.44	1237.42	1237.89
24.170	1231.00	1235.12	1234.88	1234.92	1235.06	1235.14
23.980	1227.20	1231.12	1231.96	1232.55	1233.09	1232.05
23.800	1225.20	1228.99	1229.09	1229.11	1228.93	1229.43
23.620	1222.00	1225.53	1225.25	1225.18	1225.28	1225.33
23.350	1217.60	1221.61	1221.39	1221.60	1221.50	1221.54
23.160	1215.70	1216.27	1216.43	1211.84	1211.68	1212.05
22.600	1207.40	1207.27	1207.47	1207.53	1207.63	1207.44
22.320	1201.00	1203.75	1204.24	1203.93	1204.01	1203.98
22.130	1198.40	1201.82	1201.32	1201.13	1200.78	1200.81
21.850	1194.20	1196.82	1195.85	1195.56	1195.16	1195.70
21.760	1193.30	1192.42	1193.05	1192.77	1192.62	1193.01
21.680	1192.80	1190.22	1190.84	1189.39	1189.38	1190.39
21.590	1189.80	1190.32	1189.66	1190.48	1191.58	1189.24
21.420	1187.00	1187.02	1188.43	1187.29	1186.01	1187.85
21.240	1185.80	1185.12	1184.06	1185.97	1187.87	1184.35
21.090	1177.60	1171.60	1175.39	1174.35	1177.92	1173.66
20.830	1179.20	1180.20	1179.81	1179.93	1179.19	1180.23
20.640	1174.80	1170.60	1170.25	1170.37	1170.40	1170.36
20.450	1174.10	1173.34	1173.53	1173.55	1173.51	1173.96
20.270	1171.40	1170.84	1170.78	1170.58	1170.50	1171.06
20.080	1168.50	1169.34	1168.64	1168.90	1168.38	1169.01
19.890	1163.30	1165.52	1164.79	1165.12	1164.78	1165.43
19.720	1161.40	1160.76	1161.32	1161.42	1161.66	1161.10
19.540	1160.40	1157.62	1157.88	1157.77	1158.13	1157.89
19.350	1156.40	1155.41	1155.13	1155.09	1155.18	1155.24
19.170	1153.30	1152.07	1152.34	1152.02	1152.19	1152.12
18.940	1149.30	1148.52	1150.26	1149.14	1150.05	1149.39
18.900	1146.70	1150.92	1149.84	1147.77	1147.18	1148.99
Sum of Deviation		95.83	87.20	88.04	88.42	102.28
Sum of Squares of Deviation		352.35	299.79	324.29	337.68	439.28

Where: MTC = 8, Colby; MTC = 9, Toffaleti and Schoklitsch; MTC = 10, Meyer-Peter and Muller; MTC = 12, Toffaleti and Meyer-Peter and Muller; MTC = 13, Madden's (1985);

4.5 Sensitivity Analysis

Sensitivity analysis on the hydraulic parameters has been conducted to evaluate the behavior of the model against changes in the parameter values. The three (3) parameters used in this analysis include: (i) the roughness coefficient; (ii) the inflowing sediment load; and, (iii) the sediment gradation. Only selected transport functions were used for the analysis to demonstrate their sensitivity with parameter changes.

4.5.1 Manning's Coefficient (n)

Four (4) sediment transport functions were used to evaluate their sensitivity against the changes in roughness coefficient values along the main channel of the study reach. These formulas include: Toffaleti and Schoklitsch, Meyer-Peter and Muller, Ackers and White, and Toffaleti/Meyer-Peter and Muller formulas.

(a) *Toffaleti and Schoklitsch Formula* - Figs. 4.9 (a), (b), and (c) show the response of the model using Toffaleti and Schoklitsch function under four different values of the roughness coefficient (n) [i.e., n = 0.02, n = 0.03, n = 0.04, and n = 0.05]. **Tables 4.9 to 4.10** list the section-to-section thalweg elevations derived and the evaluated sum of deviation and sum of squares of deviation. The figures indicate that the Toffaleti and Schoklitsch formula is not very sensitive to the changes in the roughness coefficients.

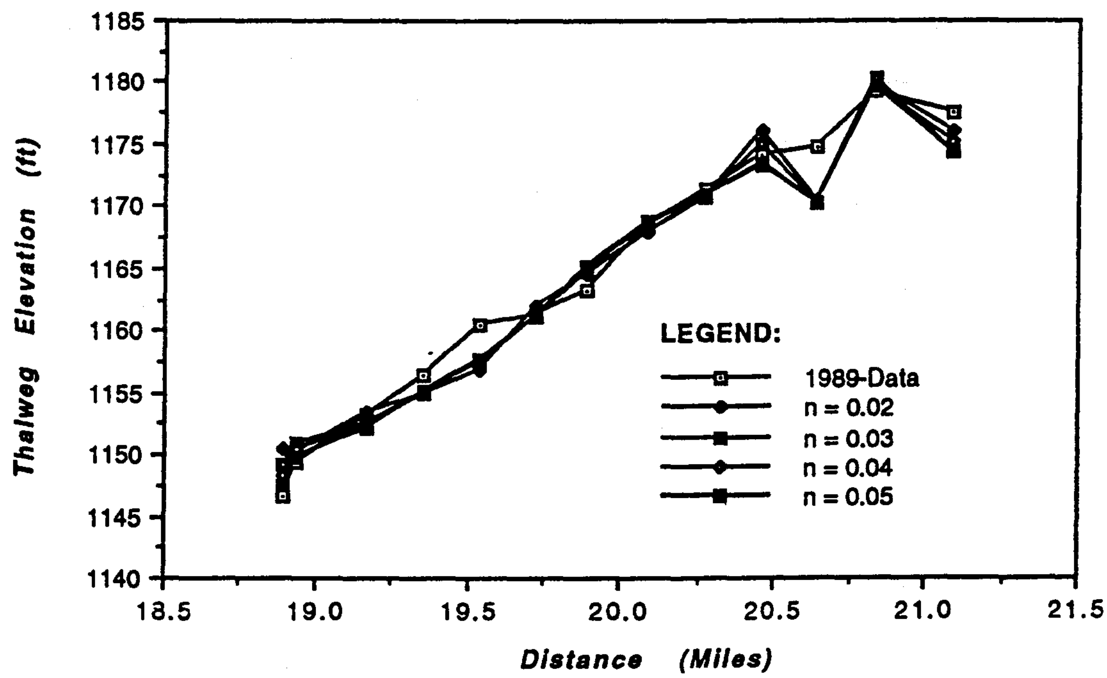

Fig. 4.9 (a) - Model response to the change in roughness coefficient [Toffaleti and Schoklitsch Formula, First segment]

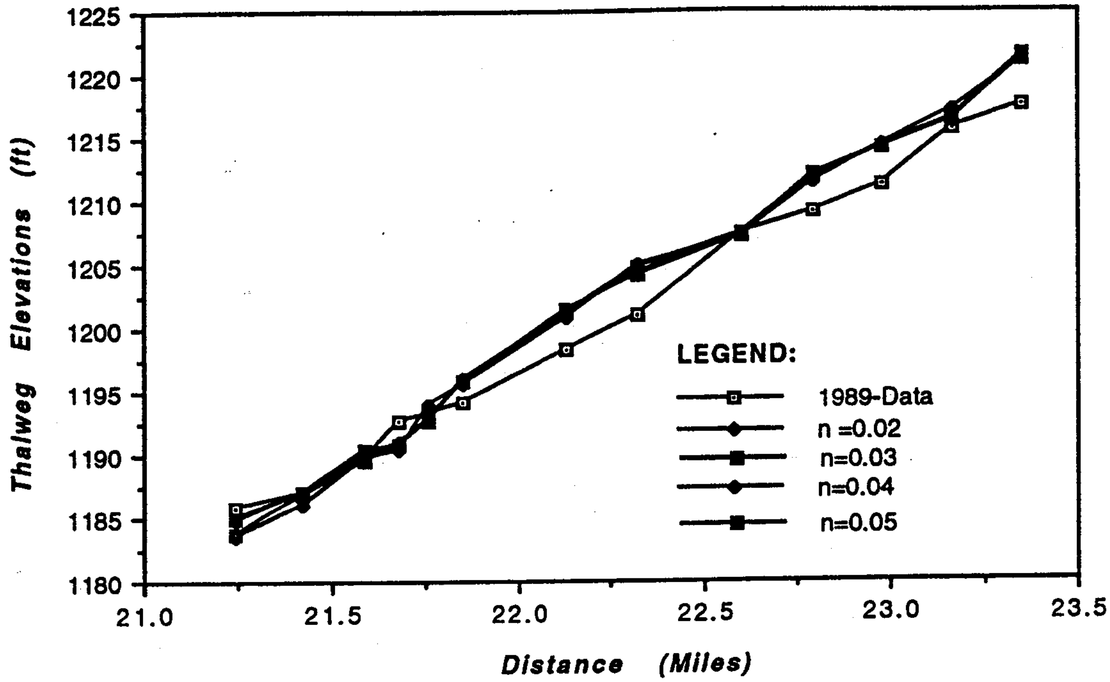

Fig. 4.9 (b) - Model response to the change in roughness coefficient [Toffaleti and Schoklitsch Formula, Second segment]

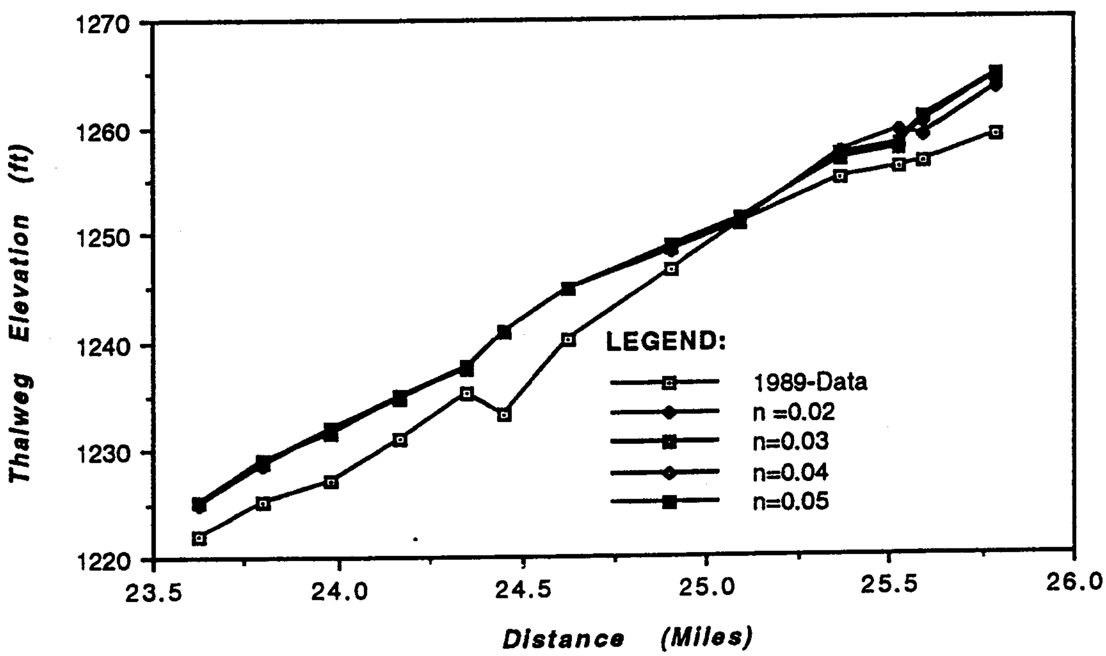

Fig. 4.9 (c) - Model response to the change in roughness coefficient [Meyer-Peter and Muller Formula, Third segment]

(b) *Ackers and White Formula* - Similar work was done for Ackers and White formula under four different values of roughness coefficient, n. **Table 4.11** shows the response of the model with these changes in the n-values. The sum of deviation and the sum of squares of deviation were also evaluated for comparison purposes. There is a slight sensitivity exhibited by the changes in roughness coefficient, n, on the performance of Ackers and White formula.

(c) *Meyer-Peter and Muller Formula* - **Table 4.12** shows the response of Meyer-Peter and Müller formula with changes in roughness coefficients. Similar to Ackers and White formula, there is a pronounced sensitivity between the performance of Meyer-Peter and Muller formula and the roughness coefficient, n, Meyer-Peter and Muller formula, however, is more sensitive to roughness coefficient, n, than Ackers and White formula.

(d) *Toffaleti/Meyer-Peter and Muller Formula* - **Table 4.13** shows the response of Toffaleti/Meyer-Peter and Muller formula with changes in roughness coefficient values. Based on the evaluated sum of deviation and sum of squares of deviation, Toffaleti/Meyer-Peter and Muller formula does not follow a definite trend as Ackers and White, and Meyer-Peter and Muller formulas do as could be verified in the evaluated sum of deviation.

(e) *Summary* - **Tables 4.10 to 13** tabulate the summary of the response of the four (4) sediment transport functions with changes in the roughness coefficient values. Based on the evaluated criteria [e.g. minimum sum of deviation and minimum sum of squares of deviation], it is observed that Toffaleti and Schoklitsch formula is not sensitive to the changes of roughness coefficients along the main channel; while the other three functions are very sensitive (see **Fig. 4.10 to 4.11**).

Table 4.10 - Sensitivity analysis of Toffaleti and Schoklitsch Formula to roughness coefficient values.

Roughness Coefficient 'n'	Sum of Deviation	Sum of Squares of Deviations
n = 0.02	90.28	315.21
n = 0.03	89.71	316.48
n = 0.04	86.43	309.06
n = 0.05	87.10	317.17

Table 4.11 - Sensitivity analysis of Ackers and White Formula to roughness coefficient values.

Roughness Coefficient 'n'	Sum of Deviation	Sum of Squares of Deviations
n = 0.02	83.08	293.06
n = 0.03	90.40	331.23
n = 0.04	94.36	353.61
n = 0.05	95.73	368.98

Table 4.12 - Sensitivity analysis of Meyer-Peter and Muller Formula to roughness coefficient values.

Roughness Coefficient 'n'	Sum of Deviation	Sum of Squares of Deviations
n = 0.02	83.49	275.27
n = 0.03	88.45	334.03
n = 0.04	92.06	379.76
n = 0.05	93.52	405.16

Table 4.13 - Sensitivity analysis of Toffaleti/Meyer-Peter and Muller Formula to roughness coefficient values.

Roughness Coefficient 'n'	Sum of Deviation	Sum of Squares of Deviations
n = 0.02	99.15	348.73
n = 0.03	93.80	372.33
n = 0.04	88.71	383.66
n = 0.05	94.86	443.77

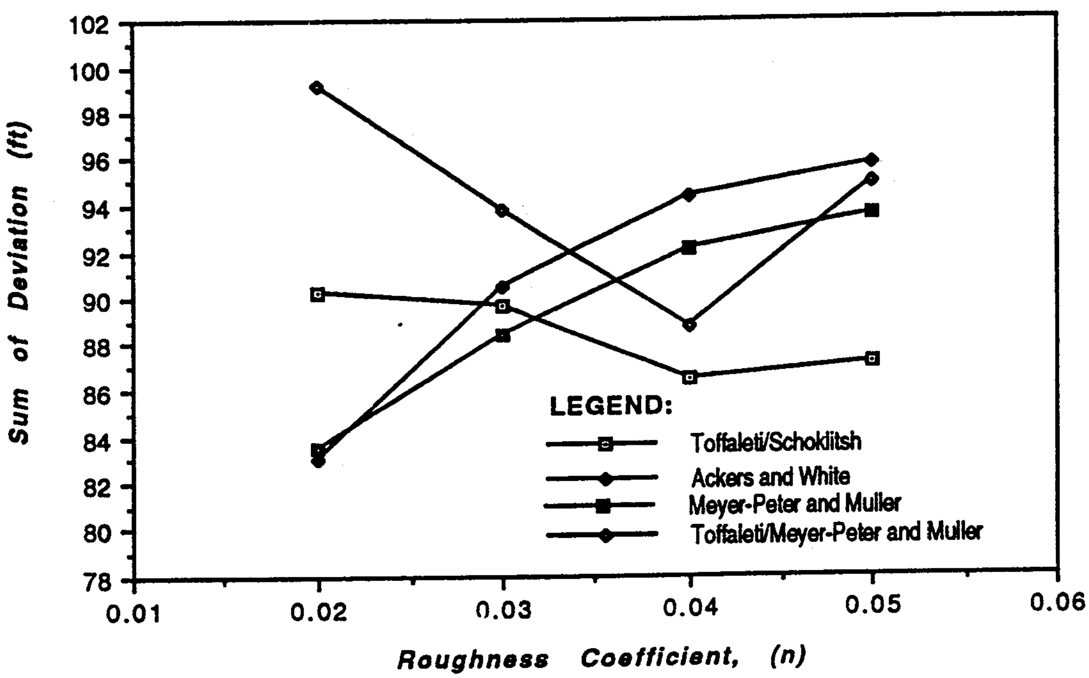

Fig. 4.10 - Sum of deviation for four sediment transport functions

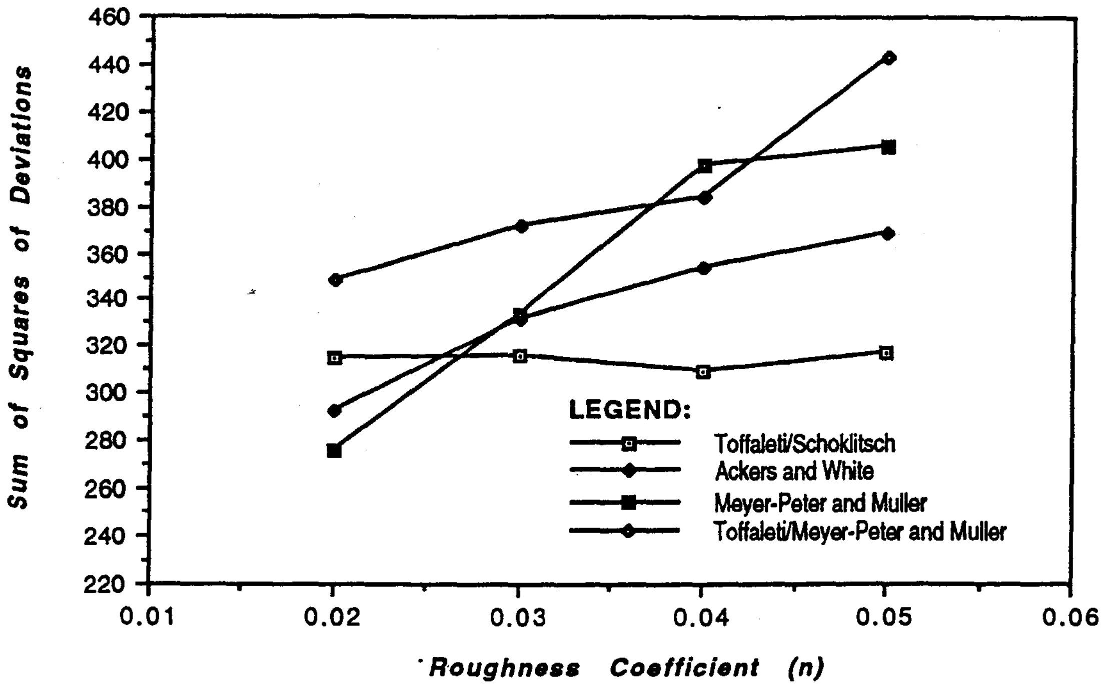

Fig. 4.11- Sum of squares of deviation for four sediment transport functions

4.5.2 Inflowing Sediment Load and Sediment Gradation Data

- Sensitivity analysis was also done on the inflowing sediment load and sediment gradation data. In all of the previous analyses, *Type-2* sediment data have been used in the model. Here,*Type-1* data coupled with zero inflowing sediment load are used as part of the sensitivity analysis to evaluate the responses of the model. Three sediment transport functions were used to demonstrate how their performance are affected by the changes in the values of the above parameters. These functions include Toffaleti and Schoklitsch, Meyer-Peter and Muller, and Ackers and White formulas,

(a) *Toffaleti and Schoklitsch Formula* - Table 4.14 lists the model response under Meyer-Peter and Muller formula to changes in sediment data and inflowing sediment load. It is observed that zero upstream boundary condition [i.e. inflowing sediment load is zero] provides better model response - a fact that is proven by lesser values of the sum of deviation and sum of squares of the deviation.These results show the sensitivity of sediment data and inflowing sediment in the use of Toffaleti and Schoklitsch formula.

(b) *Ackers and White Function* - Table 4.15 lists the response of Ackers and White formula to the changes in sediment data and inflowing sediment load. Similar to Meyer-Peter and Muller formula, Ackers and White function exhibits better performance when the inflowing sediment load is zero. This, likewise, shows that there is a significant sensitivity between these parameters and the performance of Ackers and White formula in the model.

(c) *Meyer-Peter and Muller Formula* - Table 4.16 lists the response of Yang's streampower function to the changes in inflowing sediment load and sediment data. Based on the evaluated sum of deviation and sum of squares of deviation, Meyer-Peter and Muller formula is sensitive to the parameters.

(d) *Summary* - All the three (3) sediment transport functions analyzed exhibited significant sensitivity to the changes in inflowing sediment load and sediment gradation data. This is so because the dynamics of sediment transport along the river is governed principally by the sediment characteristics, particularly the sediment size. The degrees of sensitivity of the three (3) sediment transport functions to the parameters, however, vary. Though, *Type-1* sediment data offer smaller mean grain size than the *Type-II* data, the behaviors of the three transport functions are different.

Table 4.14 - Response of Toffaleti and Schoklitsch Formula to change of inflowing sediment load

Sediment Data Classification*	Inflowing Sediment, Gs	Sum of Deviation	Sum of Squares of Deviations
Type-1	Gs = 0.0	73.79	233.06
Type-2	Gs = 0.0	82.43	269.46
Type-2	Gs > 0.0**	87.20	299.79

Note: * Type-1 data is predominantly sandy with less than 6% gravel; Type-2 is graded uniformly with about 35% gravel.
** Gs is the generated inflowing sediment load.

Table 4.15 - Response of Ackers and White Formula to change of inflowing sediment load

Sediment Data Classification*	Inflowing Sediment, Gs	Sum of Deviation	Sum of Squares of Deviations
Type-1	Gs = 0.0	78.14	260.97
Type-2	Gs = 0.0	87.70	304.82
Type-2	Gs > 0.0**	91.34	327.28

Note: * Type-1 data is predominantly sandy with less than 6% gravel; Type-2 is graded uniformly with about 35% gravel.
** Gs is the generated inflowing sediment load.

Table 4.16 - Response of Meyer-Peter and Muller Formula to change of inflowing sediment load

Sediment Data Classification*	Inflowing Sediment, Gs	Sum of Deviation	Sum of Squares of Deviations
Type-1	Gs = 0.0	80.40	273.69
Type-2	Gs = 0.0	77.74	258.15
Type-2	Gs > 0.0**	88.04	324.29

Note: * Type-1 data is predominantly sandy with less than 6% gravel; Type-2 is graded uniformly with about 35% gravel.
** Gs is the generated inflowing sediment load.

Table 4.17- Summary table for the 10 transport functions using zero inflowing sediment (Gs =0, Type-II data)

MTC No.	Sediment Transport Function	Sum of Deviation	Sum of Squares of Deviations
1	Toffaleti	90.93	318.62
3	Madden (1963)	75.35	242.00
4	Yang's Streampower	86.82	306.06
5	Duboys	75.28	294.59
7	Ackers and White	87.70	304.80
8	Colby	95.08	346.77
9	Toffaleti and Schoklitsch	82.43	269.46
10	Meyer-Peter and Muller	77.74	258.15
12	Toffaleti/Meyer-Peter and Muller	74.26	232.67
13	Madden (1985)	85.29	288.94

V MODELING DESCRIPTIONS

The sediment transport study for the Agua Fria River is aimed at using the **HEC-6** code to develop three models that describe different hydraulic scenarios associated with the existing, on-going, and proposed developments on and around the river. The three models are described in **Table 5.1.**

Table 5.1 - Scenarios of the Different Models to be Developed for the Agua Fria River

Model	Modeling Scope
Model I	Develop a model to evaluate the sediment transport under the existing condition with New Waddell Dam and the Arizona Canal Diversion Channel (ACDC) built;
Model II	Develop a future condition model using the existing condition model (Model I) to reflect the ultimate sand and gravel mining as permitted today;
Model III	Develop a future condition model by adding 1000-foot wide channel improvement along the Agua Fria River (wherever applicable) to Model II in order to evaluate the effect of the mining sites to the proposed channel;

5.1 Model I

5.1.1 Modeling Description

Development of a model that evaluates the sediment transport under the existing condition at the Agua Fria River with New Waddell Dam and the Arizona Canal Diversion Channel (ACDC) built;

5.1.2 Geometric Data

(i) River Geometry - The river geometry of the Agua Fria River is described by 96 field stations (see **Table A.1.1, Appendix A**) selected from the original 450-field stations provided by **Jerry R. Jones & Associates, Inc., (1989).** The basis of selecting 132-field stations for Model I is from the guidelines presented in **Section 2.2.1 [Chapter II]**

(ii) Bridge-Crossings in the Agua Fria River - There are 14 bridge crossings in the Agua Fria River (see **Table 2.2**). **Simons, Li and Assoc., Inc., (1983)** listed useful information on the bridge structures essential to the understanding of their hydraulic characteristics.

5.1.3 Sediment Data

The associated sediment data for the selected stations for Model I were from the field samples whose gradation curves are provided in **Appendix B.**

5.1.4 Hydrologic Data

Four hydrologic data under the post-New Waddell condition are used to run the three models developed. These data are for the 50-year, 100-year, 200- and 500-year peak releases from the New Waddell dam (see **Table 5.1.1**). Since the New River is the only significant tributary, it is essential to consider the river's contribution to the flow at the Agua Fria River. The hydrologic study of the Agua Fria River in 1981 has presented that a 100-year flood contribution of the New River during the 100-year flood at the Agua Fria River is about 5,000 cfs **[U.S. Army Corps of Engineers, Los Angeles, 1981]**. This peak discharge from the New River will be used for the four hydrographs [see **Tables C.2.1 to C.2.4 [Appendix C]**. The duration of the hydrographs to be used is equivalent to the duration of the most recent 1980-flood event of about 8.7912 days.

Table 5.1.1 - Peak discharge from the New Waddell Dam

Return Period	Peak Discharges (cfs)
50 years	18,500.00
100 years	32,000.00
200 years	54,000.00
500 years	85,000.00

The above values were determined by the US Army Corps of Engineers based on the condition that the reservoir is full when the flood inflows occur. Since the hydrographs have not been completed during the modeling phases of the current study, a triangular-shape hydrograph was assumed with peaks ocurring midway between the beginning and the ending of the flood event. Also, the hydrographs were discretized with discharge and time values computed according to the tabulated relations and values in **Table 5.1.2.**

The attenuation of the flows at various locations along the river is presented in **Table C.2.1 [Appendix C]**. The values in this table were extracted from the behavior of the flow attenuation under the existing condition [i.e., pre-New Waddell Dam, see **Table 2.4, Chapter 2]**.

Table 5.1.2 - Time duration and discharge relations in the development of hydrographs

n	Discharge Relation	Time Duration Relation	Equivalent Time Duration (days)	Cummulative Time (days)
1	0.00	-	0.000	0.000
2	0.25Q	t	1.850	1.850
3	0.50Q	0.75t	1.390	3.240
4	0.75Q	0.50t	0.925	4.150
5	1.00Q	0.25t	0.463	4.628
6	0.75Q	0.50t	0.925	5.553
7	0.50Q	0.75t	1.390	6.243
8	0.25Q	t	1.850	8.793
9	0.00	-	0.000	8.973

Where: Q is the peak discharge ; t is the time duration associated to the lowest value of discharge.

5.2 Model II

5.2.1 Modeling Description

Development of a future condition model using the existing condition (Model I) to reflect the ultimate sand and gravel mining as permitted today.

5.2.2 Description of Mining Sites Along the Agua Fria River

A number of mining sites are currently permitted along and around the Agua Fria River. The extent of bed modification as a result of sand and gravel mining undoubtedly, and will significantly, affect the sedimentation processes along the river. The extent of mining at the various sites have been incorporated in the geometry of the river in order to evaluate their ultimate hydraulic effects and to assess the associated sedimentation dynamics involved. Model II comprises this phase of the study in whose results could provide basis for decision making in terms of the extent of mining permission that could be allowed to gravel and sand mining companies.

5.2.2.1 Site A

Owner: Salt River Pima Maricopa Indian Community
Location: Between Olive Avenue and Peoria Avenue
Maximum Pit Depth: 40 feet

The mining site [see **Fig. 5.2.1**], when fully operational could be represented geometrically by four (4) section stations as presented in **Table 5.2.1.** The section geometry information are based on the orientation of the mining site relative to the direction of flow.

Table 5.2.1 - Section stations for mining site A

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Station 13.810	0.00	1080.5	-1735.00
Station 13.855	240.00	1081.0	-1735.00
Station 14.380	2220.00	1085.4	-1860.00
Station 14.412	240.00	1085.9	-1860.00

Note: Bed slope is 0.002 ft/ft.

(i) Geometric Data - The section geometry information of the above defined stations were derived from the development plan of the site made by **Barrett Consulting Group, Inc. (1987).** The bottom pit floor has a bed slope of 0.002 ft/ft.

(1) Station 13.810 - This section is the most downstream station of the mining site comprised of the existing ground surface data plus the specified revetment [Elevation: 1080.5 ft] that runs across the entire width of the property (see **Fig. 5A-1**). This station serves as the downstream boundary limit of the mining site.

(2) Station 13.885- The cross-section geometry for this station is shown in **Fig. 5A-2** and **Table 5A-2.**

(3) Station 14.380 - **Fig. 5A-3** and **Table 5A-3** present the cross-section geometry of the station.

(4) Station 14.412 - This is the most upstream station of mining site A which is comprised of the existing ground information plus the specified revetment that covers the entire development area. This station serves as the upstream boundary limit for the mining site.

(ii) Sediment Data - An 18-inch thick filter blanket at the drown-out chute and stilling basin is comprised of sediments with gradation specification as follows:

$$8.90\ \text{mm} \leq D_{15} \leq 16.00\ \text{mm}$$
$$13.30\ \text{mm} \leq D_{50} \leq 80.00\ \text{mm}$$
$$D_{85} \geq 71.10\ \text{mm}$$

A 42-inch thick revetment comprising of 21" stones is also provided which is laid over the 18-inch filter blanket. The riprap protection at the drown-out chute and top end armorment has the following gradation specification:

$$14.40\ \text{inches} \leq D_{15} \leq 21.20\ \text{inches}$$
$$21.20\ \text{inches} \leq D_{50} \leq 26.70\ \text{inches}$$
$$26.70\ \text{inches} \leq D_{100} \leq 36.20\ \text{inches}$$

(iii) Other Data - An 18-inch high berm [with 15-inch top width) is build along the western side of the mining site.

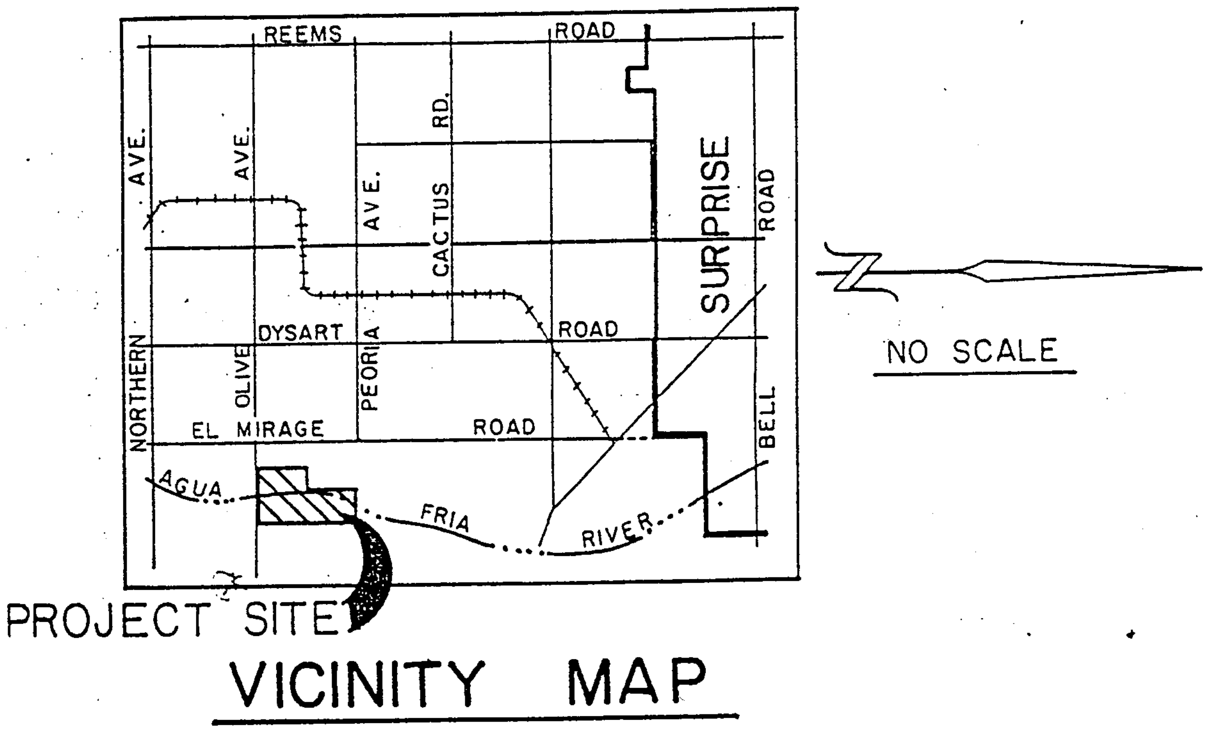

Fig. 5.2.1 - Location map of the mining site A
[Owner: Salt River Pima Maricopa Indian Community]

Table 5A-1 - Section geometry for Station 13.810

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8265.00 (PL)**	-1735.00	1080.50
3	8365.00	100.00	1080.50
4	8485.00	120.00	1080.50
5	9315.00	830.00	1080.50
6	9435.00	120.00	1080.50
7	9535.00 (PL)**	100.00	1080.50

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5A-2 - Section geometry for Station 13.855

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8265.00 (PL)**	-1735.00	1081.00
3	8365.00	100.00	1081.00
4	8485.00	120.00	1041.00
5	9315.00	830.00	1041.00
6	9435.00	120.00	1081.00
7	9535.00 (PL)**	100.00	1081.00

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5A-3 - Section geometry for Station 14.380

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8140.00 (PL)**	-1860.00	1085.40
3	8240.00	100.00	1085.40
4	8360.00	120.00	1045.40
5	9190.00	830.00	1045.40
6	9310.00	120.00	1085.40
7	9410.00 (PL)**	100.00	1085.40

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5A-4 - Section geometry for Station 14.412

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8140.00 (PL)**	-1860.00	1085.90
3	8240.00	100.00	1085.90
4	8360.00	120.00	1085.90
5	9190.00	830.00	1085.90
6	9310.00	120.00	1085.90
7	9410.00	100.00	1085.90

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

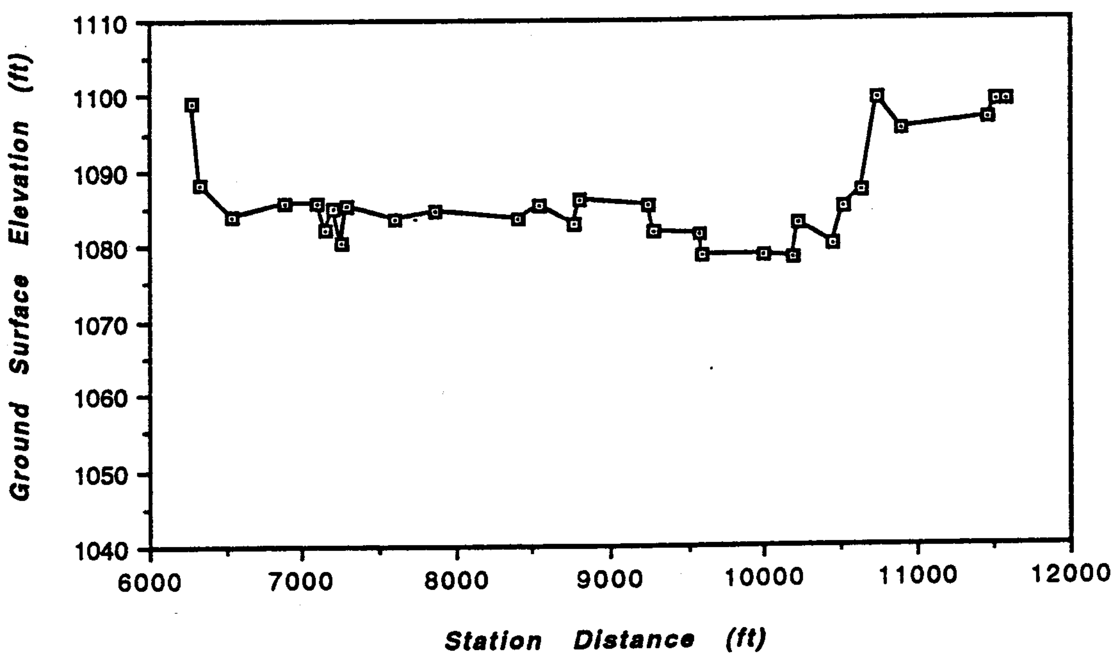

Fig. 5A-1 - Cross-section plot of Station 13.810

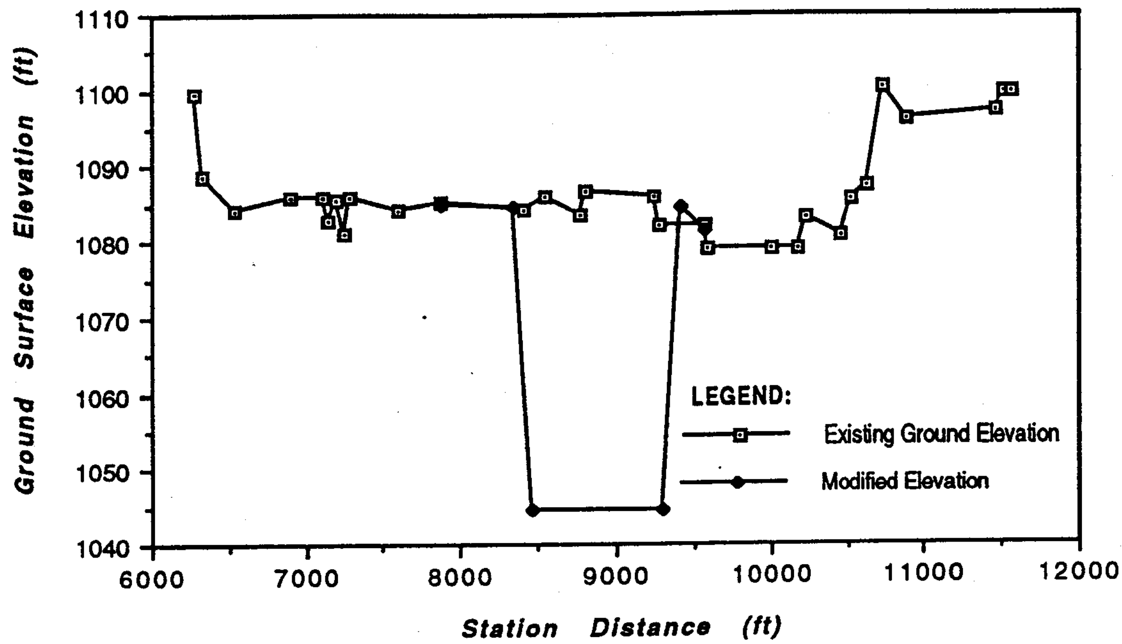

Fig. 5A-2 - Cross-section plot of Station 13.855

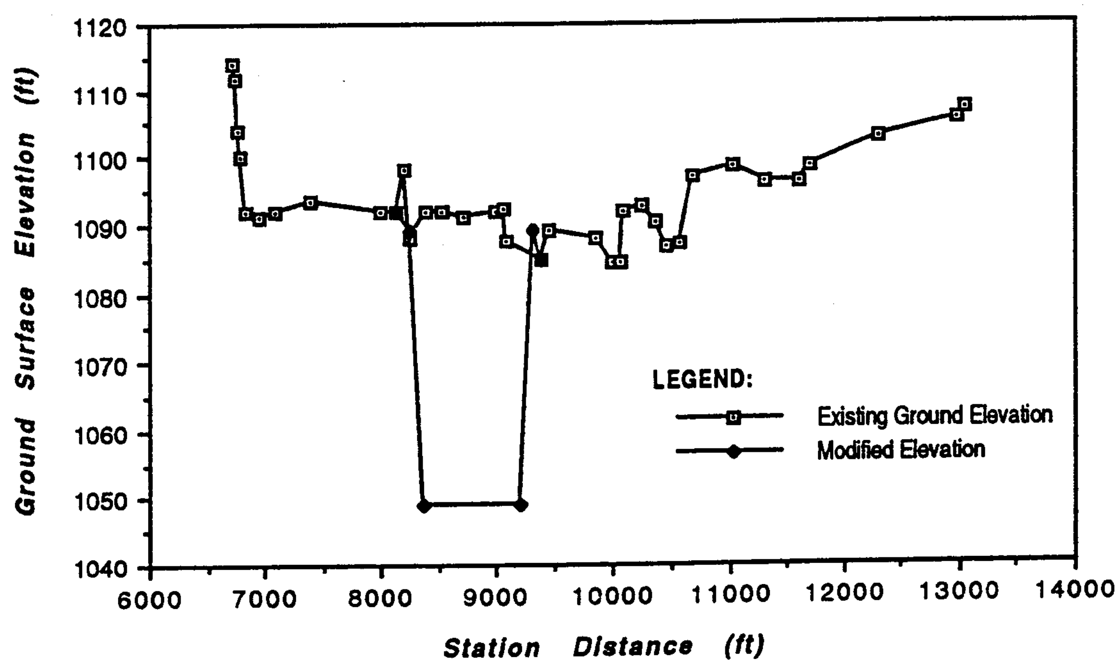

Fig. 5A-3 - Cross-section plot of Station 14.380

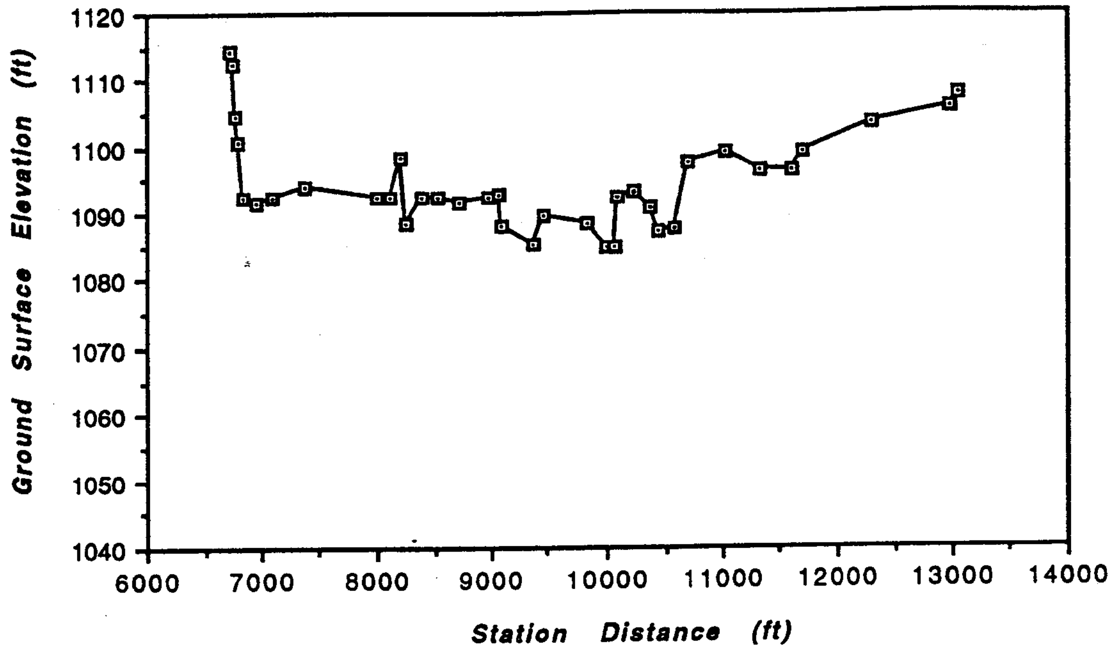

Fig. 5A-4 - Cross-section plot of Station 14.412

5.2.2.2 Site B

Owner:	Gravel Resources
Location:	Between Peoria Avenue and Cactus Road
Maximum Pit Depth:	15 feet

The mining site [see **Fig. 5.2.2**] could be represented by five (5) section stations as defined in **Table 5.2.2.** The geometry of these stations were derived from the development map made by **Barrett Consulting Group, Inc. (1988)** for **Gravel Resources Company**, owner and operator of the mining site.

Table 5.2.2 - Section stations for mining site B

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Station 14.932	0.00	1095.0	475.00
Station 14.940	45.00	1095.1	480.00
Station 15.063	650.00	1096.4	590.00
Station 15.303	1175.00	1098.8	540.00
Station 15.320	90.00	1099.0	540.00

Note: Bed slope is 0.002 ft/ft.

(i) Geometric Data - The section geometry of the above five (5) stations are described below. The top revetment elevation is designated at 1099.0 ft. at the most upstream station with development slope of 0.002 ft/ft.

(1) Station 14.932 - This is the most downstream station for the mining site which comprised of the existing field information plus the indicated 590-foot wide armorment provided in the plan [see **Fig. 5B-1**]. This station serves as the downstream boundary limit of the mining site B.

(2) Station 14.940 - The section geometry for this station is shown in **Fig. 5B-2** and **Table 5B-2.**

(3) Station 15.063 - The section geometry for this station is shown in **Fig. 5B-3** and **Table 5B-3.**

(4) Station 15.303 - **Fig. 5B-4** and **Table 5B-4** show the section geometry for this station derived from the development map of the mining site.

(5) Station 15.320 - The section geometry for this station is comprised of the existing ground information (see **Fig. 5B-5**). This section stations serves as the upstream boundary limit of the mining site.

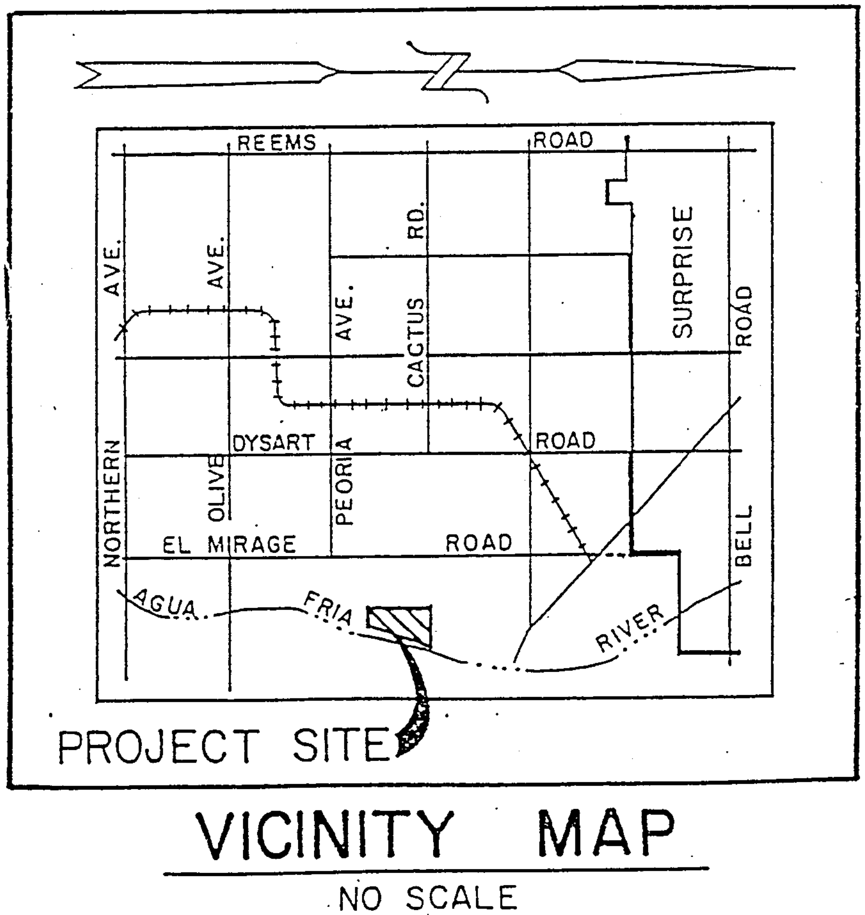

Fig. 5.2.2 - Location map of the mining site B
[Owner: Gravel Resources Company]

Table 5B-1 - Section geometry for Station 14.932

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	10475.00 (PL)**	475.00	1095.00
3	10575.00	100.00	1095.00
4	10665.00	90.00	1095.00
5	11020.00	355.00	1095.00
6	11065.00	45.00	1095.00
7	11115.00 (PL)**	50.00	1095.00

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5B-2 - Section geometry for Station 14.940

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	10480.00 (PL)**	480.00	1095.10
3	10580.00	100.00	1095.10
4	10670.00	90.00	1080.10
5	11025.00	355.00	1080.10
6	11070.00	45.00	1095.10
7	11120.00 (PL)**	50.00	1095.10

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5B-3 - Section geometry for Station 15.063

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	10590.00 (PL)**	590.00	1096.40
3	10690.00	100.00	1096.40
4	10735.00	45.00	1081.40
5	11135.00	400.00	1081.40
6	11180.00	45.00	1096.40
7	11230.00	50.00	1096.40

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5B-4 - Section geometry for Station 15.303

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	10540.00 (PL)**	540.00	1098.80
3	10640.00	100.00	1098.80
4	10685.00	45.00	1083.80
5	11085.00	400.00	1083.80
6	11130.00	45.00	1098.80
7	11180.00	50.00	1098.80

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5B-5 - Section geometry for Station 15.320

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	10540.00 (PL)**	540.00	1099.00
3	10640.00	100.00	1099.00
4	10685:00	45.00	1099.00
5	11085.00	400.00	1099.00
6	11130.00	45.00	1099.00
7	11180.00	50.00	1099.00

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

(ii) **Sediment Data** - A 9" thick filter blanket is provided for the upstream drown out chute slope made up of sediments with gradation specification as follows:

$$3.18 \text{ mm} \leq D_{15} \leq 3.20 \text{ mm}$$
$$5.08 \text{ mm} \leq D_{50} \leq 16.80 \text{ mm}$$
$$D_{85} \geq 25.40 \text{ mm}$$

An 18-inch rock-filled gabion matress laid over the 9-inch filter blanket is also provided for slope protection. Rock for matresses shall be: D_0 = 4 inches; D_{15} = 5.0 inches; D_{50} = 8.0 inches; D_{85} = 10.0 inches; and, D_{90} = 12.0 inches.

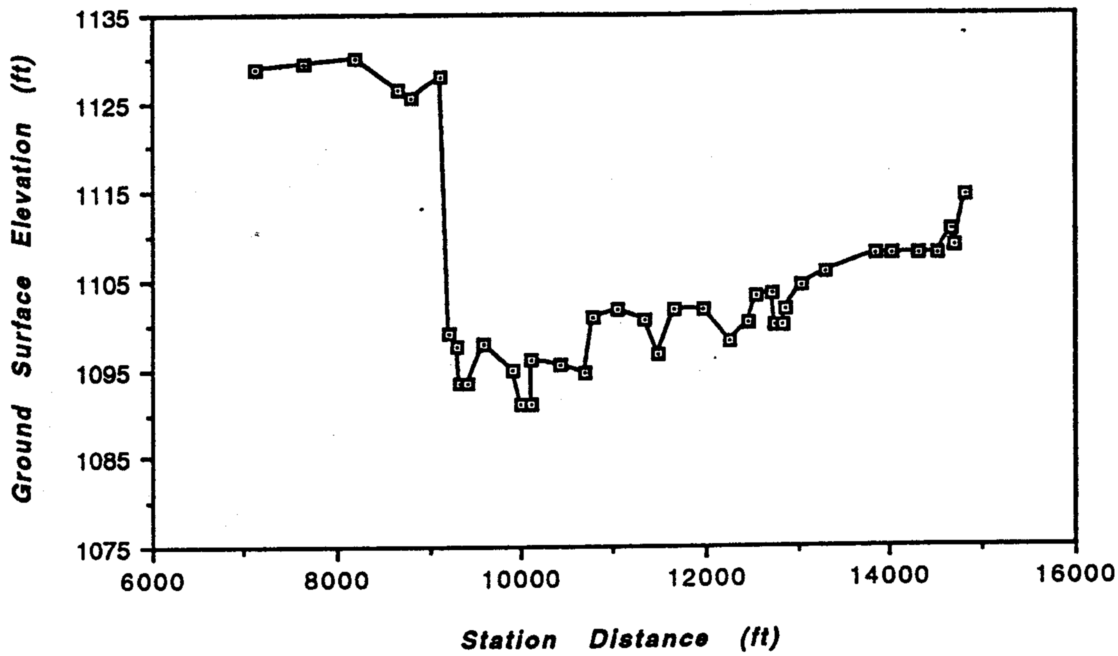

Fig. 5B-1 - Cross-section plot of Station 14.932

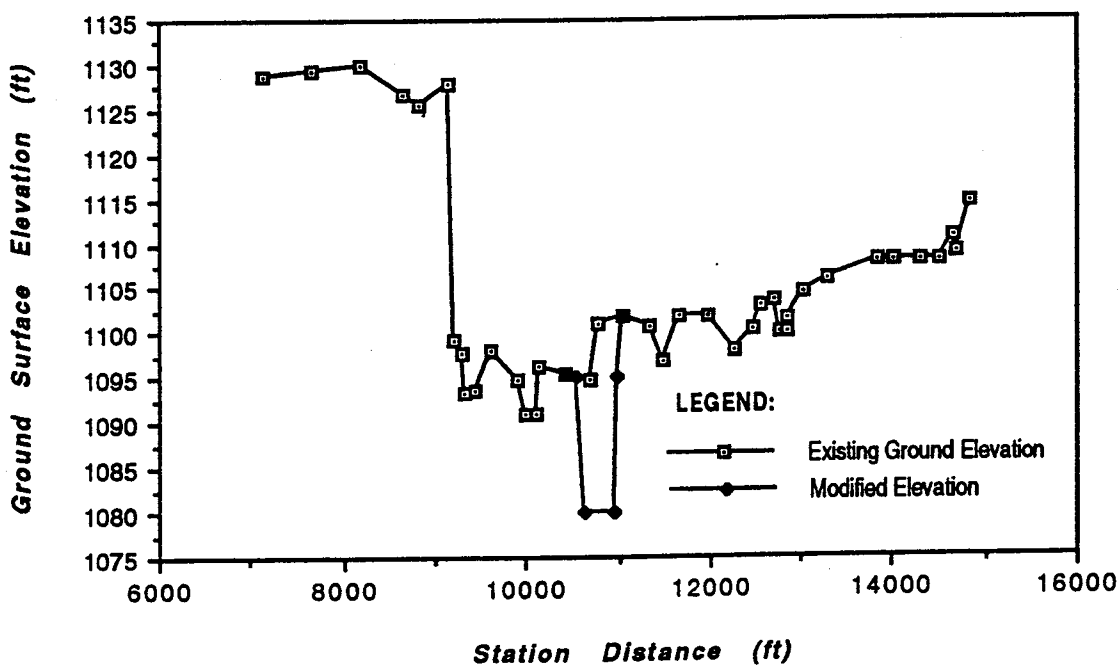

Fig. 5B-2 - Cross-section plot of Station 14.940

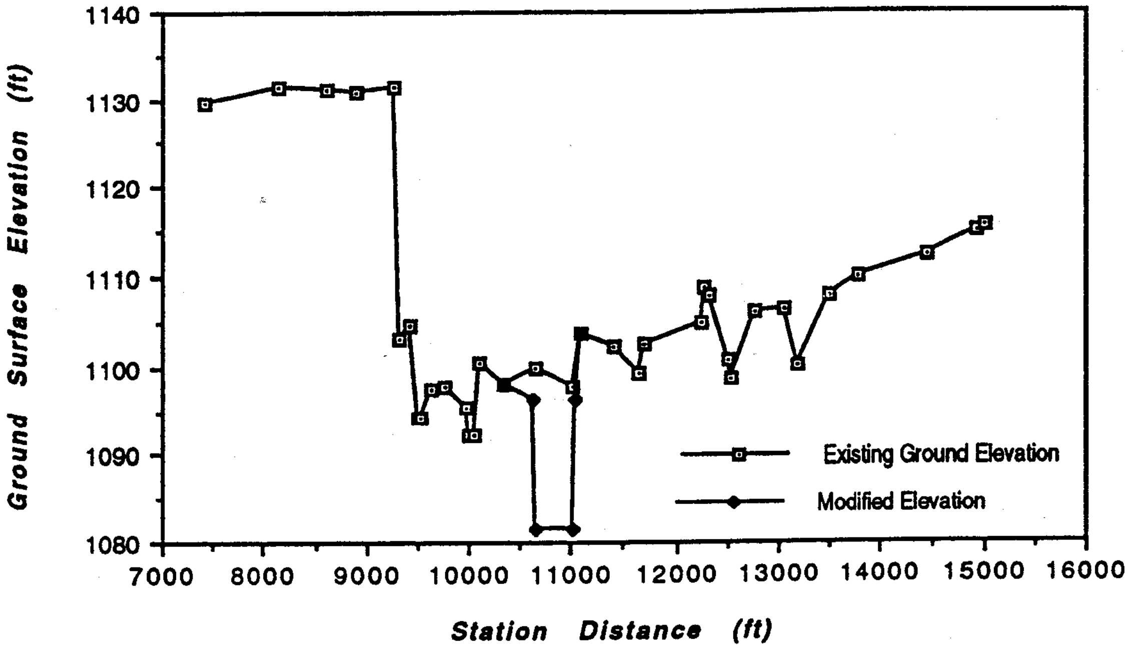

Fig. 5B-3 - Cross-section plot of Station 15.063

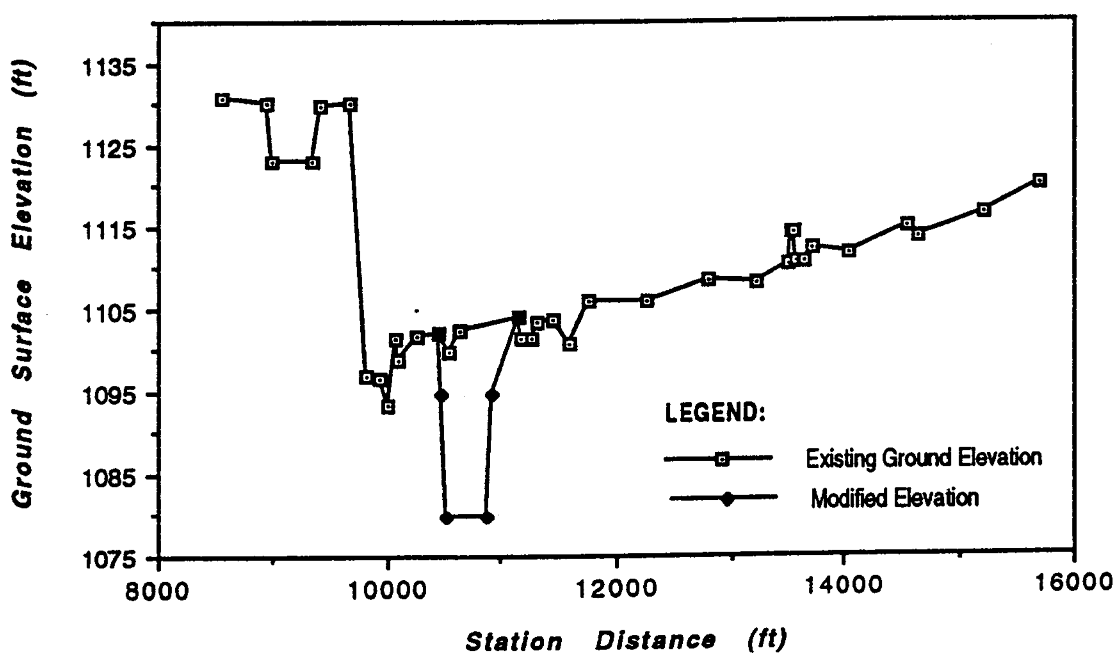

Fig.5B-4 - Cross-section plot of Station 15.303

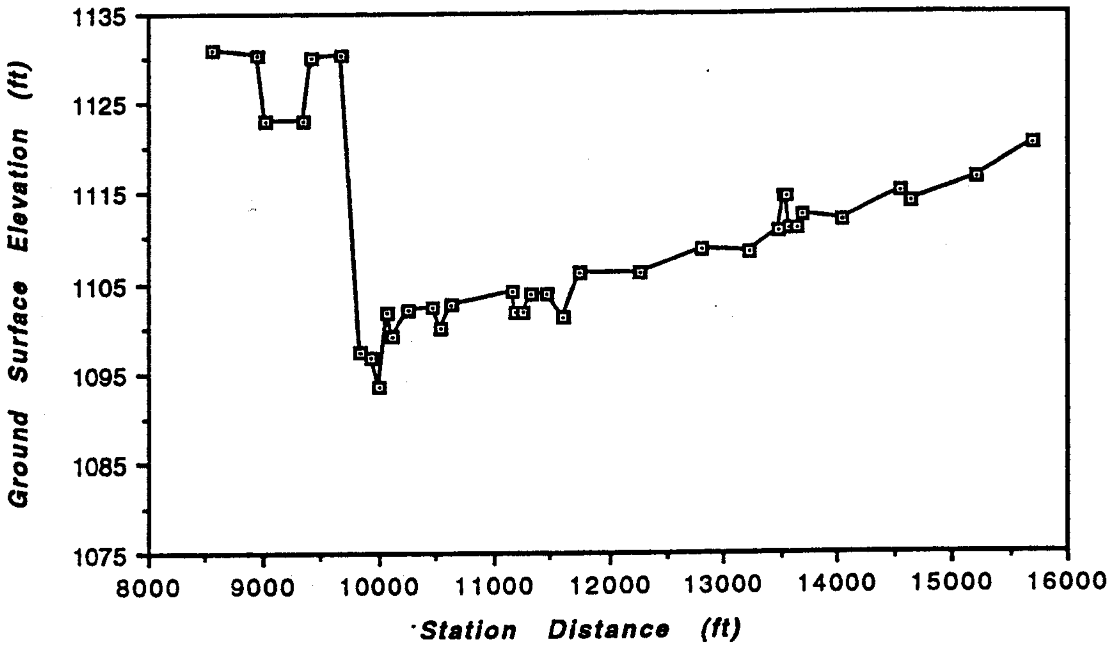

Fig. 5B-5 - Cross-section plot of Station 15.320

5.2.2.3 Site C

Owner: Agua Bell Land Development Company
Location: Between Union Hills Drive and Beardsley Road
Maximum Pit Depth: 30 feet

The extent of development plan for mining site C could be represented by the ten (10) stations identified in **Table 5.2.3.** The site is comprised of two (2) mining pits.

Table 5.2.3 - Section stations for mining site C

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Pit No. 1:			
Station 19.944	0.00	1172.0	-1858.00
Station 19.953	45.00	1172.1	-1858.00
Station 20.240	1565.00	1177.3	-2090.00
Station 20.550	1650.00	1182.7	-1955.00
Station 20.563	70.00	1182.9	-1955.00
Pit No. 2:			
Station 20.577	70.00	1183.1	-1970.00
Station 20.640	373.00	1184.3	-2000.00
Station 20.657	90.00	1184.6	-1360.00
Station 20.920	1096.00	1188.2	-1010.00
Station 20.933	70.00	1188.4	-1010.00

Note: Bed slope is 0.0033 ft/ft.

(i) Geometric Data - The section geometry of the above defined stations were derived from the development and topographic map made by **WLB Group, Inc. (1987).** The plan provided a channel slope of 0.5% but this slope could not justify a good plan since the topographic slope of the area is only about 0.33%. A bed slope of 0.33% (= 0.0033 ft/ft) was adopted instead.

(1) Station 19.944 - This is the most downstream station of the mining site which comprised of the existing field data plus the armorment over the whole development area (see **Fig. 5C-1**). This station serves as the downstream boundary limit for the said development site.

(2) Station 19.953 - The section geometry derived for this station is shown in **Fig. 5C-2** and **Table 5C-2.**

(3) Station 20.240 - The derived geometric information for this station is shown in **Fig. 5C-3** and **Table 5C-3.**

(4) Station 20.550- **Fig. 5C-4** and **Table 5C-4** show the derived geometric information for this station.

(5) Station 20.563 - The cross-section geometry for the station is comprised of the existing field information plus the armorment of 1306-foot wide (see **Fig. 5C-5**). This station will serve as the transition station between the downstream and upstream mining pits.

(6) Station 20.577 - **Fig. 5C-6** and **Table 5C-6** show the derived cross-section geometry for this station.

(7) Station 20.640 - The cross-section geometry for the station is shown in **Fig. 5C-7 and Table 5C-7.**

(8) Station 20.657 - The cross-section geometry derived for the station is shown in **Fig. 5C-8** and **Table 5C-8.**

(9) Station 20.920 - **Fig. 5C-9** and **Table 5C-9** show the cross-section geometry of the station.

(10) Station 20.933 - The section geometry for this station is comprised of the existing field information plus the armorment of 657-foot wide (see **Fig. 5C-10**). This station serves as the upstream boundary limit for the mining site.

(ii) Sediment Data - Riprap for bank protection is comprised of the following gradation specification: D_{15} = 0.19', D_{50} = 0.63', and D_{100} = 1.25'; where D_{100} rock should not be less than 2.0 times the size of the D_{50} rock and the D_{15} rock should not be less than 0.3 times the D_{50} rock. Further, the amount of rock smaller than the D_{15} size should not be greater than the available void space.

Table 5C-1 - Section geometry for Station 19.944

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8142.00 (PL)**	-1858.00	1172.00
3	8259.00	117.00	1172.00
4	8304.00	45.00	1172.00
5	8837.00	535.00	1172.00
6	8884.00	45.00	1172.00
7	9626.00 (PL)**	742.00	1172.00

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5C-2 - Section geometry for Station 19.953

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8142.00 (PL)**	-1858.00	1172.10
3	8259.00	117.00	1172.10
4	8304.00	45.00	1142.10
5	8837.00	535.00	1142.10
6	8884.00	45.00	1172.10
7	9626.00 (PL)**	742.00	1172.10

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5C-3 - Section geometry for Station 20.240

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	7910.00 (PL)**	-2090.00	1177.30
3	8027.00	117.00	1177.30
4	8072.00	45.00	1147.30
5	9091.00	1019.00	1147.30
6	9136.00	45.00	1177.30
7	9216.00 (PL)**	80.00	1177.30

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5C-4 - Section geometry for Station 20.550

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8045.00 (PL)**	-1955.00	1182.70
3	8162.00	117.00	1182.70
4	8207.00	45.00	1152.70
5	9226.00	1019.00	1152.70
6	9271.00	45.00	1182.70
7	9351.00 (PL)**	80.00	1182.70

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5C-5 - Section geometry for Station 20.563

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8045.00 (PL)**	-1955.00	1182.90
3	8162.00	117.00	1182.90
4	8207.00	45.00	1182.90
5	9226.00	1019.00	1182.90
6	9271.00	45.00	1182.90
7	9351.00 (PL)**	80.00	1182.90

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5C-6 - Section geometry for Station 20.577

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8040.00 (PL)**	-1960.00	1183.10
3	8157.00	117.00	1183.10
4	8202.00	45.00	1153.10
5	9221.00	1019.00	1153.10
6	9266.00	45.00	1183.10
7	9346.00 (PL)**	80.00	1183.10

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5C-7 - Section geometry for Station 20.640

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8000.00 (PL)**	-2000.00	1184.30
3	8117.00	117.00	1184.30
4	8162.00	45.00	1154.30
5	9181.00	1019.00	1154.30
6	9226.00	45.00	1184.30
7	9306.00 (PL)**	80.00	1184.30

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5C-8 - Section geometry for Station 20.657

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8640.00 (PL)**	-1360.00	1184.60
3	8741.00	101.00	1184.60
4	8801.00	60.00	1154.60
5	9172.00	371.00	1154.60
6	9217.00	45.00	1184.60
7	9297.00 (PL)**	80.00	1184.60

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5C-9 - Section geometry for Station 20.920

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8990.00 (PL)**	-1010.00	1188.20
3	9091.00	101.00	1188.20
4	9151.00	60.00	1158.20
5	9522.00	371.00	1158.20
5	9567.00	45.00	1188.20
5	9647.00 (PL)**	80.00	1188.20

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5C-10 - Section geometry for Station 20.933

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8990.00 (PL)**	-1010.00	1188.40
3	9091.00	101.00	1188.40
4	9151.00	60.00	1188.40
5	9522.00	371.00	1188.40
6	9567.00	45.00	1188.40
7	9647.00 (PL)**	80.00	1188.40

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

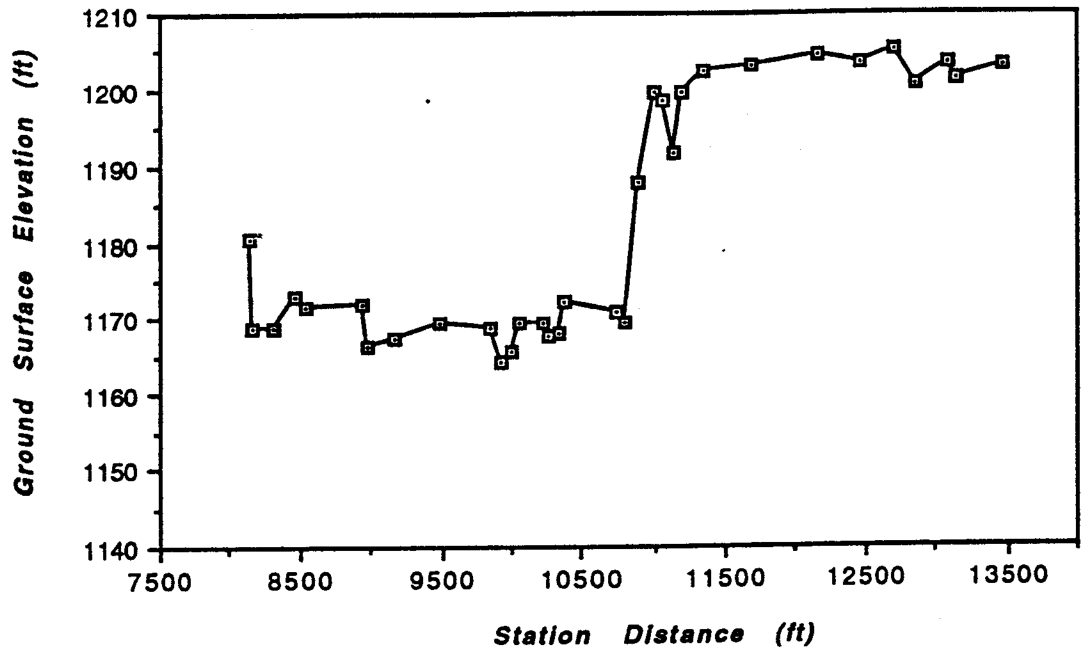

Fig. 5C-1 - Cross-section plot of Station 19.944

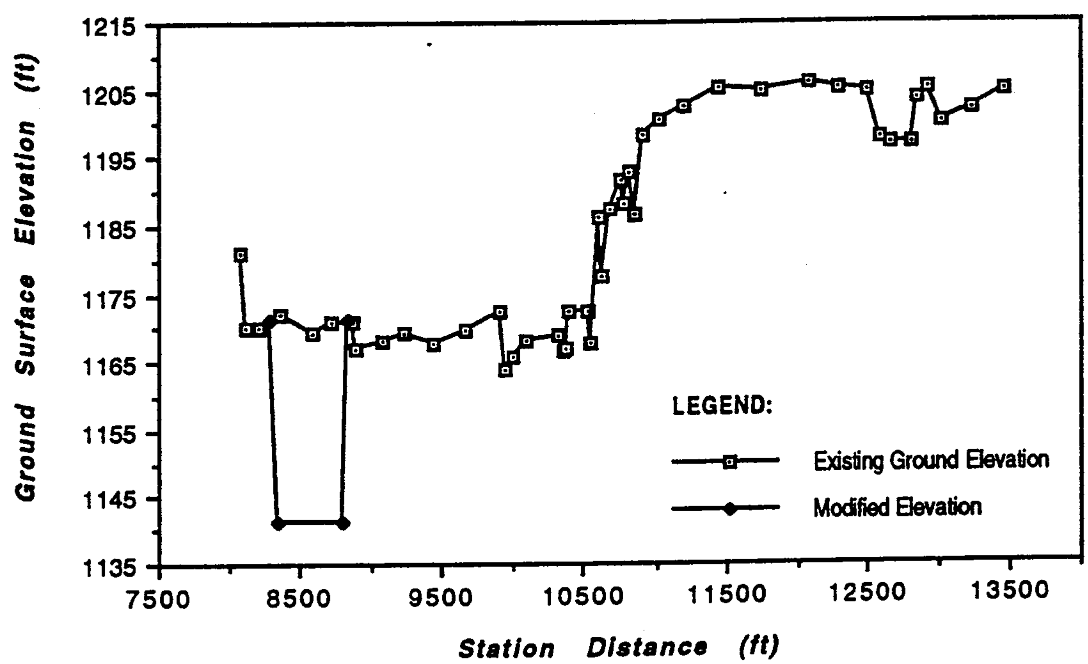

Fig.5C-2 - Cross-section plot of Station 19.953

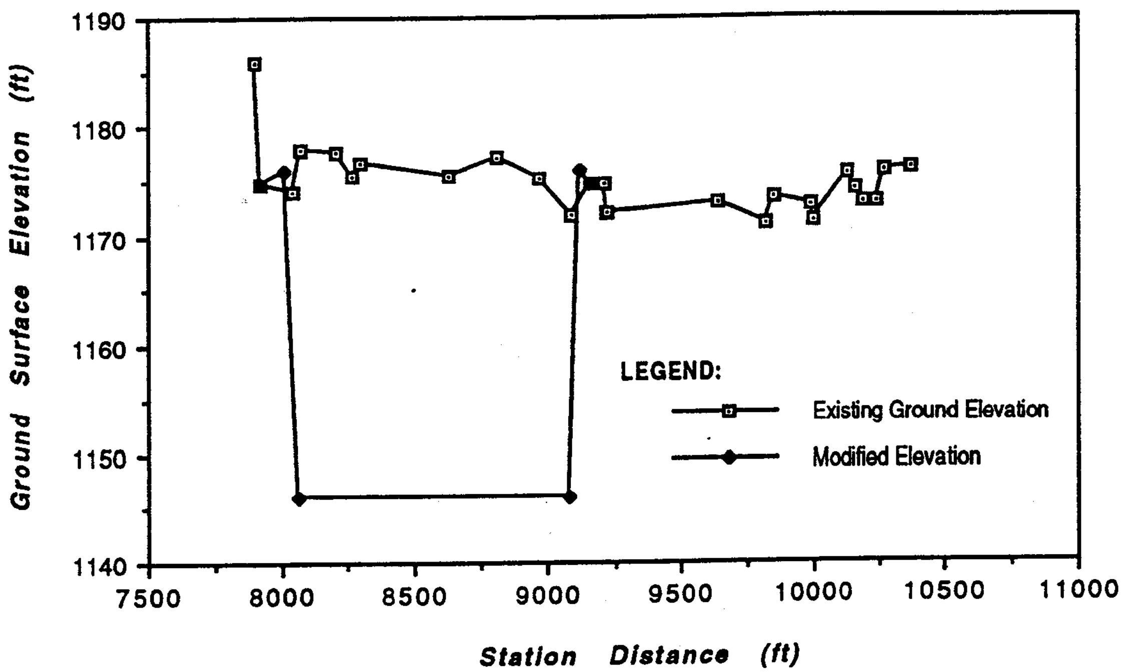

Fig.5C-3 - Cross-section plot of Station 20.240

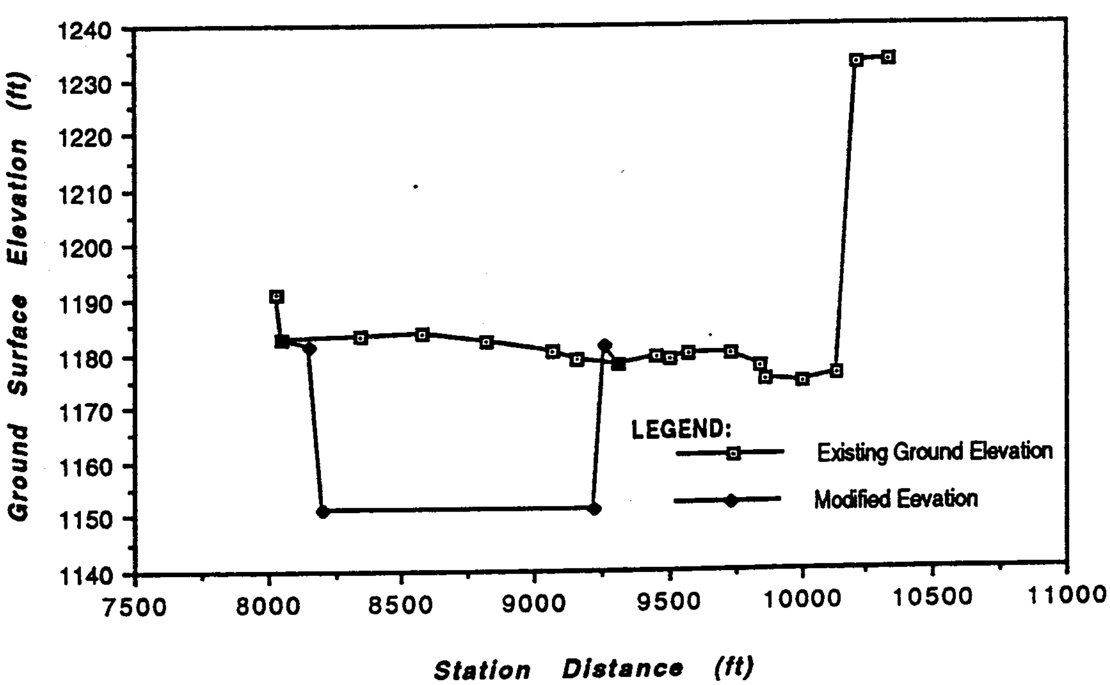

Fig. 5C-4 - Cross-section plot of Station 20.550

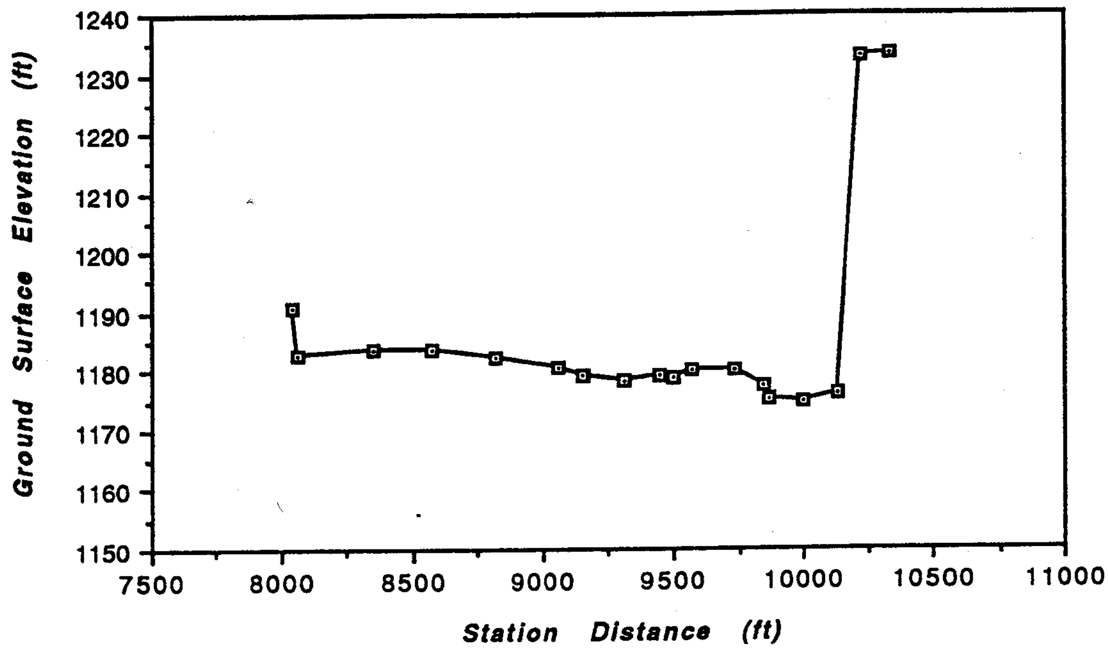

Fig. 5C-5 - Cross-section plot of Station 20.563

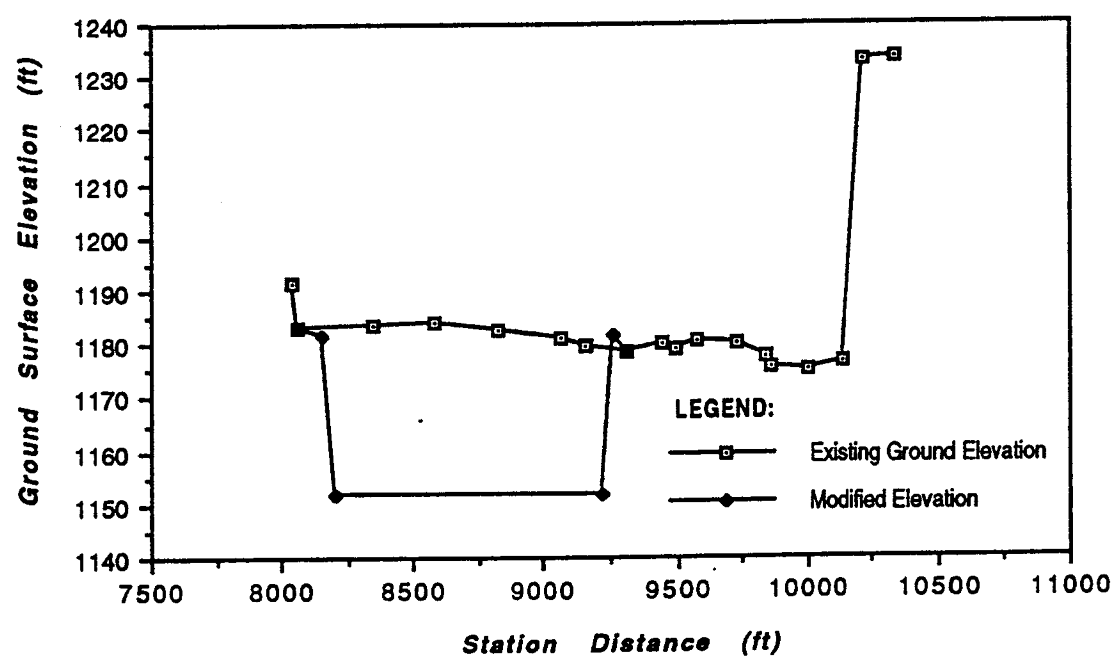

Fig. 5C-6 - Cross-section plot of Station 20.577

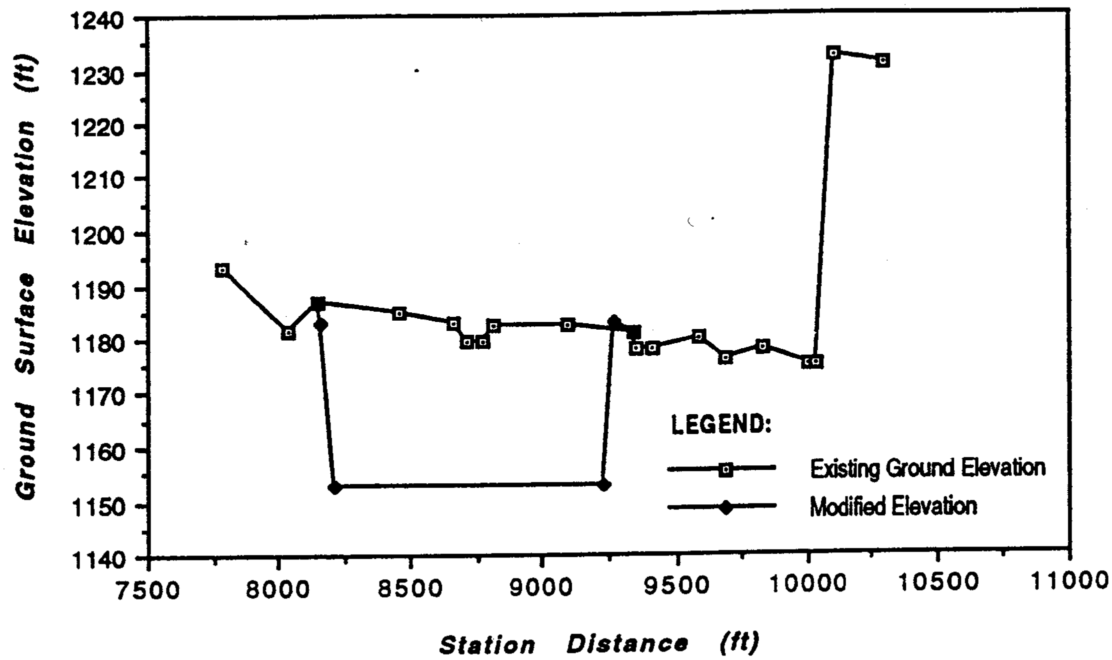

Fig.5C-7 - Cross-section plot of Station 20.640

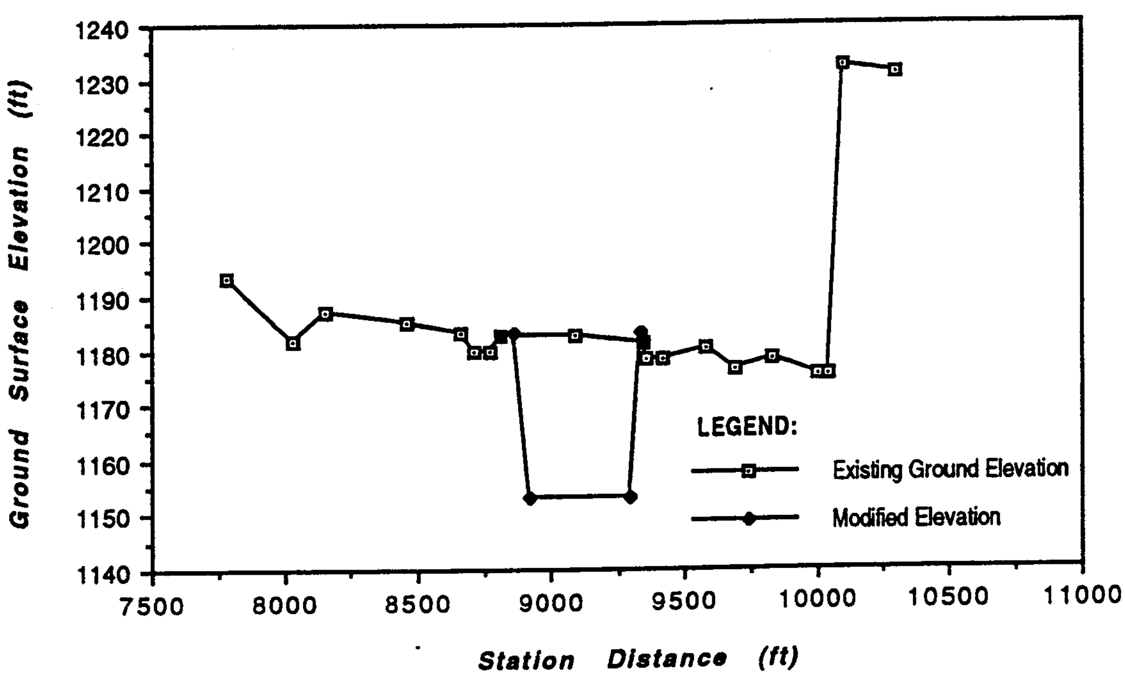

Fig. 5C-8 - Cross-section plot of Station 20.657

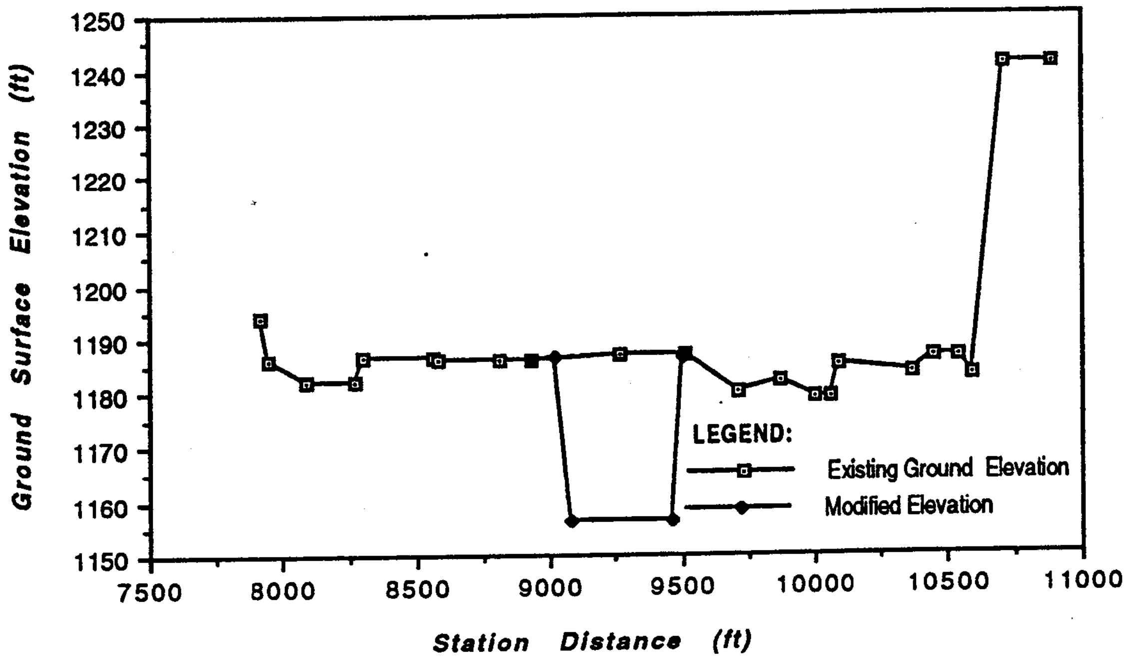

Fig.5C-9 - Cross-section plot of Station 20.920

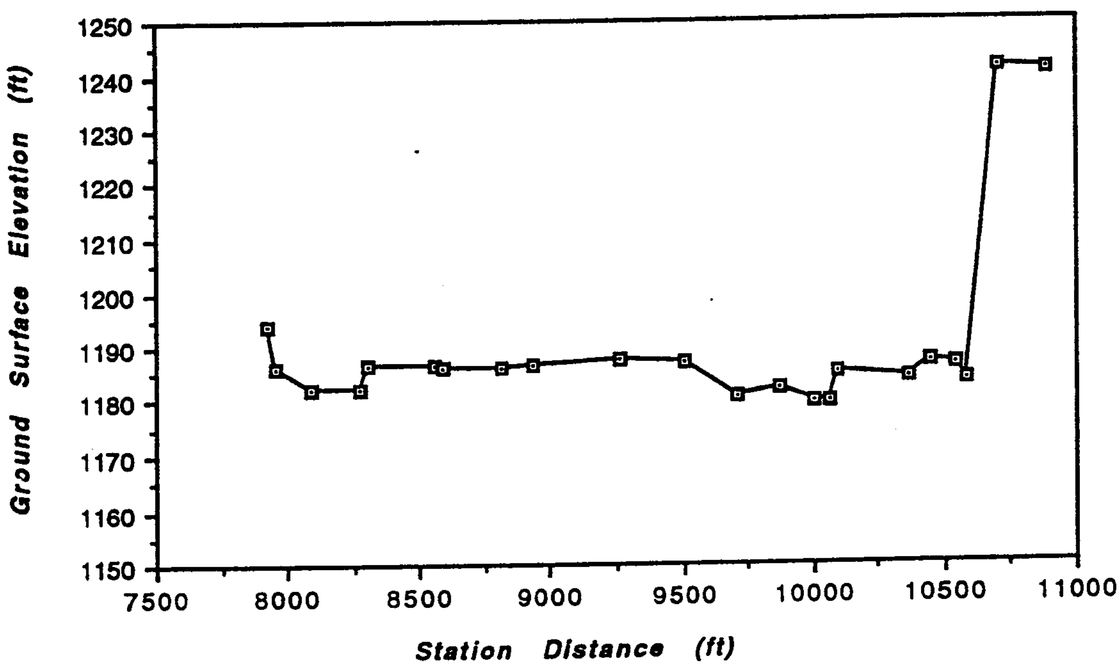

Fig. 5C-10 - Cross-section plot of Station 20.933

5.2.2.4 Site D

Owner: Finley Construction Corporation
Location: Rose Garden and 115th Avenue
Maximum Pit Depth: 40 feet

The mining site [see **Fig. 5.2.4**] when fully developed could be represented by five (5) section stations as identified in **Table 5.2.4.**

Table 5.2.4 - Section stations for mining site D

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Station 21.657	0.00	1191.2	-1040.00
Station 21.680	120.00	1191.4	- 960.00
Station 21.760	460.00	1192.3	- 505.00
Station 21.773	70.00	1192.4	- 430.00
Station 21.818	240.00	1192.9	- 250.00

Note: Bed slope is 0.002 ft/ft.

(i) Geometric Data - The section geometry information for Site D were derived from the development plan and topographic map drawn by **Barett Consulting Group, Inc., (1987)** for **Finley Construction Corporation.** The bed slope of the mining pit is given in the plan to be 0.002 ft/ft with the upstream armorment elevation of 1192.9 ft.

(1) Station 21.657 - This is the most downstream station for the mining site which comprised of the existing ground data obtained from the field (or topographic map]. This station (see **Table 5D-1** and **Fig. 5D-1** for the cross-section plot) serves as the downstream boundary limit for the development site.

(2) Station 21.680 - The section geometry for the station is shown in **Fig. 5D-2** while the associated development data are listed in **Table 5D-2.**

(3) Station 21.760 - The section geometry of the station is shown in **Fig. 5D-3** and **Table 5D-3**

(4) Station 21.773 - **Fig. 5D -4** and **Table 5D -4** show the section information on the extent of development for the station.

(5) Station 21.818 - The section geometry for the station is the existing ground information (see **Fig. 5D -5** for the cross-section plot). This station serves as the upstream boundary limit for the development site.

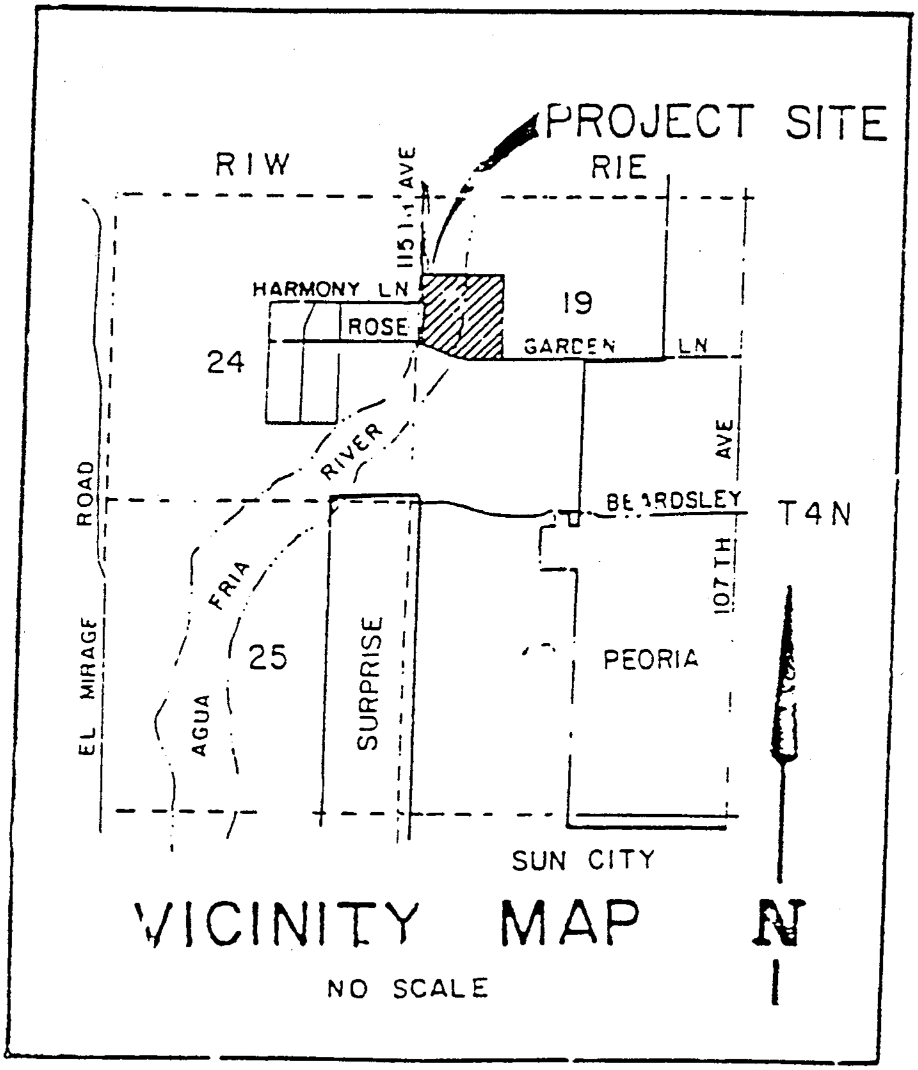

Fig. 4.2.4 - Location map of the mining site D
[Owner: Finley Construction Corporation]

(ii) **Sediment Data** - For bank protection purposes, a 9-inch filter blanket along the drown-out chute and approach is provided overlaid with an 18-inch rock-filled gabion mattress. The filter blanket has the following gradation specification:

$$4.06 \text{ mm} \le D_{15} \le 16.00 \text{ mm}$$
$$5.08 \text{ mm} \le D_{50} \le 80.00 \text{ mm}$$
$$D_{85} \ge 32.51 \text{ mm}$$

For the 18-inch rock-filled mattress, the gradation specification is as follows: D_0 = 4"; D_{15} = 5", D_{50} = 8", D_{85} = 10", and D_{90} = 12".

Table 5D -1 - Section geometry for Station 21.657

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8960.00 (PL)**	-1040.00	1204.00
3	9725.00	765.00	1204.00
4	9725.00	0.00	1191.20
5	10485.00	760.00	1191.20
6	10595.00	110.00	1191.20

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5D -2 - Section geometry for Station 21.680

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9040.00 (PL)**	- 960.00	1204.20
3	9735.00	695.00	1204.20
4	9735.00	0.00	1191.40
5	9855.00	120.00	1151.40
6	10455.00	600.00	1151.40
7	10575.00	120.00	1191.40
8	10685.00 (PL)**	110.00	1191.40

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5D -3 - Section geometry for Station 21.760

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9495.00 (PL)**	- 505.00	1205.10
3	9905.00	410.00	1205.10
4	9905.00	0.00	1192.30
5	10025.00	120.00	1152.30
6	10975.00	950.00	1152.30
7	11095.00	120.00	1192.30
8	11205.00 (PL)**	110.00	1192.30

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5D -4 - Section geometry for Station 21.773

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9570.00 (PL)**	- 430.00	1205.20
3	9925.00	355.00	1205.20
4	9925.00	0.00	1192.40
5	10045.00	120.00	1152.40
6	11040.00	995.00	1152.40
7	11160.00	120.00	1192.40
8	11270.00 (PL)**	110.00	1192.40

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5D -5 - Section geometry for Station 21.818

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9750.00 (PL)**	-250.00	1205.70
3	9955.00	205.00	1205.70
4	9955.00	0.00	1192.90
5	11405.00 (PL)**	1450.00	1192.90

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

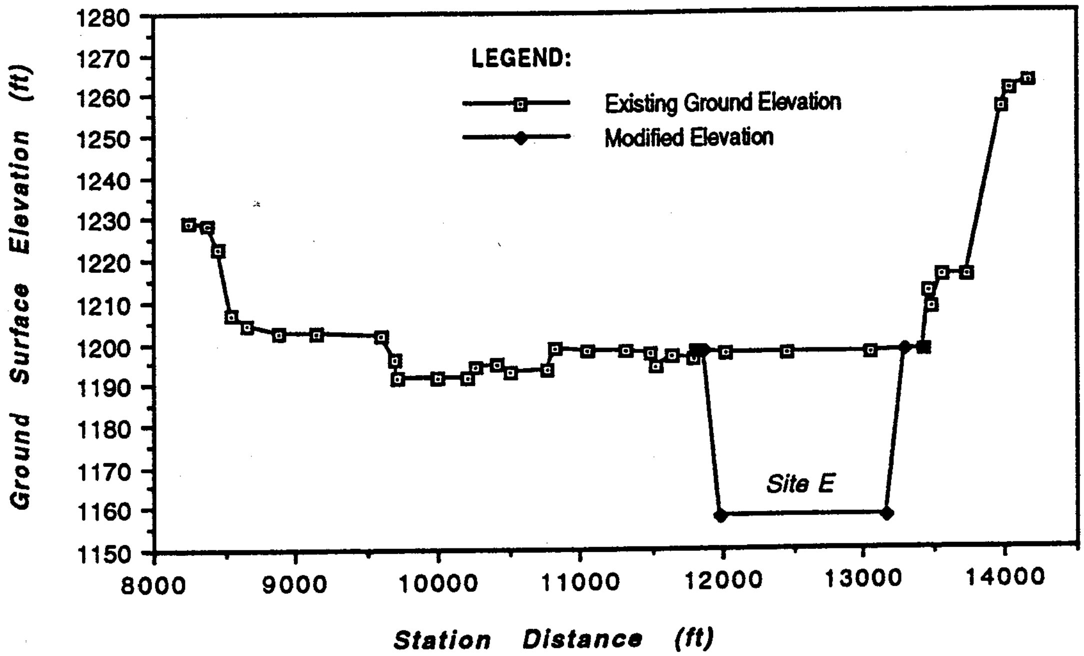

Fig. 5D -1 - Cross-section plot of Station 21.657

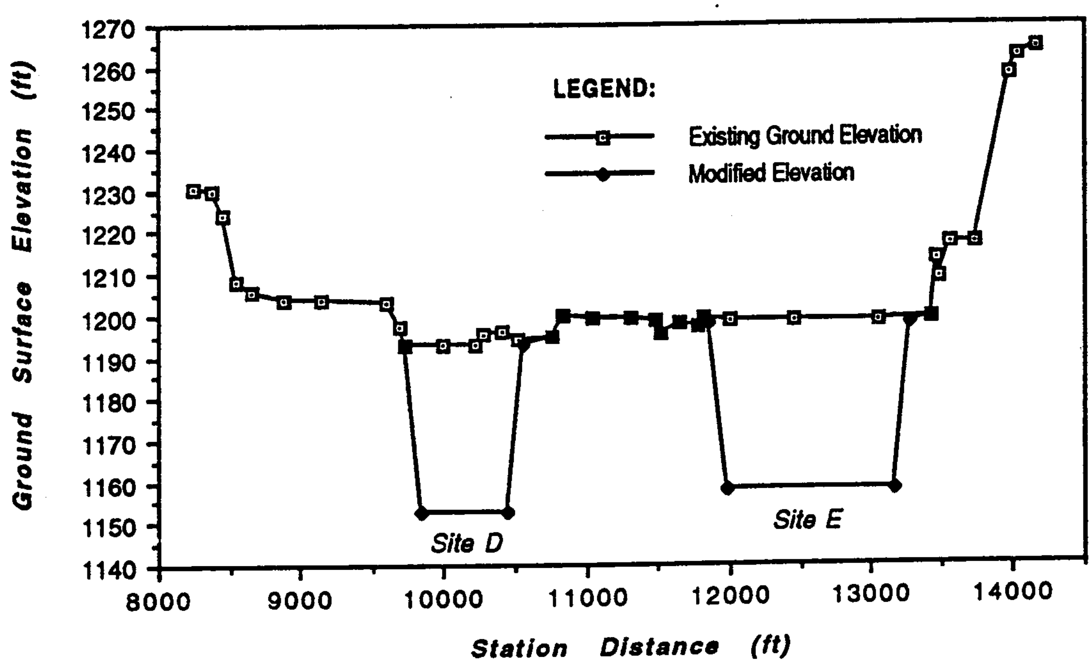

Fig. 5D -2 - Cross-section plot of Station 21.680

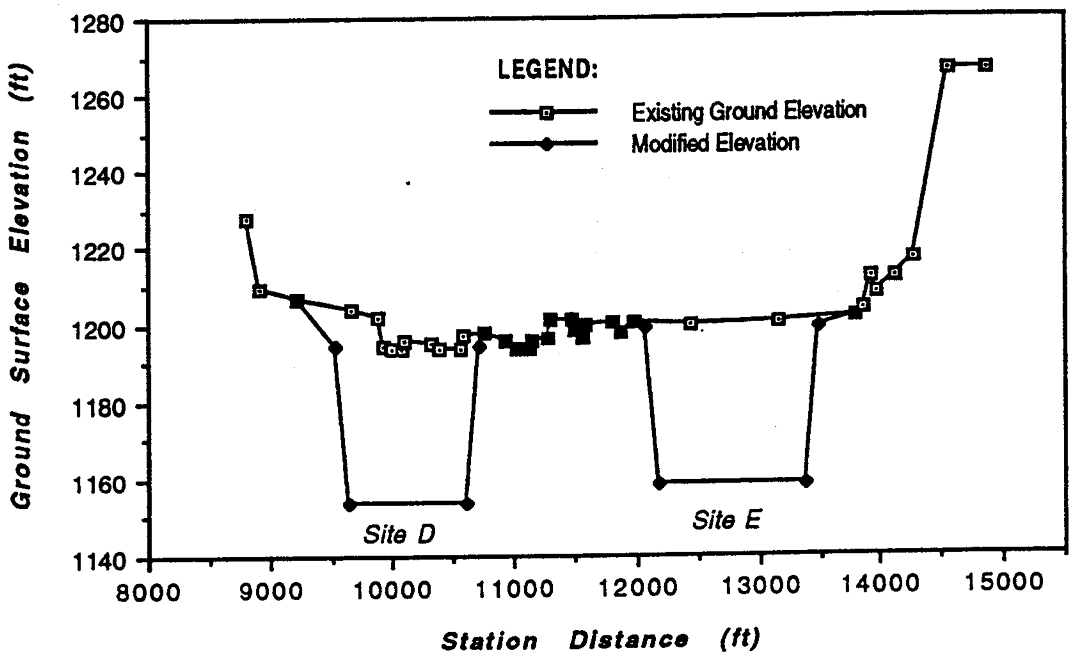

Fig. 5D -3 - Cross-section plot of Station 21.760

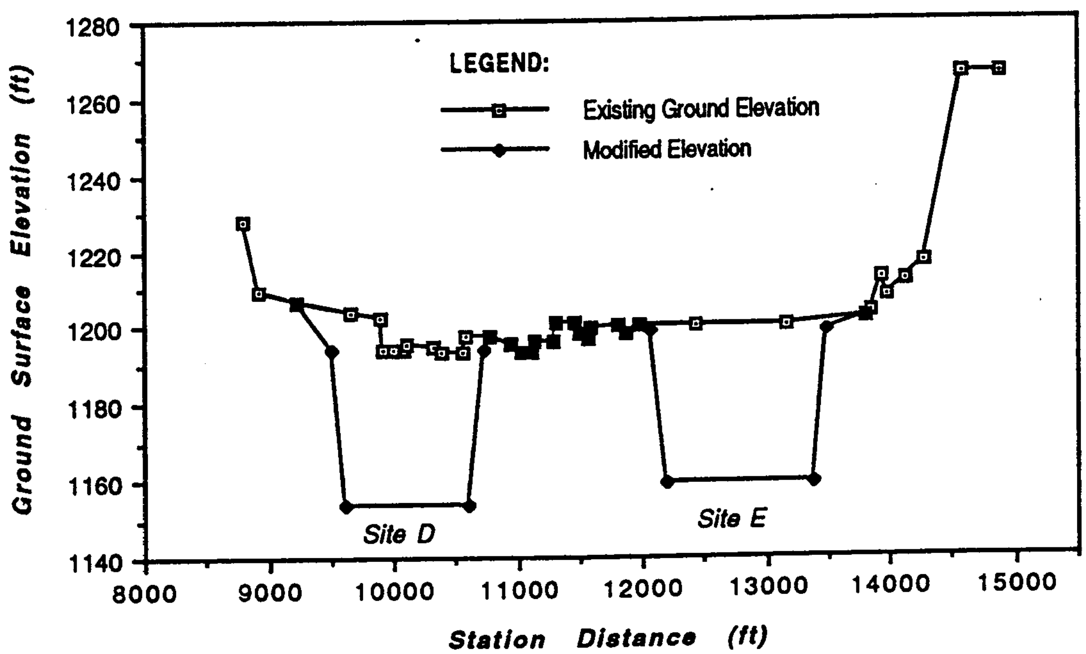

Fig. 5D -4 - Cross-section plot of Station 21.773

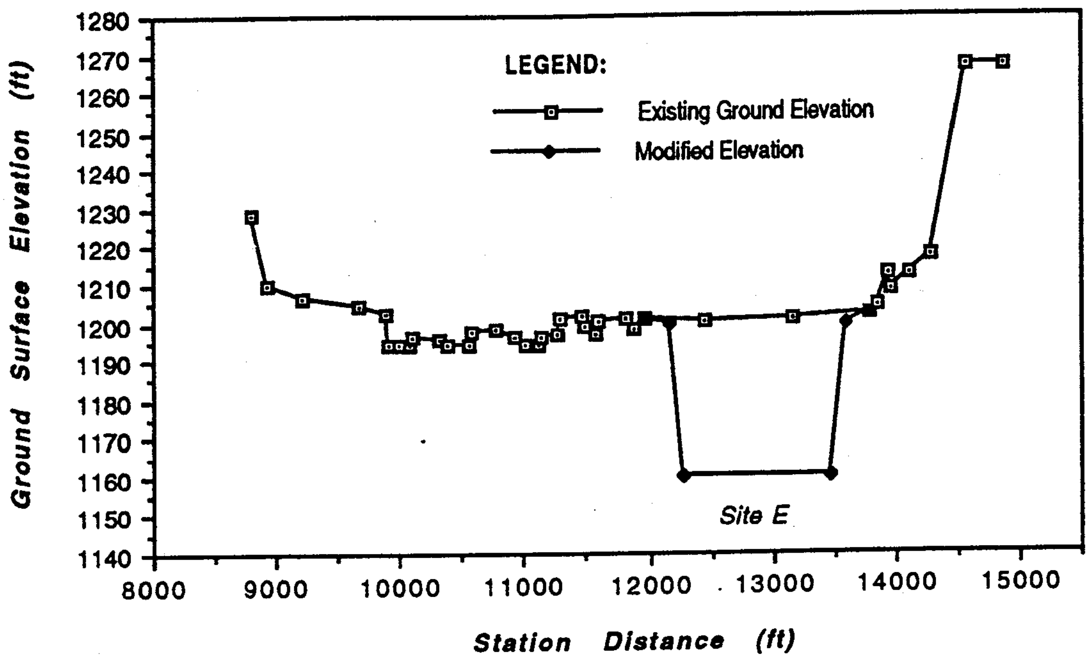

Fig. 5D -5 - Cross-section plot of Station 21.818

5.2.2.5 Site E

Owner: Ideal Rock Products
Location: South of Deer Valley Drive
Maximum Pit Depth: 40 feet

The mining site [see Fig. 5.2.5] is comprised of five (5) stations that define the extent of the development for HEC-6 [see **Table 5.2.5**. The cross-section geometry information of these stations were determined from the plan made by **Barrett Consulting Group, Inc., (1987)** for **Ideal Rock Products**, the operator and owner of the mining site.

Table 5.2.5 - Section stations for mining site E

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Station 21.500	0.00	1198.2	1615.00
Station 21.523	120.00	1198.4	1420.00
Station 21.657	710.00	1199.8	1735.00
Station 21.680	120.00	1200.0	1575.00
Station 21.760	460.00	1200.9	1625.00
Station 21.773	70.00	1201.0	1695.00
Station 21.818	240.00	1201.5	1930.00
Station 21.850	240.00	1202.0	2115.00

Note: Bed slope is 0.002 ft/ft.

(i) **Geometric Data** - The information on the cross-section geometry of the above stations are provided as follows:

(1) Station 21.500 - This is the most downstream station for the mining site which comprised of the existing data from the field (or topographic map]. This station is included together with the most downstream station in order to define the extent of the development for the mining site (see **Fig. 5E -1** for the cross-section plot). These two stations will respectively serve as transition stations after and before the mining site which will provide a basis of evaluating the effects of the mining site on the adjacent stations, the river bed, and the floodplain.

(2) Station 21.523 - **Fig. 5E -2** and **Table 5E -2** show the cross-section geometry of the station.

(3) Station 21.657 - The information on the cross-section geometry for this station is shown in **Fig. 5E -3** and **Table 5E -3.**

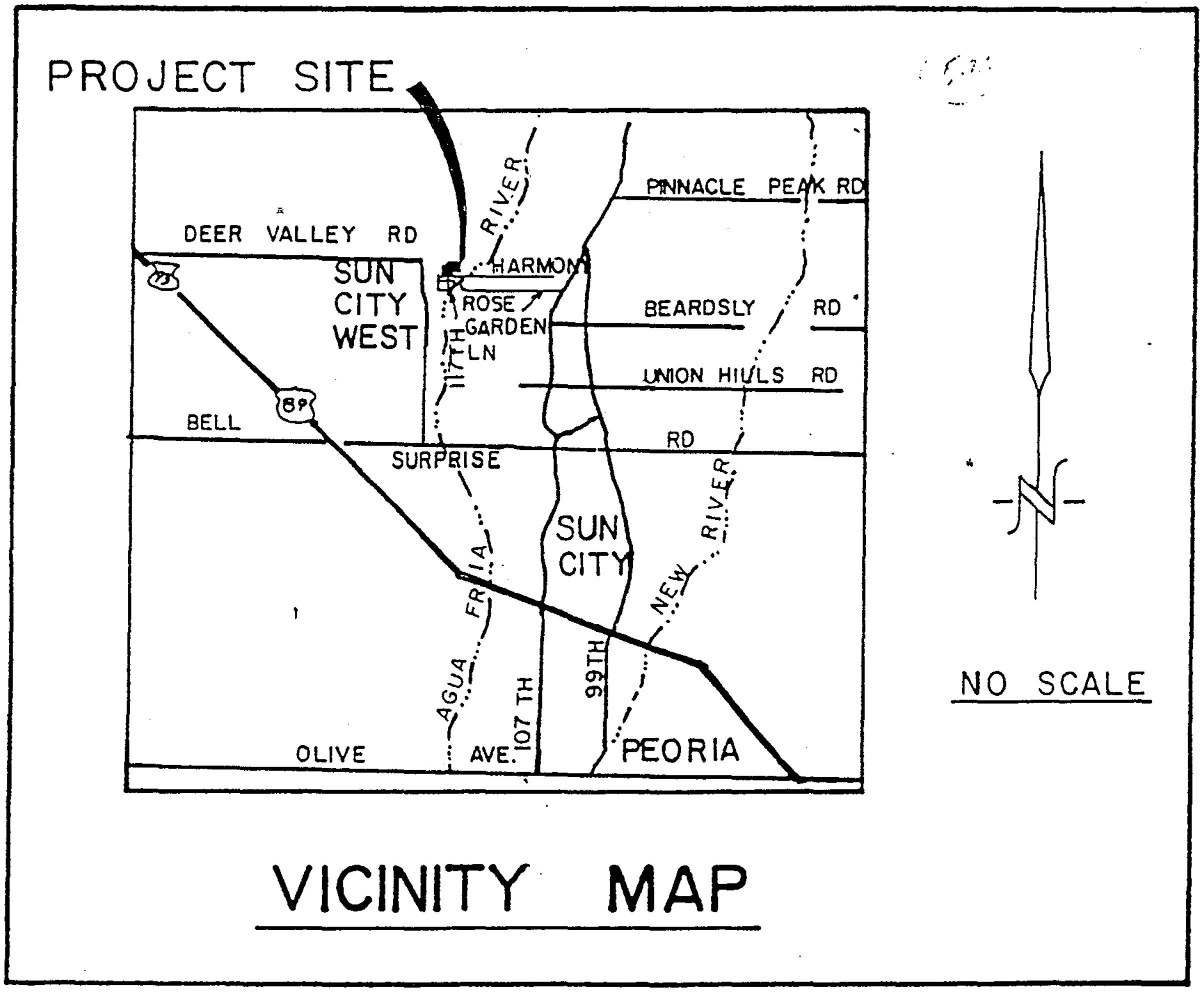

Fig. 5.2.5 - Location map of the mining site E
[Owner: Ideal Rock Products]

(4) Station 21.680 - The information on the section geometry for the station is shown in **Fig. 5E -4** and **Table 5E -4.**

(5) Station 21.760 - The ground geometry information for the station are the existing field data (see **Fig. 5E -5** for cross-section plot). This station serves as the upstream boundary limit for the mining site.

(6) Station 21.773 - The section geometry for this station is shown in **Fig. 5E -6** and **Table 5E -6.**

(7) Station 21.818 - The section geometry for this station is shown in **Fig. 5E -7** and **Table 5E -7.**

(8) Station 21.850 - **Fig. 5E -8** and **Table 5E -8** show the section geometry of this station.

(ii) Sediment Data - No information is provided in the plan.

Table 5E -1 - Section geometry for Station 21.500

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11615.00 (PL)**	1615.00	1198.20
3	11760.00	145.00	1198.20
4	11880.00	120.00	1198.20
5	12685.00	805.00	1198.20
6	12805.00 (PL)**	120.00	1198.20

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5E -2 - Section geometry for Station 21.523

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11420.00 (PL)**	1420.00	1198.40
3	11775.00	355.00	1198.40
4	11895.00	120.00	1158.40
5	12745.00	850.00	1158.40
6	12865.00	120.00	1198.40
7	12975.00 (PL)**	110.00	1198.40

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5E -3 - Section geometry for Station 21.657

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11735.00 (PL)**	1735.00	1199.80
3	11895.00	160.00	1199.80
4	12015.00	120.00	1159.80
5	13200.00	1185.00	1159.80
6	13320.00	120.00	1199.80
7	13410.00 (PL)**	90.00	1199.80

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5E -4 - Section geometry for Station 21.680

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11575.00 (PL)**	1575.00	1200.00
3	11915.00	340.00	1200.00
4	12035.00	120.00	1160.00
5	13220.00	1185.00	1160.00
6	13340.00	120.00	1200.00
7	13690.00 (PL)**	350.00	1200.00

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5E -5 - Section geometry for Station 21.760

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11625.00 (PL)**	1625.00	1200.90
3	12075.00	450.00	1200.90
4	12195.00	120.00	1160.90
5	13380.00	1185.00	1160.90
6	13500.00	120.00	1200.90
7	14100.00 (PL)**	600.00	1200.90

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5E -6 - Section geometry for Station 21.773

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11695.00 (PL)**	1695.00	1201.00
3	12095.00	400.00	1201.00
4	12215.00	120.00	1161.00
5	13400.00	1185.00	1161.00
6	13520.00	120.00	1201.00
7	14080.00 (PL)**	560.00	1201.00

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5E -7 - Section geometry for Station 21.818

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11930.00 (PL)**	1930.00	1201.50
3	12155.00	225.00	1201.50
4	12275.00	120.00	1161.50
5	13460.00	1185.00	1161.50
6	13580.00	120.00	1201.50
7	13860.00 (PL)**	280.00	1201.50

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5E -8 - Section geometry for Station 21.850

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	12115.00 (PL)**	2115.00	1202.00
3	12225.00	110.00	1202.00
4	13645.00 (PL)**	1420.00	1202.00

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

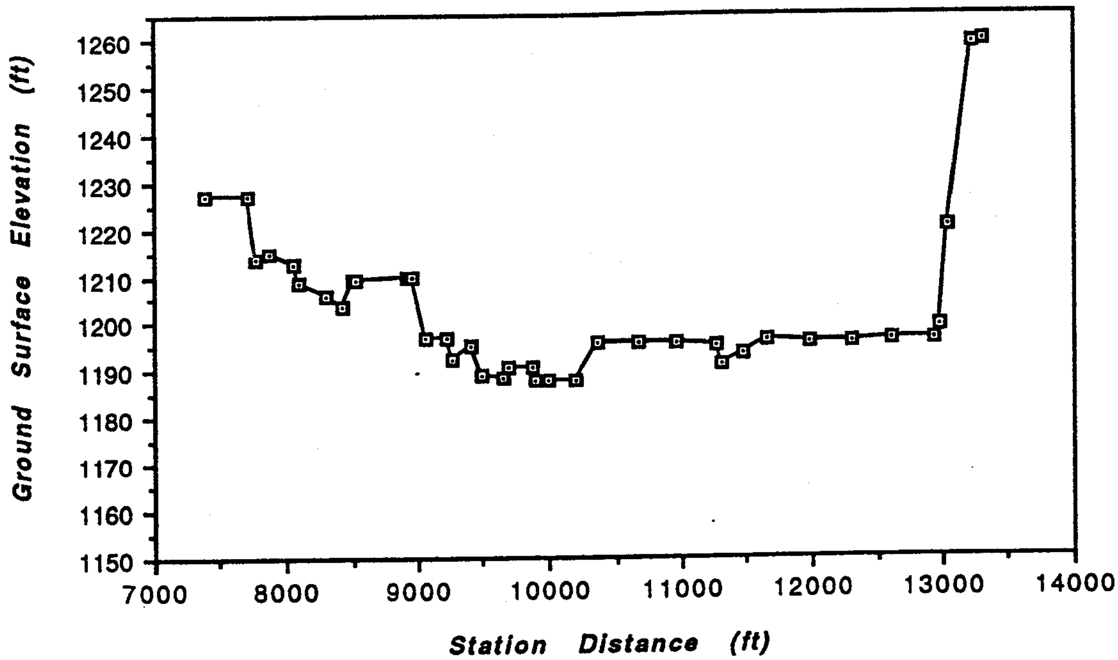

Fig. 5E -1 - Cross-section plot of Station 21.500

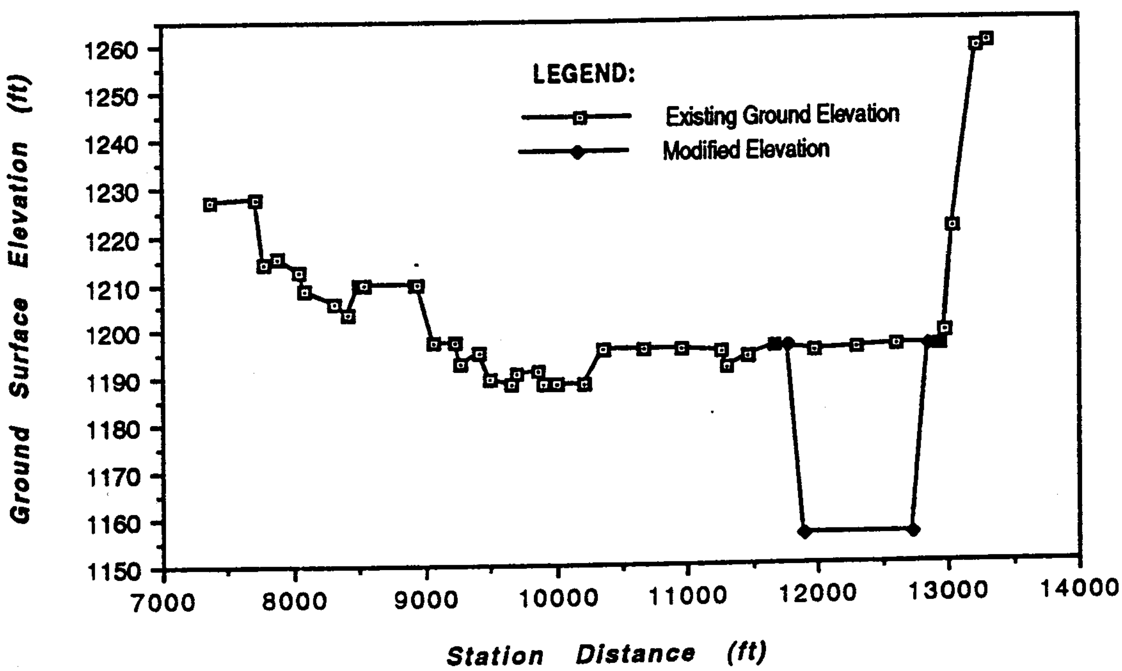

Fig. 5E -2 - Cross-section plot of Station 21.523

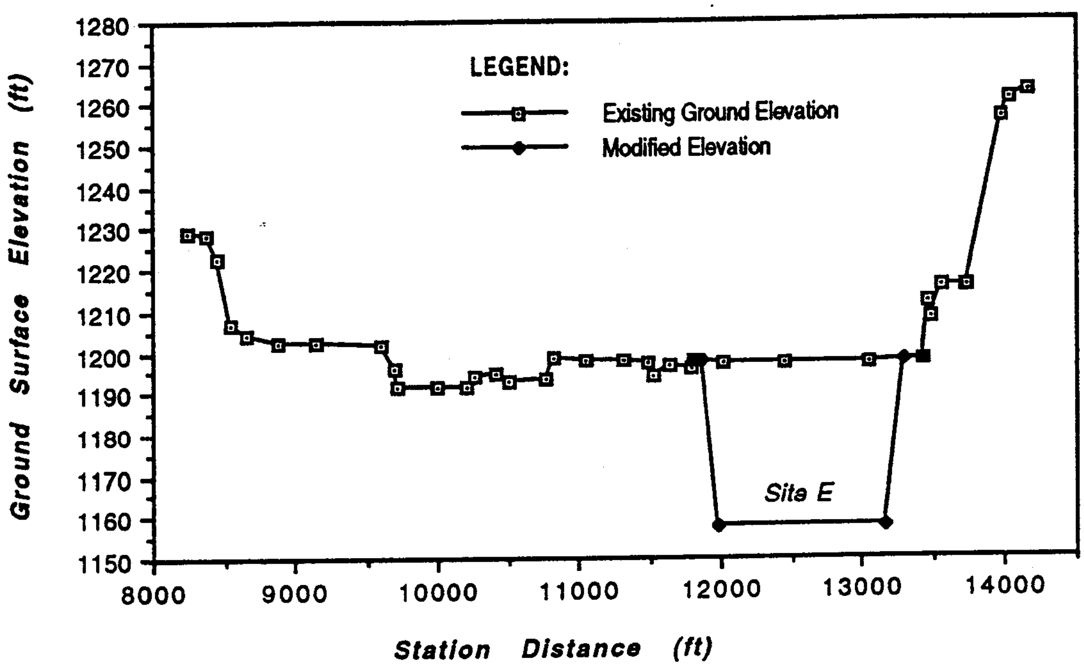

Fig. 5E -3 - Cross-section plot of Station 21.657

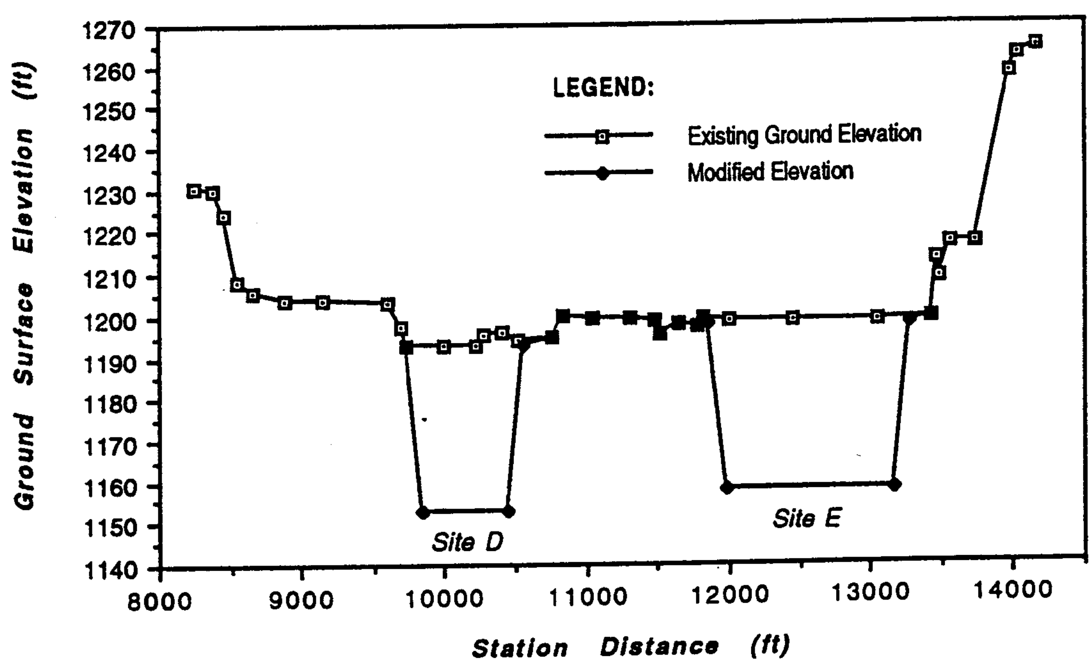

Fig. 5E -4 - Cross-section plot of Station 21.680

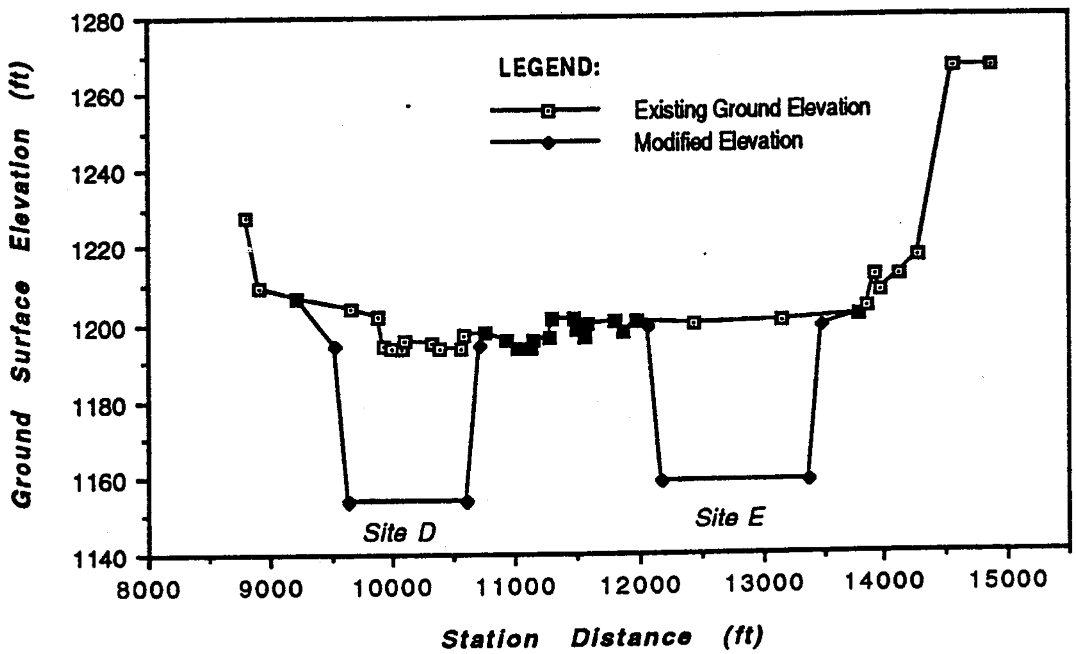

Fig. 5E -5 - Cross-section plot of Station 21.760

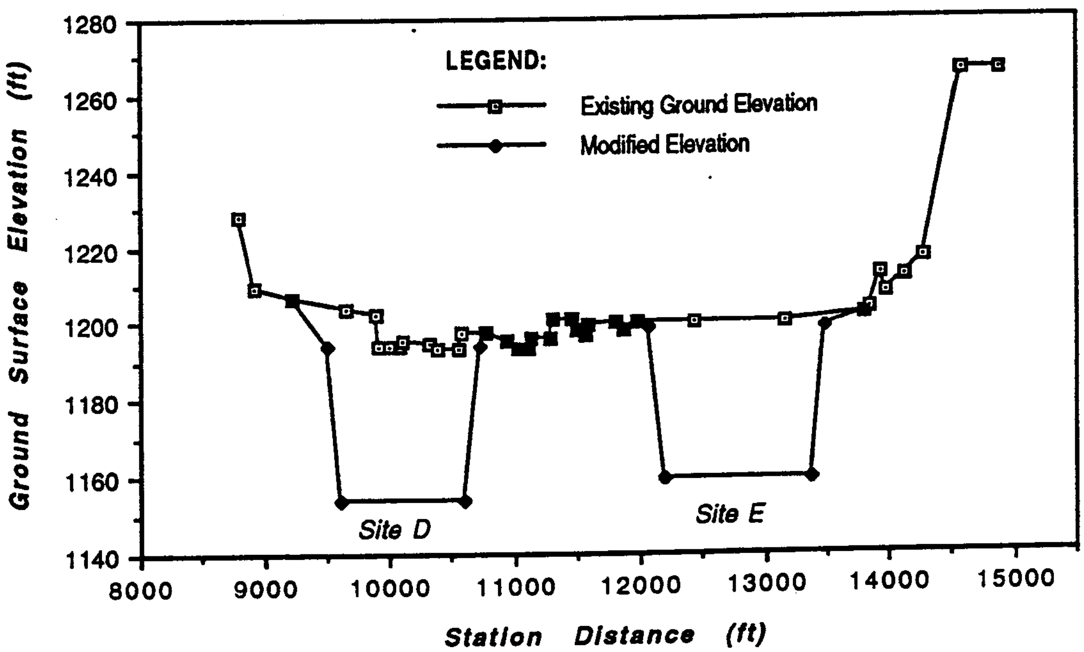

Fig. 5E -6 - Cross-section plot of Station 21.773

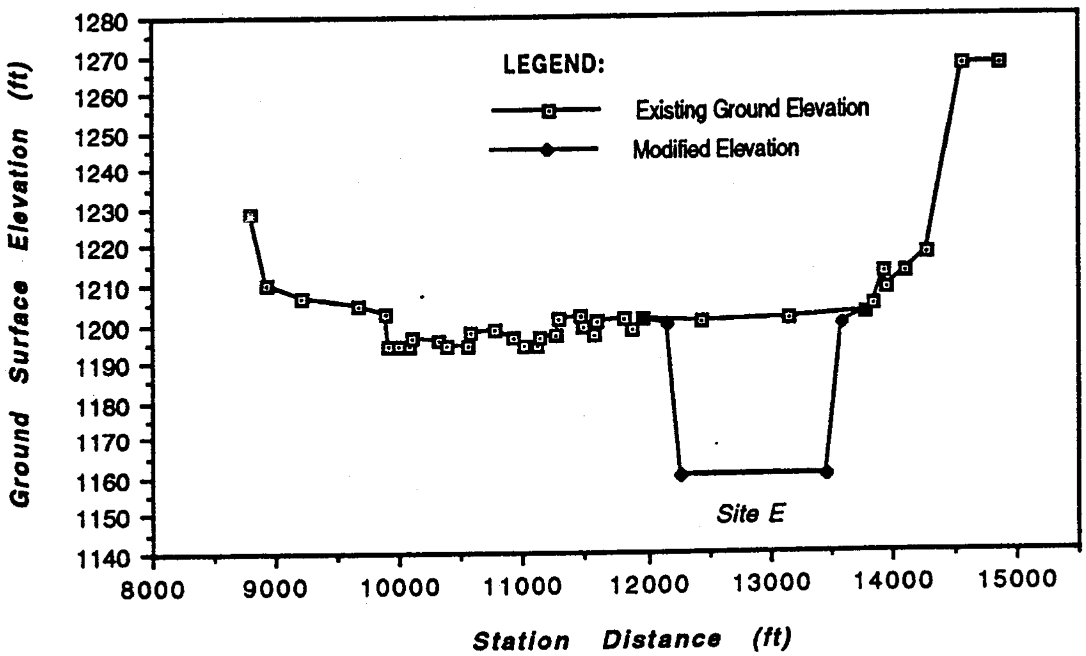

Fig. 5E -7 - Cross-section plot of Station 21.818

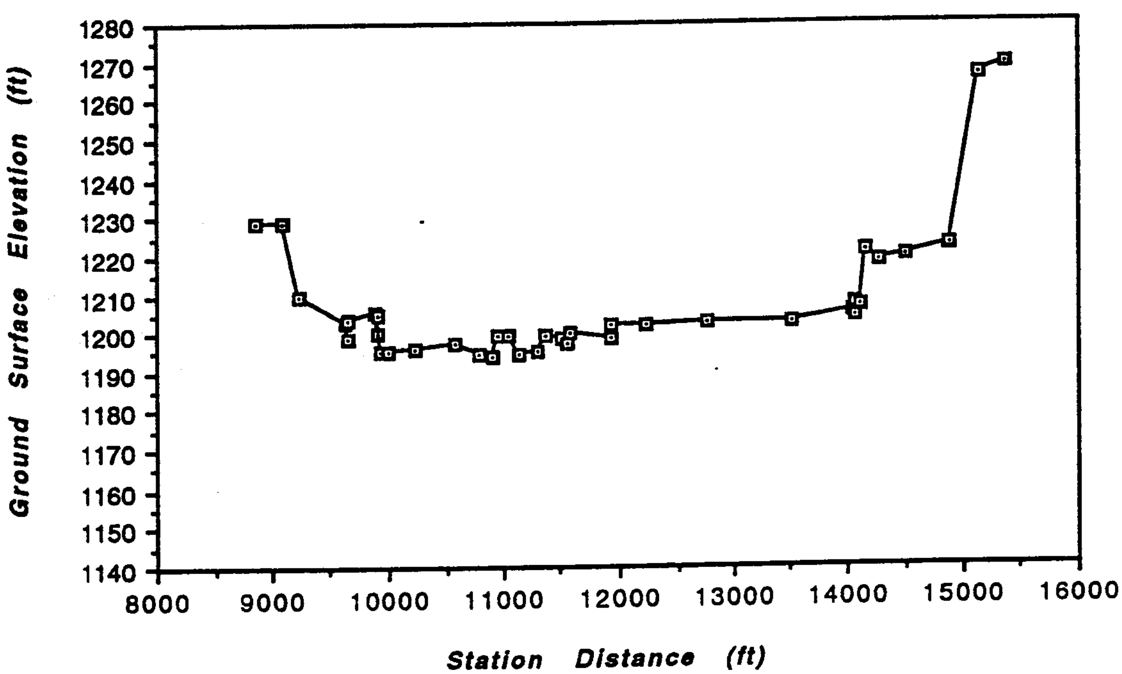

Fig. 5E -8 - Cross-section plot of Station 21.850

5.2.2.6 Site F

Owner: Finley Construction Corporation
Location: Deer Valley Drive and 115th Avenue
Maximum Pit Depth: 40 feet

The mining site (see Fig. 5.2.6) when fully operational has the following section information for HEC-6.

Table 5.2.6 - Section stations for mining site F

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Station 22.107	0.00	1200.8	1170.00
Station 22.130	120.00	1201.0	1280.00
Station 22.320	1005.00	1203.0	1625.00
Station 22.365	240.00	1203.5	1700.00

Note: Bed slope is 0.002 ft/ft.

(i) Geometric Data - The geometric data presented are based on the site plan and topographic map made by **Barrett Consulting Group, Inc. (1987)** for the **Finley Construction Corporation** that operates the mining sites.

(1) Station 22.107 - This is the most downstream station for the mining site which comprised of the existing field data (see **Fig. 5F -1** for cross-section plot) obtained from the field (or topographic map). This station serves as the downstream boundary limit of the mining site. The incorporation of this station and the most upstream station allows a more realistic assessment on the extent of sedimentation processes involved resulting from the existence of the fully-operational mining pit.

(2) Station 22.130 - The derived cross-section geometry for this station is shown in **Fig. 5F -2** and **Table 5F -2**

(3) Station 22.320 - The section geometry information are presented in **Fig. 5F -3** and **Table 5F -3.**

(4) Station 22.365 - The derived section geometry for this station is shown in **Fig. 5F -4** and **Table 5F -4.**

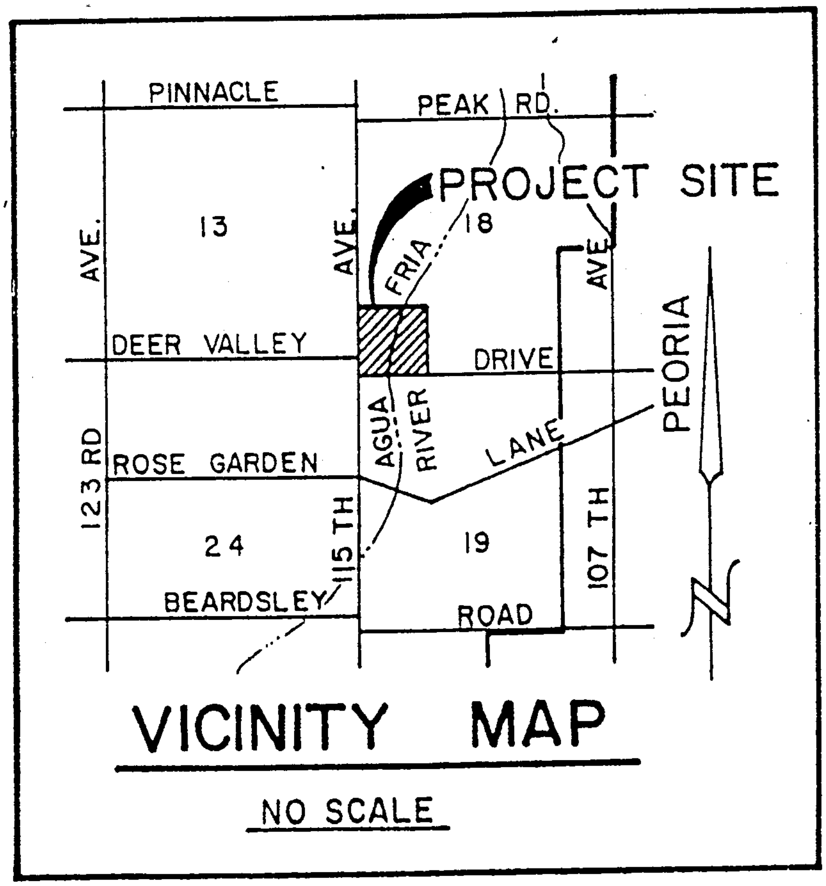

Fig. 5.2.6 - Location map of the mining site F
[Owner: Finley Construction Corporation]

(ii) Sediment Data - A 6-inch layer of 2-inch stone will be placed on top and along the edge of the levee adjacent to the drown-out chute approach. The 15-inch thick chute slope revetment is comprised of D_{50} = 8-inch stones laid over the 6" filter blanket. The filter blanket has the following gradation specification:

$3.0 \text{ mm} \leq D_{15} \leq 3.80 \text{ mm}$

$4.4 \text{ mm} \leq D_{50} \leq 17.6 \text{ mm}$

$D_{85} > 30.0 \text{ mm}$

For the riprap protection, the gradation specification is provided as follows:

$9.74 \text{ inches} \leq D_{100} \leq 12.7 \text{ inches}$

$7.43 \text{ inches} \leq D_{50} \leq 9.74 \text{ inches}$

$4.97 \text{ inches} \leq D_{15} \leq 7.43 \text{ inches}$

(iii) Other Data - An estimated 3-foot high and 5-foot top width levee is built in the south east corner of the mining site.

Table 5F -1 - Section geometry for Station 22.107

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11170.00 (PL)**	1170.00	1200.80
3	12605.00	1435.00	1200.80
4	12660.00	55.00	1200.80

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5F -2 - Section geometry for Station 22.130

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11280.00 (PL)**	1280.00	1201.00
3	11555.00	275.00	1161.00
4	12545.00	990.00	1161.00
5	12640.00	95.00	1201.00
6	12770.00 (PL)**	130.00	1201.00

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5F-3 - Section geometry for Station 22.320

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11625.00 (PL)**	1625.00	1203.00
3	11740.00	115.00	1203.00
4	12015.00	275.00	1163.00
5	12520.00	505.00	1163.00
6	12615.00	95.00	1203.00
7	13185.00 (PL)**	570.00	1203.00

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5F-4 - Section geometry for Station 22.365

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	11700.00 (PL)**	1700.00	1203.50
3	11815.00	115.00	1203.50
4	12575.00	760.00	1203.50
5	13255.00 (PL)**	680.00	1203.50

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

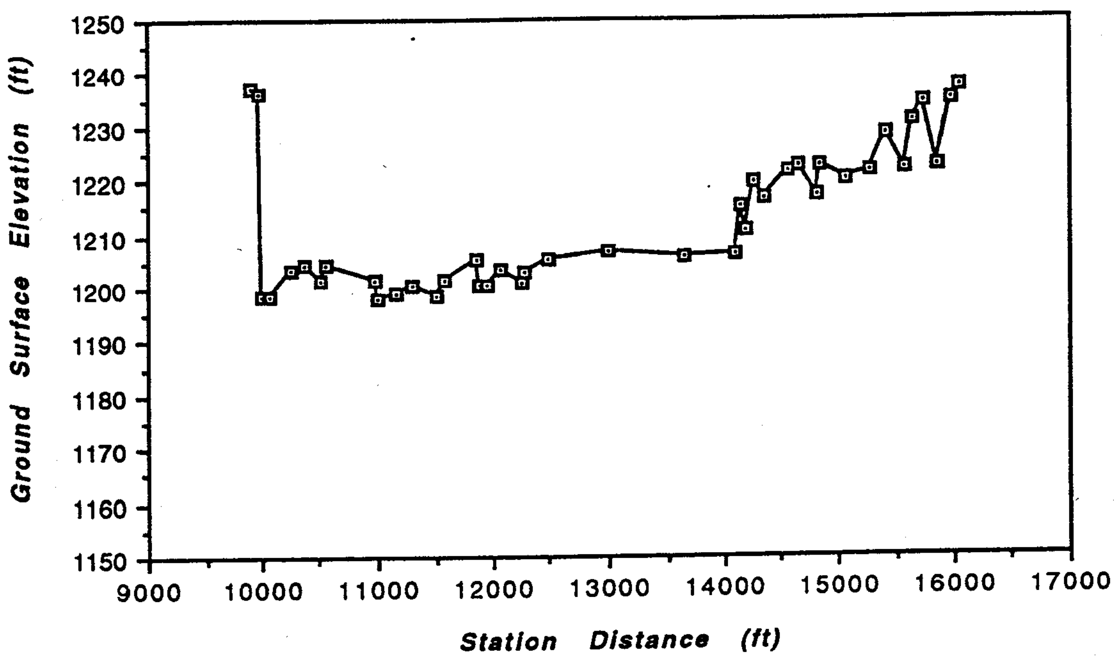

Fig. 5F -1 - Cross-section plot of Station 22.107

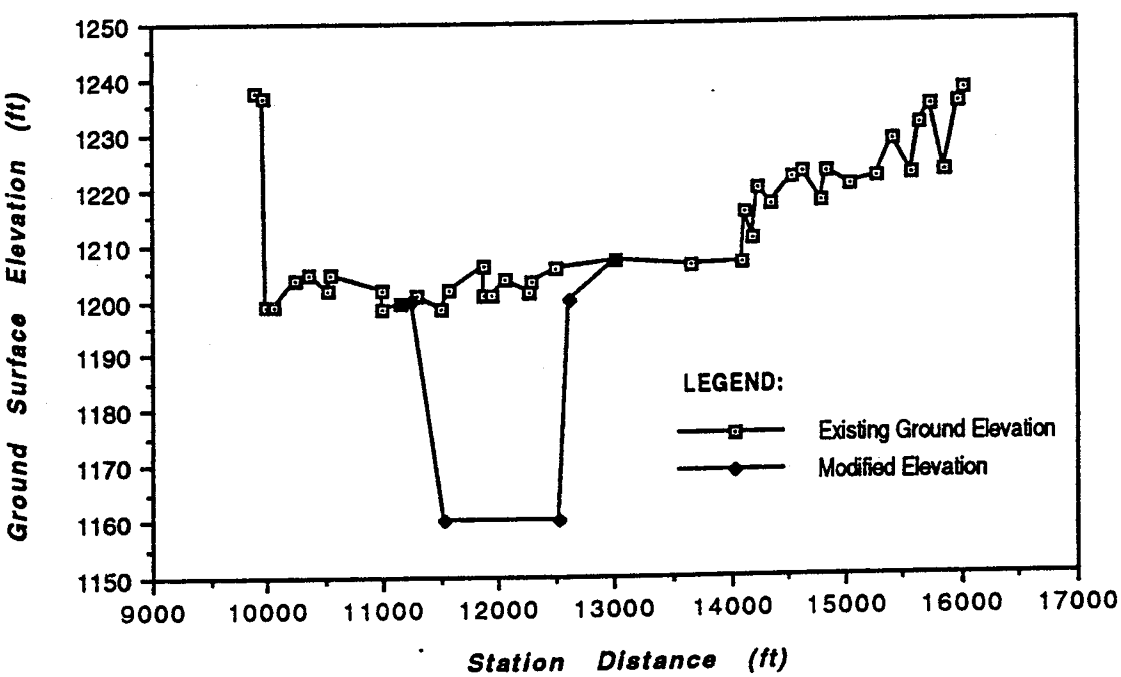

Fig. 5F -2 - Cross-section plot of Station 22.130

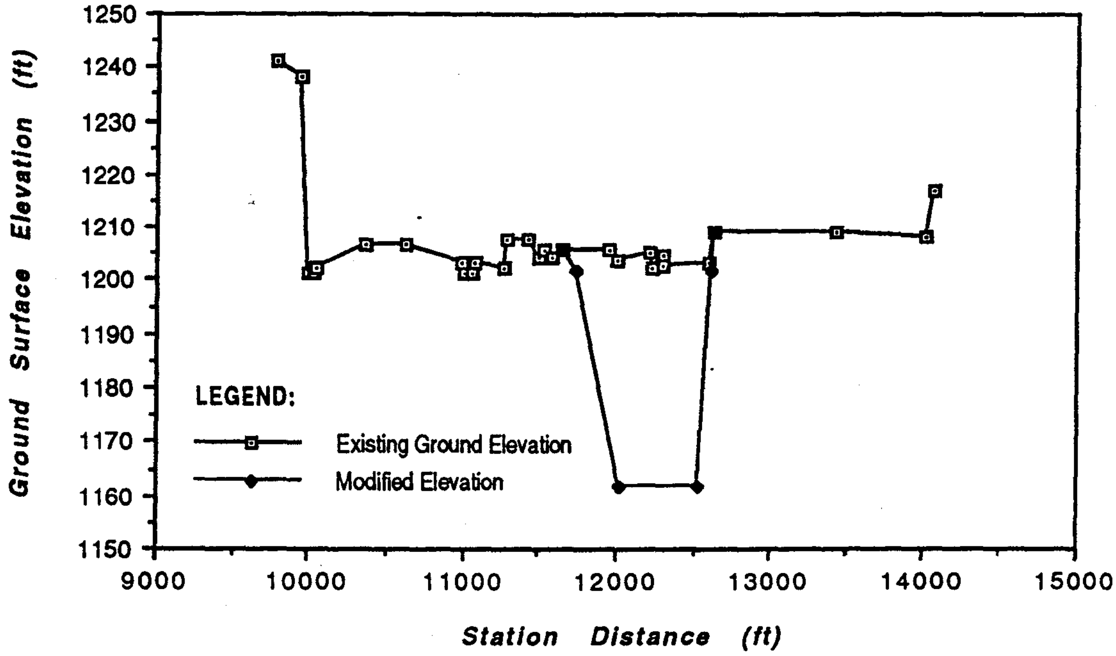

Fig. 5F -3 - Cross-section plot of Station 22.320

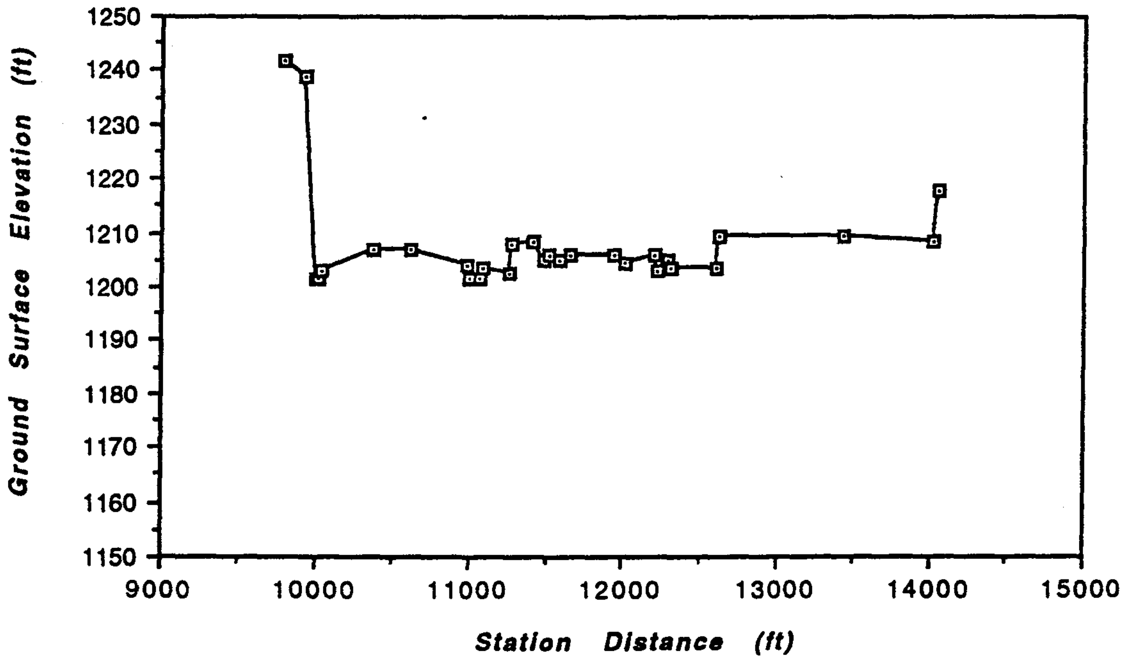

Fig. 5F -4 - Cross-section plot of Station 22.365

5.2.2.7 Site G

Owner:	Blue Circle West
Location:	North of Pinnacle Peak and South of Hatfield Road
Maximum Pit Depth:	40 feet

The mining site requires six (6) station geometry information for HEC-6 [see **Table 5.2.7**]. These geometry information could be extracted from the plan drawn by **Lemme Engineering Inc. (1987).** This mining site is the same mining site developed for **Lake End Sand and Gravel Corporation** (site H) but the development plan under this project covers only one mining pit which is the mining pit no. 1 for site H. This mining site (site G), however, has a larger extraction pit area than the mining pit no. 1 of site H. The extraction pit is planned to have 100-year storm slope bank protection (or riprap).

Table 5.2.7 - Section stations for mining site G

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Station 23.350	0.00	1220.9	-435.00
Station 23.365	80.00	1221.1	-410.00
Station 23.571	1085.00	1224.4	-330.00
Station 23.694	650.00	1226.4	-350.00
Station 23.851	830.00	1228.9	-750.00
Station 23.874	120.00	1229.30	-790.00

Note: Bed slope is 0.003 ft/ft.

(i) **Geometric Data -** The cross-section data for the stations identified were based on the topographic map and mining site plan provided by **Lemme Engineering Inc., (1987).** These information, particularly, the modifications prescribed on the channel bed based on the fully-developed mining site - are to be appended to the existing field data. Along the extraction pit, the planned bed slope is 0.00468 ft/ft. while the river slope (along the thalweg) is about 0.003 ft/ft. The inclusion of the plan in its entirety to the existing field data will comprise the field information that define the ultimate sand and gravel mining activities that are currently permitted.

(1) Station 23.350 - This is the most downstream station for the mining site which comprised of the existing field data with modification provided for the bed elevation designated at 1220.0 ft. This additional modification to the existing field data are presented in Fig. 5G-1 and Table 5G-1.

(2) Station 23.365 - The cross-section geometry for this station is shown in Fig. 5G -2 and Table 5G -2.

(3) Station 23.571 - The cross-section geometry for this station is shown in Fig. 5G -3 and Table 5G -3.

(4) Station 23.694 - Fig. 5G -4 and Table 5G -4 show the derived cross-section geometry information for the station.

(5) Station 23.851 - The section geometry for this station is shown in Fig. 5G -5 and Table 5G -5.

(6) Station 23.874 - The cross-section geometry for this station is comprised of the existing field information but with armorment provided throughout the whole property area. These information are presented in Fig. 5G -6 and Table 5G -6

(ii) **Sediment Data** - No data had been provided in the plan.

Table 5G -1 - Section geometry for Station 23.350

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9565.00 (PL)**	- 435.00	1220.90
3	9775.00	210.00	1220.90
4	11265.00	1490.00	1220.90
5	11315.00	50.00	1220.90

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5G -2 - Section geometry for Station 23.365

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9590.00 (PL)**	- 410.00	1221.10
3	9790.00	200.00	1221.10
4	9870.00	80.00	1181.10
5	11160.00	1290.00	1181.10
6	11280.00	120.00	1221.10
7	11330.00 (PL)**	50.00	1221.10

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5G -3 - Section geometry for Station 23.571

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9670.00 (PL)**	- 330.00	1224.40
3	9720.00	50.00	1224.40
4	9800.00	80.00	1184.40
5	10820.00	1020.00	1184.40
6	10940.00	120.00	1224.40
7	10990.00 (PL)**	50.00	1224.40

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5G -4 - Section geometry for Station 23.694

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9650.00 (PL)**	- 350.00	1226.40
3	9700.00	50.00	1226.40
4	9780.00	80.00	1186.40
5	10800.00	1020.00	1186.40
6	10920.00	120.00	1226.40
7	10970.00 (PL)**	50.00	1226.40

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5G -5- Section geometry for Station 23.851

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9250.00 (PL)**	- 750.00	1228.90
3	9300.00	50.00	1228.90
4	9380.00	80.00	1188.90
5	10400.00	1020.00	1188.90
6	10520.00	120.00	1228.90
7	10570.00 (PL)**	50.00	1228.90

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5G-6 - Section geometry for Station 23.874

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9210.00 (PL)**	- 790.00	1229.30
3	10530.00 (PL)**	1320.00	1229.30

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

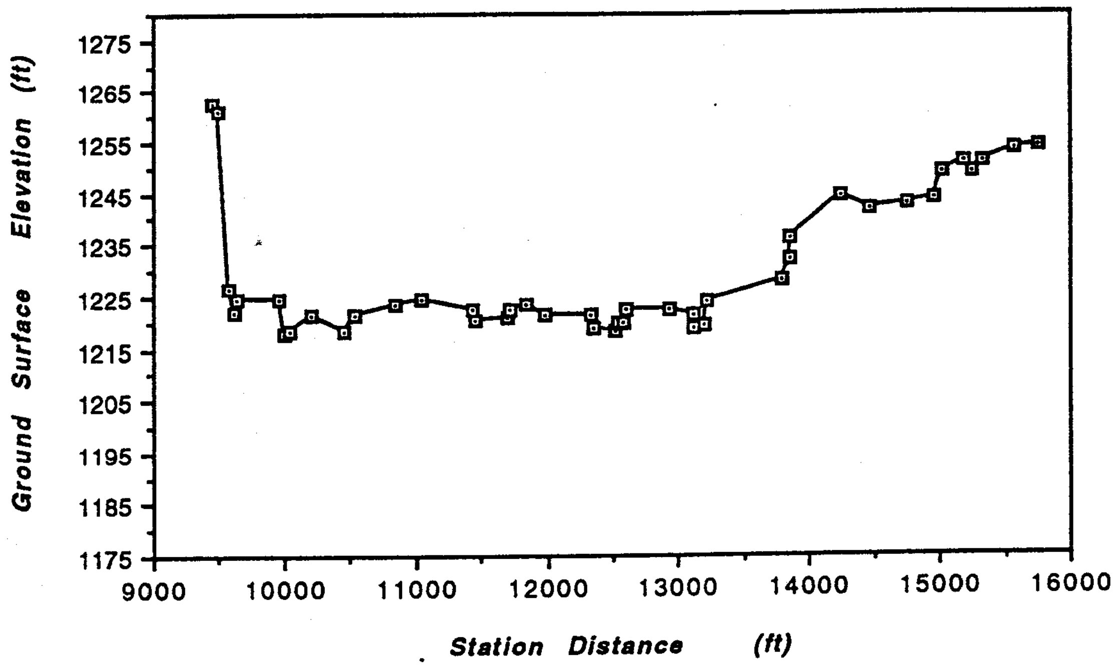

Fig. 5G -1 - Cross-section plot of Station 23.350

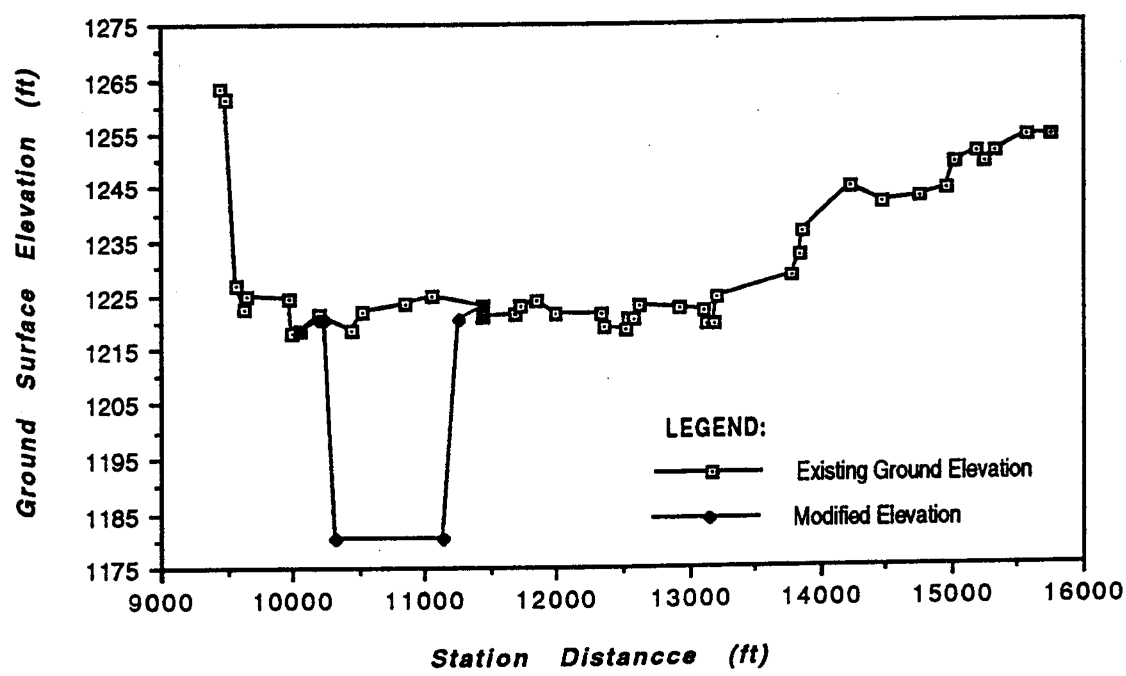

Fig. 5G -2 - Cross-section plot of Station 23.365

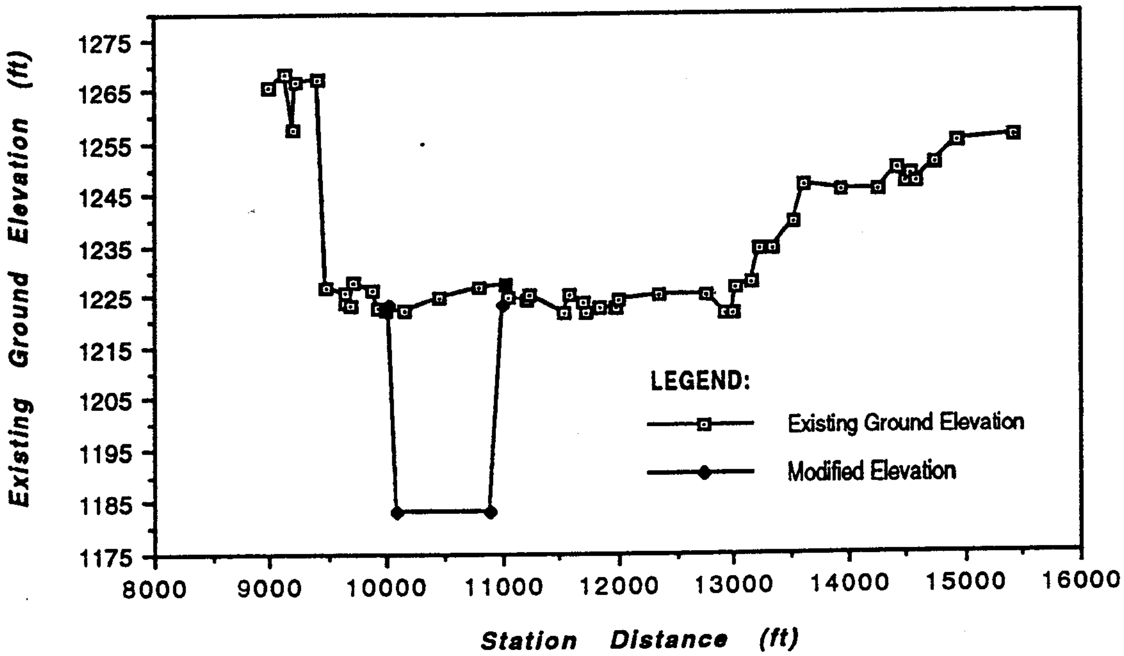

Fig. 5G -3 - Cross-section plot of Station 23.571

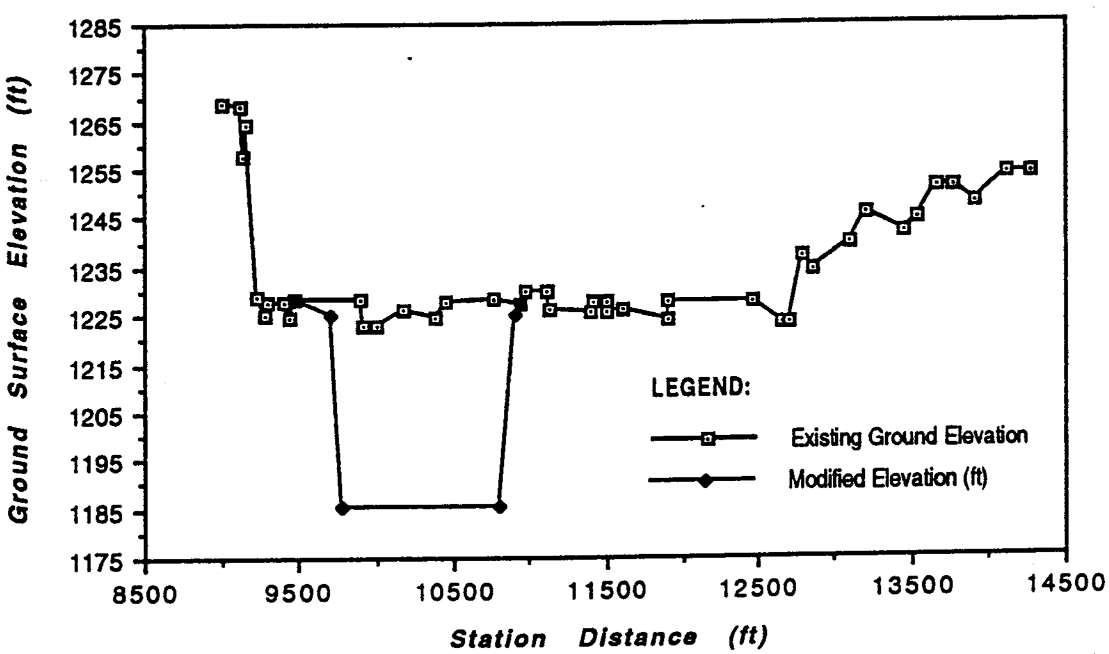

Fig. 5G -4 - Cross-section plot of Station 23.694

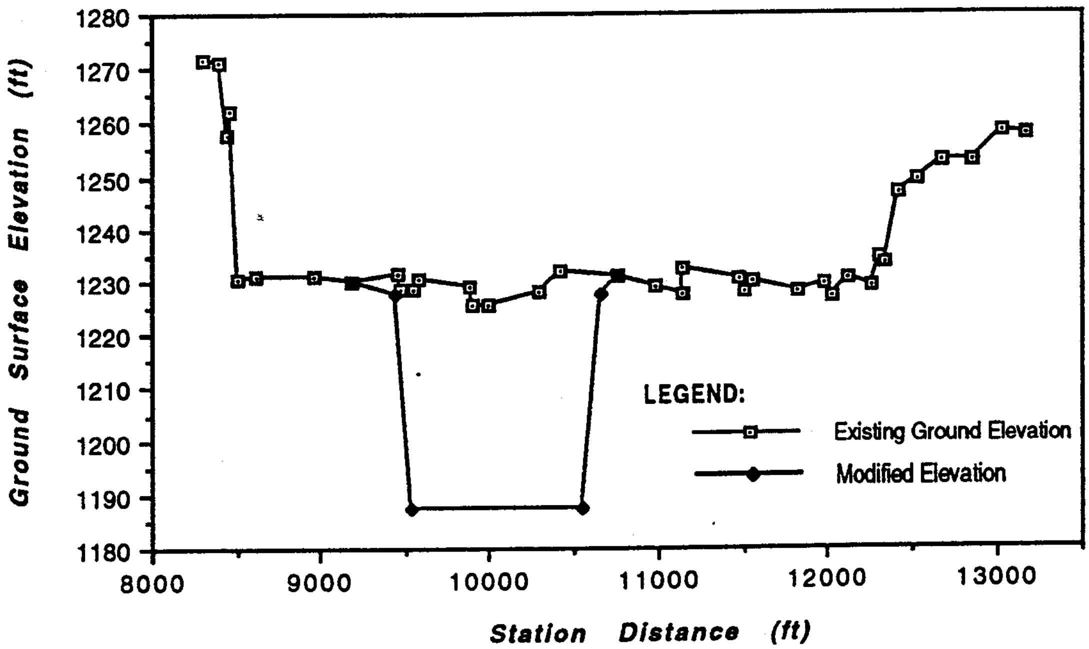

Fig. 5G -5 - Cross-section plot of Station 23.851

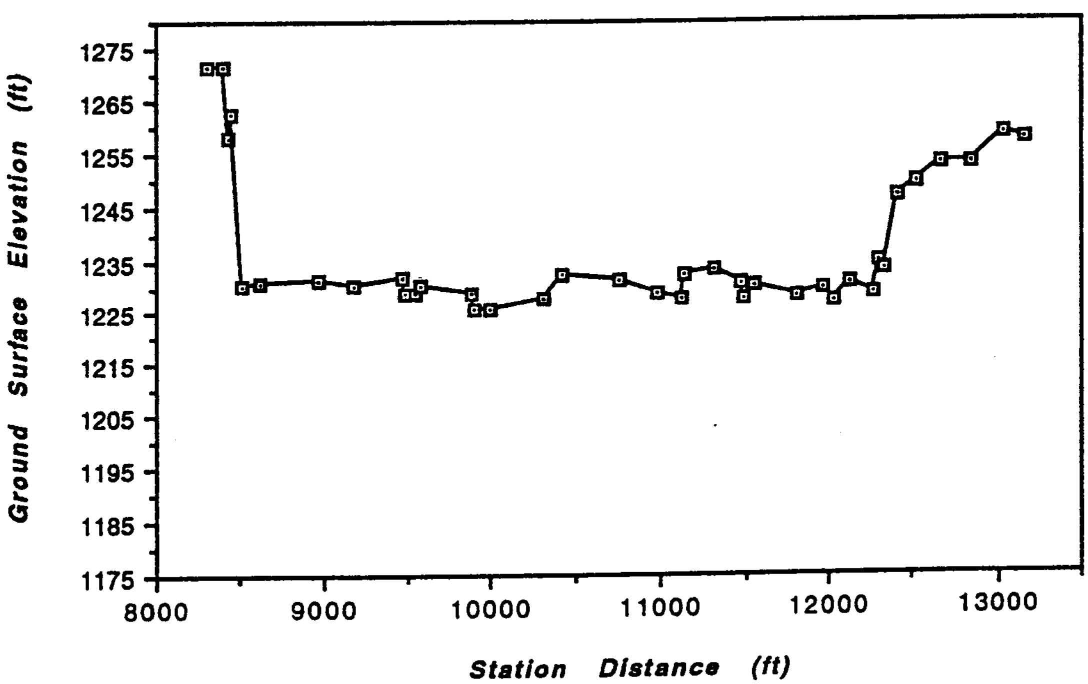

Fig. 5G -6 - Cross-section plot of Station 23.874

5.2.2.8 Site H

Owner:	Lake End Sand and Gravel
Location:	North of Pinnacle Peak
Maximum Pit Depth:	40 feet

The site is comprised of three (3) mining locations arranged in the north-south fashion. When the site would be fully developed, the extent of the development could be defined by fourteen (14) section stations for HEC-6. Stations 13.350 to 23.874 define the section stations for the most downstream mining pit; stations 24.070 to 24.193 define the section stations for the middle mining pit; and stations 24.350 to 24.491 define the section stations for the most upstream mining pit [see **Table 5.2.8**].

Table 5.2.8 - Section stations for mining site H

Station Identification	Distance Between Stations (ft)	Top Armorment Elevation (ft)	Dist. Between Thalweg and Property Line (ft)
Mining Pit No. 1:			
Station 23.350	0.00	1220.9	- 425.00
Station 23.365	80.00	1221.1	- 410.00
Station 23.571	1085.00	1224.4	- 330.00
Station 23.694	650.00	1226.4	- 425.00
Station 23.851	830.00	1228.9	- 745.00
Station 23.874	120.00	1229.3	- 790.00
Mining Pit No. 2:			
Station 24.070	1190.00	1232.9	- 935.00
Station 24.085	80.00	1233.1	- 965.00
Station 24.170	280.00	1233.9	-1030.00
Station 24.193	120.00	1234.3	-1030.00
Mining Pit No. 3:			
Station 24.350	945.00	1237.1	- 525.00
Station 24.365	80.00	1237.3	- 530.00
Station 24.468	545.00	1238.9	- 650.00
Station 24.491	120.00	1239.3	- 650.00

Note: Bed slope for mining pits 1,2, and 3 is assumed to be 0.0030 ft/ft calculated from the actual channel bed slope.

(i) Geometric Data - The section geometry information for the mining site are derived from the development plan and topographic map made by **Lemme Engineering, Inc. (1986) for Lake End Sand and Gravel Company**, the owner and the operator of the above mining sites.

(1) Station 23.350 - This is the most downstream station for the mining site which comprised of the existing ground data obtained from the field (or topographic map] . This station serves as the downstream boundary limit for mining pit no. 1 (see **Fig. 5H -1** for the cross-section plot).

(2) Station 23.365 - The cross-section geometry for the station is shown in **Fig. 5H -2** and **Table 5H -2.**

(3) Station 23.571 - The section geometry for this station is shown in **Fig. 5H -3** and **Table 5H -3**

(4) Station 23.694 - The section geometry for the station are shown in **Fig. 5H -4** and Table 5H -4.

(5) Station 23.851 - The section geometry for this station [see **Fig. 5H -5** and **Table 5H -5**] are identical to the section geometry of the previous station [**Fig. 5H -4** and **Table 5H -4**].

(6) Station 23.874 - The cross-section geometry for the station is comprised of the field ground data (see **Fig. 5H -6** for the cross-section plot). This station marks the upstream boundary limit for mining pit no. 1.

(7) Station 24.070 - This station marks the most downstream station for mining pit no. 2. The section geometry of this station resembles the existing field data (see **Fig. 5H -7** for cross-section plot).

(8) Station 24.085 - **Fig. 5H -8** and **Table 5H -8** provide the section geometry information for this station derived from the site development plan map.

(9) Station 24.170 - The cross-section geometry for this station is shown in **Fig. 5H -9** and **Table 5H -9**.

(10) Station 24.193 - The geometric information for the station are the existing field data (see **Fig. 5H -10** for cross-section plot). This station is the most upstream station for mining pit no. 2 which marks the upstream boundary limit on the extent by which mining pit no. 2 would be developed.

(11) Station 24.350 - The section information for the station are the existing field data (see **Fig. 5H -11** for cross-section plot). This station marks the most downstream station of mining pit no. 3.

(12) Station 24.365 - **Fig. 5H -12** and **Table 5H -12** show the cross-section geometry information of the station, which were determined from the site development plan map.

(13) Station 24.468 - The cross-section geometry of the pit for this station is identical to the previous station. The same information are presented in **Fig. 5H -13** and **Table 5H -13.**

(14) Station 24.491 - The section geometry of this station is comprised of the existing field data (see **Fig. 5H -14** for cross-section plot). This station marks the most upstream station for mining pit no. 3.

(ii) **Sediment Data** - No sediment data were presented in the site plan.

Table 5H -1 - Section geometry for Station 23.350

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9575.00 (PL)**	- 425.00	1220.90
3	10175.00	600.00	1220.90
4	10255.00	80.00	1220.90
5	11145.00	890.00	1220.90
6	11265.00	120.00	1220.90
7	11315.00 (PL)**	50.00	1220.90

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5H -2 - Section geometry for Station 23.365

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9590.00 (PL)**	-410.00	1221.10
3	10160.00	570.00	1221.10
4	10240.00	80.00	1181.10
5	11130.00	890.00	1181.10
6	11250.00	120.00	1221.10
7	11300.00 (PL)**	50.00	1221.10

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5H-3 - Section geometry for Station 23.571

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9670.00 (PL)**	-330.00	1224.40
3	9925.00	255.00	1224.40
4	10005.00	80.00	1184.40
5	10895.00	890.00	1184.40
6	11015.00	120.00	1224.40
7	11065.00 (PL)**	50.00	1224.40

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5H-4 - Section geometry for Station 23.694

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9575.00 (PL)**	- 425.00	1226.40
3	9630.00	55.00	1226.40
4	9710.00	80.00	1186.40
5	10730.00	1020.00	1186.40
6	10850.00	120.00	1226.40
7	10900.00 (PL)**	50.00	1226.40

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5H-5 - Section geometry for Station 23.851

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9255.00 (PL)**	- 745.00	1228.90
3	9310.00	55.00	1228.90
4	9390.00	80.00	1188.90
5	10410.00	1020.00	1188.90
6	10530.00	120.00	1228.90
7	10580.00 (PL)**	50.00	1228.90

Note: * Indicated reference point is the river thalweg (Sta 100+00).
**** Property Line**

Table 5H -6 - Section geometry for Station 23.874

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9210.00 (PL)**	- 790.00	1229.30
3	9265.00	55.00	1229.30
4	9345.00	80.00	1229.30
5	10365.00	1020.00	1229.30
6	10485.00	120.00	1229.30
7	10535.00 (PL)**	50.00	1229.30

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5H -7 - Section geometry for Station 24.070

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9065.00 (PL)**	- 935.00	1232.90
3	9195.00	130.00	1232.90
4	9275.00	80.00	1232.90
5	10215.00	940.00	1232.90
6	10335.00	120.00	1232.90
7	10385.00 (PL)**	50.00	1232.90

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5H -8 - Section geometry for Station 24.085

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9035.00 (PL)**	- 965.00	1233.10
3	9165.00	130.00	1233.10
4	9245.00	80.00	1193.10
5	10185.00	940.00	1193.10
6	10305.00	120.00	1233.10
7	10355.00 (PL)**	50.00	1233.10

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5H -9 - Section geometry for Station 24.170

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8970.00 (PL)**	-1030.00	1233.90
3	9100.00	130.00	1233.90
4	9180.00	80.00	1193.90
5	10120.00	940.00	1193.90
6	10240.00	120.00	1233.90
7	10290.00 (PL)**	50.00	1233.90

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5H -10 - Section geometry for Station 24.193

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	8970.00 (PL)**	-1030.00	1234.30
3	9100.00	130.00	1234.30
4	9180.00	80.00	1234.30
5	10120.00	940.00	1234.30
6	10240.00	120.00	1234.30
7	10290.00 (PL)**	50.00	1234.30

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5H -11 - Section geometry for Station 24.350

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9475.00 (PL)**	- 525.00	1237.10
3	9605.00	130.00	1237.10
4	9685.00	80.00	1237.10
5	10625.00	940.00	1237.10
6	10745.00	120.00	1237.10
7	10795.00 (PL)**	50.00	1237.10

Note: * **Indicated reference point is the river thalweg (Sta 100+00).**
** **Property Line**

Table 5H -12 - Section geometry for Station 24.365

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9470.00 (PL)**	- 530.00	1237.30
3	9600.00	130.00	1237.30
4	9680.00	80.00	1197.30
5	10620.00	940.00	1197.30
6	10740.00	120.00	1237.30
7	10790.00 (PL)**	50.00	1237.30

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5H -13 - Section geometry for Station 24.468

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9350.00 (PL)**	- 650.00	1238.90
3	9480.00	130.00	1238.90
4	9560.00	80.00	1198.90
5	10500.00	940.00	1198.90
6	10620.00	120.00	1238.90
7	10670.00 (PL)**	50.00	1238.90

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

Table 5H -14 - Section geometry for Station 24.491

Station No.	Ground Station (ft)	Horizontal Distance Between Stations (ft)	Ground Surface Elevation (ft)
1	10000.00*	0.00	-
2	9350.00 (PL)**	- 650.00	1239.30
3	9480.00	130.00	1239.30
4	9560.00	80.00	1239.30
5	10500.00	940.00	1239.30
6	10620.00	120.00	1239.30
7	10670.00 (PL)**	50.00	1239.30

Note: * Indicated reference point is the river thalweg (Sta 100+00).
** Property Line

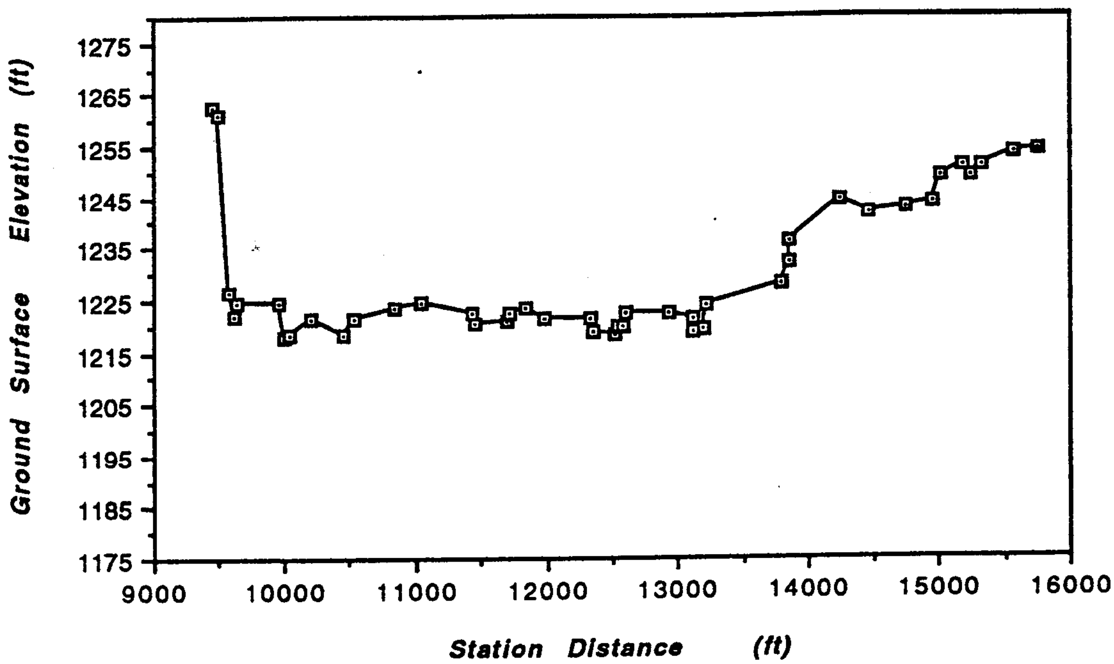

Fig. 5H -1 - Cross-section plot of Station 23.350

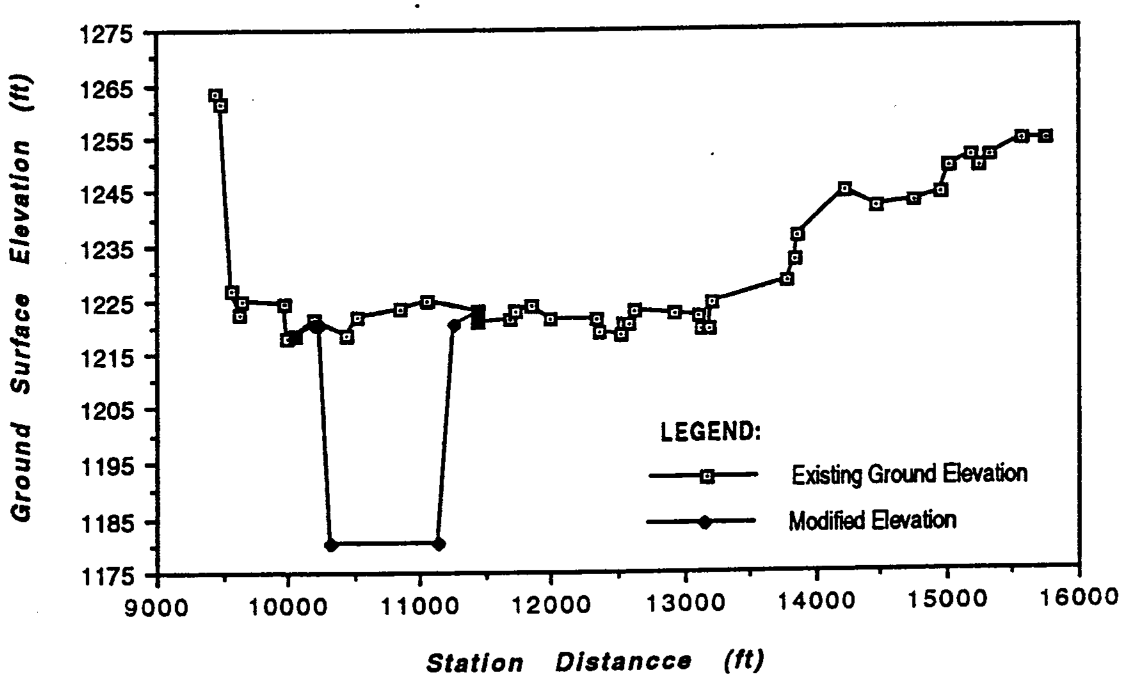

Fig. 5H -2 - Cross-section plot of Station 23.365

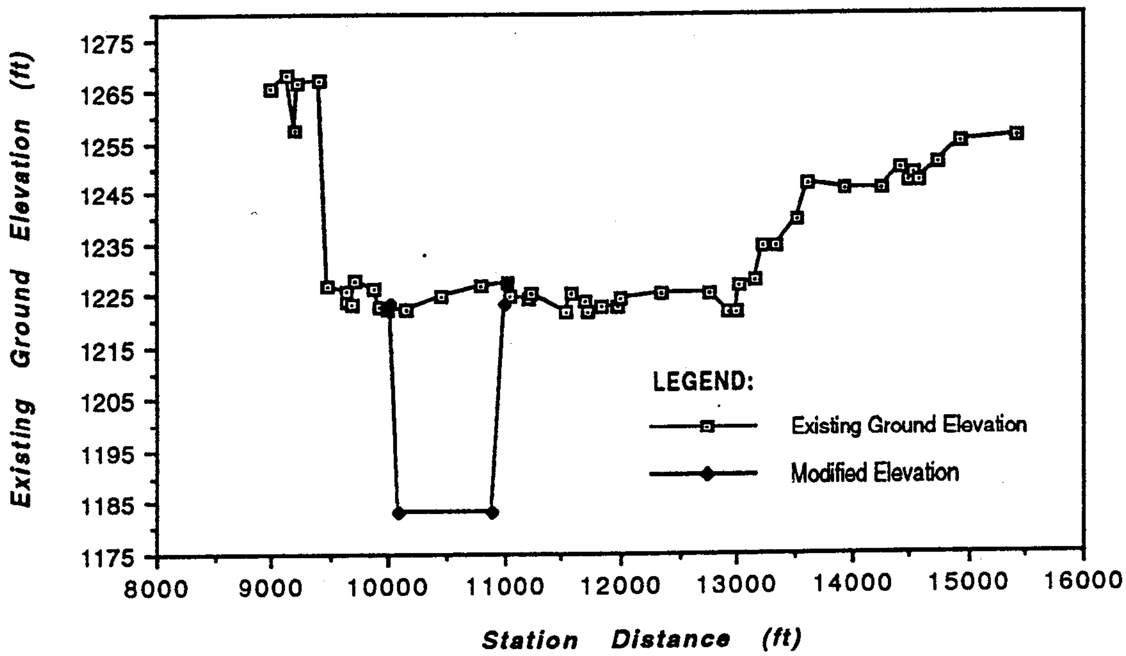

Fig. 5H -3 - Cross-section plot of Station 23.571

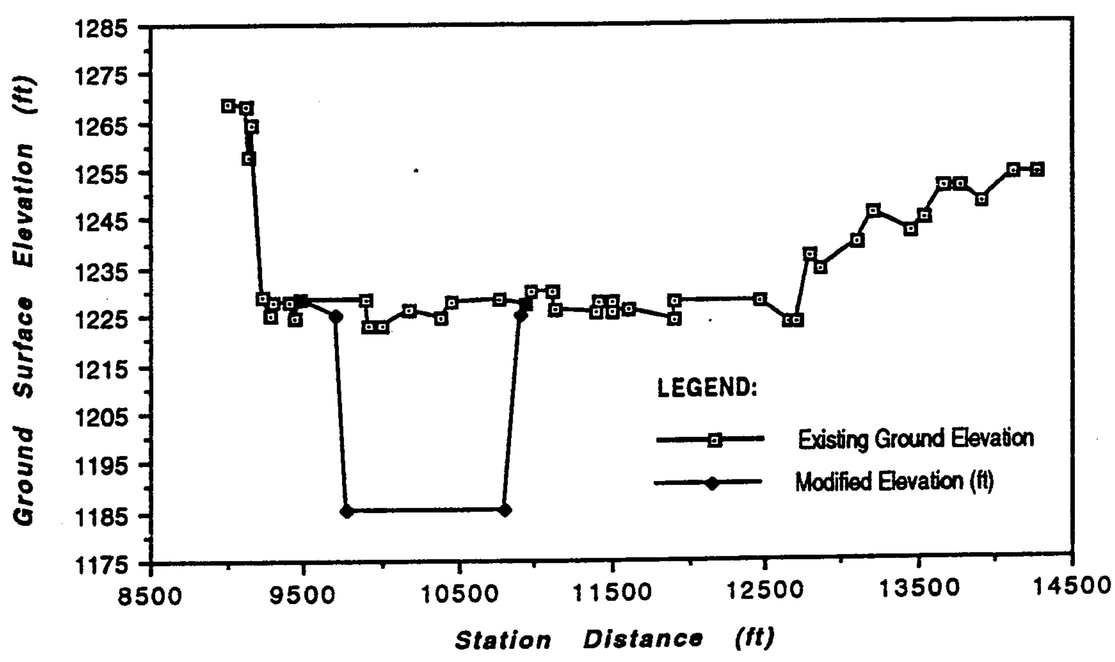

Fig. 5H -4 - Cross-section plot of Station 23.694

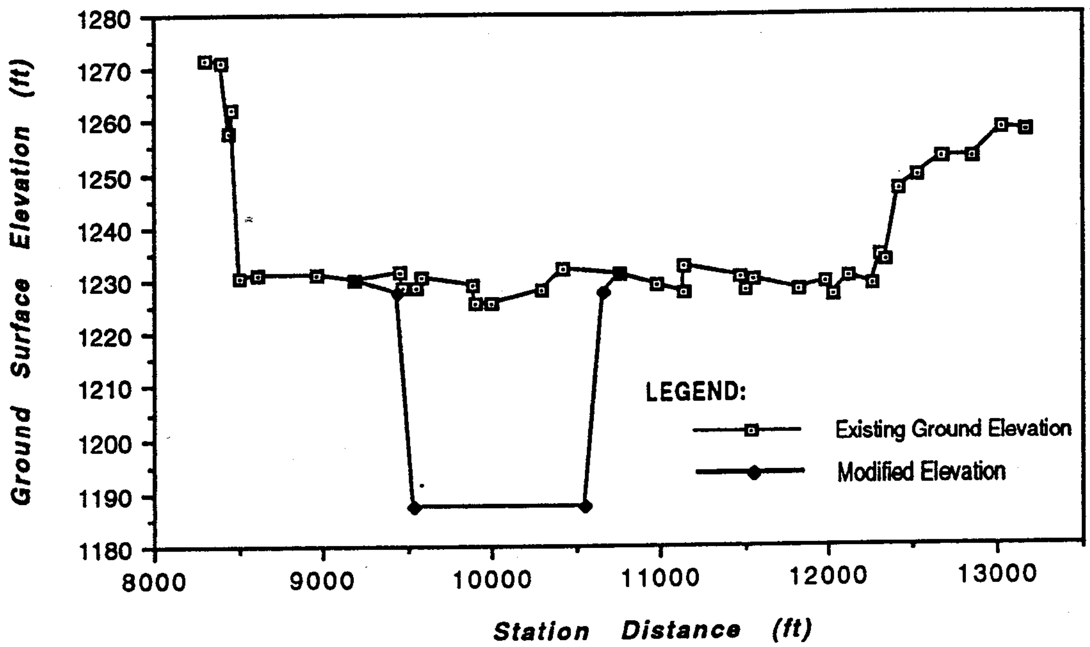

Fig. 5H -5 - Cross-section plot of Station 23.851

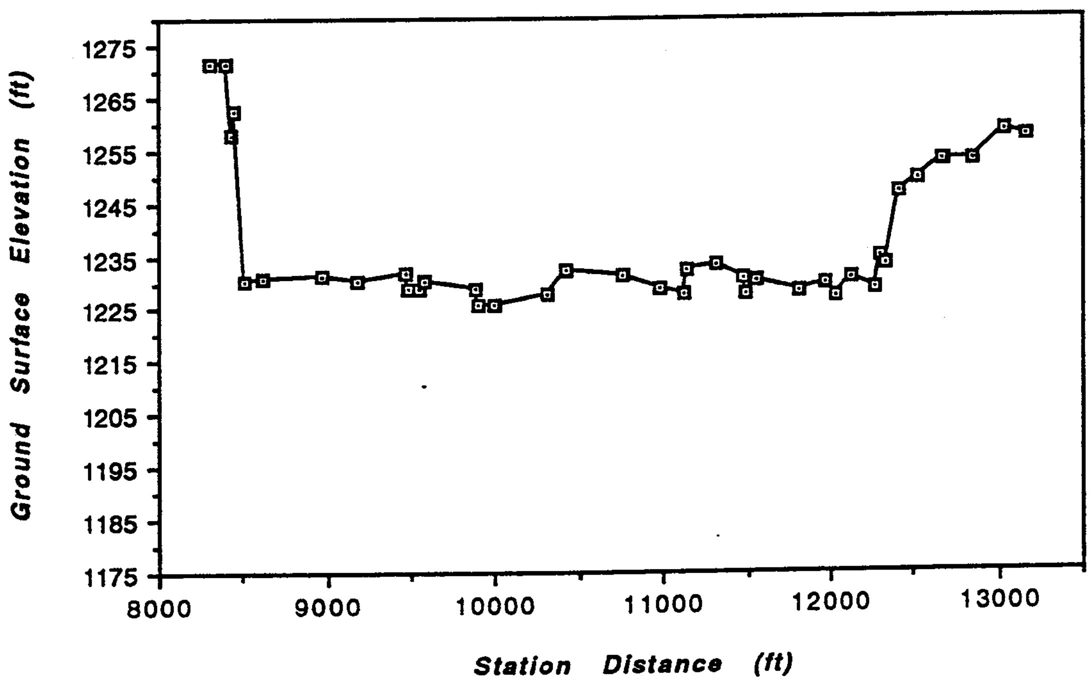

Fig. 5H -6 - Cross-section plot of Station 23.874

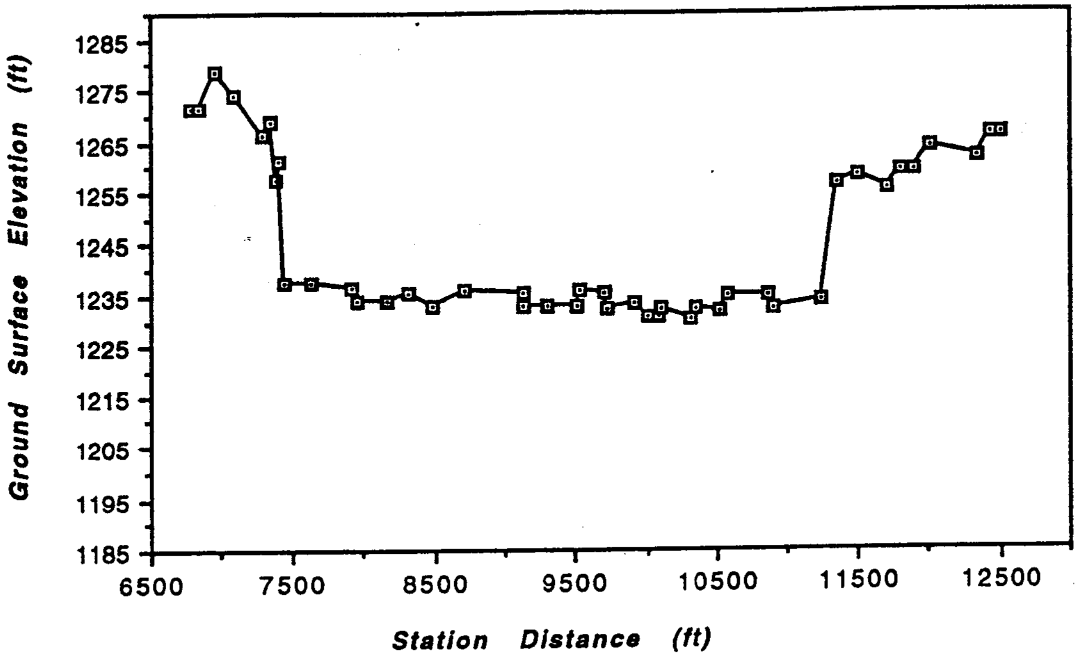

Fig. 5H -7 - Cross-section plot of Station 24.070

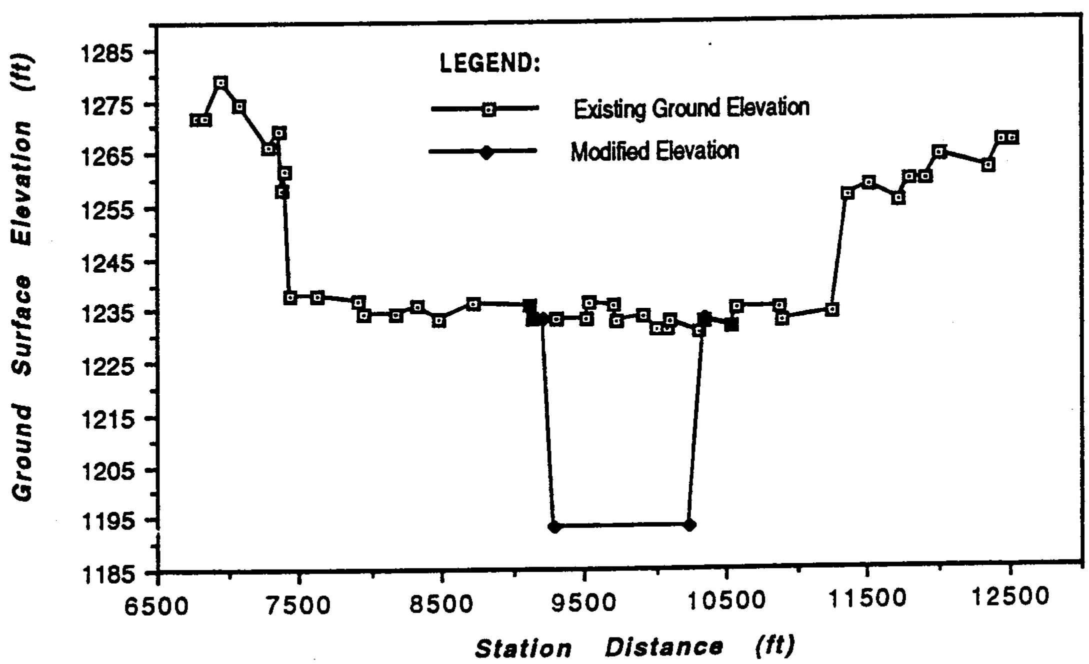

Fig. 5H -8 - Cross-section plot of Station 24.085

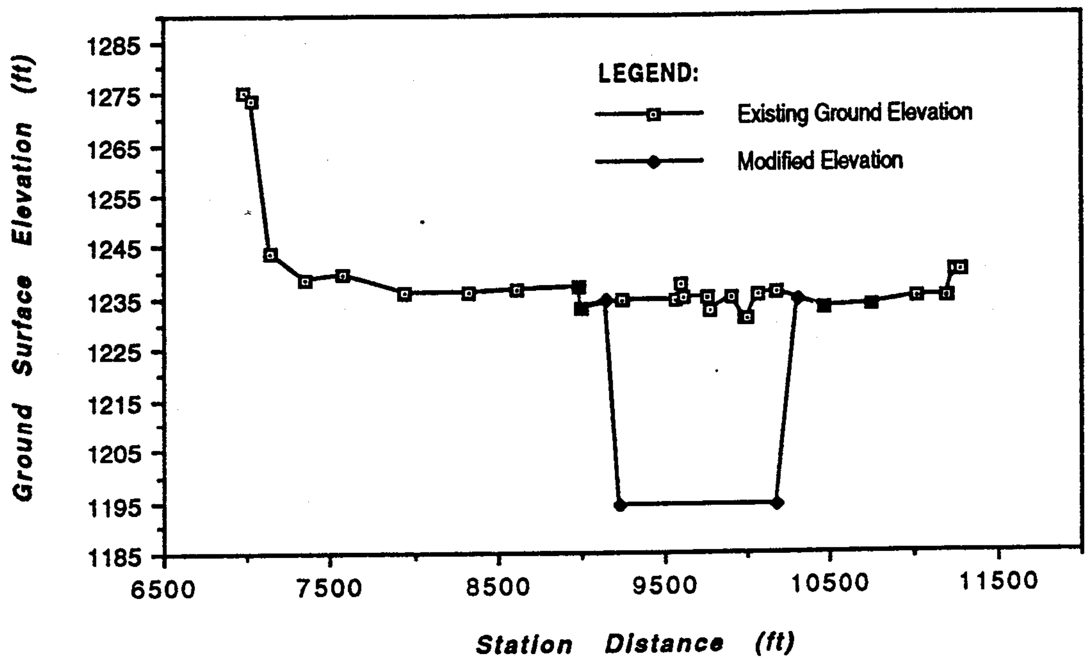

Fig. 5H -9 - Cross-section plot of Station 24.170

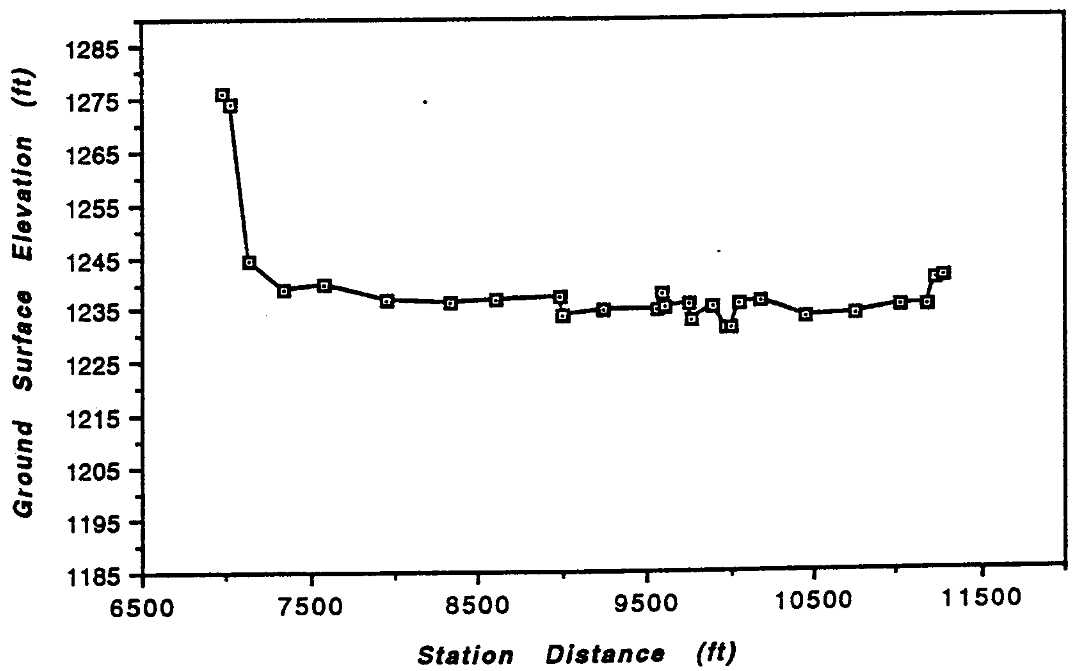

Fig. 5H -10 - Cross-section plot of Station 24.193

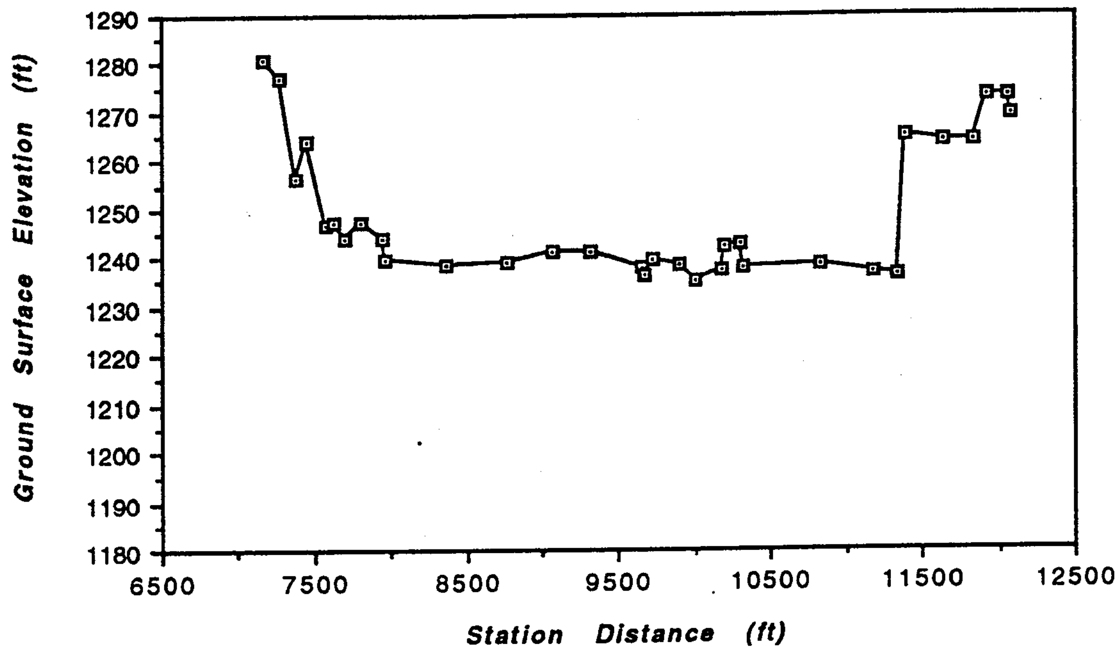

Fig. 5H -11 - Cross-section plot of Station 24.350

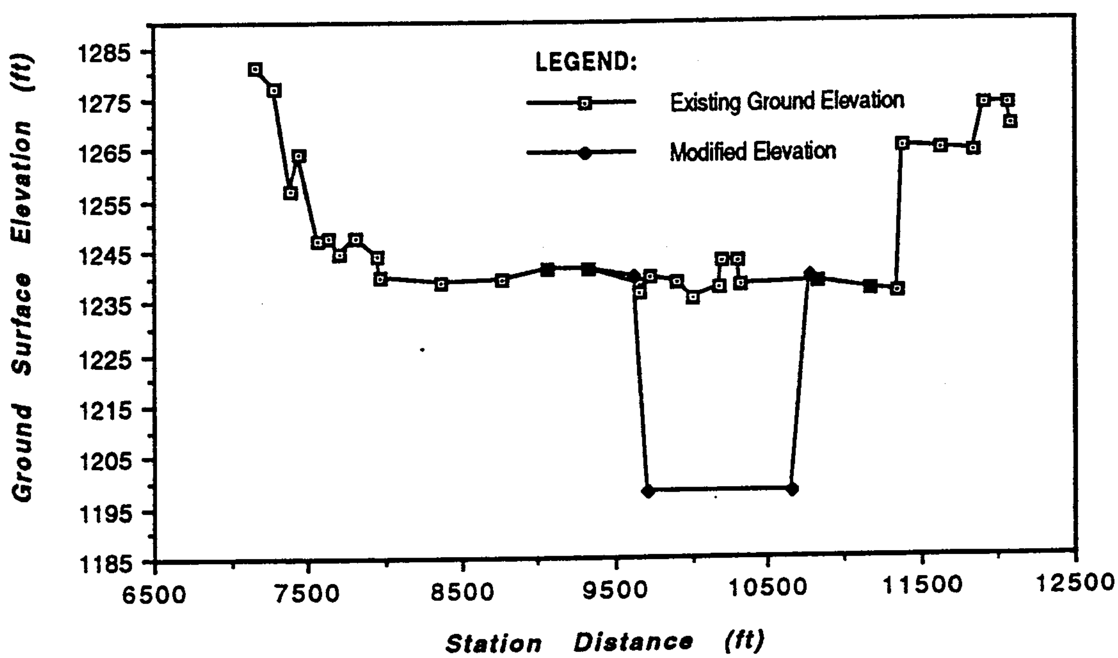

Fig. 5H -12 - Cross-section plot of Station 24.365

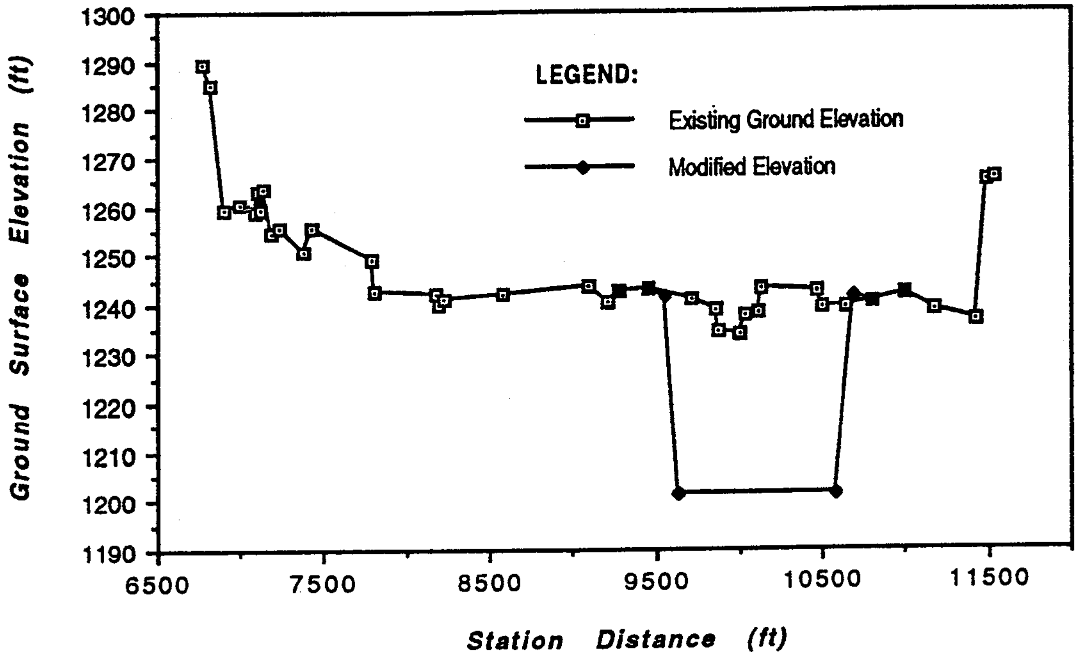

Fig. 5H -13 - Cross-section plot of Station 24.468

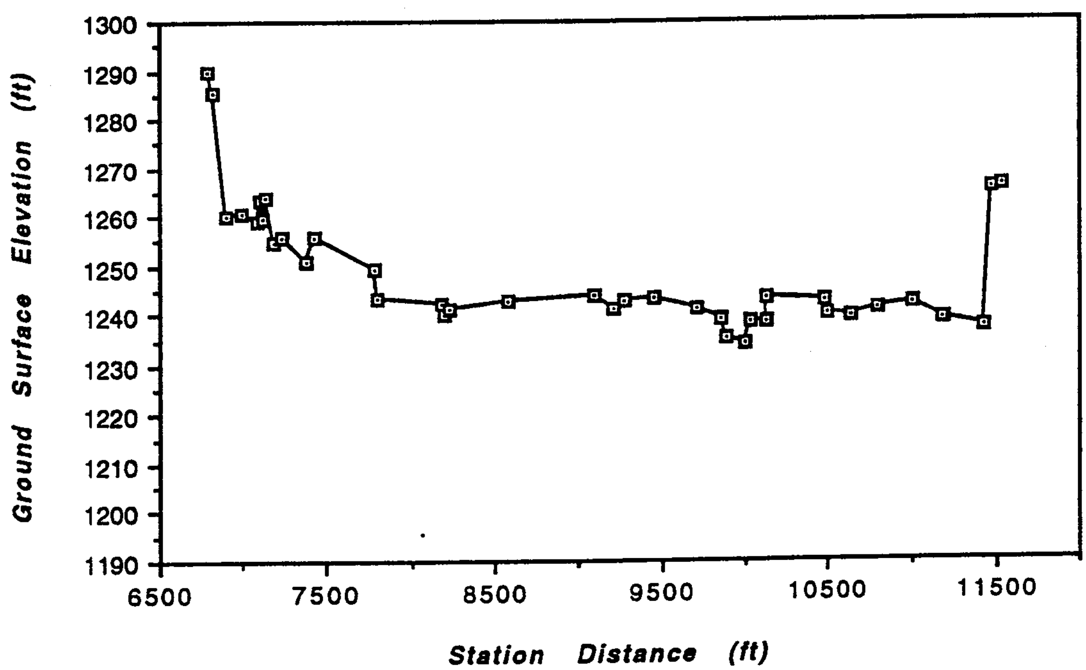

Fig. 5H -14 - Cross-section plot of Station 24.491

5.3 Model III

5.3.1 Modeling Description

Development of a future condition model by adding a 1000-foot wide channel improvement along the Agua Fria River (where applicable), to Model II to evaluate the effects of sand and gravel mining on the proposed channel.

5.3.2 Rationale of Channelization

Improvement channels of 1000-foot wide are proposed at various locations along the Agua Fria River for the following reasons:

(i) to widen constricted (or narrow) channels that permit or cause critical or supercritical flows along the existing channels;

(ii) to shorten (or narrow down) existing channels for the flows to be concentrated along a defined route; and

(iii) to contain the flow where flood easily encroaches into low-lying plains.

The second objective [(ii) above] permits reclamation of areas occupied by the river for other purposes. Narrowing of channel geometry, however, requires channel dredging.

5.3.3 Location of Improvement Channels

The existing levee along the Agua Fria River stretches from Station 1.87 to Station 8.34 along the west bank and from Station 3.76 to Station 8.100 along the east bank of the river. A break at the east bank levee is made between stations 5.48 and 5.54 to accomodate a small tributary. A similar flood protection measure is being considered for the following stretches along the Agua Fria River.

		Coverage of Channelization	
		from	to
(a)	Channel Improvement I	Station 8.10	Station 13.32
(b)	Channel Improvement II	Station 16.46	Station 19.89

The stretch from Station 8.10 to Station 13.32 is comprised of low-lying plains where the river banks are not defined. An improvement channel will certainly contain the flow at a defined route and protect the flood plains from flood encroachment. This stretch of channelization terminates at Station 13.32 because a mining site is located at some distance upstream. At the mining site, however, a channel improvement will not be proposed.The existing west bank terminates at Station 8.34. However, if a uniform 1000-foot wide channel improvement is made, the existing channel must be modified.

Similarly, the stretch from Station 16.46 [immediately after Grand Avenue] to Station 19.89 requires channelization to protect the floodplain from flood enchroachment since the flood plains on both banks are residential areas. The channelization terminates at Station 19.89 because a number of mining sites are located upstream.

Beyond these upstream mining sites, channelization is optional because the river has much more defined banks and the relatively high-lying flood plains are not residential areas. Except around the vicinity of the Jomax Road (Station 25.59 (approximately) the floodplains upstream are not flood-proned.

5.3.3.1 Channel Improvement-I - Table 5.3.1 lists the Stations covered by this channelization. Tables 4.I-1 to 4.I-14 define the channel improvement geometries of the 14 Stations.

Table 5.3.1 - Stations Covered Under Channel Improvement I

	Station (Mile No.)	Reach Length (ft)	Bed Slope** (ft/ft)	Thalweg El. (ft)	Corrected Bed Elev. (ft)	Levee Elevation (ft)***
1	8.10	-	-	1000.1	1000.1	1015.1
2	8.21	600	0.00283	1001.8	1001.8	1016.8
3	8.73	2640	0.00379	1011.8	1009.3	1024.3
4	9.13*	2090	0.00211	1016.2	1015.2	1030.2
5	9.90	3950	0.00235	1025.5	1026.5	1041.5
6	10.53	3330	0.00174	1031.3	1035.9	1050.9
7	10.72	1010	0.00277	1034.1	1038.8	1053.8
8	11.01	1430	0.00091	1035.4	1042.8	1057.8
9	11.34*	1680	0.00351	1041.3	1047.6	1062.6
10	11.52	980	0.00112	1042.4	1050.4	1065.4
11	11.80	1415	0.00466	1049.0	1054.4	1069.4
12	12.38	925	0.00465	1053.3	1057.0	1072.0
13	12.84	2485	0.00382	1062.8	1064.1	1079.1
14	13.33*	2585	0.00337	1071.5	1071.5	1086.5

* Bridge locations
** Based on thalweg elevations; average bed slope is 0.00284 ft/ft
*** A levee height of 15 ft is provided above the corrected bed elevation

Table 5I -1 - Channel Geometry at Station 8.10

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1015.10
3	9500.00	26.00	1000.10
4	10500.00	1000.00**	1000.10
5	10526.00	26.00	1015.10

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -2 - Channel Geometry at Station 8.21

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1016.80
3	9500.00	26.00	1000.80
4	10500.00	1000.00**	1000.80
5	10526.00	26.00	1016.80

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -3 - Channel Geometry at Station 8.73

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9629.00	-371.00	1024.30
3	9655.00	26.00	1009.30
4	10655.00	1000.00**	1009.30
5	10681.00	26.00	1024.30

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -4 - Channel Geometry at Station 9.13

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1030.20
3	9500.00	26.00	1015.20
4	10500.00	1000.00**	1015.20
5	10526.00	26.00	1030.20

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -5 - Channel Geometry at Station 9.90

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1041.50
3	9500.00	26.00	1026.50
4	10500.00	1000.00**	1026.50
5	10526.00	26.00	1041.50

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -6 - Channel Geometry at Station 10.53

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1050.90
3	9500.00	26.00	1035.90
4	10500.00	1000.00**	1035.90
5	10526.00	26.00	1050.90

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -7 - Channel Geometry at Station 10.72

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1053.80
3	9500.00	26.00	1038.80
4	10500.00	1000.00**	1038.80
5	10526.00	26.00	1053.80

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -8 - Channel Geometry at Station 11.01

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9050.00	-950.00	1057.80
3	9076.00	26.00	1042.80
4	10076.00	1000.00**	1042.80
5	10102.00	26.00	1057.80

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -9 - Channel Geometry at Station 11.34

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9095.00	-905.00	1062.60
3	9121.00	26.00	1047.60
4	10121.00	1000.00**	1047.60
5	10147.00	26.00	1062.60

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -10 - Channel Geometry at Station 11.52

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9065.00	-935.00	1065.40
3	9091.00	26.00	1050.40
4	10091.00	1000.00**	1050.40
5	10117.00	26.00	1065.40

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -11 - Channel Geometry at Station 11.80

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9181.00	-819.00	1069.40
3	9207.00	26.00	1054.40
4	10207.00	1000.00**	1054.40
5	10233.00	26.00	1069.40

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -12 - Channel Geometry at Station 12.38

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9250.00	-750.00	1072.00
3	9276.00	26.00	1057.00
4	10276.00	1000.00**	1057.00
5	10302.00	26.00	1072.00

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -13 - Channel Geometry at Station 12.84

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9156.00	-844.00	1079.10
3	9182.00	26.00	1064.10
4	10182.00	1000.00**	1064.10
5	10208.00	26.00	1079.10

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5I -14 - Channel Geometry at Station 13.33

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1086.50
3	9500.00	26.00	1071.50
4	10500.00	1000.00**	1071.50
5	10526.00	26.00	1086.50

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

5.3.3.2 <u>Channel Improvement-II</u> - **Table 5.3.2** lists the Stations covered under this channelization. **Tables 5II-1 to 5II-8** define the channel improvement geometries of the 8 Stations.

Table 5.3.2 - Stations Covered Under Channel Improvement II

	Station (Mile No.)	Reach Length (ft)	Bed Slope** (ft/ft)	Thalweg El. (ft)	Corrected Bed Elev. (ft)	Levee Elevation (ft)***
1	16.45*	-	-	1110.0	1110.0	1125.0
2	16.91	2440	0.00189	1114.6	1117.1	1132.1
3	17.38	2455	0.00289	1121.7	1124.3	1139.3
4	17.76	1980	0.00318	1128.0	1130.1	1145.1
5	18.24	2525	0.00305	1135.7	1137.5	1152.5
6	18.92*	3595	0.00376	1149.2	1148.0	1163.0
7	19.44	2800	0.00279	1157.0	1156.2	1171.2
8	19.89	2375	0.00265	1163.3	1163.3	1178.3

* Bridge locations
** Based on thalweg elevations; average bed slope is 0.00293 ft/ft
*** A levee height of 15 ft is provided above the corrected bed elevation

Table 5II-1 - Channel Geometry at Station 16.45

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9768.40	-231.60	1125.00 (1132.00)
3	9794.40	26.00	1110.00
4	10794.40	1000.00**	1110.00
5	10820.40	26.00	1125.00

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5II-2 - Channel Geometry at Station 16.91

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9758.00	-242.00	1132.10 (1144.80)
3	9784.00	26.00	1117.10
4	10784.00	1000.00**	1117.10
5	10810.00	26.00	1132.10

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5II-3 - Channel Geometry at Station 17.38

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1139.30
3	9500.00	26.00	1124.30
4	10500.00	1000.00**	1124.30
5	10526.00	26.00	1139.30

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5II-4 - Channel Geometry at Station 17.76

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1145.10
3	9500.00	26.00	1130.10
4	10500.00	1000.00**	1130.10
5	10526.00	26.00	1145.10

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5II-5 - Channel Geometry at Station 18.24

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9474.00	-526.00	1152.50
3	9500.00	26.00	1137.50
4	10500.00	1000.00**	1137.50
5	10526.00	26.00	1152.50

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5II-6 - Channel Geometry at Station 18.92

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	9524.90	-475.10	1163.00
3	9550.90	26.00	1148.00
4	10550.90	1000.00**	1148.00
5	10576.90	26.00	1163.00 (1163.90)

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5II-7 - Channel Geometry at Station 19.44

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	8798.00	-1202.00	1171.20
3	8824.00	26.00	1156.20
4	9824.00	1000.00**	1156.20
5	9850.00	26.00	1171.20

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

Table 5II-8 - Channel Geometry at Station 19.89

	Lateral Station (ft)	Distance Between Stations (ft)	Elevation (ft)***
1	10000.00*	-	-
2	8142.00	-1858.00	1178.30
3	8168.00	26.00	1163.30
4	9168.00	1000.00**	1163.30
5	9194.00	26.00	1178.30

* Indicated reference is the river thalweg (Sta. 100 + 00)
** Proposed 1000-ft wide channel bottom.
*** Levee height is 15.0ft

VI RESULTS AND ANALYSIS

6.1 Calibration Analysis

Prior to the development of the three (3) models that will incorporate the on-going and future improvements along the Agua Fria River, preliminary works have been made to select the sediment transport function that best describes the sediment transport dynamics in the river. This necessitates the determination of inflowing sediment load that enters the most upstream station of the study reach [i.e. from Jomax Road to Bell Road] was made.

On the selection process of sediment transport function for Agua Fria River, the ten (10) available transport functions in the current version of HEC-6 code were evaluated. **Table 6.1** lists the result of such analysis showing the two evaluated criteria in the selection process. As shown, the formula provided by the combination of Toffaleti and Schoklitsch relations gave the best predictor of transport dynamics along the reach studied.

Table 6.1- Statistical analyses between the simulated and observed data

MTC No.	Sediment Transport Function	Sum of Deviation	Sum of Squares of Deviations
0,1	Toffaleti	96.06	372.61
3	Madden (1963)	88.61	317.49
4	Yang's Streampower	92.04	339.36
5	Duboys	86.86	364.31
7	Ackers and White	91.34	327.28
8	Colby	95.83	352.35
9	Toffaleti and Schoklitsch	87.20	299.79**
10	Meyer-Peter and Muller	88.04	324.29
12	Toffaleti and Meyer-Peter & Muller	88.42	337.68
13	Madden (1985)	102.28	439.28

Note: ** Toffaleti and Schoklitsch formula provided the most appropriate predictor for the transport dynamics of sediments at the study reach.

6.2 Inflowing Sediment Loads for the Modeling of the Agua Fria River

In the consideration of the whole Agua Fria River as the study reach, determination of inflowing sediment loads at the most upstream station (i.e. Station 33.82) is vital. Also, since the New River serves as a tributary to the Agua Fria River, inflowing sediment load data must be determined at the tributary mouth (i.e. Station 9.13). These data are listed in **Tables B.2-11** and **B.2-12 (in Appendix B).**

6.3 Modeling Results

Four (4) hydrologic scenarios were used in running the **Model I**. These hydrologic scenarios were based on peak flows for return periods of 50-,100-, 200-, and 500-years when the New Waddel Dam is operational. Also, the expected contribution from the New River is shown in **Table C.2.1 [Appendix C]** for different return periods. Four (4) hydrographs associated with the four (4) return periods were assumed having a duration of about 8.79 days [i.e. equivalent to the Feb. 13-22, 1980 flood duration] are presented in **Appendix C [Tables C.3.1- C.3.4]**.

6.3.1 Model I Results

Table 6.2 lists the bed changes associated to the four (4) hydrologic data of different return periods used in running Model I. Apparently, more aggradation processes occur along the river channel at low flows (i.e., 50-year return period) than higher flows (i.e. 100-, 200-, and 500-year return periods). This means that degradation is more frequent and more extensive at high flows. Regardless of the hydrologic input, Model I gave extensive degradation at Station 3.767, 3.757, 3.734, and 3.729 because two bridges are located adjacently. These bridges are the Buckeye Road bridge and the South Pacific Railroad bridge.

Two other locations along the river exhibited too much scouring. One is at the most upstream stations of the Agua Fria River (i.e. Stations 32.984, 32.998, 33.41 and 33.82). Apparently, these stations have constricted channels most particularly the station that corresponds to Highway 74 bridge (Station 32.984). The other location of degradation is at the Grand Avenue area. Since there are two bridge crossings, the river channels at this location are relatively constricted permitting more scouring along the channel because of higher flow velocities. The stations subjected to large degradation are Stations 16.420, 16.446, and 16.45. In summary, it is observed that after a series of stations are subjected to serious degradation, an aggradation process occurs downstream to possibly deposit the sediment transported through the constricted channel.

Table 6.2 - Bed changes associated to the four hydrologic data [Model I]

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year	
1	33.820	-1.230	-2.560	-4.220	-5.200	
2	33.410	-0.610	-0.840	-1.050	-1.640	
3	32.998	-5.070	-6.370	-7.630	-8.420	HIGHWAY 74
4	32.984	-4.780	-5.170	-6.020	-6.830	
5	32.860	1.190	1.540	1.840	1.680	
6	32.430	0.210	0.220	0.270	0.630	
7	31.860	0.070	0.230	0.510	0.750	
8	31.390	-0.700	-1.150	-1.600	-0.150	
9	30.820	0.060	0.090	0.260	-0.440	
10	30.260	-0.130	-0.110	-0.110	-0.100	
11	30.070	-0.170	-0.300	-0.460	-0.350	
12	29.800	1.320	1.710	1.250	0.150	
13	29.611	-0.170	-0.360	-0.990	-0.690	
14	29.540	-0.260	-0.440	-0.250	-0.200	
15	29.040	0.080	0.180	0.320	0.130	
16	28.670	-0.190	-0.150	-0.120	-0.050	
17	28.120	-0.130	-0.160	-0.410	-0.850	
18	27.680	-0.180	-0.190	-0.190	-0.110	
19	27.030	-0.070	-0.110	-0.110	-0.120	
20	26.730	0.030	-0.050	-0.110	-0.140	
21	26.290	-0.230	-0.180	-0.160	-0.150	
22	25.860	-0.790	-0.450	-0.180	-0.090	
23	25.590	0.570	0.330	0.280	0.570	
24	25.370	-0.050	-0.050	-0.120	-0.640	
25	24.900	0.020	0.060	0.080	0.220	
26	24.540	0.180	0.290	0.440	0.220	
27	24.350	-0.110	-0.150	-0.220	-1.930	
28	23.890	-0.190	-0.190	-0.180	0.500	
29	23.350	-0.040	-0.050	-0.050	-0.150	
30	22.790	-0.150	-0.150	-0.140	-0.080	
31	22.320	-0.140	-0.040	-0.010	0.360	
32	21.760	0.130	0.000	0.050	0.210	
33	21.420	0.040	-0.030	-0.010	0.090	
34	21.010	0.810	0.920	1.040	1.160	
35	20.920	0.250	0.170	0.140	0.230	
36	20.450	-1.060	-1.210	-1.300	-1.360	
37	19.890	-0.300	-0.920	-0.980	-1.000	
38	19.440	-0.100	-0.060	-0.030	0.150	
39	18.920	-0.180	-0.200	-0.680	0.080	
40	18.240	-0.080	-0.060	0.550	-2.160	
41	17.760	0.470	0.840	0.750	1.970	
42	17.380	0.740	0.240	-0.200	0.020	
43	16.910	-0.640	-2.530	-3.180	-3.040	GRAND AVE
44	16.450	-4.830	-5.420	-4.230	-4.750	
45	16.446	0.790	-1.050	-7.670	-4.300	
46	16.420	2.210	2.740	2.210	2.430	
47	15.980	0.420	1.480	2.870	4.270	

Table 5.1 - Model I Results (continued...)

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year
48	15.510	-0.120	2.220	0.790	-0.460
49	15.320	-0.740	-0.770	-0.770	0.160
50	14.940	0.390	0.700	0.220	0.280
51	14.850	-0.180	-0.470	-0.860	0.230
52	14.380	-0.180	-0.140	0.810	-0.730
53	13.810	-0.070	-0.080	-0.590	-0.190
54	13.330	-0.080	-0.070	-0.070	0.400
55	12.380	-0.120	-0.020	0.570	0.910
56	11.800	-0.270	-0.510	-1.760	-0.950
57	11.520	-2.290	-1.770	-1.370	-1.330
58	11.340	0.240	0.140	-0.240	-0.390
59	11.010	2.420	3.060	3.420	2.570
60	10.720	0.620	0.330	0.540	0.440
61	10.530	-0.070	-0.090	-0.120	-0.160
62	9.900	-0.170	-0.170	-0.160	-0.160
63	9.130	-0.190	-0.200	-0.180	-0.220
64	8.210	-0.050	-0.040	0.390	-0.080
65	8.100	0.680	1.150	1.450	2.190
66	8.000	0.810	0.930	0.960	1.410
67	7.490	0.340	0.640	0.790	0.540
68	6.990	-0.420	-0.420	0.160	-1.810
69	6.890	-0.650	-0.180	0.090	-1.160
70	6.430	-0.170	0.170	0.060	-0.110
71	5.900	0.380	0.380	0.240	0.450
72	5.750	0.330	0.300	0.450	0.370
73	5.689	0.280	0.610	0.140	-0.150
74	5.380	-0.820	-0.060	0.070	-1.560
75	5.290	-1.580	-0.820	0.370	-2.690
76	5.150	-0.170	0.240	3.370	0.070
77	4.790	0.840	0.230	1.000	-1.340
78	4.754	2.340	0.990	1.870	3.160
79	4.700	1.380	1.230	0.470	1.680
80	4.270	0.680	0.230	-0.050	-1.220
81	4.094	-0.460	-0.840	-0.190	-4.230
82	3.767	-6.000	-5.240	-8.490	-1.010
83	3.757	-9.400	-9.410	-9.400	-1.380
84	3.734	-9.400	-9.400	-9.400	-1.010
85	3.729	-9.400	-9.400	-9.400	-1.880
86	3.430	-0.940	1.820	-1.110	3.580
87	3.400	-0.310	-2.260	-2.700	-4.490
88	3.270	2.150	3.050	1.450	5.320
89	2.800	0.300	0.120	0.290	-0.220
90	2.600	-0.140	-0.110	-0.130	0.210
91	2.020	-0.070	-0.110	-0.140	0.230
92	1.710	0.510	0.490	0.530	0.350
93	1.330	-0.030	-0.090	-0.130	-0.250
94	0.730	-0.320	-0.370	-0.270	-0.230
95	0.440	-0.190	-0.190	-0.170	0.200
96	0.160	0.000	0.000	0.000	0.000

BUCKEYE ROAD

6.3.2 Model II Results

Table 6.3 lists the bed changes associated with the four hydrologic data that represent four sediment return periods. The incorporation of the eight (8) mining sites along the river predictably exhibit more dynamic response along the river in terms of aggradation and degradation. As observed, the degradation response of the three (3) locations identified in Model I is carried over in Model II. The mining sites which have been well-protected from degradation tend to fill-up the mining pits extensively as much as the pit depth at some locations. Mining pit depths allowed at these mining locations range from 15.0 feet to 40.0 feet.

Regardless of flow magnitudes used, a degradation process occurs extensively downstream of the mining sites.

Table 6.3 - Bed changes associated to the four hydrologic data [Model II]

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year	
1	33.820	-1.230	-2.570	-4.260	-4.770	
2	33.410	-0.570	-0.850	-1.130	-1.860	
3	32.998	-5.150	-6.290	-6.870	-8.670	HIGHWAY 74
4	32.984	-4.870	-5.070	-5.320	-7.060	
5	32.860	1.190	1.460	1.210	2.030	
6	32.430	0.210	0.230	0.430	0.570	
7	31.860	0.070	0.220	0.470	0.740	
8	31.390	-0.710	-1.130	-1.520	-0.500	
9	30.820	0.060	0.090	0.200	-0.420	
10	30.260	-0.130	-0.110	-0.100	-0.100	
11	30.070	-0.170	-0.310	-0.460	-0.340	
12	29.800	1.330	1.690	1.240	0.250	
13	29.611	-0.220	-0.330	-0.980	-0.650	
14	29.540	-0.270	-0.430	-0.260	-0.140	
15	29.040	0.110	0.160	0.320	0.140	
16	28.670	-0.200	-0.150	-0.120	-0.050	
17	28.120	-0.130	-0.160	-0.410	-0.810	
18	27.680	-0.180	-0.200	-0.190	-0.120	
19	27.030	-0.070	-0.100	-0.110	-0.120	
20	26.730	0.030	-0.050	-0.110	-0.150	
21	26.290	-0.210	-0.200	-0.160	-0.160	
22	25.860	-0.820	-0.690	-0.180	-0.090	
23	25.590	0.710	0.530	0.440	0.570	
24	25.370	-0.100	-0.120	-0.190	-0.820	
25	24.900	0.030	0.030	0.000	0.200	
26	24.540	-1.940	-1.990	-1.950	-2.250	
27	24.491	0.000	0.000	0.000	0.000	
28	24.468	0.000	0.000	0.000	0.000	
29	24.365	18.150	26.890	37.640	38.680	
30	24.350	0.000	0.000	0.000	0.010	
31	24.193	0.000	0.000	0.000	0.000	
32	24.170	0.000	0.000	0.000	0.000	
33	24.085	0.230	0.380	0.850	21.330	
34	24.070	0.000	0.000	0.000	0.000	
35	23.874	0.000	0.000	0.000	0.000	
36	23.851	0.000	0.000	0.000	0.000	
37	23.694	0.430	0.830	1.750	3.630	
38	23.571	0.000	0.040	0.140	0.420	
39	23.365	0.000	0.000	0.000	0.000	
40	23.350	0.000	0.000	0.000	0.000	
41	22.790	-1.400	-2.140	-3.380	-3.850	
42	22.365	0.000	0.000	0.000	0.000	
43	22.320	0.000	0.000	0.000	0.000	
44	22.130	9.650	13.380	23.150	25.700	
45	22.107	0.000	0.000	0.000	0.000	
46	21.850	0.000	0.000	0.000	0.000	
47	21.818	0.000	0.000	0.000	0.000	
48	21.773	0.120	1.010	1.730	3.030	

Table 6.3 - Model II results (continued...)

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year	
49	21.760	0.030	0.350	0.890	1.450	
50	21.680	0.000	0.020	0.150	0.490	
51	21.657	0.000	0.010	0.050	0.190	
52	21.523	0.000	0.000	0.000	0.000	
53	21.500	0.000	0.000	0.000	0.000	
54	21.420	-5.980	-6.380	-9.500	-9.500	
55	21.010	1.300	1.500	0.940	0.670	
56	20.933	0.000	0.000	0.000	0.000	
57	20.920	0.000	0.000	0.000	0.000	
58	20.657	10.740	15.430	19.570	17.760	
59	20.640	0.050	0.390	1.540	2.900	
60	20.577	0.000	0.000	0.000	0.000	
61	20.563	0.000	0.000	0.000	0.000	
62	20.550	0.000	0.000	0.000	0.000	
63	20.240	0.020	0.110	0.730	2.700	
64	19.953	0.000	0.000	0.000	0.000	
65	19.944	0.000	0.000	0.000	0.000	
66	19.890	-4.480	-8.920	-9.500	-9.500	
67	19.440	0.420	2.500	1.490	1.130	
68	18.920	-0.200	-0.800	-1.050	-2.090	
69	18.240	-0.100	-0.040	0.010	0.460	
70	17.760	0.030	-0.070	-0.080	-0.120	
71	17.380	0.870	0.580	0.400	0.920	
72	16.910	-0.560	-2.570	-3.490	-3.930	
73	16.450	-3.870	-3.350	-5.770	-6.320	GRAND AVE
74	16.446	0.130	-2.420	-8.670	-8.810	
75	16.420	1.740	2.330	1.830	1.370	
76	15.980	0.090	1.080	1.630	2.240	
77	15.510	-2.430	-1.200	-1.780	-2.530	
78	15.320	-4.250	-2.490	-1.050	0.280	
79	15.303	6.960	11.440	11.190	11.000	
80	15.063	9.320	7.540	7.360	7.480	
81	14.940	0.000	0.340	0.230	0.010	
82	14.932	0.000	0.000	0.000	0.000	
83	14.850	-1.950	-2.610	-6.040	-8.640	
84	14.412	0.000	0.000	0.000	0.000	
85	14.380	0.000	0.000	0.000	0.000	
86	13.855	1.380	3.690	10.370	16.320	
87	13.810	0.000	0.000	0.000	0.000	
88	13.330	-0.150	-1.150	-1.140	-1.250	
89	12.380	-0.180	-0.160	-0.100	-0.060	
90	11.800	-0.240	-0.720	-0.420	-0.210	
91	11.520	-1.440	-1.660	-1.260	-1.340	
92	11.340	-0.160	-0.240	-0.260	-0.340	
93	11.010	0.430	1.940	0.860	0.450	
94	10.720	0.400	0.220	0.160	0.200	
95	10.530	-0.100	-0.110	-0.120	-0.110	
96	9.900	-0.180	-0.170	-0.170	-0.170	
97	9.130	-0.180	-0.190	-0.180	-0.210	
98	8.210	-0.040	-0.050	0.040	-0.070	
99	8.100	0.170	0.740	0.820	1.190	

Table 6.3 - Model II results (continued..)

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year	
100	8.000	0.500	0.870	0.790	0.990	
101	7.490	0.120	0.310	0.510	0.080	
102	6.990	-0.320	-0.560	0.110	-1.740	
103	6.890	-0.770	-0.320	-0.100	-1.310	
104	6.430	-0.170	-0.050	0.020	-0.110	
105	5.900	0.160	0.410	0.240	-0.160	
106	5.750	0.300	0.270	0.040	0.340	
107	5.689	0.230	0.550	0.300	-0.070	
108	5.380	-0.860	-0.010	0.070	-1.740	
109	5.290	-1.280	-0.710	0.120	-2.850	
110	5.150	-0.200	0.100	1.590	-0.100	
111	4.790	0.490	0.410	0.320	0.070	
112	4.754	2.130	1.400	1.740	2.100	
113	4.700	1.270	1.100	0.430	1.380	
114	4.270	0.430	0.200	-0.060	-1.870	
115	4.094	-0.630	-0.880	-0.190	-4.450	
116	3.767	-7.360	-6.390	-8.490	-2.310	
117	3.757	-9.400	-9.400	-9.400	-1.850	BUCKEY ROAD
118	3.734	-9.400	-9.400	-9.400	-3.950	
119	3.729	-9.400	-9.400	-9.400	-2.940	
120	3.430	-0.880	1.620	-1.540	2.680	
121	3.400	-0.010	-1.860	-2.440	-6.470	
122	3.270	2.060	3.020	1.490	4.880	
123	2.800	0.300	0.210	0.320	-0.180	
124	2.600	-0.150	-0.100	-0.130	0.340	
125	2.020	-0.070	-0.100	-0.140	0.210	
126	1.710	0.480	0.520	0.530	0.300	
127	1.330	-0.030	-0.090	-0.150	-0.250	
128	0.730	-0.310	-0.350	-0.270	-0.230	
129	0.440	-0.190	-0.180	-0.160	0.150	
130	0.160	0.000	0.000	0.000	0.000	

6.3.3 Model III Results

Table 6.4 lists the degree of aggradation or degradation associated to the four hydrologic data of different return periods. The extent of scouring and deposition at the two locations of channel improvements is evident.

6.3.3.1 Channel Improvement-I - The location identified for channelization covers the stations from Stations 8.21 to 13.33. This improvement channel is under degradation because it is located immediately after Mining Site A. Degradation occurs because the channel is reduced to 1000-ft wide permitting higher flow velocities at the improvement site.

6.3.3.2 Channel Improvement-II - The location associated to channel improvement II is comprised of eight (8) stations (i.e. Stations 16.45 to 19.89). Similar to channel improvement-I, Channel improvement-II is located downstream of a mining site (i.e. Mining Site C). For all the hydrologic data used, large degradation is encountered immediately downstream of Mining Site C.

Table 6.4- Bed changes associated to the four hydrologic data [Model III]

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year
1	33.820	-1.320	-2.560	-4.290	-3.790
2	33.410	-0.610	-0.790	-1.030	-2.030
3	32.998	-5.650	-6.400	-7.640	-9.210
4	32.984	-5.230	-4.970	-6.630	-8.820
5	32.860	1.460	1.380	1.660	2.150
6	32.430	0.180	0.270	0.390	0.570
7	31.860	0.080	0.220	0.490	0.730
8	31.390	-0.700	-1.130	-1.610	-0.740
9	30.820	0.070	0.080	0.250	-0.370
10	30.260	-0.120	-0.070	-0.230	-0.080
11	30.070	-0.170	-0.400	-0.410	-0.390
12	29.800	1.300	1.680	1.130	0.370
13	29.611	-0.140	-0.340	-1.030	-0.620
14	29.540	-0.270	-0.420	-0.210	-0.090
15	29.040	0.070	0.160	0.340	0.130
16	28.670	-0.200	-0.150	-0.130	-0.060
17	28.120	-0.130	-0.160	-0.410	-0.770
18	27.680	-0.180	-0.190	-0.190	-0.120
19	27.030	-0.060	-0.100	-0.110	-0.120
20	26.730	0.020	-0.050	-0.100	-0.150
21	26.290	-0.210	-0.200	-0.160	-0.160
22	25.860	-0.850	-0.610	-0.180	-0.100
23	25.590	0.750	0.490	0.460	0.580
24	25.370	-0.100	-0.110	-0.190	-0.790
25	24.900	0.010	0.010	0.000	0.180
26	24.540	-2.040	-2.140	-1.950	-2.460
27	24.491	0.000	0.000	0.000	0.000
28	24.468	0.000	0.000	0.000	0.000
29	24.365	18.430	26.840	35.610	38.450
30	24.350	0.000	0.000	0.000	0.010
31	24.193	0.000	0.000	0.000	0.000
32	24.170	0.000	0.000	0.000	0.010
33	24.085	0.260	0.400	1.570	17.800
34	24.070	0.000	0.000	0.000	0.000
35	23.874	0.000	0.000	0.000	0.000
36	23.851	0.000	0.000	0.000	0.000
37	23.694	0.530	1.100	2.720	6.330
38	23.571	0.000	0.050	0.140	0.400
39	23.365	0.000	0.000	0.000	0.000
40	23.350	0.000	0.000	0.000	0.000
41	22.790	-1.430	-2.010	-3.440	-4.150
42	22.365	0.000	0.000	0.000	0.000
43	22.320	0.000	0.000	0.000	0.000
44	22.130	9.230	11.880	23.810	26.510
45	22.107	0.000	0.000	0.000	0.000
46	21.850	0.000	0.000	0.000	0.000
47	21.818	0.000	0.000	0.000	0.000
48	21.773	0.360	1.790	4.380	7.610

Table 6.4 - Model III results (continued...)

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year
49	21.760	0.040	0.390	1.120	1.650
50	21.680	0.000	0.020	0.170	0.540
51	21.657	0.000	0.010	0.050	0.200
52	21.523	0.000	0.000	0.000	0.000
53	21.500	0.000	0.000	0.000	0.000
54	21.420	-6.100	-6.430	-9.500	-9.500
55	21.010	1.150	1.340	1.280	0.670
56	20.933	0.000	0.000	0.000	0.000
57	20.920	0.000	0.000	0.000	0.000
58	20.657	11.090	15.450	19.160	14.010
59	20.640	0.050	0.420	1.340	2.590
60	20.577	0.000	0.000	0.000	0.000
61	20.563	0.000	0.000	0.000	0.000
62	20.550	0.000	0.000	0.000	0.000
63	20.240	0.020	0.150	0.900	2.720
64	19.953	0.000	0.000	0.000	0.000
65	19.944	0.000	0.000	0.000	0.000
66	19.890	-9.500	-9.500	-9.500	-9.500
67	19.440	2.240	1.880	1.230	0.790
68	18.920	-0.200	-0.660	-0.850	-2.260
69	18.240	-0.070	-0.070	-0.020	0.230
70	17.760	0.430	-0.020	-0.540	-1.180
71	17.380	0.120	0.260	0.150	0.430
72	16.910	0.010	0.250	-0.140	-0.390
73	16.450	0.050	-1.000	-8.960	-8.960
74	16.446	-2.050	-2.840	-3.340	-5.670
75	16.420	0.400	0.540	4.000	2.810
76	15.980	-0.100	0.060	2.150	1.470
77	15.510	-2.790	-2.980	-1.910	-2.360
78	15.320	-4.630	-2.700	-0.970	-0.430
79	15.303	8.740	10.400	10.550	11.220
80	15.063	8.530	7.190	7.740	6.150
81	14.940	0.000	0.000	0.010	0.010
82	14.932	0.000	0.000	0.000	0.000
83	14.850	-1.960	-2.840	-8.290	-8.870
84	14.412	0.000	0.000	0.000	0.000
85	14.380	0.000	0.000	0.000	0.000
86	13.855	1.410	3.570	12.000	15.330
87	13.810	0.000	0.000	0.000	0.000
88	13.330	-0.170	-0.880	-1.610	-1.870
89	12.840	-0.190	-0.150	-0.120	0.030
90	12.380	-1.550	-1.850	-2.250	-4.790
91	11.800	-0.190	-0.130	-0.040	0.090
92	11.520	-2.220	-2.280	-2.810	-5.150
93	11.340	-0.030	-0.010	-0.410	0.570
94	11.010	0.910	0.670	0.900	1.770
95	10.720	0.870	0.820	0.960	1.050
96	10.530	-0.090	-0.160	-0.390	-0.670
97	9.900	-0.190	-0.720	-1.070	-1.150
98	9.130	-0.200	-0.510	-1.190	-1.950
99	8.730	-0.200	-0.200	-0.180	-0.090

Table 6.4 - Model III results (continued...)

N	Mile Number	Simulated Bed Changes (ft) 50-year	100-year	200-year	500-year
100	8.210	-0.010	0.100	0.910	1.860
101	8.100	0.310	1.240	1.260	1.570
102	8.000	0.430	0.710	0.790	1.070
103	7.490	0.230	0.480	0.650	0.820
104	6.990	-0.440	-0.490	0.940	-1.590
105	6.890	-0.710	-0.190	-0.410	-0.650
106	6.430	-0.170	-0.050	-0.160	-0.120
107	5.900	0.170	0.440	0.070	0.470
108	5.750	0.310	0.550	0.110	0.350
109	5.689	0.210	0.390	-0.730	-0.390
110	5.380	-0.920	0.040	-2.070	-1.700
111	5.290	-1.480	-0.850	-3.310	-3.180
112	5.150	-0.160	0.130	0.620	0.620
113	4.790	0.590	0.180	-0.700	0.370
114	4.754	2.130	1.900	3.130	1.930
115	4.700	1.300	0.910	1.740	1.480
116	4.270	0.510	0.260	0.180	-1.980
117	4.094	-0.570	-0.710	-4.020	-4.550
118	3.767	-6.900	-6.310	-2.500	-1.770
119	3.757	-9.400	-9.410	-2.020	-1.470
120	3.734	-9.400	-9.410	-2.180	-1.270
121	3.729	-9.400	-9.410	-2.780	-2.230
122	3.430	-0.680	2.860	2.460	3.050
123	3.400	-0.980	1.520	-5.250	-6.680
124	3.270	2.350	1.400	3.390	5.100
125	2.800	0.300	0.400	0.410	-0.200
126	2.600	-0.140	-0.130	-0.040	0.230
127	2.020	-0.070	-0.100	-0.140	-0.230
128	1.710	0.500	0.510	0.750	0.340
129	1.330	-0.030	-0.090	-0.120	-0.250
130	0.730	-0.320	-0.350	-0.230	-0.230
131	0.440	-0.190	-0.190	-0.010	0.200
132	0.160	0.000	0.000	0.000	0.000

6.4 Comparison with Previous Studies

A study of the Agua Fria River in 1986 - particularly the reach between Jomax Road and Bell Road - described Yang's streampower and Shield's functions as the more 'appropriate' sediment transport functions applicable for the Agua Fria study **[Dust, et al., 1986]**. In an earlier study, however, **Dust (1982)** had used the Engelund-Hansen relationship in the sedimentation modeling of the Agua Fria River. It is the high transport rates of the Engelund-Hansen formula that motivated its use for the said study.

A hydraulic and geomorphic analysis of the Agua Fria River conducted by **Simons, Li & Associates, Inc.**, in 1983 employed the Meyer-Peter and Muller bed load function in combination with Einstein integration of the suspended bed-material load to estimate the sediment transport capacity in the river. The justification presented by **Simons, Li & Associates, Inc. (1983)** in using these equations is due to their apparent success in modeling other rivers having similar bed characteristics as the Agua Fria River.

Another sedimentation study conducted by **Water Resources Associates, Inc., (1986)** for the Agua Fria River - particularly aimed at determining the effects of gravel mining below the Lower Buckeye Road - had used Meyer-Peter and Muller formula to estimate the bed load and the Einstein integration of the suspended bed material load to estimate the suspended load. However, there were no basis presented to merit or justify the use of these functions in the study.

The library of the most recent version of **HEC-6** code does not, however, include Engelund-Hansen, Einstein, and Shield's relations among the sediment transport function options. It is, therefore, not possible to evaluate the performance of these three relations against the 'overall best' function - combination of Toffaleti and Schoklitsch formulas as the most appropriate descriptor of the sediment transport dynamics for the modeling of the Agua Fria River.

In summary, the previous studies conducted for the Agua Fria River are listed in **Table 6.5.**

Table 6.5 - Current and previous sedimentation studies of the Agua Fria River

Author (Year)	Study Reach/Length	Sediment Transport Function/Code
(1) David Dust (1982)	Bell Road-Jomax Road (Mile 18.925 to Mile 25.59) Reach length = 6.7 miles;	Engelund-Hansen formula using HEC-6 code (HEC, 1977)
(2) Simons, Li & Assoc., Inc, (1983)	Gila Confluence -Glendale Avenue (Mile 0.00 to Mile 11.4); Reach length = 11.4 miles	Meyer-Peter and Muller for bed load computation and Einstein Integration for suspended load computation using QUASED code (Simons, & Li, Inc., Inc. (1981);
(3) Water Resources Assoc., Inc. (1986)	Gila Confluence to Buckeye Road (Mile 0.00 to Mile 3.734); Reach length = 3.734 miles.	Meyer-Peter and Muller for bed load computation and Einstein Integration for suspended load computation. **
(4) Dust, et. al. (1986)	Bell Road-Jomax Road (Mile 18.925 to Mile 25.59)	Yang's streampower and Shield's function using HEC-6 code (HEC,1977);
(5) A.S.U. (1993)	Gila Confluence to New Waddell Dam (Mile 0.00 to Mile 33.82); Reach length = 34.00 miles;	Toffaleti and Schoklitsch formula using HEC-6 code (HEC, 1991);

Note: ** The study used three methods: (i) local scour was estimated using armor control method, Neil method, and Shen method; (ii) regional method scour was computed by equilibrium slope method; and (iii) head-cut migration was estimated using a simplified routing scheme.

VII CONCLUSIONS AND RECOMMENDATIONS

7.1 Calibration Study

(1) The sediment transport relation provided by Toffaleti and Schoklitsch formulas [MTC=9] described very closely the transport dynamics along the study reach from Bell Road to Jomax Road. The function provided the most stable output among the ten (10) sediment transport functions tested in relation to the observed thalweg elevations [i.e., 1989-data]. This performance of closely predicting the sediment movements along the study reach merits its consideration for the sedimentation modeling of the entire Agua Fria River.

(2) The selection of the most appropriate sediment transport for the Agua Fria River is more extensive under this study than in previous studies conducted. Extensive because all the sediment transport function options in the most recent version of HEC-6 code (HEC, 1991) were used in the selection process.

(3) The performance by Duboys gave the least deviation (criterion I) among the ten (10) sediment transport functions evaluated (see **Table 6.1**); however, the formula exhibited very poor performance under criterion II which indicates that Duboys gave excellent predictions at some stations while also giving poor predictions at other stations.

(4) The sediment transport relation provided by Meyer-Peter and Muller offers a good alternative to Toffaleti and Schoklitsch formula for the modeling of the Agua Fria River. This conclusion is based on the performance of Meyer-Peter and Muller formula through the two criteria used in the selection process (see **Table 6.1**). This transport function had been used twice in the previous sedimentation modeling studies for Agua Fria River (i.e. **Simons, Li and Assoc., Inc, 1983**; and **Water Resources Assoc., Inc., 1986**) and so, there is a good level of confidence to use it as the most appropriate alternative for Toffaleti and Schoklitsch formula.

7.2 Previous Sedimentation Modeling for Agua Fria River

(5) Previous sedimentation studies of the Agua Fria River had used other sediment transport functions to model the sediment transport dynamics along the river. These transport functions include: Yang's streampower function, Shield's formula, Meyer-Peter and Muller, Engelund and Hansen, and Einstein integration method. In summary, these studies are listed in **Table 6.5.** Because the river reaches are different for these studies, and because of the inhomogeneity of the hydraulic characteristics along the river, selection of sediment transport functions were made based on the most pronounced significant factor considered at the time of modeling.

7.3 Sensitivity Analysis

(6) The selected transport function for the modeling of the Agua Fria River (i.e. Toffaleti and Schoklitsch) is not very sensitive to the changes in the Manning's coefficient, n. This demonstrates that the value of n is not a critical parameter in the use of Toffaleti and Schoklitsch formula for the modeling of Agua Fria River. Other functions tested (i.e. Ackers and White, Meyer-Peter and Muller, and Toffaleti/Meyer-Peter and Muller formulas), however, have shown pronounced sensitivity to Manning's n. From the four (4) transport functions analyzed, Toffaleti/Meyer-Peter and Muller formula exhibited the greatest sensitivity to Manning's n.

(7) Realistically, as expected, all the sediment transport functions tested exhibited significant sensitivity to the inflowing sediment load and sediment gradation data.

7.4 Model I

(8) Pronounced degradation is observed at the most upstream stations (i.e. Stations 33.82, 33.41, 32.998, and 32.984) for the four (4) sets of hydrologic data used. The cross-section geometry of these stations are relatively constricted permitting significant degradation at these sites. Station 32.984, which defines the cross-section geometry of the Highway 74 bridge needs bed protection made up of boulders. One measure to effectively reduce such large degradation at these sites is through channelization to widen the channel.

(9) Another site which is extensively degraded is at Grand Avenue area (i.e., Stations 16.446, 16.450, and 16.910) which comprises of two bridge crossings constructed about 25 feet apart. These bridges are the Santa Fe Railroad bridge (Station 16.450) and Grand Avenue bridge (Station 16.446). The channel upstream of these two stations obviously needs widening and improvement to reduce the degradation. This Grand Avenue area, particularly around the location of the two bridge crossings (Stations 16.45 and 16.446) needs large boulders as streambed protection.

(10) A very serious location that is badly degraded is at the Buckeye Road area (Stations 3.729, 3.734, 3.767, 4.094) where two bridge crossings are also located. These two bridges are the Buckeye Road bridge (Station 3.734) and the South Pacific Railroad bridge (Station 3.767). Like the other sites identified earlier to have serious degradation, the bridge locations (Stations 3.734 and 3.767) have to be protected by boulders or large rocks. Channelization is also important upstream and downstream of these bridge stations.

(11) The bed profile at other locations are not substantially changed except at Stations 11.01 and 3.27 where aggradation occurs. Improvement of the channel along the braided areas by dredging or by channelization helps improve the hydraulic condition of the channel, thereby, reducing the aggradation process .

7.5 Model II

(12) The three (3) locations identified under Model I which had serious degradation are carried over under Model II. These sites are :

Site 1 - This site is comprised of the most upstream stations of the river reach (i.e. Stations 33.82, 33.41, 32.998, and 32.984).

Site 2 - This site is comprised of the stations at Grand Avenue area that includes two bridge crossings (i.e. Stations 16.446, 16.45, and 16.91);

Site 3 - This site is comprised of the stations at Buckeye Road area that includes two bridge crossings (i.e. Stations 3.729, 3.734, 3.757 and 3.767).

(13) The stations where substantial aggradation (or deposition) occurs are predominantly located at mining sites. Since the mining sites are protected from degradation, sediment deposition, as much as the mining pit depth, is observed. observed because the sediments tend to fill up the pit. The mining sites that exhibited such substantial aggradation are listed as follows:

Site A - This mining site includes Stations 13.81, 13.855, 14.38, and 14.412. A large deposition occurs at higher flows;

Site B - This mining site includes Stations 14.932, 14.940, 15.063, 15.303, and 15.320. A serious case of degradation occurs at the immediate downstream station (i.e. Station 14.850);

Site C - This mining site includes Stations 19.944, 19.953, 20.24, 20.550, 20.563, 20.577, 20.64, 20.657, 20.920, and 20.933. The immediate station downstream of site C (i.e., Station 19.89) show serious degradation which could be called a head-cut;

Site D - The mining site is comprised of Stations 21.657, 21.680, 21.76, 21.773, and 21.818. No serious aggradation is encountered at the site because of the presence of mining site E which is laterally situated alongside site D.

Site E - This mining site includes the Stations of 21.50, 21.523, 21.657, 21.68, 21.76, 21.773, 21.818, and 21.85. No pronounced aggradation process is observed for similar reason as stated in site D.

Site F - This mining site is consisted of Stations 22.107, 22.13, 22.32, and 22.365. Serious aggradation occurs at higher flows in this site, while at the same time a serious degradation occurs at the immediate upstream station (i.e. Station 22.79);

Site G - This mining site is comprised of Stations 23.35, 23.365, 23.571, 23.694, 23.851, and 23.874 . No pronounced aggradation occurs under low flows;

Site H - The mining site is comprised of three (3) mining pits with 14 stations (i.e. 23.35, 23.365, 23.571, 23.694, 23.851, 23.874, 24.070, 24.085, 24.17, 24.193, 24.35, 24.365, 24.468, 24.491). The most upstream mining pit aggrades seriously for all flows while the middle mining pit is aggraded only at higher flows. A slight head-cut migration is observed at the immediate upstream station of site H (i.e. Station 24.54).

7.5 Model III

(14) The Improvement Channel-I, which is situated downstream of mining site A is comprised of 14 stations (i.e Stations 8.10, 8.21, 8.73, 9.13, 9.90, 10.53, 10.72, 11.01, 11.34, 11.52, 11.80, 12.38, 12.84, and 13.33). Pronounced degradation occurs at the upstream stations because the channel width had been reduced significantly from mining site A to the site of Improvement Channel-I. Such channel width reduction permits scouring specially at the upstream stations because of the increased flow velocity. To reduce the occurence of degradation at this site, the upstream stations have to be covered with boulders for bed protection;

(15) The Improvement Channel-II, which is also situated downstream of a mining site (i.e. Mining site C) is comprised of eight (8) stations (i.e. Stations 16.45, 16.91, 17.38, 17.76, 18.24, 18.92, 19.44, and 19.89). Identical to Improvement Channel-I, a serious degradation occurs at the most upstream station of Improvement Channel-II. This is because the channel width is reduced significantly at Station 18.89.

VIII REFERENCES

Arizona State University [ASU] (1992), Gradation Analysis of Sediment Samples Collected at Various Locations in the Agua Fria River, Conducted by the Civil Engineering Department, ASU, January-February, 1992.

ABC Sand & Rock Co., (1991), A Laboratory Report for Three Sediment Data *[Courtesy of the Maricopa Flood Control District]*.

Barrett Consulting Group, Inc., (1987), Development plan map of the mining site to be operated by Salt River Pima Maricopa Indian Community, Project No. 72500, Drawn on September 21, 1987.

Barrett Consulting Group, Inc., (1987), Development plan map of the mining site to be operated by Finley Construction Corporation, Project No. ____.

Barrett Consulting Group, Inc., (1987), Development plan map of the mining site to be operated by Ideal Rock Products, Project No. 73200, Drawn on November 10, 1987.

Barrett Consulting Group, Inc., (1987), Development plan map of the mining site to be operated by Finley Construction Corporation, Project No. 72001, Drawn on December 28, 1987.

Barrett Consulting Group, Inc., (1988), Development plan map of the mining site to be operated by Gravel Resources Company, Project No. 72200, Drawn on January 21, 1988.

Dust, D. W., (1982), Data Development, HEC-6 Computations, and Analysis of the Results for the Agua Fria River - Arizona, submitted to Prof. Paul Ruff as a course requirement, Civil Engineering Department, Arizona State University, August 1982 (unpublished).

Dust, David W., (1983), Computer Modeling of Bull Creek with HEC-6, ***A Final Report.***, submitted to the Environmental Resources Engineering Faculty, Humboldt State University, May, 1983, pp.44.

Dust, D.W., M.T. Bowers, and P. F. Ruff, (1986), Application of HEC-6 to Ephemeral Rivers of Arizona, ***Report Number: FHWA/AZ86/214.*** Prepared for Arizona Department of Transportation, January 1986, pp.159.

Hoggan, D. H., (1989), Computer-Assisted Floodplain Hydrology and Hydraulics, McGraw-Hill Publishing Company, New York, USA.

Hydrologic Engineering Center, (1977), HEC: Scour and Deposition in Rivers and Reservoirs, User's Manual, U.S. Army Corps of Engineers, 1977.

Hydrologic Engineering Center, (1991), HEC-6: Scour and Deposition in Rivers and Reservoirs, User's Manual, U.S. Army Corps of Engineers, June 1991.

Jerry R. Jones & Associates, Inc., (1989), Agua Fria River Flood Insurance Study, Contract FCD 87-2, JJA Job No. 286-080.01, Prepared for Flood Control District of Maricopa County, January, 1989, pp. 40.

Lemme Engineering, Inc., (1986), Site plan and development map for the mining site to be operated by Lake End Sand and Gravel Company, Drawn on November, 1986.

Lemme Engineering, Inc., (1987), Development plan map of the mining site to be operated by Blue Circle West, drawn on December, 1987.

Ryan, K., (1991), Sediment Sample Gradation Study of a Selected Site in the Agua Fria River Bed., A Report, Submitted as a Requirement for CEE 590, Civil Engineering Department, Arizona State University, June, 1991.

Sergent, Hauskin & Beckwith [SHB] (1980), A Compilation of Test Borings Taken at Various Bridge Locations in the Agua Fria River, *[Courtesy of the Maricopa Flood Control District]*.

Sergent, Hauskin & Beckwith [SHB] (1991), A Compilation of Test Borings Taken at the Agua Fria River Between Indian School and Camelback Roads, *[Courtesy of the Maricopa Flood Control District]*.

Simons, Li & Assoc., Inc. (1983), Hydraulic and Geomorphic Analysis of the Agua Fria River, *Proj. No. AZ-MC-05.* A Report submitted to the Flood Control District of Maricopa County, Arizona, May 16, 1983.

Stevens, Jr., H. H. and C. T. Yang, (1989), Summary and Use of Selected Fluvial Sediment-Discharge Formulas, *Water Resources Investigations Report No. 89-4026*, U.S. Geological Survey, Denver, Colorado, USA.

United Metro (UM), (1986), A Laboratory Report of Sediment Data Obtained at Mining Site, *[Courtesy of the Maricopa Flood Control District]*.

U.S. Army Corps of Engineers, (1968), Flood Plain Information Study, Agua Fria River, Maricopa County, Arizona, *Report* by U.S. Army Corps of Engineers - Los Angeles District, California, March 1968.

U.S. Army Corps of Engineers, (1990), HEC-6: Scour and Deposition in Rivers and Reservoirs, *User's Manual*, Hydrologic Engineering Center, Davis, California, U.S.A., September, 1990.

U.S. Army Corps of Engineers, (1991), HEC-6: Scour and Deposition in Rivers and Reservoirs, *User's Manual*, June 1991 Release.

Water Resources Associates, Inc., (1986), Agua Fria River Sedimentation Study, submitted to Development Engineering, Phoenix, Arizona, May 30, 1986.