Low Flow Channel Design Analysis for Rio Salado (Salt River), Arizona

TECHNICAL APPENDICES II (4 – 7)

Prepared for

U.S. Army Corps of Engineers, Los Angeles District

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1. INTRODUCTION

Sediment transport simulations for the existing conditions and proposed low flow channel in the Phoenix Reach of the Salt River have been performed using HEC-6T, Version 5.13.05, dated June 29, 1999. HEC-6T is a one-dimensional movable boundary open channel flow numerical code designed to simulate and predict changes in river profiles resulting from scour and/or deposition over long time periods. HEC-6T is an enhanced version of HEC-6 (US Army Corps of Engineers, 1993) written by William A. (Tony) Thomas, who developed the original HEC-6 model. The inputs for the HEC-6T model include geometric data, sediment data and hydrologic data. The following sediment transport models have been developed for both the existing and proposed conditions:

1. Long-term sediment transport simulations with a 25-year hydrograph.

2. Simulations of the 100-, 50- and 25-year peak flood events before the 25-year hydrograph.

3. Simulations of the 100-, 50- and 25-year peak flood events after the 25-year hydrograph.

The sensitivity of the model results with respect to the inflowing sediment load and sediment transport method has also been evaluated. The HEC-6T model inputs and results are presented in the following sections.

2. HEC-6T MODEL INPUTS

The HEC-6T model inputs include geometric data, sediment data and hydrologic data. The geometric data include cross section geometry, Manning *n* values, deposition and erosion limits and depth of the bed sediment reservoir. The bed gradations, sediment transport method and inflowing sediment load are part of the sediment data. The hydrologic data include the discharge-elevation rating curve and discharge hydrographs. The inputs and associated modeling assumptions are described in the following sections.

2.1. GEOMETRIC DATA

2.1.1. EXISTING CONDITIONS GEOMETRIC DATA

The cross section geometry used in the existing conditions HEC-6T model is derived from a modified HEC-RAS cross section geometry (see Hydraulic Analysis Appendix). This geometry differs slightly from the original HEC-RAS geometry. In the original HEC-RAS model, the bank stations are located at the top of the flood control channel levees. For the sediment transport analysis, the bank stations, which determine the channel boundaries, are relocated to the approximate existing low flow channel. The channel top widths with the relocated bank stations vary from 200 to 600 feet. The channel hydraulics determine sediment transport rates. If the original bank stations were used, the entire cross section would have been used to determine channel hydraulics, resulting in unreasonably low velocities for low to moderate discharges. This would have resulted in an underestimation of the actual sediment transport.

In the modified HEC-RAS model, the flood control channel is divided into three strips: left overbank (from the left most conveyance area to the left bank station), channel, and right overbank (from right bank station to the right most conveyance area). Cross section orientations are based upon left to right looking in the downstream direction. The overbank areas beyond the original channel banks are eliminated because the flow never overtops the original bank stations; the overbank reach lengths are adjusted accordingly. The cross section plots, which include the adjusted bank stations, are included in the Hydraulic Analysis Appendix. The Manning *n* value is constant across the channel as was in the original model. The difference in the 100-year water surface profiles between the original HEC-RAS model and the model with the adjusted bank stations is less than 4 percent of the flow depth.

The Salt River Reach modeled in HEC-6T extends approximately one mile upstream of the project limits and one mile downstream of the project limits. The upstream cross sections are used to calculate the equilibrium inflowing sediment load. Cross sections are added downstream of the project reach to eliminate boundary effects from the numerical computations in the project area. The number of cross sections used in the HEC-6T model is less than that used in the HEC-RAS model. The number of cross

sections is reduced in order to decrease the computation time and improve computational stability related to sediment continuity. The number of cross sections is thinned to approximately one per 1,000 feet except at locations of existing and proposed grade control structures, at major changes in the bed profile, at points where the channel width significantly changes, at changes in roughness, at locations dictated by hydraulic calibration and at other locations deemed necessary.

At the bridges, most of the friction losses result from pier losses. The bridge pier and deck information is not coded into the HEC-6T geometry since the highest water elevations did not encounter any bridge decks. However, the cross section of the upstream face of each bridge is retained. A list of the cross sections and associated reach lengths used in the HEC-6T model is included in Table 2.1.

The hydraulic results of the HEC-6T model run in fixed-bed mode were compared to the HEC-RAS model with adjusted bank stations (includes all cross sections and bridges). The comparison was performed to identify modifications needed in the sediment model to account for energy losses determined in HEC-RAS that were not determined in HEC-6T (such as bridge losses) and to ensure that the cross section thinning did not significantly alter the hydraulics. The water surface profiles associated with discharges equal to 6,000 cfs, the 12,200 cfs low flow channel design flow, the 5-year peak (20,200 cfs), the 20-year peak (87,000 cfs) and the 100-year peak (166,000 cfs) were compared for both models. Modifications were made in the HEC-6T geometry until the water surface elevation differences did not exceed 6 percent of the flow depth and the channel velocity difference were within 1 foot per second at each cross section. These modifications included the addition of cross sections and minor adjustments to the Manning *n* values at several locations. The NV record was used to change the Manning *n* value with discharge.

The depth of the bed sediment reservoir was set to 20 feet, except at grade control locations, in the HD record. Both the deposition and erosion limits were set at the main channel banks to approximately 10 feet above the channel bottom.

Table 2.1. List of cross sections and reach lengths input in the HEC-6T model.

Cross Section (downstream to upstream)	Downstream Channel Reach Length	Comments
210.64	0.0	Boundary condition rating curve location.
210.83	1009.0	
211.02	998.3	
211.12	507.5	
211.21	493.1	
211.31	523.3	
211.44	675.4	
211.50	310.0	Existing grade control and downstream project limit.
211.53	204.5	Upstream face of 19th Avenue Bridge.
211.63	462.8	
211.76	676.4	Downstream start of the low flow channel cut.
211.86	539.7	
211.98	642.3	
212.12	721.2	
212.16	293.1	
212.27	553.7	
212.345	315.8	Upstream face of conveyor bridge.
212.46	677.8	
212.56	502.7	
212.68	710.1	Upstream face of 7th Avenue Bridge.
212.84	780.4	Low flow channel cut at full depth.
212.93	501.9	
213.03	495.0	
213.11	459.4	
213.26	806.2	Upstream face of Central Avenue Bridge and proposed grade control structure.
213.38	606.5	
213.57	994.0	
213.66	491.1	
213.75	488.8	Upstream face of 7th Street Bridge.
213.85	520.0	
213.95	504.3	
214.14	1003.6	
214.23	494.5	
214.33	507.2	
214.52	997.0	

214.62	543.8	
214.651	150.0	Proposed grade control structure.
214.71	408.6	
214.79	400.2	Upstream face of 16th Street Bridge.
214.90	594.6	
214.99	505.2	
215.09	506.2	
215.125	158.0	Upstream face of conveyor bridge.
215.18	324.0	
215.27	493.3	
215.36	489.2	
215.46	519.8	
215.53	348.2	
215.62	495.4	Downstream end of proposed grade control structure.
215.65	150.0	Upstream end of proposed grade control structure.
215.75	500.7	
215.82	354.3	Upstream face of 24th Street Bridge
215.94	689.8	
216.04	507.8	
216.13	500.5	
216.19	317.6	
216.23	200.0	Full depth low flow channel. Proposed grade control structure.
216.33	490.2	Transition from main channel to low flow channel.
216.38	203.7	Transition from main channel to low flow channel.
216.40	200.0	Downstream sill of existing grade control structure.
216.42	85.0	Upstream sill of existing grade control structure.
216.48	323.3	
216.52	233.3	Upstream face of I-10 Bridge
216.63	523.0	
216.72	508.4	
216.91	1001.6	
217.10	987.9	
217.19	502.5	
217.29	511.8	
217.38	491.6	Cross section used to calculate sediment inflow.
217.48	502.8	Cross section used to calculate sediment inflow.
217.57	481.4	Cross section used to calculate sediment inflow.
217.66	512.7	Cross section used to calculate sediment inflow.
217.76	497.0	Cross section used to calculate sediment inflow.
217.86	512.7	Cross section used to calculate sediment inflow.
217.95	489.8	Cross section used to calculate sediment inflow.

2.1.2. LOW FLOW CHANNEL GEOMETRIC DATA

The cross section geometry used in the HEC-6T model is derived from the low flow channel alternative HEC-RAS cross section geometry. The cross section numbering corresponds to those used in the existing conditions HEC-6T model. The channel geometry is partitioned into five strips representing portions of the cross section with similar Manning *n* values. The five strips are described below:

Left Overbank: from the first coordinate of the cross section to the left bank station of the low flow channel. The Manning *n* value is 0.045 between cross sections 211.76 and 212.68, 0.085 between cross sections 212.84 and 216.23, and 0.045 in the transition zone at cross sections 216.33 and 216.38.

Left Channel Side Slope: from the left bank station to the toe of the left side slope. The Manning *n* value is 0.045 between cross sections 211.76 and 212.68, 0.06 between cross sections 212.84 and 216.23, and 0.035 in the transition zone at cross sections 216.33 and 216.38.

Channel Invert: between the toes of the channel side slope. The Manning *n* value is 0.032.

Right Channel Side Slope: from the toe of the right side slope to the right bank station. The Manning *n* value is 0.045 between cross sections 211.76 and 212.68, 0.06 between cross sections 212.84 and 216.23, and 0.035 in the transition zone at cross sections 216.33 and 216.38.

Right Overbank: from the right bank station to the last coordinate of the cross section. The Manning *n* value is 0.045 between cross sections 211.76 and 212.68, 0.085 between cross sections 212.84 and 216.23, and 0.045 in the transition zone at cross sections 216.33 and 216.38.

For those cross sections beyond the project limits, the channel was also partitioned into five strips, but the Manning *n* values remained the same as in the existing conditions model.

The hydraulic results of the HEC-6T model executed in fixed-bed mode were compared to the results of the HEC-RAS model. The Manning *n* values at several locations were adjusted slightly (using NV records, which varies *n* by discharge) to produce water surface elevations that resulted in less than a 6 percent difference in the flow depth compared to HEC-RAS. The calibration was performed for 6,000 cfs, the low flow channel design flow (12,200 cfs), the 5-year peak (20,200 cfs), the 20-year peak (87,000 cfs) and the 100-year peak (166,000 cfs).

The depth of the bed sediment reservoir was set at 20 feet except at grade control structures. At the grade control structures, hard points are input on the H record at the low flow channel design invert at 216.23, 215.65, & 214.65 and at the overexcavated

depth at 213.26 (Central Avenue). For the low flow channel, the deposition and erosion limits were set inside the bank stations between cross sections 216.23 and 212.84 and then gradually transitioned to the main channel banks between cross sections 212.84 and 211.76 where the low flow channel daylights to the existing flood control channel. For those cross sections beyond the low flow channel limits, the deposition and erosions limits were the same as those in the existing conditions model.

2.2. SEDIMENT DATA

2.2.1. BED SEDIMENT SAMPLES

The US Army Corps of Engineers (the Corps) collected sediment samples at various cross sections along the Salt River just upstream of I-10, in the project area between I-10 and the 19th Avenue Bridge, and just downstream of 19th Avenue. The locations of the sampling sites are included in Table 2.2.

Table 2.2. Bed sediment sampling locations.

CROSS SECTION	NUMBER OF SAMPLE SITES
217.48	2
217.00	2
I-10	
216.33	2
215.94	2
215.56	2
215.09	2
214.71	2
214.14	2
213.57	2
Between 213.11 and 213.03	1
212.93	2
212.37	2
Between 212.12 and 211.98	1
211.98	3
19th Avenue Bridge	
Between 211.98 and 211.86	2
211.41	2
210.93	2

At each site, samples were taken at different depths (layers) down to approximately 16 feet. The Corps performed sieve analyses for grain sizes less than 3

inches. Quantitative measurements were not performed for the larger grain sizes; however, visual estimates of the mass percentage of boulders and cobbles were included in the field notes for most of the samples. Photographs of most of the sampling sites and trenches were also provided by the Corps. The estimates of the amounts of boulders and cobbles included in the field notes seemed to agree with observations from the photographs.

2.2.2. EXISTING CONDITIONS BED GRADATIONS

The gradation of the armored layer in the existing river bed cannot be determined from the Corps' sediment samples. For the sediment transport analysis, the armored layer depth and gradation (also referred to as the active layer) at each cross section were calculated and input on the OF records using the following methodology:

1. Develop composite gradation curves from the Corps' samples from depths between zero to six feet, and input these gradations on the PF records. The largest grain size (d_{max}) in the PF records is 304.8 mm (12 inches). Grain sizes between 304.8 and 0.0725 mm are included in the PF records.

2. Run the HEC-6T model for 30 days at the 5-year peak discharge (20,200 cfs) with the equilibrium inflowing load.

3. Input the active layer depths and bed gradations from Step 2 on the OF record for each cross section.

The gradations input on the PF records were developed using the Corps' sieve analyses and field notes. The percent finer values from the sieve analyses were adjusted by multiplying the measured value by the estimated mass percentage of the material less than 3 inches included in the total sample. For the existing conditions model, composite curves were developed at various locations using the individual samples down to depths of 6 feet. The composite gradation curves were calculated by weighting the individual gradations by the thickness of the sampling layer and then adding the results. Some samples were composed of very fine material. In most instances, the fine sediment is an anomaly of the sampling site rather than a consistent feature of the channel at that location. Therefore, these samples were excluded from the composite gradation curve calculations.

The composite gradation curves input on the PF records in the existing conditions HEC-6T models are included in Appendix 4A. The grain size classification is based on the American Geophysical Union scale with sand from 0.0625 to 2 mm, gravel from 2 to 64 mm and cobbles from 64 to 256 mm.

2.2.3. LOW FLOW CHANNEL BED GRADATIONS

The low flow channel will be constructed by excavating the existing channel bed. Since the low flow channel invert is 4 to 10 feet below the existing bed elevation, the

existing armored layer will be removed during excavation. Therefore, the active layer depths equaled zero on the OF records for those cross sections within the low flow channel (cross sections 216.23 through 211.76). Composite bed gradations, which were input on the PF records, for cross sections within the low flow channel were developed from the Corps' sediment samples taken between zero to six feet below the low flow channel invert. These gradations are included in Appendix 4B. The bed gradations for cross sections outside of the low flow channel limits were the same as those in the existing conditions model.

2.2.4. SEDIMENT TRANSPORT METHOD

The sediment bed is composed of sand (20 percent), gravel (60 percent) and cobbles (20 percent). Since sand transport is the main transport size and there is a high percentage of gravel in the bed, the Toffaleti, Meyer-Peter and Muller (TMPM) combination transport method is used in the HEC-6T sediment transport simulations because the method suitably transports gravel as well as sand.

HEC-6T simulations using the Laursen-Copeland method will be used to evaluate the sensitivity of the sediment transport results to the selection of the transport method. The Laursen-Copeland method results in higher gravel transport and can be used to estimate the maximum long-term scour. The active layer depths and gradations were calculated for both the TMPM and Laursen-Copeland transport methods.

Copeland's solution of the Exner equation (EXNER 7 HEC-6T option) is used in all of the sediment transport simulations.

2.2.5. INFLOWING SEDIMENT LOAD

The sediment transport model cannot be directly calibrated to historical conditions because detailed historical bed elevation data are not readily available and the bed elevation changes have been influenced by man-made changes to the Salt River (including sand/gravel mining and channelization). Therefore, the equilibrium bed material load at the upstream reach of the model was calculated for a range of discharges up to 166,000 cfs and used as a basis for the inflowing sediment load for the HEC-6T model.

The equilibrium bed material load calculations were performed upstream of I-10 between cross sections 217.38 and 217.95. This reach has an average slope of 0.0022 ft/ft. First the active layer depths and gradations were determined and then the equilibrium bed material load was calculated. This process is outlined below:

1. The active layer depths and gradations are determined from a 30-day HEC-6T simulation at the 5-year peak discharge (20,200 cfs) with the recirculating option activated ($RE). The recirculating option takes sediment passing cross section 217.38 and recirculates it to become the inflowing sediment discharge for the next event.

2. The active layer depths and gradations are input on the OF records to represent the initial armor layer.

3. The equilibrium bed material load is then calculated from trial and error with HEC-6T using the updated gradations. The equilibrium inflowing sediment load corresponds to load that minimizes the changes in bed elevations between cross sections 217.76 and 217.48. Cross sections 217.95, 217.86 and 217.38 experience boundary effects.

The equilibrium bed material load curves for the Toffaleti, Meyer-Peter and Muller combination and the Laursen-Copeland transport methods are shown on Figure 2.1 and Figure 2.2.

A sensitivity analysis of the inflowing load was conducted to bracket the sediment transport results and to estimate the effects of gravel mining, flows from Indian Bend Wash, and deflation of the Tempe Dam on the low flow channel (see Section 4.3).

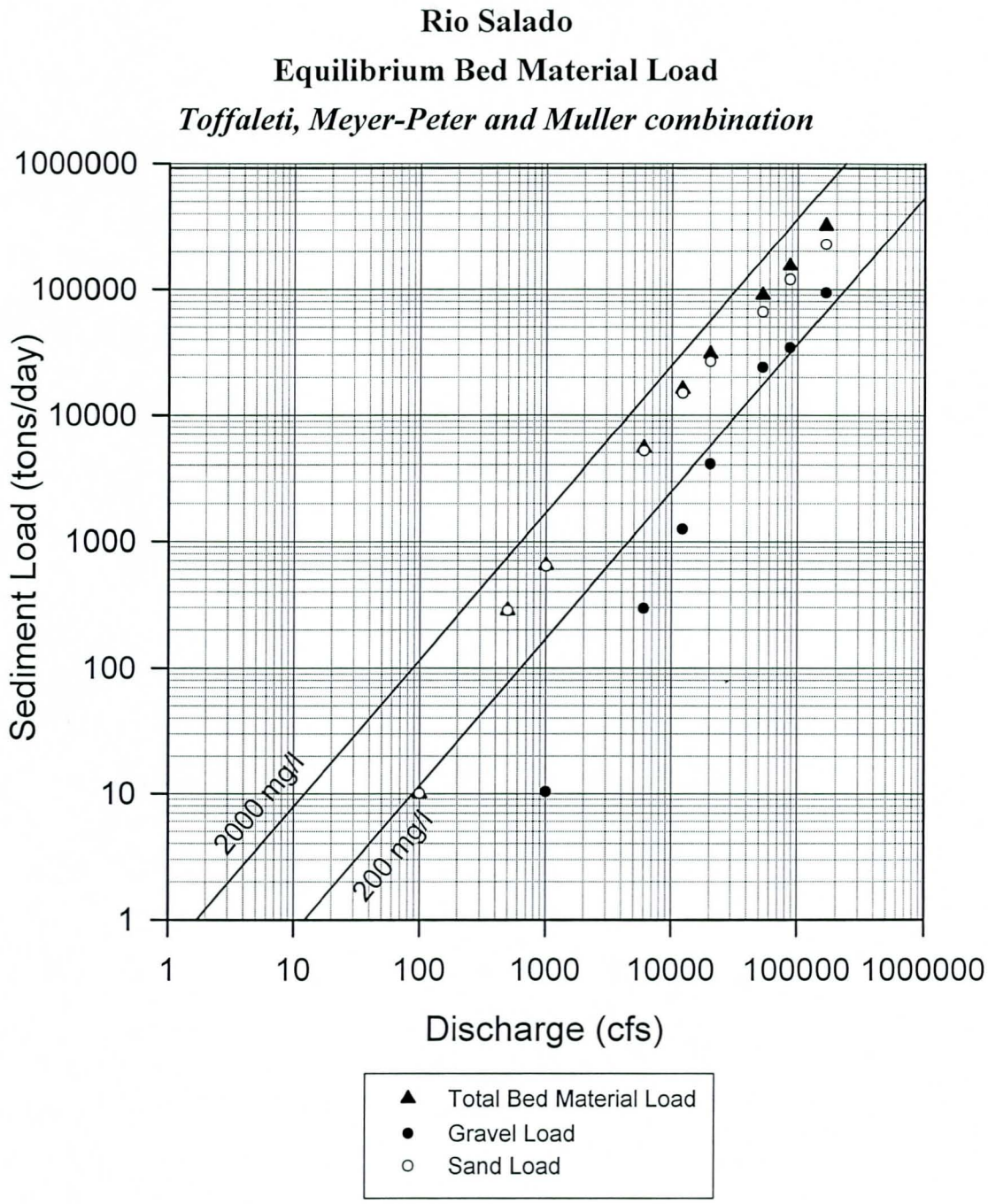


Figure 2.1. Equilibrium bed material load calculated using the Toffaleti, Meyer-Peter and Muller combination transport method.

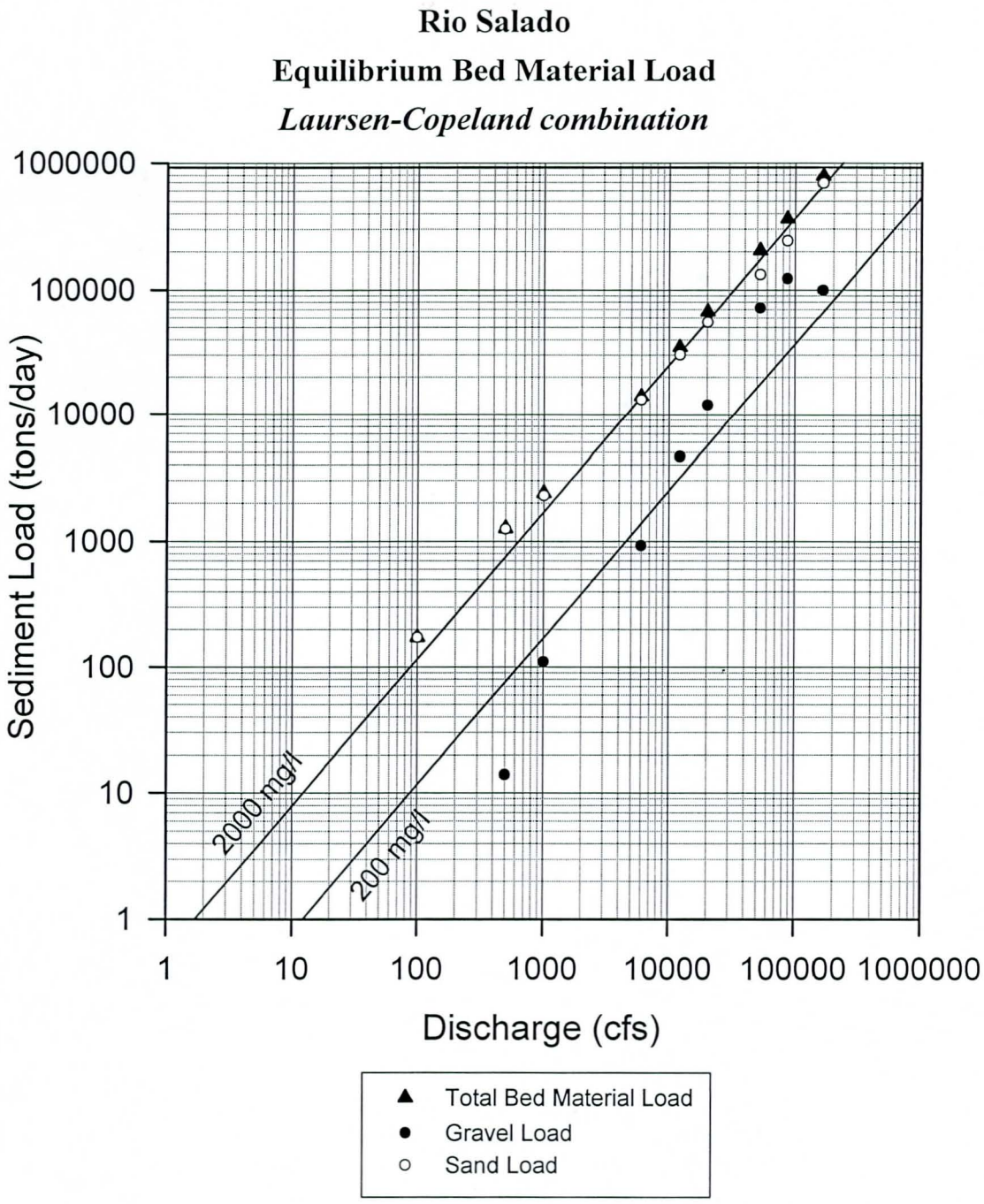


Figure 2.2. Equilibrium bed material load calculated using the Laursen-Copeland transport method.

2.2.6. HYDROLOGIC DATA

2.2.6.1. Hydrographs

In the Rio Salado HEC-6T models, 25-year long-term simulations were performed. The 25-year long-term hydrograph was taken from a portion of a longer hydrograph, which is based on hind-cast flows at Granite Reef Diversion Dam. Created by the Corps, the hydrograph is a simulation of the Salt River Project system performed by routing historical hydrographs (1888-1995) through the Salt River reservoirs between Roosevelt Dam and Granite Reef Diversion Dam, with the Modified Roosevelt Dam in place (Corps, 1996). In WEST's Tres Rios study, the same hydrograph was used to develop a 50-year simulation hydrograph. WEST took the Granite Reef Diversion Dam overflow hydrographs from the Corps and extended the rising and receding limbs to base flow. For the Rio Salado project, the time period between 1905 and 1929 was used as the "worst case" 25-year simulation period because of the high frequency of flow events between these dates. The peak annual discharges are listed in Table 2.3 and the hydrographs are included in Appendix 4C. The overflow hydrographs from the Granite Reef Diversion Dam are translated to the Phoenix Reach without attenuation, which is a reasonable approach given that there is very little storage available between the two locations. For the HEC-6T simulations, 6-hour time increments were used for the 25-year long-term hydrograph. During the dry periods, sediment transport is not computed. Discharges less than 100 cfs were not included because no significant sediment transport occurs below this flow rate.

Long-term simulations are also performed with the 25-, 50- and 100-year peak events at the beginning and end of the 25-year period. The hydrographs for the 25-, 50- and 100-year events (included in Appendix 4C) are based on the 100-year hydrograph, prepared by Nick Adelmeyer of the Corps. This hydrograph corresponds to the 100-year peak discharge at Central Avenue based on the Modified Roosevelt Dam. The Corps does not have hydrographs for the 25- and 50-year events. Therefore, the 100-year hydrograph has been proportioned to the peak 25- and 50-year values. The 25-year peak was interpolated between the 20- and 50-year values using the frequency plot (included in Appendix 4C) derived from the peak discharges given in Table 4.1 of the Feasibility Report. The peak discharges corresponding to the 25-, 50- and 100-year events are given in Table 2.4.

Table 2.3. Peak discharges from the 25-year long-term hydrograph.

Year	Peak Flow (cfs)
1905	60,542
1906	48,315
1907	38,503
1908	7,514
1909	6,473
1910	*No flow*
1911	16,397
1912	*No flow*
1913	*No flow*
1914	*No flow*
1915	9,924
1916	100,764
1917	39,314
1918	32,104
1919	*No flow*
1920	97,978
1921	*No flow*
1922	18,060
1923	*No flow*
1924	11,814
1925	*No flow*
1926	*No flow*
1927	58,486

Table 2.4. Peak discharges associated with the 25-, 50- and 100-year events.

Event	**Discharge (cfs)**
25-year	97,000
50-year	135,000
100-year	166,000

2.2.6.2. Rating Curve

The input rating curve for the downstream boundary condition in HEC-6T was obtained from the HEC-RAS model results for a range of flows at cross section 210.64. The cross section 210.64 is downstream of the project limits and approximately 2.7 miles upstream of the last downstream cross section in the HEC-RAS model (207.99). It was determined that no matter what estimate of the starting energy grade slope is used at cross section 207.99, the water surface in HEC-RAS converges to the same elevation at cross section 210.64 for a given discharge. This was verified over a range of discharges.

3. EXISTING CONDITIONS MODEL RESULTS

Existing condition sediment transport simulations were completed for the 10 scenarios listed in Table 3.1. The model results are discussed in detail in the following sections.

Table 3.1. Summary of existing condition HEC-6T modeling scenarios.

Scenario	Hydrograph	Transport Method	Inflowing Load
E-1	25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	Equilibrium
E-2	25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	50% Equilibrium
E-3	25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	150% Equilibrium
E-4	25-year hydrograph	Laursen-Copeland	Equilibrium
E-5a	100-year peak discharge event after 25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	Equilibrium
E-5b	100-year peak discharge event before 25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	Equilibrium
E-6a	50-year peak discharge event after 25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	Equilibrium
E-6b	50-year peak discharge event before 25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	Equilibrium

E-7a	25-year peak discharge event after 25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	Equilibrium
E-7b	25-year peak discharge event before 25-year hydrograph	Toffaleti, Meyer-Peter and Muller combination	Equilibrium

3.1. 25-YEAR LONG-TERM SIMULATION

A long-term sediment transport simulation (25 years) was completed for the existing conditions using the equilibrium bed material load and the Toffaleti, Meyer-Peter and Muller combination transport method (Scenario E-1). The average bed elevation profiles at five-year increments are shown in Figure 3.1. During the 25-year period, the bed appears to achieve a stable configuration with some deposition and scour that fills-in and smoothes some bed irregularities. The magnitude of bed scour and deposition is limited to approximately 2 feet except at two locations: 1) between cross sections 214.14 and 214.79 and 2) between cross sections 211.02 and 211.21.

The deposition that occurs between cross sections 214.14 and 214.79 fills a cavity in the channel that is probably related to mining activities. The deposition that occurs downstream of cross section 212.46 results from the decrease in the channel slope. The deposition between cross sections 211.02 and 211.21, which is far downstream of the project reach, can be attributed to a change in the bed geometry (see cross section plots in the Hydraulic Appendix).

In general, the model results indicate that the upper reach is in a quasi-equilibrium condition, which may be due to the equilibrium inflowing sediment load and armoring. However, the downstream reach experiences some deposition as a result of the recent channelization and a milder channel slope. This result is supported by field observations at the grade control below 19th Avenue bridge where both the upstream and downstream channel elevations are flush with the grade control sill.

Rio Salado Existing Conditions

HEC-6T 25-Year Long-Term Simulation - Average Bed Elevation Every 5 Years

Scenario E-1

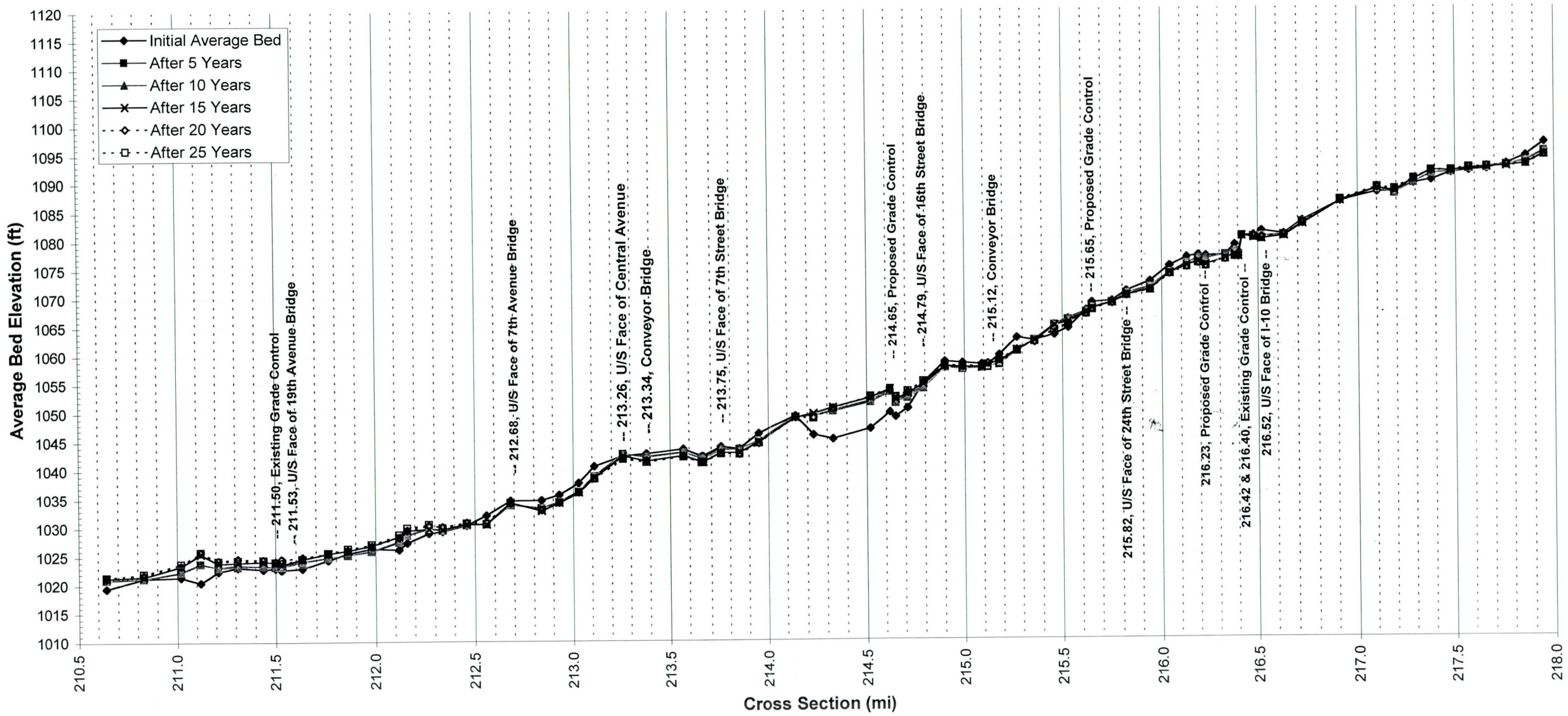


Figure 3.1. Average bed elevations at 5-year increments for existing conditions 25-year long-term simulation (Scenario E-1).

3.2. COMPARISON OF TRANSPORT METHODS

A comparison of the average bed elevations at the end of the 25-year simulation period using the Toffaleti, Meyer-Peter Muller combination transport method (Scenario E-1) and the Laursen-Copeland transport method (Scenario E-4) is included in Figure 3.2. The sensitivity analysis shows that the different transport methods have the same overall scour and deposition trends. Since the Laursen-Copeland method results in more gravel transport (see Figure 2.1 and Figure 2.2), there is more scour in the upstream portion of the reach between cross sections 216.40 and 215.46. This increase in scour results in more deposition in the downstream end of the reach where the channel slope decreases (downstream of cross section 212.46). However, the differences in the scour and deposition between the two transport methods are limited to 1.5 feet. The small difference may be attributed to the armored sediment bed.

3.3. SENSITIVITY TO INFLOWING SEDIMENT LOAD

A comparison of the average bed elevations at the end of the 25-year simulation period for different inflowing sediment loads (50%, 100% in and 150% equilibrium bed material load in Scenarios E-2, E-1 and E-3, respectively) is shown in Figure 3.3.

When the inflowing load in decreased by one half, scour increased because the system is starved and the average bed elevations decreased throughout the reach. However, the changes in the average bed elevations were less than 1 foot.

The overall scour decreases and the deposition increases when the inflowing load is increased by 1.5 because the system is overloaded. The differences in the average bed elevations from those for the equilibrium load are generally less than 1 foot.

In general, the sediment transport results for the existing conditions are not sensitive to the inflowing sediment load because the bed is initially armored.

3.4. IMPACT OF PEAK DISCHARGE EVENTS

The impacts of the 25-, 50- and 100-year peak discharge events on the sediment transport results before and after the 25-year long-term simulation period have been evaluated.

When the 100-year peak discharge event occurs after the 25-year simulation period (Scenario 5a), scour increases in the degradational regions by less than one foot and deposition increases in the aggradation zones between one to two feet (see Figure 3.4). Figure 3.5 shows that the same trends occur when the 25- and 50-year peak discharge events occur after the 25-year simulation period (Scenarios E-7a and E-6a, respectively). However, the magnitudes of the average bed elevation changes are reduced.

When the 100-year peak discharge event occurs before the 25-year simulation period (Scenario E-5b, Figure 3.6), the overall scour and deposition trends are the same as in Scenario E-1, which is the 25-year simulation. After the 100-year event, the average bed elevations are within one foot of those in Scenario E-1 at the end of the 25-year simulation. During the 25 years after the 100-year event, the deposition and scour depths increase by 0.5 to 1 feet. Figure 3.7 shows that the trends are the same when the 25- and 50-year peak discharge events occur before the 25-year simulation period. However, the magnitudes of differences in the average bed elevations from those in Scenario E-1 decrease.

3.5. SUMMARY

The 25-year long-term sediment transport simulation for the existing conditions (Scenario E-1) shows that the bed achieves a quasi-stable configuration with some deposition and scour the fills-in or smoothes some bed irregularities. The maximum scour and deposition is generally less than 2 feet. The average bed elevations are slightly affected by the inflowing sediment load, sediment transport method, and the 25-, 50- and 100-year peak discharge events where the changes in the elevations are less than 1 foot in degradation zones and less than 2 feet in aggradation zones. The small differences may be attributed to the armored sediment bed.

Rio Salado Existing Conditions

HEC-6T 25-Year Long-Term Simulation - Final Average Bed Elevation

Comparison of Transport Methods

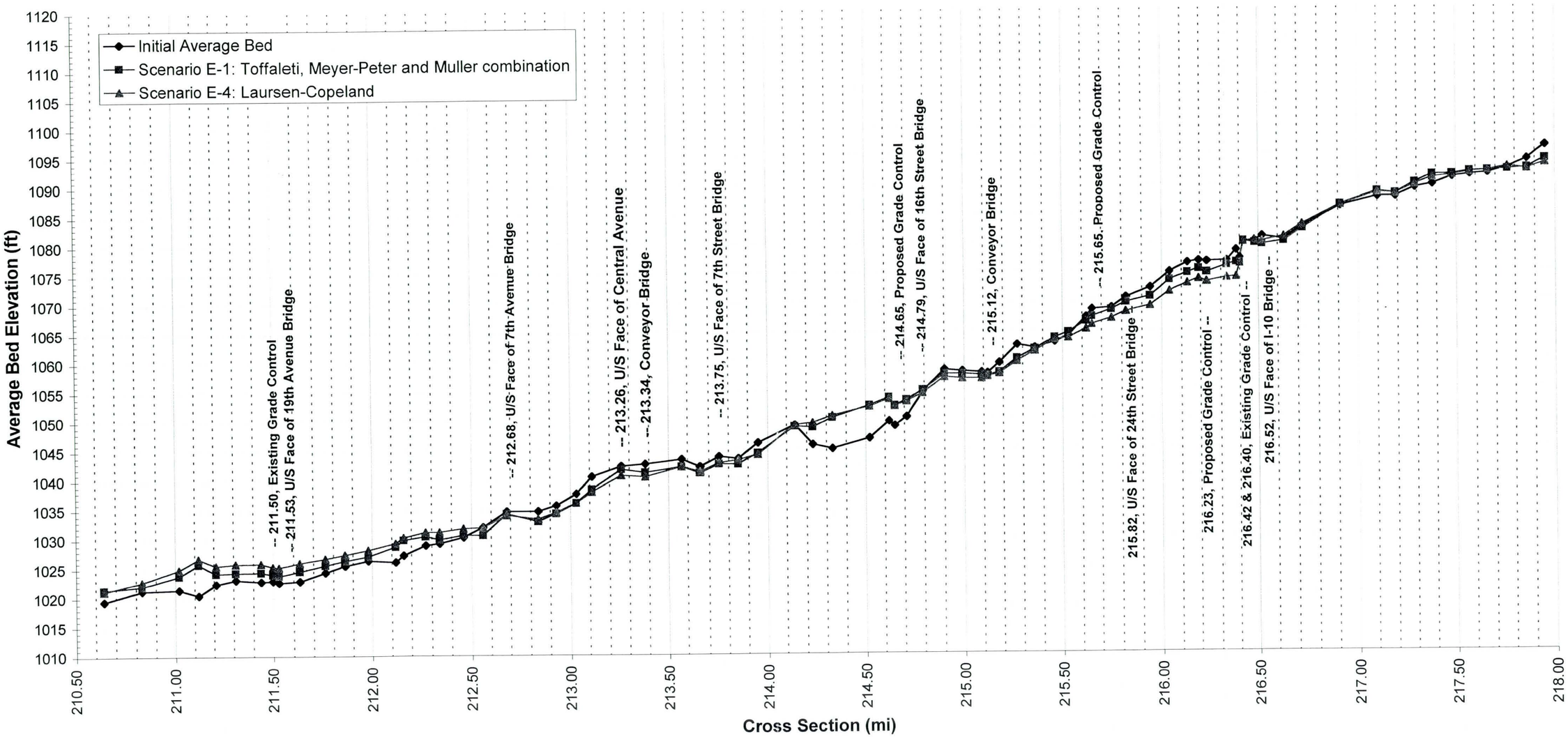


Figure 3.2. Sensitivity of sediment transport results to transport method for the existing conditions. A comparison of the average bed elevations at the end of the 25-year simulation period for Scenarios E-1 and E-4.

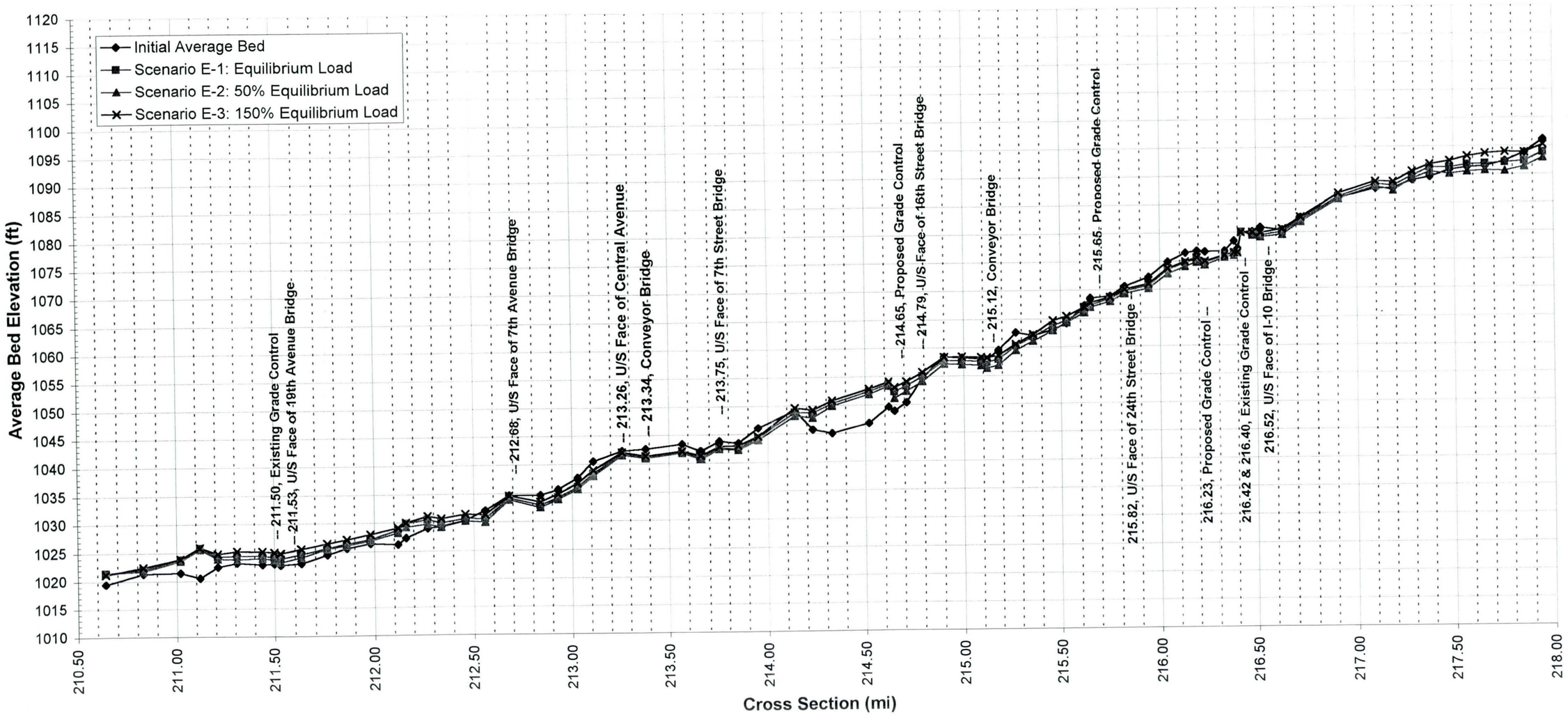


Figure 3.3. Sensitivity of sediment transport results to inflowing load for the existing conditions. A comparison of the average bed elevations at the end of the 25-year simulation period for Scenarios E-1, E-2 and E-3.

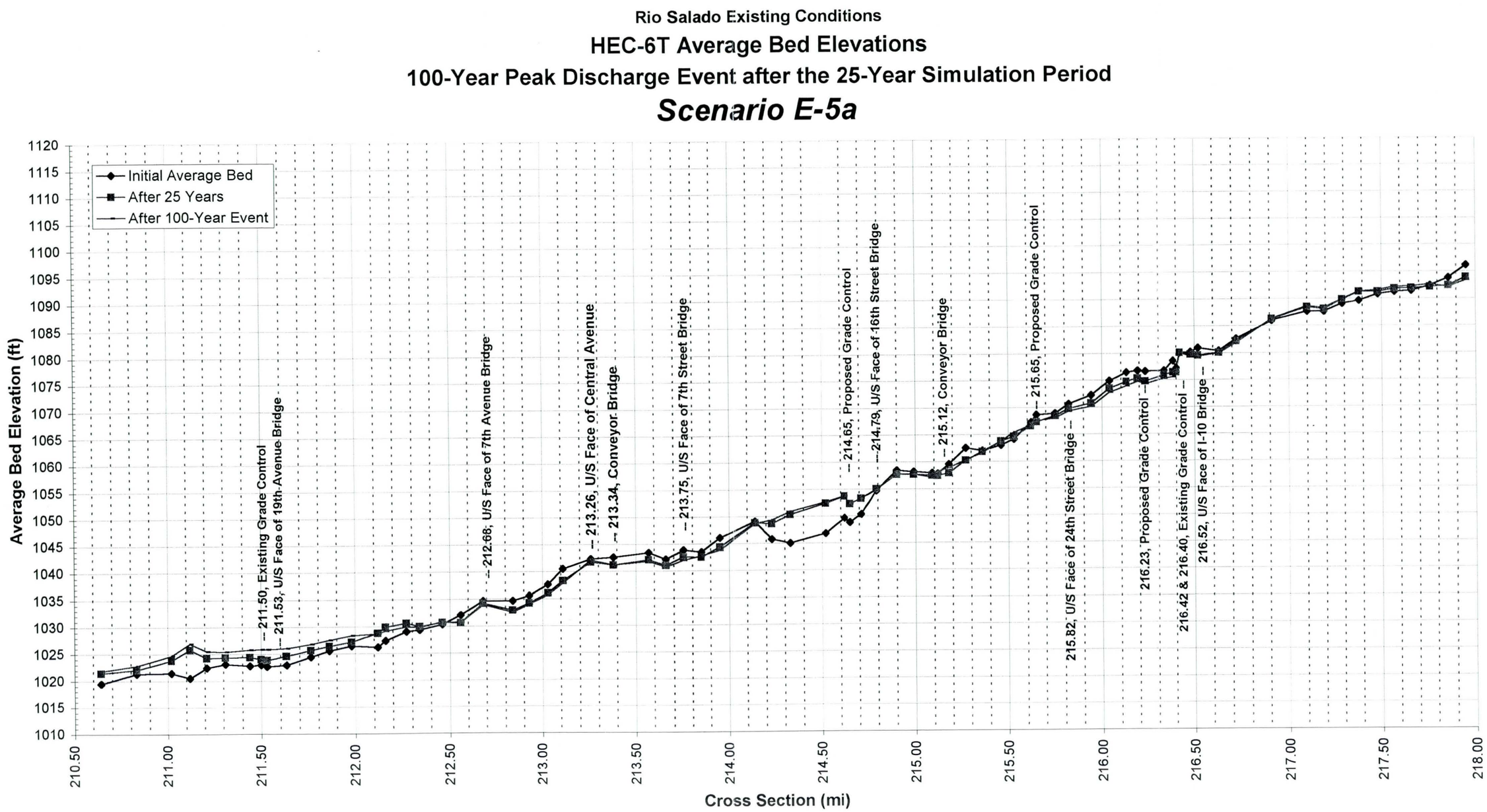


Figure 3.4. Average bed elevations for the existing conditions when the 100-year peak discharge event occurs after the 25-year simulation period (Scenario 5a).

Rio Salado Existing Conditions

HEC-6T Comparison of Average Bed Elevations

25-, 50- and 100-Year Peak Discharge Events After 25-Year Simulation Period

Scenarios E-5a, 6a & 7a

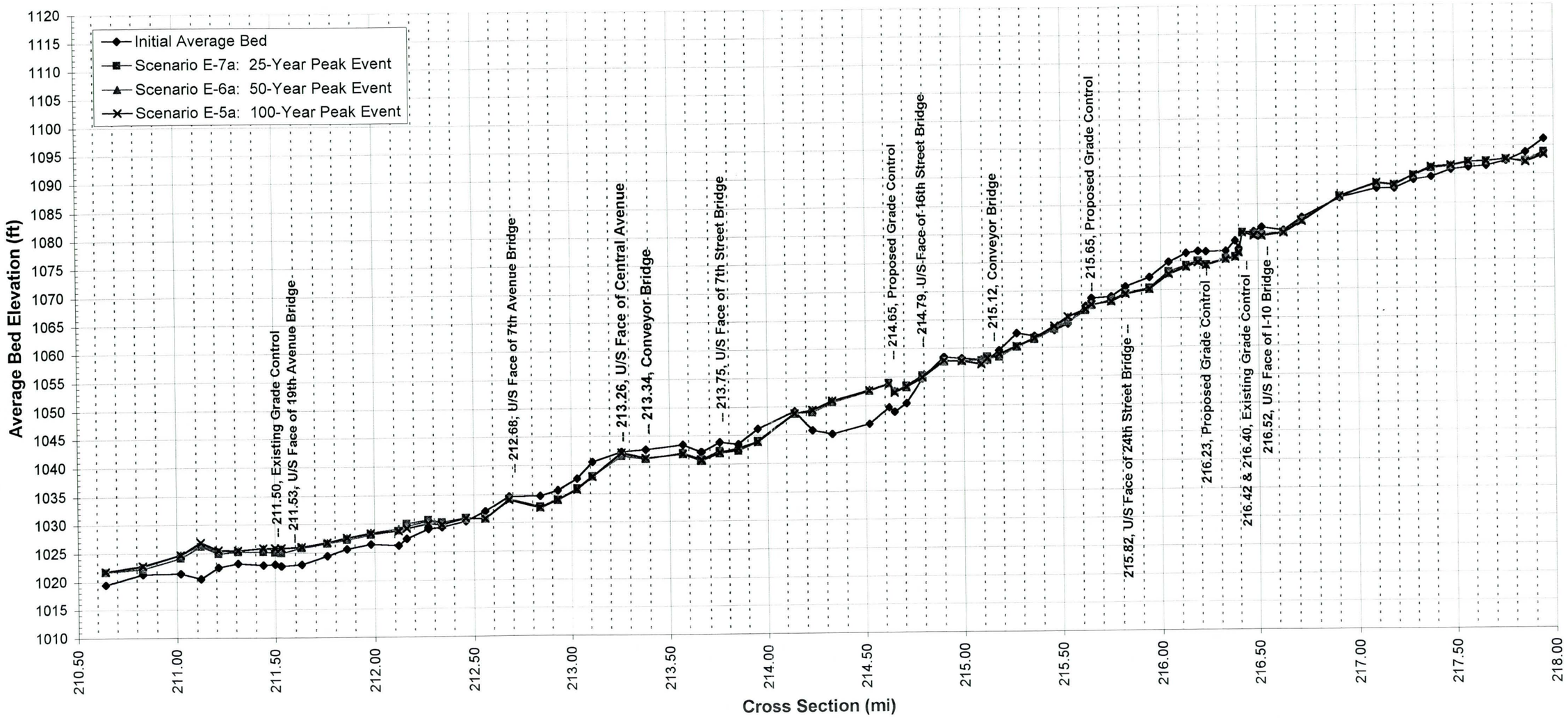


Figure 3.5. Comparison of the average bed elevations for the existing conditions when the 25-, 50- and 100-year peak discharge events occur after the 25-year simulation period (Scenarios E-7a, E-6a and E-5a, respectively).

Rio Salado Existing Conditions

HEC-6T Average Bed Elevations

100-Year Peak Discharge Event Before the 25-Year Simulation Period

Scenario E-5b

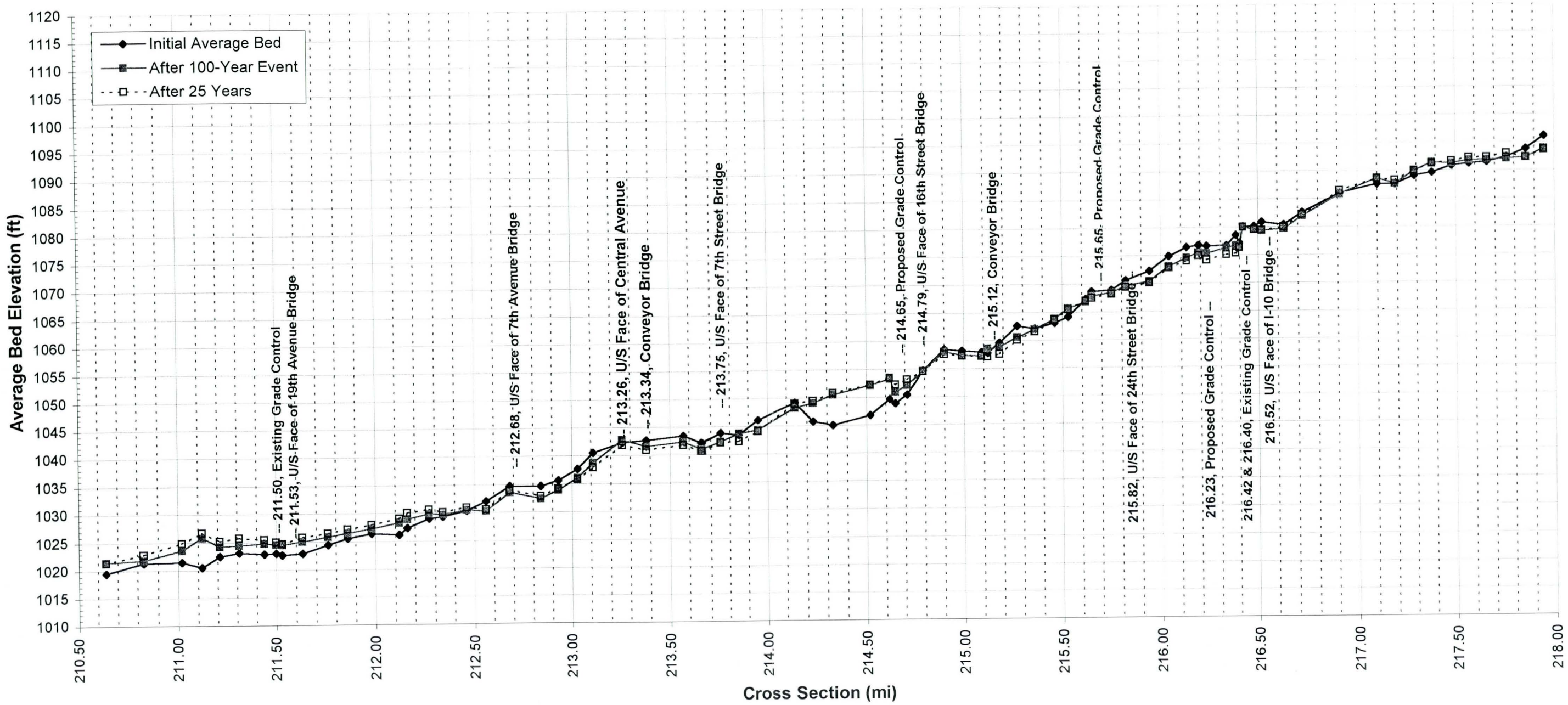


Figure 3.6. Average bed elevations for the existing conditions when the 100-year peak discharge event occurs before the 25-year simulation period (Scenario E-5b).

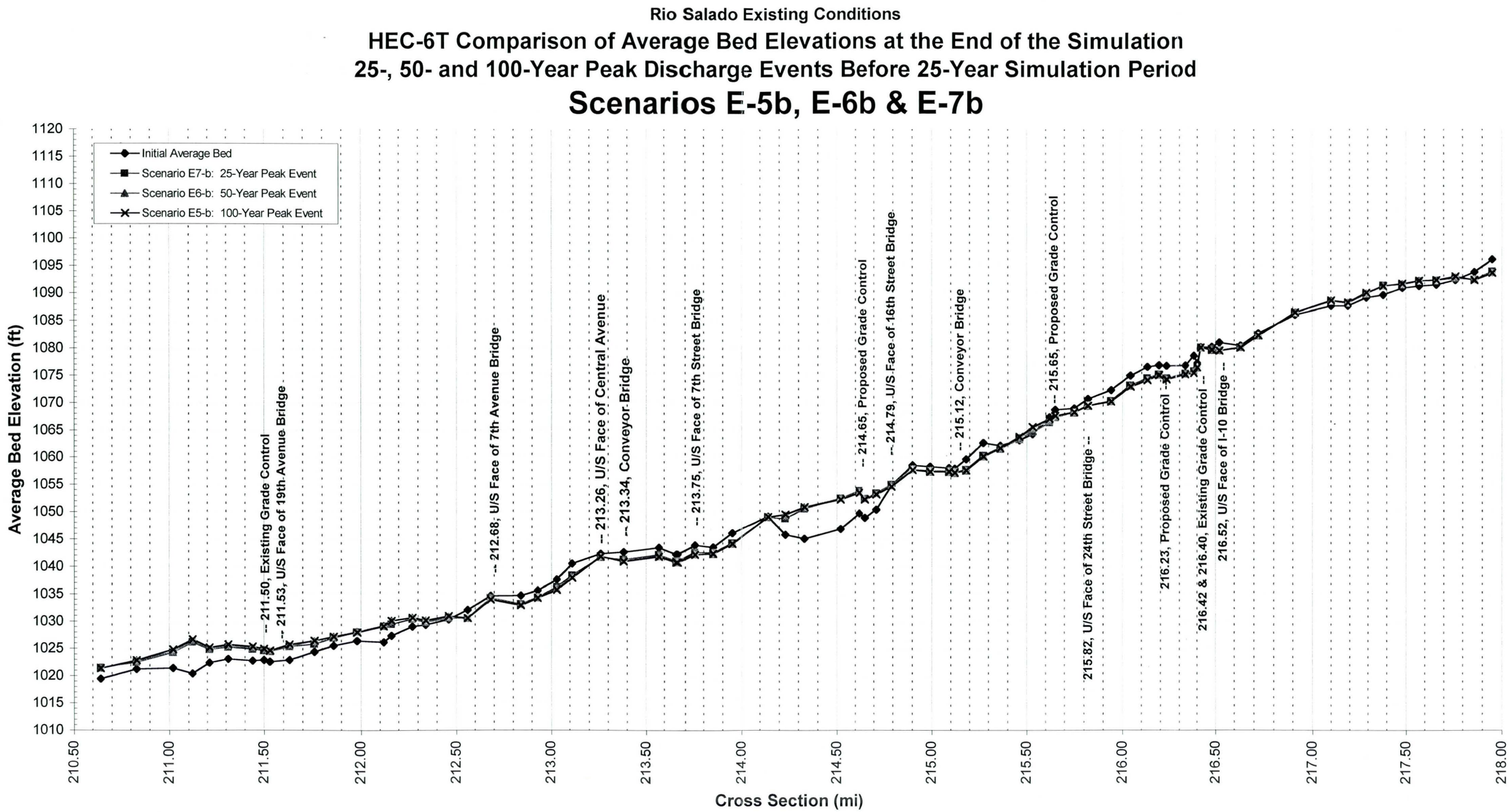


Figure 3.7. Comparison of the average bed elevations for the existing conditions when the 25-, 50- and 100-year events occur before the 25-year simulation period (Scenarios (E-7b, E-6b and E-5b, respectively).

4. LOW FLOW CHANNEL MODEL RESULTS

Long-term sediment transport simulations were completed for the proposed low flow channel. The modeling scenarios are listed in Table 4.1. The sediment transport results were used to 1) evaluate grade control locations to minimize bed scour, 2) determine overexcavation depth in depositional areas, 3) determine annual maintenance requirements in the depositional areas, and 4) estimate the impacts of the 25-, 50- and 100-year peak discharge events. Sensitivity analyses were conducted to bracket the sediment transport results.

Table 4.1. Summary of low flow channel HEC-6T modeling scenarios. TMPM refers to the Toffaleti, Meyer-Peter and Muller transport method. L-C corresponds to the Laursen-Copeland transport method.

Scenario	Hydrograph	No. of Proposed Grade Controls	Transport Function	Equilibrium Inflowing Load	Overexcavation & Maintenance
L-0	25-yr long-term	0	TMPM	100%	None
L-1	25-yr long-term	1	TMPM	100%	None
L-2	25-yr long-term	2	TMPM	100%	None
L-3	25-yr long-term	3	TMPM	100%	None
L-4	25-yr long-term	4	TMPM	100%	None
L-5a	25-yr long-term	4	TMPM	100%	1-foot
L-5b	25-yr long-term	4	TMPM	100%	2-foot
L-5c	25-yr long-term	4	TMPM	100%	3-foot
L-5d	25-yr long-term	4	TMPM	100%	4-foot
L-6b	25-yr long-term	4	TMPM	50%	2-foot
L-7a	25-yr long-term	4	TMPM	150%	1-foot
L-7b	25-yr long-term	4	TMPM	150%	2-foot
L-7c	25-yr long-term	4	TMPM	150%	3-foot
L-7d	25-yr long-term	4	TMPM	150%	4-foot
L-8a	25-yr long-term	3	TMPM	150%	2-foot
L-9a	100-yr event after	4	TMPM	100%	2-foot
L-9b	100-yr event before	4	TMPM	100%	2-foot
L-10a	50-yr event after	4	TMPM	100%	2-foot

L-10b	50-yr event before	4	TMPM	100%	2-foot
L-11a	25-yr event after	4	TMPM	100%	2-foot
L-11b	25-yr event before	4	TMPM	100%	2-foot
L-12	25-yr long-term	4	L-C	100%	2-foot

4.1. LOW FLOW CHANNEL GRADE CONTROL SCENARIOS

Sediment transport simulations were performed for the following five grade control scenarios: 1) existing grade control structures only (Scenario L-0), 2) one proposed grade control structure at cross section 216.23 (Scenario L-1), 3) two proposed grade control structures at cross sections 216.23 and 215.65 (Scenario L-2), 4) three proposed grade control structures at cross sections 216.23, 215.65 and 214.65 (Scenario L-3), and 4) four proposed grade control structures at cross sections 216.23, 215.65, 214.65 and 213.26 (Scenario L-4). Comparisons of the average bed elevations at the end of the 25-year simulation period for the five scenarios are shown in Figure 4.1 and Figure 4.2.

The sediment transport results show the same general trend for all of the grade control scenarios with scour upstream of cross section 214.65, 4 to 7 feet of deposition between cross sections 214.13 and 214.62, and 1 to 3 feet of deposition in the remaining downstream cross sections in the low flow channel. The proposed grade control structures are added sequentially from upstream to downstream in the analysis. The benefits of each of the proposed grade control structures are discussed below.

In Scenario L-0, the bed scours 16 feet in the transition between the existing grade control at cross section 216.40 and the beginning of the low flow channel at cross section 216.23. The upstream limit of the low flow channel at cross section 216.23 scours 10 feet. Between cross sections 216.23 and 215.65, the low flow channel scours 7 to 10 feet but achieves a similar slope as the design invert.

By adding a grade control structure at the upstream low flow channel limit (216.23) in Scenario L-1, the scour depth decreases from 16 feet down to 7 feet for those cross sections between the proposed grade control structure (216.23) and the existing grade control structure (216.40). However, the scour between cross sections 216.23 and 215.65 increases by 1 to 2 feet to total scour depths of 8 to 12 feet.

The scour between cross sections 216.23 and 215.65 decreases by 5 feet with the addition of the grade control structure at cross section 215.65 (Scenario L-2). The total scour depth between the proposed grade control structures at 216.23 and 214.65 ranges from 3 to 7 feet. However, the scour increases by 1 to 3 feet between cross sections 215.65 and 214.65.

This addition of the proposed grade control structure at 214.65 (Scenario L-3) does not reduce the scour between cross sections 215.65 and 214.65. However, a 36-inch water line crosses the channel at 214.80, which is just upstream of the 16th Street Bridge at cross section 214.79. The concrete block encasing the waterline is 4 feet below the low flow channel design invert. The proposed grade control structure at 214.65 protects against excessive scour at the bridge and the waterline, should there be a decrease in the inflowing sediment load or with a larger flood event (i.e. the 100-year flood). Further explanation is included in Section 4.2

Bridge scour analysis and structural analysis of Central Avenue Bridge (cross section 213.26) showed that the structural integrity of the bridge would be jeopardized unless additional scour protection measures were implemented at the bridge. A grade control structure was added at Central Avenue Bridge for scour protection. Since this grade control structure was in a depositional area, the structure does not significantly change the sediment transport results. The difference in the average bed elevations with and without the Central Avenue grade control structure (213.26) is less than 0.5 feet (see Figure 4.2).

This analysis demonstrates the need for grade control structures at several proposed locations. The functions of the proposed structures are listed below:

1. The proposed grade control structure located at 216.23 limits the scour below the existing grade control structure at 216.40, which is one-tenth of a mile downstream of I-10 (216.52).

2. The proposed grade control structure located at 215.65 reduces scour in the upstream low flow channel reach.

3. The proposed grade control structure located at 214.65 is added to protect 16th Street Bridge (214.79) and 36" water line at (214.80) from excessive scour.

4. The proposed grade control structure located at Central Avenue (cross section 213.26) protects the bridge from localized pier scour.

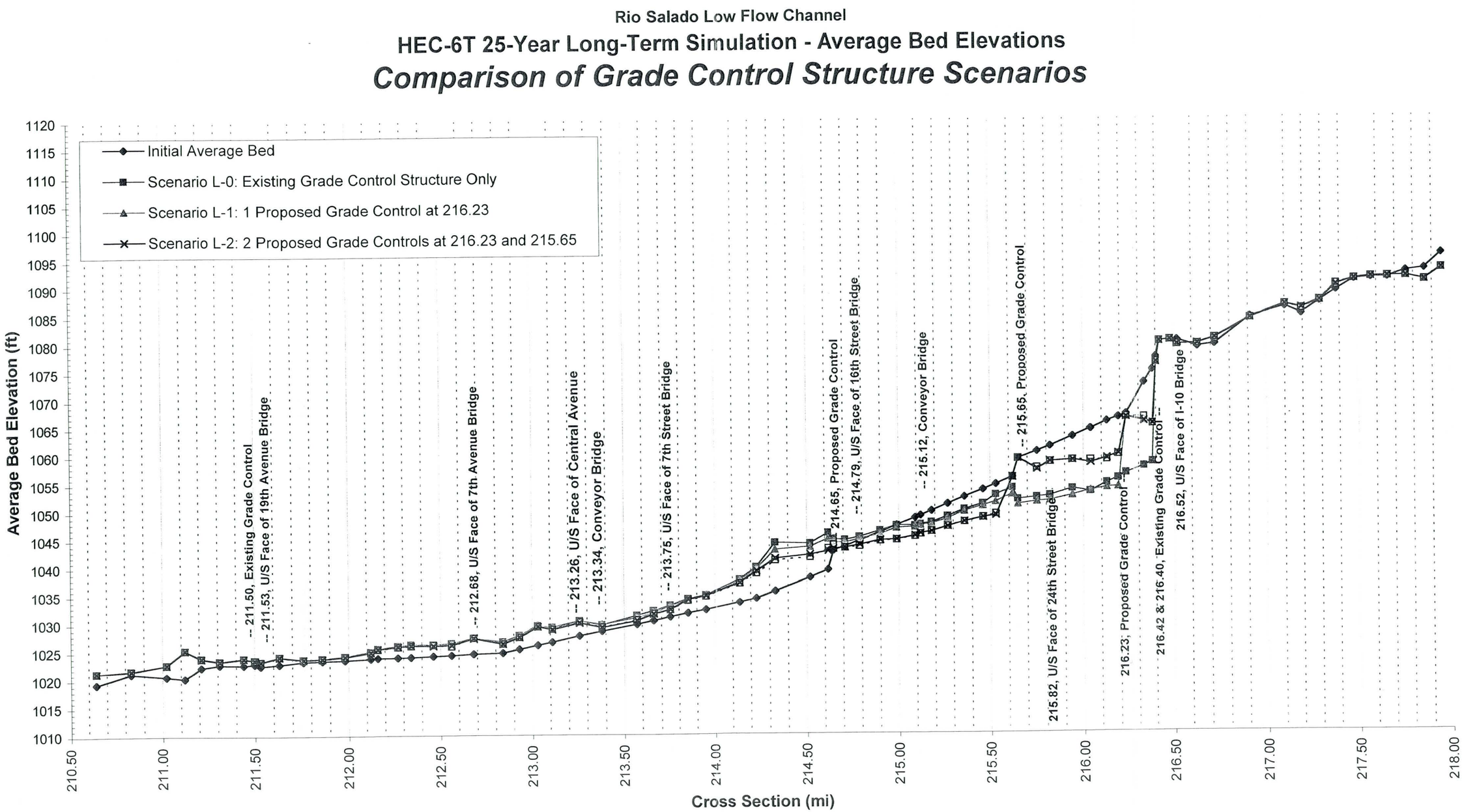


Figure 4.1. Comparison of average bed elevations at the end of the 25-year simulation period for the different grade control scenarios (Scenarios L-0, L-1, L-2 and L-3).

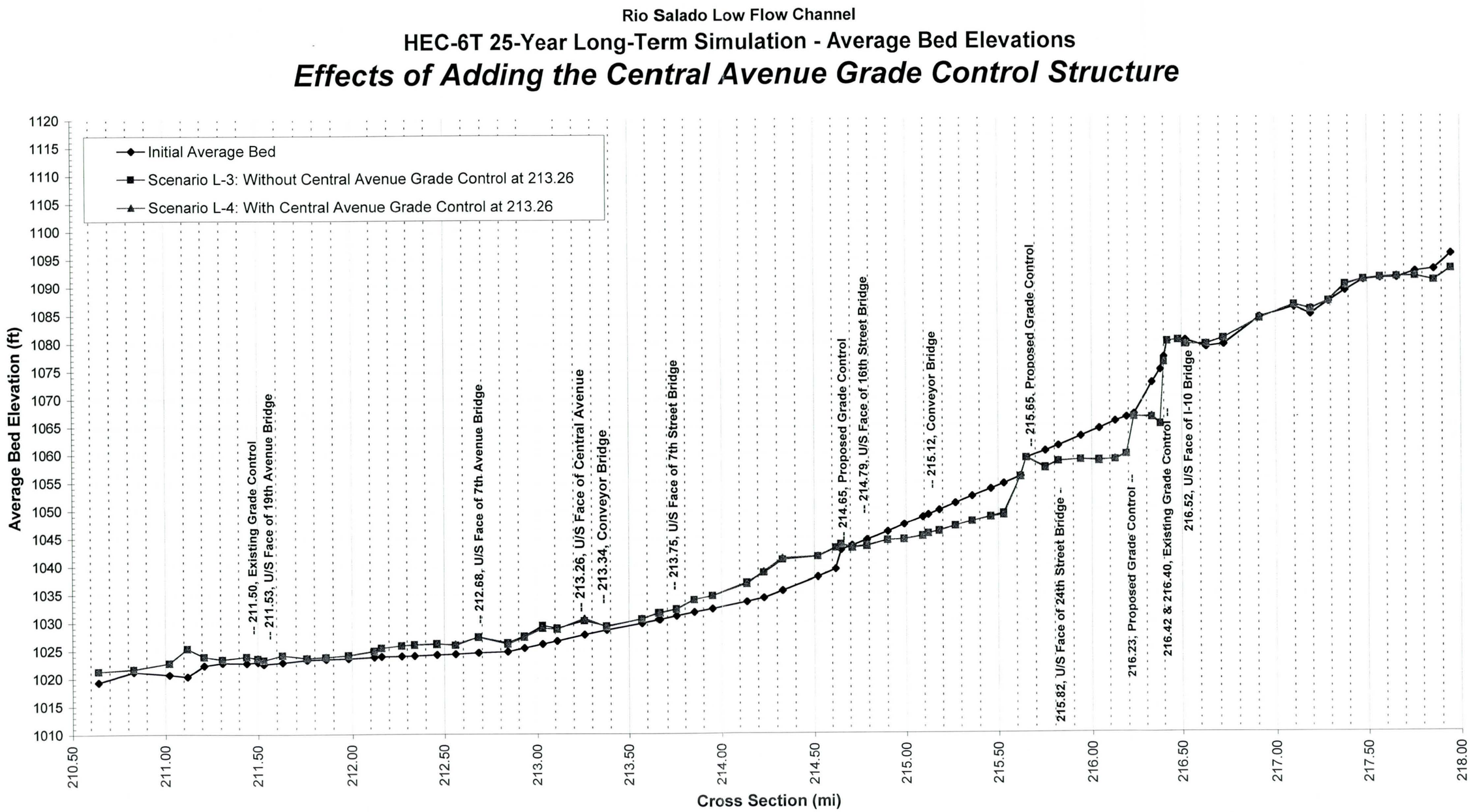


Figure 4.2. Comparison of average bed elevations at the end of the 25-year simulation period with and without the Central Avenue grade control structure (Scenarios L-3 and L-4).

4.2. OVEREXCAVATION & ANNUAL MAINTENANCE

The long-term simulations show that deposition occurs in the downstream reach of the low flow channel (4 to 7 feet between cross sections 214.13 and 214.65, and 1 to 3 feet between cross section 214.13 to the downstream limit of the low flow channel at cross section 211.76). Deposition decreases the low flow channel capacity which in turn increases flooding and damage in the overbanks. Therefore, overexcavation and annual maintenance plans need to be formulated to improve the channel efficiency and minimize overbank damage.

Four overexcavation and annual maintenance scenarios have been evaluated for the cross sections between 214.65 and the downstream limit of the low flow channel at 211.76. Each of the scenarios consist of the following:

1. Initial overexcavation below the design invert during the low flow channel construction.

2. Annual excavation during the dry season at locations where the low flow channel design invert elevation is exceeded. Where excavation is needed, the channel is overexcavated below the design invert.

The difference between the scenarios is the amount of overexcavation. Overexcavation ranges from 1 foot to 4 feet. The elevations of the Central Avenue grade control structure equals the elevation with overexcavation Since the amount of deposition is sensitive to the inflowing sediment load, the overexcavation scenarios have been evaluated for both the equilibrium load and 150% of the equilibrium load. The scenarios with 150% equilibrium load will be used to determine the worst-case maintenance requirements. The average bed elevations at 5-year intervals are shown in Figure 4.3 and Figure 4.4 with the equilibrium bed material load and 150% of the equilibrium load, respectively. The corresponding excavations volumes and frequencies are included in Table 4.2 and Table 4.3.

With the equilibrium inflowing sediment load, the scour upstream of the proposed grade control structure at 214.65 varies with the overexcavation depth. The scour at the 36" water line upstream of 16th Street is 3.1 feet with 1- and 2-foot overexcavation, 3.4 feet with 3-foot overexcavation, and 3.6 feet with 4-foot overexcavation. Excavation is required during all years with flows during the 25-year simulation period. However, the average annual excavation volume varies with the overexcavation scenarios: 14,843 tons with 1-foot overexcavation; 14,006 tons with 2-foot overexcavation; 14,055 tons with 3-foot overexcavation; and 13,537 feet with 4-foot overexcavation.

With 150% of the equilibrium inflowing sediment load, the scour depth at the 36" water line upstream of 16th Street decreases by 1 foot for all of the overexcavation scenarios. Excavation is required during all years with flows during the 25-year simulation period. The average annual excavation volume more than doubles the volumes for the scenarios with the equilibrium inflowing sediment load: 35,150 tons

with 1-foot overexcavation; 37,172 tons with 2-foot overexcavation; 38,679 tons with 3-foot overexcavation; and 38,962 feet with 4-foot overexcavation.

The 2-foot overexcavation scenario provides more cover at the 36" water line than the 3-foot and 4-foot overexcavation for both equilibrium and 150% equilibrium inflowing sediment load. The differences between annual excavation volumes for the 2-foot, 3-foot and 4-foot overexcavation scenarios are less than 5 percent. Since the 2-foot overexcavation scenario results in more cover at the 36" water line and has similar maintenance requirements compared to the other scenarios, the 2-foot overexcavation scenario is recommended and will be used for the sediment transport analyses in the following sections. Table 4.4 lists the low flow channel invert elevation as well as the overexcavation depth for the cross sections downstream of 214.65. In the table, overexcavation depths less than 2 feet reflect the transition to natural grade.

Figure 4.5 shows a comparison of the average bed elevations at the end of the 25-year simulation period with and without the proposed grade control structure at cross section 214.65 assuming equilibrium inflowing sediment load and 2-foot overexcavation (Scenarios L-5b and L-8a). The scour depth between cross sections 214.65 and 215.65 is 0.5 to1 foot less with the proposed grade control in place. At the 36" water line, the bed scours 3.1 feet with the grade control and 214.65 and 4.2 feet without the grade control. This analysis demonstrates that the grade control 214.65 is necessary to protect structural integrity of the water line.

Table 4.2. Comparison of excavation volumes and frequency with 1-foot, 2-foot, 3-foot and 4-foot overexcavation with equilibrium inflowing sediment load.

	Excavation Volumes (yd^3)			
	Overexcavate 1 foot	Overexcavate 2 feet	Overexcavate 3 feet	Overexcavate 4 feet
Initial Overexcavation	151,987	274,700	361,327	442,570
Year After Project Completion				
1	93,601	77,537	59,065	39,561
2	24,671	5,851	7,310	9,265
3	4,741	5,667	7,337	9,261
4	15,548	16,463	9,622	11,299
5	8,855	5,224	8,962	12,144
6 - no flow				
7	3,746	4,791	7,287	10,311
8 - no flow				
9 - no flow				
10 - no flow				
11	11,637	8,234	8,694	11,120
12	76,444	107,525	119,660	141,156
13	14,276	6,984	9,015	11,034
14	15,089	17,701	8,516	12,123
15 - no flow				
16	55,170	32,392	62,289	33,070
17 - no flow				
18	9,469	6,512	8,734	11,130
19 - no flow				
20	18,425	21,138	10,416	14,061
21 - no flow				
22 - no flow				
23	19,398	34,138	24,470	12,891
24 - no flow				
25 - no flow				
Total	371,070	350,157	351,377	338,426
Average Annual	14,843	14,006	14,055	13,537
Total Excavation Events	14	14	14	14

Table 4.3. Comparison of excavation volumes and frequency with 1-foot, 2-foot, 3-foot and 4-foot overexcavation with 150% of the equilibrium inflowing sediment load.

	Excavation Volumes (yd^3)			
	Overexcavate 1 foot	Overexcavate 2 feet	Overexcavate 3 feet	Overexcavate 4 feet
Initial Overexcavation	151,987	274,700	361,327	442,570
Year After Project Completion				
1	118,667	82,982	86,004	70,379
2	47,416	64,371	10,932	13,193
3	25,494	29,712	13,464	14,272
4	34,744	32,032	14,565	17,068
5	33,011	32,649	32,836	33,657
6 - no flow				
7	5,210	8,339	14,073	16,573
8 - no flow				
9 - no flow				
10 - no flow				
11	34,572	34,240	47,517	35,835
12	169,721	213,030	228,815	271,395
13	70,257	29,203	47,604	16,171
14	47,772	88,192	75,958	94,948
15 - no flow				
16	144,748	174,886	235,200	191,875
17 - no flow				
18	15,404	11,565	16,069	19,149
19 - no flow				
20	50,394	78,950	65,067	38,066
21 - no flow				
22 - no flow				
23	81,336	49,139	78,863	141,470
24 - no flow				
25 - no flow				
Total	878,746	929,290	966,967	974,051
Average Annual	35,150	37,172	38,679	38,962
Total Excavation Events	14	14	14	14

Table 4.4. Low flow channel design inverts and overexcavation depths for cross sections between 211.76 and 214.62. Overexcavation depths less than 2 feet reflect the transition to the natural grade.

Cross Section	Design Invert Elevation (ft)	Overexcavation depth (ft)
211.76	1023.33	1.3
211.86	1023.46	1.4
211.98	1023.62	1.6
212.12	1023.81	1.8
212.16	1023.89	1.9
212.27	1024.03	2.0
212.345	1024.11	2.0
212.46	1024.28	2.0
212.56	1024.40	2.0
212.68	1024.61	2.0
212.84	1024.78	2.0
212.93	1025.46	2.0
213.03	1026.10	2.0
213.11	1026.74	2.0
213.26	1027.84	2.0
213.38	1028.60	2.0
213.57	1029.82	2.0
213.66	1030.44	2.0
213.75	1031.06	2.0
213.85	1031.71	2.0
213.95	1032.34	2.0
214.14	1033.59	2.0
214.23	1034.21	2.0
214.33	1035.45	2.0
214.52	1037.94	2.0
214.62	1039.30	1.0

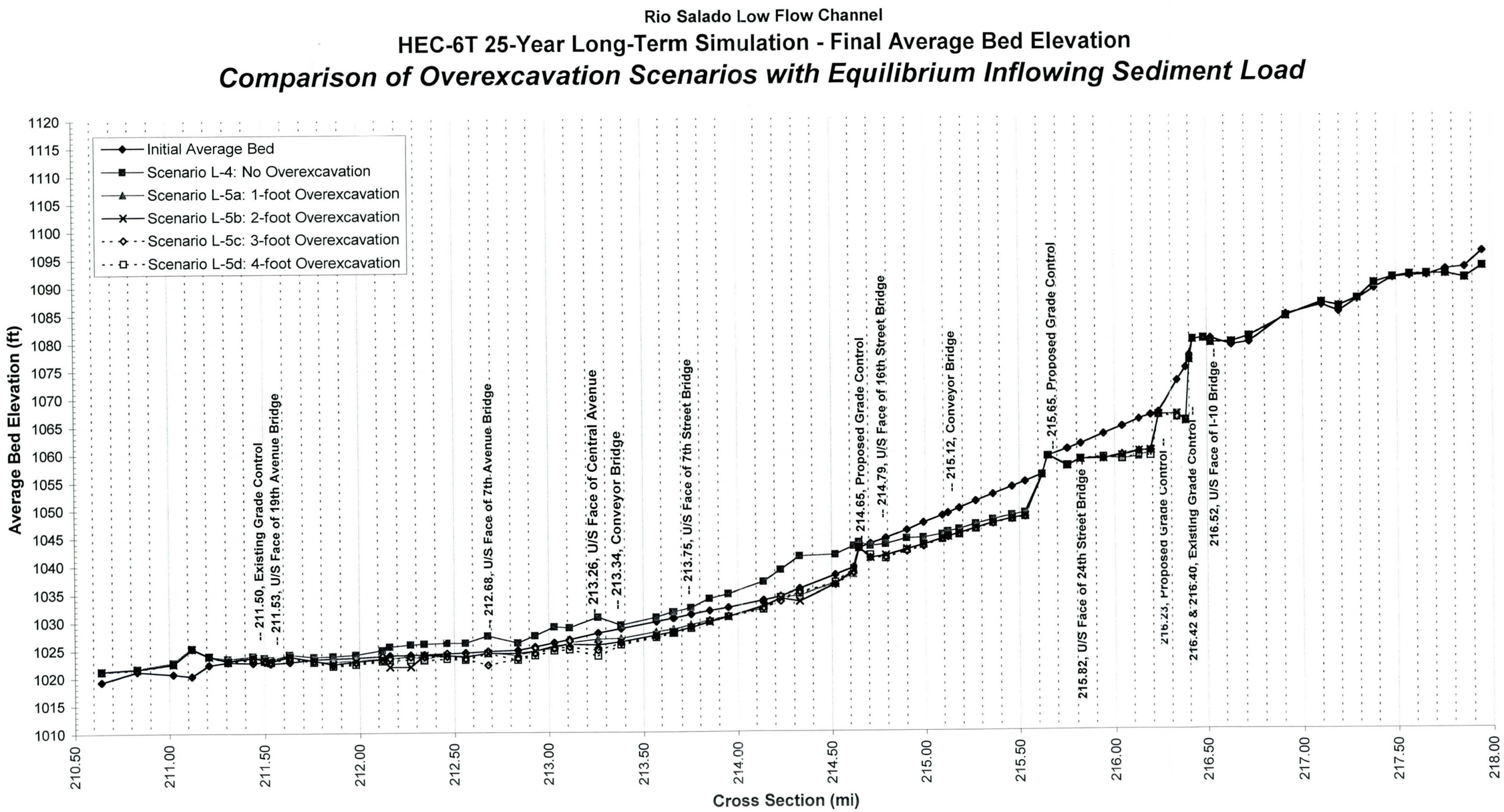


Figure 4.3. Comparison of average bed elevations at the end of the 25-year simulation period for the overexcavation scenarios for the low flow channel with equilibrium inflowing sediment load (Scenarios L-4, L-5a, L-5b, L-5c and L-5d).

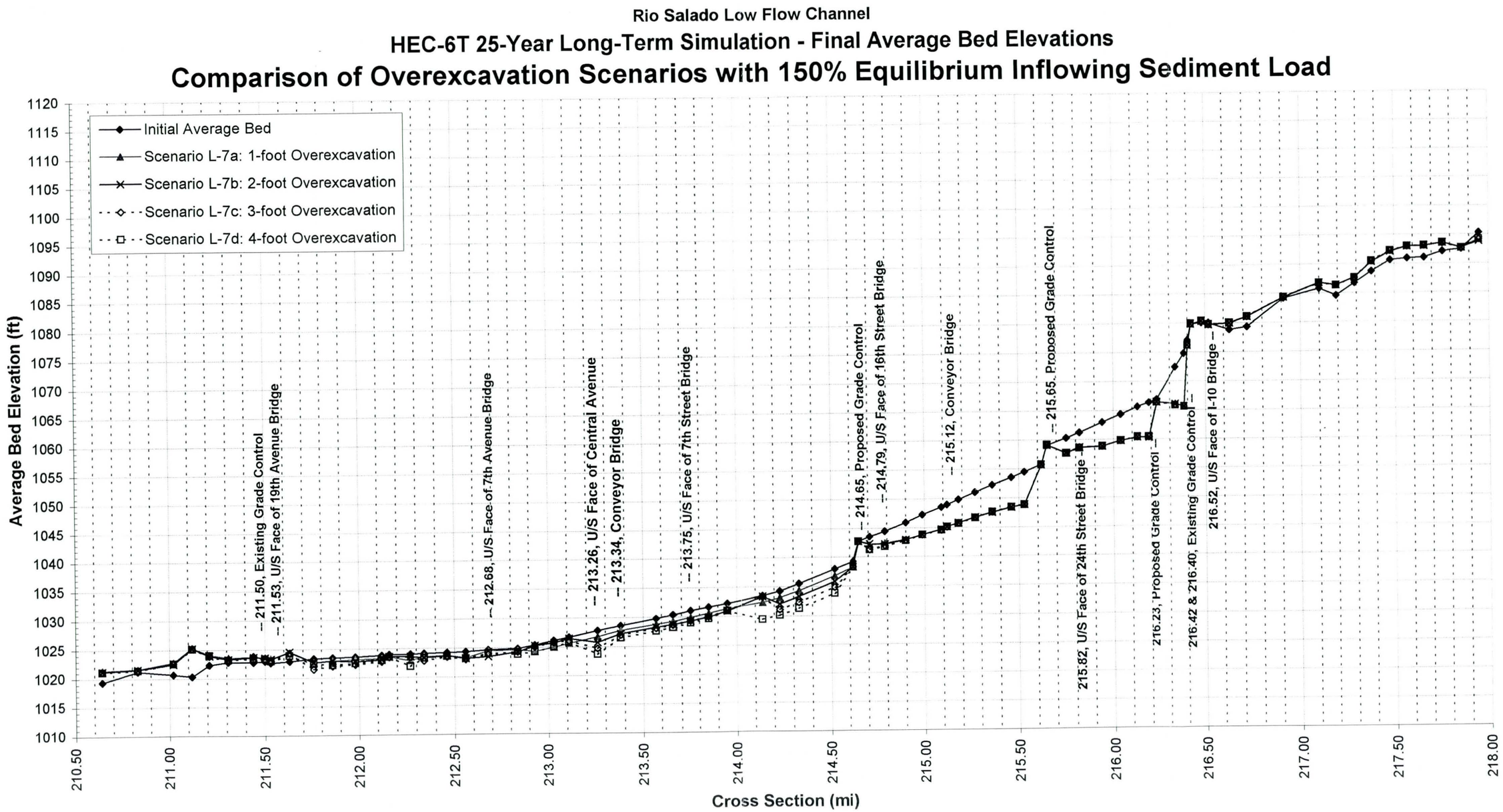


Figure 4.4. Comparison of average bed elevations at the end of the 25-year simulation period for the overexcavation scenarios for the low flow channel with 150% of the equilibrium inflowing sediment load (Scenarios L-7a, L-7b, L-7c and L-7d).

Rio Salado Low Flow Channel

HEC-6T 25-Year Long-Term Simulation

Comparison of Grade Control Scenarios with Equilibrium Sediment Load and 2-foot Overexcavation

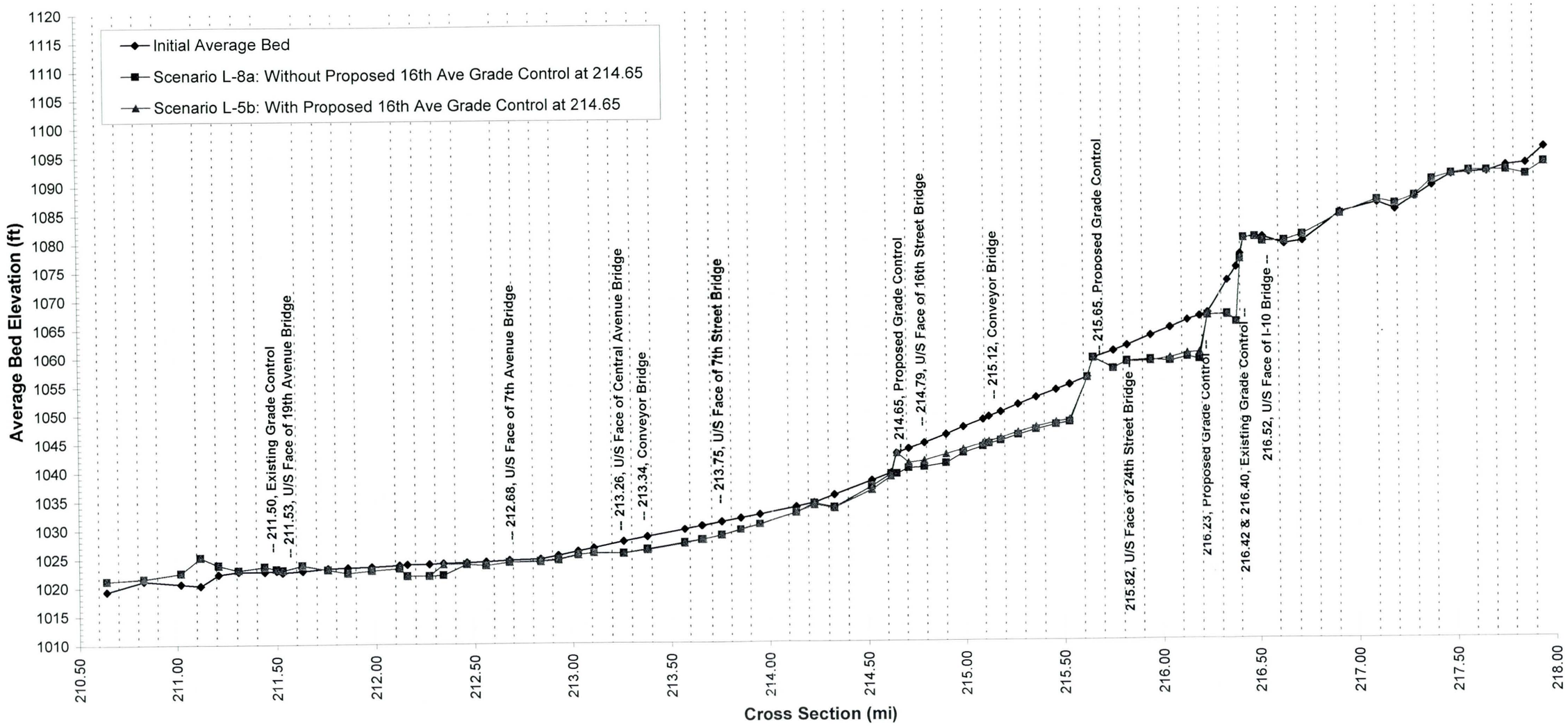


Figure 4.5. Comparison of average bed elevations at the end of the 25-year simulation period with and without the proposed grade control structure at 214.65 assuming equilibrium inflowing load and 2-foot overexcavation (Scenarios L-5b and L-8a).

4.3. SENSITIVITY TO INFLOWING SEDIMENT LOAD

A comparison of the average bed elevations at the end of the 25-year simulation period with 50%, 100% and 150% of the equilibrium bed material load and 2-foot overexcavation (Scenarios L-6b, L-5b and L-7b, respectively) is shown in Figure 4.6. The average bed elevations for the upstream reach of the low flow channel between cross sections 216.23 and 215.65 are within a 1-foot range for all three inflowing loads. However, for the cross sections downstream of 215.65, the average bed elevations decrease by 1 to 2 feet when the inflowing load is reduced by one-half. Conversely, the average bed elevations increase by 0.5 feet when the inflowing load is increased by a factor of 1.5. In general, the low flow channel is moderately sensitive to changes in the inflowing sediment load with scour increasing as the inflowing sediment load decreases.

Sand and gravel mining upstream of the low flow channel would cause a decrease in the inflowing sediment load. The effects of such mining are bracketed between Scenarios L-6b and L-5b in which the inflowing sediment loads are 50% and 100% of the equilibrium load, respectively. Sediment discharges resulting from flows in Indian Bed Wash and/or the deflation of the Tempe Dam would increase the inflowing sediment load to the low flow channel. The effects are bracketed between Scenarios L-5b and L-7b in which the inflowing sediment loads are 100% and 150% of the equilibrium load, respectively.

4.4. COMPARISON OF TRANSPORT METHODS

A comparison of the average bed elevations at the end of the 25-year simulation period using the Toffaleti, Meyer-Peter and Muller combination and the Laursen-Copeland transport methods (Scenarios L-5b and L-12) is included in Figure 4.7. These results are based on the 2-foot overexcavation scenario and include the four proposed grade control structures. Both transport methods result in the same overall scour and deposition trends. Upstream of cross section 214.65, scour depths are 2 to 5 feet greater for the Laursen-Copeland transport method because of the higher gravel transport. The Laursen-Copeland method results in the "worst case" long-term degradation, and therefore these values will be used in the bridge scour analysis.

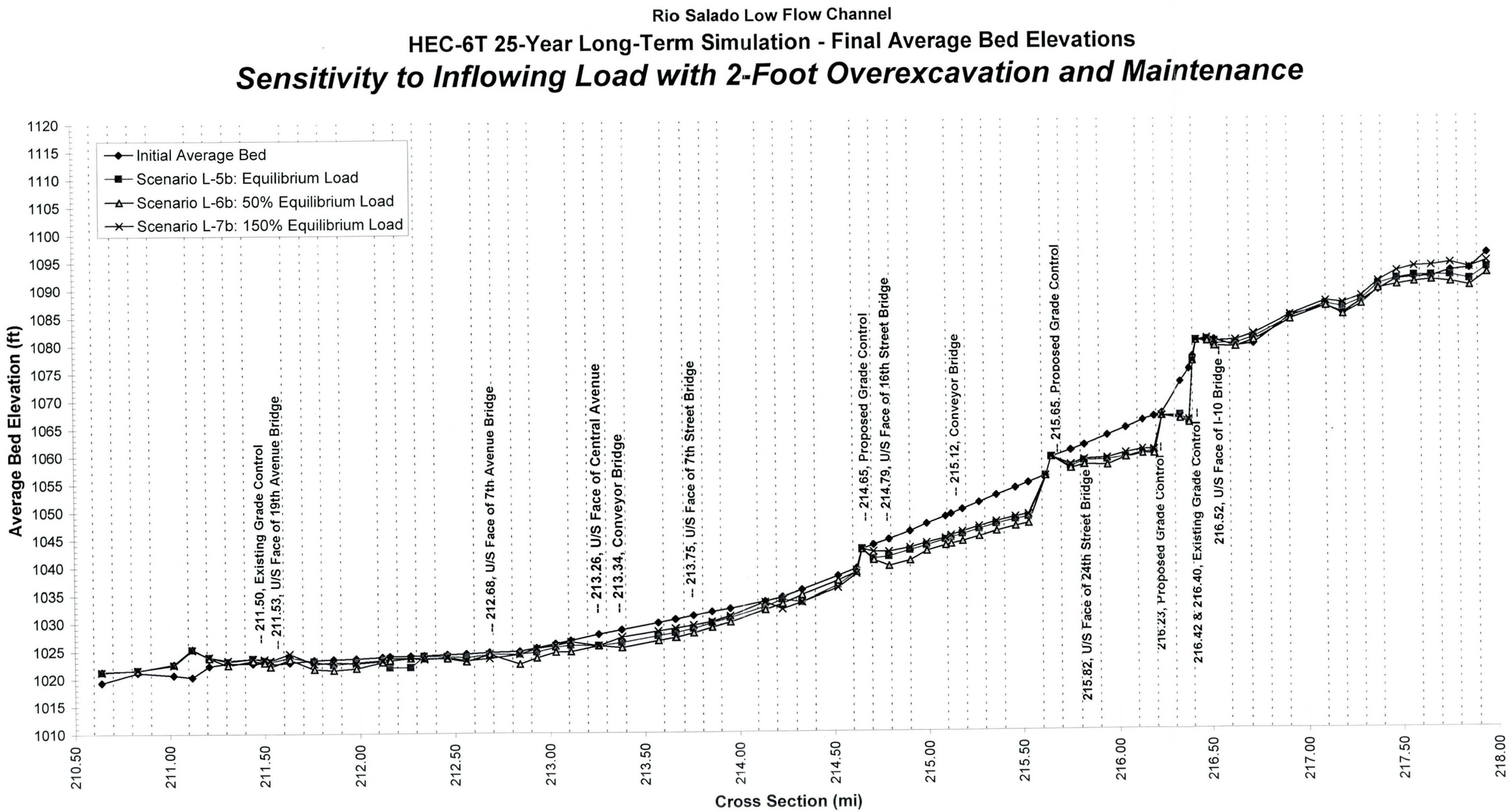


Figure 4.6. Sensitivity of sediment transport results to the inflowing sediment load for the low flow channel with 2-foot overexcavation. A comparison of the average bed elevations at the end of the 25-year simulation period for Scenarios L-6b, L-5b and L-7b.

Rio Salado Low Flow Channel

HEC-6T 25-Year Long-Term Simulation - Final Average Bed Elevation

Comparison of Transport Methods with 2-foot Overexcavation

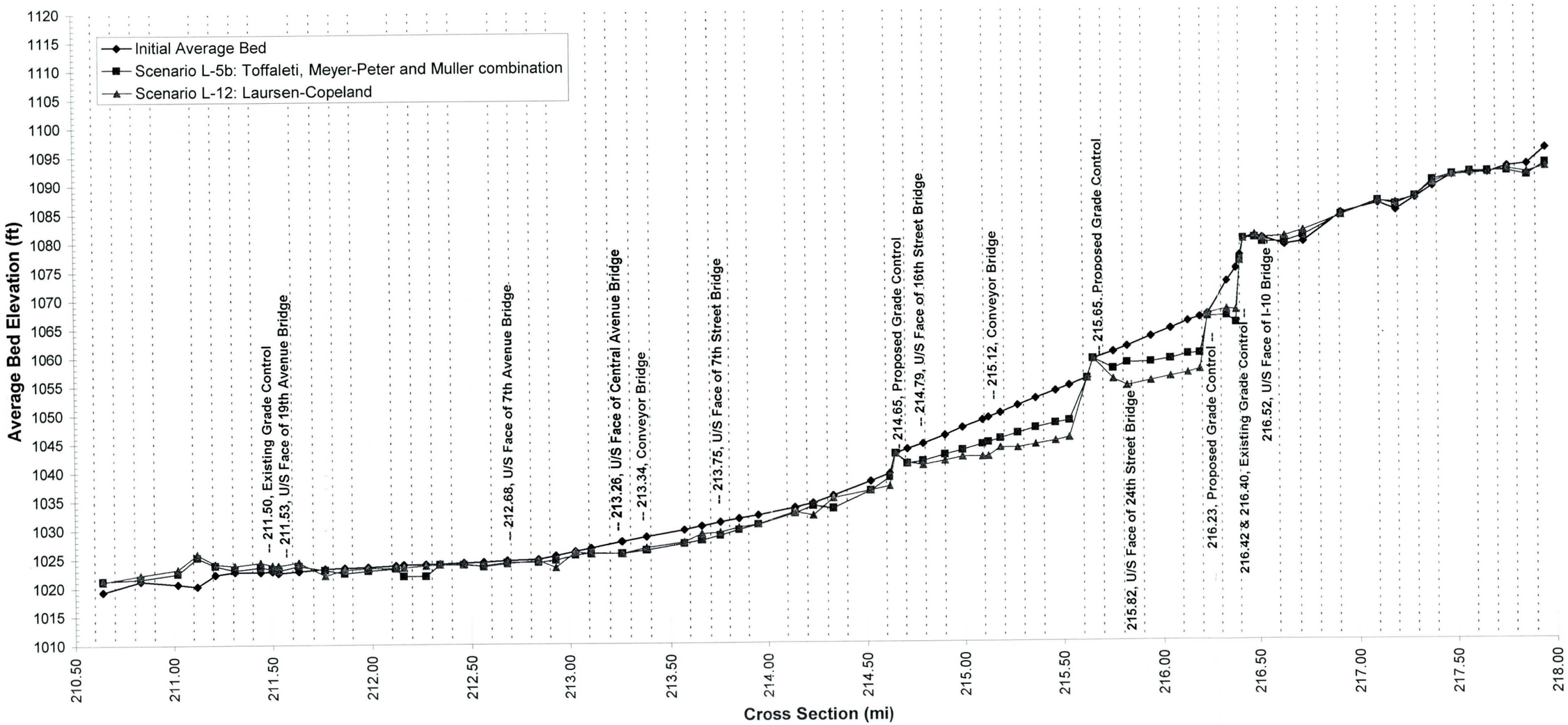


Figure 4.7. Comparison of sediment transport results for the low flow channel with the Toffaleti, Meyer-Peter and Muller combination and the Laursen-Copeland transport methods (Scenarios L-5b and L-12).

4.5. IMPACT OF PEAK DISCHARGE EVENTS

The impacts of the 25-, 50- and 100-year peak discharge events on the sediment transport results for the low flow channel before and after the 25-year long-term simulation have been evaluated.

When the 100-year peak discharge event occurs after the 25-year simulation period (Scenario L-9a), scour increases upstream of the proposed grade control structure at 214.65 (see Figure 4.8). The scour depths increase by 1 foot between the grade controls located at 214.65 and 215.65 and increase by 2 to 3 feet between the grade controls at 215.65 and 216.23. Deposition occurs downstream of the grade control at 214.65. The analysis includes periodic maintenance for 25 years, but the final average bed elevation in Figure 4.8 is before the maintenance after the 100-year peak discharge event. The same trends occur when the 25- and 50-year peak discharge events occur after the 25-year simulation period (Scenarios L-11a and L-10a, respectively), but the magnitudes of the scour and deposition are reduced (see Figure 4.9).

When the 100-year peak discharge event occurs before the 25-year simulation period (Scenario L-9b), the bed scours 4 to 6 feet upstream of the grade control located at 214.65 (see Figure 4.10). Deposition occurs downstream of the grade control at 214.65. At the end of the 25-year simulation period, the average bed elevations upstream of 214.65 are 1 to 2 feet lower in Scenario L-9b than in Scenario L-5b (25-year simulation without the 100-year peak event). The trends are the same when the 25- and 50-year peak discharge events (Scenarios L-11b and L-10b, respectively) occur before the 25-year simulation period (see Figure 4.11), but the magnitudes of the scour and deposition are reduced.

Rio Salado Low Flow Channel

HEC-6T Average Bed Elevations

100-Year Peak Discharge Event After the 25-Year Simulation Period

Scenario L-9a

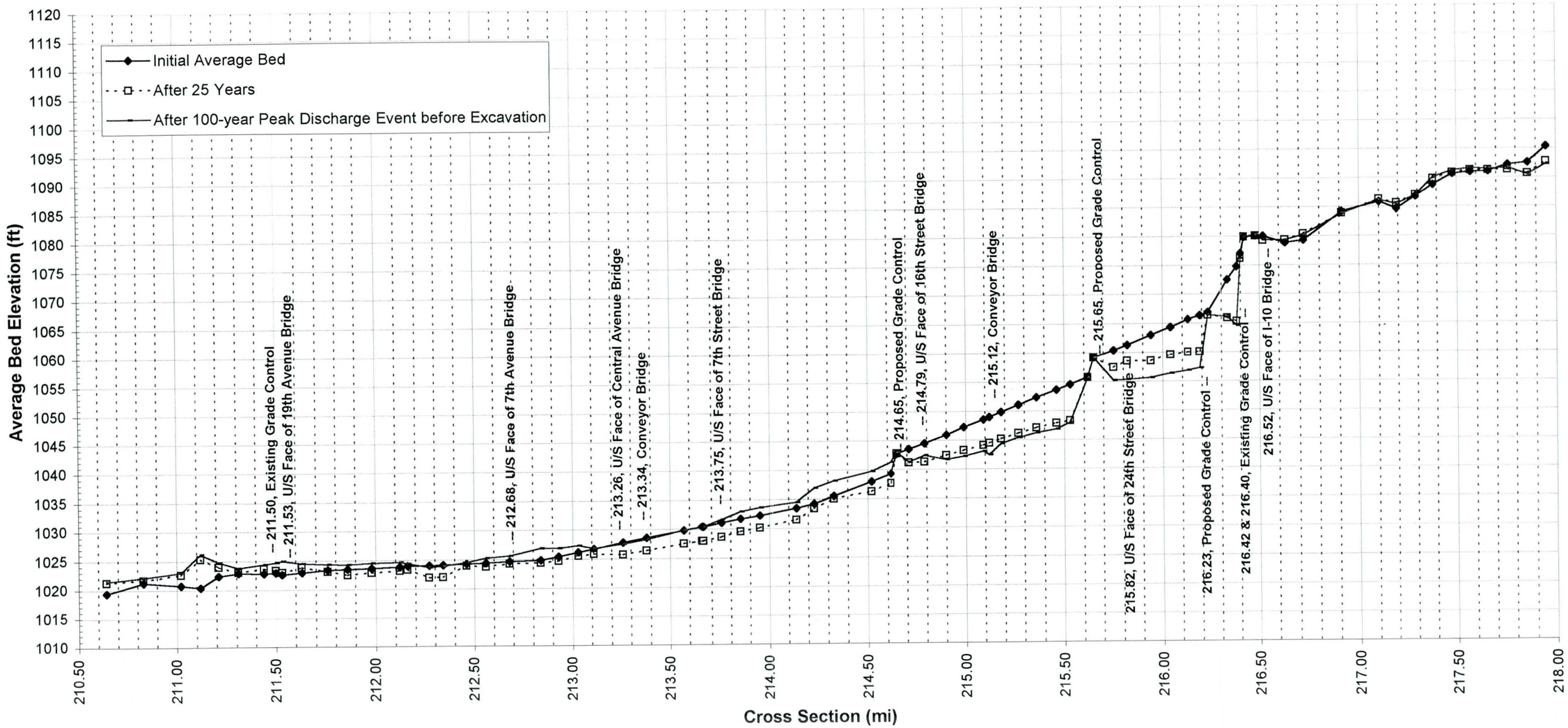


Figure 4.8. Average bed elevations of the low flow channel when the 100-year peak discharge event occurs after the 25-year simulation period (Scenario L-9a).

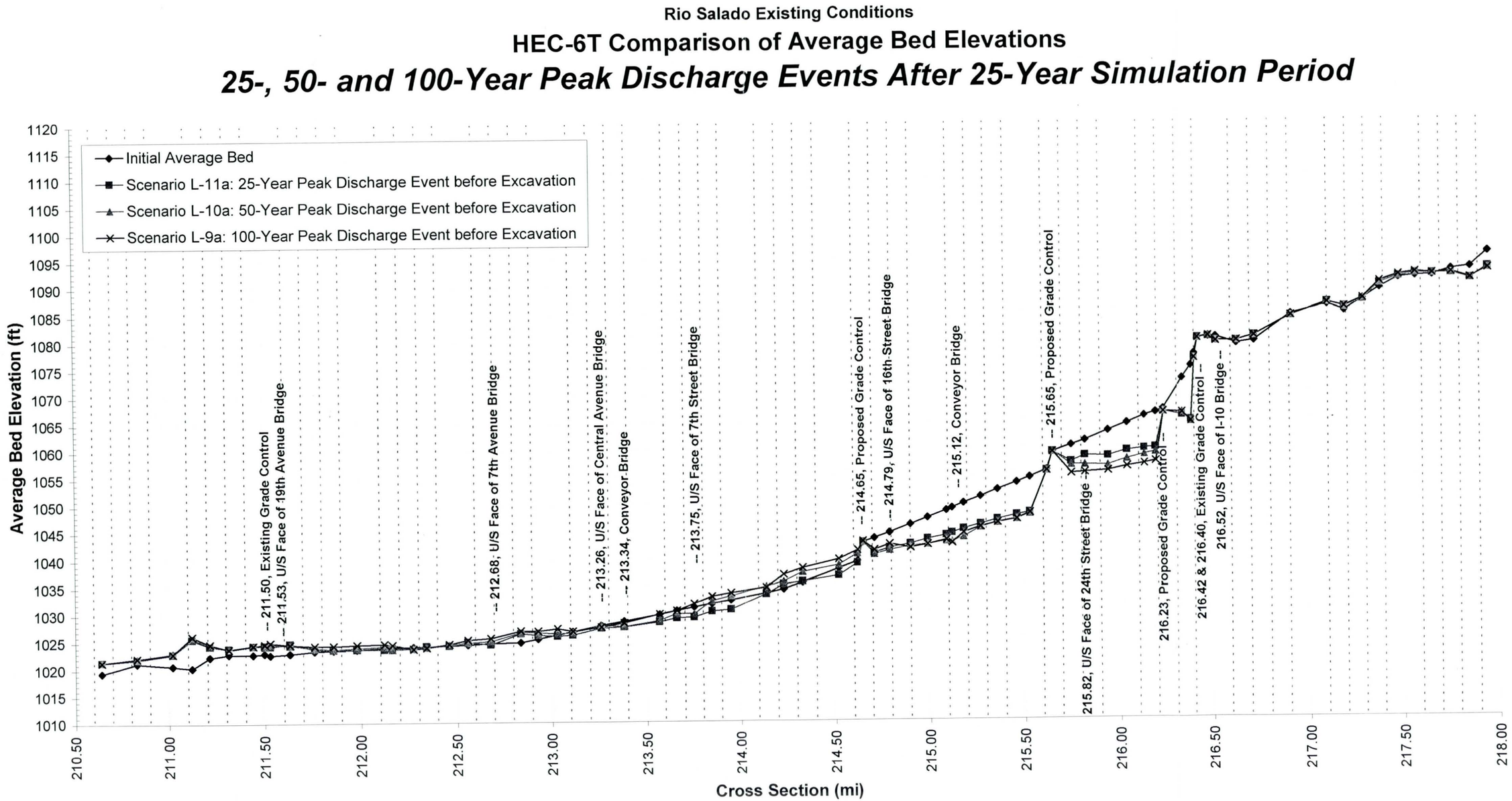


Figure 4.9. Comparison of the average bed elevations of the low flow channel when the 25-, 50- and 100-year peak discharge events occur after the 25-year simulation period (Scenarios L-11a, L-10a and L-9a, respectively).

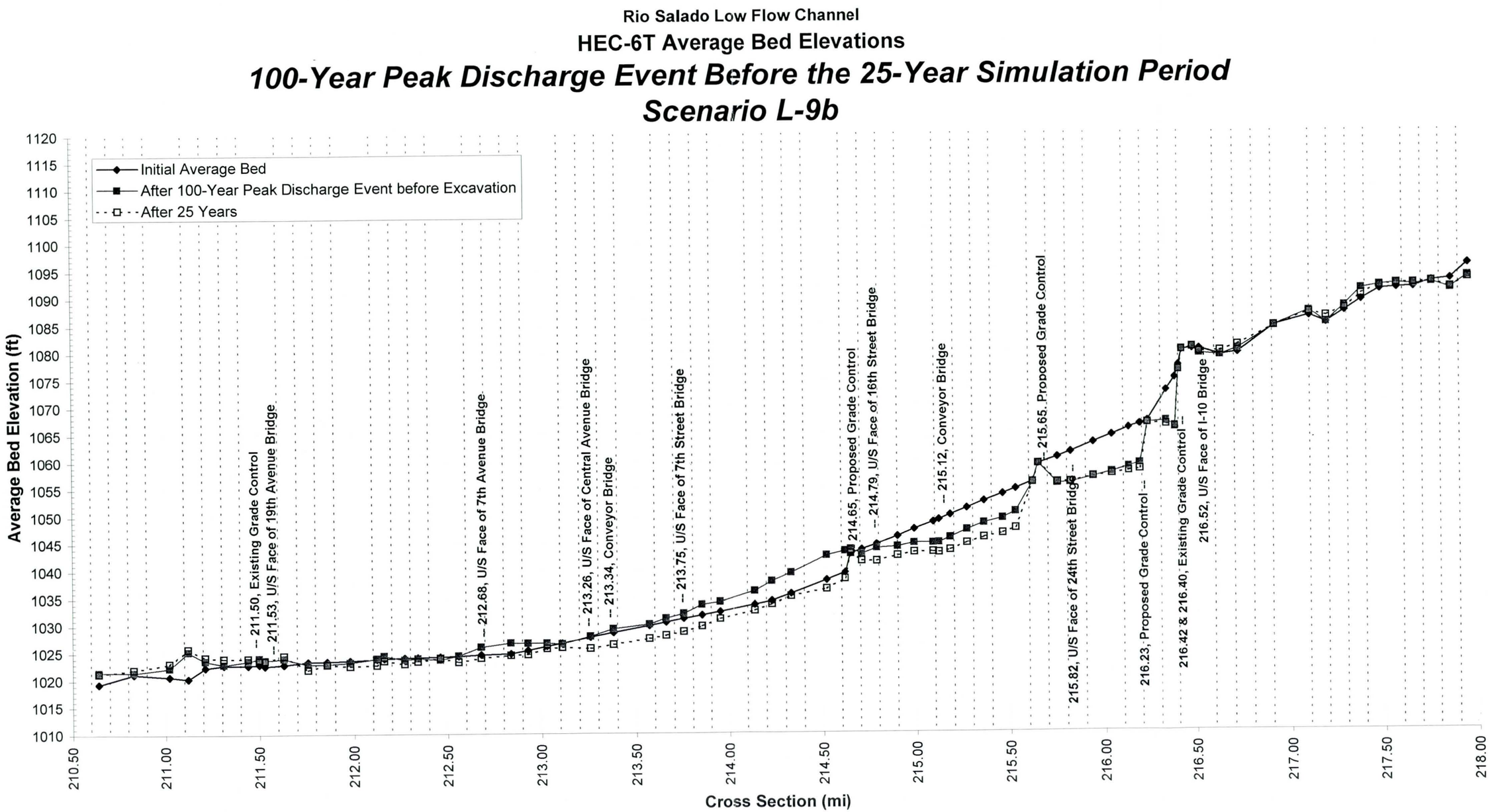


Figure 4.10. Average bed elevations of the low flow channel when the 100-year peak discharge event occurs before the 25-year simulation period (Scenario L-9b).

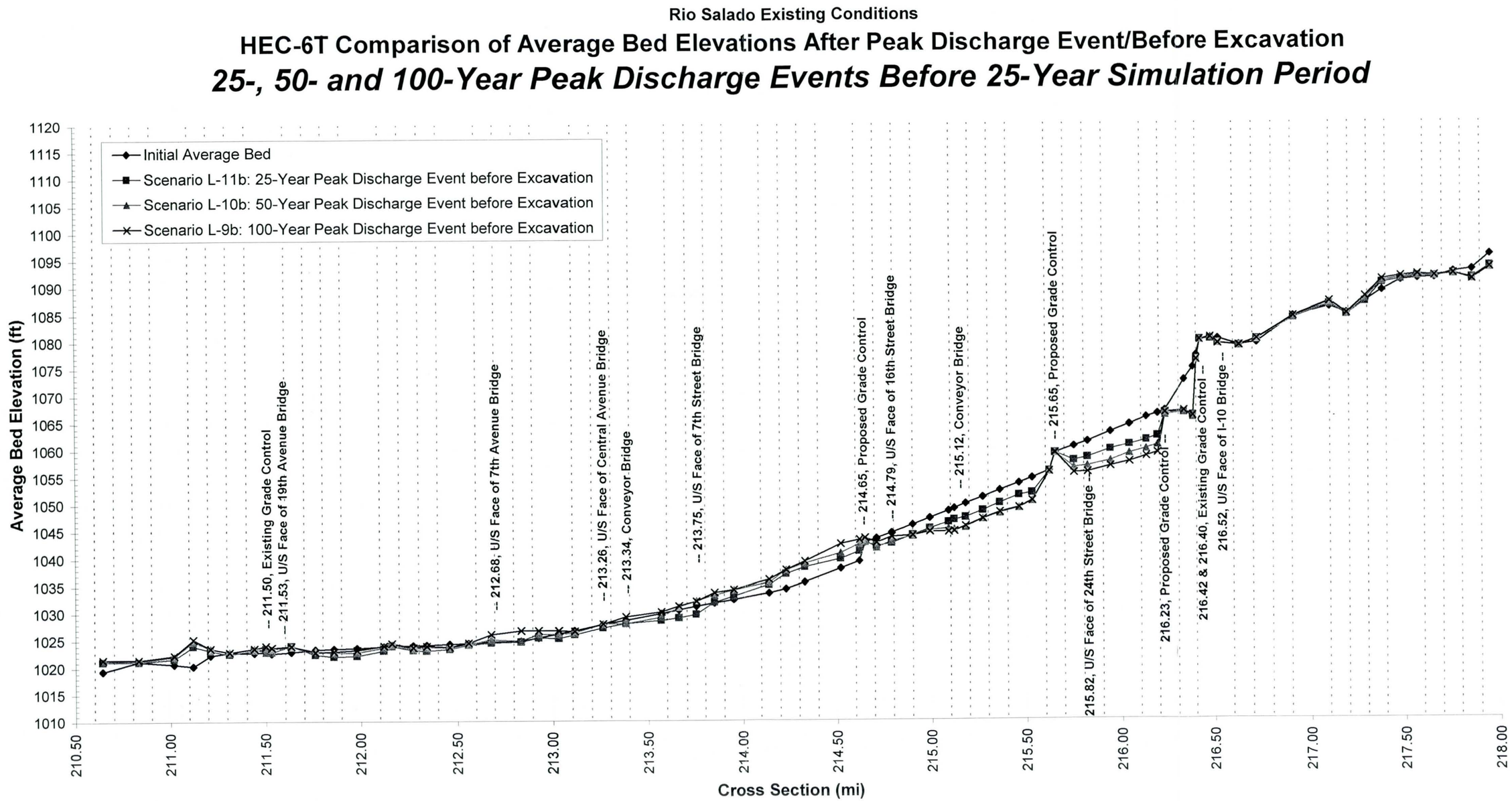


Figure 4.11. Comparison of the average bed elevations of the low flow channel when the 25-, 50- and 100-year peak discharge events occur before the 25-year simulation period (Scenarios L-11b, L-10b and L-9b, respectively).

4.6. SUMMARY

Twenty-two long-term sediment transport simulations were completed for the low flow channel analysis (see Table 4.1). The transport results were used to:

1. Evaluate grade control locations
2. Determine overexcavation depth
3. Determine annual maintenance requirements
4. Estimate the impacts of the 25-, 50- and 100-year discharge events

Sediment transport simulations with the equilibrium inflowing bed material load were used to evaluate the following four grade control scenarios:

1. Existing grade control structures only
2. One proposed grade control structure at cross section 216.23
3. Two proposed grade control structures at cross sections 216.23 and 215.65
4. Three proposed grade control structures at cross sections 216.23, 215.65 and 214.65
5. Four proposed grade control structures at cross sections 216.23, 215.65, 214.65 and 213.26

The analysis demonstrated the need for and the locations of the four grade control structures. The functions of the proposed structures are listed below:

1. The proposed grade control located at 216.23 limits the scour below the existing grade control 216.40, which is one-tenth of a mile downstream of I-10 (216.52).
2. The proposed grade control located at 215.65 reduces scour in the upstream low flow channel reach.
3. The proposed grade control located at 214.65 is added to protect the 16th Street Bridge (214.79) and 36" water line at (214.80) from excessive scour. Without this grade control, the bed scours to the top of the water line's casing with equilibrium inflowing sediment load and downstream channel overexcavation and maintenance (Scenario L-8a).
4. The proposed grade control structure located at Central Avenue (cross section 213.26) protects the bridge from localized pier scour.

With the equilibrium inflowing sediment load, deposition occurs in the downstream reach of the low flow channel (4 to 7 feet between cross sections 214.13 and 214.65 and 1 to 3 feet downstream of cross section 214.13 to the downstream limit of the low flow channel). The deposition decreases the low flow channel capacity which in turn increases flooding and damage in the overbanks. Therefore, channel excavation is needed periodically to maintain the low flow channel capacity.

Four overexcavation scenarios (1-foot, 2-foot, 3-foot and 4-foot overexcavation depths) were evaluated and the resulting annual maintenance (i.e. channel excavation) examined. The 2-foot overexcavation scenario is recommended because it results in the least amount of scour above the grade control located at 214.65 (i.e. at the 36" water line). For the 2-foot overexcavation scenario, the scour depth at the 36" inch water line is 0.5 feet less than that for the 3-foot and 4-foot excavation scenarios.

The low flow channel scour upstream of the grade control structure located at 214.65 increases by 2 to 5 feet when the Laursen-Copeland transport method is used. This scenario results in the greatest amount of long-term scour and will be used in the bridge scour analysis.

The 25-, 50- and 100-year peak discharge events increase scour upstream of the grade control structure located at 214.65 and deposition downstream. When the 100-year peak discharge event occurs after the 25-year simulation period, the scour depths increase by 1 foot between the grade control structures at 214.65 and 215.65 and by 2 to 3 feet between the grade control structures at 215.65 and 216.23.

When the 100-year peak discharge event occurs before the 25-year simulation period, 4 to 6 feet of scour occurs upstream of the grade control at 214.65. At the end of the simulation period, the average bed elevations upstream of the grade control at 214.65 are generally 1 to 2 feet lower than those without the 100-year peak event.

APPENDIX 4A

Bed Gradations for Existing Conditions HEC-6T Models

Rio Salado - Existing Conditions

Composite Bed Gradations for PF Records in the HEC-6T Model

Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Sections 217.1 to 217.95																		
189	TT99-1	217.48	0.0	3.0	3.0	100.0	100.0	80.0	40.0	20.0	16.0	14.4	13.6	12.8	11.2	6.4	3.2	1.6
190	TT99-1	217.48	3.0	6.0	3.0	100.0	100.0	80.0	44.0	23.2	19.2	16.8	15.2	13.6	11.2	8.0	6.4	3.2
194	TT99-2	217.48	0.0	3.0	3.0	100.0	100.0	95.0	77.9	64.6	51.3	43.7	39.9	35.2	20.9	5.7	2.9	1.0
199	TT99-3	217.00	0.0	3.0	3.0	100.0	90.0	75.0	25.5	7.5	5.3	4.5	3.8	3.8	3.0	1.5	0.8	0.8
204	TT99-4	217.00	0.0	3.0	3.0	100.0	98.0	88.0	64.2	46.6	35.2	29.9	27.3	23.8	13.2	5.3	2.6	1.8
205	TT99-4	217.00	3.0	6.0	3.0	100.0	98.0	83.0	64.6	41.5	33.2	30.4	29.5	27.7	14.8	3.7	1.8	0.9
Composite					***18.0***	***100.0***	***97.7***	***83.5***	***52.7***	***33.9***	***26.7***	***23.3***	***21.5***	***19.5***	***12.4***	***5.1***	***2.9***	***1.5***
Cross Section 216.33																		
209	TT99-5	216.33	0.0	3.0	3.0	100.0	90.0	70.0	54.4	36.6	24.1	17.1	14.8	12.4	8.6	4.7	3.1	1.6
210	TT99-5	216.33	3.0	5.0	2.0	100.0	90.0	70.0	44.1	32.2	23.1	18.9	16.1	13.3	9.8	7.0	4.9	2.8
214	TT99-6	216.33	0.0	3.0	3.0	100.0	85.0	60.0	46.2	35.4	26.4	20.4	16.8	10.8	4.2	1.2	0.6	0.6
215	TT99-6	216.33	3.0	7.0	4.0	100.0	85.0	60.0	27.6	16.2	10.8	7.8	4.8	3.0	1.2	0.6	0.6	0.6
Composite					***12.0***	***100.0***	***87.1***	***64.2***	***41.7***	***28.8***	***20.1***	***15.1***	***12.2***	***9.0***	***5.2***	***2.8***	***1.9***	***1.2***
Cross Section 215.94																		
216	TT99-7	215.94	0.0	3.0	3.0	100.0	90.0	65.0	51.4	39.7	29.9	23.4	20.8	15.6	7.8	3.3	1.3	0.7
217	TT99-7	215.94	3.0	6.0	3.0	100.0	90.0	65.0	44.9	24.7	18.2	15.0	13.7	11.7	7.8	3.9	2.6	1.3
221	TT99-8	215.94	0.0	3.0	3.0	100.0	95.0	75.0	67.9	51.2	37.9	29.1	23.8	17.6	10.6	4.4	1.8	0.9
222	TT99-8	215.94	3.0	6.0	3.0	100.0	95.0	75.0	46.5	27.0	21.8	17.3	15.8	13.5	9.8	3.8	1.5	0.8
Composite					***12.0***	***100.0***	***92.5***	***70.0***	***52.7***	***35.6***	***26.9***	***21.2***	***18.5***	***14.6***	***9.0***	***3.8***	***1.8***	***0.9***

Rio Salado - Existing Conditions

Composite Bed Gradations for PF Records in the HEC-6T Model

Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Section 215.53																		
224	TT99-9	215.56	0.0	3.0	3.0	100.0	95.0	80.0	64.8	48.8	38.4	33.6	31.2	25.6	15.2	5.6	2.4	0.8
225	TT99-9	215.56	3.0	6.0	3.0	100.0	95.0	75.0	60.0	44.3	36.0	15.8	15.0	13.5	10.5	6.0	3.0	0.8
230	TT99-10	215.56	0.0	3.0	3.0	100.0	95.0	75.0	55.5	42.8	33.0	25.5	22.5	19.5	15.0	6.8	3.8	0.8
231	TT99-10	215.56	3.0	7.0	4.0	100.0	95.0	70.0	51.1	37.8	29.4	25.2	23.1	19.6	11.9	4.9	2.1	0.7
Composite					***13.0***	***100.0***	***95.0***	***74.6***	***57.3***	***43.0***	***33.8***	***25.0***	***23.0***	***19.6***	***13.1***	***5.7***	***2.8***	***0.7***
Cross Section 215.09																		
235	TT99-11	215.09	0.0	3.0	3.0	100.0	98.0	88.0	71.3	55.4	44.0	36.1	33.4	27.3	16.7	7.9	4.4	2.6
236	TT99-11	215.09	3.0	6.0	3.0	100.0	98.0	88.0	61.6	39.6	29.9	26.4	25.5	23.8	12.3	2.6	0.9	0.9
240	TT99-12	215.09	0.0	2.0	2.0	100.0	100.0	95.0	57.0	40.9	31.4	26.6	24.7	21.9	14.3	4.8	1.9	1.0
242	TT99-12	215.09	5.0	8.0	3.0	100.0	100.0	100.0	77.0	68.0	63.0	61.0	60.0	56.0	34.0	11.0	2.0	1.0
Composite					***11.0***	***100.0***	***98.9***	***92.5***	***67.6***	***51.9***	***43.0***	***38.5***	***36.9***	***33.2***	***19.8***	***6.7***	***2.3***	***1.4***
Cross Section 214.71																		
243	TT99-13	214.71	0.0	3.0	3.0	100.0	100.0	95.0	81.7	58.0	41.8	34.2	30.4	22.8	8.6	2.9	1.0	1.0
244	TT99-13	214.71	3.0	6.0	3.0	100.0	100.0	97.0	86.3	66.9	49.5	38.8	32.0	20.4	5.8	1.0	1.0	1.0
248	TT99-14	214.71	0.0	2.0	2.0	100.0	100.0	85.0	68.0	50.2	37.4	30.6	27.2	24.7	16.2	4.3	0.9	0.9
249	TT99-14	214.71	2.0	6.0	4.0	100.0	98.0	78.0	46.8	18.7	16.4	14.8	13.3	10.1	5.5	2.3	1.6	0.8
Composite					***12.0***	***100.0***	***99.3***	***88.2***	***68.9***	***45.8***	***34.5***	***28.3***	***24.6***	***18.3***	***8.1***	***2.4***	***1.1***	***0.9***

Rio Salado - Existing Conditions

Composite Bed Gradations for PF Records in the HEC-6T Model

Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Section 214.14																		
252	TT99-15	214.14	0.0	4.0	4.0	100.0	100.0	90.0	65.7	49.5	36.0	29.7	24.3	18.9	9.0	2.7	0.9	0.9
257	TT99-16	214.14	0.0	2.0	2.0	100.0	100.0	98.0	85.3	61.7	48.0	42.1	41.2	37.2	19.6	4.9	1.0	1.0
258	TT99-16	214.14	2.0	3.0	1.0	100.0	100.0	100.0	89.0	82.0	73.0	67.0	63.0	58.0	49.0	31.0	9.0	1.0
259	TT99-16	214.14	3.0	4.0	1.0	100.0	100.0	95.0	80.8	66.5	58.0	51.3	46.6	39.0	24.7	13.3	6.7	1.9
260	TT99-16	214.14	4.0	5.0	1.0	100.0	98.0	88.0	78.3	73.9	71.3	69.5	51.0	25.5	11.4	5.3	1.8	0.9
Composite					***9.0***	***100.0***	***99.8***	***93.2***	***75.7***	***60.4***	***49.1***	***43.4***	***37.8***	***30.3***	***17.8***	***7.8***	***2.6***	***1.0***
Cross Section 213.57																		
264	TT99-17	213.57	0.0	3.0	3.0	100.0	95.0	80.0	54.4	40.8	28.8	22.4	19.2	16.0	8.0	2.4	0.8	0.8
265	TT99-17	213.57	3.0	6.0	3.0	100.0	95.0	80.0	66.4	47.2	36.0	29.6	26.4	24.0	17.6	11.2	5.6	0.8
269	TT99-18	213.57	0.0	3.0	3.0	100.0	100.0	80.0	61.6	49.6	38.4	32.0	29.6	26.4	17.6	7.2	2.4	0.8
270	TT99-18	213.57	3.0	6.0	3.0	100.0	98.0	78.0	53.8	37.4	27.3	21.1	17.9	16.4	12.5	7.0	2.3	0.8
Composite					***12.0***	***100.0***	***97.0***	***79.5***	***59.1***	***43.8***	***32.6***	***26.3***	***23.3***	***20.7***	***13.9***	***7.0***	***2.8***	***0.8***
Cross Section 212.93																		
338	TT99-33	*213.08*	0.0	1.0	1.0	100.0	100.0	85.0	66.3	44.2	33.2	26.4	23.0	19.6	10.2	4.3	1.7	0.9
339	TT99-33	*213.08*	1.0	2.0	1.0	100.0	100.0	90.0	90.0	85.5	72.9	46.8	41.4	34.2	22.5	13.5	6.3	2.7
340	TT99-33	*213.08*	2.0	8.0	6.0	100.0	100.0	90.0	86.4	79.2	61.2	44.1	37.8	29.7	18.9	9.9	5.4	2.7
273	TT99-19	212.93	0.0	3.0	3.0	100.0	100.0	80.0	58.4	44.0	34.4	29.6	28.0	24.0	13.6	5.6	2.4	0.8
274	TT99-19	212.93	3.0	6.0	3.0	100.0	100.0	75.0	50.3	33.8	27.0	24.8	24.0	21.0	9.8	1.5	0.8	0.8
277	TT99-20	212.93	0.0	2.0	2.0	100.0	100.0	95.0	84.6	66.8	53.2	42.8	37.6	31.3	18.8	9.4	6.3	3.1
278	TT99-20	212.93	2.0	3.0	1.0	100.0	100.0	100.0	99.0	87.0	73.0	62.0	57.0	54.0	44.0	35.0	29.0	23.0
Composite					***17.0***	***100.0***	***100.0***	***86.5***	***74.6***	***62.3***	***49.2***	***38.1***	***34.1***	***28.4***	***17.5***	***9.0***	***5.4***	***3.2***

Rio Salado - Existing Conditions

Composite Bed Gradations for PF Records in the HEC-6T Model

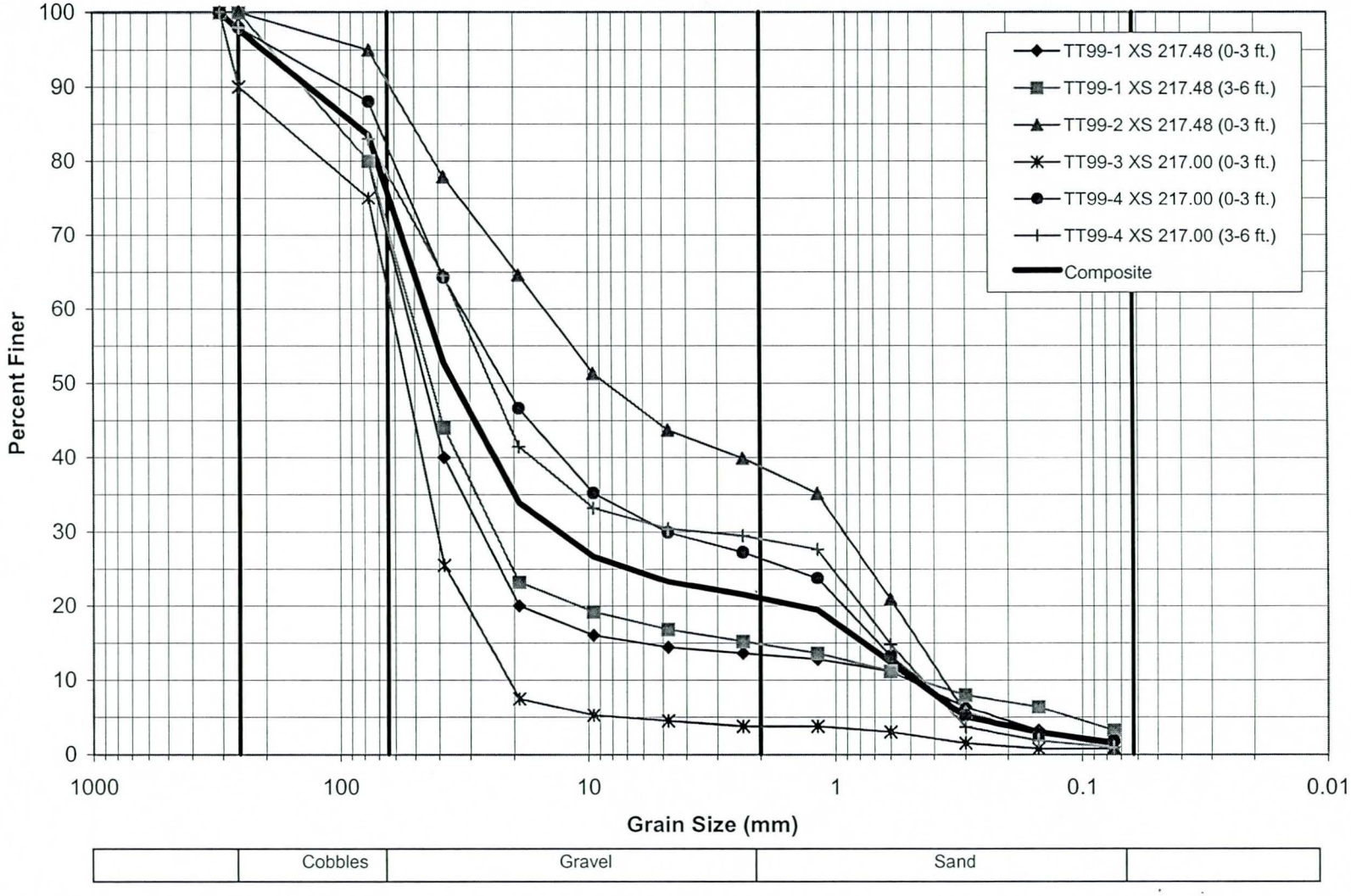
Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Section 212.34																		
284	TT99-21	212.37	0.0	3.0	3.0	100.0	95.0	75.0	51.0	37.5	28.5	23.3	21.0	18.8	13.5	6.8	3.8	2.3
289	TT99-22	212.37	0.0	3.0	3.0	100.0	80.0	55.0	41.8	28.1	20.9	16.5	14.9	12.7	8.8	3.9	1.7	0.6
290	TT99-22	212.37	3.0	6.0	3.0	100.0	100.0	85.0	68.0	48.5	35.7	27.2	23.8	20.4	11.1	3.4	0.9	0.9
Composite					***9.0***	***100.0***	***91.7***	***71.7***	***53.6***	***38.0***	***28.4***	***22.3***	***19.9***	***17.3***	***11.1***	***4.7***	***2.1***	***1.2***
Cross Sections 210.64 to 211.44																		
293	TT99-23	211.41	0.0	3.0	3.0	100.0	100.0	90.0	68.4	48.6	37.8	30.6	27.9	24.3	16.2	8.1	5.4	3.6
294	TT99-23	211.41	3.0	6.0	3.0	100.0	100.0	90.0	67.0	47.1	36.6	30.3	27.2	20.9	10.5	4.2	2.1	1.0
298	TT99-24	211.41	0.0	3.0	3.0	100.0	98.0	93.0	77.1	59.2	47.6	41.2	39.1	34.9	21.1	5.3	1.1	1.1
299	TT99-24	211.41	3.0	6.0	3.0	100.0	98.0	93.0	70.7	50.2	39.1	32.6	28.8	24.2	14.0	4.7	0.9	0.9
303	TT99-25	210.93	0.0	1.0	1.0	100.0	100.0	90.0	81.0	67.5	59.4	45.9	43.2	39.6	24.3	5.4	1.8	0.9
305	TT99-25	210.93	2.0	3.0	1.0	100.0	100.0	85.0	40.6	28.0	23.2	21.3	20.3	18.4	9.7	1.0	1.0	1.0
306	TT99-25	210.93	3.0	5.0	2.0	100.0	100.0	95.0	71.3	50.4	39.9	22.8	20.0	18.1	9.5	1.9	1.0	1.0
307	TT99-25	210.93	5.0	6.0	1.0	100.0	100.0	50.0	17.5	11.0	9.0	8.0	7.5	7.0	4.5	1.0	0.5	0.5
310	TT99-26	210.93	0.0	1.0	1.0	100.0	100.0	98.0	86.2	68.6	62.7	57.8	54.9	51.9	36.3	10.8	2.9	1.0
Composite					***18.0***	***100.0***	***99.3***	***89.5***	***67.6***	***49.5***	***39.8***	***32.4***	***29.7***	***25.9***	***15.5***	***4.9***	***2.0***	***1.4***

Rio Salado - Existing Conditions

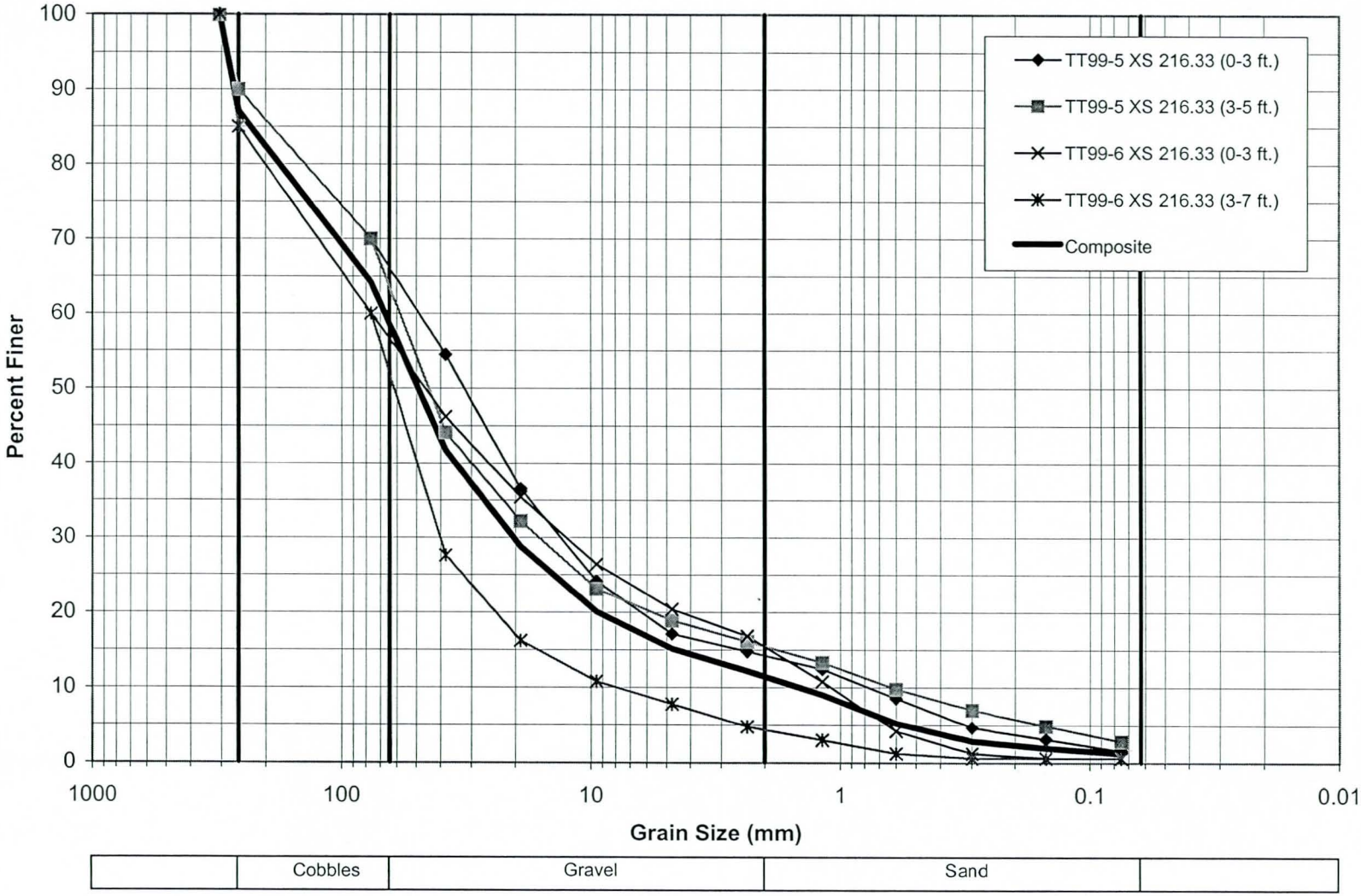
Composite Bed Gradations for PF Records in the HEC-6T Model

Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Section 211.98																		
315	TT99-27	211.98	0.0	1.0	1.0	100.0	100.0	85.0	58.7	44.2	37.4	32.3	30.6	28.9	23.0	16.2	11.1	6.8
316	TT99-27	211.98	1.0	6.0	5.0	100.0	98.0	83.0	39.0	32.4	29.1	26.6	24.9	22.4	18.3	11.6	5.0	0.8
320	TT99-28	211.98	0.0	4.0	4.0	100.0	98.0	83.0	75.5	61.4	37.4	29.9	27.4	24.1	15.8	6.6	2.5	0.8
321	TT99-28	211.98	4.0	8.0	4.0	100.0	95.0	75.0	62.3	46.5	33.8	24.0	20.3	15.8	8.3	3.0	0.8	0.8
324	TT99-29	211.98	0.0	2.0	2.0	100.0	98.0	88.0	56.3	45.8	35.2	29.0	26.4	20.2	9.7	2.6	0.9	0.9
325	TT99-29	211.98	2.0	8.0	6.0	100.0	98.0	78.0	51.5	32.8	24.2	19.5	15.6	12.5	7.0	0.8	0.8	0.8
328	TT99-30	*211.95*	0.0	5.0	5.0	100.0	98.0	88.0	44.0	32.3	26.4	22.5	20.5	15.6	7.8	2.9	1.0	1.0
332	TT99-31	*212.08*	0.0	6.0	6.0	100.0	100.0	80.0	39.1	28.4	22.2	19.6	18.7	16.9	9.8	2.7	0.9	0.9
335	TT99-32	*211.87*	0.0	1.0	1.0	100.0	98.0	83.0	68.4	52.9	45.6	40.1	38.3	36.5	27.4	14.6	7.3	2.7
336	TT99-32	*211.87*	1.0	10.0	9.0	100.0	100.0	80.0	60.0	40.0	32.8	28.8	27.2	24.8	16.8	7.2	2.4	0.8
Composite					***43.0***	***100.0***	***98.5***	***81.4***	***53.2***	***38.9***	***30.0***	***25.2***	***23.0***	***19.9***	***12.7***	***5.4***	***2.2***	***1.0***

Rio Salado - Existing Conditions
Bed Gradation for Cross Sections 217.1 to 217.95



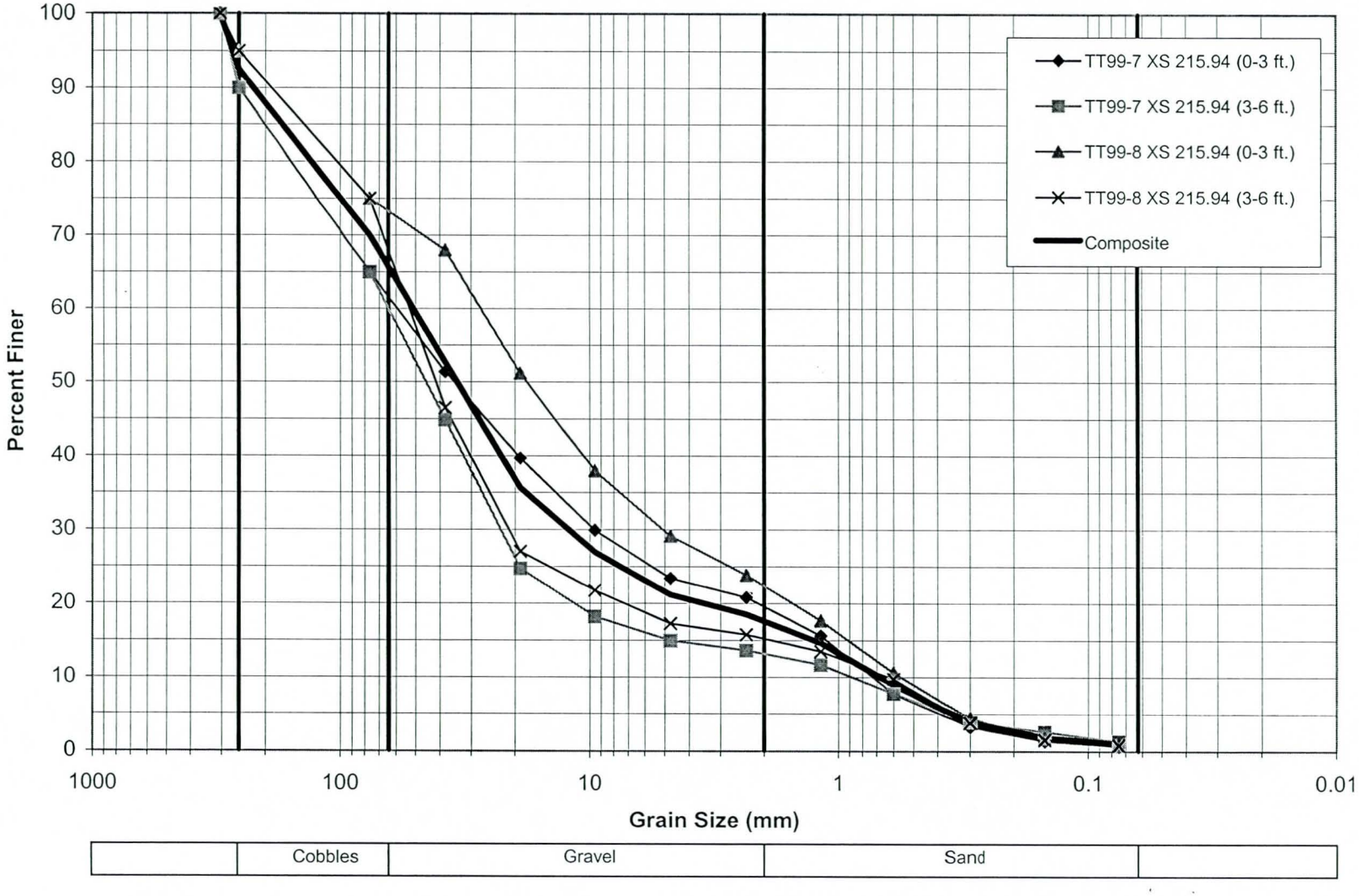
Rio Salado - Existing Conditions
Bed Gradation at Cross Section 216.33



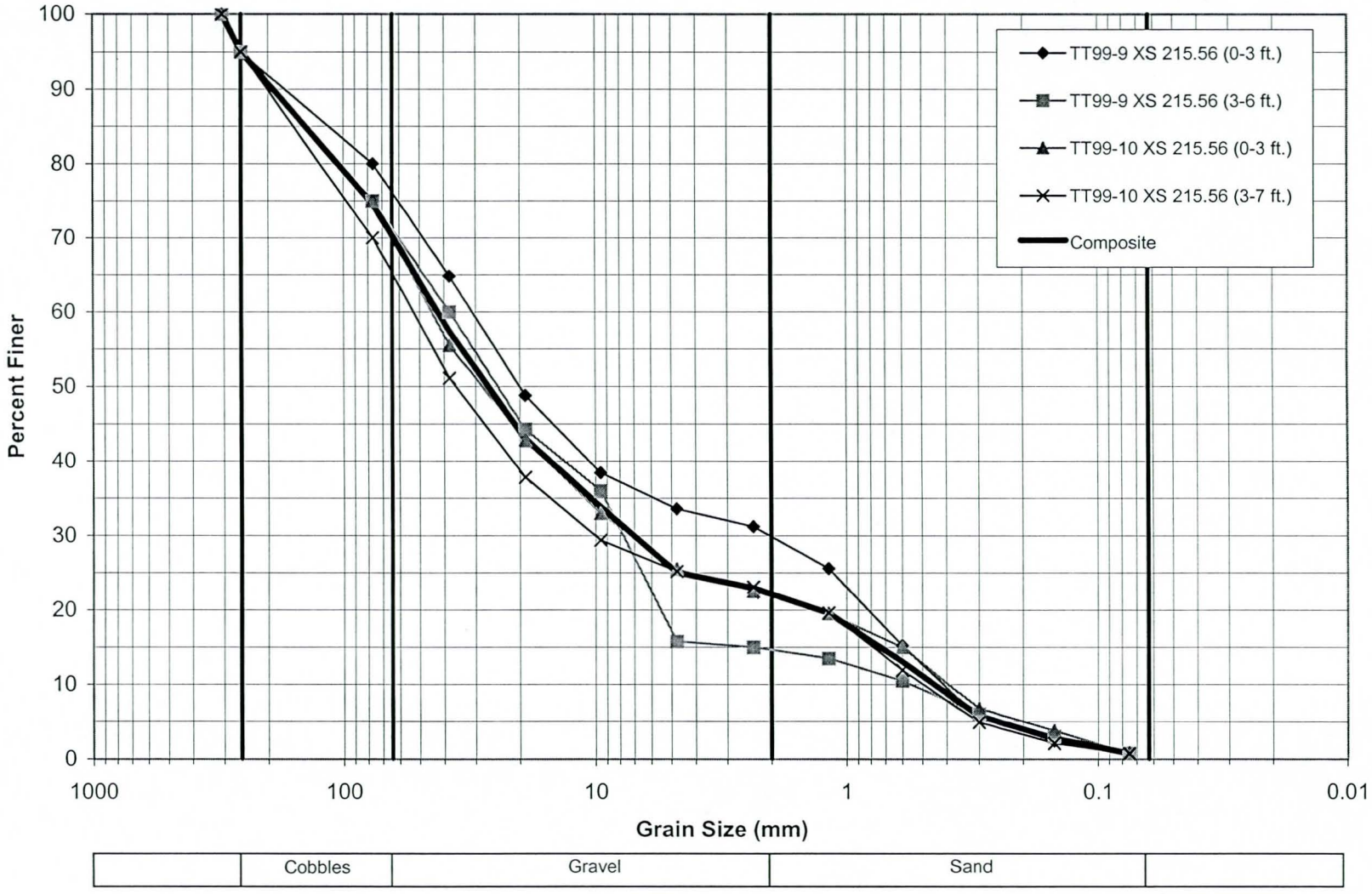
Prepared by SMF

Gradation SMF.xls
4/14/99

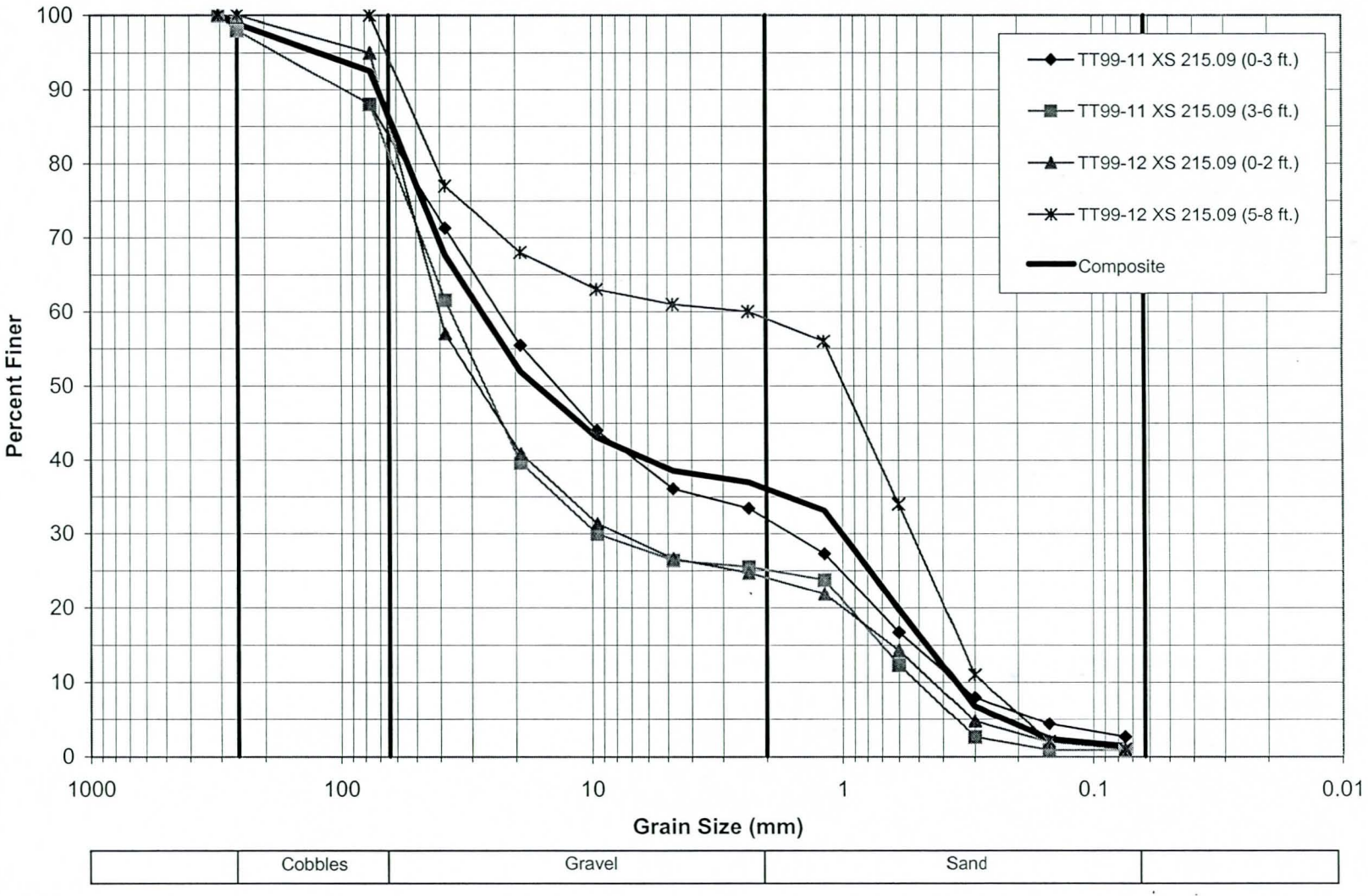
Rio Salado - Existing Conditions
Bed Gradation at Cross Section 215.94



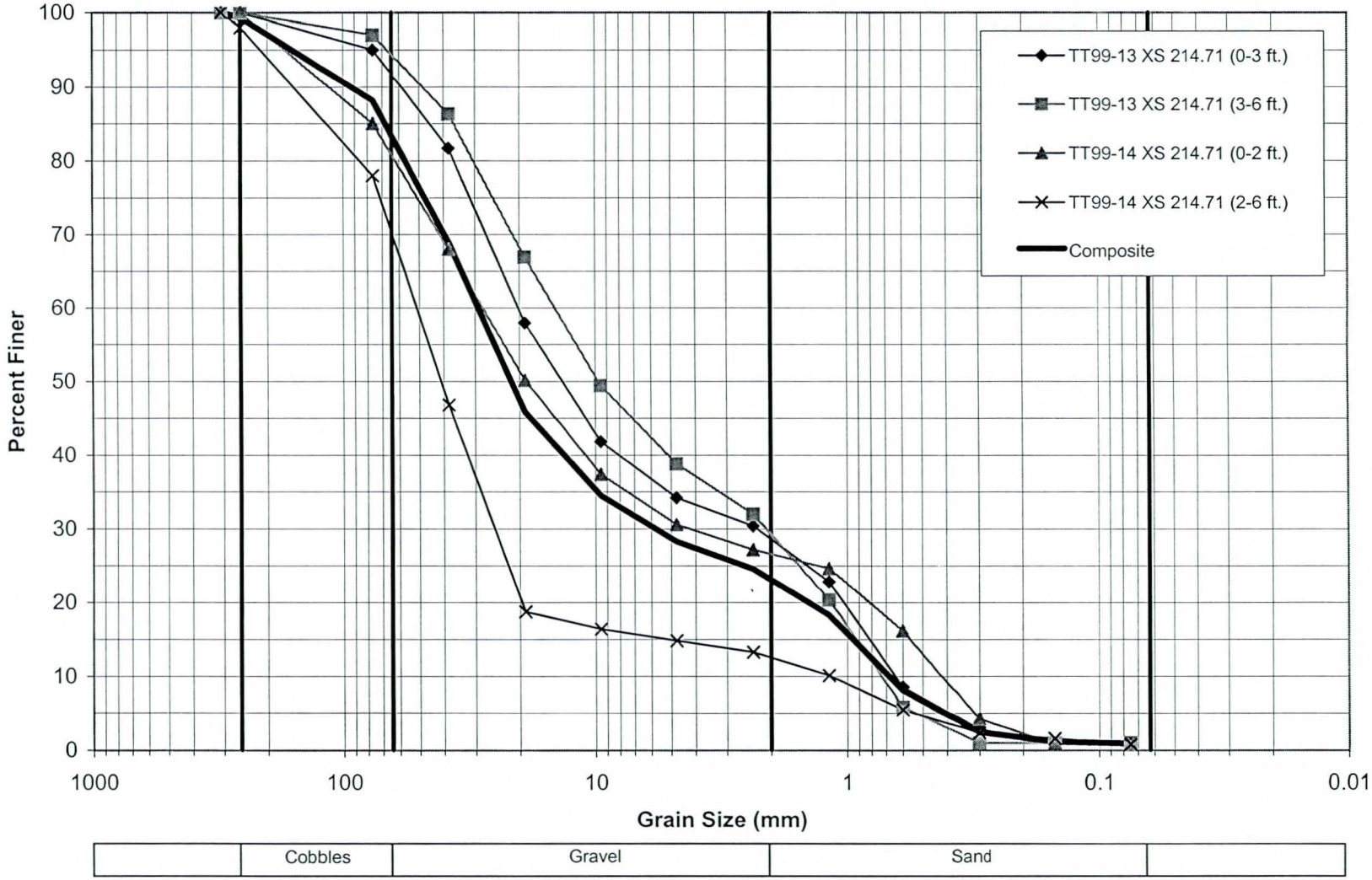
Rio Salado - Existing Conditions
Bed Gradation at Cross Section 215.53



Rio Salado - Existing Conditions
Bed Gradation at Cross Section 215.09



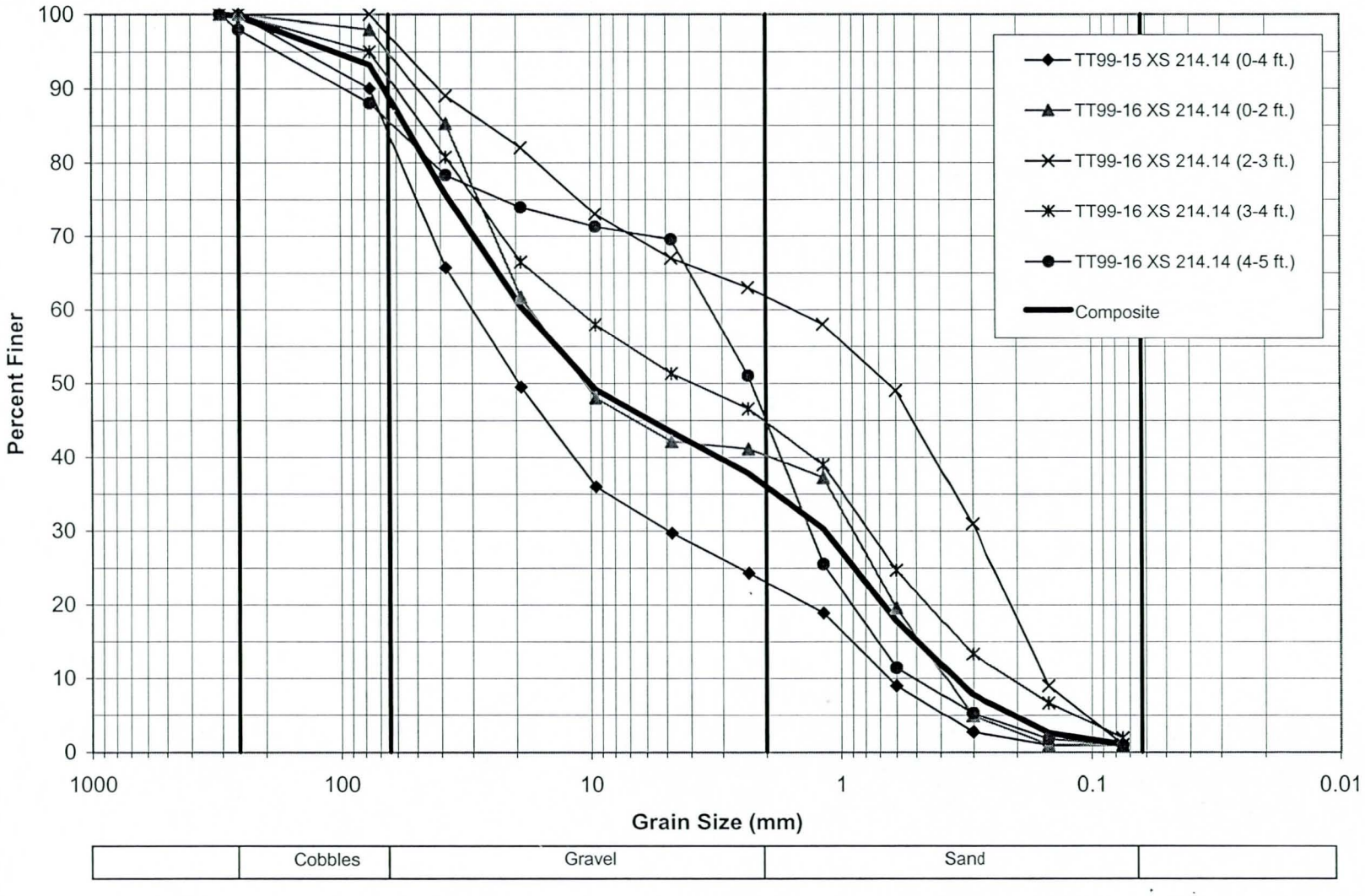
Rio Salado - Existing Conditions
Bed Gradation at Cross Section 214.71



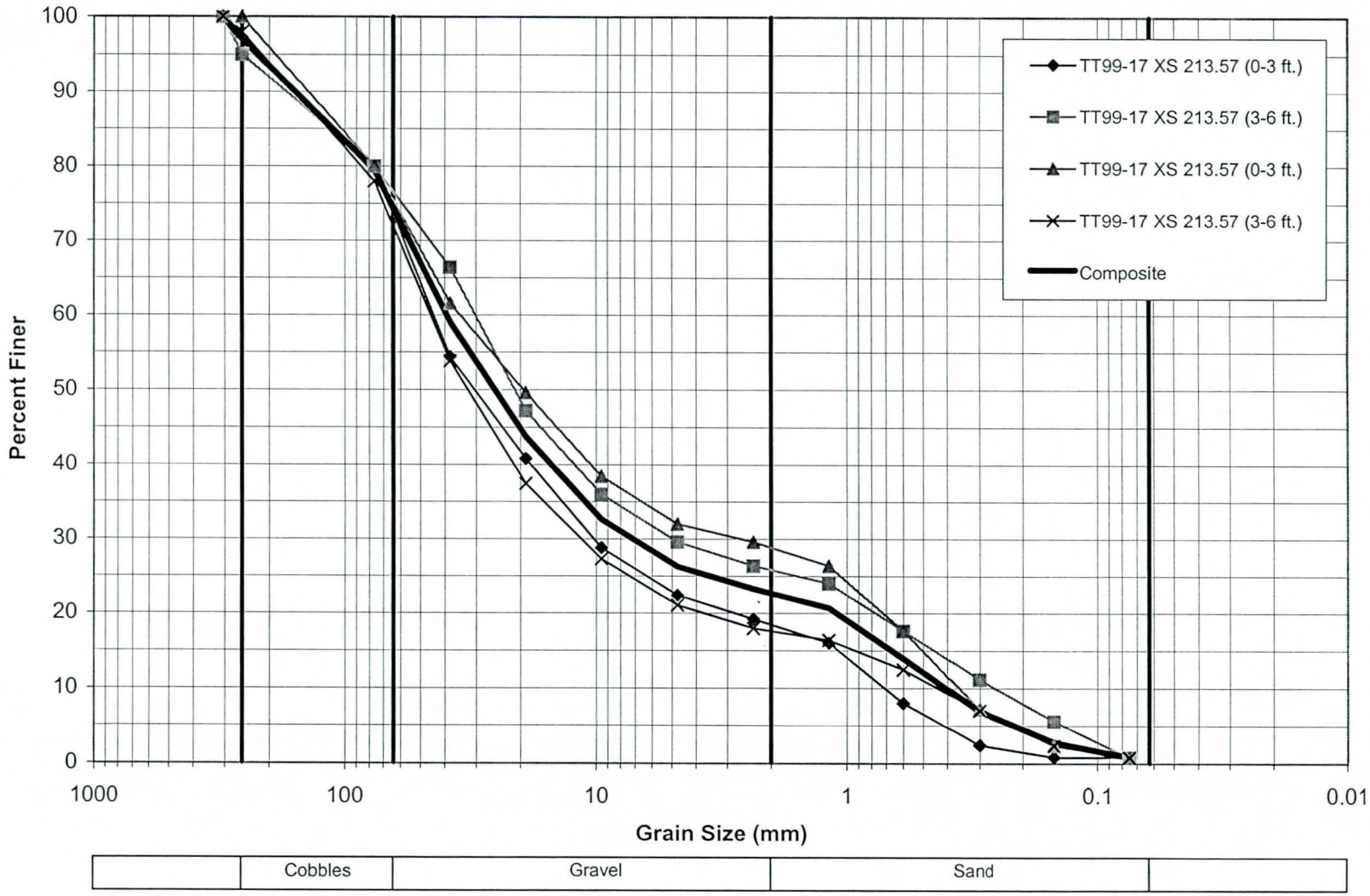
Prepared by SMF

Gradation SMF.xls
4/14/99

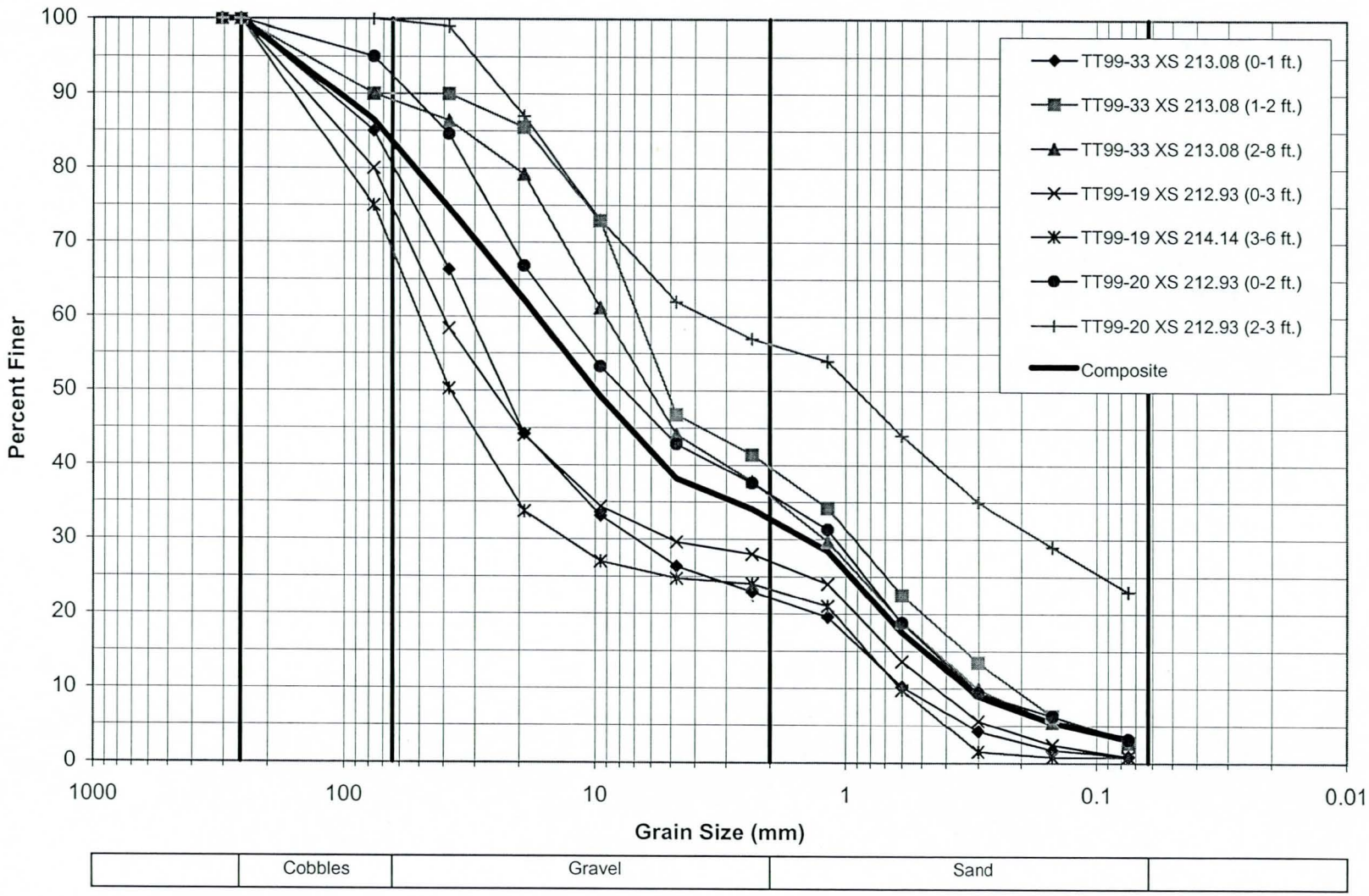
Rio Salado - Existing Conditions
Bed Gradation at Cross Section 214.14



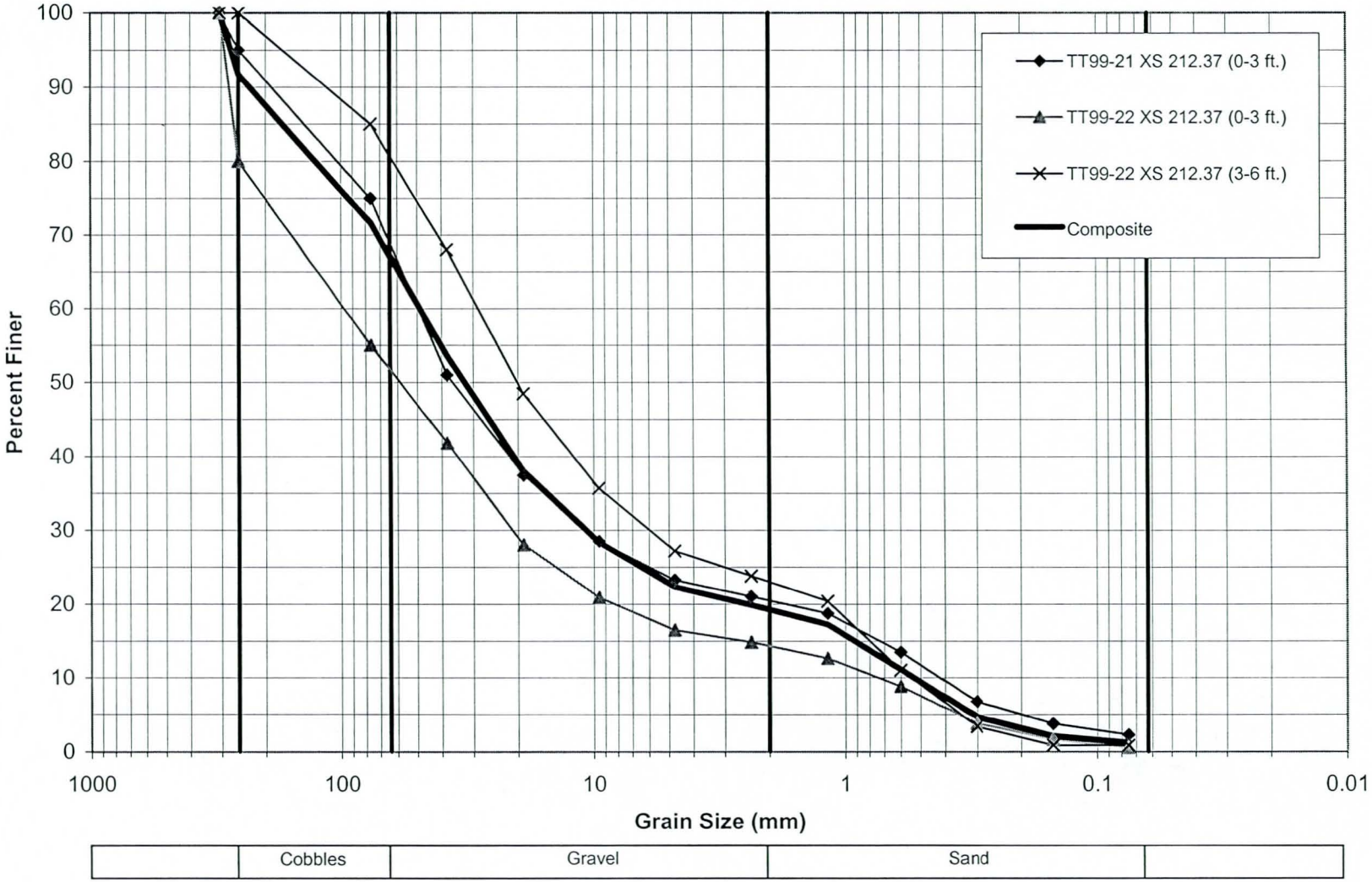
Rio Salado - Existing Conditions
Bed Gradation at Cross Section 213.57



Rio Salado - Existing Conditions
Bed Gradation at Cross Section 212.93



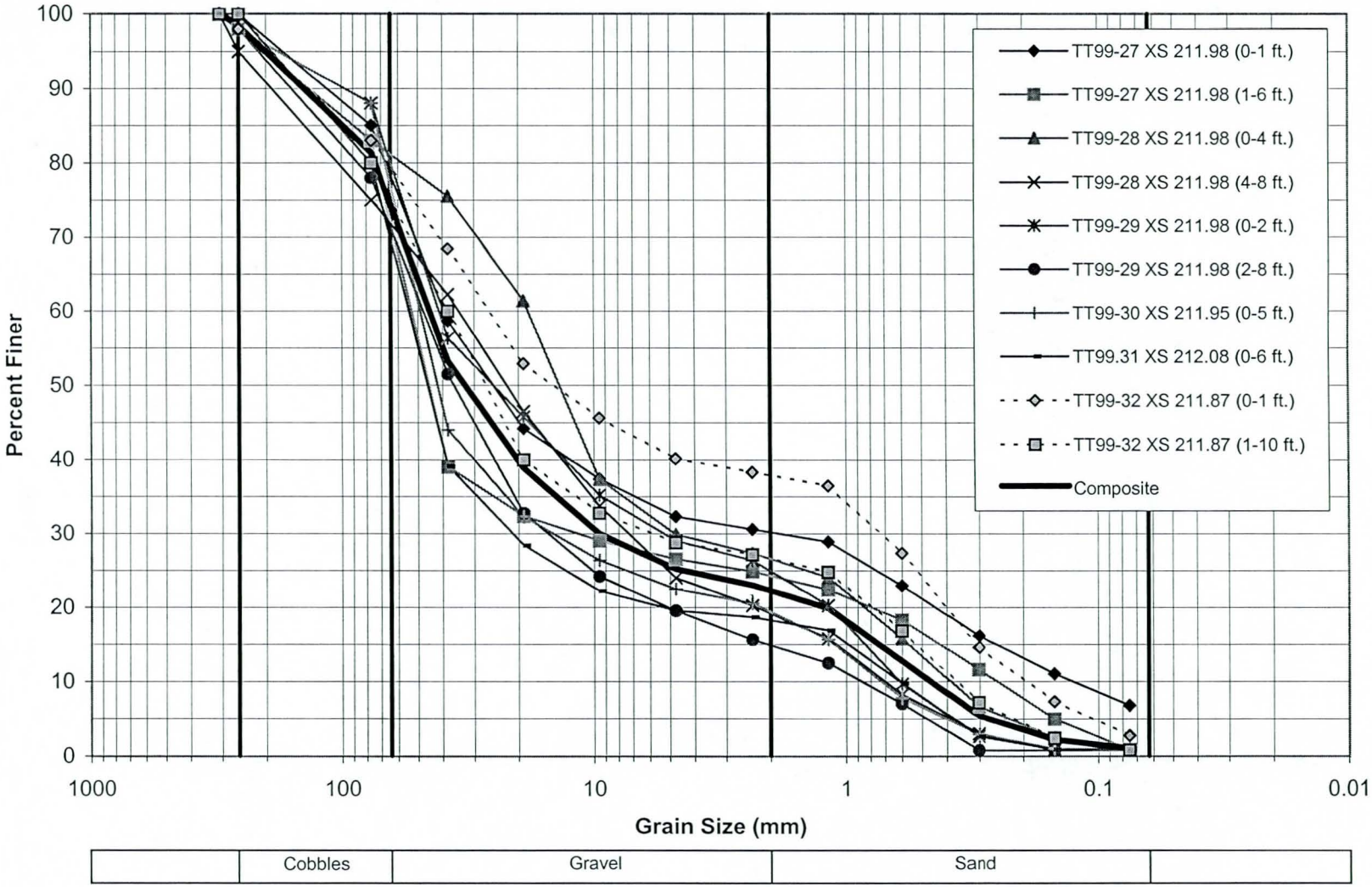
Rio Salado - Existing Conditions
Bed Gradation at Cross Section 212.34



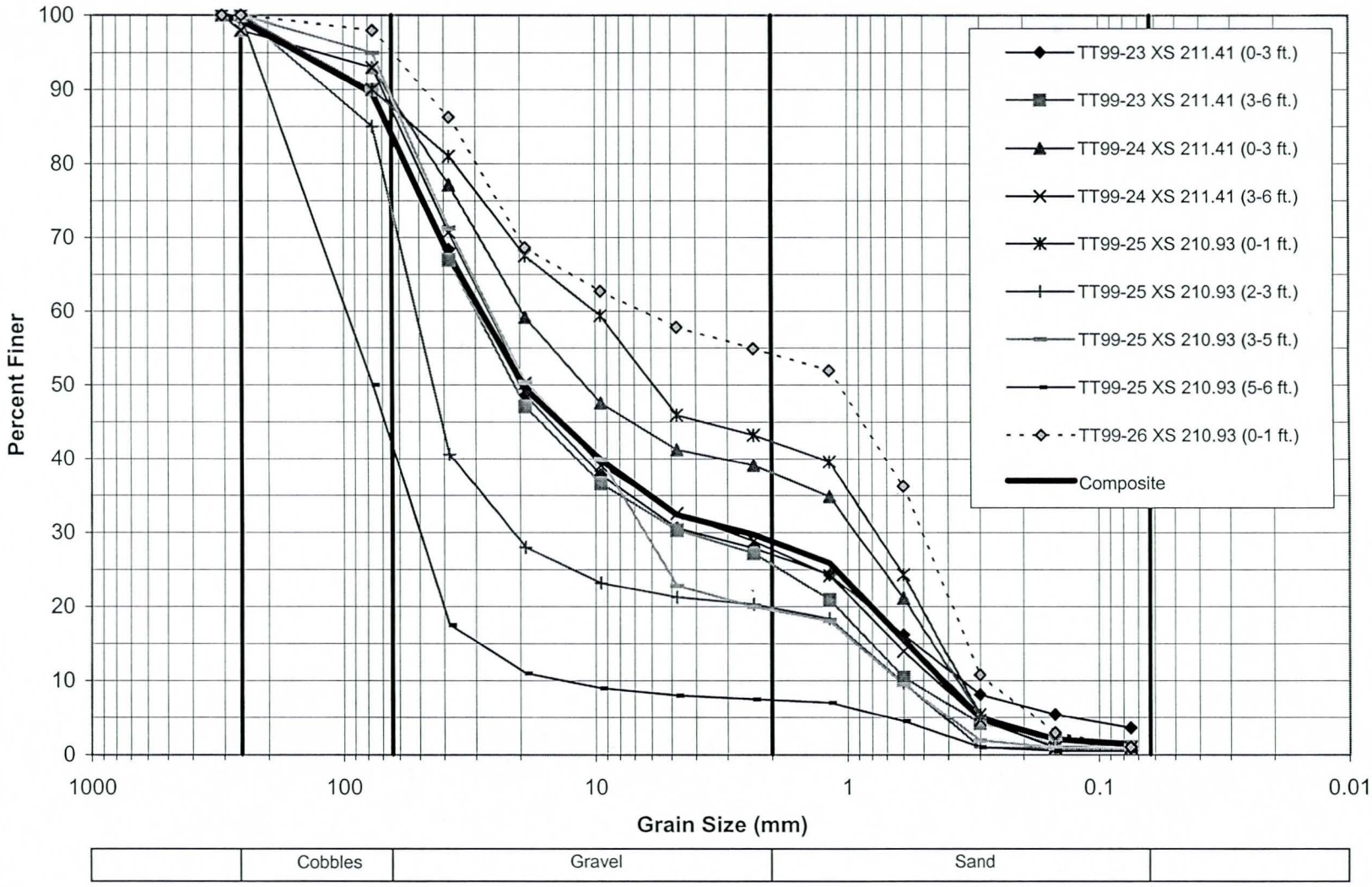
Prepared by SMF

Gradation SMF.xls
4/14/99

Rio Salado - Existing Conditions
Bed Gradation at Cross Sections 211.98



Rio Salado - Existing Conditions
Bed Gradation for Cross Sections 210.64 to 211.44



APPENDIX 4B

Bed Gradations for Low Flow Channel HEC-6T Models

Rio Salado - Low Flow Channel

Composite Bed Gradations for PF Records in the HEC-6T Model

Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Section 216.23																		
210	TT99-5	216.33	3.0	5.0	2.0	100.0	90.0	70.0	44.1	32.2	23.1	18.9	16.1	13.3	9.8	7.0	4.9	2.8
213	TT99-5	216.33	11.0	16.0	5.0	100.0	100.0	98.0	76.4	54.9	43.1	38.2	36.3	32.3	21.6	9.8	5.9	2.9
215	TT99-6	216.33	3.0	7.0	4.0	100.0	85.0	60.0	27.6	16.2	10.8	7.8	4.8	3.0	1.2	0.6	0.6	0.6
Composite					***11.0***	***100.0***	***92.7***	***79.1***	***52.8***	***36.7***	***27.7***	***23.6***	***21.2***	***18.2***	***12.0***	***5.9***	***3.8***	***2.1***
Cross Section 215.94																		
218	TT99-7	215.94	8.0	10.0	2.0	100.0	90.0	65.0	51.4	39.7	29.9	23.4	20.8	15.6	7.8	3.3	1.3	0.7
219	TT99-7	215.94	10.0	13.0	3.0	100.0	90.0	65.0	44.9	24.7	18.2	15.0	13.7	11.7	7.8	3.9	2.6	1.3
220	TT99-7	215.94	13.0	14.0	1.0	100.0	100.0	80.0	54.4	37.6	28.8	23.2	22.4	20.8	16.8	7.2	3.2	1.6
223	TT99-8	215.94	6.0	9.0	3.0	100.0	95.0	75.0	52.5	32.3	24.0	19.5	18.8	16.5	11.3	6.0	3.8	2.3
Composite					***9.0***	***100.0***	***92.8***	***70.0***	***49.9***	***32.0***	***23.9***	***19.3***	***17.9***	***15.2***	***10.0***	***4.8***	***2.8***	***1.5***
Cross Sections 215.53																		
226	TT99-9	215.56	7.0	8.0	0.0	100.0	100.0	95.0	85.5	73.2	66.5	62.7	57.0	51.3	40.9	23.8	11.4	3.8
227	TT99-9	215.56	8.0	10.0	2.0	100.0	100.0	100.0	81.0	65.0	52.0	43.0	40.0	33.0	22.0	10.0	5.0	2.0
228	TT99-9	215.56	10.0	13.0	3.0	100.0	100.0	90.0	40.5	18.0	11.7	9.0	8.1	7.2	5.4	3.6	2.7	1.8
229	TT99-9	215.56	13.0	16.0	3.0	100.0	85.0	60.0	45.0	32.4	24.0	19.2	16.8	13.2	9.0	4.8	1.8	0.6
232	TT99-10	215.56	7.0	10.0	3.0	100.0	100.0	95.0	74.1	53.2	40.9	33.3	30.4	24.7	10.5	4.8	3.8	2.9
233	TT99-10	215.56	10.0	13.0	3.0	100.0	100.0	95.0	64.6	39.0	24.7	19.0	17.1	13.3	7.6	3.8	2.9	1.0
234	TT99-10	215.56	13.0	16.0	3.0	100.0	100.0	95.0	80.8	56.1	39.0	33.3	31.4	28.5	16.2	5.7	2.9	1.9
Composite					***17.0***	***100.0***	***97.4***	***88.5***	***63.3***	***42.7***	***30.9***	***25.1***	***23.0***	***19.2***	***11.2***	***5.2***	***3.1***	***1.7***

Rio Salado - Low Flow Channel

Composite Bed Gradations for PF Records in the HEC-6T Model

Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Section 215.09																		
237	TT99-11	215.09	6.0	9.0	3.0	100.0	95.0	80.0	60.8	42.4	30.4	24.0	22.4	20.0	12.0	3.2	0.8	0.8
238	TT99-11	215.09	9.0	13.0	0.0	100.0	100.0	98.0	87.2	73.5	66.6	61.7	58.8	51.9	27.4	5.9	2.0	2.0
239	TT99-11	215.09	13.0	14.0	1.0	100.0	100.0	95.0	58.9	40.9	32.3	27.6	25.7	22.8	13.3	3.8	1.9	1.0
242	TT99-12	215.09	5.0	8.0	0.0	100.0	100.0	100.0	77.0	68.0	63.0	61.0	60.0	56.0	34.0	11.0	2.0	1.0
Composite					***4.0***	***100.0***	***96.3***	***83.8***	***60.3***	***42.0***	***30.9***	***24.9***	***23.2***	***20.7***	***12.3***	***3.4***	***1.1***	***0.8***
Cross Section 214.71																		
244	TT99-13	214.71	3.0	6.0	3.0	100.0	100.0	97.0	86.3	66.9	49.5	38.8	32.0	20.4	5.8	1.0	1.0	1.0
245	TT99-13	214.71	6.0	8.0	2.0	100.0	100.0	98.0	87.2	67.6	51.0	38.2	34.3	28.4	17.6	9.8	6.9	3.9
246	TT99-13	214.71	8.0	11.0	3.0	100.0	95.0	85.0	75.6	62.3	48.2	37.8	31.2	22.7	11.3	3.8	1.9	0.9
247	TT99-13	214.71	11.0	14.0	3.0	100.0	100.0	95.0	73.2	48.5	38.0	30.4	27.6	23.8	11.4	2.9	1.0	1.0
249	TT99-14	214.71	3.0	6.0	3.0	100.0	98.0	78.0	46.8	18.7	16.4	14.8	13.3	10.1	5.5	2.3	1.6	0.8
250	TT99-14	214.71	6.0	10.0	4.0	100.0	98.0	78.0	58.5	41.3	30.4	25.0	21.8	18.7	9.4	2.3	0.8	0.8
251	TT99-14	214.71	10.0	14.0	4.0	100.0	98.0	73.0	50.4	32.1	23.4	18.3	15.3	11.7	5.8	1.5	0.7	0.7
Composite					***22.0***	***100.0***	***98.3***	***84.8***	***66.2***	***46.3***	***35.1***	***27.9***	***24.1***	***18.6***	***9.0***	***2.9***	***1.6***	***1.1***
Cross Section 214.14																		
254	TT99-15	214.14	8.0	10.0	2.0	100.0	100.0	98.0	73.5	53.9	44.1	38.2	36.3	33.3	19.6	6.9	2.0	1.0
255	TT99-15	214.14	10.0	12.0	0.0	100.0	100.0	100.0	93.0	88.0	86.0	84.0	83.0	76.0	19.0	2.0	1.0	1.0
256	TT99-15	214.14	12.0	16.0	4.0	100.0	100.0	90.0	73.8	52.2	39.6	35.1	33.3	29.7	13.5	2.7	0.9	0.9
262	TT99-16	214.14	8.0	11.0	3.0	100.0	100.0	80.0	68.0	47.2	33.6	26.4	23.2	19.2	9.6	4.0	1.6	0.8
263	TT99-16	214.14	11.0	16.0	5.0	100.0	90.0	68.0	51.0	43.5	38.8	36.0	33.3	28.6	14.3	4.1	0.7	0.7
Composite					***14.0***	***100.0***	***96.4***	***81.1***	***64.4***	***48.3***	***38.7***	***34.0***	***31.6***	***27.6***	***13.8***	***4.1***	***1.1***	***0.8***

Rio Salado - Low Flow Channel

Composite Bed Gradations for PF Records in the HEC-6T Model

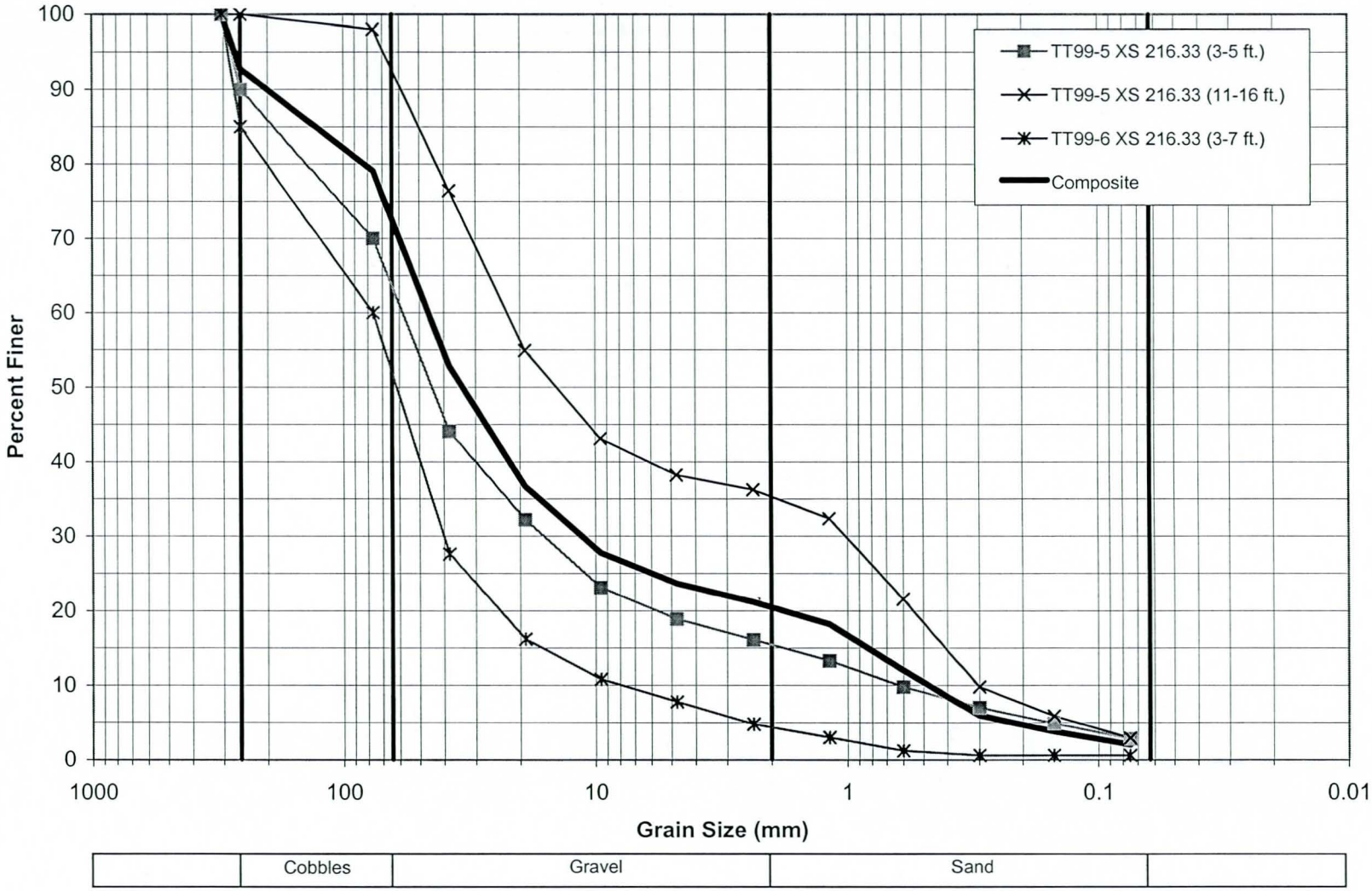
Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Sections 213.57																		
266	TT99-17	213.57	8.0	9.0	1.0	100.0	90.0	70.0	59.3	45.7	32.7	25.1	22.8	19.0	9.9	3.0	0.8	0.8
267	TT99-17	213.57	9.0	12.0	3.0	100.0	95.0	80.0	71.2	53.6	42.4	36.0	32.0	23.2	11.2	3.2	0.8	0.8
268	TT99-17	213.57	12.0	16.0	4.0	100.0	95.0	80.0	65.2	43.5	31.3	25.2	22.6	20.0	11.3	3.5	0.9	0.9
271	TT99-18	213.57	8.0	10.0	2.0	100.0	98.0	83.0	58.9	44.8	34.9	28.2	24.9	21.6	13.3	5.8	1.7	0.8
272	TT99-18	213.57	10.0	16.0	6.0	100.0	98.0	78.0	56.9	39.8	29.6	22.6	18.7	15.6	10.1	3.9	1.6	0.8
Composite					***16.0***	***100.0***	***96.2***	***79.0***	***62.1***	***44.3***	***33.3***	***26.6***	***23.2***	***19.1***	***11.0***	***3.8***	***1.2***	***0.8***
Cross Section 212.93																		
274	TT99-19	212.93	4.0	6.0	2.0	100.0	100.0	75.0	50.3	33.8	27.0	24.8	24.0	21.0	9.8	1.5	0.8	0.8
275	TT99-19	212.93	6.0	10.0	4.0	100.0	100.0	80.0	46.4	34.4	24.8	20.8	19.2	15.2	5.6	1.6	0.8	0.8
276	TT99-19	212.93	10.0	14.0	4.0	100.0	100.0	80.0	59.2	33.6	20.0	16.0	15.2	13.6	10.4	5.6	2.4	1.6
279	TT99-20	212.93	4.0	6.0	0.0	100.0	100.0	100.0	99.0	98.0	98.0	98.0	98.0	97.0	96.0	95.0	91.0	75.0
280	TT99-20	212.93	6.0	8.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	99.0	97.0	87.0
281	TT99-20	212.93	8.0	11.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	99.0	97.0	73.0	31.0
282	TT99-20	212.93	11.0	13.0	0.0	100.0	100.0	100.0	100.0	99.0	98.0	98.0	97.0	97.0	95.0	93.0	81.0	46.0
283	TT99-20	212.93	13.0	14.0	0.0	100.0	100.0	95.0	75.1	75.1	70.3	67.5	65.6	63.7	56.1	50.4	41.8	23.8
Composite					***10.0***	***100.0***	***100.0***	***79.0***	***52.3***	***34.0***	***23.3***	***19.7***	***18.6***	***15.7***	***8.4***	***3.2***	***1.4***	***1.1***

Rio Salado - Low Flow Channel

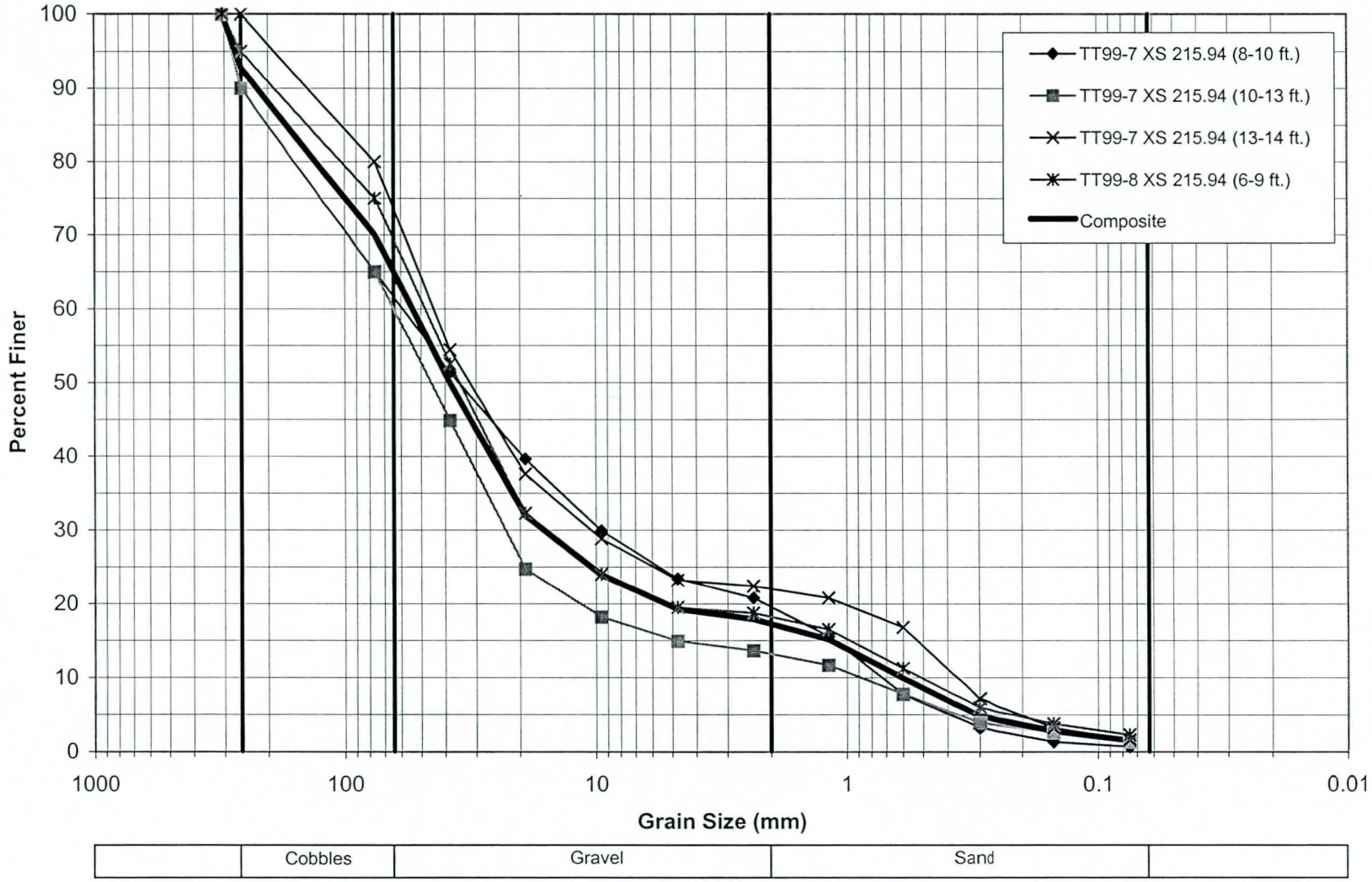
Composite Bed Gradations for PF Records in the HEC-6T Model

Lab No.	Hole No.	Station	Depth (ft) Top	Depth (ft) Bot	Layer Thickness (ft)	D100 304.8 12 in	256	GRAVEL (in) 76.2 3.0	38.1 1.5	19.05 3/4	9.525 3/8	SAND (sieve no.) 4.75 4	2.36 8	1.18 16	0.6 30	0.3 50	0.15 100	FINES 0.075 200
Cross Section 212.34																		
284	TT99-21	212.37	2.0	3.0	1.0	100.0	95.0	75.0	51.0	37.5	28.5	23.3	21.0	18.8	13.5	6.8	3.8	2.3
285	TT99-21	212.37	3.0	6.0	0.0	100.0	95.0	75.0	75.0	67.5	61.7	58.3	57.5	55.0	49.2	34.2	15.8	3.3
286	TT99-21	212.37	6.0	9.0	3.0	100.0	98.0	78.0	67.9	49.1	39.8	34.3	32.0	28.9	21.8	14.0	5.5	1.6
287	TT99-21	212.37	9.0	10.0	1.0	100.0	98.0	88.0	51.0	20.2	13.2	11.4	10.6	9.7	7.9	3.5	0.9	0.9
289	TT99-22	212.37	2.0	3.0	1.0	100.0	80.0	55.0	41.8	28.1	20.9	16.5	14.9	12.7	8.8	3.9	1.7	0.6
290	TT99-22	212.37	3.0	6.0	3.0	100.0	100.0	85.0	68.0	48.5	35.7	27.2	23.8	20.4	11.1	3.4	0.9	0.9
291	TT99-22	212.37	6.0	10.0	4.0	100.0	100.0	85.0	54.4	34.9	23.8	18.7	17.0	15.3	7.7	1.7	0.9	0.9
Composite					***13.0***	***100.0***	***97.5***	***80.5***	***59.2***	***39.8***	***29.6***	***23.9***	***21.7***	***19.2***	***12.3***	***5.6***	***2.2***	***1.1***
Cross Section 212.12																		
332	TT99-31	212.08	2.0	6.0	4.0	100.0	100.0	80.0	39.1	28.4	22.2	19.6	18.7	16.9	9.8	2.7	0.9	0.9
333	TT99-31	212.08	6.0	8.0	2.0	100.0	100.0	75.0	50.3	32.3	24.0	19.5	18.0	15.8	7.5	1.5	0.8	0.8
Composite					***6.0***	***100.0***	***100.0***	***78.3***	***42.8***	***29.7***	***22.8***	***19.5***	***18.4***	***16.5***	***9.0***	***2.3***	***0.8***	***0.8***
Cross Section 211.98																		
325	TT99-29	211.98	2.0	8.0	6.0	100.0	98.0	78.0	51.5	32.8	24.2	19.5	15.6	12.5	7.0	0.8	0.8	0.8
328	TT99-30	211.95	2.0	5.0	3.0	100.0	98.0	88.0	44.0	32.3	26.4	22.5	20.5	15.6	7.8	2.9	1.0	1.0
329	TT99-30	211.95	5.0	8.0	0.0	100.0	100.0	100.0	98.0	94.0	91.0	88.0	71.0	52.0	37.0	23.0	14.0	6.0
Composite					***9.0***	***100.0***	***98.0***	***81.3***	***49.0***	***32.6***	***24.9***	***20.5***	***17.2***	***13.5***	***7.3***	***1.5***	***0.8***	***0.8***

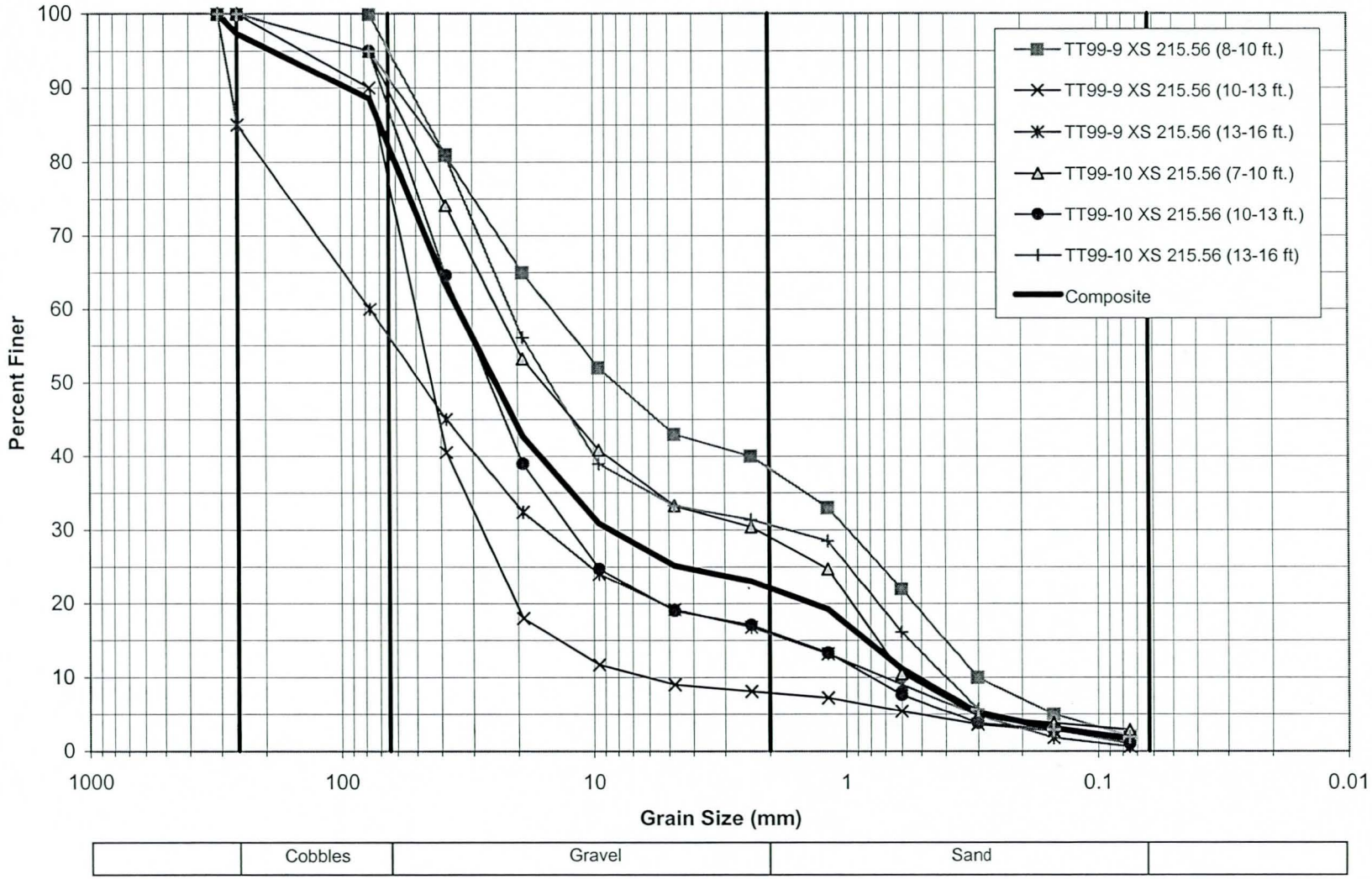
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 216.23



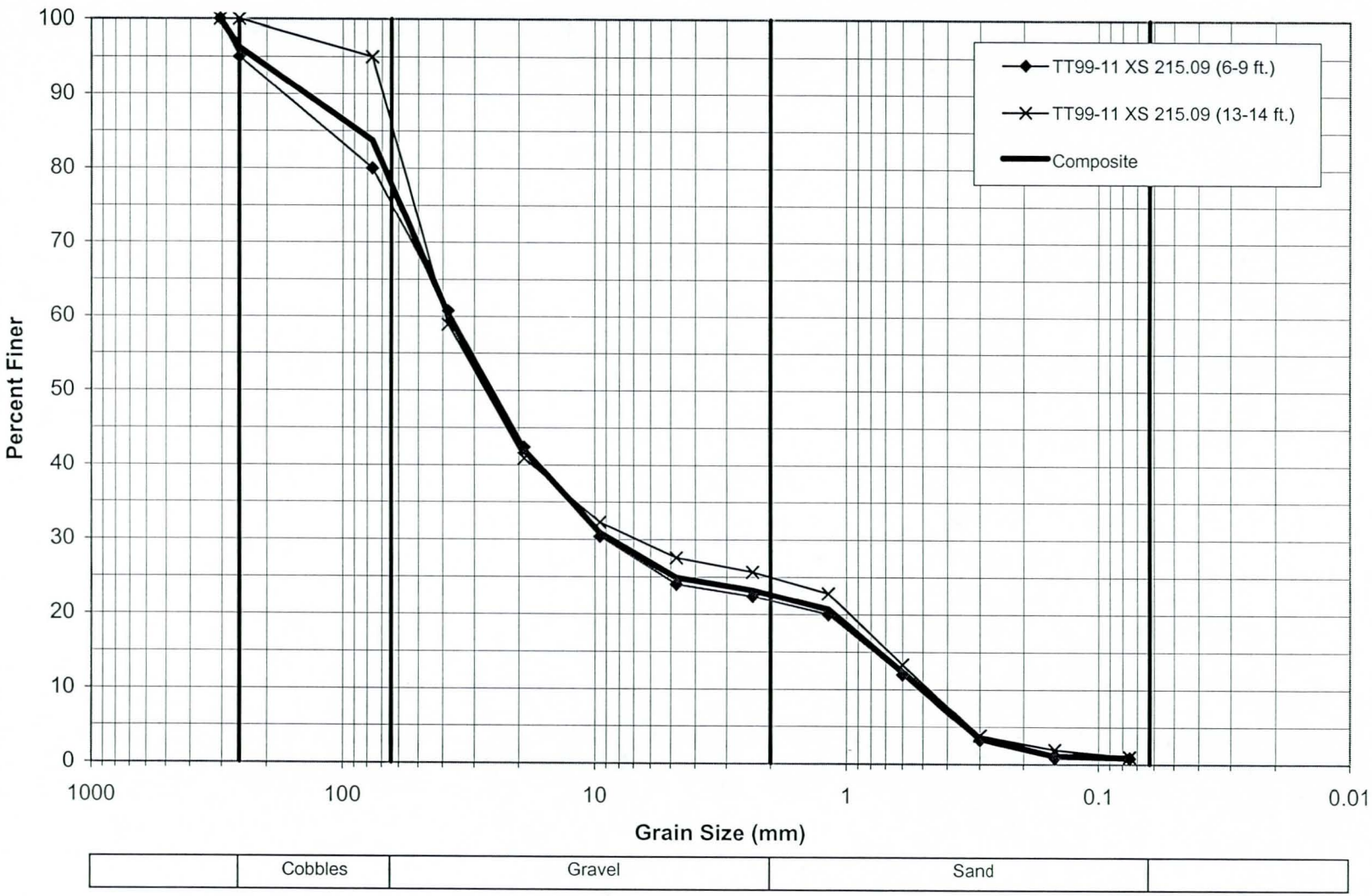
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 215.94



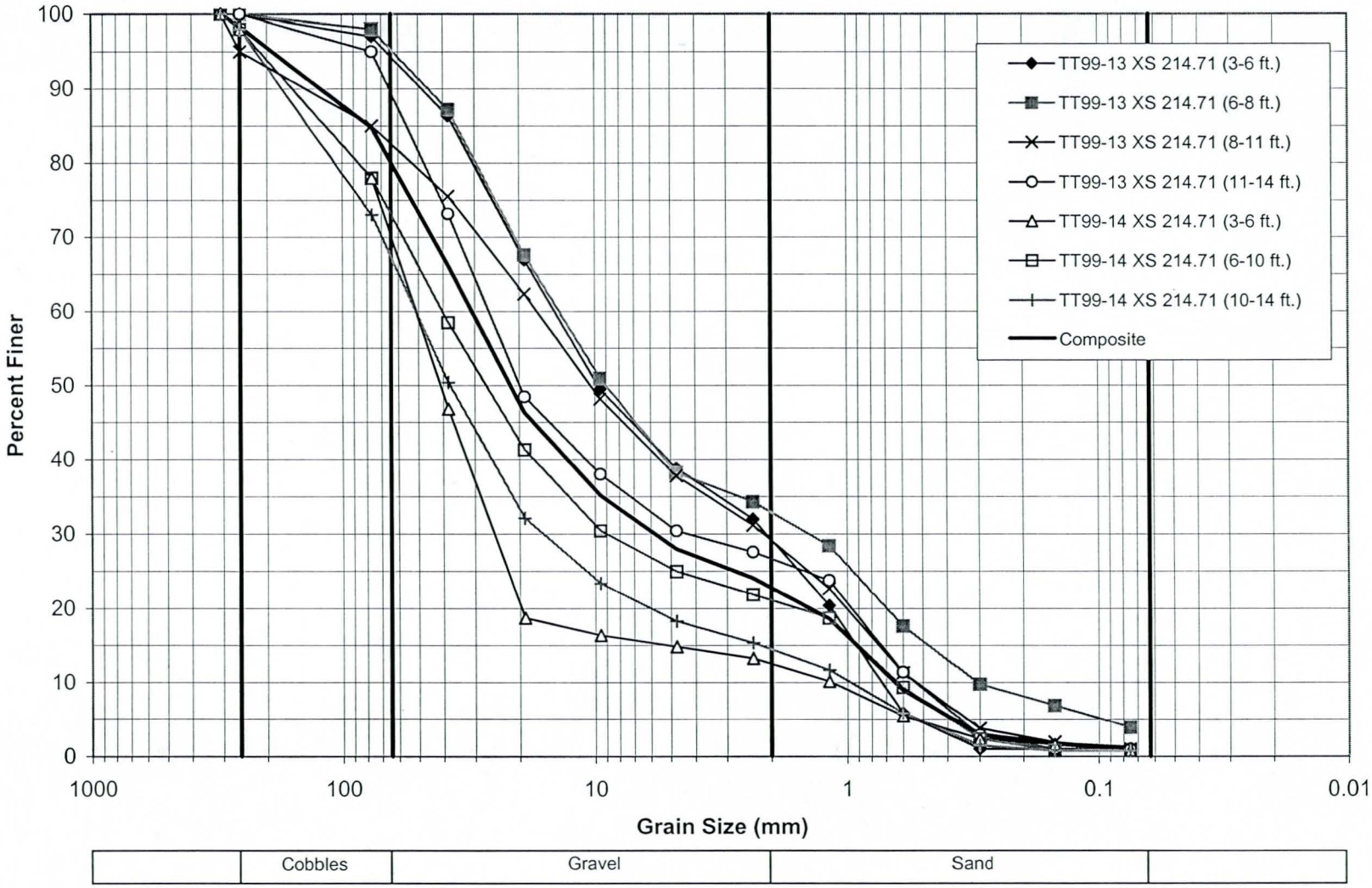
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 215.53



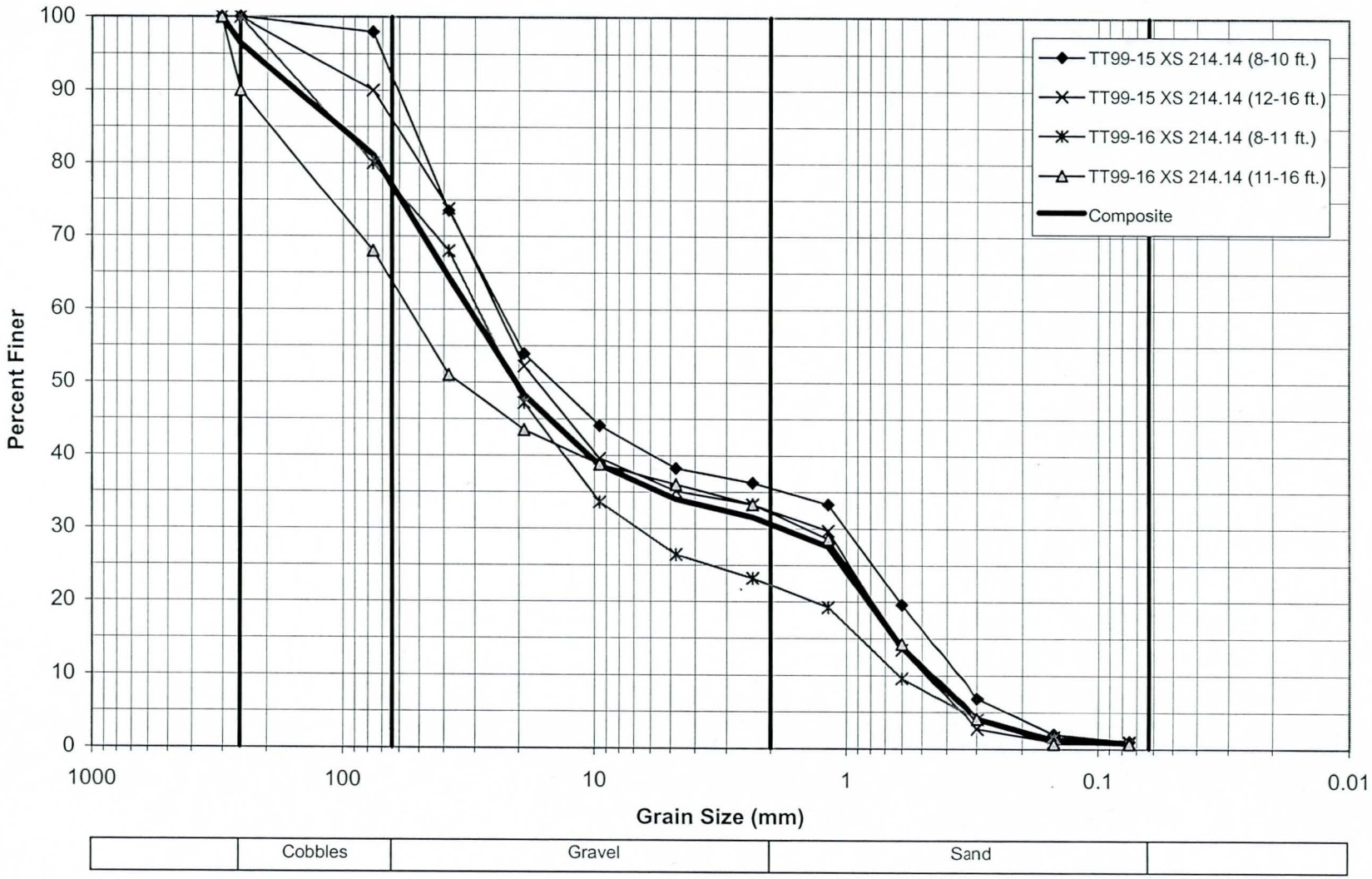
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 215.09



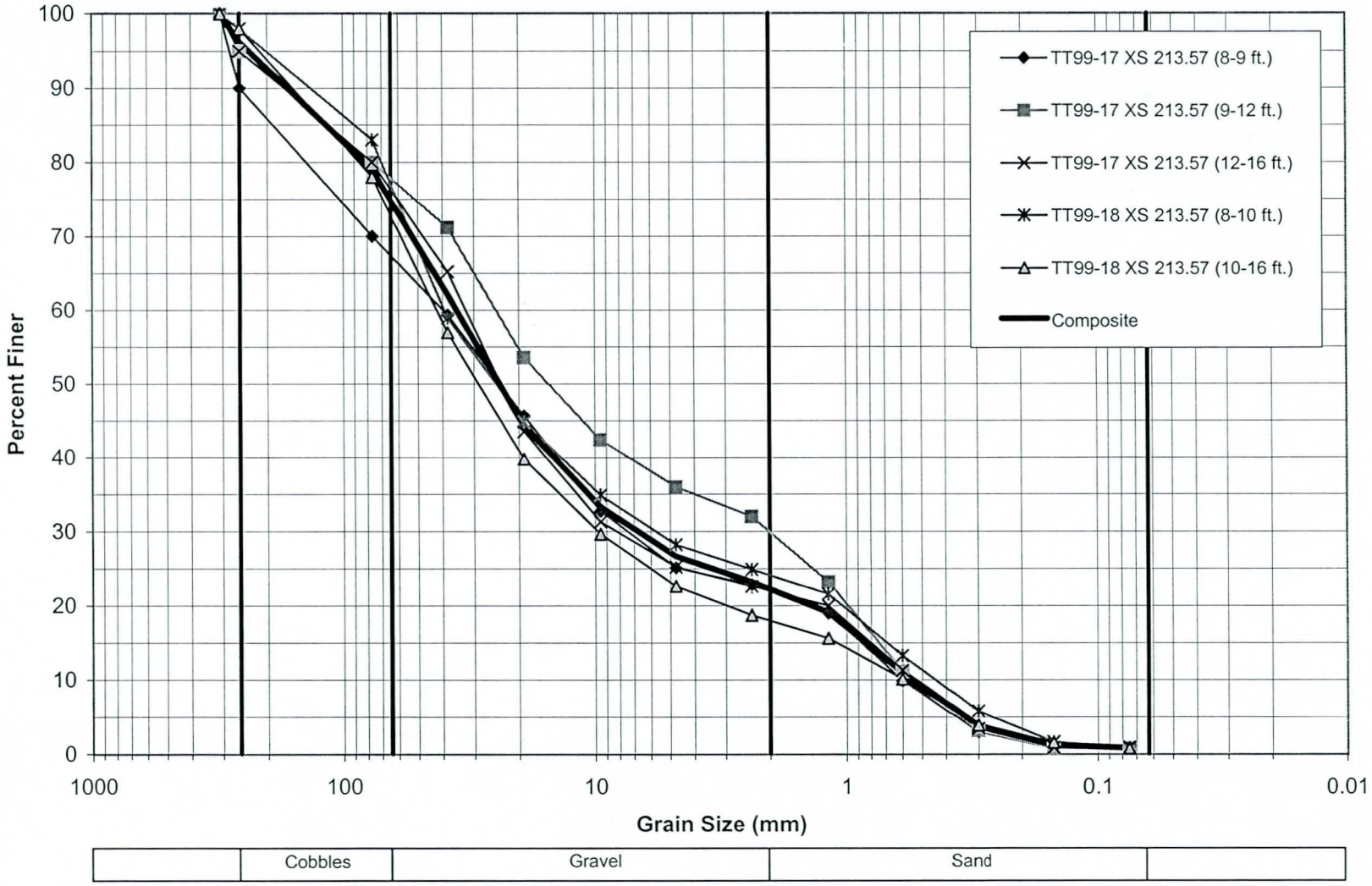
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 214.71



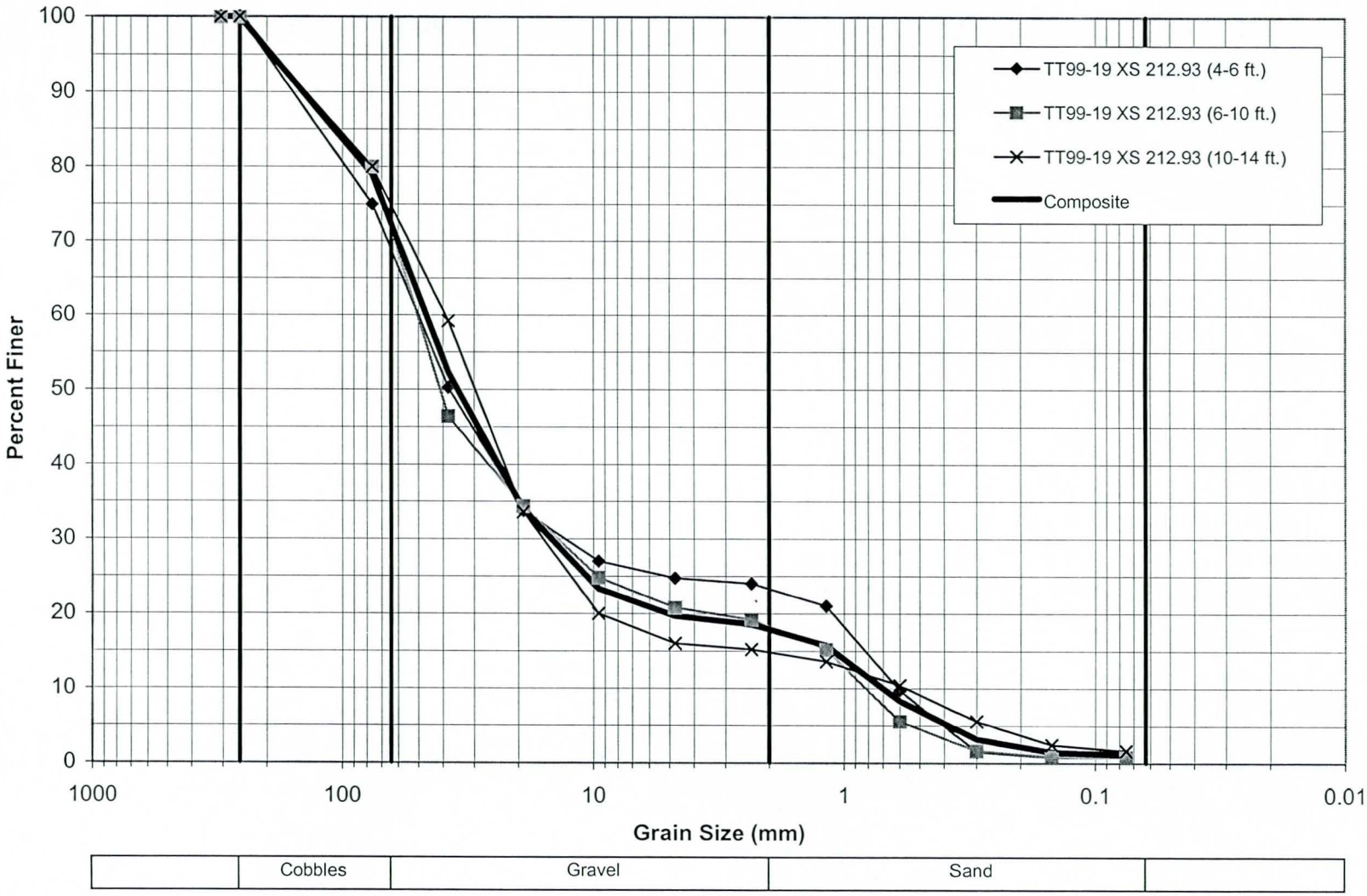
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 214.14



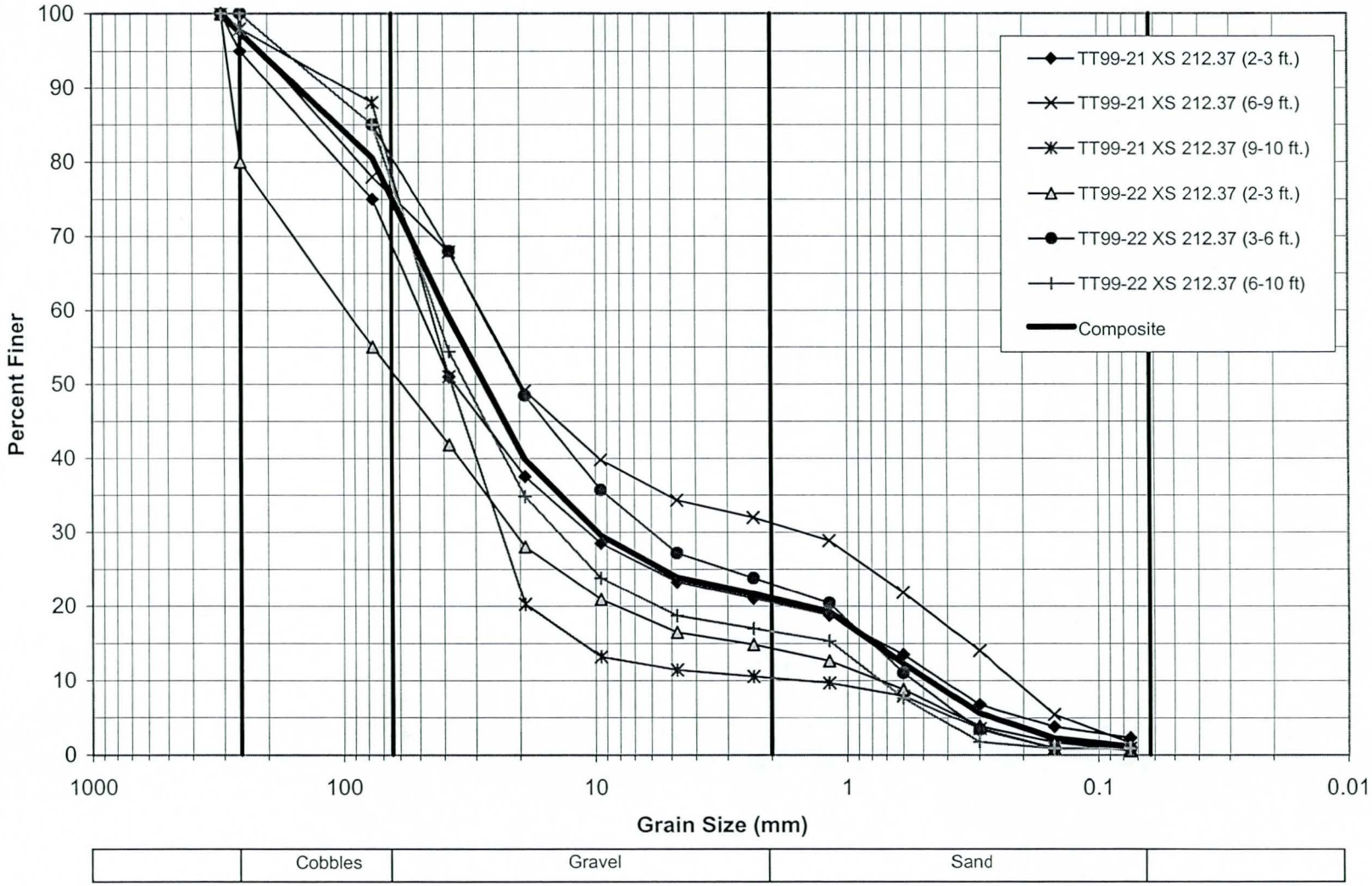
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 213.57



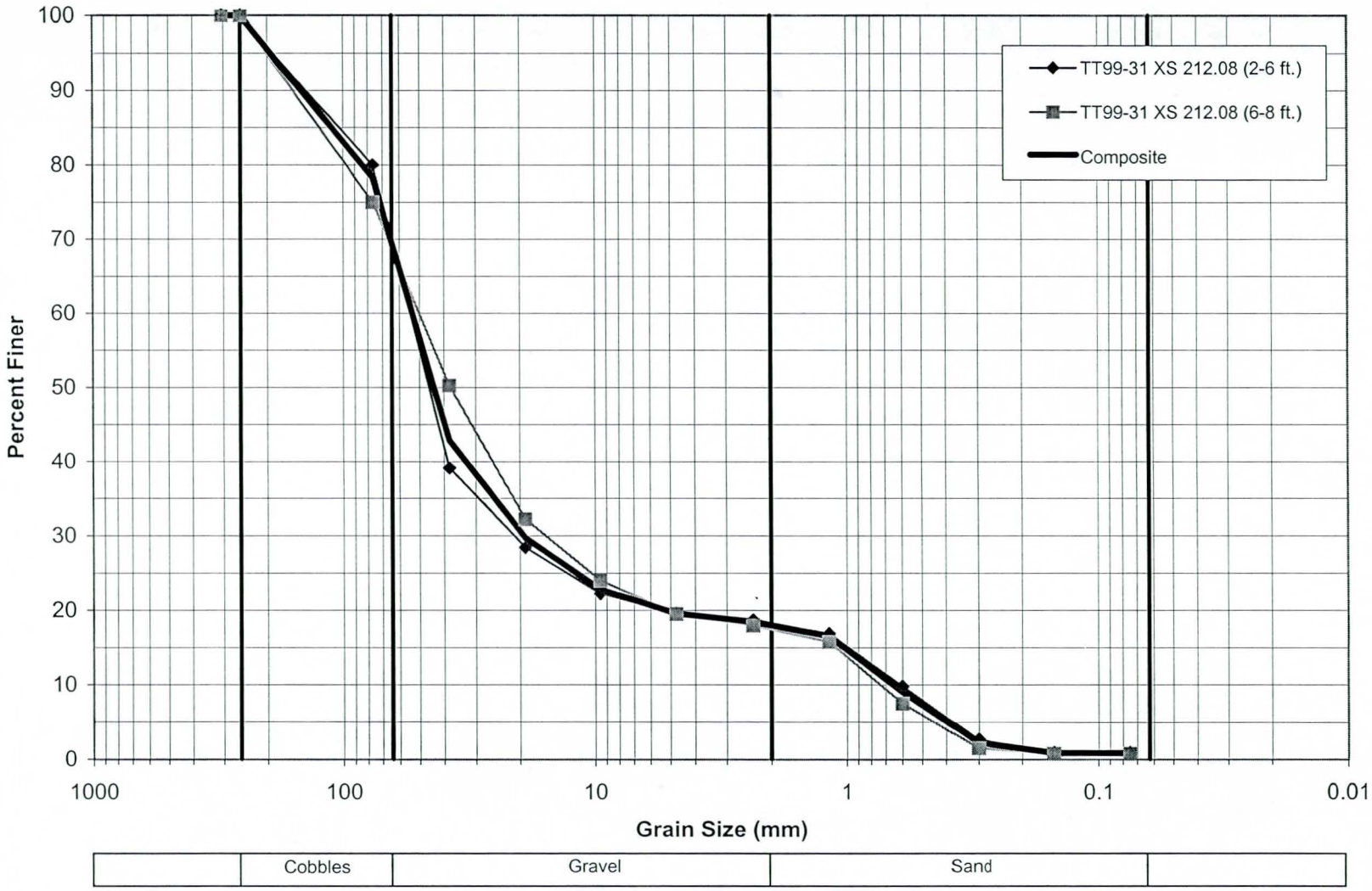
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 212.93



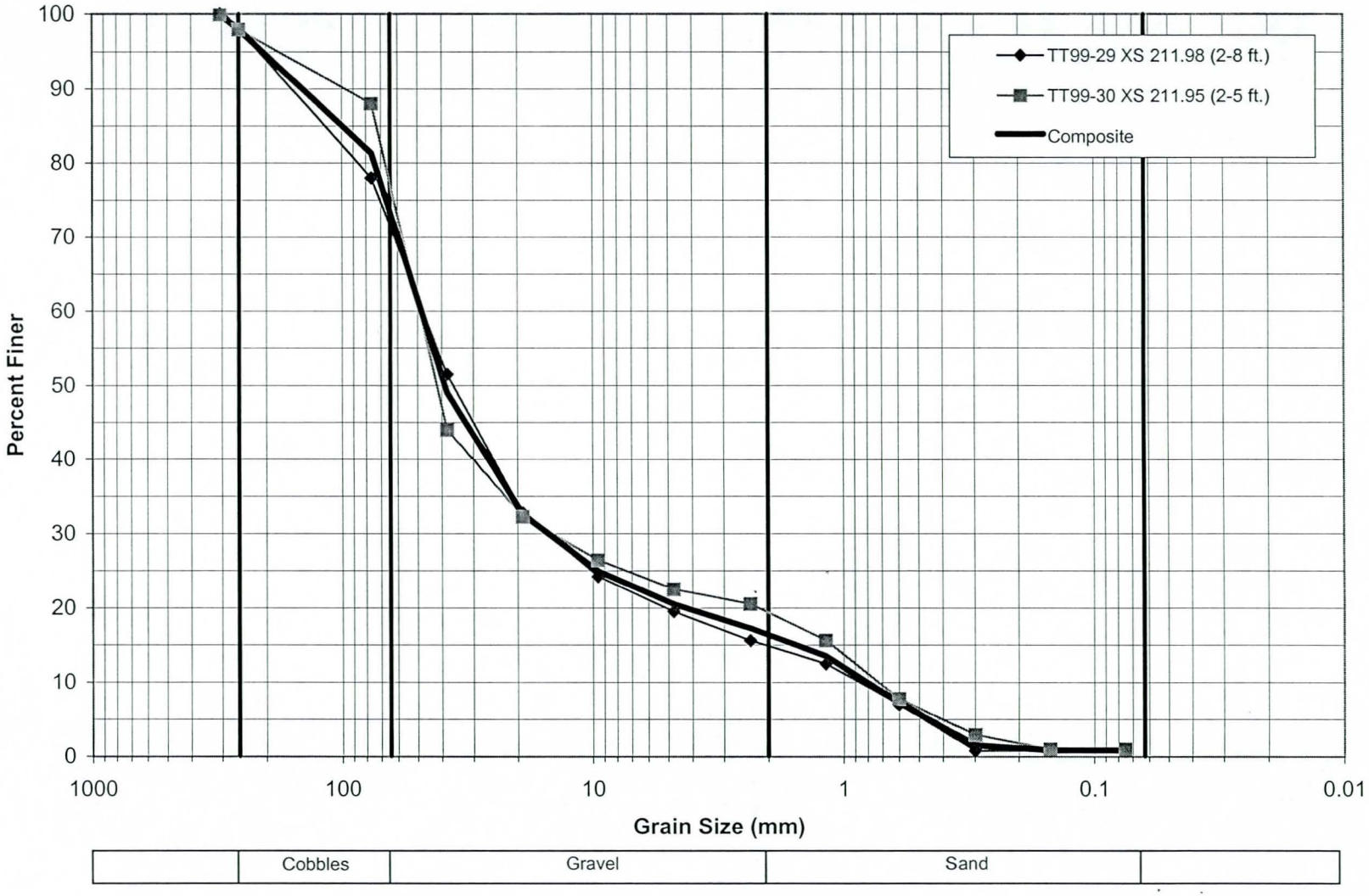
Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 212.34



Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 212.12



Rio Salado - Low Flow Channel
Bed Gradation for Cross Section 211.98



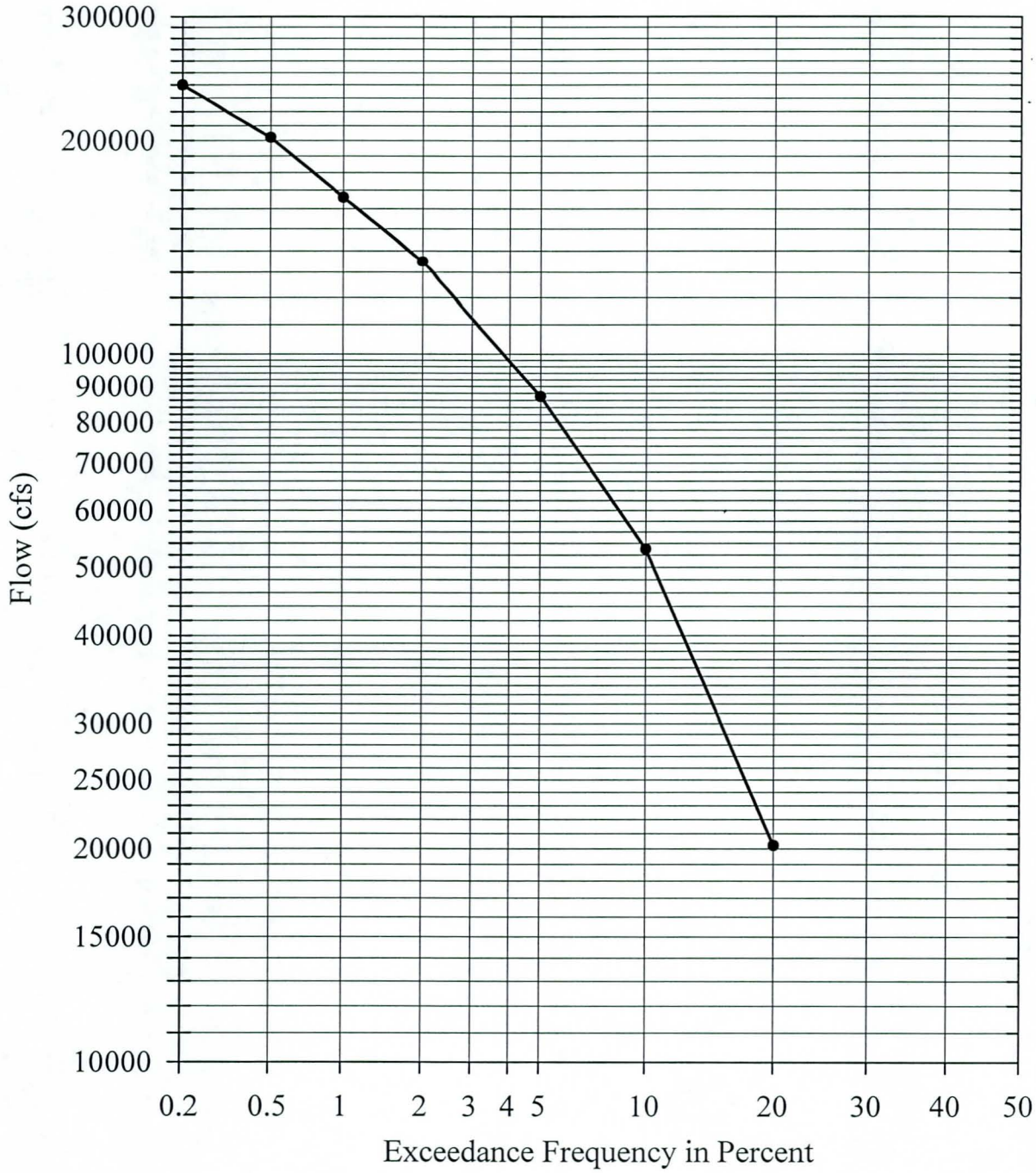
APPENDIX 4C

Discharge Frequency Curve & Hydrographs

Rio Salado

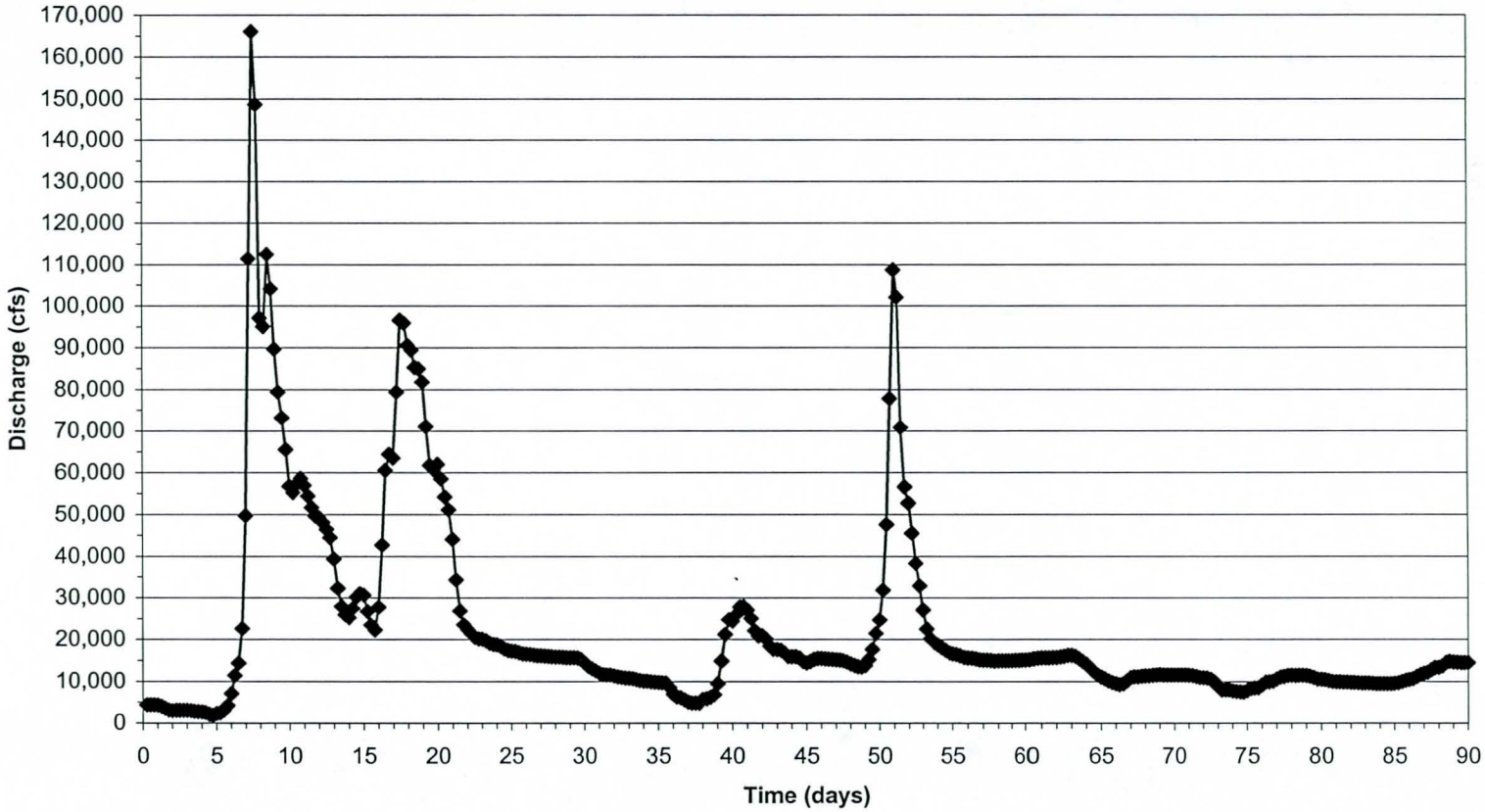
Salt River Discharge-Frequency Curve at Central Avenue

(Feasibility Report, US Army Corps of Engineers, 1998, Table 4.1)



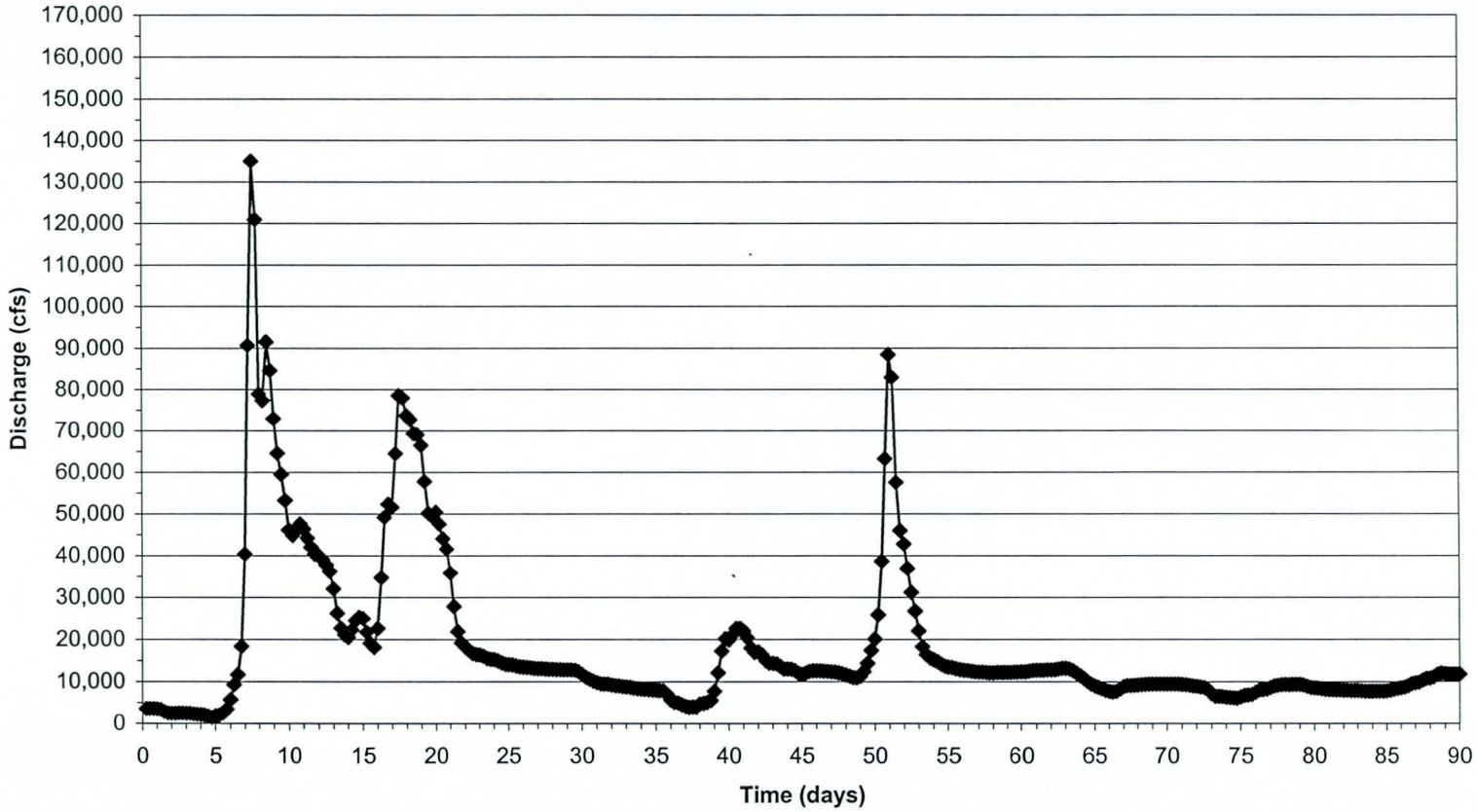
Rio Salado

Hydrograph for 100-Year Event - Peak 166,000 cfs



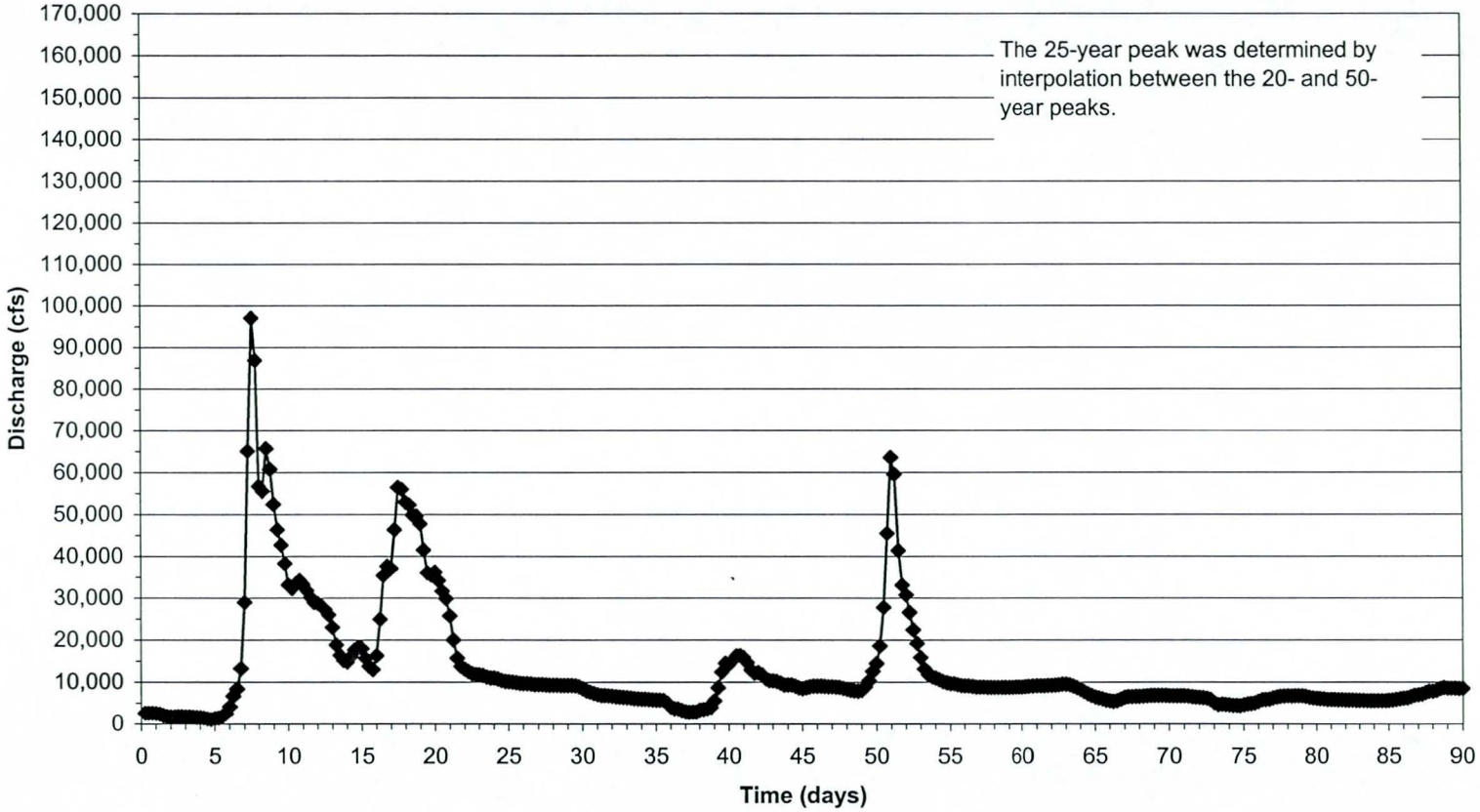
Rio Salado

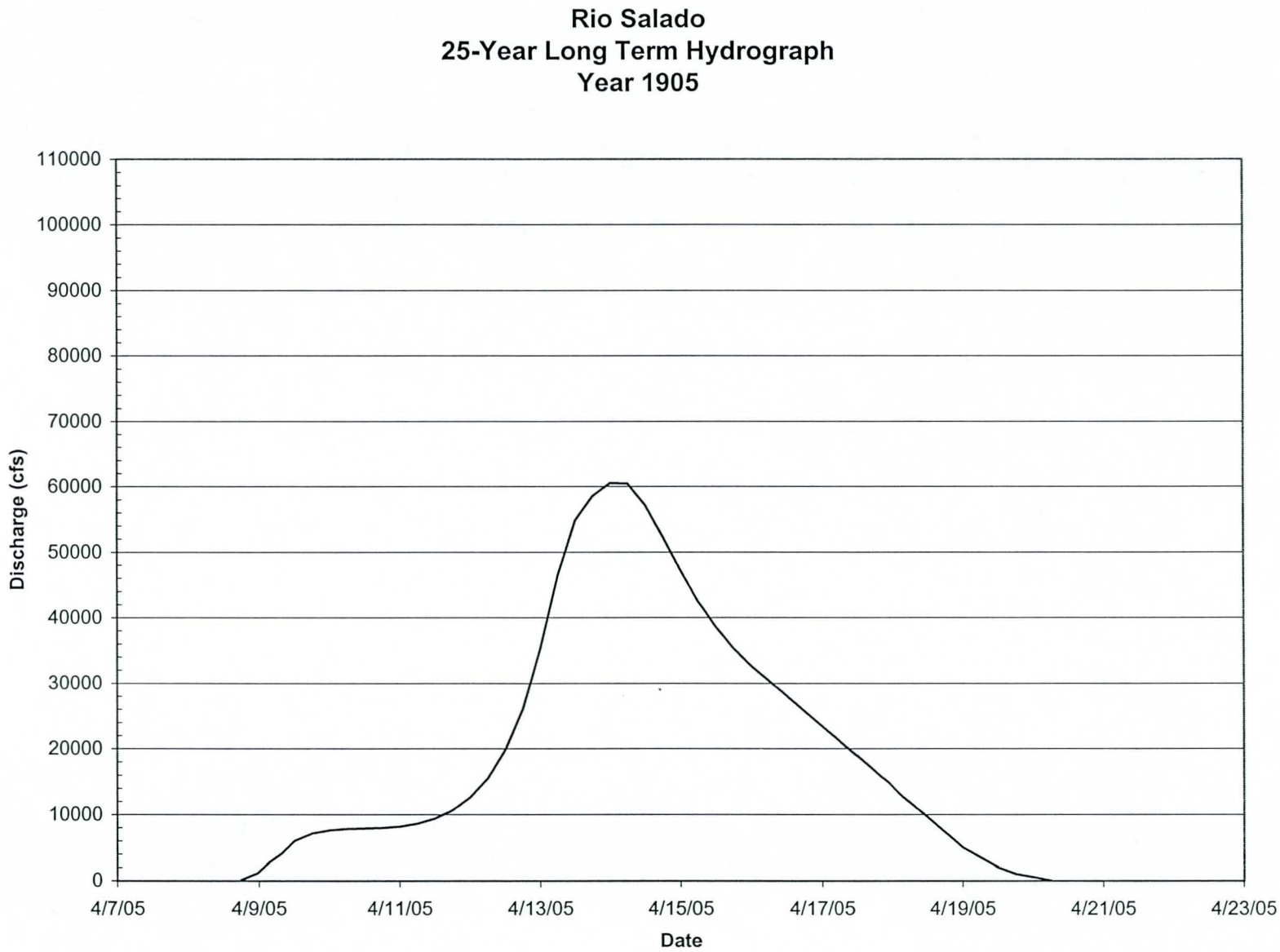
Hydrograph for 50-Year Event - Peak 135,000 cfs

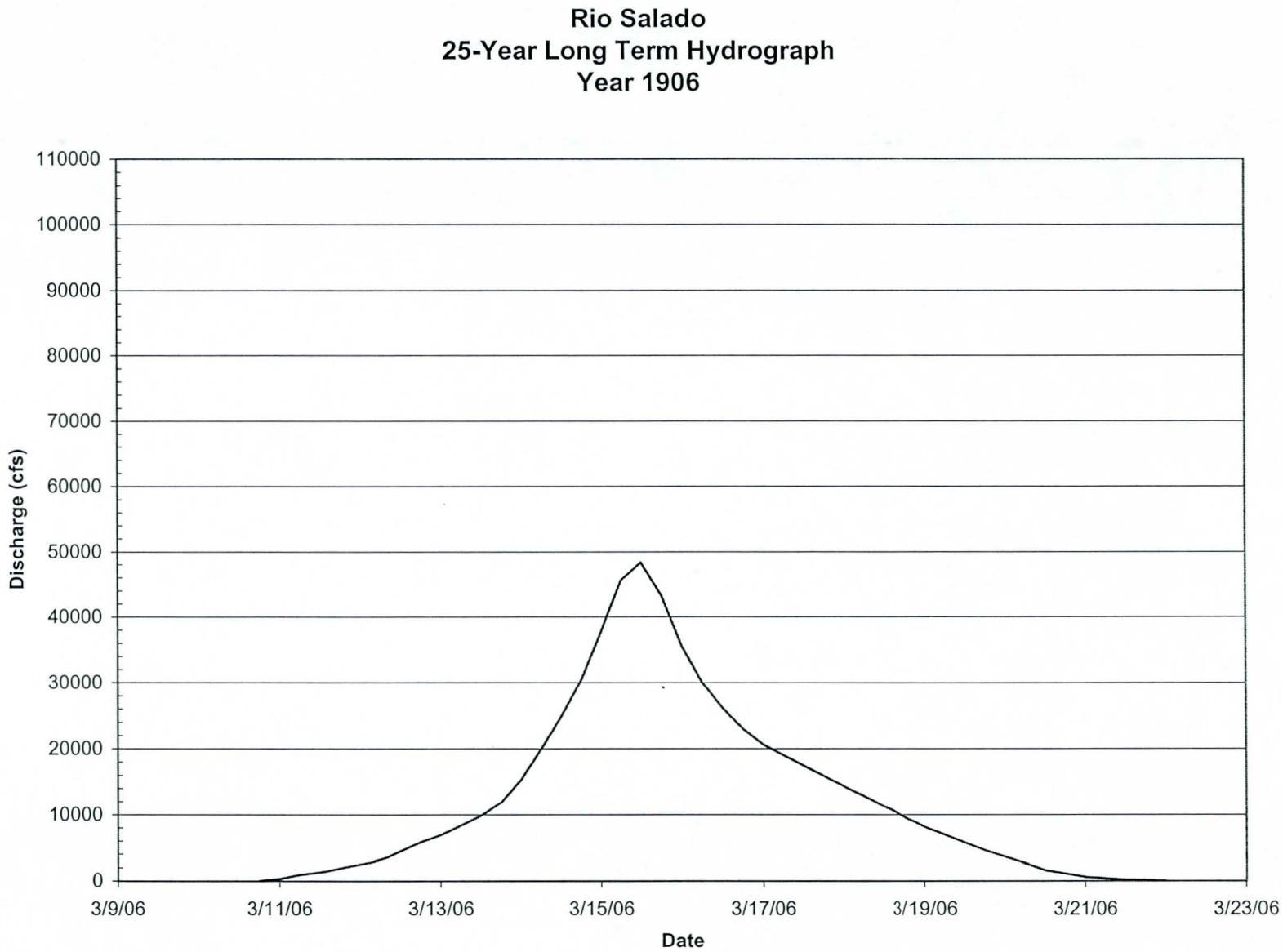


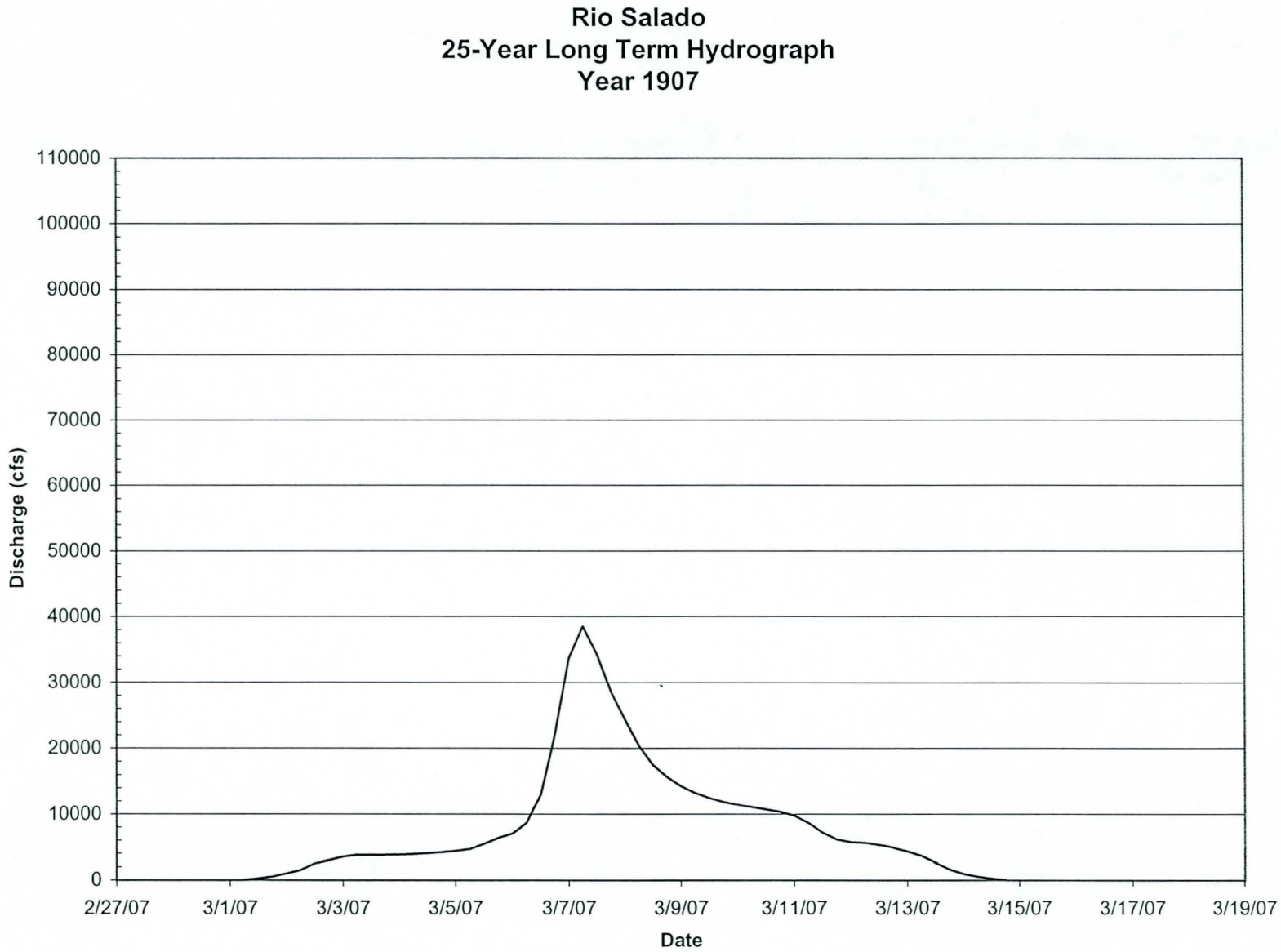
Rio Salado

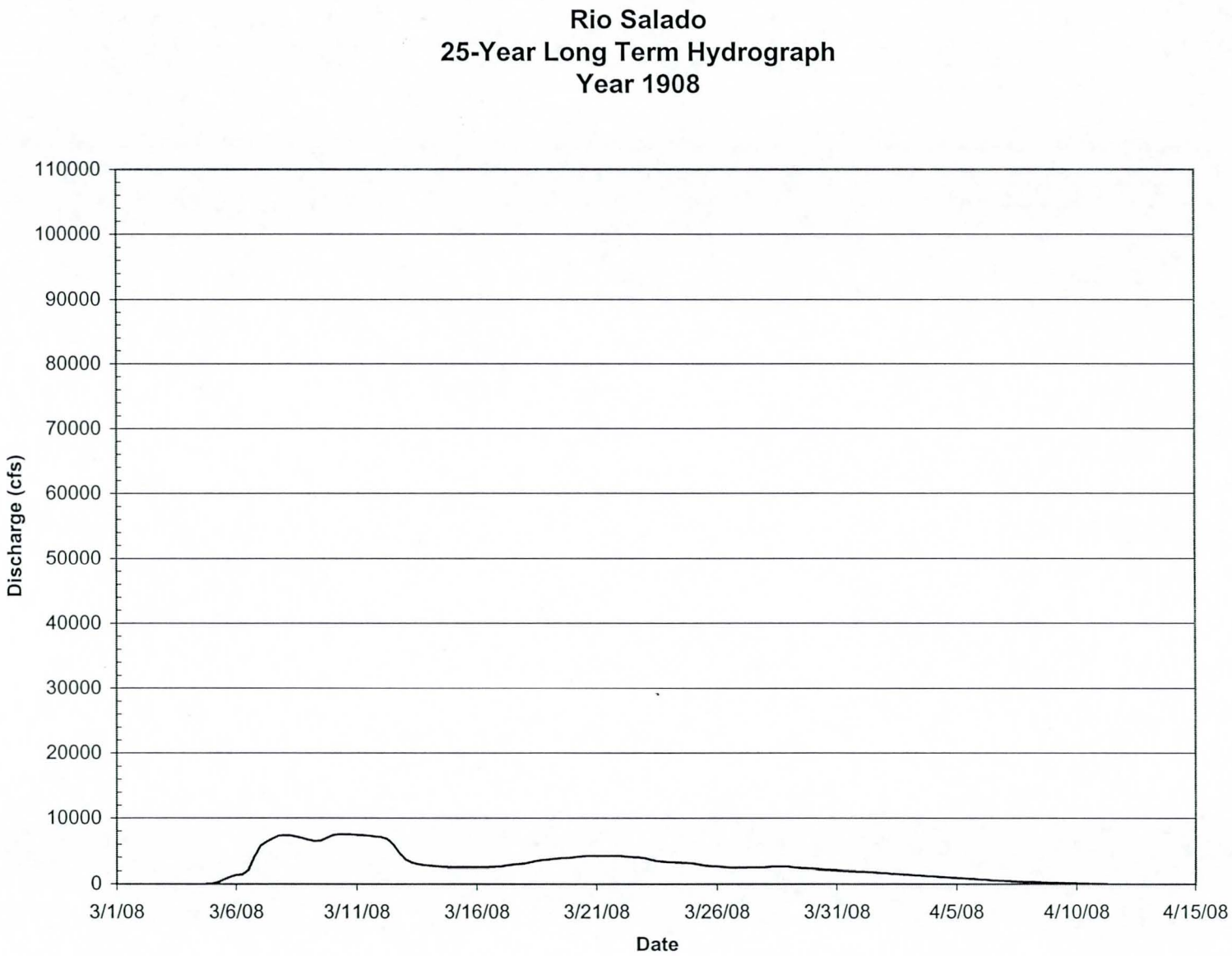
Hydrograph for 25-Year Event - Peak 97,000 cfs

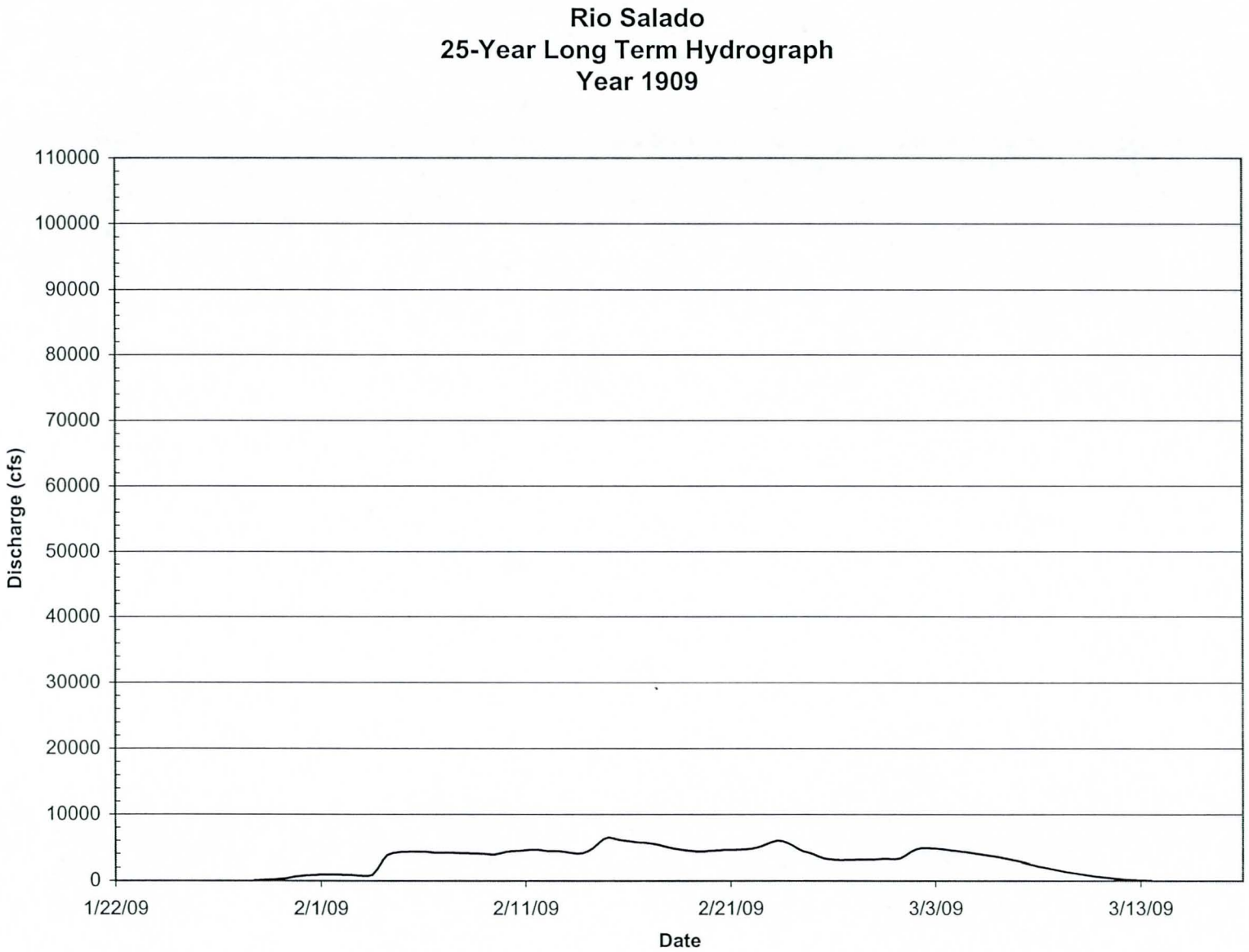


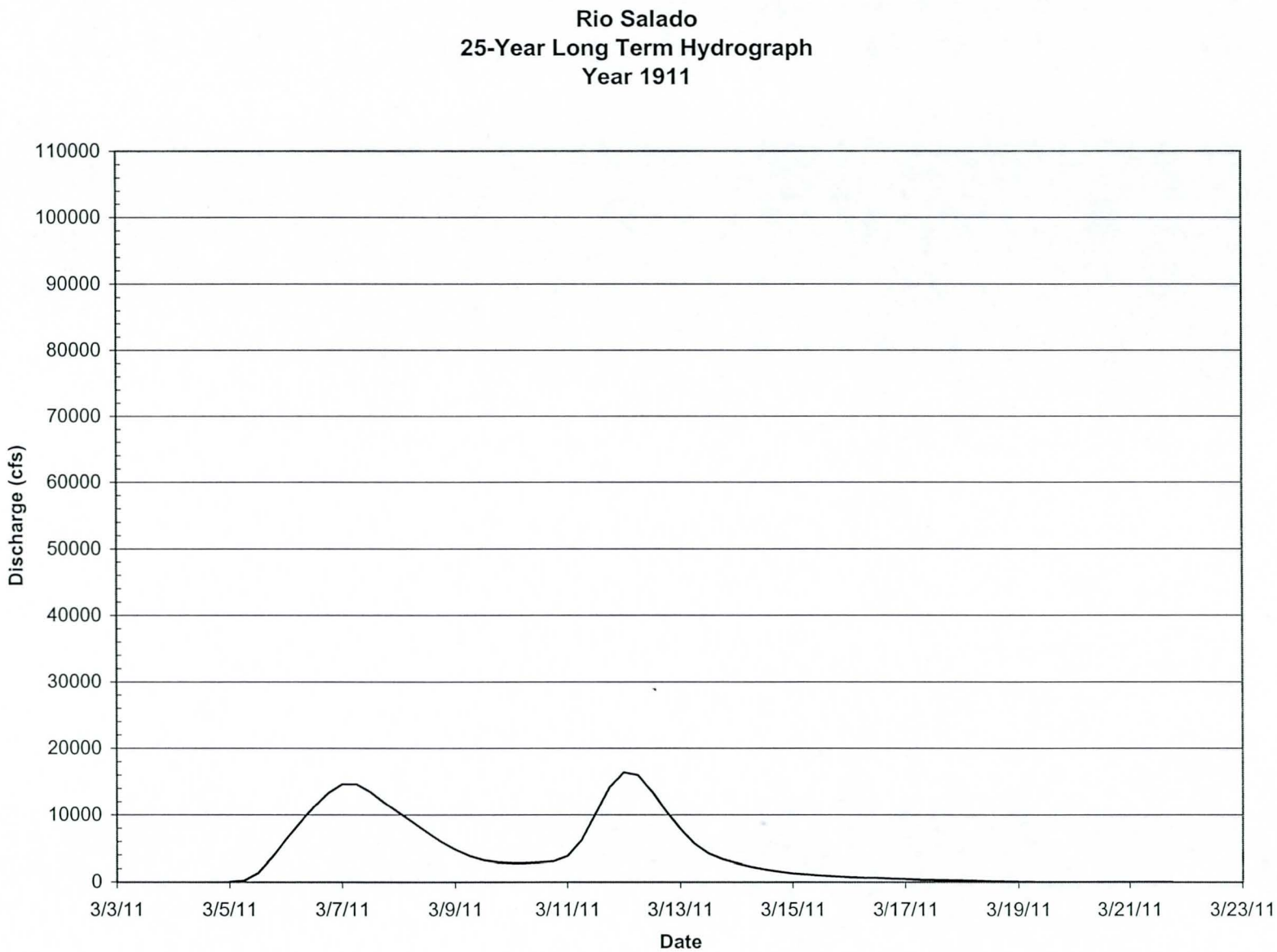

Rio Salado
25-Year Long Term Hydrograph
Year 1905
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
4/7/05
4/9/05
4/11/05
4/13/05
4/15/05
4/17/05
4/19/05
4/21/05
4/23/05
Date

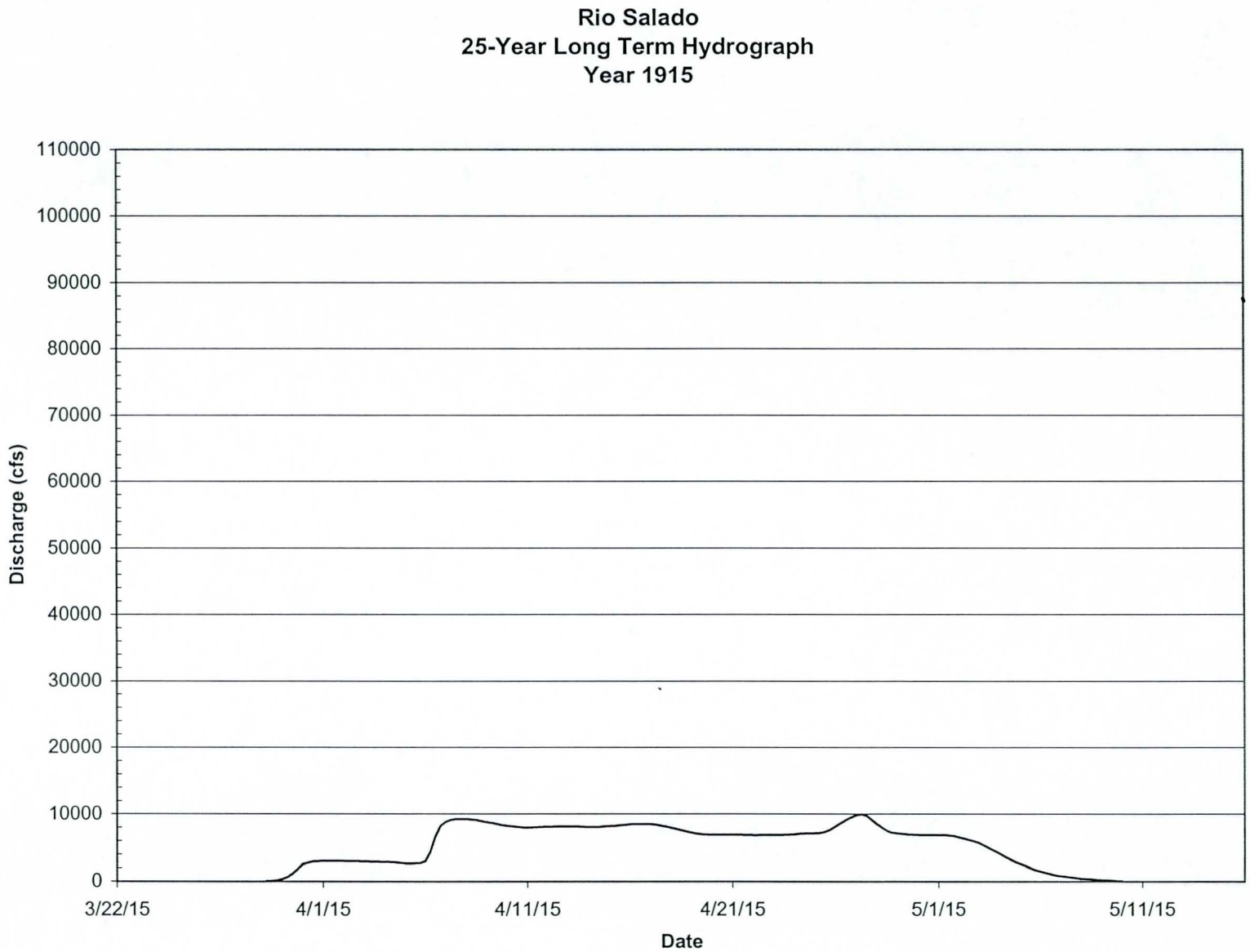

Rio Salado
25-Year Long Term Hydrograph
Year 1906
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
3/9/06
3/11/06
3/13/06
3/15/06
3/17/06
3/19/06
3/21/06
3/23/06
Date

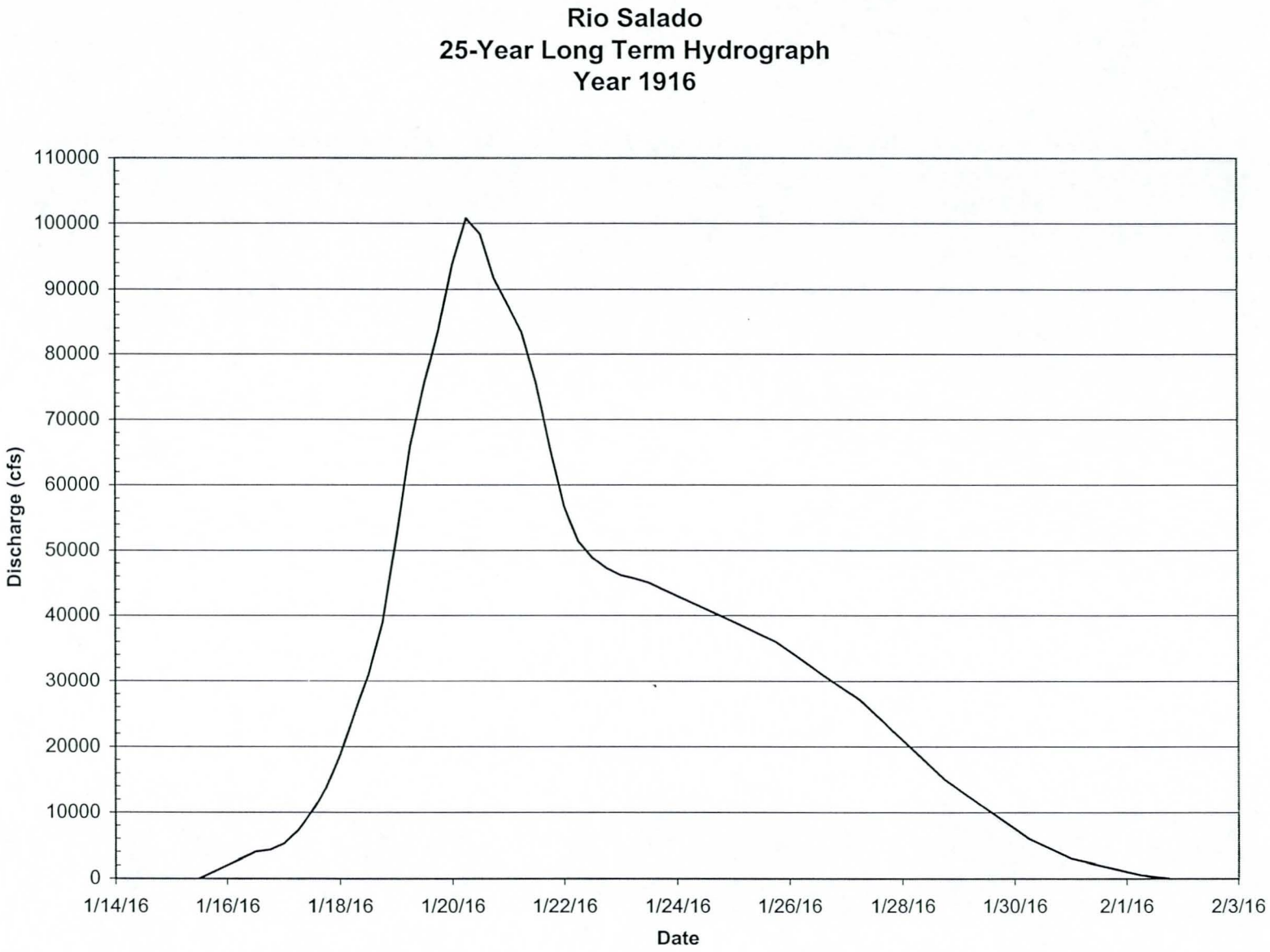

Rio Salado
25-Year Long Term Hydrograph
Year 1907
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2/27/07
3/1/07
3/3/07
3/5/07
3/7/07
3/9/07
3/11/07
3/13/07
3/15/07
3/17/07
3/19/07
Date

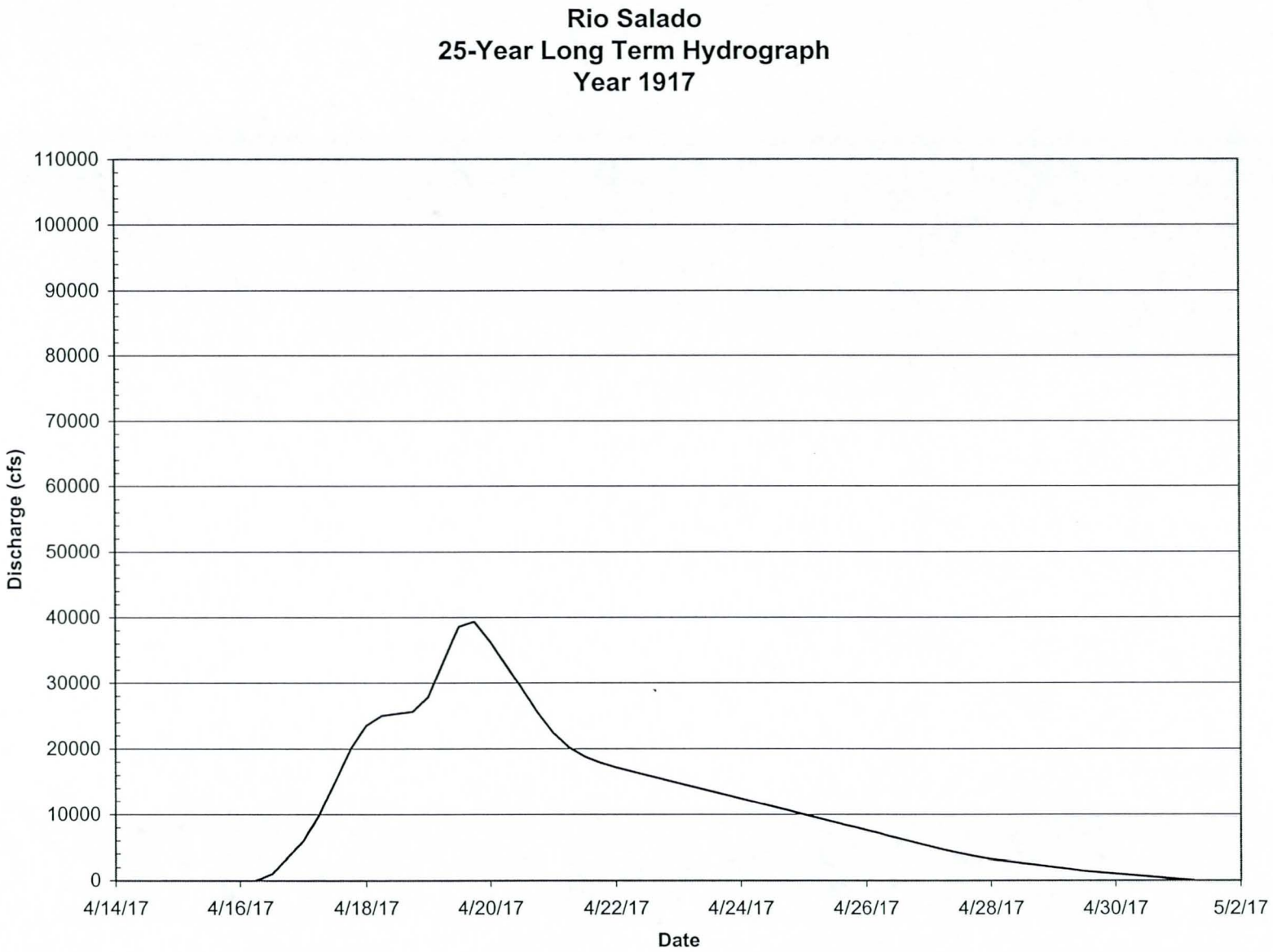

Rio Salado
25-Year Long Term Hydrograph
Year 1908
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
3/1/08
3/6/08
3/11/08
3/16/08
3/21/08
3/26/08
3/31/08
4/5/08
4/10/08
4/15/08
Date

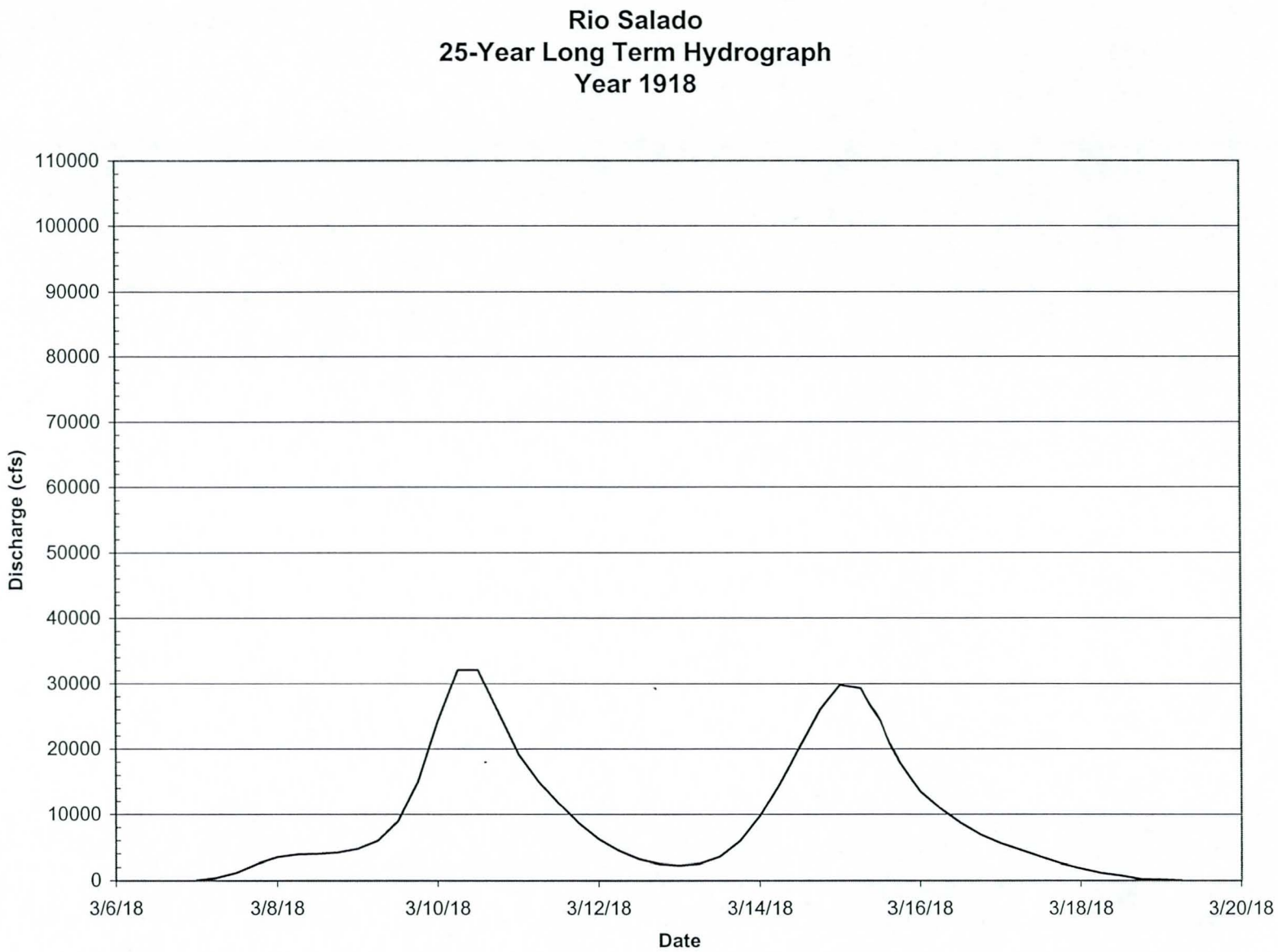

Rio Salado
25-Year Long Term Hydrograph
Year 1909
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Discharge (cfs)
1/22/09
2/1/09
2/11/09
2/21/09
3/3/09
3/13/09
Date

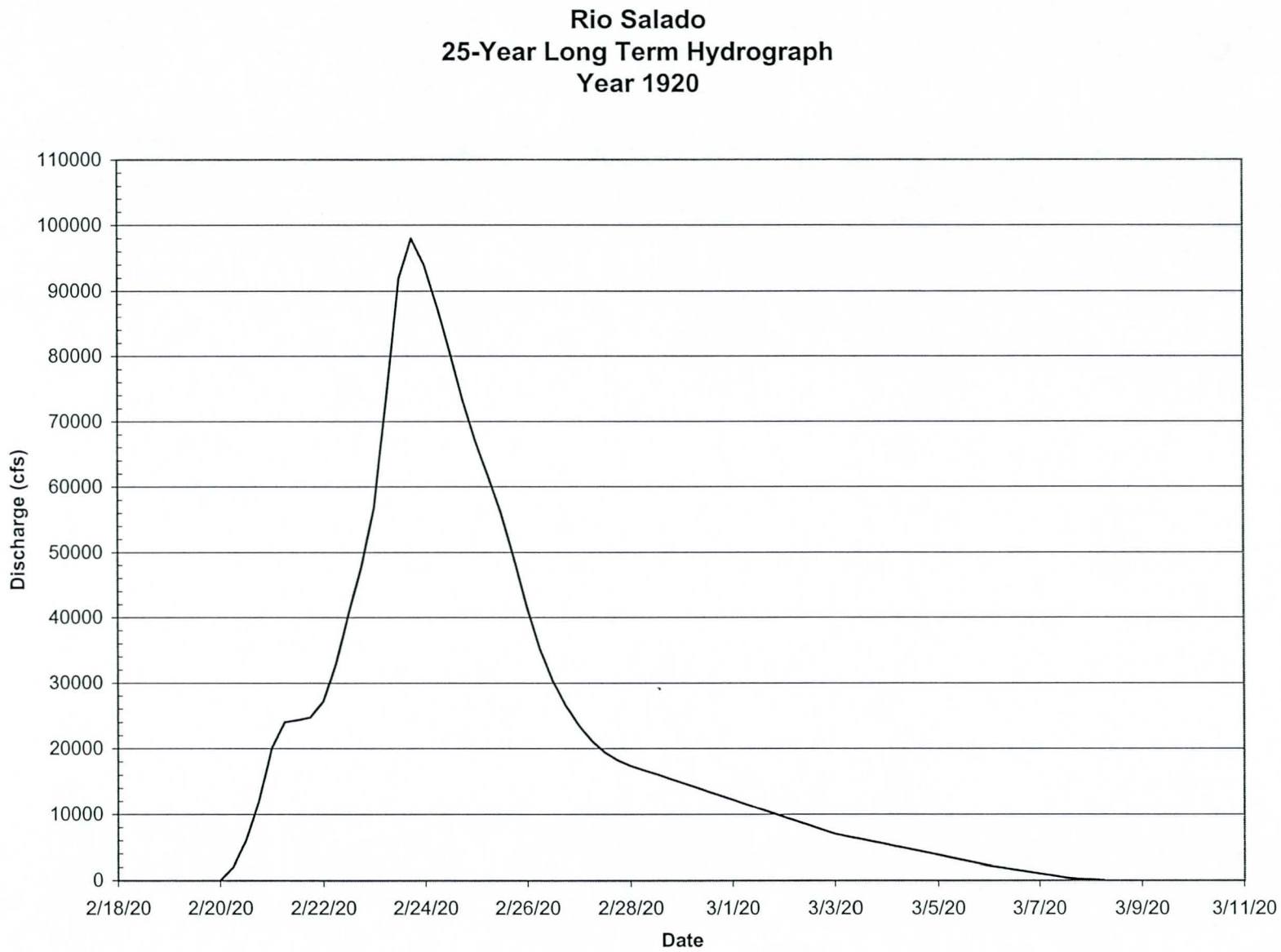

Rio Salado
25-Year Long Term Hydrograph
Year 1911
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
3/3/11
3/5/11
3/7/11
3/9/11
3/11/11
3/13/11
3/15/11
3/17/11
3/19/11
3/21/11
3/23/11
Date

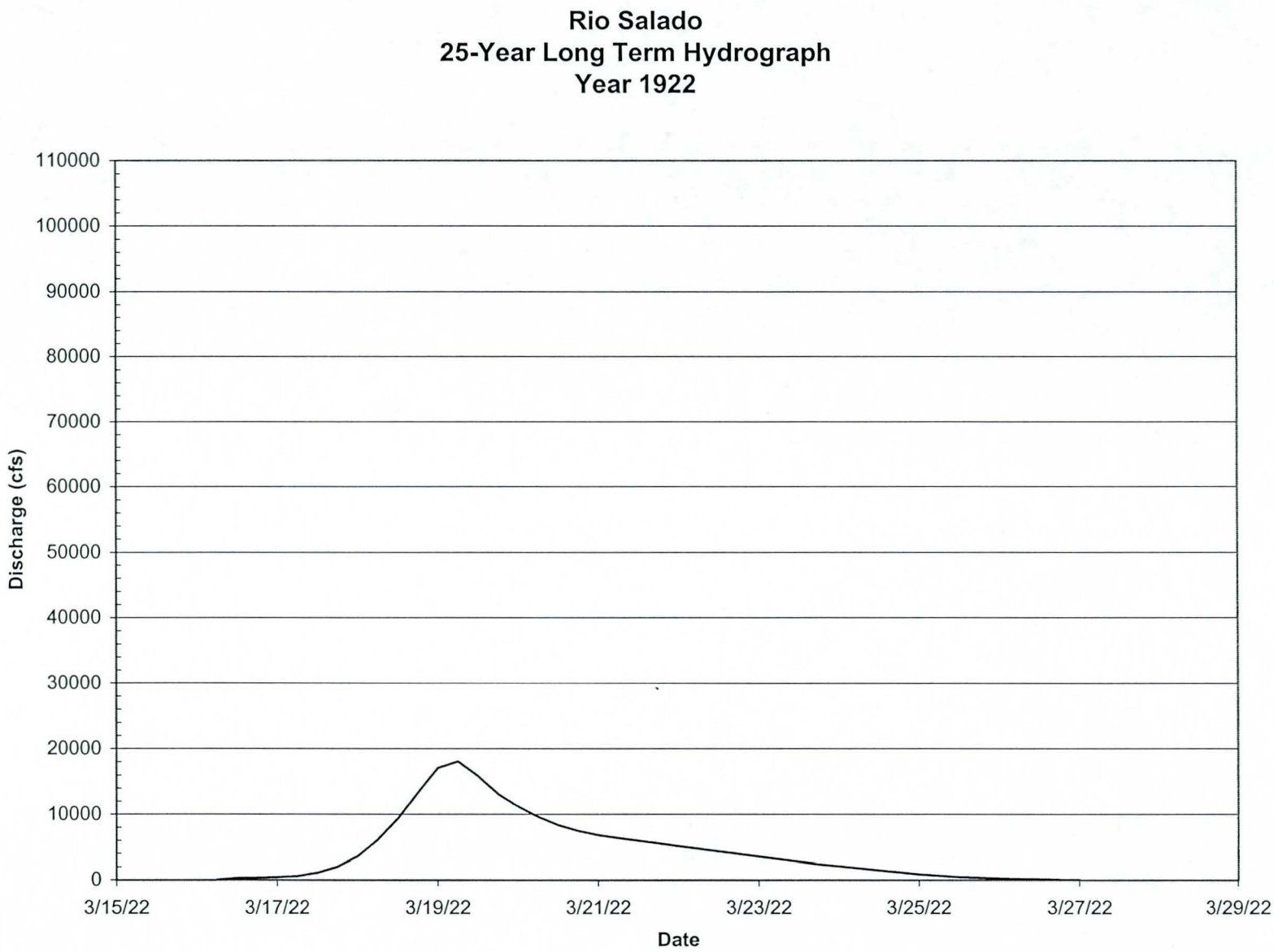

Rio Salado
25-Year Long Term Hydrograph
Year 1915
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Discharge (cfs)
3/22/15
4/1/15
4/11/15
4/21/15
5/1/15
5/11/15
Date

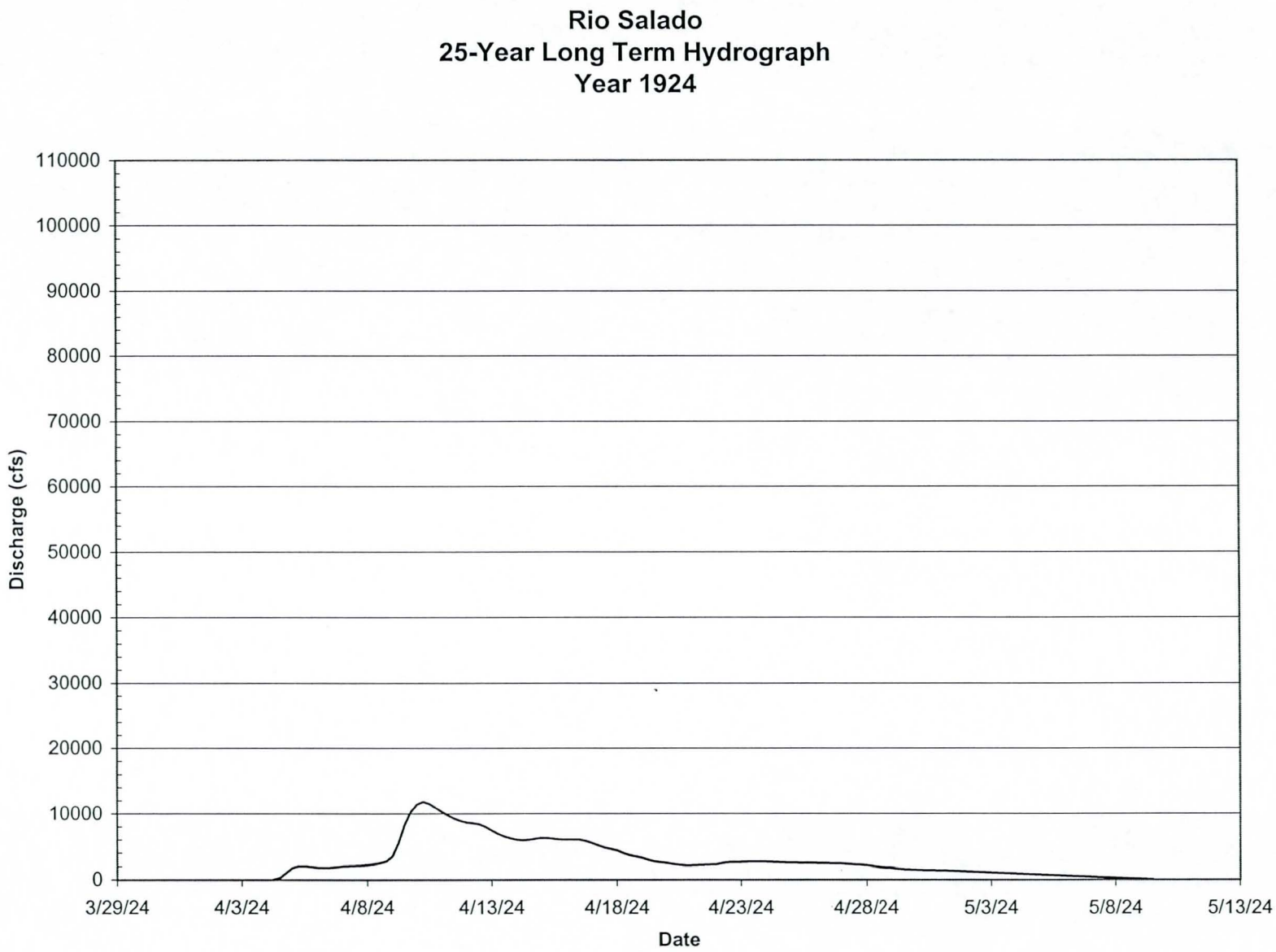

Rio Salado
25-Year Long Term Hydrograph
Year 1916
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/14/16
1/16/16
1/18/16
1/20/16
1/22/16
1/24/16
1/26/16
1/28/16
1/30/16
2/1/16
2/3/16
Date

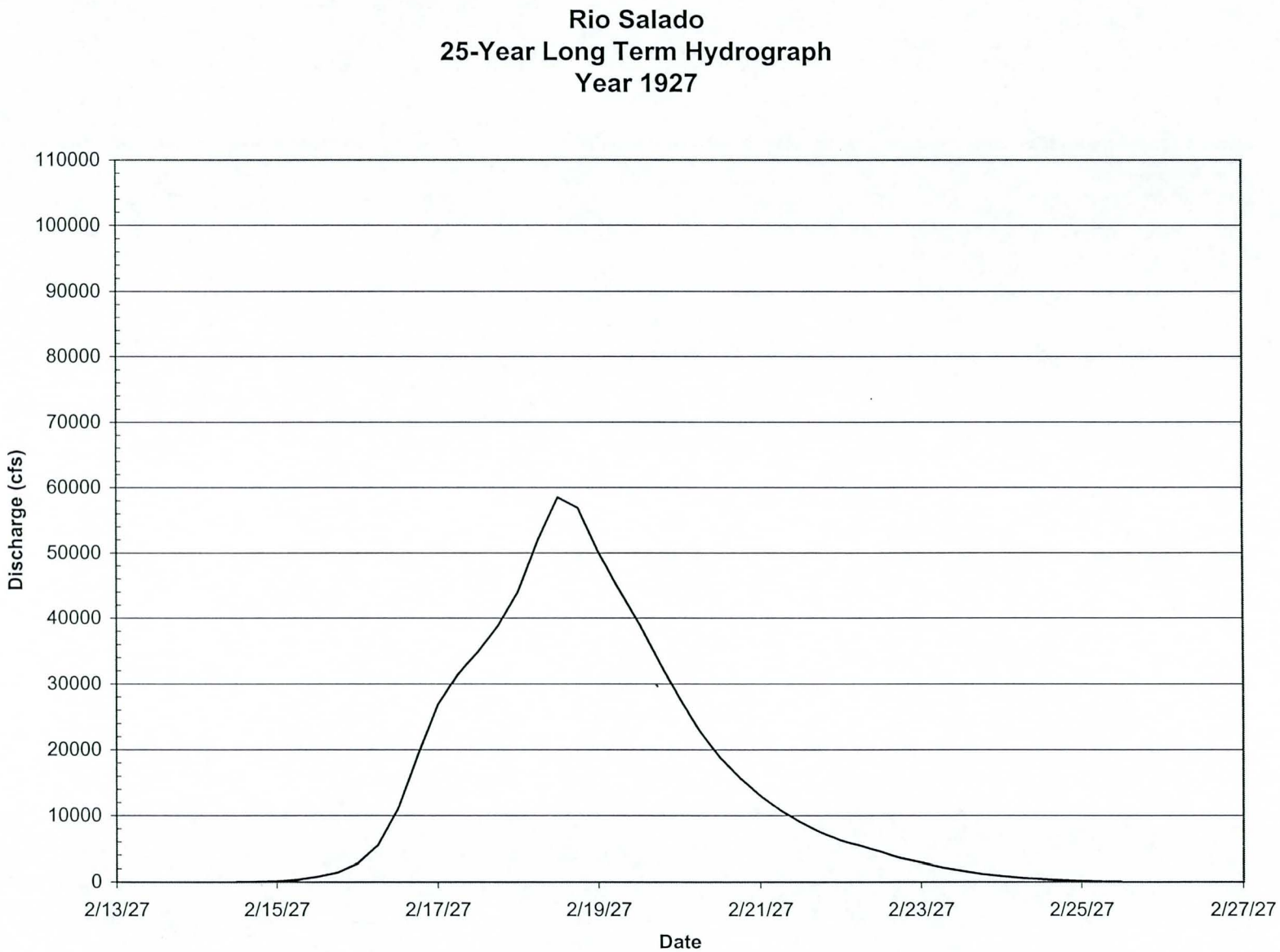

Rio Salado
25-Year Long Term Hydrograph
Year 1917
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
4/14/17
4/16/17
4/18/17
4/20/17
4/22/17
4/24/17
4/26/17
4/28/17
4/30/17
5/2/17
Date


Rio Salado
25-Year Long Term Hydrograph
Year 1918
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
3/6/18
3/8/18
3/10/18
3/12/18
3/14/18
3/16/18
3/18/18
3/20/18
Date


Rio Salado
25-Year Long Term Hydrograph
Year 1920
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2/18/20
2/20/20
2/22/20
2/24/20
2/26/20
2/28/20
3/1/20
3/3/20
3/5/20
3/7/20
3/9/20
3/11/20
Date


Rio Salado
25-Year Long Term Hydrograph
Year 1922
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
3/15/22
3/17/22
3/19/22
3/21/22
3/23/22
3/25/22
3/27/22
3/29/22
Date

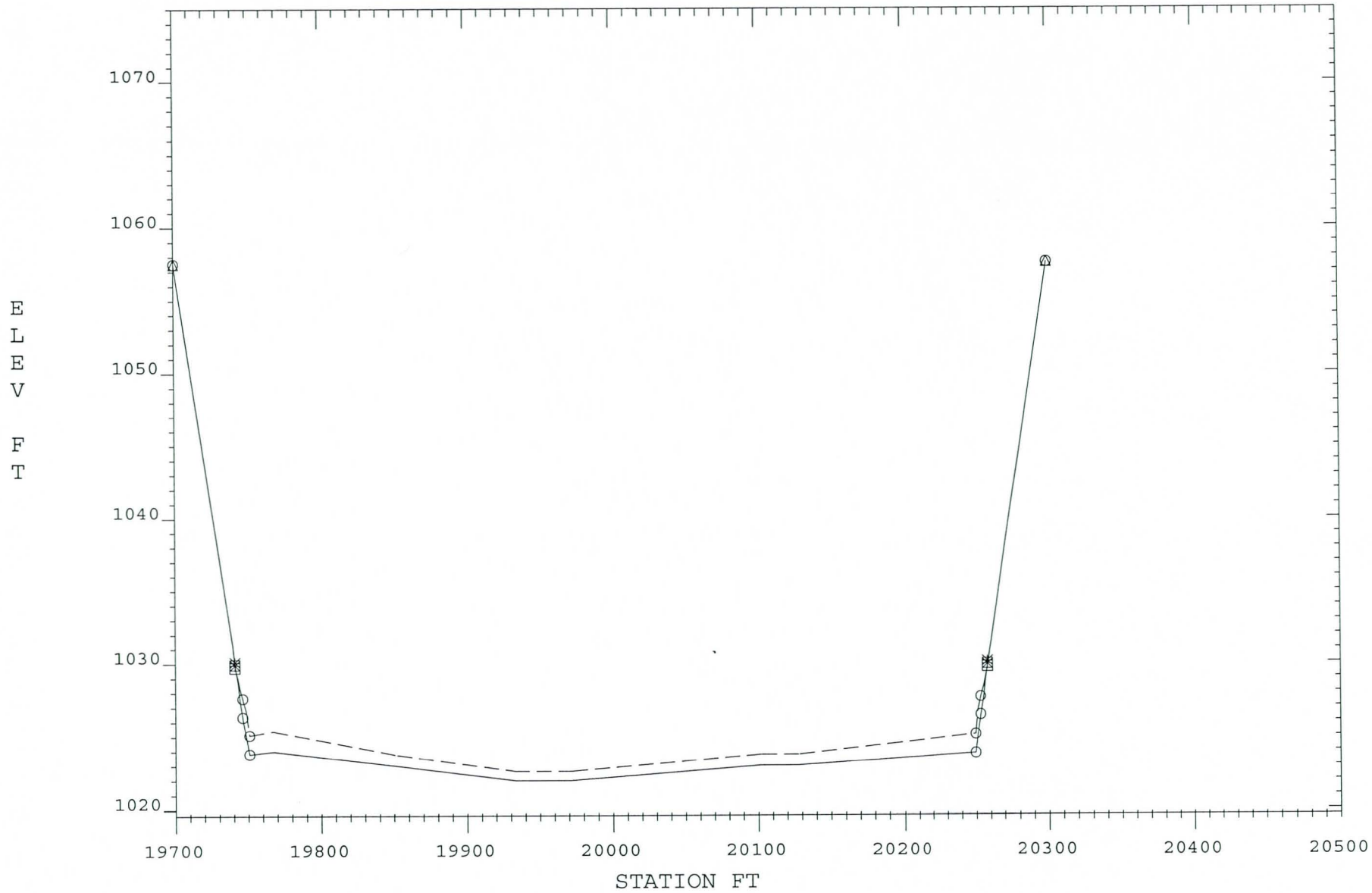

Rio Salado
25-Year Long Term Hydrograph
Year 1924
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
3/29/24
4/3/24
4/8/24
4/13/24
4/18/24
4/23/24
4/28/24
5/3/24
5/8/24
5/13/24
Date


Rio Salado
25-Year Long Term Hydrograph
Year 1927
Discharge (cfs)
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2/13/27
2/15/27
2/17/27
2/19/27
2/21/27
2/23/27
2/25/27
2/27/27
Date

APPENDIX 4D

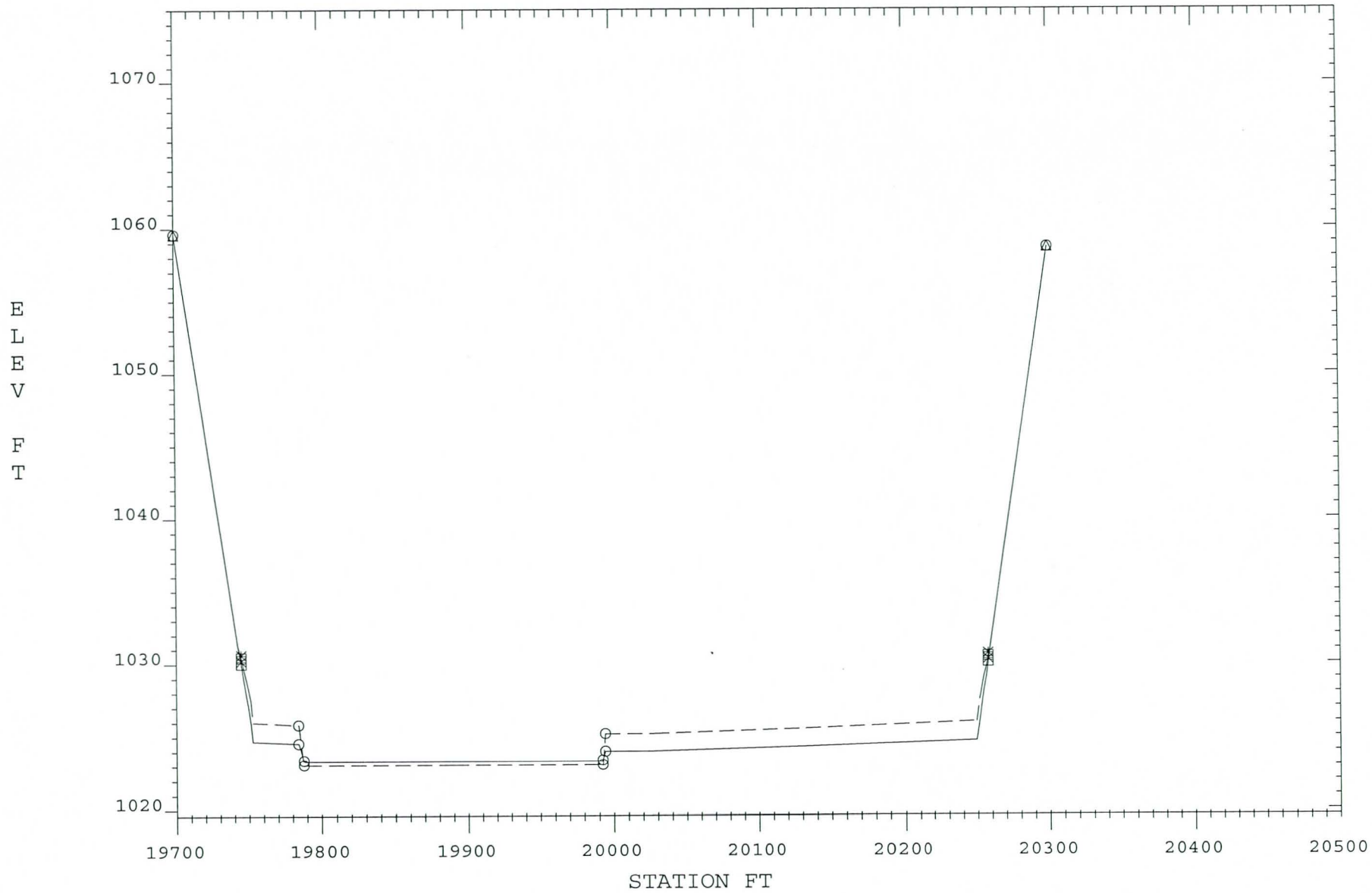
Low Flow Channel Cross Section Plots Before and After 25-Year Long-Term Simulation for Scenario L-5b

1 LFC INITIAL GEOME



——— XSEC 1-211.63 DAYS= 0.000
– – – – XSEC 1-211.63 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-211.76 DAYS= 0.000
– – – - XSEC 1-211.76 DAYS= 290.021

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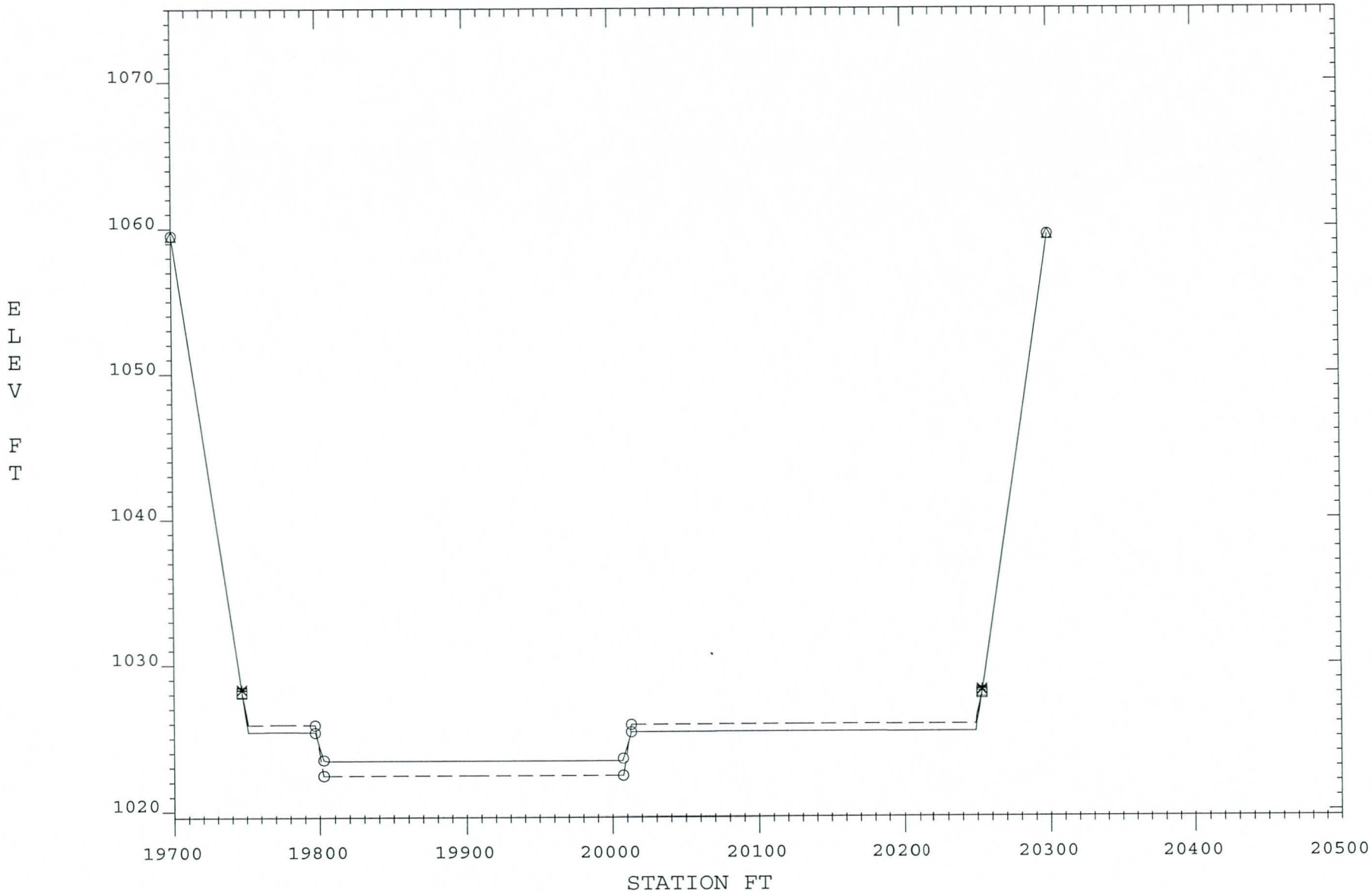
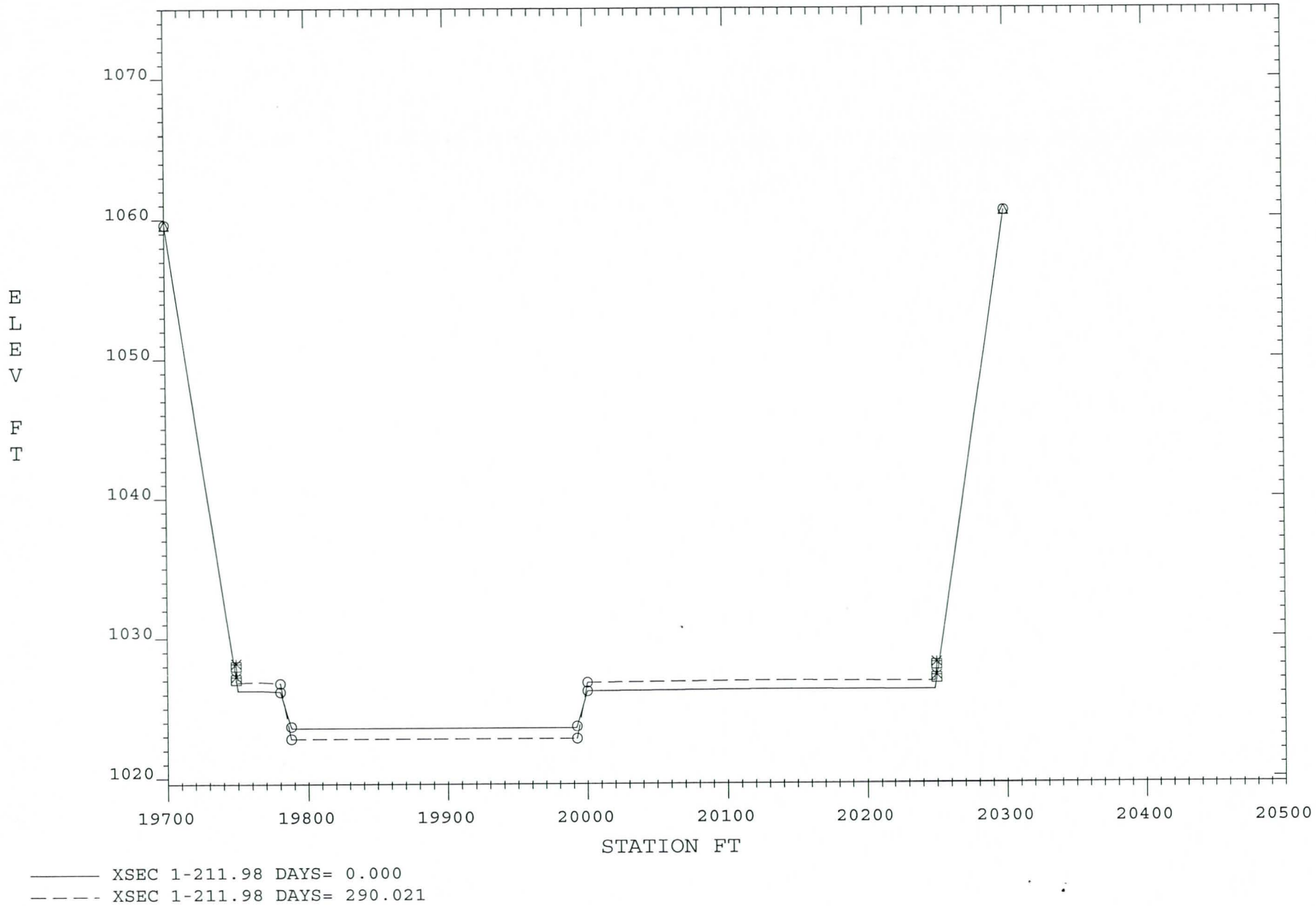
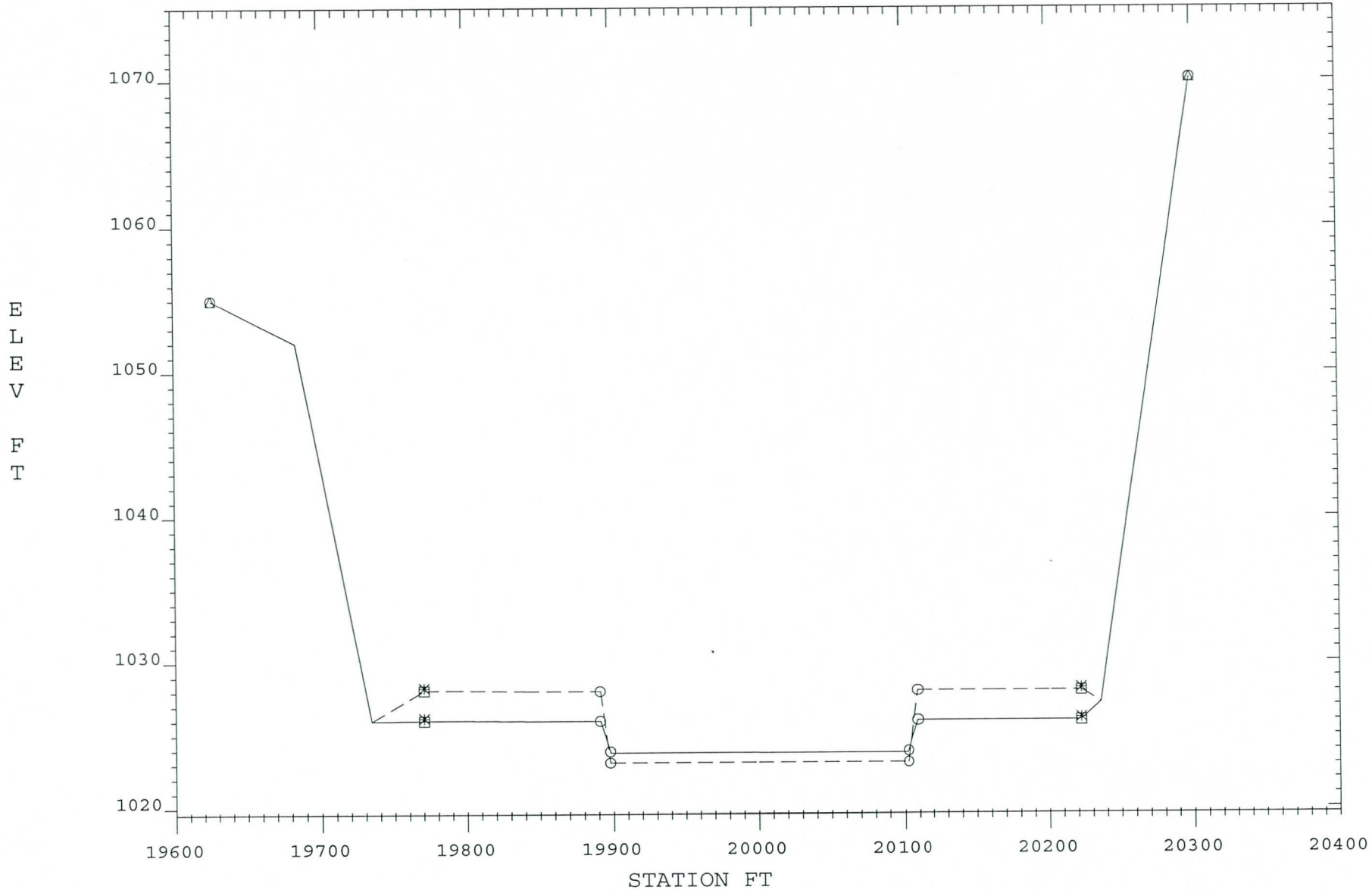


——— XSEC 1-211.86 DAYS= 0.000
– – – - XSEC 1-211.86 DAYS= 290.021

1 LFC INITIAL GEOME

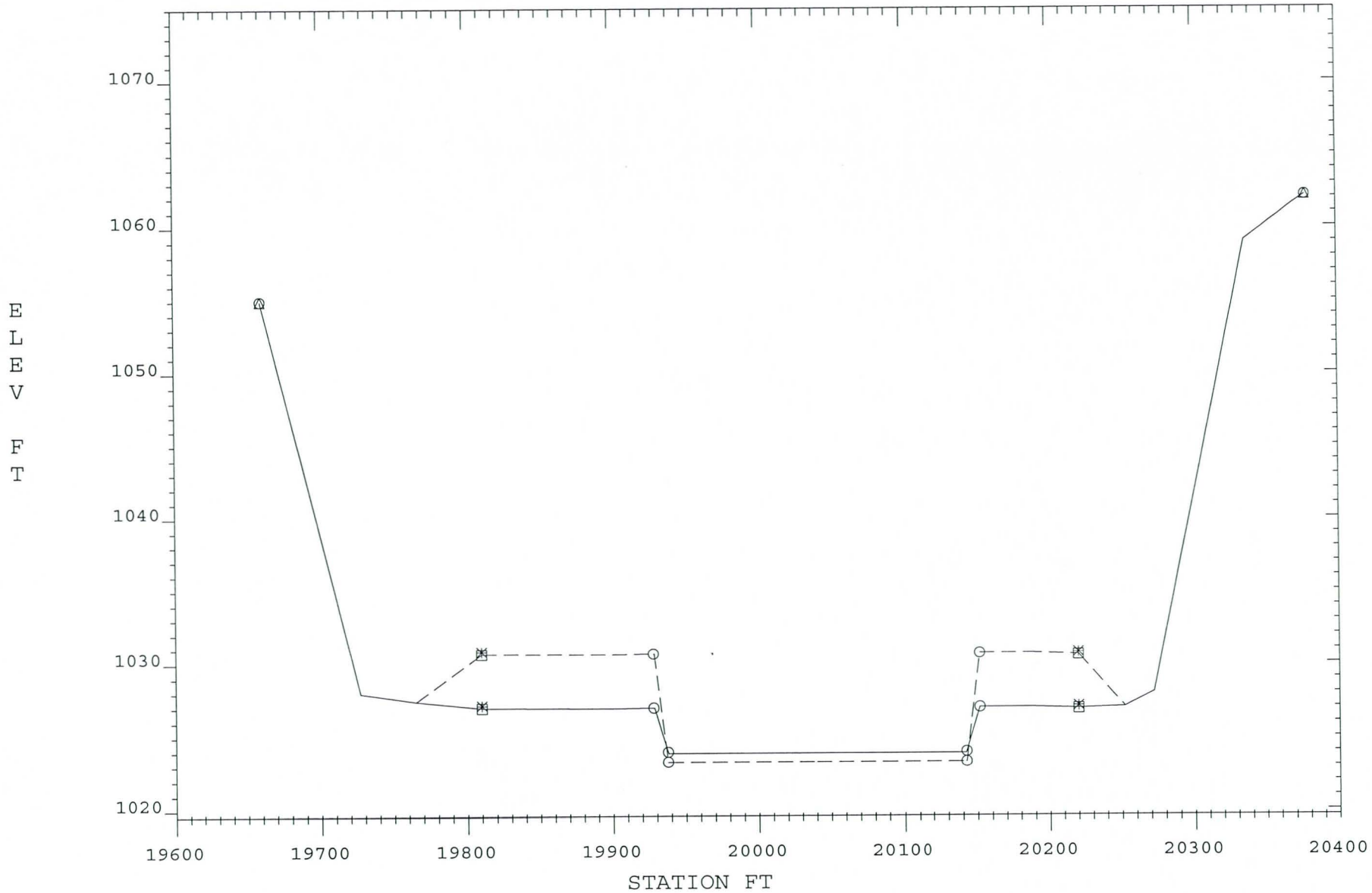


1 LFC INITIAL GEOME



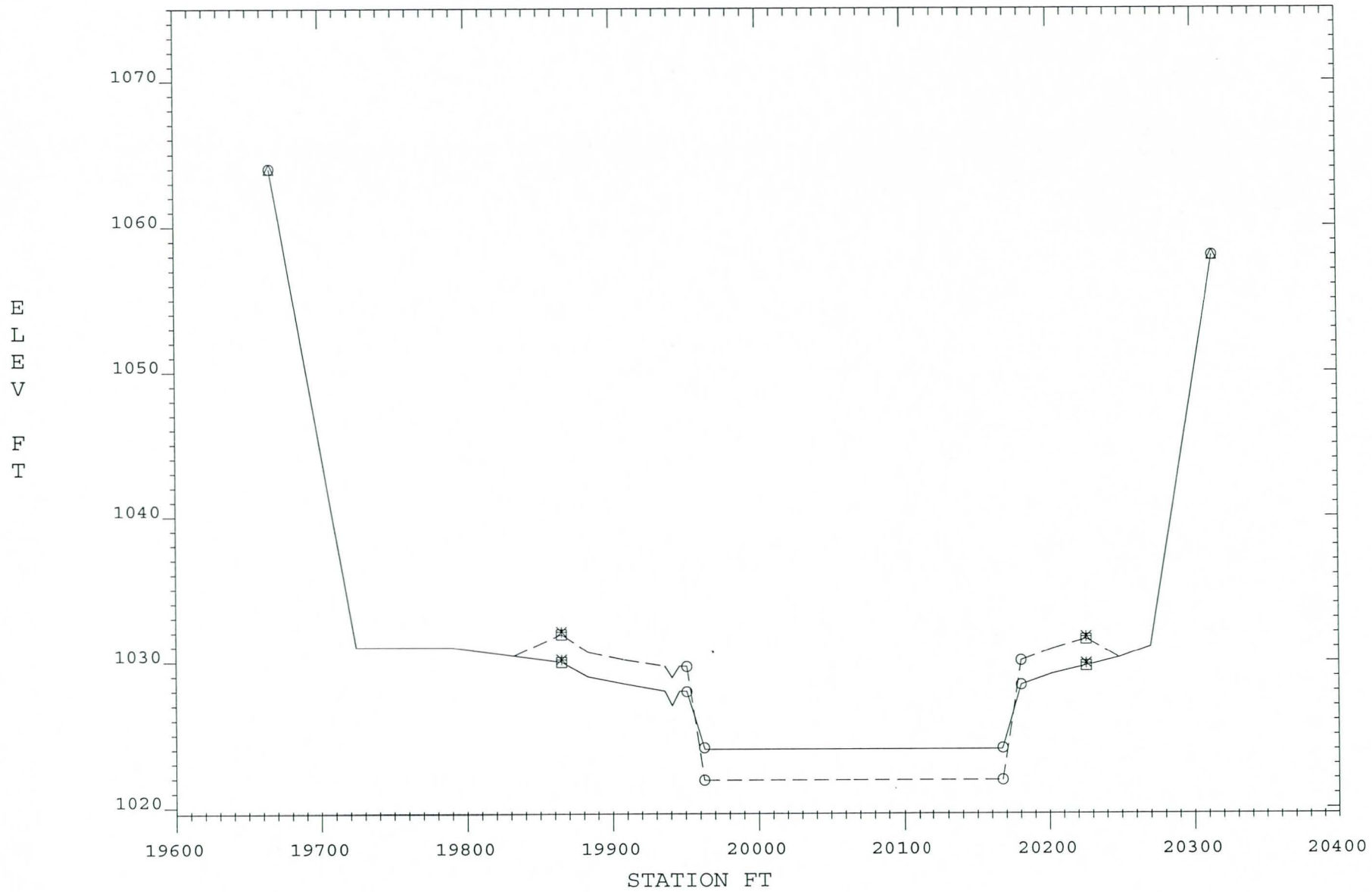
——— XSEC 1-212.12 DAYS= 0.000
– – – - XSEC 1-212.12 DAYS= 290.021

1 LFC INITIAL GEOME



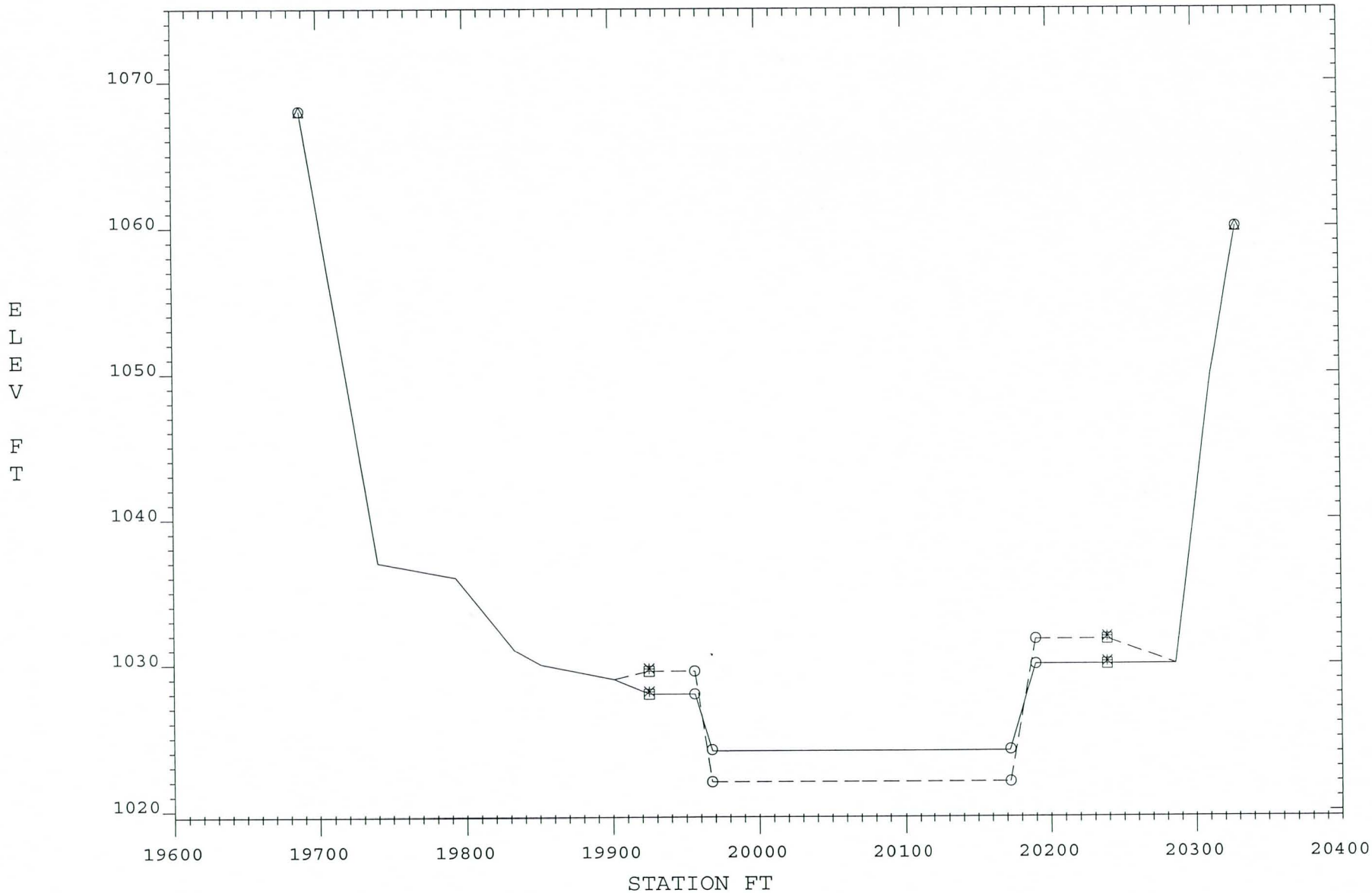
——— XSEC 1-212.16 DAYS= 0.000
— — — - XSEC 1-212.16 DAYS= 290.021

1 LFC INITIAL GEOME



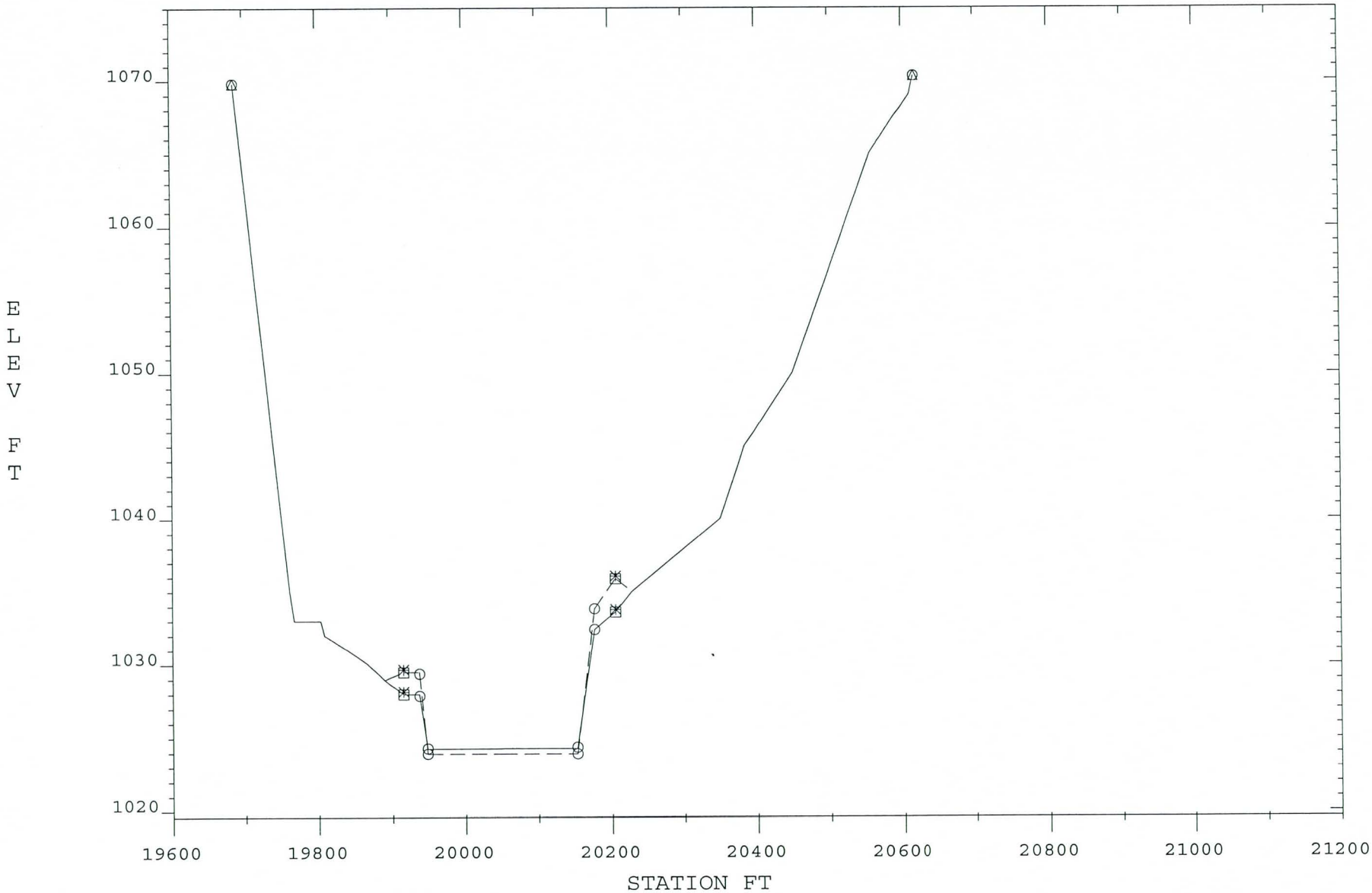
——— XSEC 1-212.27 DAYS= 0.000
— — — - XSEC 1-212.27 DAYS= 290.021

1 LFC INITIAL GEOME



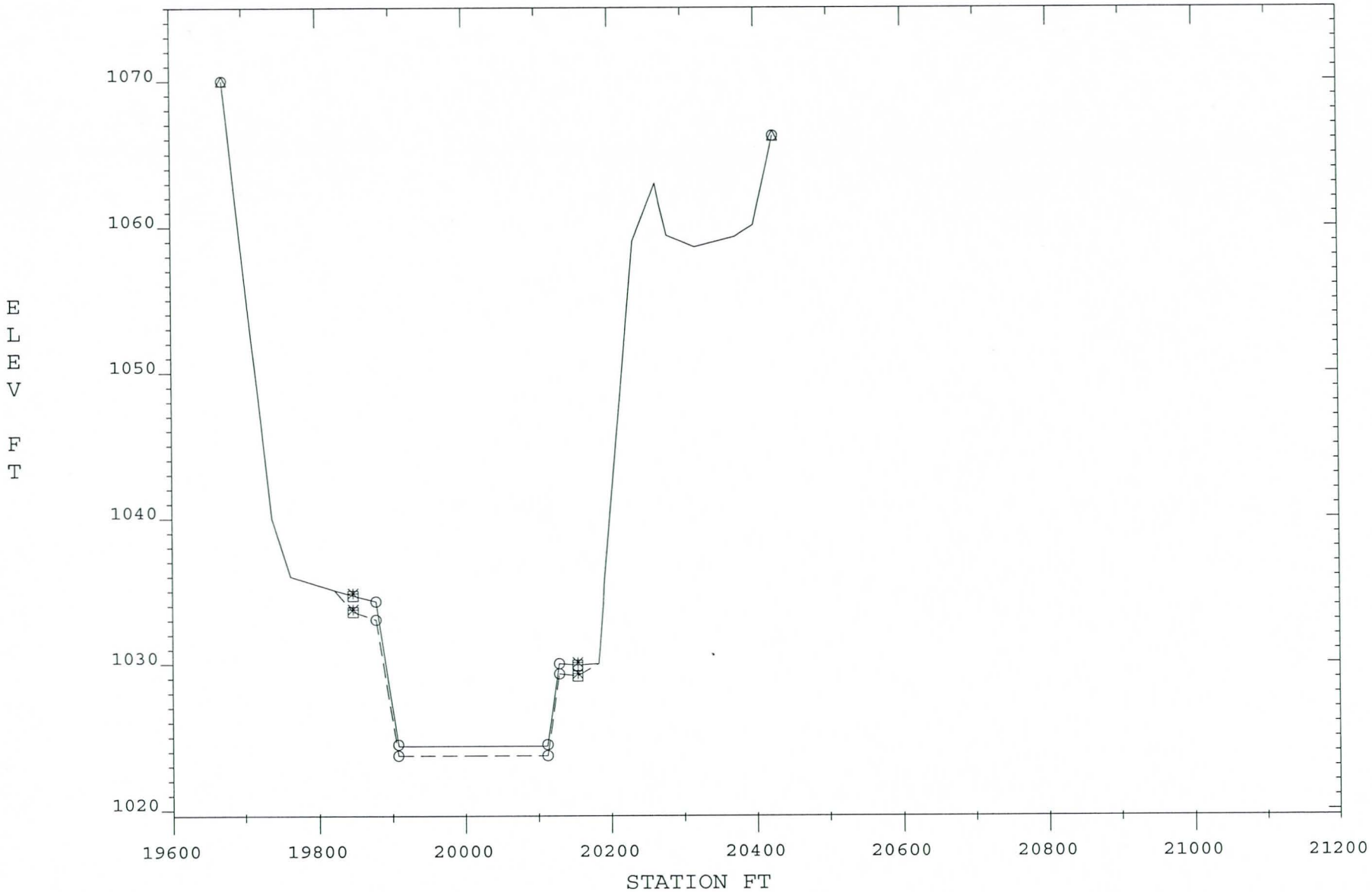
——— XSEC 1-212.34 DAYS= 0.000
— — — XSEC 1-212.34 DAYS= 290.021

1 LFC INITIAL GEOME



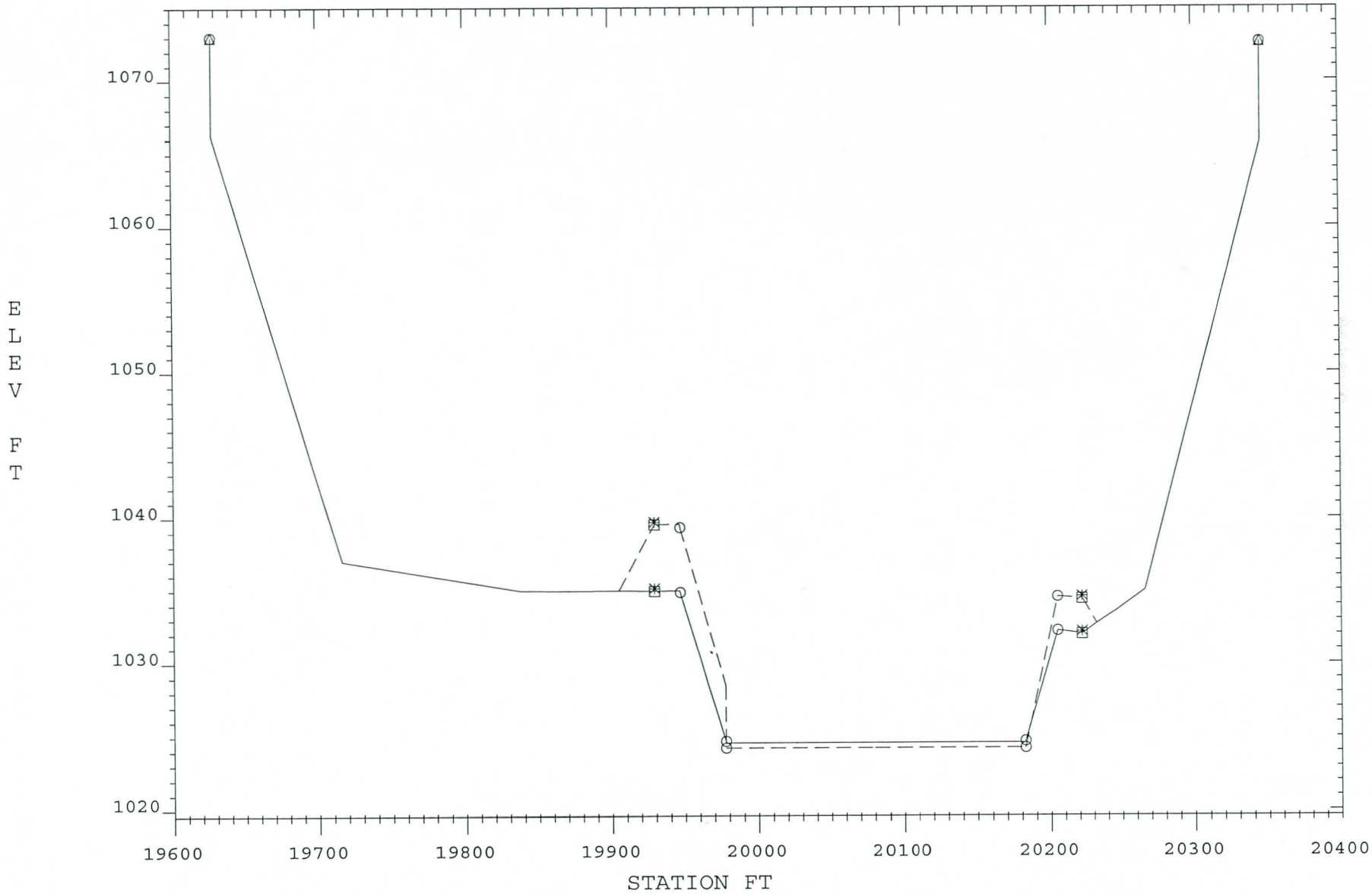
——— XSEC 1-212.46 DAYS= 0.000
— — — - XSEC 1-212.46 DAYS= 290.021

1 LFC INITIAL GEOME



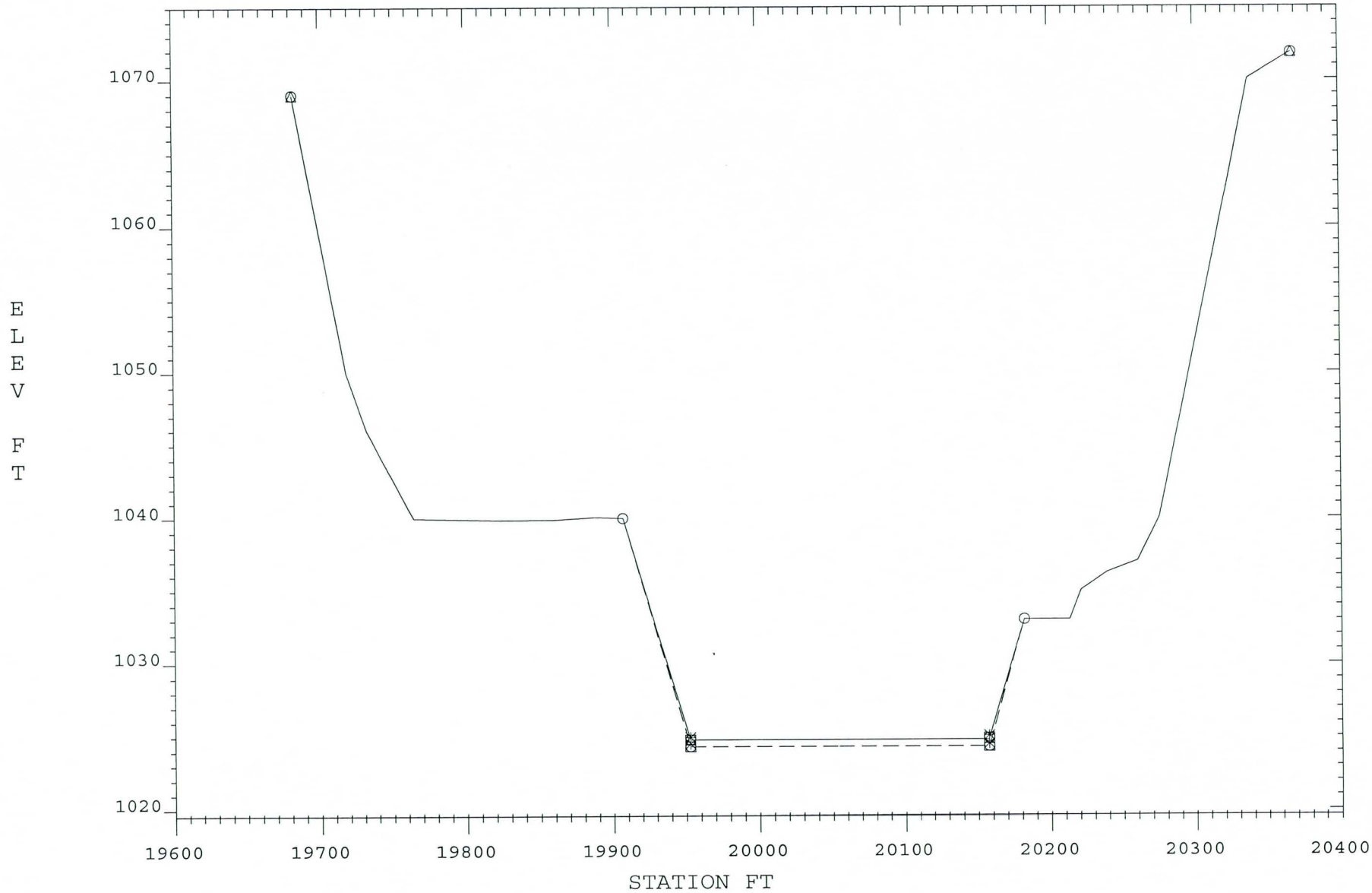
——— XSEC 1-212.56 DAYS= 0.000
— — — - XSEC 1-212.56 DAYS= 290.021

1 LFC INITIAL GEOME



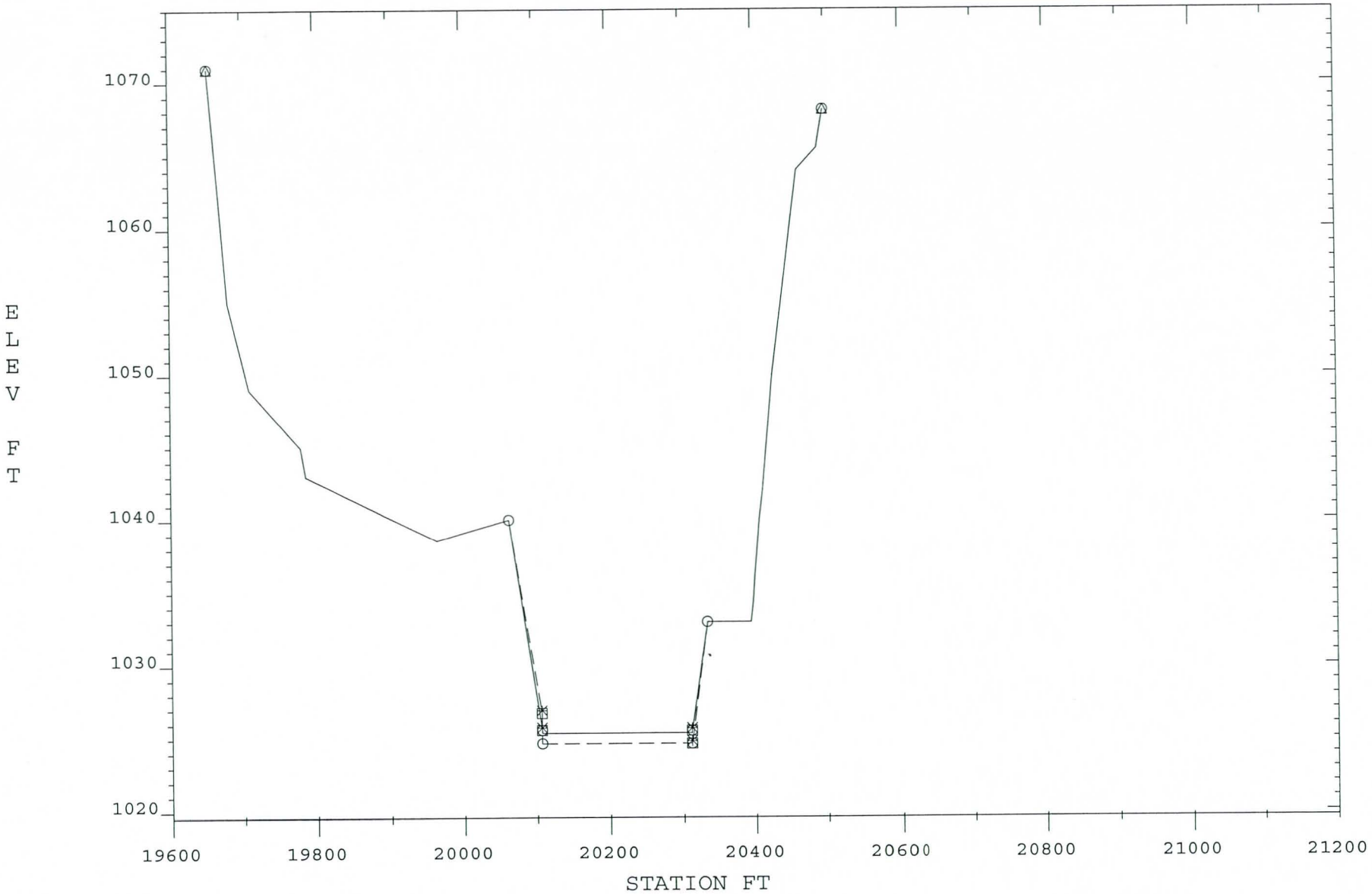
——— XSEC 1-212.68 DAYS= 0.000
– – – - XSEC 1-212.68 DAYS= 290.021

1 LFC INITIAL GEOME



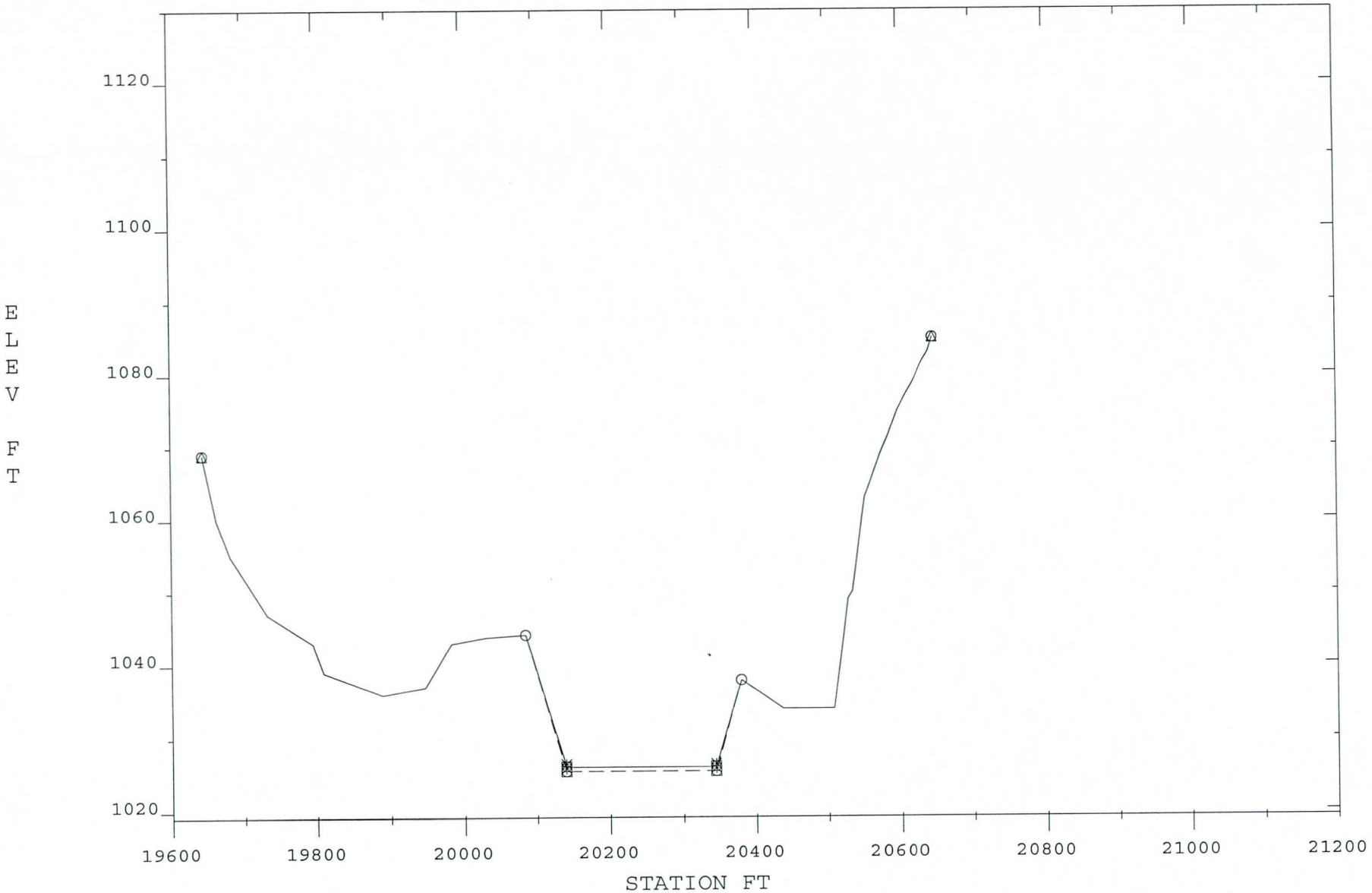
——— XSEC 1-212.84 DAYS= 0.000
— — — - XSEC 1-212.84 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-212.93 DAYS= 0.000
— — — - XSEC 1-212.93 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-213.03 DAYS= 0.000
– – – - XSEC 1-213.03 DAYS= 290.021

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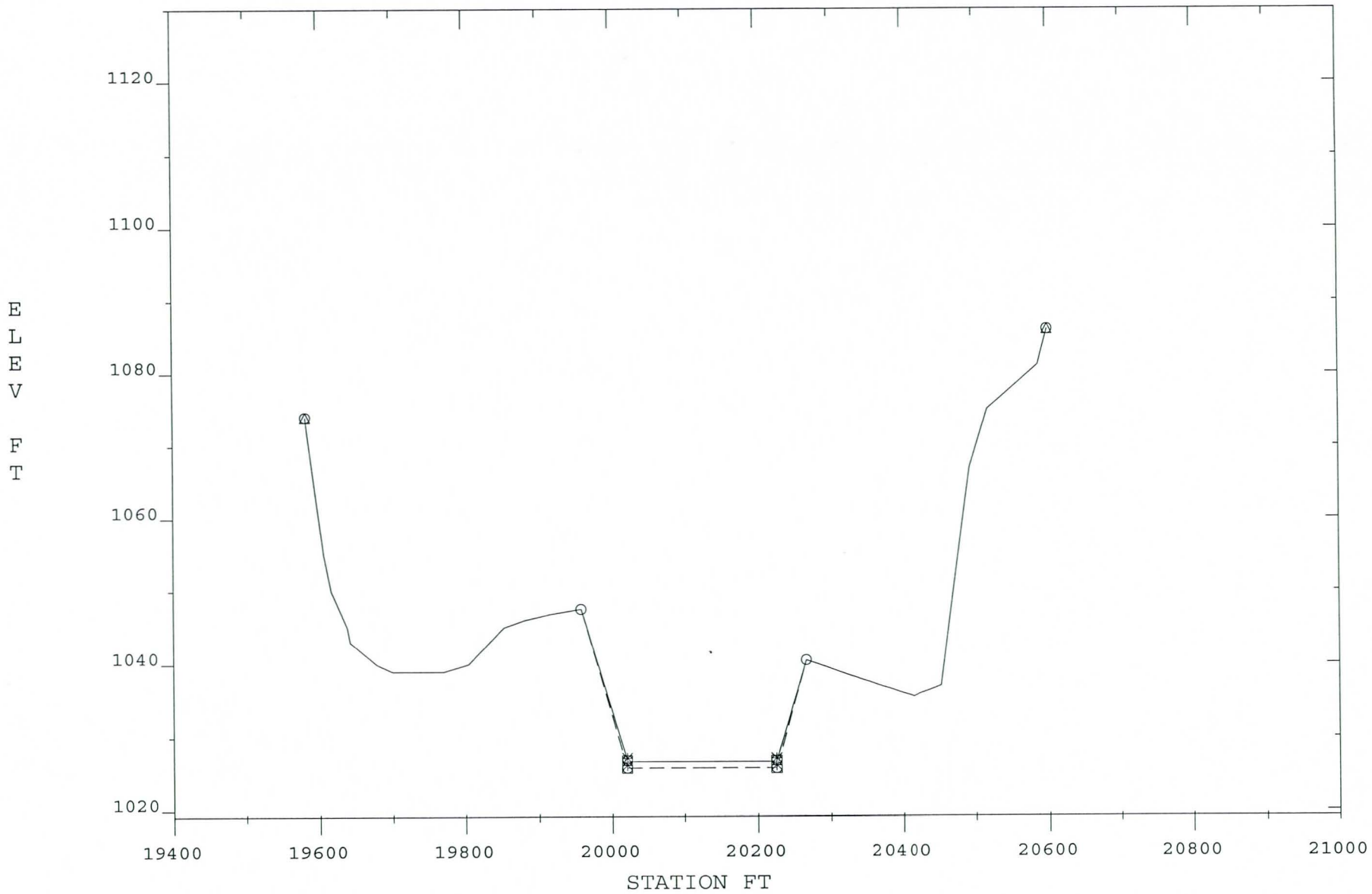
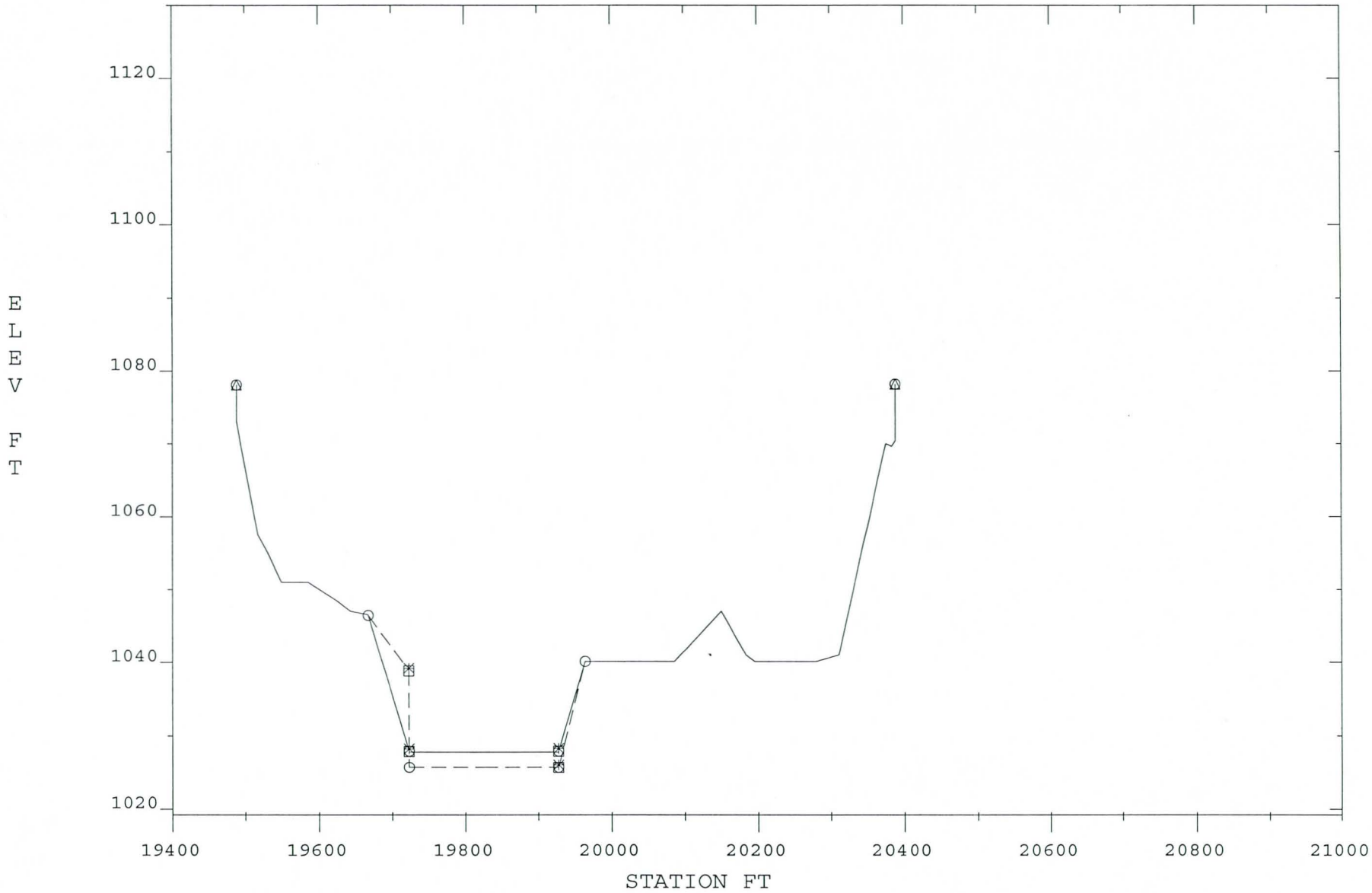


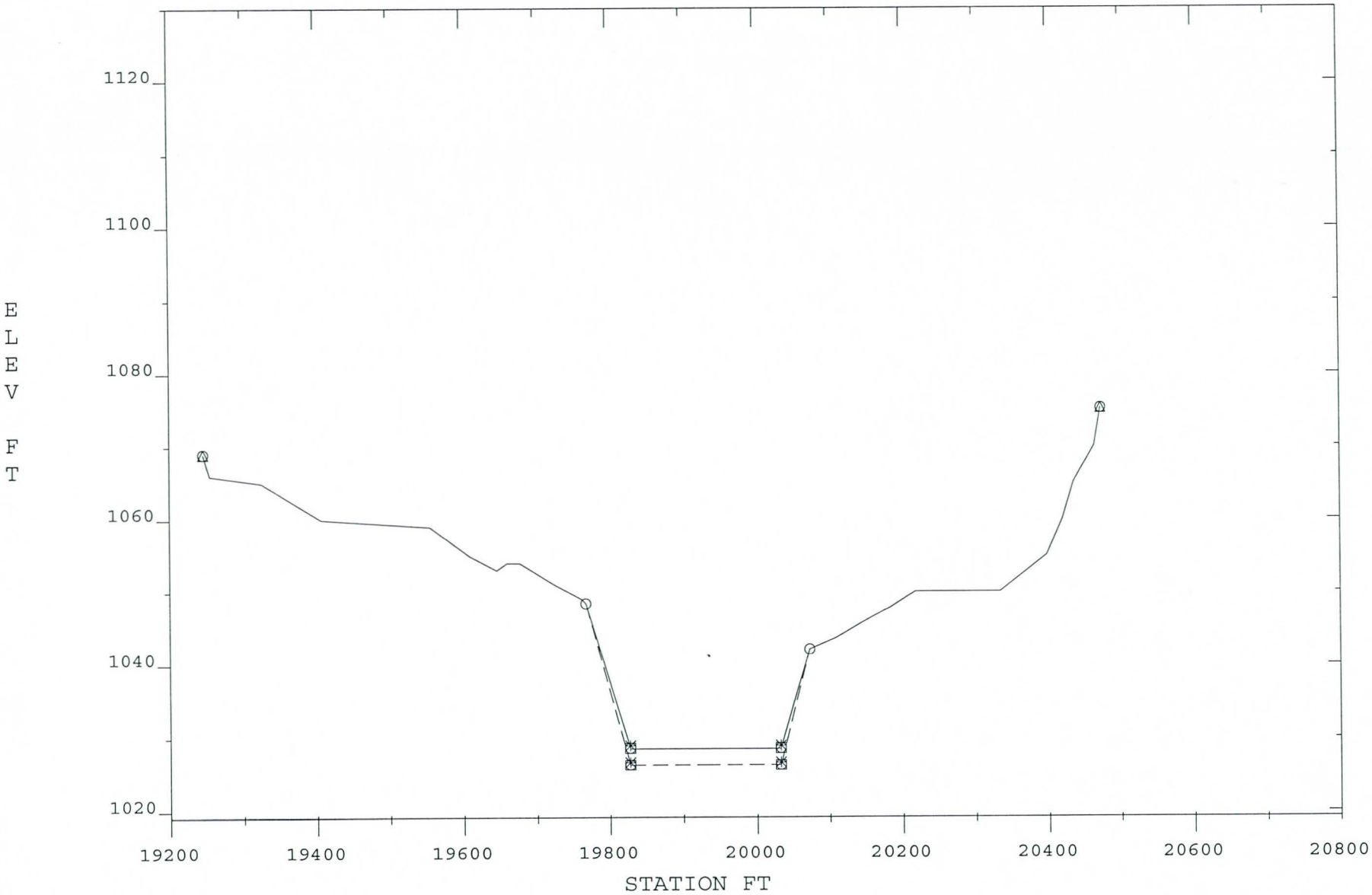
——— XSEC 1-213.11 DAYS= 0.000
– – – - XSEC 1-213.11 DAYS= 290.021

1 LFC INITIAL GEOME



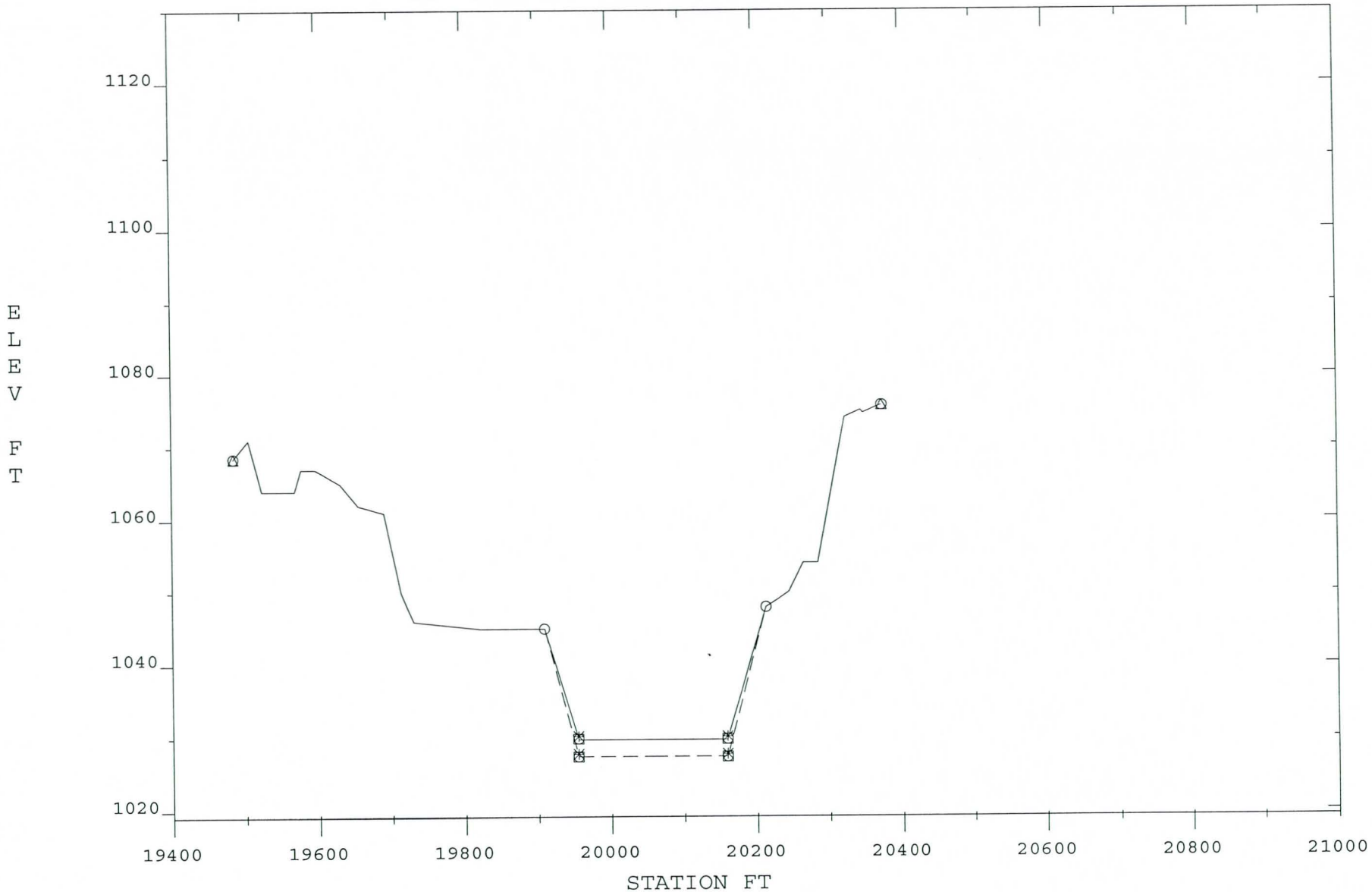
——— XSEC 1-213.26 DAYS= 0.000
– – – - XSEC 1-213.26 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-213.38 DAYS= 0.000
– – – - XSEC 1-213.38 DAYS= 290.021

1 LFC INITIAL GEOME



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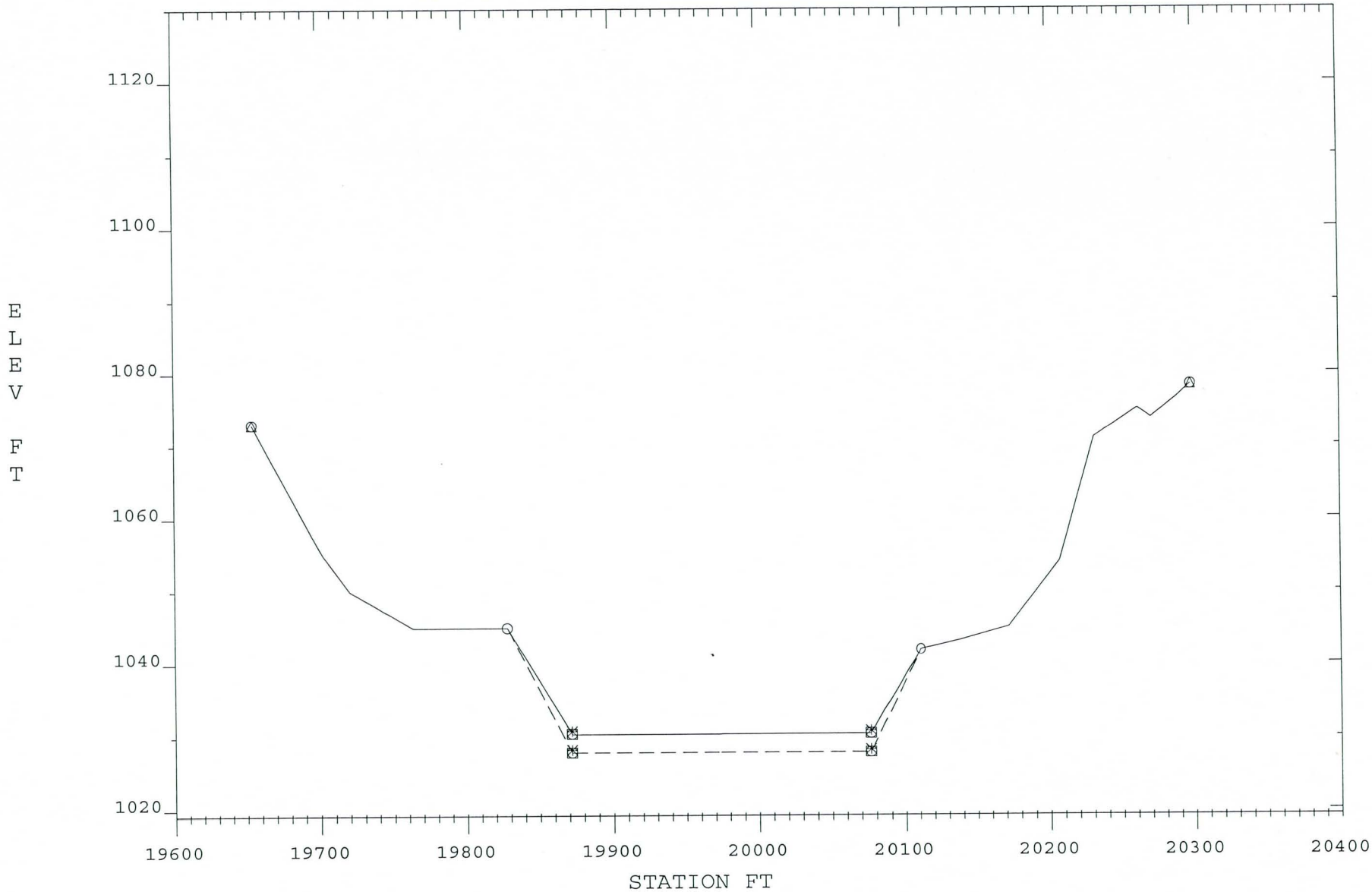
– – – – XSEC 1-213.57 DAYS= 290.021

1 LFC INITIAL GEOME



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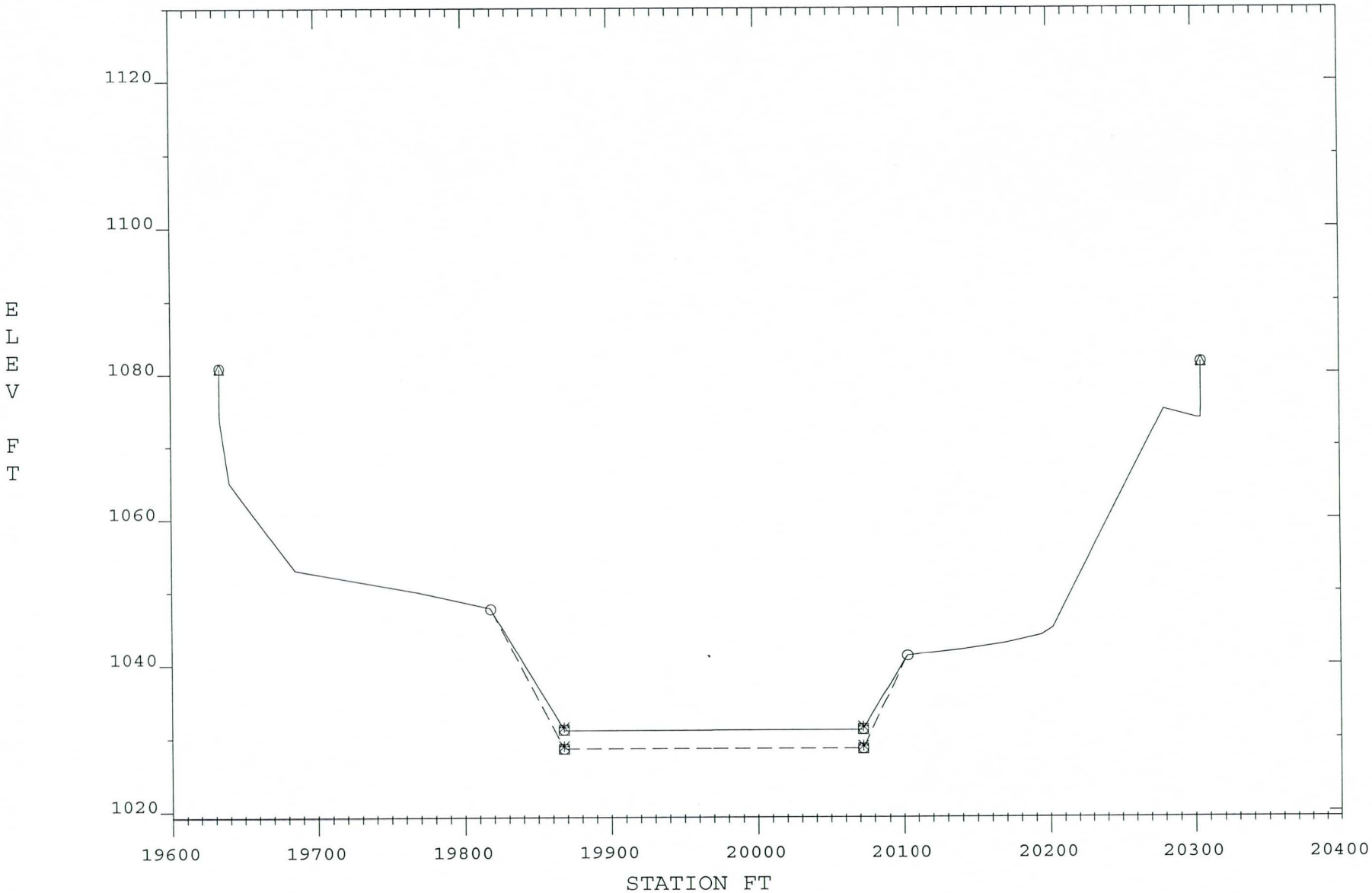
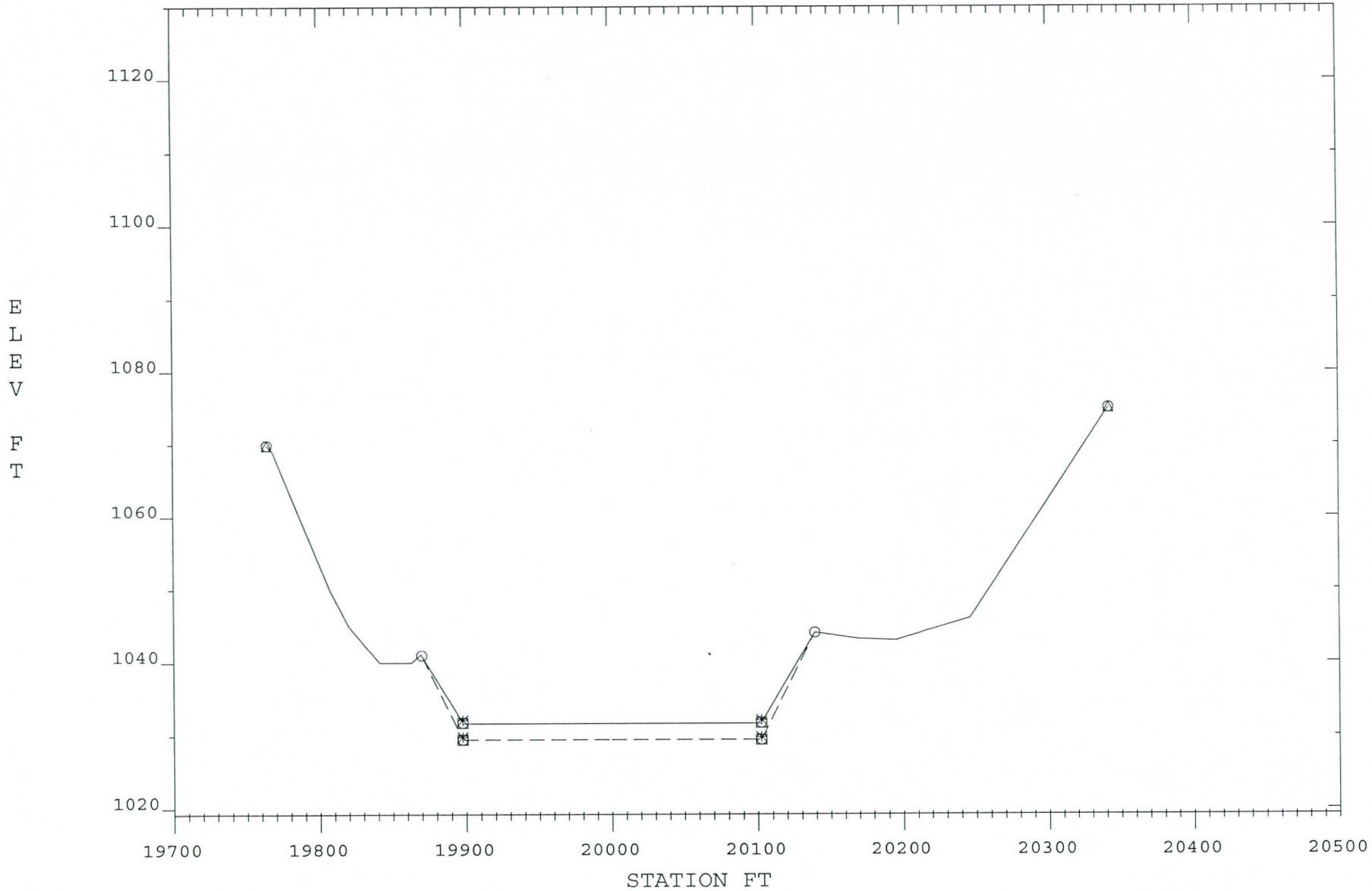
— — — - XSEC 1-213.66 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-213.75 DAYS= 0.000
— — — XSEC 1-213.75 DAYS= 290.021

1 LFC INITIAL GEOME



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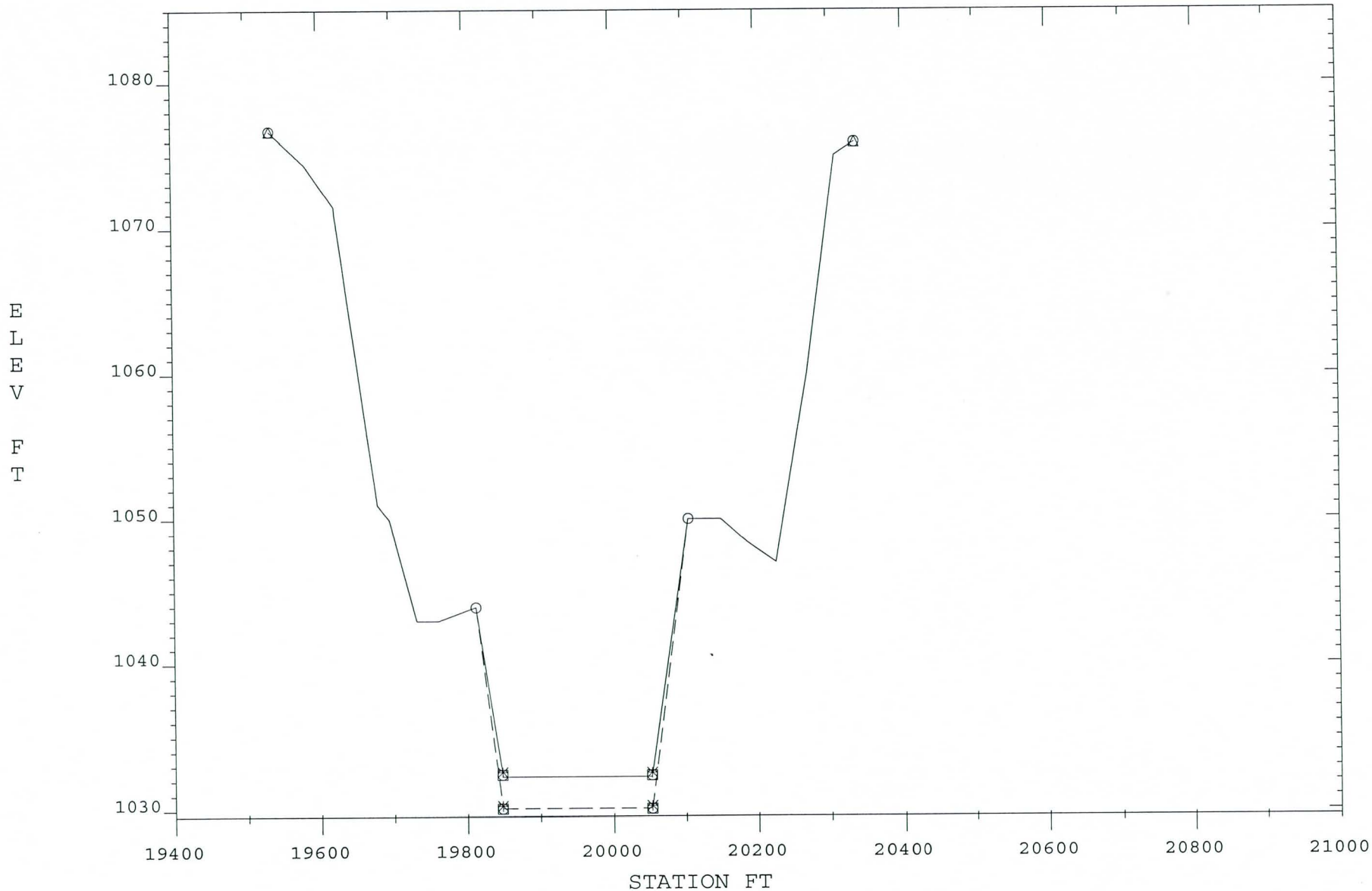
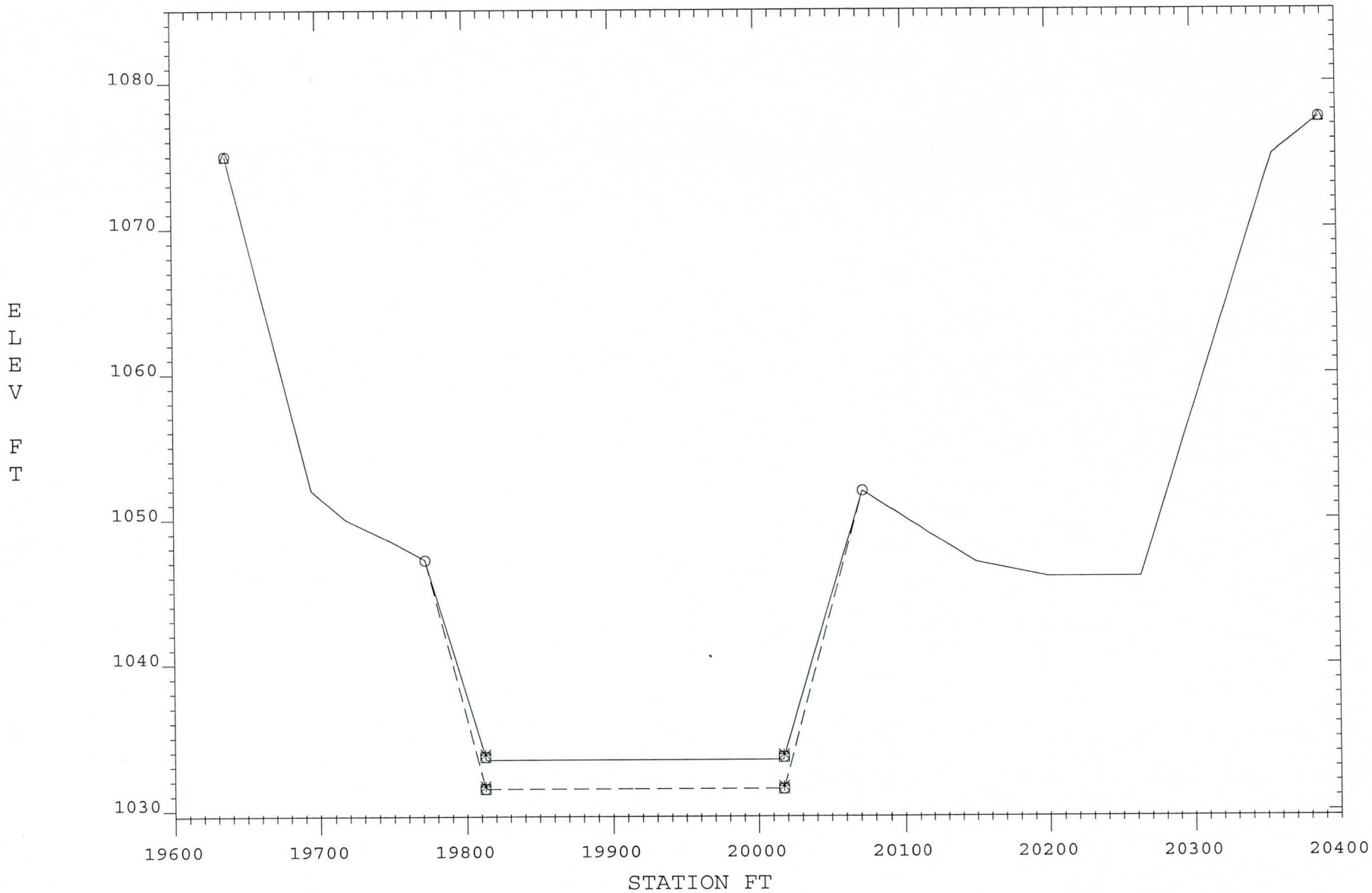
— — — XSEC 1-213.85 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-213.95 DAYS= 0.000
— — — - XSEC 1-213.95 DAYS= 290.021

1 LFC INITIAL GEOME



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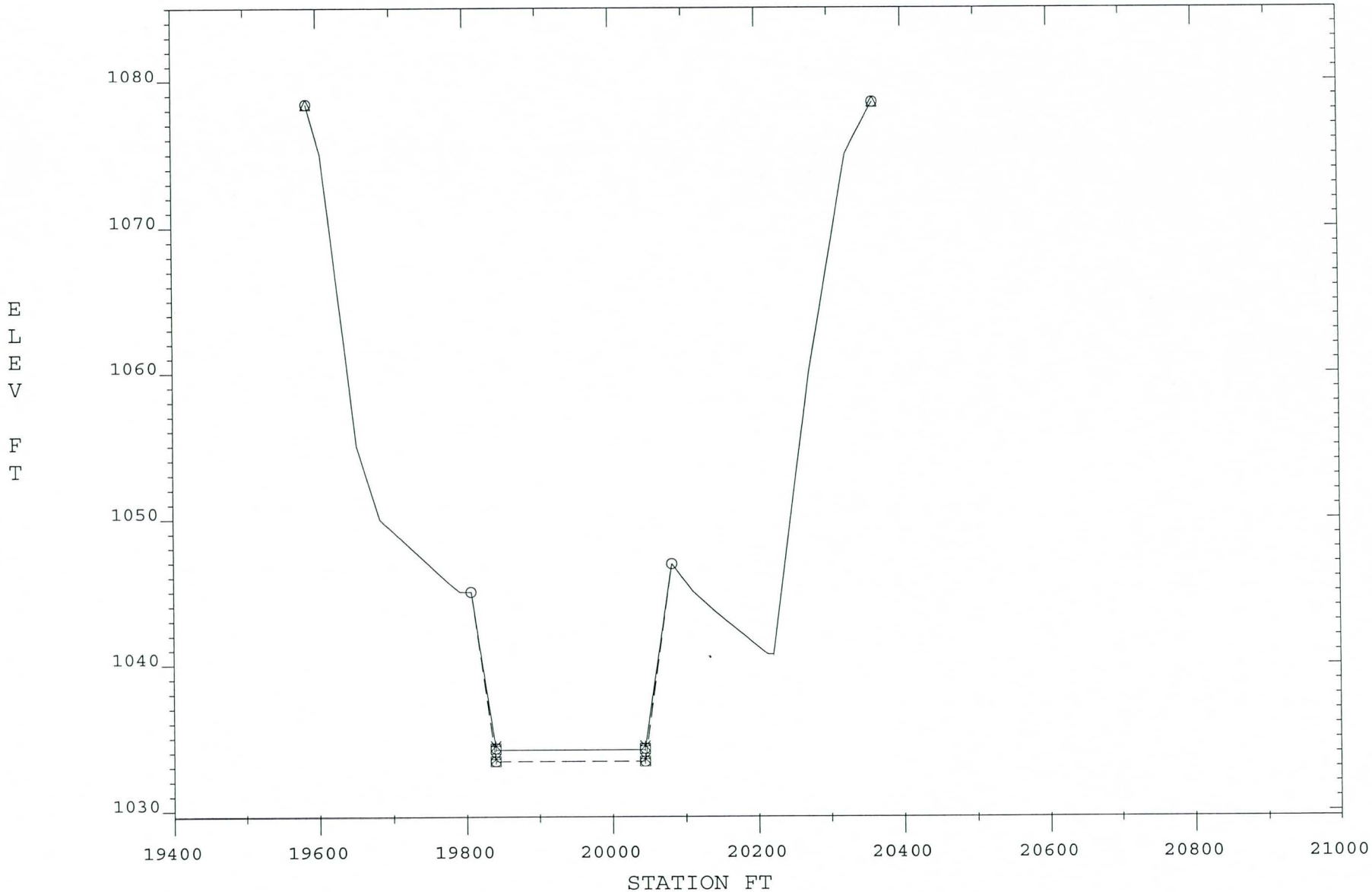
— — — XSEC 1-214.14 DAYS= 290.021

1 LFC INITIAL GEOME



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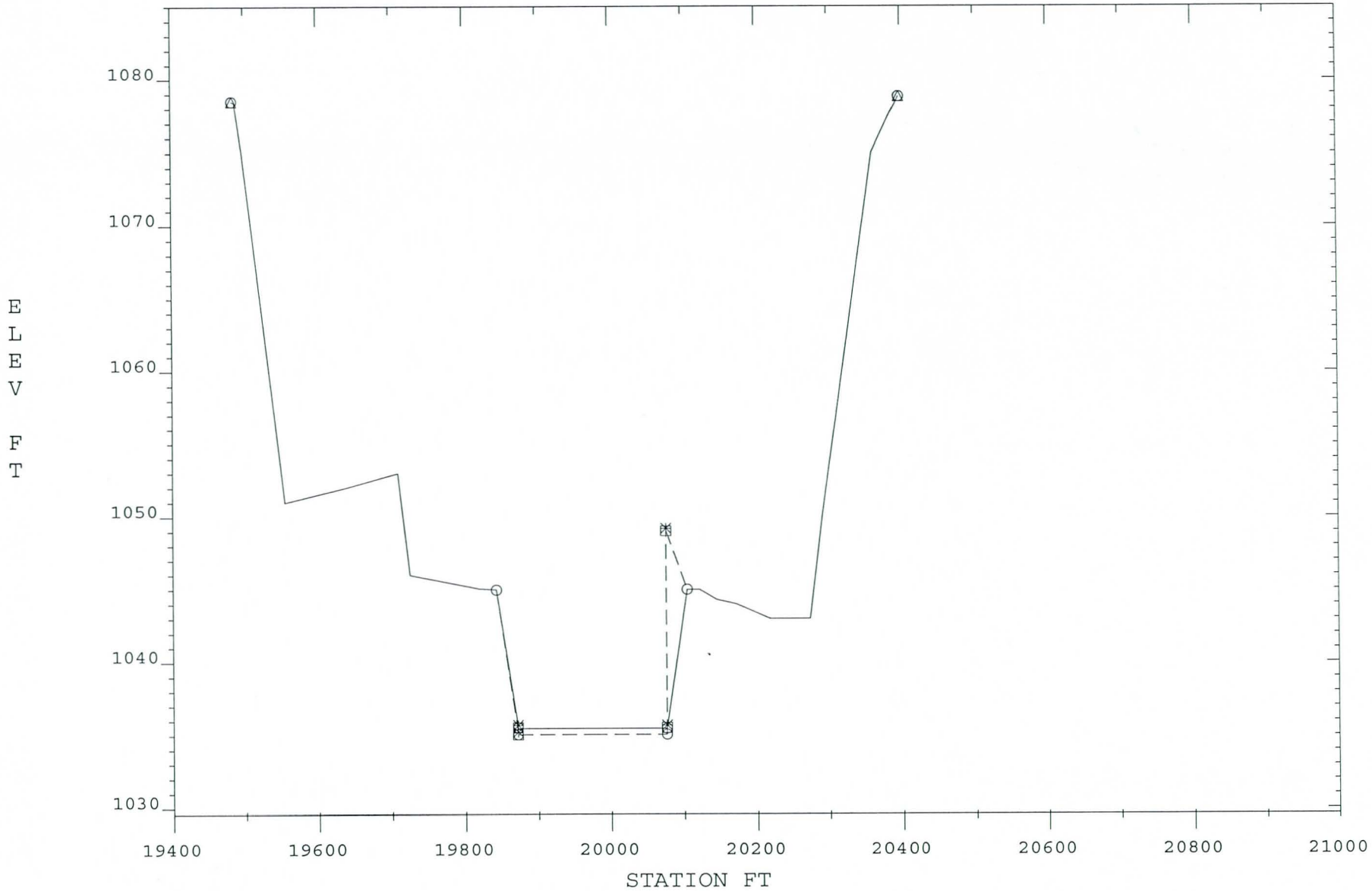

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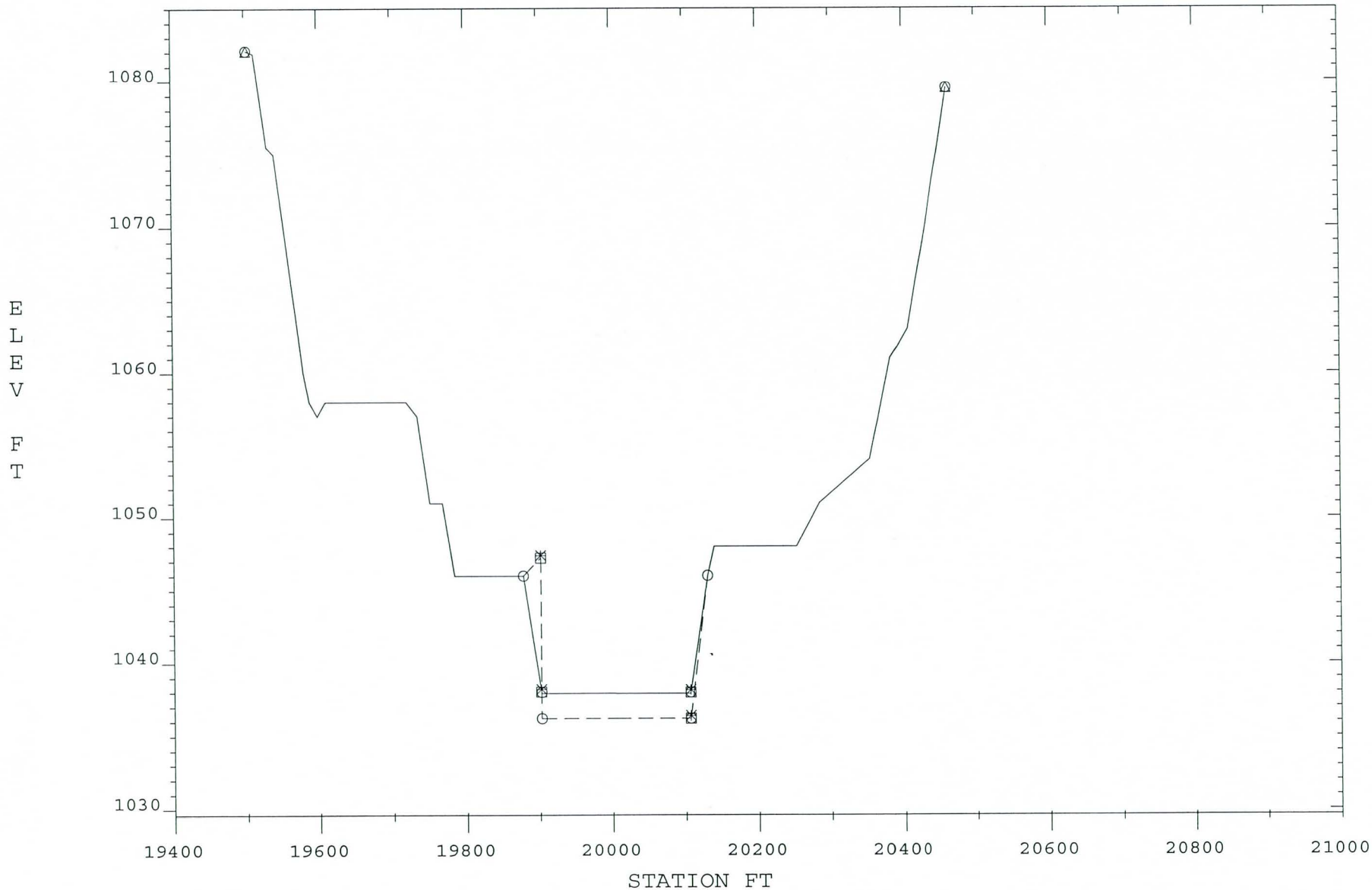
— — — - XSEC 1-214.33 DAYS= 290.021

1 LFC INITIAL GEOME



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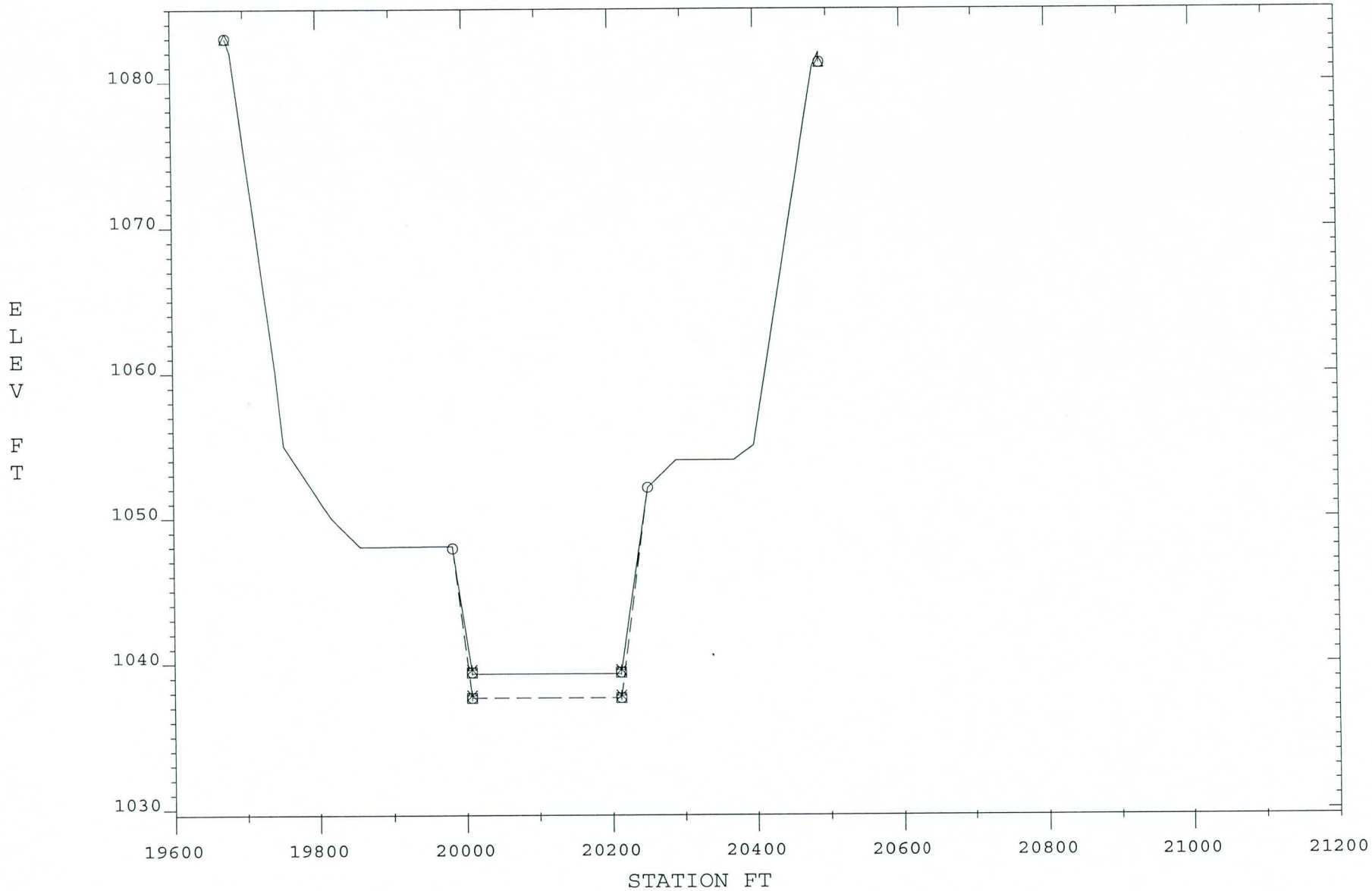
1 LFC INITIAL GEOME



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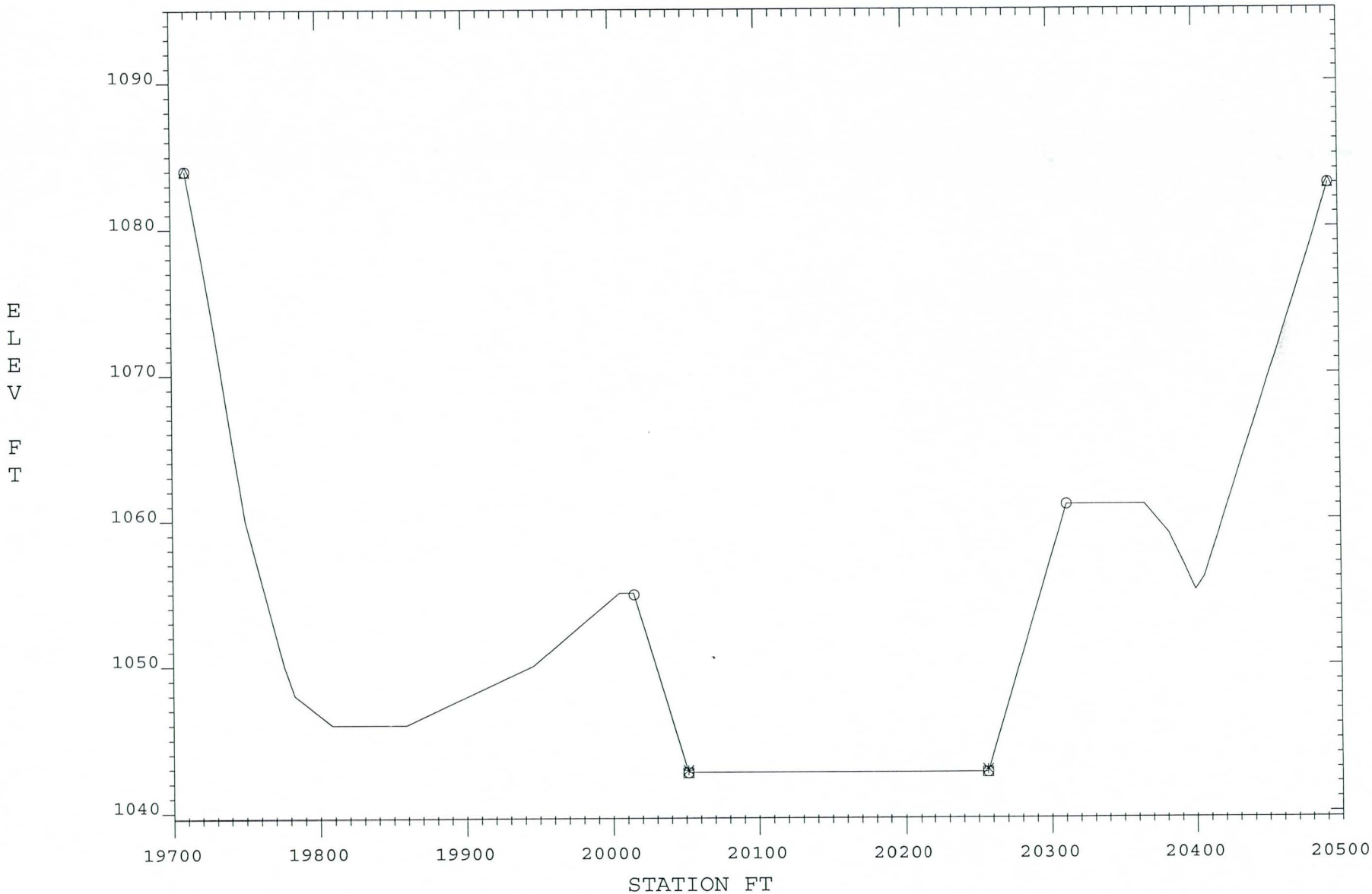
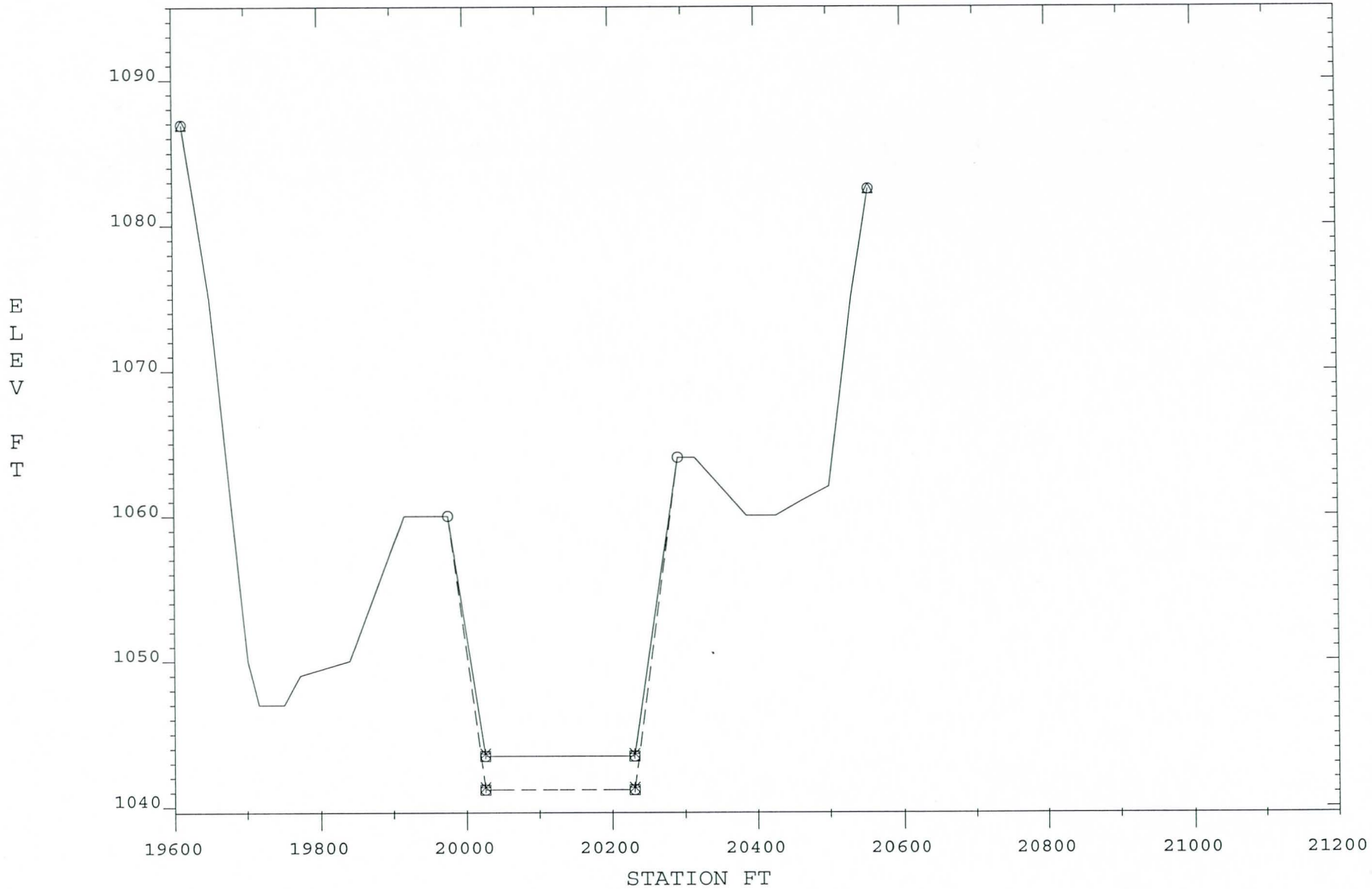
– – – - XSEC 1-214.62 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-214.65 DAYS= 0.000
— — — - XSEC 1-214.65 DAYS= 290.021

1 LFC INITIAL GEOME



——— XSEC 1-214.71 DAYS= 0.000
— — — - XSEC 1-214.71 DAYS= 290.021

APPENDIX 5

Detailed Bridge Scour Results

BRIDGE DATA

The following is a summary of the bridge data used in the scour analysis.

24th Street (Cross-Section 215.815)

City of Phoenix, Engineering Department Division of Design. *24th Street Bridge Structure and Approaches: BR-79159.03*. Signed by James D.A (name illegible), #4751 and Carl H.(name illegible), P.E. Adam, Hamlyn, Anderson Consulting Engineers, Inc. As-Built October, 20, 1982. Cover Page and Sheets 2, 2a, 3-9 of 15 and 16 of 16.

Conveyor (Cross-Section 215.12)

Thomas Hartig & Associates, Inc. Report on Geotechnical Engineering Services Conveyor Bridge Over Salt River Near University Drive & 16th Street Phoenix, AZ. 28 September, 1993. Stamped by Kenneth Ricker, P.E. 27pp. Incl. Appendices.

16th Street (Cross-Section 214.785)

City of Phoenix, Engineering Department Division of Design. *16th Street Salt River Crossing: Index No. BR-789743*. Stamped by Christopher J. Baker, P.E. and others. Sverdrup and Parcel & Associates, Inc. May, 1981. Cover Page and Sheets 35-39, and 82-87 of 100.

7th Street (Cross-Section 213.745)

City of Phoenix, Engineering Department Division of Design. *Seventh Street Bridge Over the Salt River: BR-78040.04, ER-900(14), Phase III (Index No. BR-789164)*. Stamped by Dan R. Lundwell, P.E. RGA Consulting Engineers. June 27, 1982. Cover Page and Sheets 1-9 of 57.

South Central Avenue (Cross-Section 213.255)

City of Phoenix. *South Central Avenue - Phoenix Bridge Over Salt River Maricopa County*. Hoffman, Miller Engineers. Stamped by Ronald R. Davis, P.E. and others. As-Built June 14, 1977. Sheets 43-62 of 62.

7th Avenue (Cross-Section 212.675)

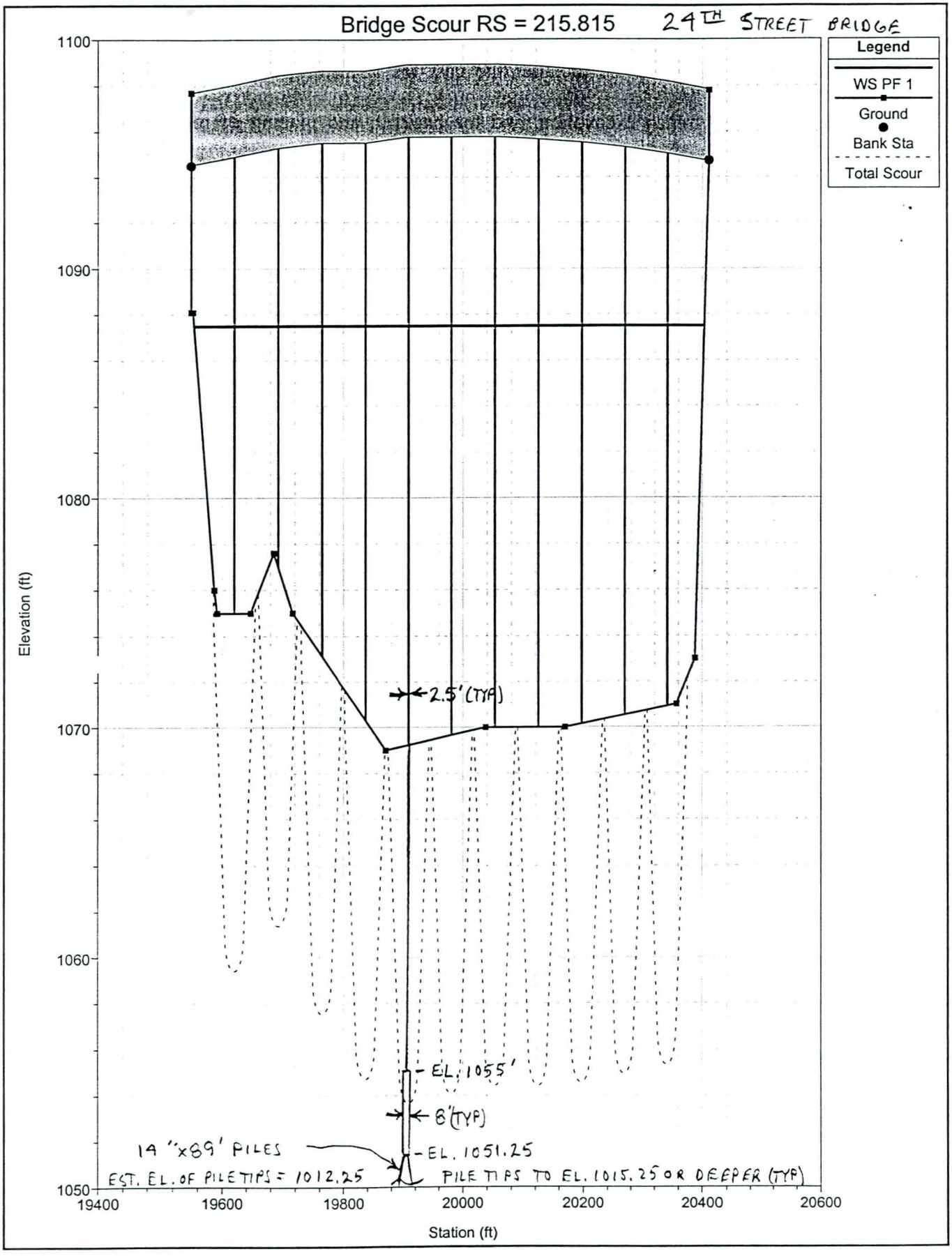
City of Phoenix, Engineering Department Division of Design. *Seventh Avenue Bridge Over the Salt River: BR-845479, BRM-500-8(2)*. Stamped by Daniel A. Sherwood, P.E. Adam, Hamlyn, Anderson Consulting Engineers, Inc. September 1986. Cover Page and Sheets 56-63 of 72.

Conveyor (Cross-Section 212.34)

Peter Kiewit Sons' Co. *Union Rock Conveyor Relocation*. DWG No. 1: Plans for Conveyor: Elevation, Plan, Detail A, Section X-X. DWG No. 2: Column, Cap, Footing: Sections and Details. Omaha Nebraska. Revised September 29, 1979. 2 Sheets.

APPENDIX 5

EXISTING CONDITIONS BRIDGE SCOUR RESULTS


Bridge Scour RS = 215.815
24TH STREET BRIDGE
Legend
WS PF 1
Ground
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1100
1090
1080
1070
1060
1050
19400
19600
19800
20000
20200
20400
20600
2.5' (TYP)
EL. 1055'
8' (TYP)
14"x89' PILES
EL. 1051.25
EST. EL. OF PILE TIPS = 1012.25
PILE TIPS TO EL. 1015.25 OR DEEPER (TYP)

Base Conditions Bridge Scour, River Station 215.815, 24th Street Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

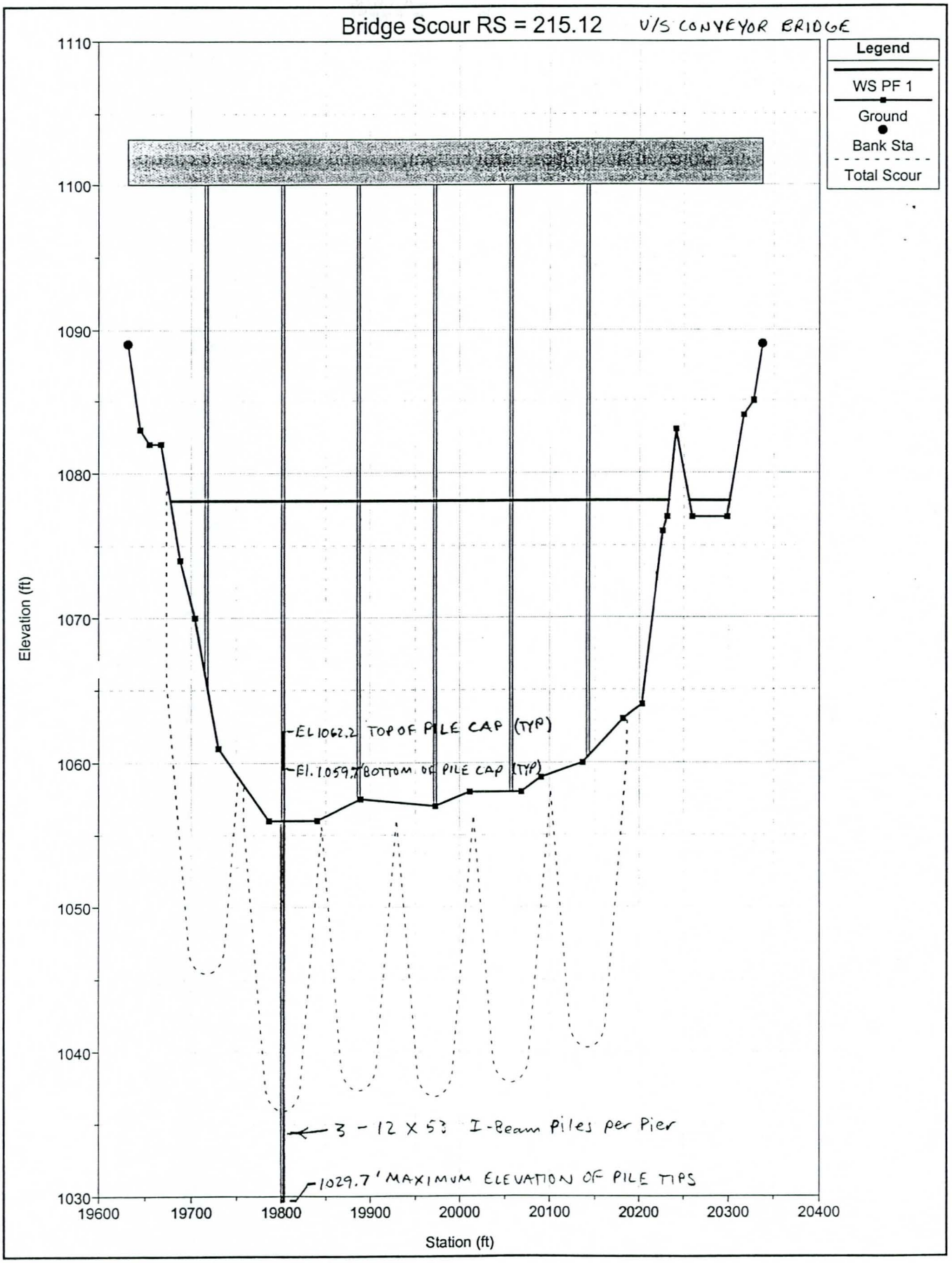
Input Data

Pier Shape:	Round nose
Pier Width (ft):	6.5
Grain Size D50 (ft):	0.0919
Depth Upstream (ft):	18.71
Velocity Upstream (ft/s):	13.46
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	64
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.4921
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**15.6**
Froude #:	0.55
Equation:	CSU equation

Pier Scour Limited to Maximum of Ys = 2.4 * a


Bridge Scour RS = 215.12
U/S CONVEYOR BRIDGE
Legend
WS PF 1
Ground
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1110
1100
1090
1080
1070
1060
1050
1040
1030
19600
19700
19800
19900
20000
20100
20200
20300
20400
EL 1062.2 TOP OF PILE CAP (TYP)
El. 1059.7 BOTTOM OF PILE CAP (TYP)
3 - 12 X 53 I-Beam Piles per Pier
1029.7' MAXIMUM ELEVATION OF PILE TIPS

Base Conditions Pier Scour, River Station 215.12, Conveyor Bridge

Notes: Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines
Results reflect the worst case scenario for exposed footings.
The pile cap is the same width as the piers.
Basis is geotech. report covering "two piers and three spans"

Hydraulic Design Data

Pier Scour

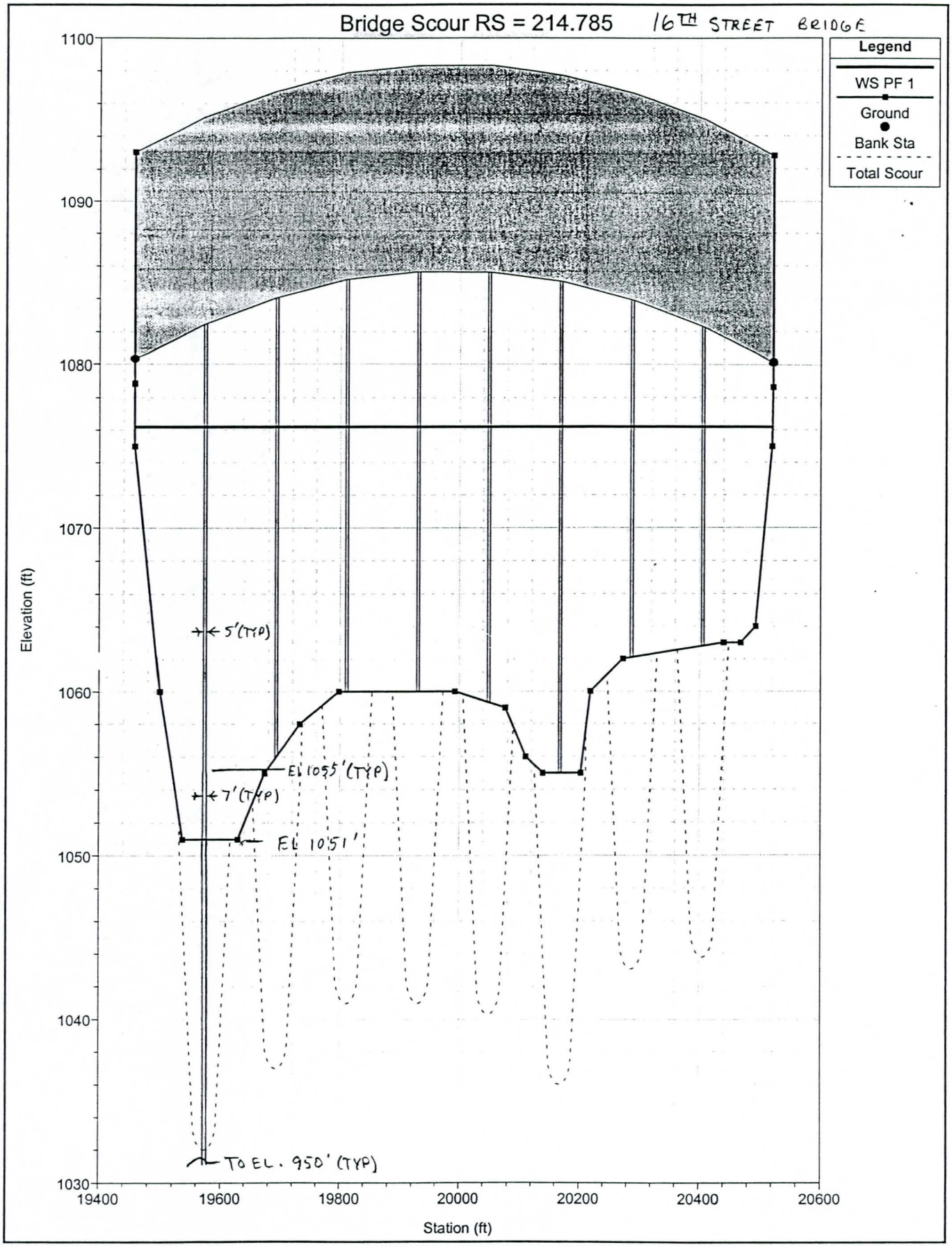
All piers have the same scour depth

Input Data

Pier Shape:	Circulare cylinder
Pier Width (ft):	7.5
Grain Size D50 (ft):	0.0328
Depth Upstream (ft):	22.92
Velocity Upstream (ft/s):	17.35
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	8
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2297
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**20.12**
Froude #:	0.64
Equation:	CSU equation


Bridge Scour RS = 214.785
16TH STREET BRIDGE
Legend
WS PF 1
Ground
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1100
1090
1080
1070
1060
1050
1040
1030
19400
19600
19800
20000
20200
20400
20600
5'(TYP)
EL 1055'(TYP)
7'(TYP)
EL 1051'
TO EL. 950' (TYP)

Base Conditions Pier Scour, River Station 214.785, 16th Street Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Group of Cylinders
Pier Width (ft):	9
Grain Size D50 (ft):	0.0328
Depth Upstream (ft):	25.1
Velocity Upstream (ft/s):	11.24
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	64
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2297
K4 Armouring Coef:	1

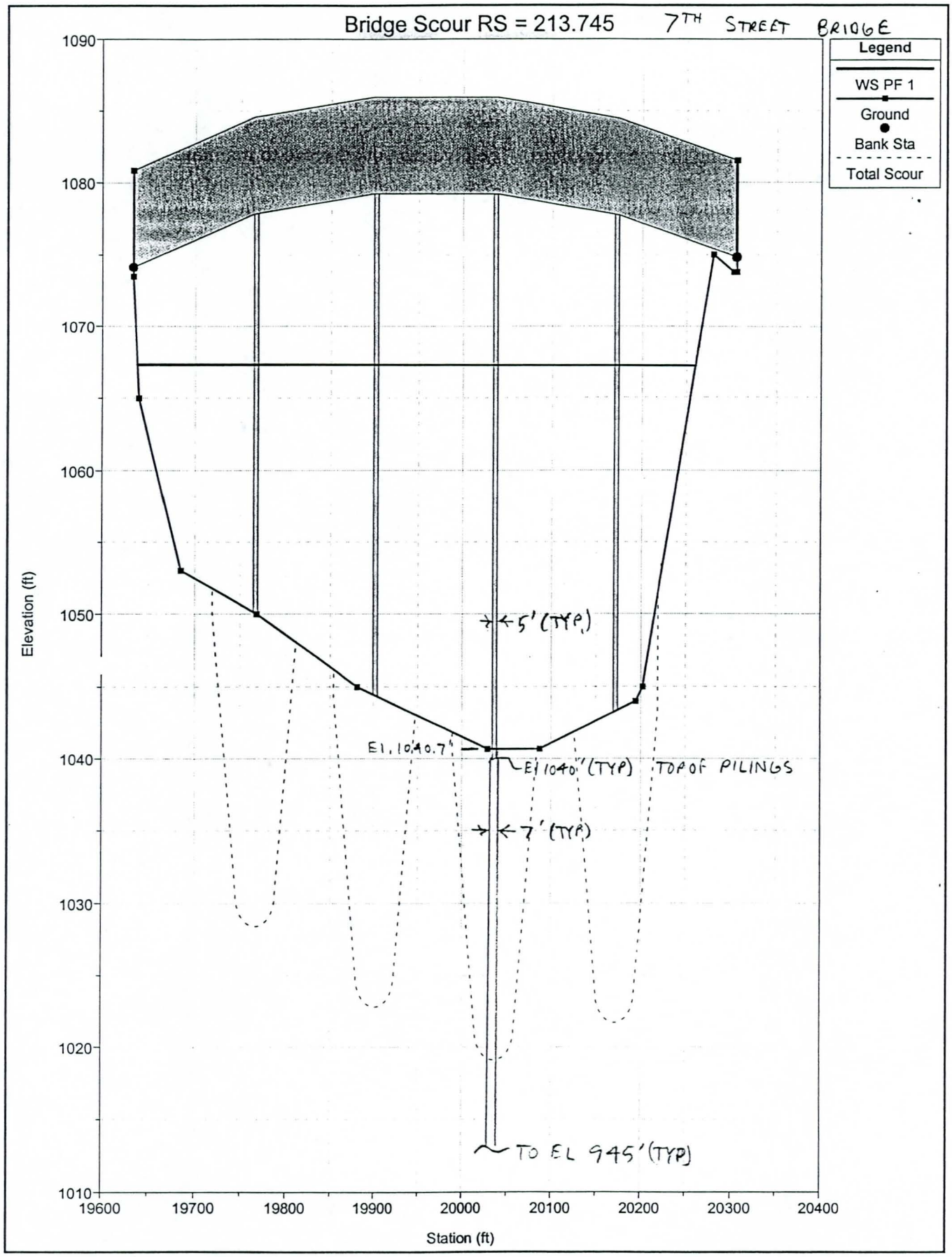
Results

Scour Depth Ys (ft):	**19.03**
Froude #:	0.4
Equation:	CSU equation

Alternative case analysis:

Yf	Y1	Yf/Y >>	Vf/V1	V1	Vf
5.45	25.1	0.2171	0.7	11.24	7.868

Notes: Exposed pile cap is 7' wide, which should not be bulked. The near bottom velocity on the unbulked pier will clearly produce less scour, so it is not computed herein.


Bridge Scour RS = 213.745
7TH STREET BRIDGE
Legend
WS PF 1
Ground
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1090
1080
1070
1060
1050
1040
1030
1020
1010
19600
19700
19800
19900
20000
20100
20200
20300
20400
5' (TYP)
EL. 1040.7'
EL 1040' (TYP) TOP OF PILINGS
7' (TYP)
TO EL 945' (TYP)

Base Conditions Pier Scour, River Station 213.745, 7th Street Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data
Pier Scour
All piers have the same scour depth

Input Data

Pier Shape:	Group of Cylinders
Pier Width (ft):	9
Grain Size D50 (ft):	0.0787
Depth Upstream (ft):	26.95
Velocity Upstream (ft/s):	14.78
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	115.36
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.5741
K4 Armouring Coef:	1

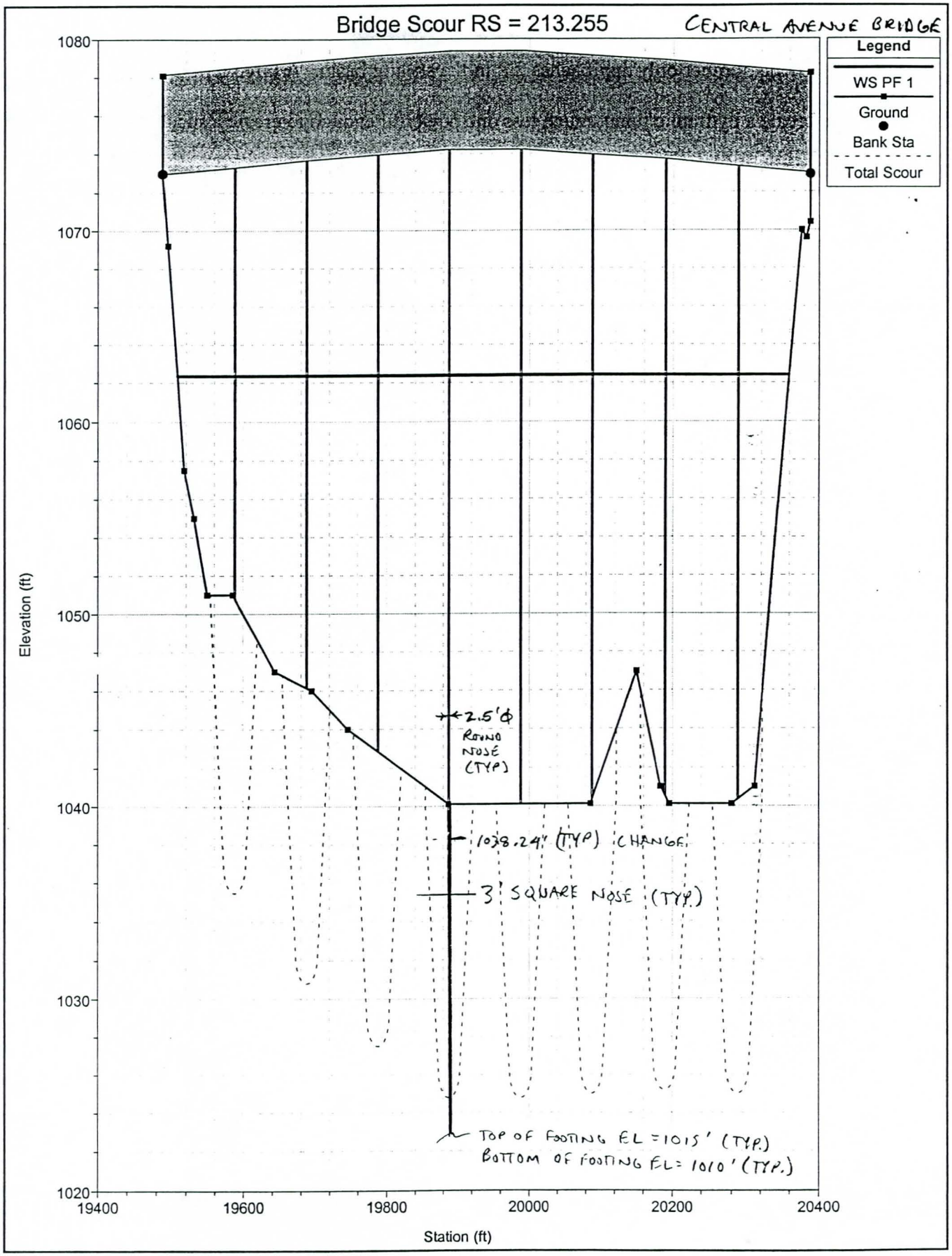
Results

Scour Depth Ys (ft):	**21.61**
Froude #:	0.5
Equation:	CSU equation

Alternative case analysis:

Yf	Y1	Yf/Y >>	Vf/V1	V1	Vf
0.42	26.95	0.0156	0.2	14.78	2.956

Notes: Exposed pile cap is 7' wide, which should not be bulked. The near bottom velocity on the unbulked pier will clearly produce less scour, so it is not computed herein.


Bridge Scour RS = 213.255
CENTRAL AVENUE BRIDGE
Legend
WS PF 1
Ground
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1080
1070
1060
1050
1040
1030
1020
19400
19600
19800
20000
20200
20400
2.5'ϕ ROUND NOSE (TYP)
1038.24' (TYP) CHANGE
3' SQUARE NOSE (TYP)
TOP OF FOOTING EL = 1015' (TYP.)
BOTTOM OF FOOTING EL = 1010' (TYP.)

Base Conditions Pier Scour, River Station 213.255, Central Avenue Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

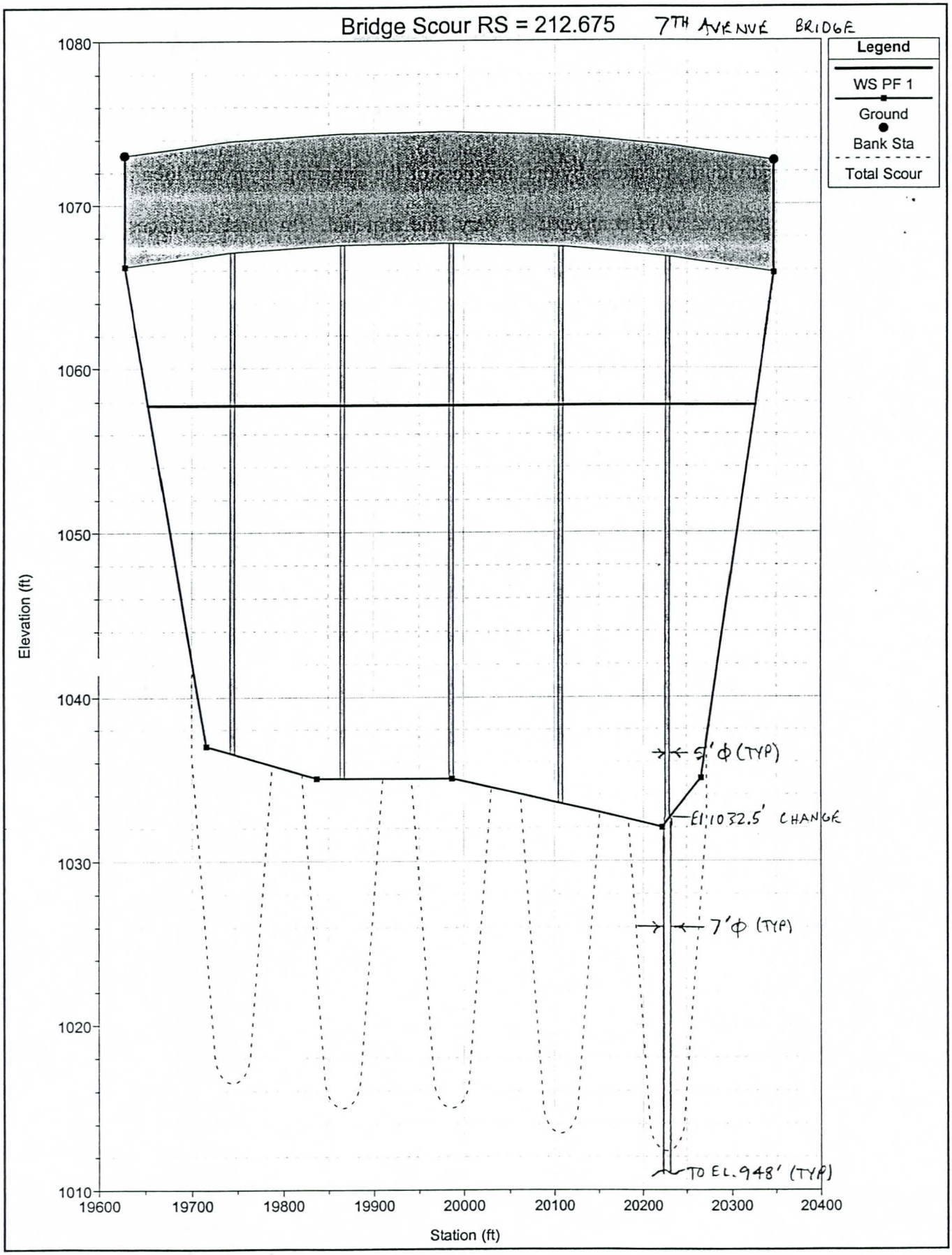
All piers have the same scour depth

Input Data

Pier Shape:	Round nose
Pier Width (ft):	6.5
Grain Size D50 (ft):	0.0787
Depth Upstream (ft):	22.48
Velocity Upstream (ft/s):	11.54
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	151.22
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.5741
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**15.34**
Froude #:	0.43
Equation:	CSU equation


Bridge Scour RS = 212.675
7TH AVENUE BRIDGE
Legend
WS PF 1
Ground
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1080
1070
1060
1050
1040
1030
1020
1010
19600
19700
19800
19900
20000
20100
20200
20300
20400
5' ϕ (TYP)
EL 1032.5' CHANGE
7' ϕ (TYP)
TO EL. 948' (TYP)

Base Conditions Pier Scour, River Station 212.675, 7th Avenue Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Group of Cylinders
Pier Width (ft):	9
Grain Size D50 (ft):	0.0197
Depth Upstream (ft):	25.72
Velocity Upstream (ft/s):	12.59
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	153.01
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2461
K4 Armouring Coef:	1

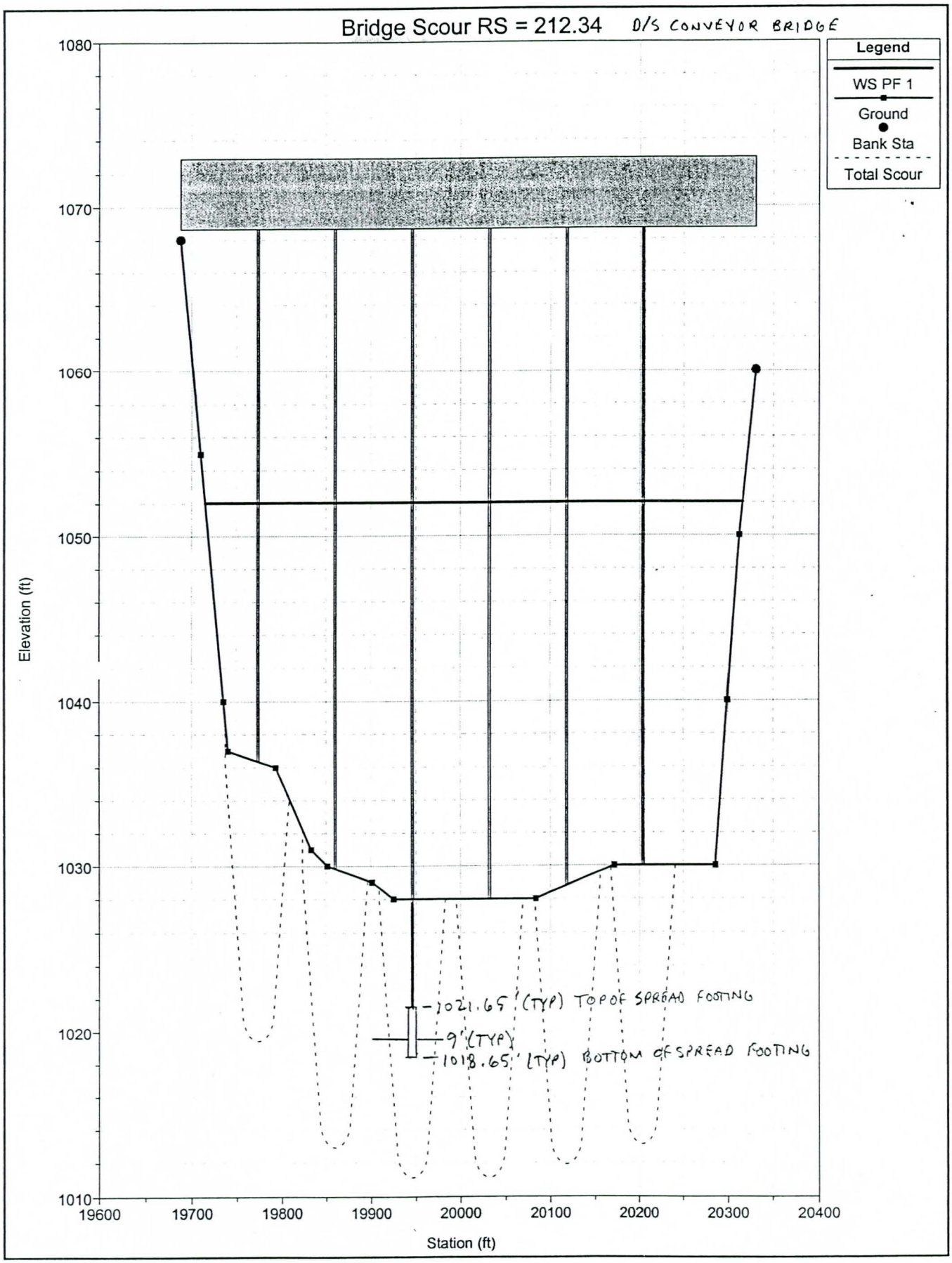
Results

Scour Depth Ys (ft):	**20.04**
Froude #:	0.44
Equation:	CSU equation

Alternative case analysis:

Yf	Y1	Yf/Y >>	Vf/V1	V1	Vf
0.96	25.72	0.0373	0.2	12.59	2.518

Notes: Exposed pile cap is 7' wide, which should not be bulked. The near bottom velocity on the unbulked pier will clearly produce less scour, so it is not computed herein.


Bridge Scour RS = 212.34
D/S CONVEYOR BRIDGE
Legend
WS PF 1
Ground
Bank Sta
Total Scour
1080
1070
1060
1050
1040
1030
1020
1010
Elevation (ft)
19600
19700
19800
19900
20000
20100
20200
20300
20400
Station (ft)
1021.65' (TYP) TOP OF SPREAD FOOTING
9' (TYP)
1018.65' (TYP) BOTTOM OF SPREAD FOOTING

Base Conditions Pier Scour, River Station 212.34, Conveyor Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

Input Data

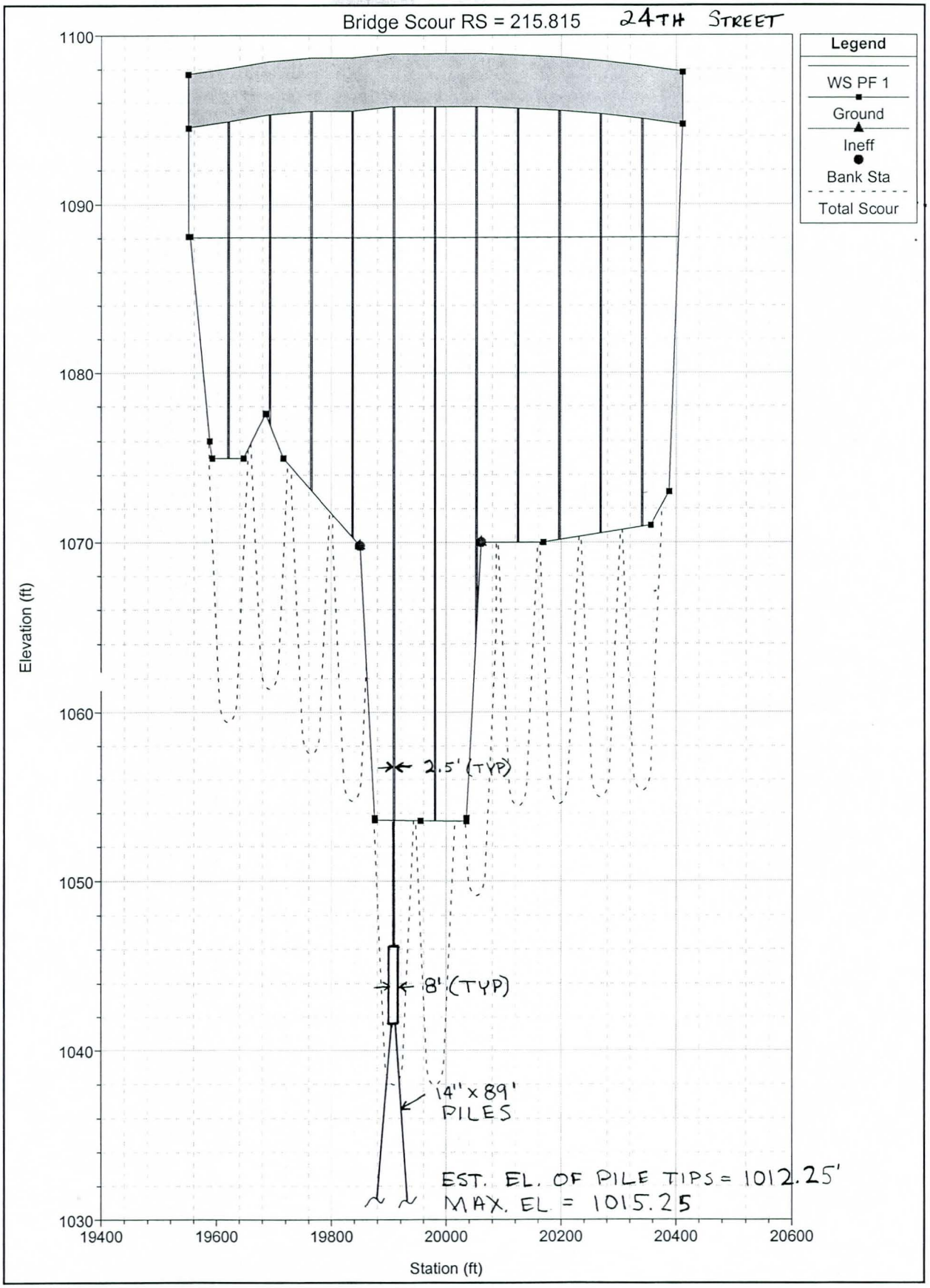
Pier Shape:	Circulare cylinder
Pier Width (ft):	6.5
Grain Size D50 (ft):	0.01969
Depth Upstream (ft):	24.24
Velocity Upstream (ft/s):	14.12
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	8
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2461
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**16.9**
Froude #:	0.51
Equation:	CSU equation

APPENDIX 5

LOW FLOW CHANNEL BRIDGE SCOUR RESULTS


Bridge Scour RS = 215.815
24TH STREET
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1100
1090
1080
1070
1060
1050
1040
1030
19400
19600
19800
20000
20200
20400
20600
2.5' (TYP)
8' (TYP)
14" x 89' PILES
EST. EL. OF PILE TIPS = 1012.25'
MAX. EL = 1015.25

Alternative 1 Bridge Scour, River Station 215.815, 24th Street Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

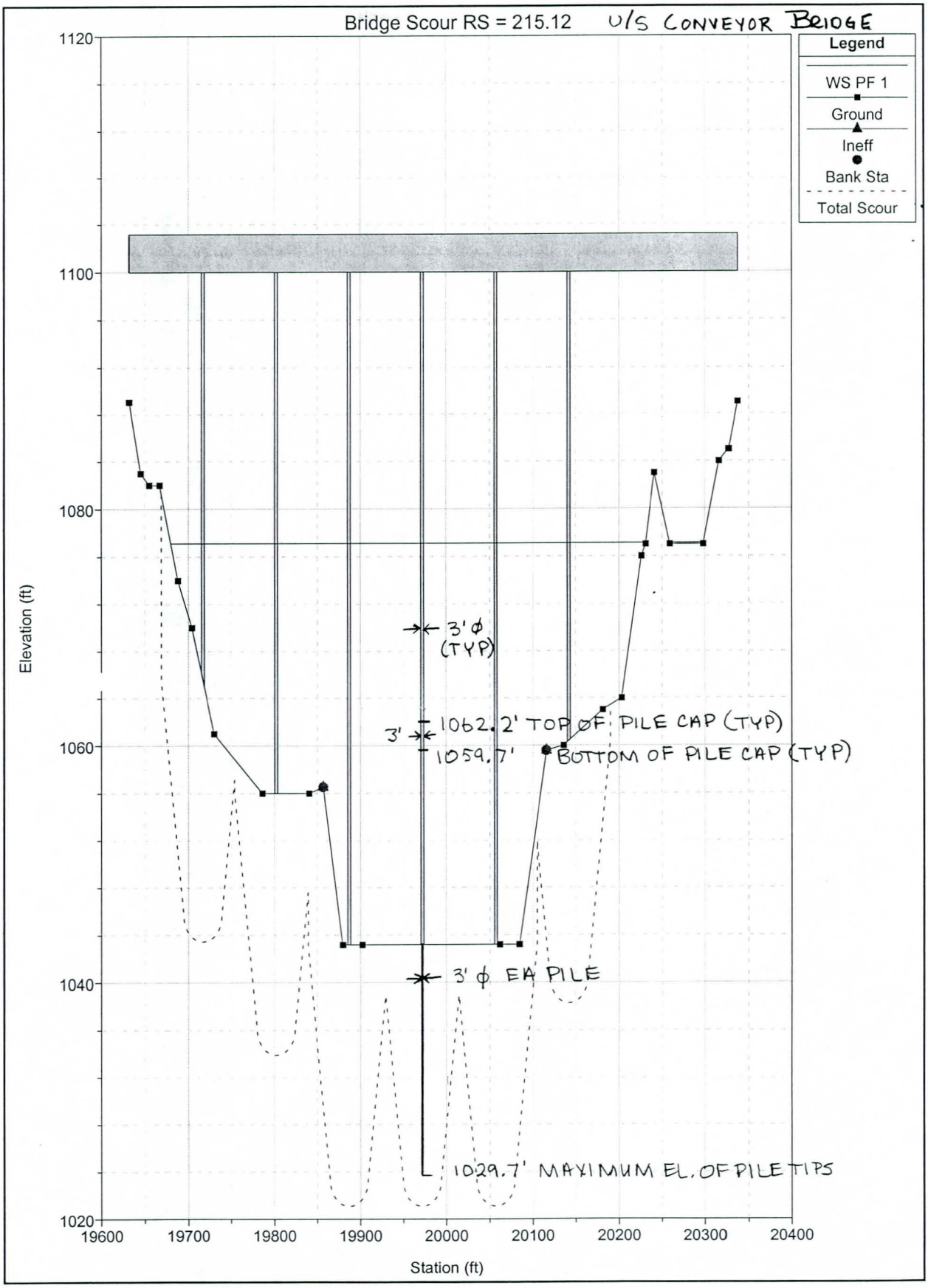
Input Data

Pier Shape:	Round nose
Pier Width (ft):	6.5
Grain Size D50 (ft):	0.0919
Depth Upstream (ft):	34.79
Velocity Upstream (ft/s):	19.12
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	64
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.4921
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**15.6**
Froude #:	0.57
Equation:	CSU equation

Pier Scour Limited to Maximum of Ys = 2.4 * a


Bridge Scour RS = 215.12
U/S CONVEYOR BRIDGE
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1120
1100
1080
1060
1040
1020
19600
19700
19800
19900
20000
20100
20200
20300
20400
3' ϕ (TYP)
3'
1062.2' TOP OF PILE CAP (TYP)
1059.7' BOTTOM OF PILE CAP (TYP)
3' ϕ EA PILE
1029.7' MAXIMUM EL. OF PILE TIPS

Alternative 1 Bridge Scour, River Station 215.12, Conveyor Bridge

Notes: Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines
Results reflect the worst case scenario for exposed footings.
The pile cap is the same width as the piers.
Basis is geotech. report covering "two piers and three spans"

Hydraulic Design Data

Pier Scour

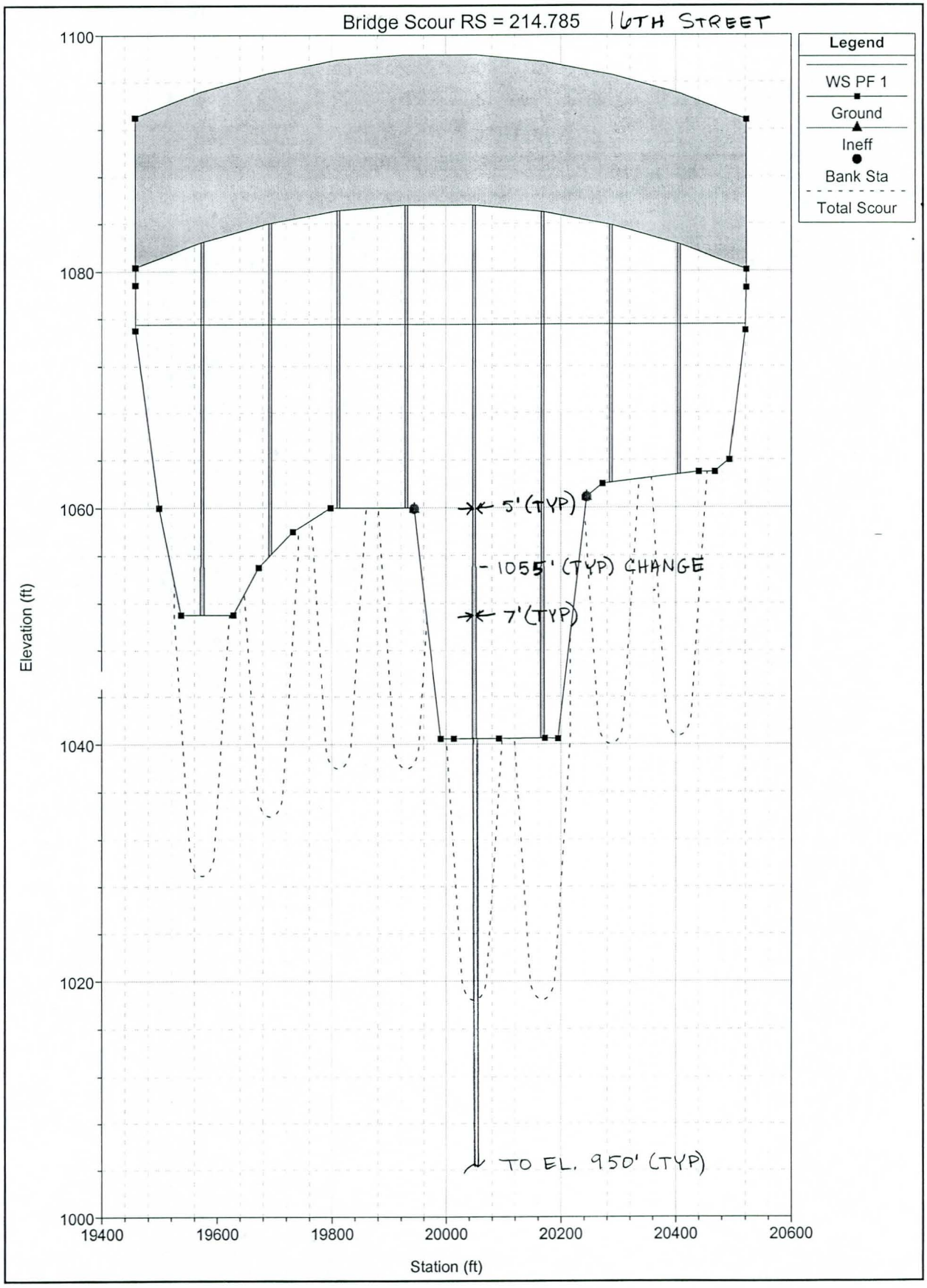
All piers have the same scour depth

Input Data

Pier Shape:	Circulare cylinder
Pier Width (ft):	7.5
Grain Size D50 (ft):	0.0328
Depth Upstream (ft):	34
Velocity Upstream (ft/s):	19.09
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	8
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2297
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**22.11**
Froude #:	0.58
Equation:	CSU equation


Bridge Scour RS = 214.785
16TH STREET
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
1100
1080
1060
1040
1020
1000
Elevation (ft)
19400
19600
19800
20000
20200
20400
20600
Station (ft)
5' (TYP)
1055' (TYP) CHANGE
7' (TYP)
TO EL. 950' (TYP)

Alternative 1 Bridge Scour, River Station 214.785, 16th Street Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Group of Cylinders
Pier Width (ft):	9
Grain Size D50 (ft):	0.0328
Depth Upstream (ft):	35.18
Velocity Upstream (ft/s):	14.3
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	64
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2297
K4 Armouring Coef:	1

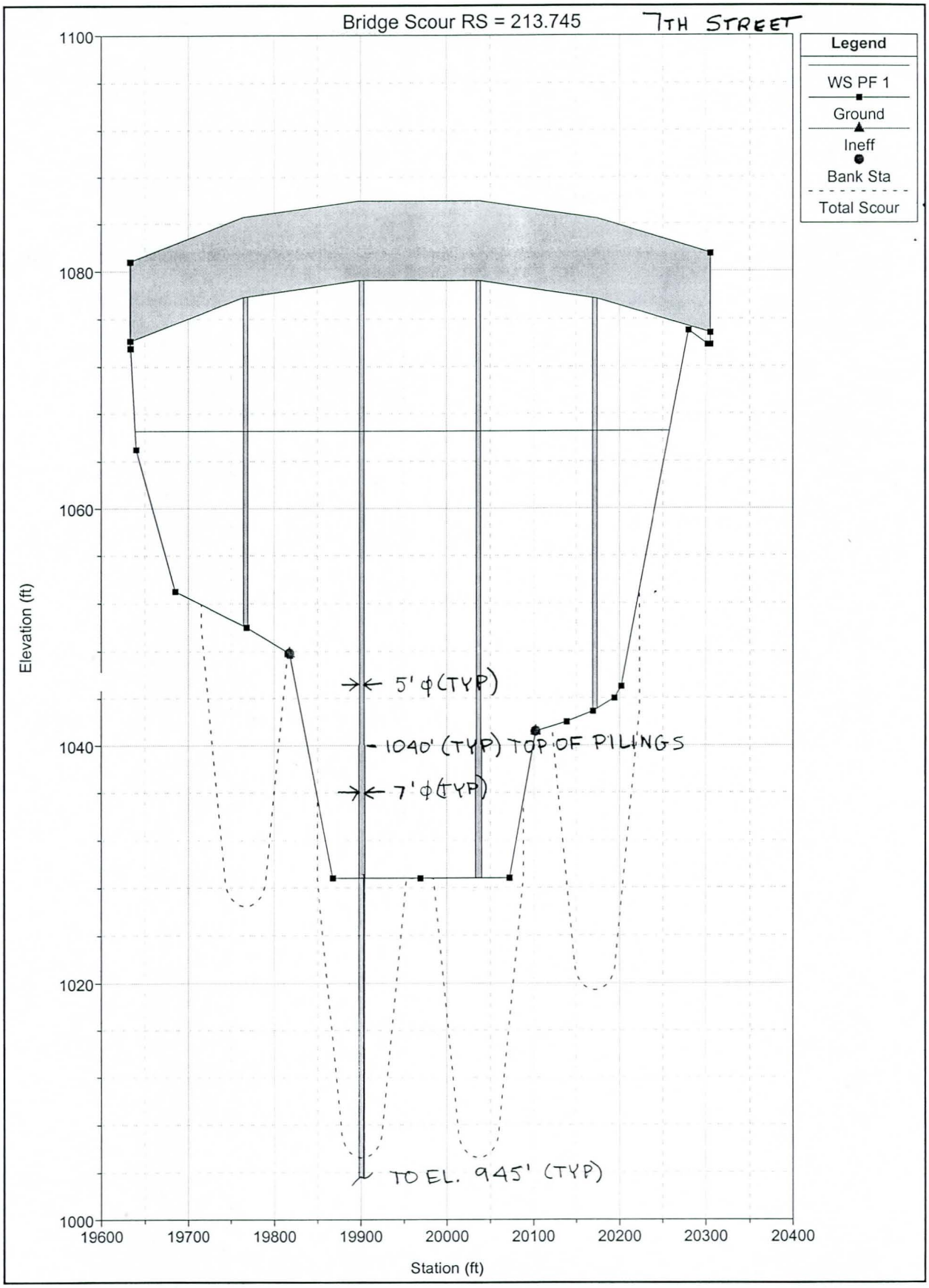
Results

Scour Depth Ys (ft):	**22.08**
Froude #:	0.42
Equation:	CSU equation

Alternative case analysis:

Yf	Y1	Yf/Y >>	Vf/V1	V1	Vf
10.52	35.18	0.2990	0.81	14.3	11.58

Notes: Exposed pile cap is 7' wide, which should not be bulked. The near bottom velocity on the unbulked pier will produce less scour, so it is not computed herein.


Bridge Scour RS = 213.745
7TH STREET
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1100
1080
1060
1040
1020
1000
19600
19700
19800
19900
20000
20100
20200
20300
20400
5' ϕ (TYP)
1040' (TYP) TOP OF PILINGS
7' ϕ (TYP)
TO EL. 945' (TYP)

Alternative 1 Bridge Scour, River Station 213.745, 7th Street Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Group of Cylinders
Pier Width (ft):	9
Grain Size D50 (ft):	0.0787
Depth Upstream (ft):	37.93
Velocity Upstream (ft/s):	16.26
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	115.36
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.5741
K4 Armouring Coef:	1

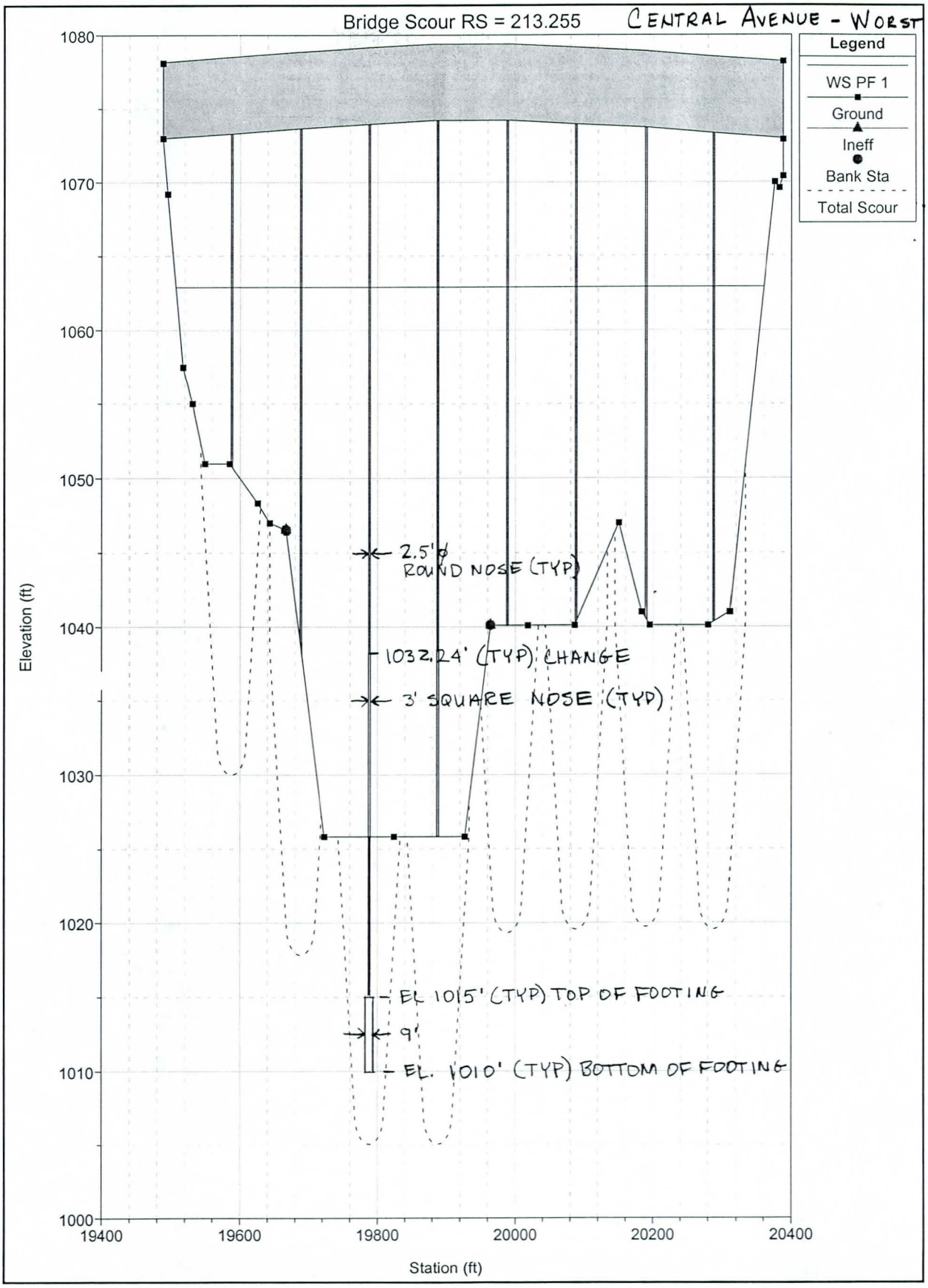
Results

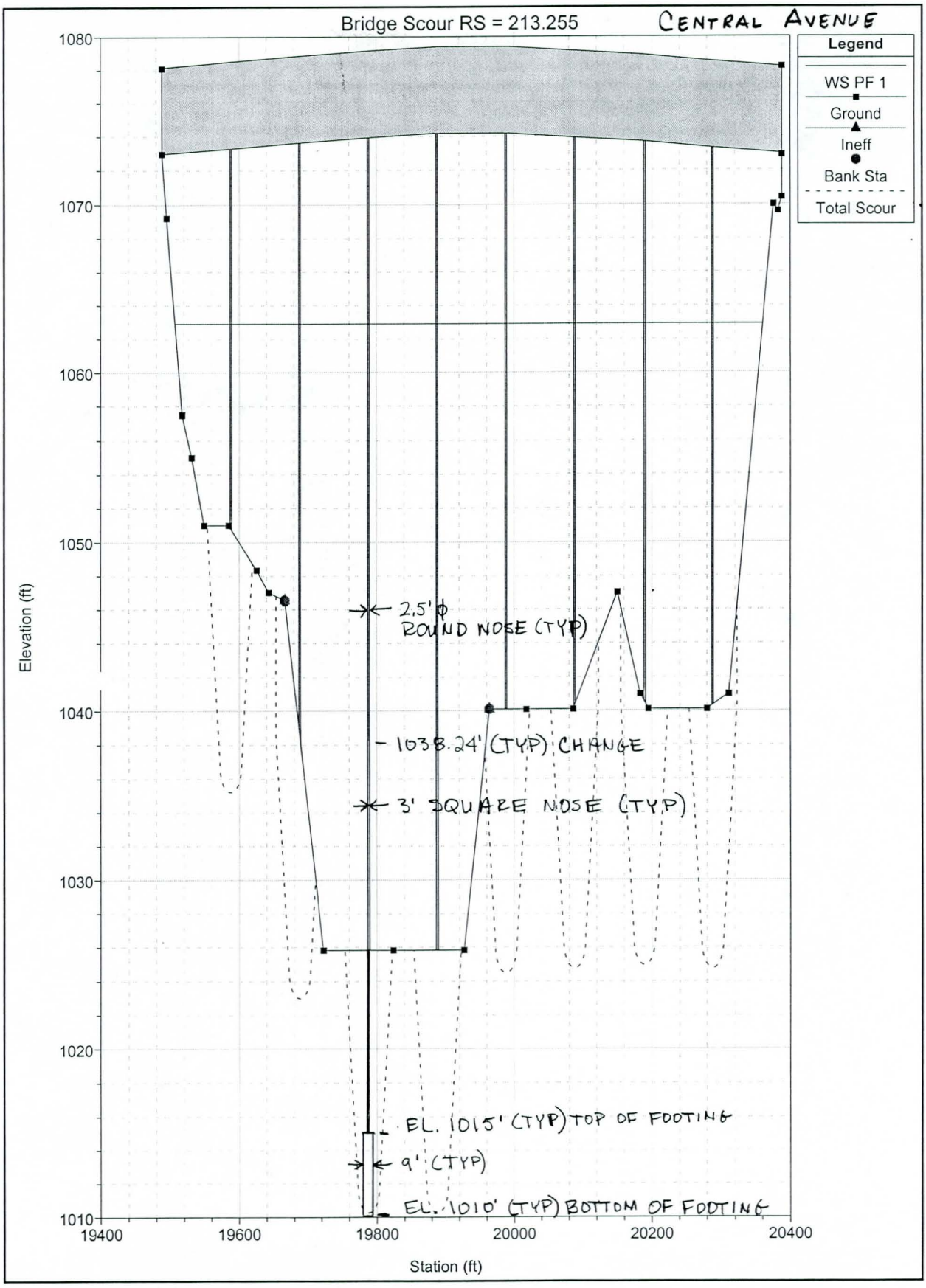
Scour Depth Ys (ft):	**23.58**
Froude #:	0.47
Equation:	CSU equation

Alternative case analysis:

Yf	Y1	Yf/Y >>	Vf/V1	V1	Vf
8.93	37.93	0.2354	0.74	16.26	12.03

Notes: Exposed pile cap is 7' wide, which should not be bulked. The near bottom velocity on the unbulked pier will clearly less scour, so it is not computed herein.


Bridge Scour RS = 213.255
CENTRAL AVENUE - WORST CASE
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1080
1070
1060
1050
1040
1030
1020
1010
1000
19400
19600
19800
20000
20200
20400
2.5' ϕ ROUND NOSE (TYP)
1032.24' (TYP) CHANGE
3' SQUARE NOSE (TYP)
EL 1015' (TYP) TOP OF FOOTING
9'
EL. 1010' (TYP) BOTTOM OF FOOTING


Bridge Scour RS = 213.255
CENTRAL AVENUE
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1080
1070
1060
1050
1040
1030
1020
1010
19400
19600
19800
20000
20200
20400
2.5' ϕ ROUND NOSE (TYP)
1038.24' (TYP) CHANGE
3' SQUARE NOSE (TYP)
EL. 1015' (TYP) TOP OF FOOTING
9' (TYP)
EL. 1010' (TYP) BOTTOM OF FOOTING

Alternative 1 Bridge Scour, River Station 213.255, Central Avenue Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data
Pier Scour
All piers have the same scour depth

Input Data

Pier Shape:	Round nose
Pier Width (ft):	6.5
Grain Size D50 (ft):	0.0787
Depth Upstream (ft):	37.24
Velocity Upstream (ft/s):	14.33
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	151.22
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.5741
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**15.6**
Froude #:	0.41
Equation:	CSU equation

Pier Scour Limited to Maximum of Ys = 2.4 * a

Alternative case analysis:

Yf	Y1	Yf/Y >>	Vf/V1	V1	Vf
10.4	37.24	0.2793	0.82	14.33	11.75

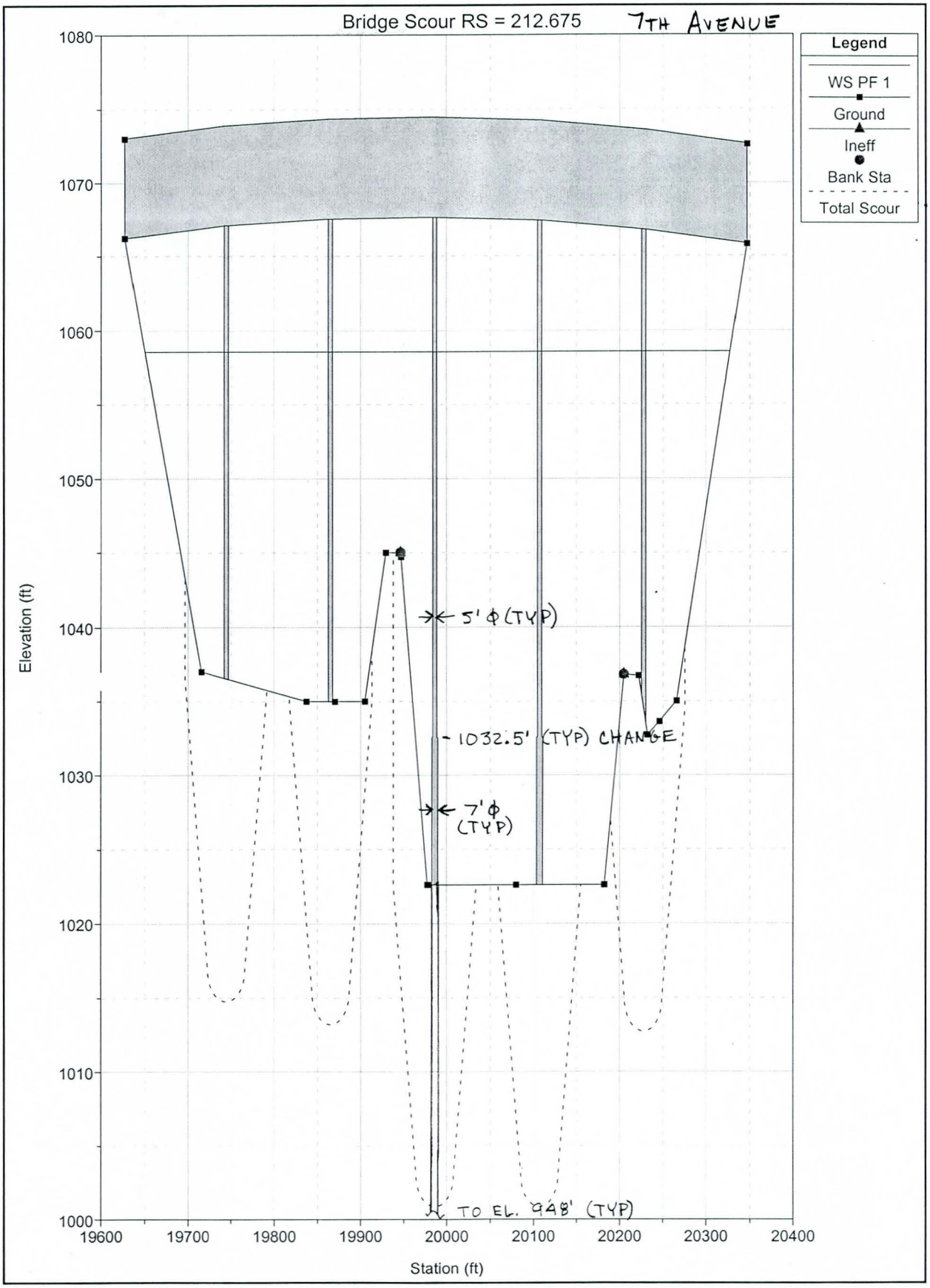
Hydraulic Design Data
Pier Scour
All piers have the same scour depth

Input Data

Pier Shape:	Square nose
Pier Width (ft):	7
Grain Size D50 (ft):	0.0787
Depth Upstream (ft):	37.24
Velocity Upstream (ft/s):	14.33
K1 Nose Shape:	1.1
Pier Angle:	0
Pier Length (ft):	151.22
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.5741
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**20.81**
Froude #:	0.41
Equation:	CSU equation


Bridge Scour RS = 212.675
7TH AVENUE
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1080
1070
1060
1050
1040
1030
1020
1010
1000
19600
19700
19800
19900
20000
20100
20200
20300
20400
5' ϕ (TYP)
1032.5' (TYP) CHANGE
7' ϕ (TYP)
TO EL. 948' (TYP)

Alternative 1 Bridge Scour, River Station 212.675, 7th Avenue Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Group of Cylinders
Pier Width (ft):	9
Grain Size D50 (ft):	0.0197
Depth Upstream (ft):	36.16
Velocity Upstream (ft/s):	13.71
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	153.01
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2461
K4 Armouring Coef:	1

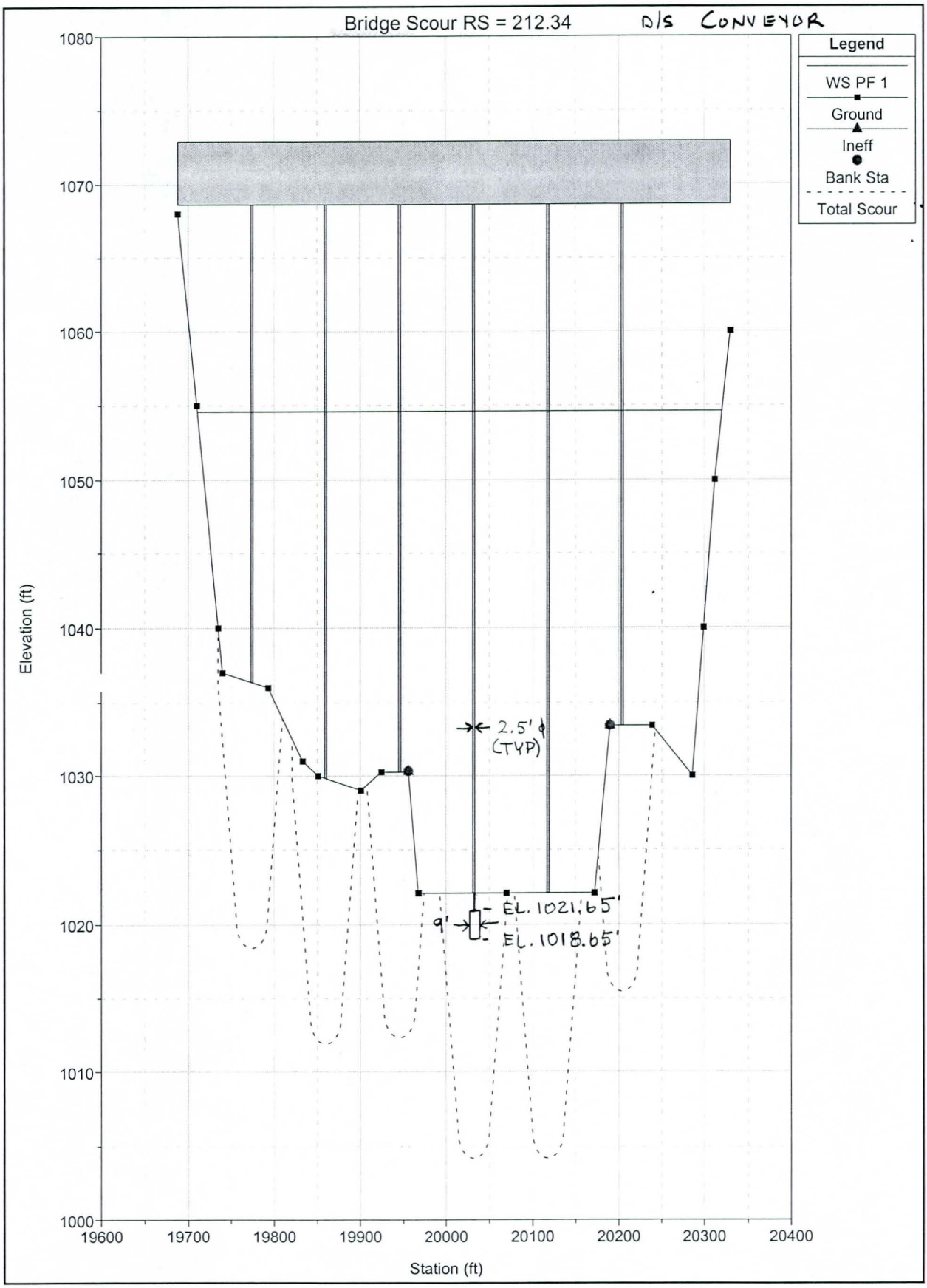
Results

Scour Depth Ys (ft):	**21.77**
Froude #:	0.4
Equation:	CSU equation

Alternative case analysis:

Yf	Y1	Yf/Y >>	Vf/V1	V1	Vf
7.89	36.16	0.2182	0.74	13.71	10.1454

Notes: Exposed pile cap is 7' wide, which should not be bulked. The near bottom velocity on the unbulked pier will produce less scour, so it is not computed herein.


Bridge Scour RS = 212.34
D/S CONVEYOR
Legend
WS PF 1
Ground
Ineff
Bank Sta
Total Scour
Elevation (ft)
Station (ft)
1080
1070
1060
1050
1040
1030
1020
1010
1000
19600
19700
19800
19900
20000
20100
20200
20300
20400
2.5' ϕ (TYP)
EL. 1021.65'
9'
EL. 1018.65'

Alternative 1 Bridge Scour, River Station 212.34, Conveyor Bridge

Results Computed Using HEC-RAS Version 2.2 and HEC-18 Guidelines

Hydraulic Design Data

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Circulare cylinder
Pier Width (ft):	6.5
Grain Size D50 (ft):	0.01969
Depth Upstream (ft):	32.69
Velocity Upstream (ft/s):	14.78
K1 Nose Shape:	1
Pier Angle:	0
Pier Length (ft):	8
K2 Angle Coef:	1
K3 Bed Cond Coef:	1.1
Grain Size D90 (ft):	0.2461
K4 Armouring Coef:	1

Results

Scour Depth Ys (ft):	**17.95**
Froude #:	0.46
Equation:	CSU equation

APPENDIX 6

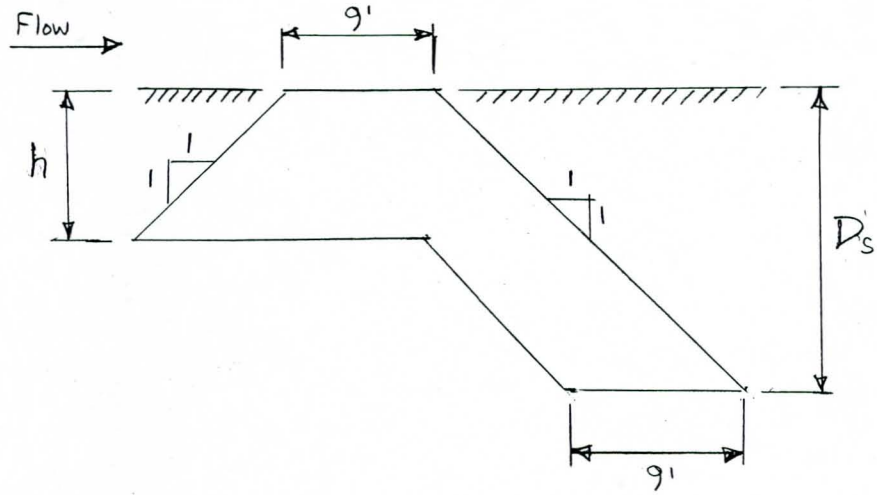
Quantity Calculations for Cost Estimates

APPENDIX 6

GRADE CONTROL STRUCTURE QUANTITIES

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

OVERBANK - SOIL CEMENT VOLUME



Volume per unit length

$$= \left[\frac{2(9') + 2h}{2}\right] \times h + (D_s - h) \times 9'$$

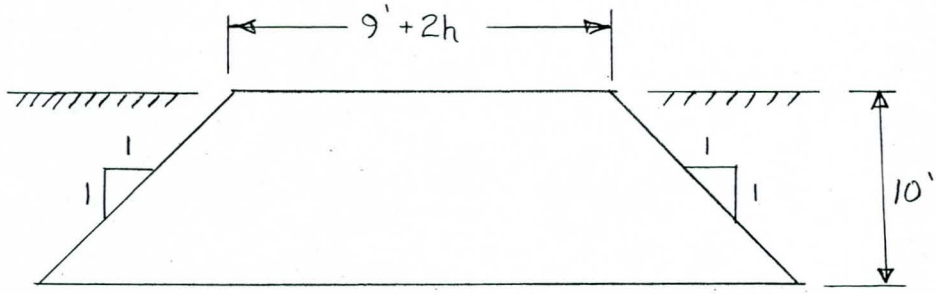
$h = 8'$, $D_s = 16'$

$$= \left[\frac{2(9) + 2(8)}{2}\right] \times 8' + (16' - 8') \times 9'$$

$$= 208\ ft^3/ft = 7.7\ yd^3/ft$$

GRADE CONTROL STATION	Vol./L (yd^3/ft)	L (ft.)	Vol (yd^3)
213.26	7.7	(920 - 280 - 100) = 540	4,158.0
214.65	7.7	(775 - 259 - 100) = 416	3,203.2
215.65	7.7	(920 - 214 - 100) = 606	4,666.2
216.23	7.7	(1050 - 214 - 100) = 736	5,667.2

LOW FLOW CHANNEL - SOIL CEMENT VOLUME



h – Difference between elev. of overbank wier crest and LFC wier crest

Volume per unit length

$$= \left[\frac{2(9+2h) + 2(10)}{2}\right] * 10' = (19+2h)(10)$$

GRADE CONTROL STATION	h (ft)	Vol./L (yd³/ft)	L (ft)	Vol. (yd³)
213.26	12.5	16.3	280	4,564.0
214.65	9	13.7	259	3,548.3
215.65	9	13.7	214	2,931.8
216.23	9	13.7	214	2,931.8

$L_{213.26} = 205 + 2(3)(12.5) = 280$ ft.

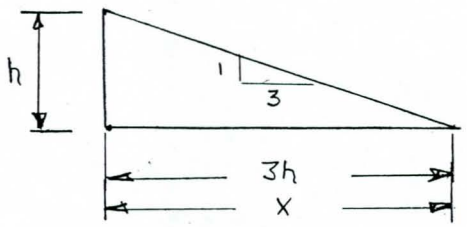
$L_{214.65} = 205 + 2(3)(9) = 259$ ft.

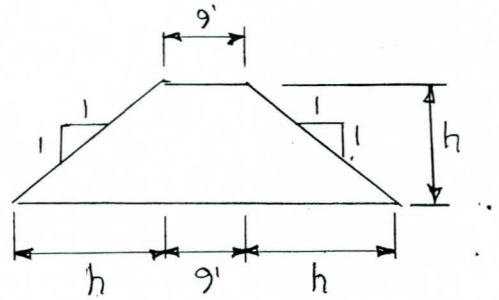
$L_{215.65} = 160 + 2(3)(9) = 214$ ft.

$L_{216.23} = 160 + 2(3)(9) = 214$ ft.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

LOW FLOW CHANNEL SIDE SLOPES — SOIL CEMENT VOLUME





FOR $h = 9$ ft. $\quad x = 27$ ft. $\quad h = \frac{1}{3}x$

EACH SIDE

$$\frac{dV}{dx} = \frac{1}{2}\left[\left(\frac{2}{3}x + 9\right) + 9\right]\left(\frac{1}{3}x\right) = \frac{1}{9}x^2 + 3x$$

$$V = \int_0^{27} \frac{dV}{dx}\,dx = \int_0^{27}\left(\frac{1}{9}x^2 + 3x\right)dx$$

$$= \frac{1}{27}x^3 + \frac{3}{2}x^2 \Big|_0^{27} = 1{,}822.5 \text{ ft}^3$$

$$= 67.5 \text{ yd}^3 \text{ / SIDE SLOPE}$$

FOR $h = 12.5$ ft. $\quad x = 37.5$ ft. $\quad h = \frac{1}{3}x$ $\qquad$ STA. 213.26

$$\frac{dV}{dx} = \frac{1}{2}\left[\left(\frac{2}{3}x + 9\right) + 9\right]\left(\frac{1}{3}x\right) = \frac{1}{9}x^2 + 3x$$

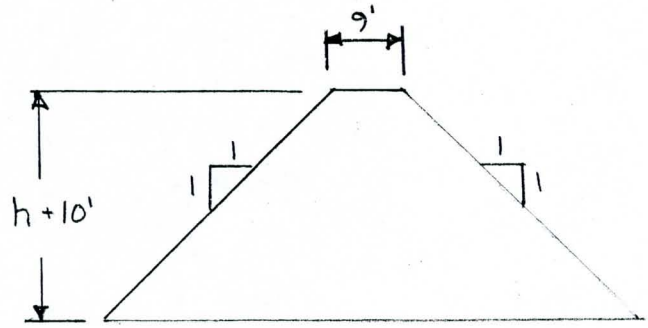
$$V = \int_0^{37.5} \frac{dV}{dx} = \int_0^{37.5}\left(\frac{1}{9}x^2 + 3x\right)dx$$

$$= \frac{1}{27}x^3 + \frac{3}{2}x^2 \Big|_0^{37.5} = 4{,}062.5 \text{ ft}^3$$

$$= 150.5 \text{ yd}^3 \text{/ side slope}$$

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

TRANSITION FROM LFC TO OVERBANK - VOLUME (APPROX)



Volume per unit length

$$= \frac{1}{2}\left[2(h+10)+9+9\right] \times h$$

$$= h^2 + 19h$$

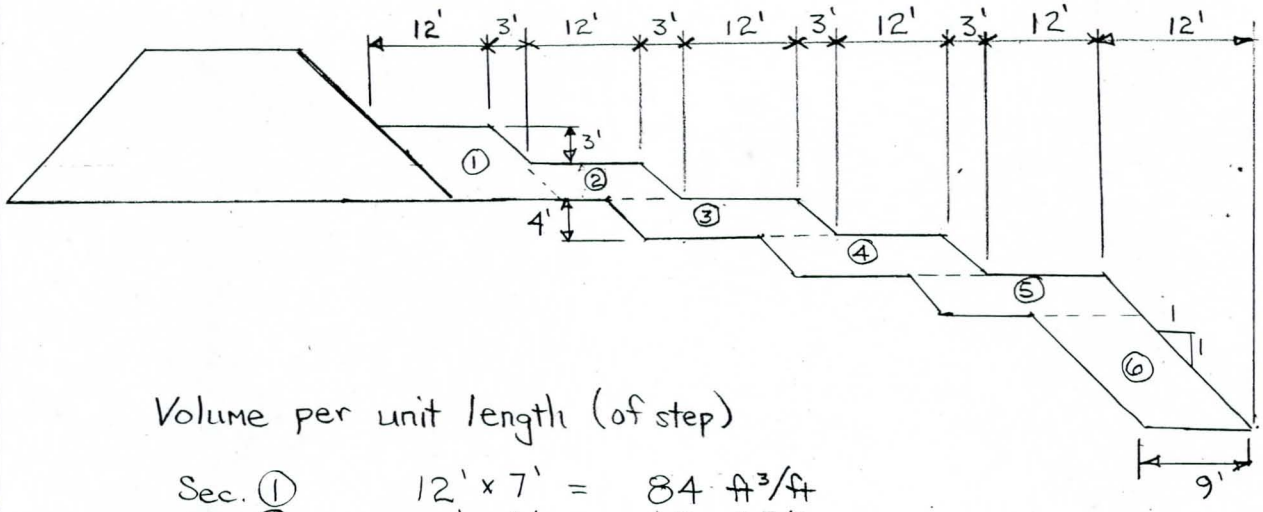
Assume transition length of 100 ft.. (50 ft. each end)

GRADE CONTROL STATION	h (ft)	VOL./L (yd^3/ft)	L (ft)	VOL. (yd^3)
213.26	12.5	14.58	100	1,458.3
214.65	9	9.33	100	933.3
215.65	9	9.33	100	933.3
216.23	9	9.33	100	933.3

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

DOWNSTREAM APRON



Volume per unit length (of step)

Sec. 1	12' × 7'	=	84 ft³/ft
Sec. 2	12' × 4'	=	48 ft³/ft
Sec 3	18' × 4'	=	72 ft³/ft
Sec 4	18' × 4'	=	72 ft³/ft
Sec 5	18' × 4'	=	72 ft³/ft
Sec 6	8' × 9'	=	72 ft³/ft
			420 ft³/ft = 15.56 yd³/ft.

GRADE CONTROL STATION	VOL./L (yd³/ft)	L* (ft)	VOL (yd³)
213.26	15.56	300	4,667
214.65	15.56	280	4,356
215.65	15.56	235	3,656
216.23	15.56	235	3,656

* ASSUMES STEPS EXTEND 10 FEET BEYOND TOP OF LFC ON EACH SIDE

AMPAD 22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS

GRADE CONTROL STATION	OVERBANK VOL. (yd^3)	LFC VOL. INCL. SIDESLOPES (yd^3)	TRANSITION (yd^3)	DOWNSTREAM APRON (yd^3)	TOTAL VOLUME (yd^3)
213.26	4,158	4,865	1,458	4,667	15,148
214.65	3,203	3,683	935	4,356	12,177
215.65	4,666	3,067	935	3,656	12,324
216.23	5,667	3,067	935	3,656	13,325

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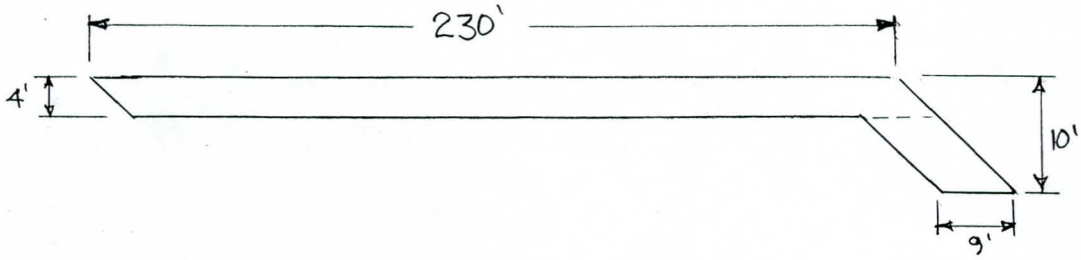
STATION 213.26 UPSTREAM APRON



WIDTH ~ 360'

$$VOL = [230(4') + (10-4)(9)](360)$$

$$= 350{,}640 \text{ ft}^3$$

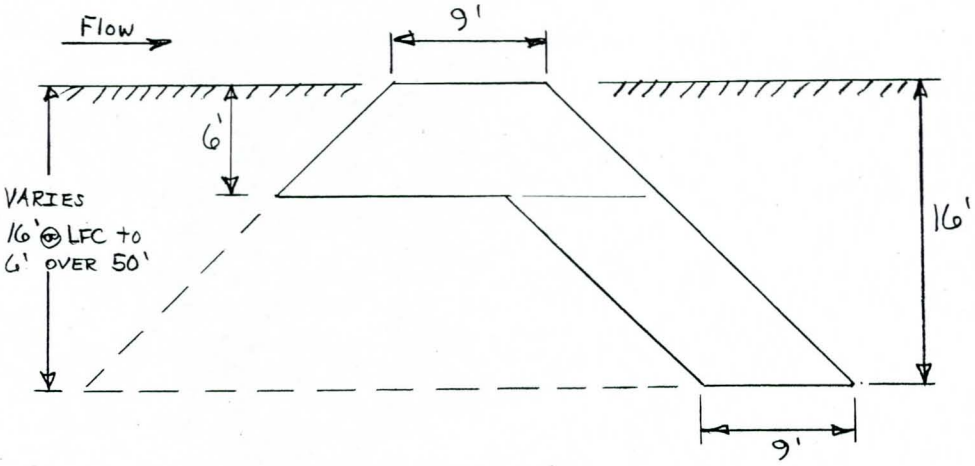
$$= 12{,}987 \text{ yd}^3$$

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

APPENDIX 6

GUIDE DIKE QUANTITIES

TYPICAL SECTION FOR SECTION ADJACENT TO LFC



AT LFC

$$\text{VOL./FT.} \doteq \tfrac{1}{2}[(9+32)+9](16) = 400\ ft^3/ft$$

$$= 14.81\ yd^3/ft$$

AT 50' FROM LFC

$$\text{VOL./FT.} = \tfrac{1}{2}[(9'+12')+9'](6') + (16'-6')(9')$$

$$= 180\ ft^3/ft.$$

$$= 6.67\ yd^3/ft$$

$$\text{VOL.} = \tfrac{1}{2}(14.81\ yd^3/ft + 6.67\ yd^3/ft)(50\ ft)$$

$$= 537\ yd^3$$

34 GUIDE DIKES

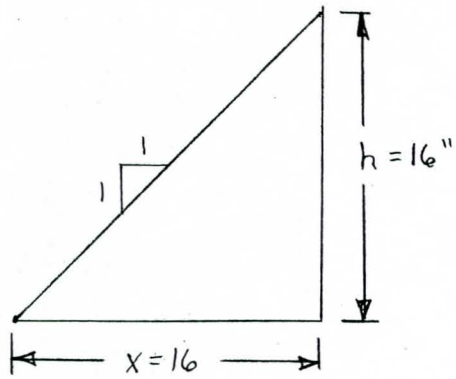
$$\text{VOL} = 537\ yd^3 \times 34$$

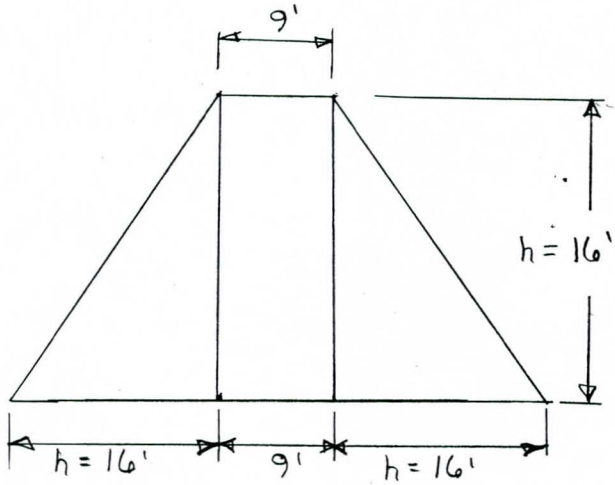
$$= 18{,}258\ yd^3$$

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

LFC END CONDITION





$h = x$

$$\frac{dV}{dx} = \frac{1}{2}\left[(2x+9)+9\right]x = x^2 + 9x$$

$$V = \int_0^{16} \frac{dV}{dx}\,dx = \int_0^{16} (x^2+9x)\,dx$$

$$= \tfrac{1}{3}x^3 + \tfrac{9}{2}x^2 \Big|_0^{16}$$

$$= 2{,}517.3 \text{ ft}^3$$

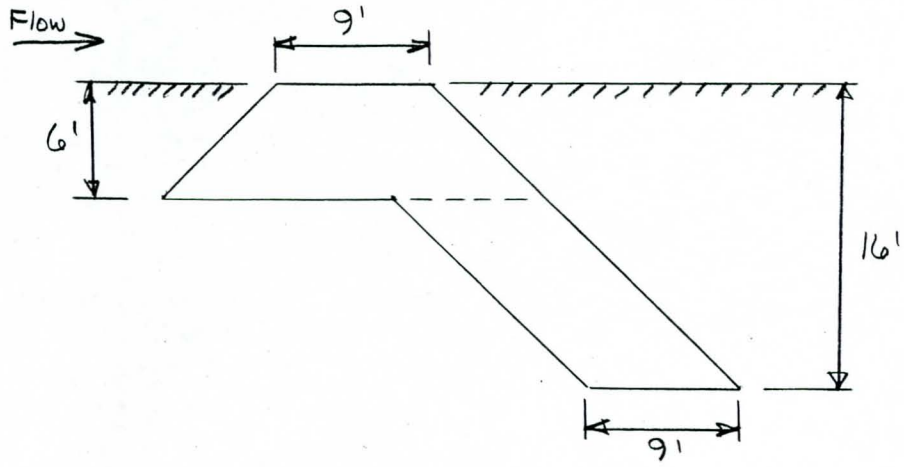
$$= 93.24 \text{ yd}^3$$

34 GUIDE DIKES

$$\text{VOL} = 93.24 \text{ yd}^3 \times 34$$

$$= 3{,}170.2 \text{ yd}^3$$

GDS SECTION NEAR OVERBANK (SOIL CEMENT SECTION)



$$VOL/L = \tfrac{1}{2}[(9'+12')+9'](6) + (16'-6')(9')$$
$$= 180\ ft^3/ft$$
$$= 6.67\ yd^3/ft$$

TOTAL LENGTH FOR 34 GUIDE DIKE STRUCTURES = 5855 ft.

∴ SOIL CEMENT OVERBANK = 5,855 - 34(50) - 34(50)

= 2,455 ft.

VOL = 6.67 yd^3/ft x 2,455 ft.

= 16,374.9 yd^3

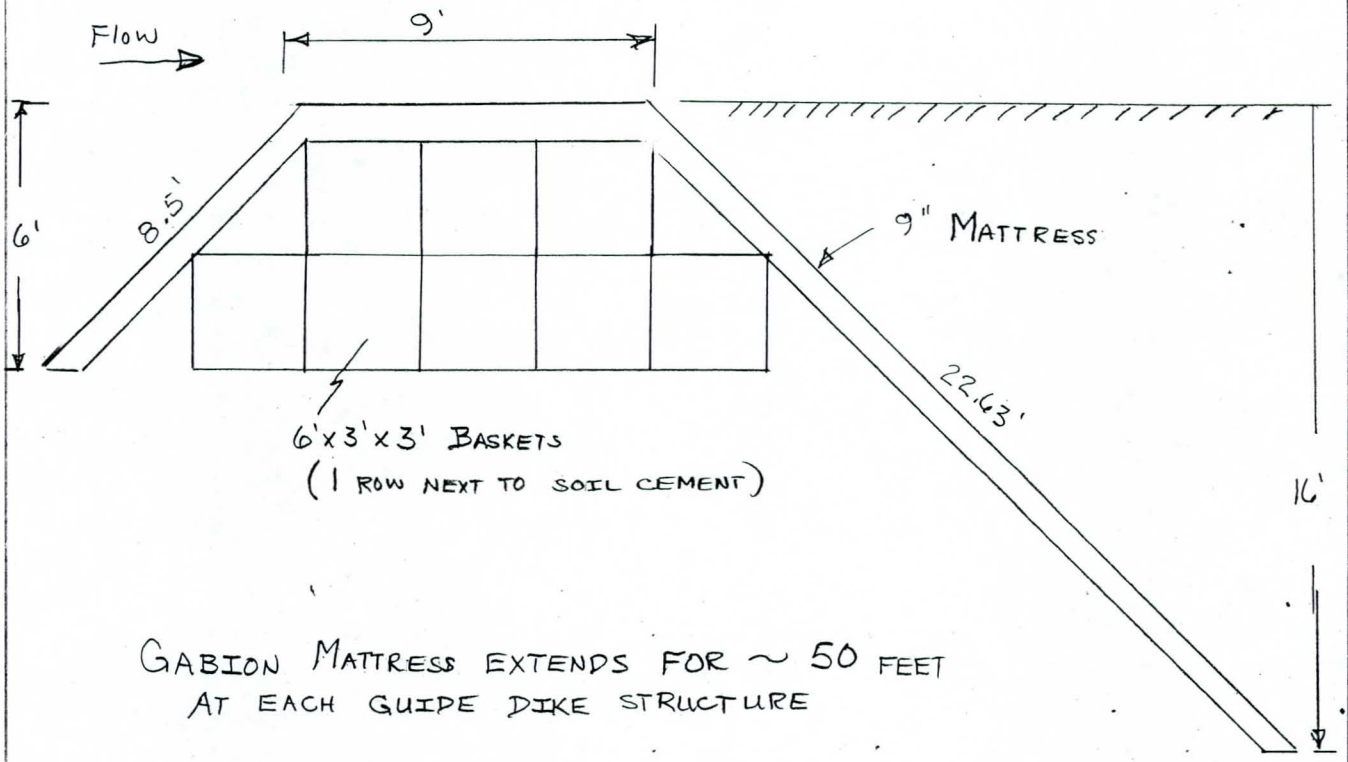
TOTAL SOIL CEMENT = 16,374.9 yd^3 + 18,258 yd^3 + 3170.2 yd

= 37,803 yd^3

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

GABION SECTION



GABION MATTRESS EXTENDS FOR ~ 50 FEET AT EACH GUIDE DIKE STRUCTURE

VOL. (BASKETS) = 8 (6'x3'x3') = 432 ft^3

= 16 yd^3

VOL. (MATTRESS) = 40' x 9"/12" x 50' = 1,500 ft^3

= 55.56 yd^3

VOL. (PER GDS) = 16 yd^3 + 55.56 yd^3

= 71.56 yd^3

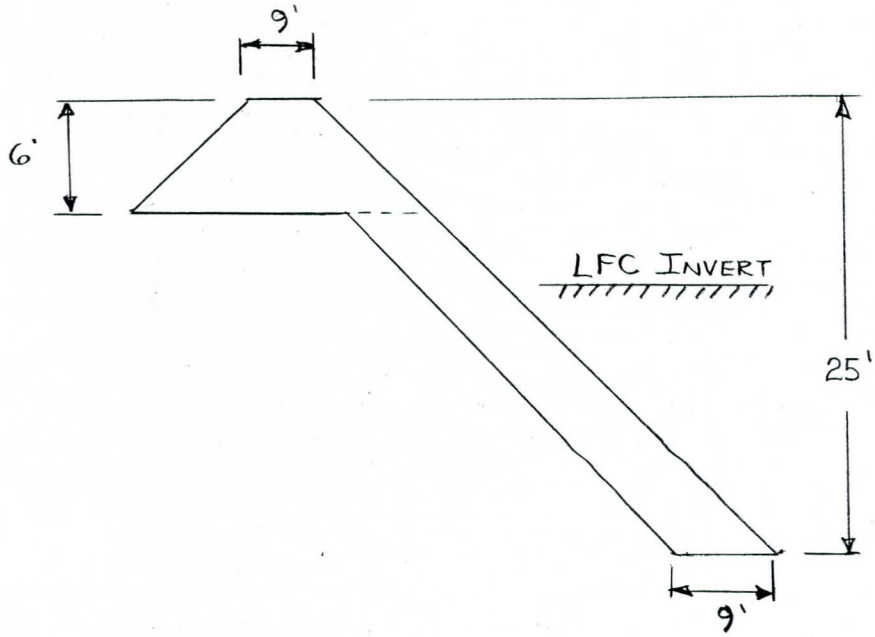
VOL (GABIONS) = 71.56 yd^3/GDS x 34 GDS

= 2,433 yd^3

APPENDIX 6

BANK PROTECTION QUANTITIES

TYPICAL SECTION



NORTH BANK DOWNSTREAM OF CENTRAL:
(CROSS-SECTION 213.24 TO CROSS-SECTION 212.84)

$H = 25'$ (10' CHANNEL DEPTH + 15' TOEDOWN)

$W = 9'$

LENGTH $= 2{,}400'$

$$\text{VOLUME} = \left[(25'-6')(9') + \tfrac{1}{2}(21'+9')(6')\right](2400')$$

$$= 626{,}400 \text{ ft}^3$$

$$= 23{,}200 \text{ yd}^3$$

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

APPENDIX 7

Value Engineering Review

RIO SALADO

Value Engineering Recommendation Review

Idea No.	Idea Description	Summary of WEST Comments
C-03	Plant project in phases using previous areas as nursery stock.	For the same discharge, the overbank velocities will be higher during the early planting phases than during flows with the fully matured, planted phase. Therefore, during the initial planting phases, the potential for damage in the overbanks increases.
C-04	Replace large boxes of plants with cuttings/whips/bare root stock from local sources such as Tres Rios.	See comment for Idea No. C-03.
C-18	Use renewable energy, such as methane from landfill or solar, for pump energy.	The use of renewable energy does not affect the hydraulic design considerations of the low flow channel (LFC) and the overbanks.
C-54	Plant at appropriate time of year.	The planting window does not affect the hydraulic design considerations of the low flow channel and the overbanks.
C-59	Post flood, recover vegetation and replant.	Vegetation recovery may be feasible for moderate to low flood events. However, for larger floods or floods with long durations, the uprooted vegetation will be transported far downstream and impractical to recover.
C-63	Plant perennial stream bank with indigenous species with low n-value and high habitat value. The proposed Manning's n value is 0.035 and a side slope of 3:1.	WEST Consultants' LFC design alternatives incorporate the 3:1 side slope and anticipate high-density vegetation on the stream banks ($n \sim 0.06$). Further analysis could be performed to determine the type of protection (i.e. non-rigid revetments) required.

C-68	Design shape of planting to be hydraulically stable.	The proposal does not affect the viability of the LFC project as long as the overall roughness is not significantly altered.
M-26	Construct grade control structures full-width with notches for low-flow channel.	Full-width grade control design is part of WEST's LFC analysis. The locations will be optimized for stability.
M-34	Replace drop structures and use pool and riffle sequence.	Preliminary investigations show that the required median rock size for the proposed riprap structure (slope of 7 percent) with full-channel flow (12,200 cfs) is 7 feet, which is unreasonably large. The grade control must withstand the 100-year event, which would require even larger riprap. Furthermore, studies from the Soil Conservation Service show that stable rock slopes on the channel bottom are limited to a maximum of 2 percent which is 3.5 times less than the slope of the proposed structure.
M-66	Limit the meander of LFC with cut-off walls.	The vertical walls are smoother than the natural LFC and will therefore tend to capture and concentrate the flows near the walls. Furthermore, when the flow extends beyond the LFC, the walls will encourage the flow to cut a new channel along the backside of the walls.
M-105	Raise LFC to flood the terrace more frequently to lower retardance.	Three different LFC sizes are currently being investigated. The wetting of the overbanks increases as the channel size decreases. Hydraulic models are used to evaluate the velocities in the overbanks and the potential for damage. An evaluation will be made to ensure that the water surface elevation of the 100-year event with the LFC will not exceed the elevations with the existing conditions.

P-03	Line the low flow channel only in the portions of the channel with the highest stress.	The current LFC designs incorporate natural bed material. The need for protection at severe bends and impinging flows will be evaluated. The channel protection must be stable under the 100-year event. WEST is considering protection alternatives such as side spurs and cable revetment systems.
P-15	Line low flow channel only a short distance downstream of grade control structures.	The length of the lining below the grade control structure must be sufficient to dissipate energy and to ensure stability of the structure. An effort will be made to minimize the length. The length will vary with the drop structure design (i.e. traditional versus a sloping grade control).
P-23	Provide provisions to protect habitat from the receding side of the flood.	The proposed measures are acceptable as long as they do not affect of overall roughness of the overbanks. WEST is investigating the possibility of installing buried dikes in the overbanks to transition the flow and to limit the propensity of channel formation in the overbanks.
P-31	Develop "adopt a river" or streams team programs.	The proposal is a good idea and does not affect the hydraulic design considerations of the low flow channel and the overbanks.
P-59	Develop fire breaks in landscape plan.	Provided that the fire breaks make up a small percentage of the total overbank area, the hydraulics will not be affected. The fire breaks should be perpendicular to the flow line.
R-28	Provide gateway visitor/interpretative center.	The visitor center must be located outside of the 100-year flow line. In this case, the proposal does not affect the hydraulic design considerations of the low flow channel and the overbanks.