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Draft Sediment Trend Analysis

Salt River

between Granite Reef Dam and the confluence with the Gila River

Prepared for:
404(b)(1) Applicants on the Salt River

091137.00
December, 1996
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Kimley-Horn
and Associates, Inc.
Engineering, Planning, and Environmental Consultants

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REMARKS

Suite 250
7600 N. 15th Street
Phoenix, Arizona
85020

December 3, 1997

Mr. Richard G. Perreault
Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009

Re: Salt River Sediment Trend Analysis

Dear Dick,

Here is a courtesy copy of the sediment trend analysis which we prepared for the Salt River. Please consider the following when making use of this document:

1. It is our understanding that the Corps hired an independent consultant to review this work who generally agreed with the approach and results. We have never received formal comments or acceptance from the Corps, therefore, this analysis is still subject to change.

2. This analysis was performed to show general trends only. It includes several simplifying assumptions and should not be used in any way without written authorization and adaptation by Kimley-Horn and Associates, Inc.

3. The results are based on the cumulative impacts of multiple users in the river including mining operations, channelization, grade controls, bridge crossings, and other factors that impact river bed stability.

Should you have any questions regarding our efforts on this project, please do not hesitate to call Doug Plasencia or myself.

Sincerely,

KIMLEY-HORN AND ASSOCIATES, INC.

W. D. Mathews

William D. Mathews, P.E., R.L.S.
Vice President

enclosures

TEL 602 944 5500
FAX 602 944 7423

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1.0 Introduction

Summary

Kimley-Horn and Associates, Inc. has been retained by several sand and gravel operators in the Salt River to pursue permits as described in Section 404 of the Clean Water Act. As part of the permit application and public notice process, comments were made by several reviewing agencies regarding the cumulative impacts of sand and gravel mining in the Salt River on the channel bed profile and related potential impacts to infrastructure crossing the river. This study is prepared in response to these comments and is limited to an evaluation of channel bed profile changes as projected through the use of standard sediment transport modeling and the application of these results to interpret potential impacts to infrastructure crossings.

Background

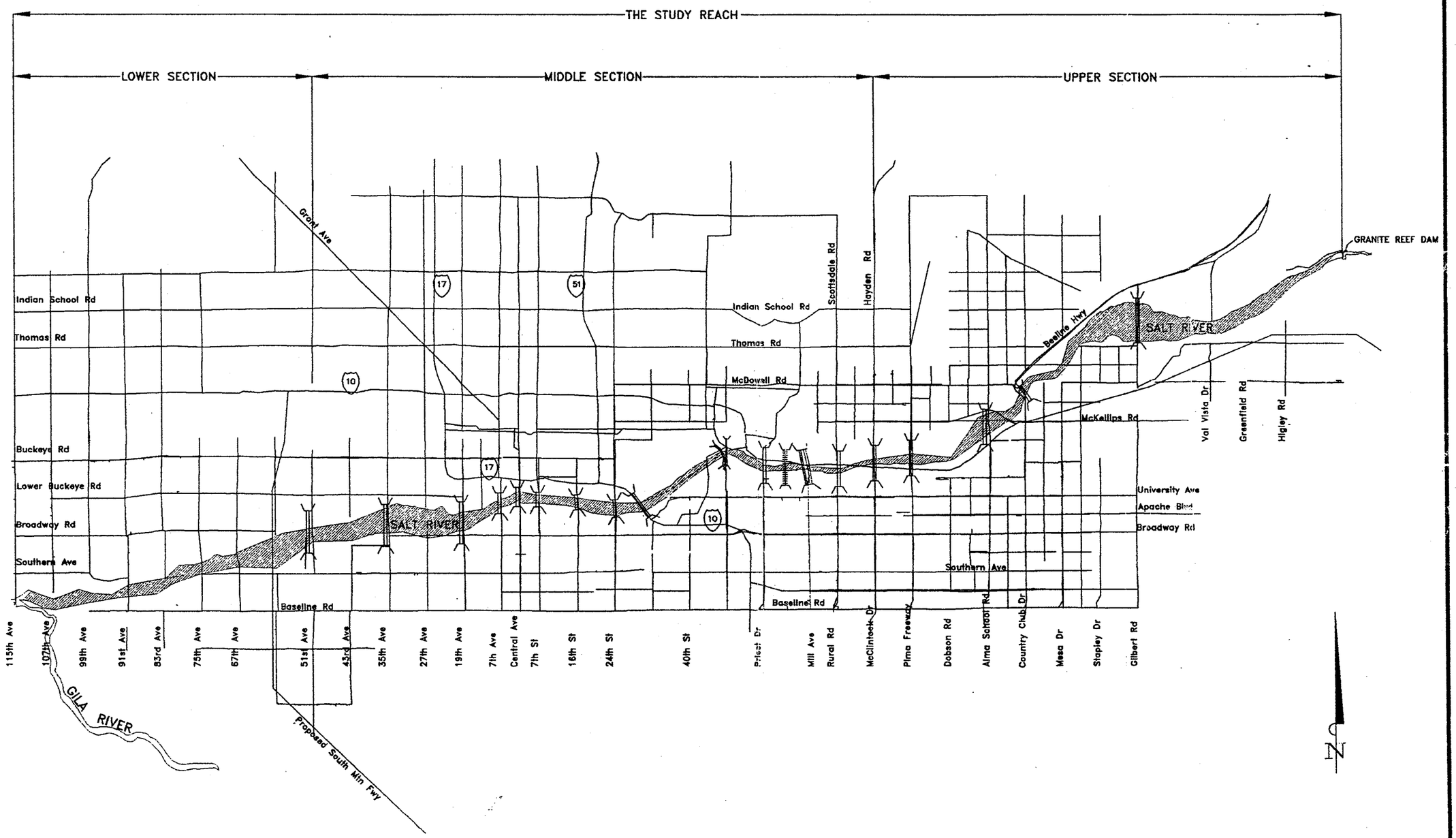
The sand and gravel industry has a long history of mining from the rivers of Arizona. The Salt River through central Phoenix has been a location where high quality sand and gravel resources are located in the river bed, and has been a very desirable location due to the ephemeral nature of the river and the proximity to local markets. .

New judicial interpretation of Section 404 of the Clean Water Act has led to the inclusion of sand and gravel mining as a jurisdictional activity. As a result, 404 permit applications and supporting documentation was previously submitted for a number of sand and gravel operations in the Salt River. Several agencies that commented on the applications suggested that a sediment transport analysis be undertaken that considers the cumulative impacts of mining activities on channel bed profile. This sediment trend analysis is in response to these requests and is a compilation of reasonable projections of channel bed change. The analysis includes nearly 38 miles of the Salt River system from Granite Reef Dam to the confluence with the Gila River (See Figure 1). This is the first comprehensive sediment transport model developed for this extended reach of the Salt River system.

Kimley-Horn and Associates, Inc. prepared this sediment trend analysis. West Consultants, Inc. assisted with the development of the HEC-6 model. Western Technologies, Inc. was retained to obtain sediment samples and gradations.

This report summarizes the analysis of the sediment transport trends of the Salt River as measured through the cumulative impacts of additional mining activity. These results provide a projection of channel bed profile change, but do not take into consideration

local scour, which is highly independent of sediment balance and transport functions. The modeling has been performed at a resolution that would not allow for the indiscriminate application of these results for subsequent localized design decisions. Due to this reason, and other simplifying assumptions which are described below, these results should not be applied for uses outside the scope of this analysis.



Kimley-Horn and Associates, Inc.

STE. 250 7600 N. 16TH STREET
PHOENIX, ARIZONA 85020
Phone (602) 944-5500

FIGURE 1
THE STUDY AREA

PROJECT NO.:	091137.01
DESIGNED/DRAWN:	JJL
CHECKED:	DJR
SCALE:	NTS
DATE:	12-26-96

2.0 Historic Conditions

The Salt River system through Phoenix has been significantly impacted by human imposed changes to the river and watershed. These impacts include:

Upstream Control Structures - Construction of upstream dams and reservoirs has made the Salt River system ephemeral. It has also led to the capture of sediments at the control structures for a significant portion of the watershed. This has reduced the supply of sediments to recharge the river system and promoted degradation downstream of Granite Reef Dam. The control structures also influence the system hydrology such that the types of flows the river system receives downstream of Granite Reef Dam are generally flood release flows.

Channelization and Bank Protection - Significant segments of the Salt River system through central Phoenix have been channelized for the purposes of flood control. Portions of both the north and south banks have been protected to inhibit lateral erosion. The resulting increases in velocity and flow depth have increased the sediment transport capacity of these river reaches. Furthermore, the reduction in the overbank flow has limited the sediment supply to the main channel and promoted degradation of the channel.

Bridges and Crossings - The construction of bridged roadway crossings has concentrated flood flows through the bridge openings. The roadway crossings have created contracted flow hydraulics at the bridges, with local scour effects at the piers and abutments. Furthermore, the approach embankments have blocked overbank flow at the bridge crossings, further constricting flow and increasing velocities at the bridges. Some of the early bridges included approaches built on piers to allow large flood events to effectively flow in the overbanks of the Salt River. This type of overbank flow to relieve the bridge is no longer provided at the bridge crossings.

Urbanization of the Watershed - Urbanization of the watershed along the banks of the Salt River has diminished sediment supply into the study reach from adjacent lands. The urbanization has also contributed to the pressure for channelization and bank protection, which has the effects described above.

Sand and Gravel Mining - Sand and gravel mining within the active bed has led to the creation of low flow channels and has influenced the location of the main channel flow. The pits and excavations by mining operations can capture

sediment during flood flows. The cut slopes and bed changes can also be somewhat unstable as they are reshaped by river flows.

System Hydrology - The Salt River system is now an ephemeral stream due to upstream dam construction. The only perennial flow in the reach is artificial and is a result of irrigation tailwater return and effluent discharge. Other flows are generally a result of rainfall events, or limited releases from the Salt River Project system.

Collectively these changes have significantly altered the river environment, hydrology, hydraulics, morphology, and sediment balance from its natural state. These alterations have been documented by others who have reported on the historical trend of degradation in the Salt River system. Based on the previously mentioned changes to the Salt River system, the reported degradation is not surprising and is the result of many impacts to the system.

Attempts at the development of a comprehensive, river management system have been sporadic, and continue to be heavily influenced by created needs. The most notable recent example of this is the Rio Salado initiatives by the City of Tempe which have attempted to create an urban river park setting in the Salt River system. The Salt River system has been managed historically by passive management tools that have been premised to a certain degree on limited self protection and to a certain degree on allowing reasonable impacts to all shared users of the system. For example, current floodplain management regulations for the river are premised on encroachment zones that provide for limited impact to flood stage and velocity. This provides for flood protection while allowing continued managed growth.

Human imposed changes have evolved sporadically, and have also introduced potential spatial and operational conflicts between adjacent uses. The evolution of use in the Salt River system has been in response to multiple individual interests, all of which impact adjacent users. Elimination of sand and gravel mining activities will not change this situation or result in a balanced or restored Salt River system.

3.0 Study Approach

The purpose of the study is to evaluate the impacts that additional sand and gravel mining activities could have on channel bed profile changes in the Salt River system. This is accomplished by developing two sediment transport models using the US Army Corps of Engineers Engineering Model HEC-6. The first model is a "without additional mining" model and the second model is a "with additional mining" model.

Without Additional Mining - Includes modeling of "current" conditions on the Salt River system. It is based on the same topographic mapping being used by the Flood Control District of Maricopa County for a flood plain mapping study for the Salt River system. The without additional mining model includes modeling of existing bridges, grade control structures, bank stabilization, and channelization projects.

With Additional Mining - Differs from the without additional mining model only by incorporating the anticipated additional mining activities. The initial model development is based on the sand and gravel withdrawals as enumerated in the public notices for all applications submitted on the Salt River system. Through conversations with the applicants it was determined that several applications have been withdrawn, leaving only fifteen active permit applications. Reduced mining withdrawals were then considered as part of the alternatives analysis for the 404(b)(1) guidelines documentation. The results of the alternatives analysis were used to develop the model based on an average depth of mining of twenty feet for all applicants. This represents a reduction in the withdrawal volume of approximately seventy-five percent from the amount in the public notices and a reduction in the mining area of approximately forty percent. It is important to note that this average depth was agreed to by involved Kimley-Horn clients. There are three applicants in the Salt River system not represented by Kimley-Horn. For the purposes of this study, these three applicants have been held to the same average depth constraint as the other applicants in the Salt River system. It is possible that they might choose to request a mining depth and volume greater than the twenty foot average. The results of this analysis can be revised to reflect those changes and any subsequent changes in mining volumes requested by other applicants in the Salt River system.

The overall goal of developing the two models is to determine the impacts of sand and gravel mining on the Salt River system. These impacts include potential degradation of the channel bed and potential exposure of bridge foundations, underground utilities, and other infrastructure crossing the Salt River.

4.0 Methodology

General

The sediment trend analysis was conducted through use of the US Army Corps of Engineers' general engineering computer program, HEC-6, Scour and Deposition in Rivers and Reservoirs. HEC-6 is a one dimensional sediment transport program that can be used to project variations in channel bed elevations. The model uses a set of standard transport equations that quantify the predicted sediment transport capacity of a channel for varying hydraulic conditions. HEC-6 compares the estimated suspended sediment load with the estimated sediment transport capacity and either suspends or deposits material on the channel bed, such that the estimated sediment capacity equals the estimate of the suspended sediment load. For this analysis, the sediment transport equation by Yang is used with the full ten size classes of sand and gravel.

The HEC-6 model is driven by geometric and hydraulic data, similar to that which is used in a standard backwater model such as HEC-2. It is further augmented with data that describes channel soil gradations, inflowing suspended sediment load, active bed limits, channel bed hard points, channel excavation, and a continuous record of flow for the period of simulation.

Hydraulics

HEC-6 makes certain simplifying assumptions in its hydraulic calculations and cannot model certain complex hydraulic situations. Due to these simplifying assumptions, it is necessary to first establish a representative backwater model for use in developing a proper HEC-6 model. The representative backwater model for this analysis was developed using a combination of HEC-2 and HEC-RAS backwater computation software.

Since the purpose of this analysis is to evaluate trends in channel bed profile change, it was not determined to be necessary to commission new aerial photography. Recent topographic mapping of the Salt River system would suffice in establishing a baseline geometry. The Flood Control District of Maricopa County (the District), is currently developing revised floodplain mapping of the Salt River system. The District provided the base topographic mapping (1"= 400' scale) which was flown in 1991 and 1992, and the coded cross sections from the HEC-2 model currently under development. The data provided by the District is from a project in progress, however, and should not be interpreted as being representative data from which to predict regulatory flood elevations. The District's topography provides a reasonable continuous baseline geometry for use in this analysis.

The District data was provided as an HEC-2 input file, and was converted to an HEC-RAS input file to facilitate the checking and modification of the base data as necessary to develop channel hydraulic profiles. In general, the base data was found to be reasonable, with the most significant modifications occurring at bridge sections to take advantage of the more powerful bridge analysis routines of HEC-RAS. The HEC-RAS model was then run for multiple flood profiles to develop rating curves for the study reach. The rating curve at the downstream boundary of the model (River Mile 199.91 approximately 115th Avenue) was developed in HEC-RAS as shown in Figure 2.

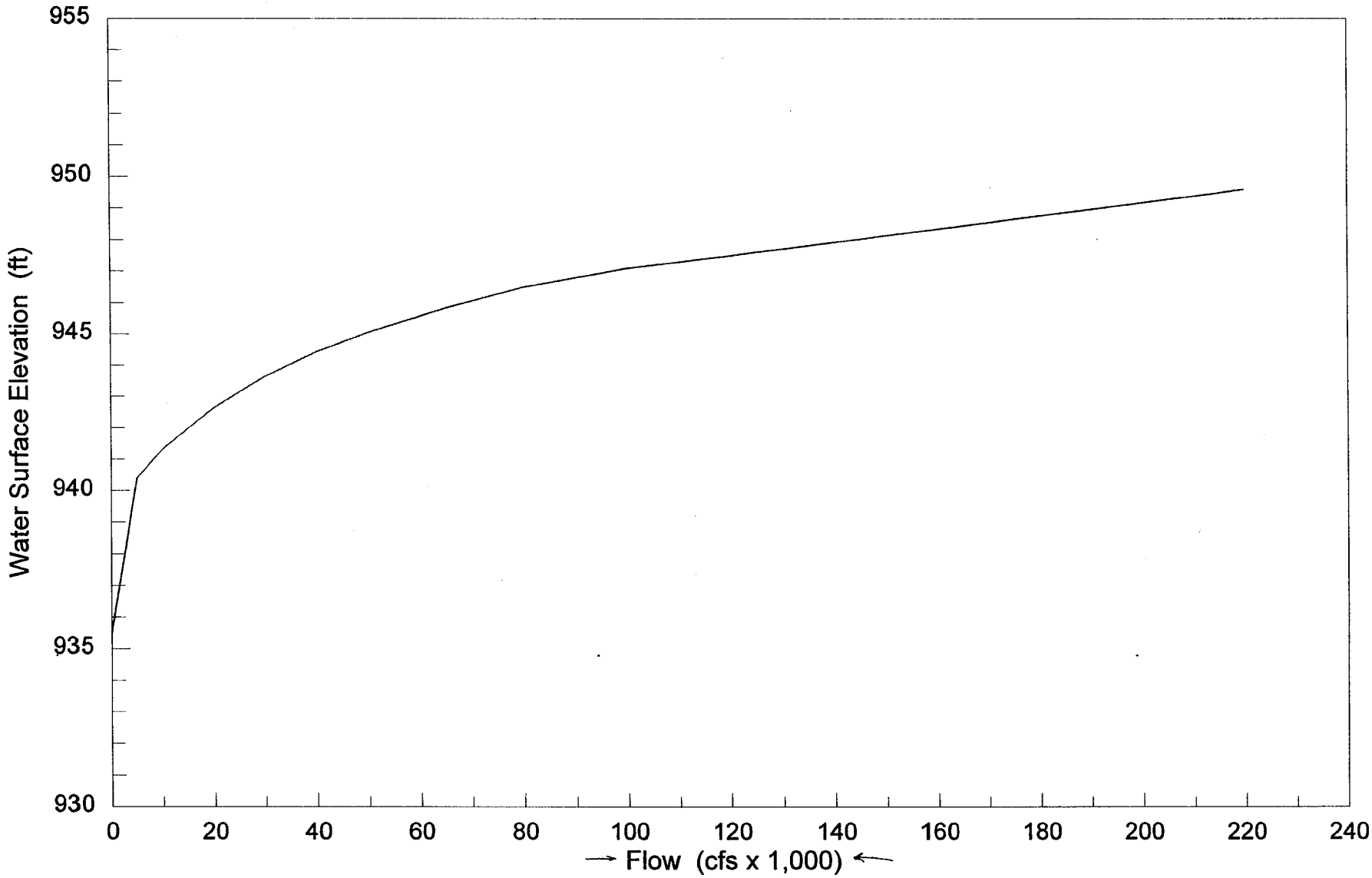
Following the development of a representative hydraulic model in HEC-RAS, the original HEC-2 model code was modified to incorporate changes determined to be necessary in the HEC-RAS analysis and to simulate the backwater influences of bridges in a compatible format to HEC-6. The revised HEC-2 model code was then imported into the HEC-6 model and further modified. The number of cross sections in the HEC-6 model was reduced to provide at least one representative section every one half mile. This reduction in the total number of sections allowed for a reasonable representation of the channel without exceeding the total number of cross sections allowed by HEC-6. Finally, the HEC-6 model was run and calibrated to the rating curves from the HEC-RAS model. Head loss for bridges and other complex hydraulics that cannot be directly solved in HEC-6 were simulated by artificially increasing the losses in HEC-6. The HEC-6 model was revised until the hydraulics were determined to be basically within ten percent (10%) of those in the HEC-RAS model at every cross section in the HEC-6 model.

Sediment Transport

The HEC-6 input variables for sediment are based on near surface sediment samples taken from the Salt River system for this analysis in October 1996. Samples were collected and gradations performed by Western Technologies Inc. and the results are reported in two letter reports, dated October 24, 1996 and October 28, 1996. The samples were taken at approximately one-half mile intervals throughout the study area, with one representative sample taken at each sampling location. The test results are shown in Figure 3. High and low "outliers" were then evaluated for inclusion or dismissal based on how representative they were with comparison to adjacent sampling locations. As a whole, the samples are representative of the low to moderately coarse material in the bed. Large diameter material, which is not evident in the sampling results, is likely to be a small percentage of the active bed and not large enough to resist the overall degradation during high flows.

Salt River Sediment Trend Analysis

Figure 2 - Rating Curve at River Mile 199.91



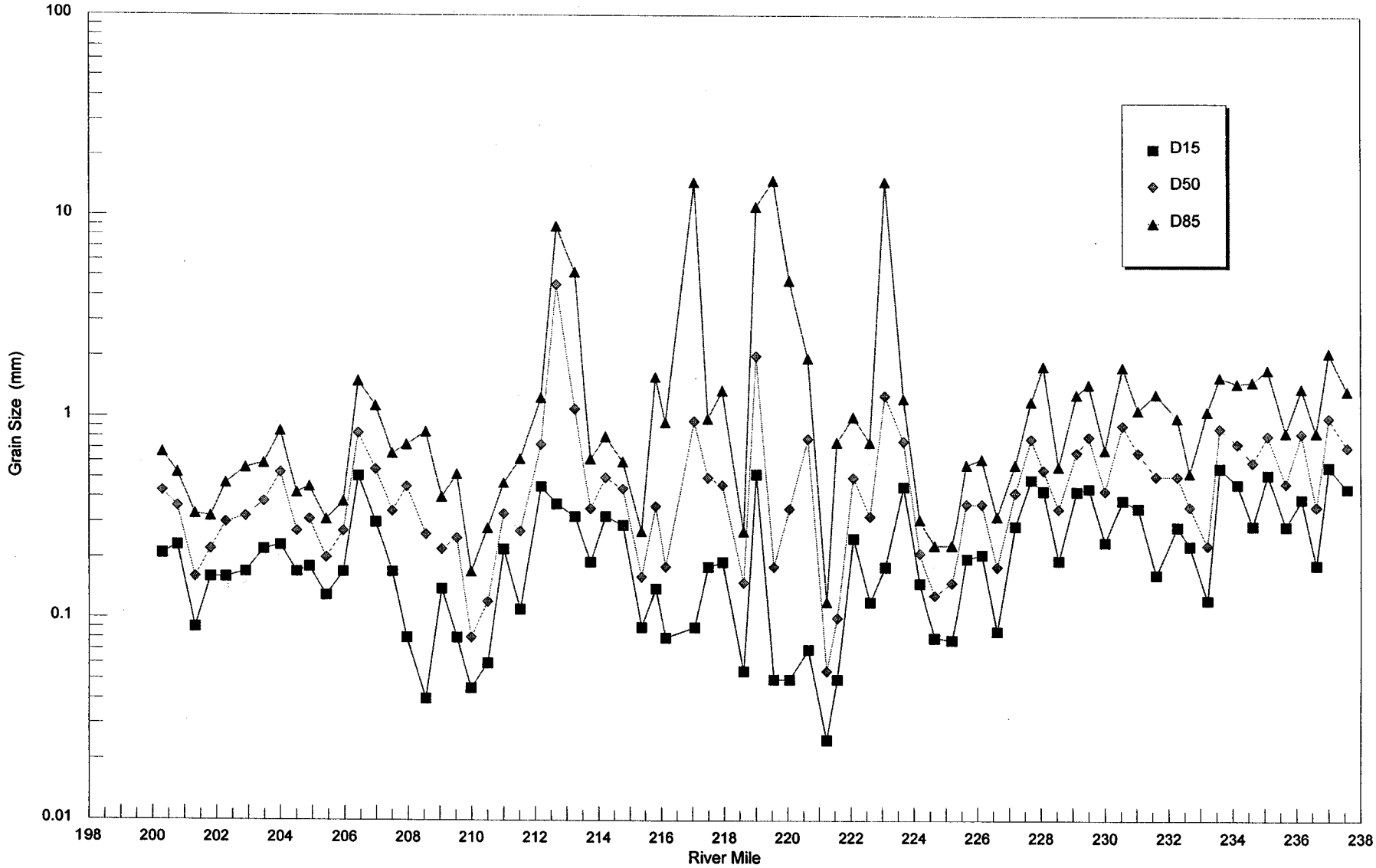
Salt River Sediment Trend Analysis
Table 1 - Sand and Gravel Mining Summary

17-Dec-96
mining.wk4

Applicant Name	River Mile	Permit Application Number	Total Mining Area (ac)	Total Mining Volume (cy)	Average Mining Depth (ft)
Cashway Concrete and Mesa Materials/	201.81	944-1129-00-RWF			
91st Ave.	201.99	944-1208-00-RWF			
	202.29		49	1,581,645	20.0
BCW Inc./ 75th Ave. and Sunland/ 67th	203.96	944-1049-00-RWF			
Ave.	204.34	944-1207-00-RWF			
	204.78				
	204.97				
	205.15		137	4,421,452	20.0
Pioneer Sand/ 59th Ave. and Cashway	206.03	944-1136-00-RWF			
Concrete/ 51st Ave.	206.51	944-0380-00-RWF			
	206.79				
	206.88				
	207.07				
	207.27		168	5,423,609	20.0
Phoenix Ready Mix/ 37th Ave.	208.48	944-1054-00-RWF			
	208.95				
	209.33		66	2,127,660	20.0
United Metro/ 19th Ave.	210.07	944-1166-00-RWF			
	210.36				
	210.64				
	210.93				
	211.21		80	2,581,673	20.0
Salt River Sand & Rock/ Dobson Rd.	224.43	944-1120-00-RWF			
	224.81				
	225.28				
	225.66				
	226.04				
	226.23		55	1,771,739	20.0
Chandler Ready Mix/ Country Club Rd.	227.08	964-0011-00-RWF			
	227.46				
	227.63		15	483,051	20.0
Salt River Sand & Rock/ Country Club Rd.	227.88	944-1119-00-RWF			
and United Metro/ Beeline Hwy	228.17	944-1167-00-RWF			
	228.64				
	229.12		85	2,741,935	20.0
Salt River Sand & Rock/ Beeline Hwy	230.09	944-1121-00-RWF			
	230.47				
	230.94				
	231.32		170	5,479,452	20.0
Chandler Ready Mix/ Lehi Rd.	232.74	944-1137-00-RWF			
	233.03		15	484,262	20.0
Salt River Sand & Rock/ Higley Rd.	233.95	944-1122-00-RWF			
	234.53				
	235.01				
	235.38				
	235.67		60	1,935,484	20.0
TOTALS			900	29,031,961	20.0

Salt River Sediment Trend Analysis

Figure 3 - Sediment Test Results



Based on visual observations and previous sampling, a sensistivity analysis was conducted to quantify the affects of large diameter material on channel degradation trends. CMG Drainage Engineering provided a soil sample obtained near Center Street in Mesa in 1988. This gradation was used as representative of the entire study reach and run in the HEC-6 model. While the gradation was considerably more coarse, it did not significantly change the HEC-6 results. The change in the average bed was a decrease in the total degradation of approximately 0.5 feet over the entire period of record. The change in gradation also shifted the areas of minimum and maximum degradation at many of the cross sections. Based on this sensitivity analysis, the gradations based on the soil samples were determined to be adequate for this analysis.

To include the mining operations in the HEC-6 model, a dredging template was coded for the HEC-6 cross sections at which mining is proposed in the 404 permit applications. The depth of dredging and volume of dredging were determined by HEC-6 iterations until the volume excavated by the model was within five percent (5%) of the volume of material that is proposed in the permit applications. Since the rate at which the mining will occur is only limited by the length of time for the permit, the entire volume of dredging was modeled in the first time step. This approach allows for an analysis of how the river responds at the conclusion of the permitted period. Table 1 shows a summary of the mining operations which were modeled in the with additional mining model.

The HEC-6 model requires an inflowing sediment load curve, however, our literature research produced no accounts of inflowing sediment load at Granite Reef Dam. As the study was initially envisioned, a peak flow analysis close to a 25-year event was anticipated and it was determined that a clear water inflow assumption at Granite Reef Dam would be reasonable based on the lack of available data and generally low flow levels. However, the Corps of Engineers regulatory section requested a peak flow analysis similar to a 100-year event, which made the clear water assumption unreasonably conservative for large flows. An alternative approach was developed. An analysis was conducted to determine the approximate equilibrium sediment load based on the channel's transport capacity near Granite Reef Dam. A sediment load of zero (0) tons per day of sediment (clear water assumption) was used for the entire period of flow record to conduct the analysis. The average amount of suspended sediment load exiting the reach just downstream of Granite Reef Dam was determined in HEC-6 and compared to the inflowing sediment load. The inflowing sediment load was then increased until the amount exiting the reach was equal to the amount entering the reach. This calculated sediment load near Granite Reef Dam is the calculated equilibrium sediment load for the upstream reach.

Next, the inflowing sediment load curve for the HEC-6 model was developed to account for the sediment trapped by Granite Reef Dam. The inflowing sediment load was modeled at zero (0) tons per day for flows up to 1,000 cfs, which represents a clear water assumption for all low flows. The inflowing sediment load for 10,000 cfs was modeled at one half of the calculated equilibrium sediment load. Finally, the full calculated equilibrium sediment load was modeled for 220,000 cfs. This transition represents the reduced trap efficiency of the dam at higher flow rates when the dam is under greater submergence. The inflowing sediment load curve used in the HEC-6 model and the calculated equilibrium sediment load are both shown in Figure 4.

Hydrology

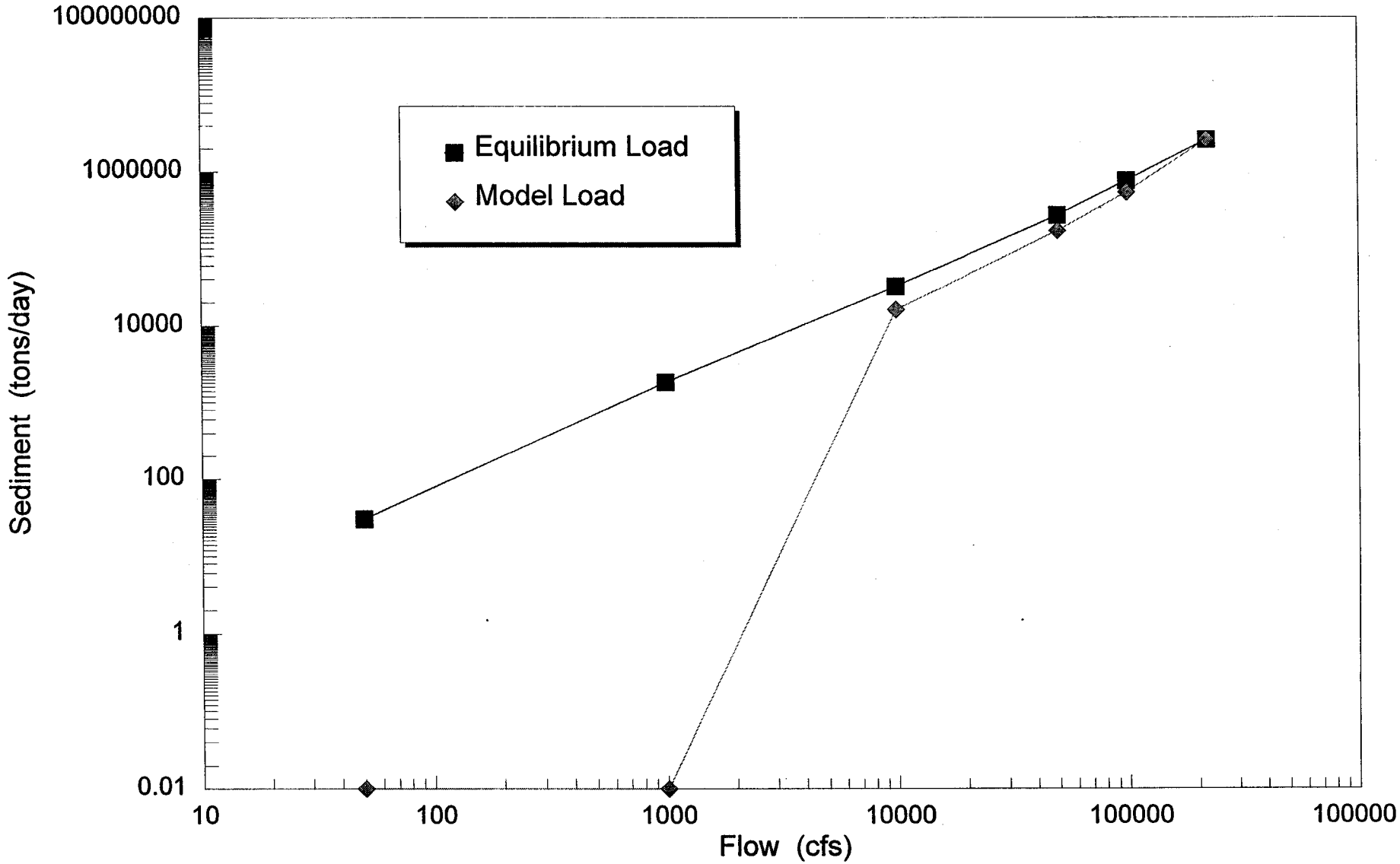
The HEC-6 model is typically not run for a single peak flow, since sediment transport and channel shaping functions are heavily influenced by the more frequent low intensity flows. Based on discussions with the Corps of Engineers, it was agreed that the impacts of mining would be simulated for a ten year period of record and a peak flow event approximating the 100-year peak flow.

Flow data at Granite Reef Dam were obtained for a fifty year period of record and analyzed for average daily flows and total annual flow volume. Within the 50 years of data, a representative ten year period of record (1983 - 1992) was then selected. The representative flows were analyzed using a sediment weighted histogram generator utility program. The program combines the flows over the ten-year period into a smaller number of simultaneous flows. This preserves the flow volume and the sediment transport potential, but requires significantly less computation time. Flows less than 50 cfs were then eliminated because very small flows will seep into the channel bottom and do not cause sediment transport in the channel. Figures 5 through 14 show the histogram data which was used in the HEC-6 model.

A hydrograph of the peak flow event was then added at the end of the ten-year flow period. The peak flow event is a single storm event with a peak discharge of 215,000 cfs and a hydrograph shape based on the documented shape of the 1980 flood hydrograph in the Salt River system below Granite Reef Dam. Figure 15 shows the 1980 flood hydrograph and the synthetic hydrograph used for the peak event in the HEC-6 model.

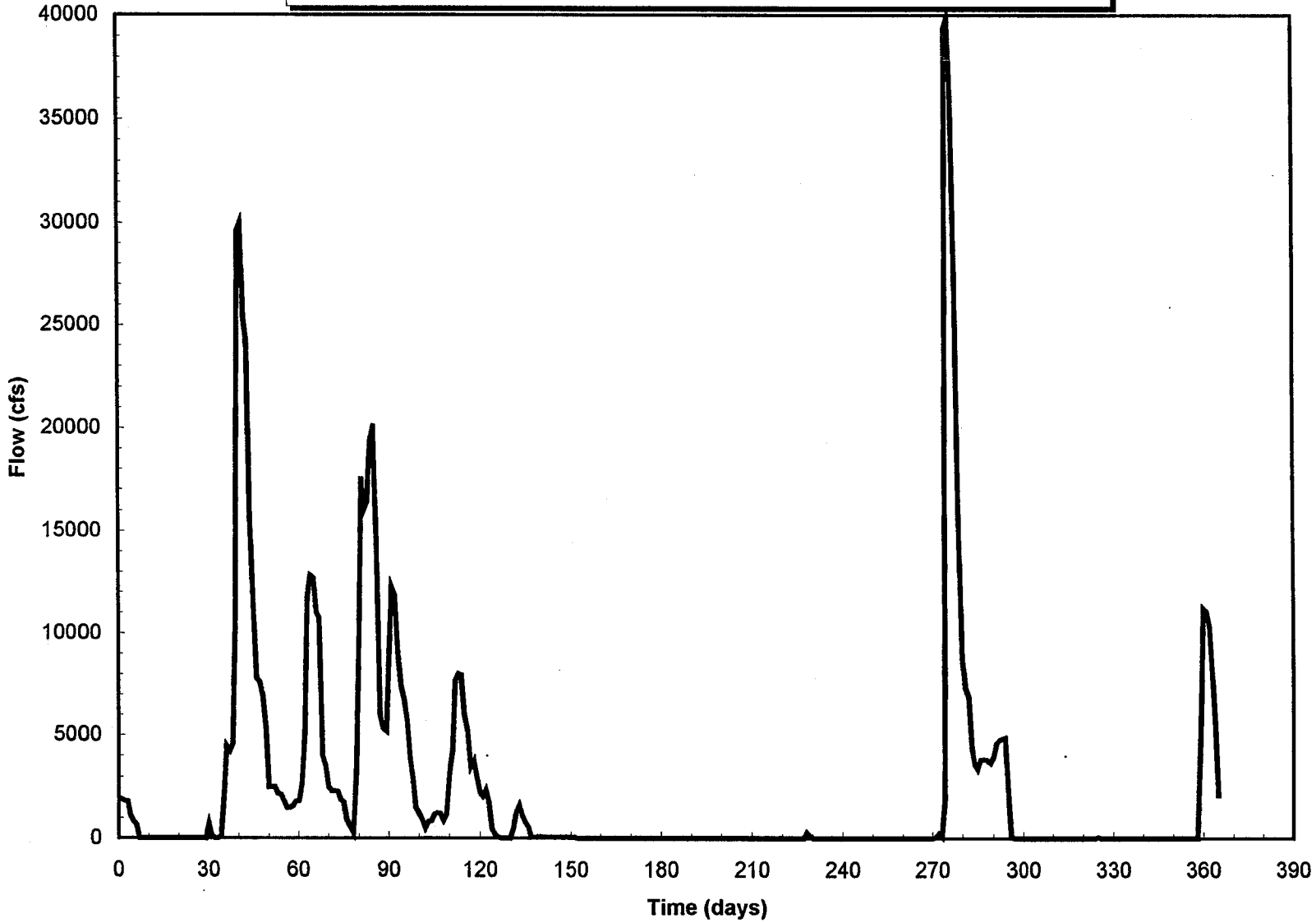
Salt River Sediment Trend Analysis

Figure 4 - Equilibrium Sediment Load at Granite Reef Dam



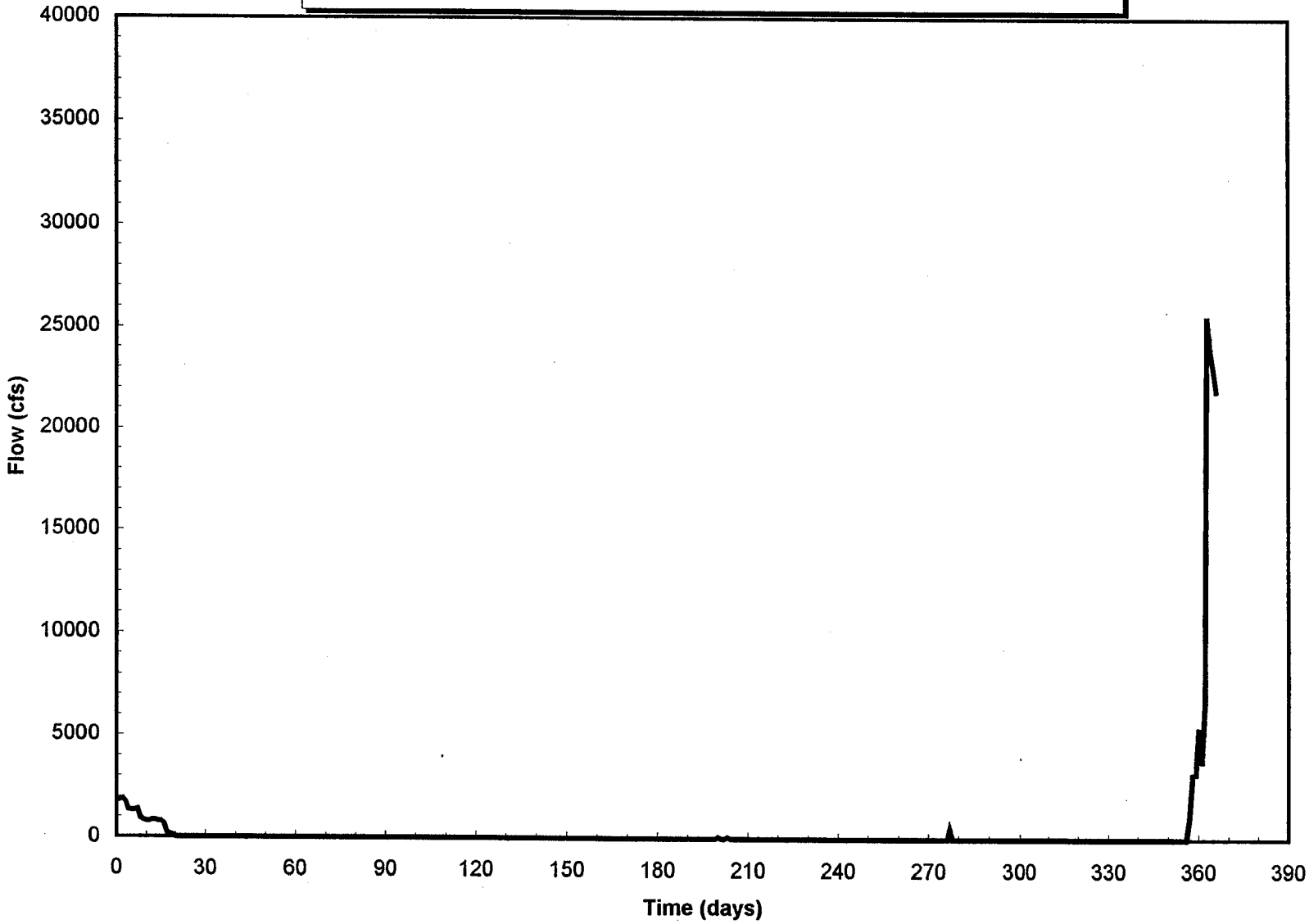
Salt River Sediment Trend Analysis

Figure 5 - 1983 Discharge Histogram



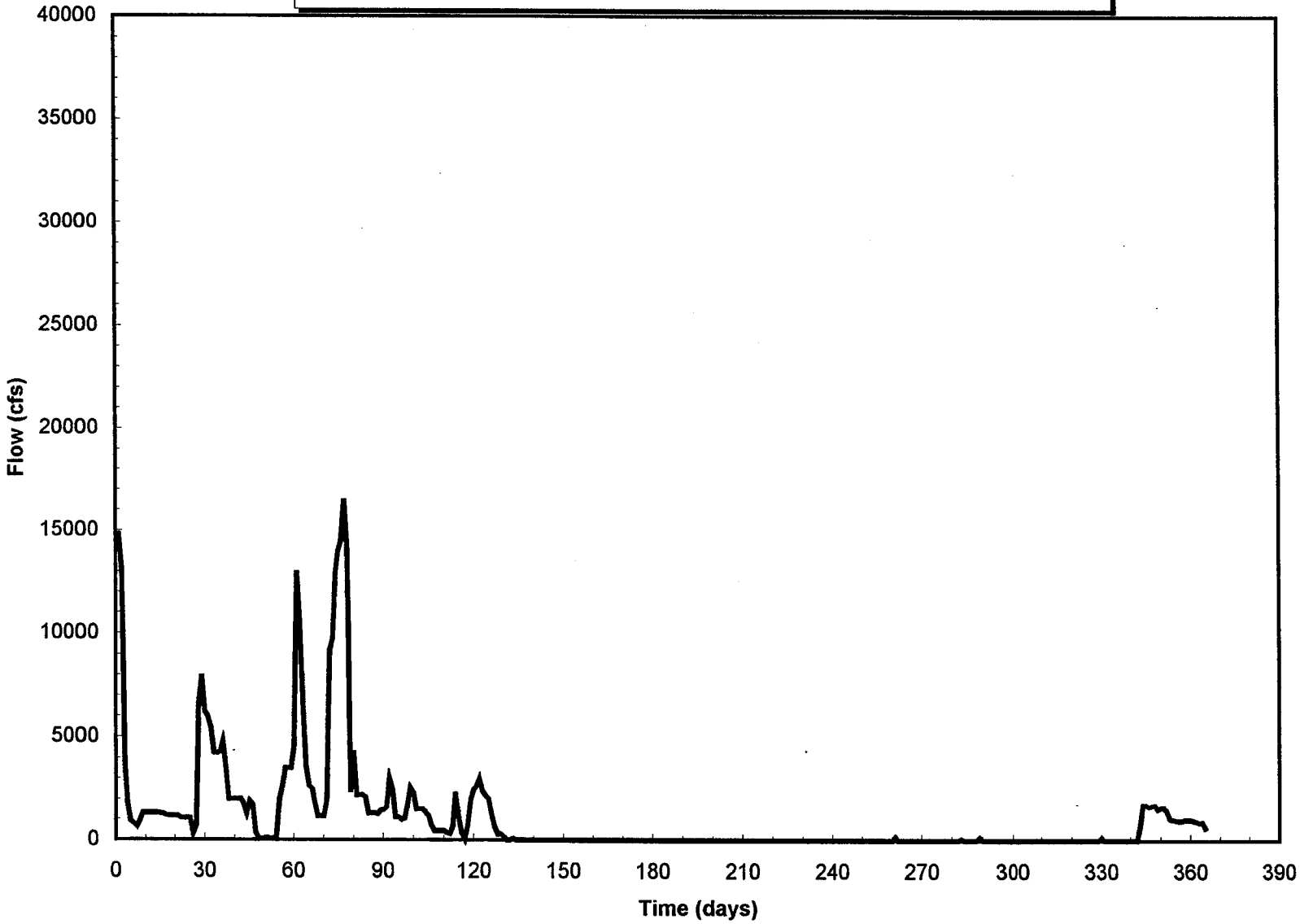
Salt River Sediment Trend Analysis

Figure 6 - 1984 Discharge Histogram



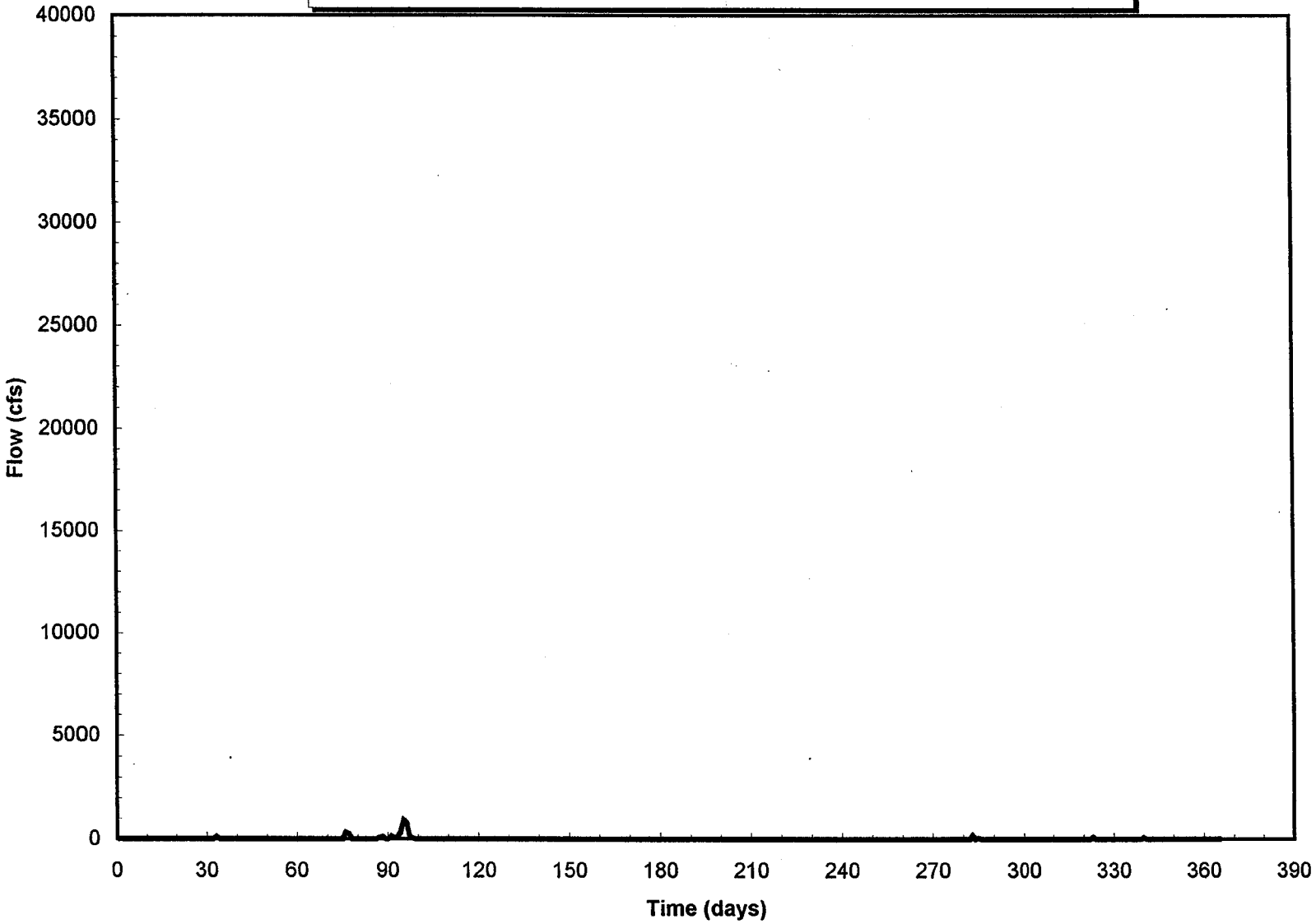
Salt River Sediment Trend Analysis

Figure 7 - 1985 Discharge Histogram



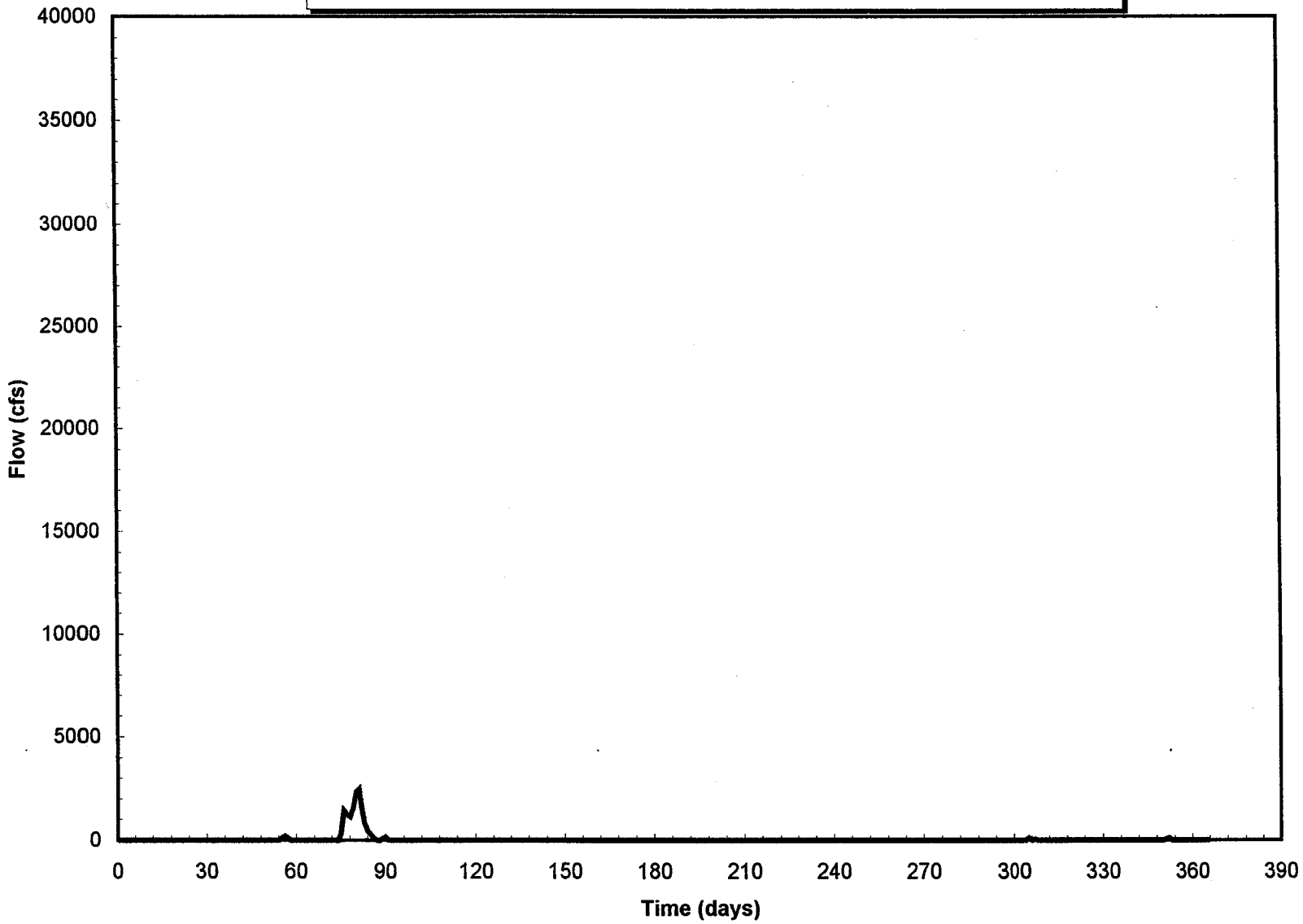
Salt River Sediment Trend Analysis

Figure 8 - 1986 Discharge Histogram



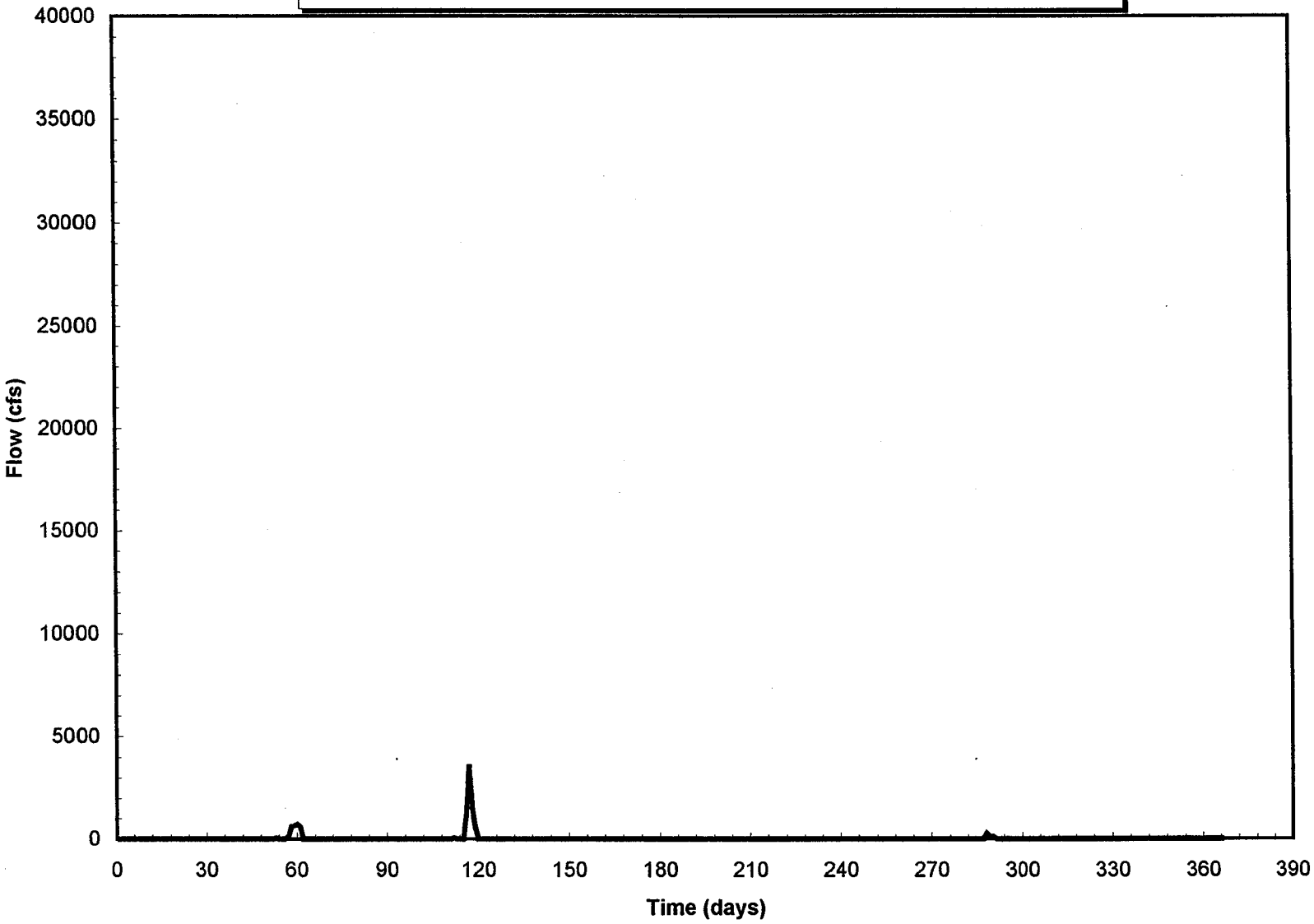
Salt River Sediment Trend Analysis

Figure 9 - 1987 Discharge Histogram



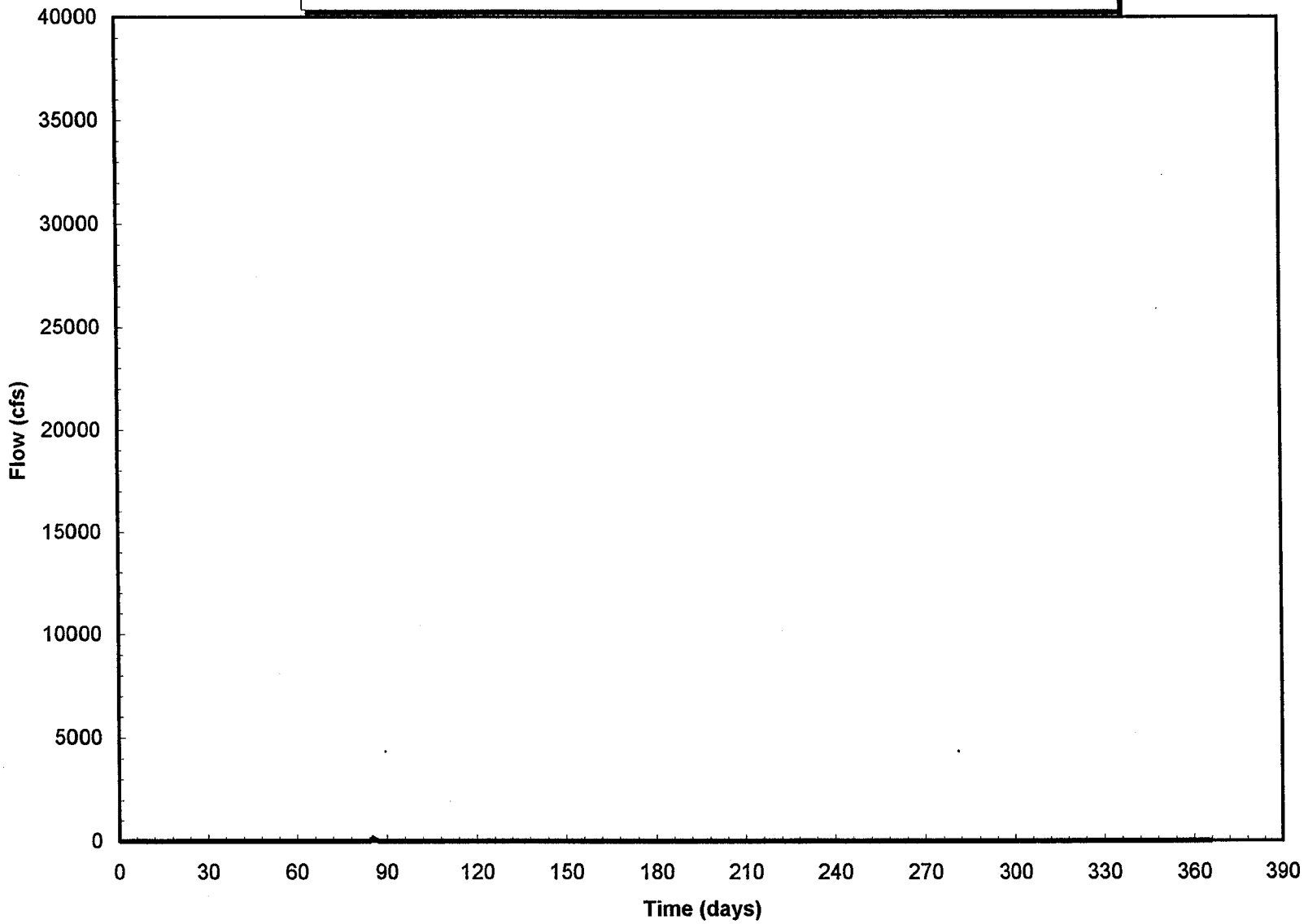
Salt River Sediment Trend Analysis

Figure 10 - 1988 Discharge Histogram



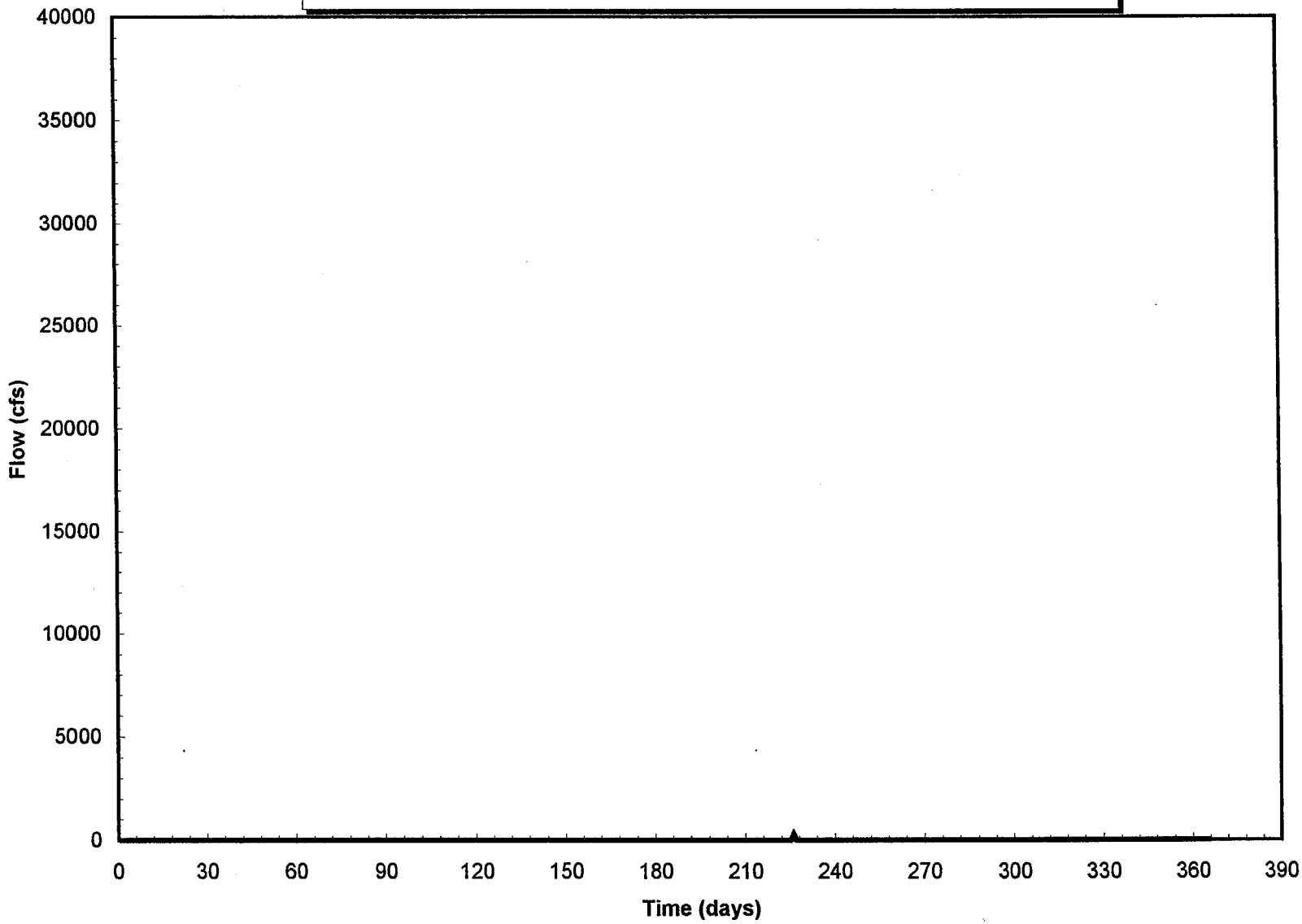
Salt River Sediment Trend Analysis

Figure 11 - 1989 Discharge Histogram



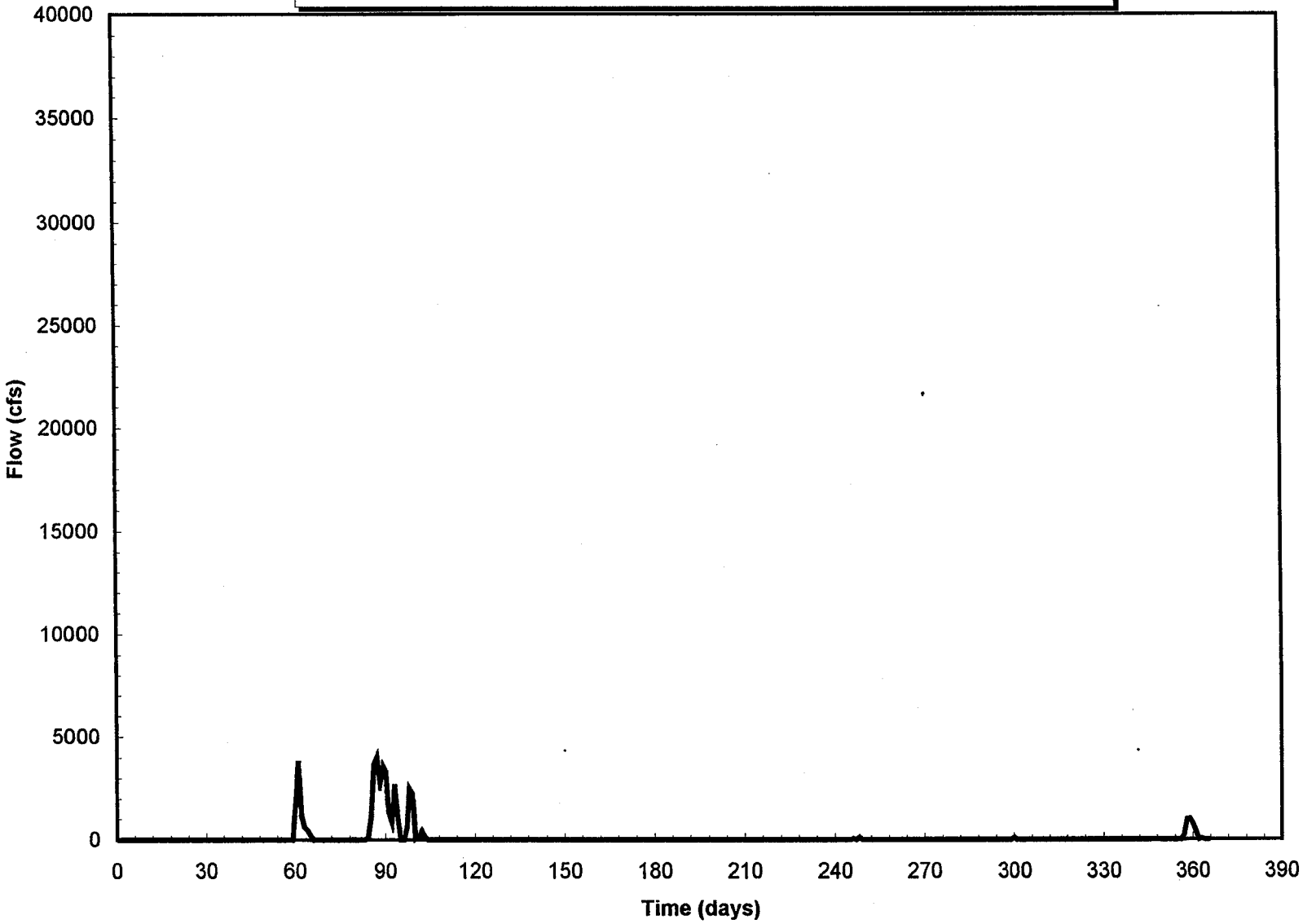
Salt River Sediment Trend Analysis

Figure 12 - 1990 Discharge Histogram



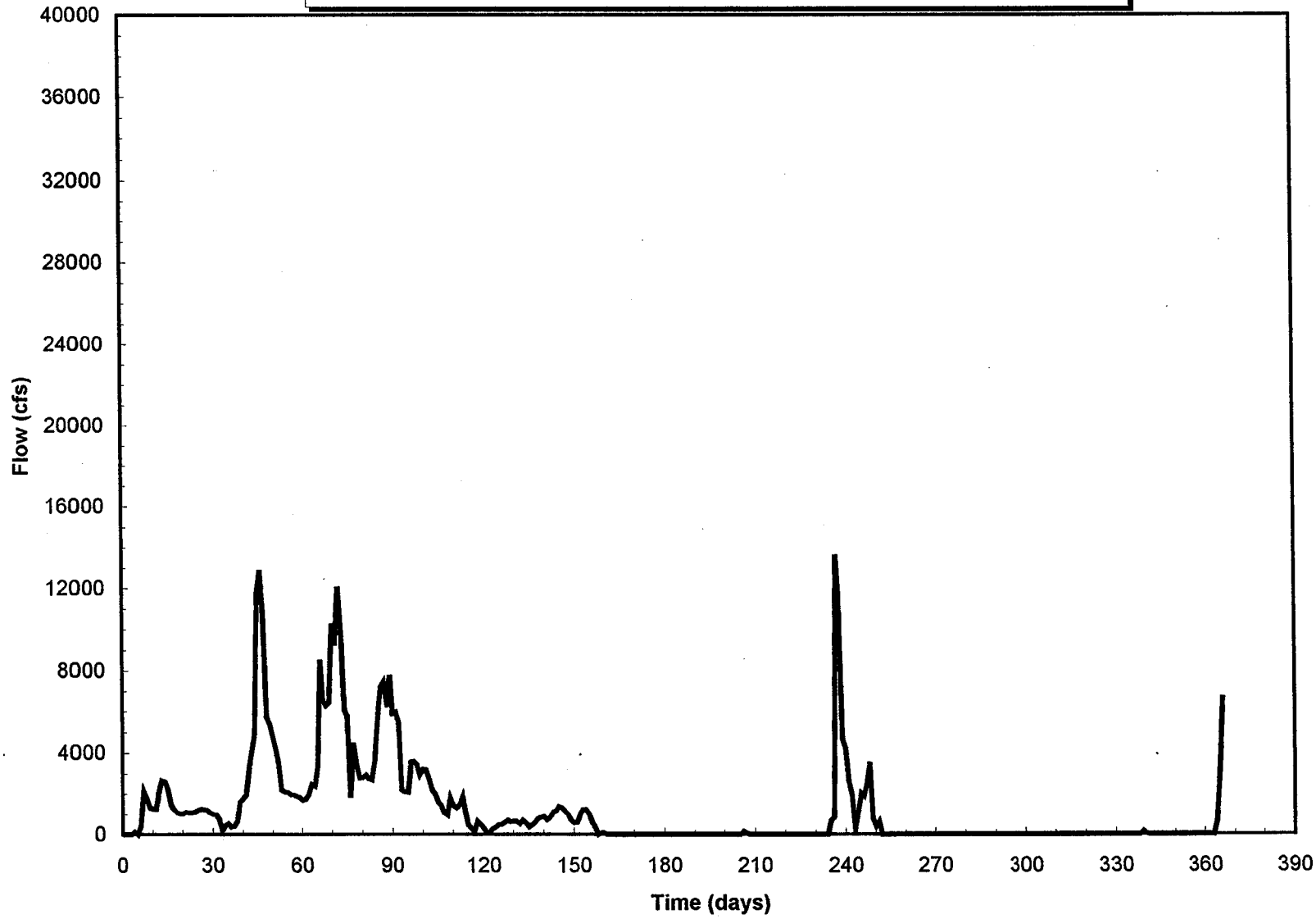
Salt River Sediment Trend Analysis

Figure 13 - 1991 Discharge Histogram



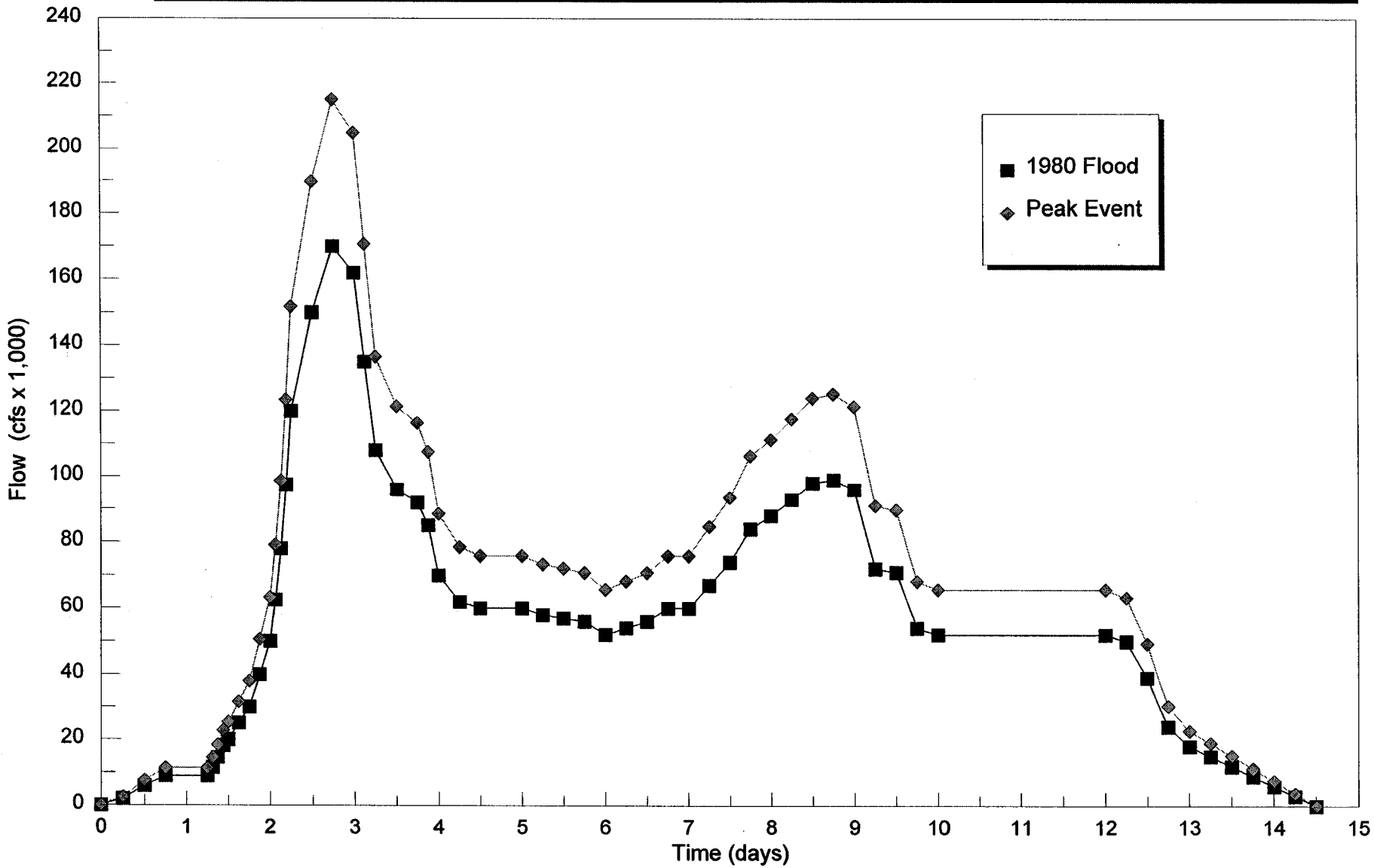
Salt River Sediment Trend Analysis

Figure 14 - 1992 Discharge Histogram



Salt River Sediment Trend Analysis

Figure 15 - Peak Event Hydrograph



5.0 Analysis of Results

General

The results of the two HEC-6 models were analyzed by coding HEC-6 to write output at the beginning of the model, at the end of each year of simulation, at the peak flow of the peak event, and at the end of the peak event. This HEC-6 output was then used to develop a table of average bed elevations at each cross section. Since the purpose of this study is to analyze sediment trends, the data was then adjusted using three point averaging. This provides a truly average bed result and facilitates the analysis of the results based on trends in the channel bed elevation. These average beds were then tabulated and graphed to facilitate the analysis of the bed changes during the simulation, the final bed elevations, and the lowest bed elevations.

Without Additional Mining

The without additional mining model shows a trend of minor aggradation in approximately 9.6 miles of the study reach from the confluence with the Gila River to 35th Avenue. The lowest bed elevations for fourteen out of twenty-six cross sections in the lower section occur at the beginning of the period of record. Sixteen out of twenty-six cross sections show some aggradation at the end of the period of record. The median aggradation amount for this lower section is 0.3 feet.

The middle 13.6 miles of the study reach between 35th Avenue and McClintock Drive are highly channelized and stabilized. The results reflect these conditions and show limited degradation over the period of record. Thirty-eight out of forty-seven cross sections in the middle section show degradation at the end of the period of record, however, the median degradation is only 1.6 feet.

The upper 14.5 miles between McClintock Drive and Granite Reef Dam are influenced by the sediment trapping efficiency of Granite Reef Dam and the upstream reservoirs. This is evident since thirty-one out of forty-two cross sections show degradation. The median amount of degradation over the period of record for the upper section is 2.4 feet. Moreover, the median amount of degradation for the 7.5 miles nearest to Granite Reef Dam is 4.2 feet.

These trends show that the Salt River system downstream of Granite Reef Dam is degrading, even without additional mining. The greatest degradation is shown in the upper section, with some degradation occurring in the middle section. The lower section,

however, shows some minor aggradation. The median degradation for the total study reach without additional mining is 1.5 feet.

With Additional Mining

The with additional mining model shows trends which can be analyzed based on the same three sections of the study reach used for the without additional mining analysis. The lower section shows degradation due to the influences of mining. The lowest bed elevations for sixteen out of twenty-six cross sections in the lower section occurred at the end of the first year. Furthermore, every cross section shows some degradation after the first year, with a median degradation after the first year of 7.2 feet. It can be seen, however, that the bed elevations partially recover at nineteen out of twenty-six cross sections over the remainder of the period of record. The median aggradation for the remainder of the period of record is 0.3 feet. The total median degradation over the period of record in the lower section is 5.1 feet.

The results in the middle section show reduced degradation due to the channelization and stabilization and due to the absence of additional mining activities in this section. Although forty-four out of forty-seven cross sections show degradation, the median degradation is only 3.3 feet, or a net additional median degradation of 1.7 feet.

The upper section is still influenced by Granite Reef Dam, however, the additional mining activities increase the degradation of the channel bed. Thirty-eight out of forty-two cross sections show degradation in the upper section. Twenty-two out of forty-two cross sections show some aggradation after the first year, with the median aggradation being 0.2 feet. The median amount of degradation over the period of record for the upper section is 9.3 feet, or a net additional median degradation of 6.9 feet. These results in the upper section show that mining increases degradation, however, they also show that the bed has a tendency to recover some of the degradation during the period of record. The section nearest to Granite Reef Dam, however, continues to degrade throughout the period of record, because of the sediment trapping efficiency of Granite Reef Dam.

The median degradation for the total study reach with additional mining is 4.0 feet or a net increase of 2.5 feet for the entire reach based on median values. The results of the HEC-6 models as described above are also summarized in Table 2.

Infrastructure

Once the average bed elevations were analyzed, it was necessary to project the effects the channel bed elevation changes could have on infrastructure crossing the Salt River. Plans for utility crossings, bridges, at grade crossings, and grade control structures in the study reach were researched and obtained when available. This resulted in data on

approximately 150 crossings of the Salt River, of which approximately 100 crossings were buried in the channel. The other 50 crossings are either overhead power lines without utility poles in the channel or are attached to the superstructure of a bridge. All identified utility crossings are listed in Table 3 and Table 4. They are located at the nearest cross section in the HEC-6 model. For the buried crossings, estimates of foundation types, depths, and other parameters were also determined for use in evaluating the effects of degradation. For bridges with spread footings, the top of the footing was identified. For bridges with caissons or piles, the tip of the pile/caisson was identified. For grade control structures, the downstream toe elevation was identified. For utility crossings, the top of the utility was identified. Lacking specific structural stability data, it was necessary to develop guidelines to determine threshold values for infrastructure that could be threatened by degradation as a result of additional mining. A comparative tolerance elevation was calculated at each crossing, to be compared to the channel bed elevation. Bridges were determined to require at least one-half of the remaining embedment or 15' of embedment, whichever is greater. Grade control structures were determined to require bed elevations higher than the downstream toe elevation. Utility crossings were determined to require one-half of the remaining embedment or 5' of embedment, whichever is greater.

It is important to note that the owners of these utility crossings have varied policies regarding allowable degradation at their structures. Kimley-Horn has discussed the study assumptions with all of the utility owners and some have provided input into the development of these comparative tolerance elevations. The definition of the comparative tolerance elevations was based primarily on a need for a consistent, quantitative way of grouping infrastructure into facilities which are potentially at risk and infrastructure not likely to be at risk.

The analysis of risk potential at the infrastructure crossings was based on the thalweg (lowest point) of the channel. This was necessary since the channel can meander significantly within the active bed of the Salt River. The results for each set of output were then compared to determine the worst case degradation at each cross section. This approach means that in the areas where the channel recovers from the effects of mining over the period of record, only the lowest bed elevations are used for comparison to the infrastructure.

The final results for the without additional mining model are reported in Table 3 and Figure 16 through Figure 23. The final results for the with additional mining model are reported in Table 4 and Figure 24 through Figure 31. Each of the figures shows five miles of the study reach, with the thalweg elevation, worst case bed elevation, and the final bed elevations. The tip/toe elevations of all of the buried utility crossings are also shown, with the comparative tolerance elevations shown for comparison to the degraded channel bed elevations.

The list of infrastructure potentially at risk due to the degradation in the without additional mining model is in Table 5. The list of infrastructure potentially at risk due to the degradation in the with additional mining model is in Table 6.

Salt River Sediment Trend Analysis
Table 2 - Summary of Results

26-Dec-96
hec6sum.wk4

Section Name	Section Description	Approximate Reach Length (miles)	Total Median Degradation Without Additional Mining (ft)	Total Median Degradation With Additional Mining (ft)	Total Median Degradation Difference (ft)
Lower	From Gila River Confluence to 35th Avenue	9.6	0.3	-5.1	5.4
Middle	From 35th Avenue to McClintock Drive	13.6	-1.6	-3.3	1.7
Upper	From McClintock Road to Granite Reef Dam	14.5	-2.4	-9.3	6.9
Total	From Gila River Confluence to Granite Reef Dam	37.7	-1.5	-4.0	2.5

Salt River Sediment Trend Analysis
Table 3 - Results Without Additional Mining

26-Dec-96
womine.wk4

Approx. River Mile	Description	Starting Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
199.91		932.10	-0.44	-0.21	931.66	931.89			
200.30	20" El Paso Natural Gas pipeline	937.70	-0.12	0.21	937.58	937.91	922.00	929.85	N
200.77		936.90	-0.28	0.12	936.62	937.02			
201.33		943.00	0.00	1.40	943.00	944.40			
201.81		946.00	0.00	1.98	946.00	947.98			
201.99		948.70	0.00	2.57	948.70	951.27			
202.29	12 KV SRP distribution line	955.50	0.00	2.39	955.50	957.89	no poles		
202.29	91st Avenue At GradeCrossing	955.50	0.00	2.39	955.50	957.89	955.50	953.50	N
202.80		956.40	0.00	2.78	956.40	959.18			
203.29	500 KV SRP transmission line	960.70	0.00	3.16	960.70	963.86	no poles		
203.96		964.10	0.00	1.49	964.10	965.59			
204.34	69 KV SRP transmission line	969.30	0.00	0.82	969.30	970.12	937.00	952.00	N
204.78		967.60	0.00	0.45	967.60	968.05			
204.97		973.30	0.00	1.33	973.30	974.63			
205.15	12 KV SRP distribution line	973.10	-0.42	-0.20	972.68	972.90	no poles		
205.15	67th Avenue At Grade Crossing	973.10	-0.42	-0.20	972.68	972.90	973.10	971.10	N
205.15	12" City of Phoenix water line	973.10	-0.42	-0.20	972.68	972.90	966.00	971.00	N
206.03		984.50	0.00	0.01	984.50	984.51			
206.51	230 KV and 69 KV SRP transmission lines	981.80	0.00	1.88	981.80	983.68	no poles		
206.79		981.80	0.00	5.43	981.80	987.23			
206.88		981.70	0.00	4.06	981.70	985.76			
207.07		992.80	-0.44	-0.44	992.36	992.36			
207.27		993.30	-3.57	-3.57	989.74	989.74			
207.49	54" City of Phoenix sewer siphon	992.20	-2.58	-2.58	989.62	989.62	955.00	973.60	N
207.49	51st Avenue Bridge	992.20	-2.58	-2.58	989.62	989.62	925.00	958.60	N
207.49	8" Santa Fe Petroleum Pipeline (SPPL)	992.20	-2.58	-2.58	989.62	989.62	attached to bridge		
207.49	48" City of Phoenix sewer siphon	992.20	-2.58	-2.58	989.62	989.62	956.00	974.10	N
207.49	12 KV SRP distribution line	992.20	-2.58	-2.58	989.62	989.62	no poles		
207.49	6" Santa Fe Petroleum Pipeline (SPPL)	992.20	-2.58	-2.58	989.62	989.62	attached to bridge		
207.99	16" El Paso Natural Gas pipeline	999.90	-1.59	-1.59	998.31	998.31	987.20	993.55	N
207.99	Two 230 KV WAPA transmission lines	999.90	-1.59	-1.59	998.31	998.31	no poles		
208.48	12 KV SRP distribution line	1007.60	-3.10	-2.99	1004.50	1004.61	no poles		
208.48	69 KV SRP transmission line	1007.60	-3.10	-2.99	1004.50	1004.61	978.00	992.80	N
208.95		1013.80	-6.44	-6.02	1007.36	1007.78			

15ft

Salt River Sediment Trend Analysis
Table 3 - Results Without Additional Mining

26-Dec-96
womine.wk4

Approx. River Mile	Description	Starting Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
209.33		1012.00	-8.03	-6.19	1003.97	1005.81			
209.54	35th Avenue Bridge	1009.40	-6.04	-5.34	1003.36	1004.06	930.00	969.70	N
209.54	48" City of Phoenix water line	1009.40	-6.04	-5.34	1003.36	1004.06	1008.00	1013.00	Y
210.07		1018.50	-2.24	-2.24	1016.27	1016.27			
210.36		1017.40	0.00	0.63	1017.40	1018.03			
210.64		1017.70	0.00	1.88	1017.70	1019.58			
210.93		1018.70	0.00	2.79	1018.70	1021.49			
211.21		1021.10	0.00	1.19	1021.10	1022.29			
211.37		1027.10	0.00	0.49	1027.10	1027.59			
211.41		1028.00	-1.06	-1.06	1026.94	1026.94			
211.45	12 KV SRP distribution line	1027.10	-1.77	-1.77	1025.33	1025.33	attached to bridge		
211.45	19th Ave Bridge	1027.10	-1.77	-1.77	1025.33	1025.33	915.00	967.50	N
211.45	GCS downstream of 19th Avenue	1027.10	-1.77	-1.77	1025.33	1025.33	980.83	980.83	N
211.45	8" and 20" City of Phoenix water lines	1027.10	-1.77	-1.77	1025.33	1025.33	attached to bridge		
211.89		1029.90	-3.53	-3.53	1026.37	1026.37			
212.37		1036.60	-5.55	-5.55	1031.05	1031.05			
212.68	7th Ave Bridge	1036.90	-5.71	-5.41	1031.19	1031.49	945.00	990.95	N
213.26	US WEST telephone duct	1040.40	-3.28	-3.28	1037.12	1037.12	attached to bridge		
213.26	Central Avenue Bridge	1040.40	-3.28	-3.28	1037.12	1037.12	1010.00	1025.20	N
213.75	7th Street Bridge	1044.60	-1.21	-1.04	1043.39	1043.56	945.00	994.80	N
213.75	US SPRINT telephone duct	1044.60	-1.21	-1.04	1043.39	1043.56	attached to bridge		
213.75	10" Southwest Gas gas pipeline	1044.60	-1.21	-1.04	1043.39	1043.56	1042.00	1047.00	Y
214.14		1048.70	0.00	1.42	1048.70	1050.12			
214.52		1048.00	0.00	1.95	1048.00	1049.95			
214.79	36" City of Phoenix water line	1057.60	0.00	2.10	1057.60	1059.70	1038.00	1048.40	N
214.79	16th Street Bridge	1057.60	0.00	2.10	1057.60	1059.70	950.00	1004.40	N
214.79	36" City of Phoenix water line	1057.60	0.00	2.10	1057.60	1059.70	1043.00	1050.90	N
214.79	12KV SRP distribution line	1057.60	0.00	2.10	1057.60	1059.70	attached to bridge		
215.09		1061.70	-0.67	-0.58	1061.03	1061.12			
215.65		1068.30	-3.64	-3.35	1064.66	1064.95			
215.82	24th Street Bridge	1076.00	-4.66	-4.41	1071.34	1071.59	1013.00	1044.50	N
216.29		1080.80	-4.34	-4.14	1076.46	1076.66			
216.33	GCS downstream of I-10	1082.00	-2.42	-2.33	1079.58	1079.67	1075.50	1075.50	N
216.37		1080.80	-2.26	-2.08	1078.54	1078.72			

Salt River Sediment Trend Analysis
Table 3 - Results Without Additional Mining

26-Dec-96
womine.wk4

Approx. River Mile	Description	Starting Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
216.52	I-10 Bridge	1083.20	-1.07	-0.81	1082.13	1082.39	1070.00	1068.20	N
217.00		1085.70	-3.32	-3.10	1082.38	1082.60			
217.82	APS transmission line	1101.30	-4.85	-4.64	1096.45	1096.66	1004.00	1044	N
217.86	GCS between I-10 and SR 153	1101.30	-7.35	-7.09	1093.95	1094.21	1057.20	1057.20	N
217.90	City of Phoenix water lines in Salt River	1101.30	-5.79	-5.31	1095.51	1095.99	varies		
217.90	City of Phoenix sewer lines in Salt River	1101.30	-5.79	-5.31	1095.51	1095.99	varies		
218.33		1102.70	-4.23	-4.03	1098.47	1098.67			
218.92	60" City of Phoenix water line	1112.80	-2.73	-2.73	1110.07	1110.07	1086.00	1098.50	N
218.92	GCS downstream of SR 153	1112.80	-2.73	-2.73	1110.07	1110.07	1075.40	1075.40	N
218.96	SR-153 Sky Harbor Expressway Bridge	1113.50	-2.47	-2.47	1111.03	1111.03	1037.00	1074.90	N
219.00		1112.80	-1.97	-1.97	1110.83	1110.83			
219.03	US WEST and AT&T telephone duct	1112.90	-1.29	-1.29	1111.61	1111.61	1097.50	1106.85	N
219.03	18" City of Phoenix sewer siphon	1112.90	-1.29	-1.29	1111.61	1111.61	1099.00	1106.85	N
219.03	12" Southwest Gas gas pipeline	1112.90	-1.29	-1.29	1111.61	1111.61	1096.00	1105.35	N
219.03	SR-143 Hohokam Freeway Bridge	1112.90	-1.29	-1.29	1111.61	1111.61	1045.00	1078.95	N
219.03	48" City of Phoenix sewer siphon	1112.90	-1.29	-1.29	1111.61	1111.61	1097.00	1105.85	N
219.51		1117.30	-1.33	-1.33	1115.97	1115.97			
220.04		1122.90	-1.66	-1.66	1121.24	1121.24			
220.06	69 KV SRP transmission line	1122.90	-1.56	-1.56	1121.34	1121.34	no poles		
220.06	69 KV APS transmission line	1122.90	-1.56	-1.56	1121.34	1121.34	no poles		
220.06	36" City of Tempe water line	1122.90	-1.56	-1.56	1121.34	1121.34	1116.00	1121.00	N
220.06	Priest Drive Bridge	1122.90	-1.56	-1.56	1121.34	1121.34	1100.00	1107.90	N
220.06	48" City of Tempe sewer siphon	1122.90	-1.56	-1.56	1121.34	1121.34	1116.00	1121.00	N
220.88	6" Southwest Gas gas pipeline	1126.00	-0.80	-0.80	1125.20	1125.20	1124.00	1129.00	Y
220.92	GCS downstream of Southern Pacific Railroad	1129.40	-0.40	-0.25	1129.00	1129.15	1101.00	1101.00	N
220.96	Southern Pacific Transportation Company line	1126.00	-0.60	-0.06	1125.40	1125.94	attached to bridge		
220.96	12 KV APS distribution line	1126.00	-0.60	-0.06	1125.40	1125.94	no poles		
220.96	MCI Communications line	1126.00	-0.60	-0.06	1125.40	1125.94	attached to bridge		
220.96	Southern Pacific Railroad Bridge	1126.00	-0.60	-0.06	1125.40	1125.94	1100.00	1111.00	N
221.19	APS distribution duct	1126.00	-0.69	-0.18	1125.31	1125.82	attached to bridge		
221.19	230 KV SRP transmission line	1126.00	-0.69	-0.18	1125.31	1125.82	no poles		
221.19	Old Mill Avenue Bridge	1126.00	-0.69	-0.18	1125.31	1125.82	1100.00	1113.00	N
221.19	12" City of Tempe reclaimed water line	1126.00	-0.69	-0.18	1125.31	1125.82	attached to bridge		
221.19	US WEST telephone duct	1126.00	-0.69	-0.18	1125.31	1125.82	attached to bridge		

Salt River Sediment Trend Analysis 26-Dec-96
Table 3 - Results Without Additional Mining womine.wk4

Approx. River Mile	Description	Starting Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
221.26	8" Southwest Gas gas line	1130.00	-0.17	-0.07	1129.83	1129.93	attached to bridge		
221.26	New Mill Avenue Bridge	1130.00	-0.17	-0.07	1129.83	1129.93	1114.00	1115.00	N
221.26	US WEST telephone duct	1130.00	-0.17	-0.07	1129.83	1129.93	attached to bridge		
221.26	6" AP&C Nitrogen Gas line	1130.00	-0.17	-0.07	1129.83	1129.93	attached to bridge		
221.26	12" City of Tempe water main	1130.00	-0.17	-0.07	1129.83	1129.93	attached to bridge		
221.70		1134.00	-0.61	-0.40	1133.39	1133.60			
222.09	Rural Road Bridge	1136.00	-0.79	-0.45	1135.21	1135.55	1085.00	1110.50	N
222.09	US WEST telephone cable	1136.00	-0.79	-0.45	1135.21	1135.55	attached to bridge		
222.09	21"/18" City of Tempe sewer siphon	1136.00	-0.79	-0.45	1135.21	1135.55	1126.00	1131.00	N
222.09	30" City of Tempe water line	1136.00	-0.79	-0.45	1135.21	1135.55	1125.00	1130.50	N
222.55	230 KV and 69KV SRP transmission lines	1139.00	-2.26	-1.97	1136.74	1137.03	no poles		
222.93	69 KV APS transmission line	1140.00	-1.90	-1.83	1138.10	1138.17	1046.00	1095	N
223.07	12" Southwest Gas gas pipeline	1150.00	-1.65	-1.65	1148.35	1148.35	1126.00	1137.00	N
223.07	36" City of Tempe water line	1146.30	-1.65	-1.65	1144.65	1144.65	1141.50	1146.50	Y
223.07	18" City of Mesa sewer siphon	1150.00	-1.65	-1.65	1148.35	1148.35	1126.50	1137.25	N
223.07	21" City of Mesa sewer siphon	1150.00	-1.65	-1.65	1148.35	1148.35	1127.00	1137.50	N
223.07	10" Southwest Gas gas pipeline	1150.00	-1.65	-1.65	1148.35	1148.35	1126.00	1137.00	N
223.09	GCS downstream of McClintock Drive	1146.30	-0.37	-0.37	1145.93	1145.93	1131.20	1131.20	N
223.11	McClintock Drive Bridge	1150.00	0.00	2.85	1150.00	1152.85	1046.00	1096.15	N
223.67	Loop 202, Red Mountain Freeway Bridge	1132.70	0.00	2.85	1132.70	1135.55	1010.00	1073.15	N
224.09	Loop 101, Pima Freeway Bridge	1152.00	0.00	7.13	1152.00	1159.13	1038.00	1095.00	N
224.25		1152.00	0.00	4.64	1152.00	1156.64			
224.43		1158.40	0.00	3.65	1158.40	1162.05			
224.81		1162.10	0.00	2.16	1162.10	1164.26			
225.28		1163.00	0.00	2.99	1163.00	1165.99			
225.66		1158.80	0.00	1.71	1158.80	1160.51			
226.04		1173.10	-2.62	-1.37	1170.48	1171.73			
226.23		1177.60	-3.53	-2.97	1174.07	1174.64			
226.48		1180.50	-2.89	-2.78	1177.61	1177.72			
226.52	GCS downstream of Alma School Road	1186.00	-0.11	-0.05	1185.89	1185.95	1161.00	1161.00	N
226.52		1186.00	-0.11	-0.05	1185.89	1185.95			
226.56	12 KV SRP distribution line	1180.50	-1.41	-1.37	1179.09	1179.13	no poles		
226.56	Alma School Road Bridges	1180.50	-1.41	-1.37	1179.09	1179.13	1148.00	1164.25	N
226.80	McKellips Road At Grade Crossing	1191.70	-2.54	-2.48	1189.16	1189.22	1191.70	1189.70	Y

Salt River Sediment Trend Analysis
Table 3 - Results Without Additional Mining

26-Dec-96
womine.wk4

Approx. River Mile	Description	Starting Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
227.08		1194.10	-3.20	-2.88	1190.90	1191.22			
227.46		1194.10	-1.89	-1.47	1192.21	1192.63			
227.63	4" City of Mesa gas pipeline	1194.90	-0.73	-0.73	1194.17	1194.17	1175.20	1185.05	N
227.63	Country Club Drive Bridge	1194.90	-0.73	-0.73	1194.17	1194.17	1111.00	1152.95	N
227.88		1196.80	0.00	0.55	1196.80	1197.35			
228.17		1197.20	0.00	2.20	1197.20	1199.40			
228.64		1201.30	0.00	2.74	1201.30	1204.04			
229.12		1206.10	0.00	2.18	1206.10	1208.28			
229.40		1207.70	-1.45	-1.45	1206.25	1206.25			
229.68		1215.40	-2.88	-2.88	1212.52	1212.52			
230.09		1219.00	-5.84	-5.84	1213.16	1213.16			
230.47		1227.40	-7.35	-7.35	1220.05	1220.05			
230.94		1232.00	-9.83	-9.81	1222.17	1222.19			
231.32		1236.00	-9.92	-9.69	1226.08	1226.31			
231.56	Gilbert Road Bridge	1239.90	-8.01	-8.01	1231.89	1231.89	1159.00	1199.45	N
231.56	Two 230 KV WAPA transmission lines	1239.90	-8.01	-8.01	1231.89	1231.89	1230.50	1235.50	Y
231.89		1246.10	-5.70	-5.52	1240.40	1240.58			
232.45		1247.80	-3.48	-3.20	1244.32	1244.60			
232.74		1249.10	-2.43	-2.17	1246.67	1246.93			
233.03		1253.70	-2.30	-2.30	1251.40	1251.40			
233.51		1256.20	-3.57	-3.57	1252.63	1252.63			
233.95	Grusp canal crossing	1258.50	-4.22	-4.22	1254.28	1254.28	at grade		
234.53		1265.80	-4.08	-4.08	1261.72	1261.72			
235.01		1266.70	-4.11	-4.11	1262.59	1262.59			
235.38		1271.50	-2.98	-2.98	1268.52	1268.52			
235.67		1271.90	-2.38	-2.38	1269.52	1269.52			
236.05		1274.80	-2.02	-2.02	1272.78	1272.78			
236.43		1276.80	-3.45	-3.45	1273.35	1273.35			
236.81		1278.30	-5.62	-5.62	1272.68	1272.68			
237.19		1282.50	-7.04	-7.04	1275.46	1275.46			
237.59	69 KV SRP transmission line	1288.40	-8.03	-8.03	1280.37	1280.37	no poles		
237.59	21' CAP Canal siphon	1288.40	-8.03	-8.03	1280.37	1280.37	1258.40	1275.40	N

Salt River Sediment Trend Analysis

Table 4 - Results With Additional Mining (20 ft Average Depth)

26-Dec-96

wmine.wk4

Approx. River Mile	Description	Minimum Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
199.91		932.10	-0.53	-0.28	931.57	931.83			
200.30	20" El Paso Natural Gas pipeline	937.70	-0.40	-0.07	937.30	937.63	922.00	929.85	N
200.77		936.90	-1.01	-0.67	935.89	936.23			
201.33		943.00	-0.79	-0.16	942.21	942.84			
201.81		946.00	-1.29	-0.37	944.71	945.63			
201.99		948.70	-2.67	-0.86	946.03	947.84			
202.29	12 KV SRP distribution line	955.50	-4.32	-1.93	951.18	953.57	no poles		
202.29	91st Avenue At GradeCrossing	955.50	-4.32	-1.93	951.18	953.57	955.50	953.50	Y
202.80		956.40	-5.22	-2.39	951.18	954.01			
203.29	500 KV SRP transmission line	960.70	-5.54	-2.64	955.16	958.06	no poles		
203.96		964.10	-6.71	-3.74	957.39	960.36			
204.34	69 KV SRP transmission line	969.30	-7.54	-4.88	961.76	964.42	937.00	952.00	N
204.78		967.60	-7.48	-5.36	960.12	962.24			
204.97		973.30	-6.82	-5.22	966.48	968.08			
205.15	12 KV SRP distribution line	973.10	-9.12	-8.27	963.98	964.83	no poles		
205.15	67th Avenue At Grade Crossing	973.10	-9.12	-8.27	963.98	964.83	973.10	971.10	Y
205.15	12" City of Phoenix water line	973.10	-9.12	-8.27	963.98	964.83	966.00	971.00	Y
206.03		984.50	-9.11	-8.56	975.39	975.94			
206.51	230 KV and 69 KV SRP transmission lines	981.80	-7.54	-7.49	974.26	974.31	no poles		
206.79		981.80	-3.26	-2.93	978.54	978.87			
206.88		981.70	-4.80	-4.80	976.90	976.90			
207.07		992.80	-8.88	-8.61	983.92	984.19			
207.27		993.30	-11.89	-11.75	981.41	981.55			
207.49	54" City of Phoenix sewer siphon	992.20	-11.11	-11.11	981.09	981.09	955.00	973.60	N
207.49	51st Avenue Bridge	992.20	-11.11	-11.11	981.09	981.09	925.00	958.60	N
207.49	8" Santa Fe Petroleum Pipeline (SPPL)	992.20	-11.11	-11.11	981.09	981.09	attached to bridge		
207.49	48" City of Phoenix sewer siphon	992.20	-11.11	-11.11	981.09	981.09	956.00	974.10	N
207.49	12 KV SRP distribution line	992.20	-11.11	-11.11	981.09	981.09	no poles		
207.49	6" Santa Fe Petroleum Pipeline (SPPL)	992.20	-11.11	-11.11	981.09	981.09	attached to bridge		
207.99	16" El Paso Natural Gas pipeline	999.90	-12.10	-12.10	987.80	987.80	987.20	993.55	Y
207.99	Two 230 KV WAPA transmission lines	999.90	-12.10	-12.10	987.80	987.80	no poles		
208.48	12 KV SRP distribution line	1007.60	-13.06	-13.06	994.54	994.54	no poles		
208.48	69 KV SRP transmission line	1007.60	-13.06	-13.06	994.54	994.54	978.00	992.80	N
208.95		1013.80	-15.09	-15.09	998.71	998.71			

Salt River Sediment Trend Analysis 26-Dec-96

Table 4 - Results With Additional Mining (20 ft Average Depth) wmine.wk4

Approx. River Mile	Description	Minimum Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
209.33		1012.00	-12.96	-12.63	999.04	999.38			
209.54	35th Avenue Bridge	1009.40	-11.04	-10.61	998.36	998.79	930.00	969.70	N
209.54	48" City of Phoenix water line	1009.40	-11.04	-10.61	998.36	998.79	1008.00	1013.00	Y
210.07		1018.50	-5.99	-5.54	1012.51	1012.96			
210.36		1017.40	-4.55	-3.13	1012.85	1014.27			
210.64		1017.70	-2.61	-1.59	1015.09	1016.11			
210.93		1018.70	-1.93	-1.93	1016.77	1016.77			
211.21		1021.10	-3.34	-3.34	1017.76	1017.76			
211.37		1027.10	-4.57	-4.57	1022.53	1022.53			
211.41		1028.00	-6.08	-6.08	1021.92	1021.92			
211.45	12 KV SRP distribution line	1027.10	-7.71	-7.71	1019.39	1019.39	attached to bridge		
211.45	19th Ave Bridge	1027.10	-7.71	-7.71	1019.39	1019.39	915.00	967.50	N
211.45	GCS downstream of 19th Avenue	1027.10	-7.71	-7.71	1019.39	1019.39	980.83	980.83	N
211.45	8" and 20" City of Phoenix water lines	1027.10	-7.71	-7.71	1019.39	1019.39	attached to bridge		
211.89		1029.90	-10.00	-10.00	1019.90	1019.90			
212.37		1036.60	-11.69	-11.69	1024.91	1024.91			
212.68	7th Ave Bridge	1036.90	-10.50	-10.50	1026.40	1026.40	945.00	990.95	N
213.26	US WEST telephone duct	1040.40	-6.89	-6.89	1033.51	1033.51	attached to bridge		
213.26	Central Avenue Bridge	1040.40	-6.89	-6.89	1033.51	1033.51	1010.00	1025.20	N
213.75	7th Street Bridge	1044.60	-3.30	-3.30	1041.30	1041.30	945.00	994.80	N
213.75	US SPRINT telephone duct	1044.60	-3.30	-3.30	1041.30	1041.30	attached to bridge		
213.75	10" Southwest Gas gas pipeline	1044.60	-3.30	-3.30	1041.30	1041.30	1042.00	1047.00	Y
214.14		1048.70	-0.17	-0.02	1048.53	1048.68			
214.52		1048.00	0.00	1.01	1048.00	1049.01			
214.79	36" City of Phoenix water line	1057.60	0.00	1.34	1057.60	1058.94	1038.00	1048.40	N
214.79	16th Street Bridge	1057.60	0.00	1.34	1057.60	1058.94	950.00	1004.40	N
214.79	36" City of Phoenix water line	1057.60	0.00	1.34	1057.60	1058.94	1043.00	1050.90	N
214.79	12KV SRP distribution line	1057.60	0.00	1.34	1057.60	1058.94	attached to bridge		
215.09		1061.70	-1.15	-0.89	1060.55	1060.82			
215.65		1068.30	-3.96	-3.62	1064.34	1064.68			
215.82	24th Street Bridge	1076.00	-4.89	-4.63	1071.11	1071.37	1013.00	1044.50	N
216.29		1080.80	-4.38	-4.18	1076.42	1076.62			
216.33	GCS downstream of I-10	1082.00	-2.45	-2.31	1079.55	1079.69	1075.50	1075.50	N
216.37		1080.80	-2.46	-2.19	1078.34	1078.61			

Salt River Sediment Trend Analysis 26-Dec-96

Table 4 - Results With Additional Mining (20 ft Average Depth) wmine.wk4

Approx. River Mile	Description	Minimum Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
216.52	I-10 Bridge	1083.20	-1.35	-1.08	1081.85	1082.12	1070.00	1068.20	N
217.00		1085.70	-3.48	-3.32	1082.22	1082.38			
217.82	APS transmission line	1101.30	-4.90	-4.73	1096.40	1096.57	1004.00	1044	N
217.86	GCS between I-10 and SR 153	1101.30	-7.24	-7.02	1094.06	1094.28	1057.20	1057.20	N
217.90	City of Phoenix water lines in Salt River	1101.30	-5.80	-5.46	1095.50	1095.84	varies		
217.90	City of Phoenix sewer lines in Salt River	1101.30	-5.80	-5.46	1095.50	1095.84	varies		
218.33		1102.70	-4.44	-4.35	1098.26	1098.35			
218.92	60" City of Phoenix water line	1112.80	-3.29	-3.29	1109.51	1109.51	1086.00	1098.50	N
218.92	GCS downstream of SR 153	1112.80	-3.29	-3.29	1109.51	1109.51	1075.40	1075.40	N
218.96	SR-153 Sky Harbor Expressway Bridge	1113.50	-3.14	-3.14	1110.36	1110.36	1037.00	1074.90	N
219.00		1112.80	-2.72	-2.72	1110.08	1110.08			
219.03	US WEST and AT&T telephone duct	1112.90	-2.51	-2.51	1110.39	1110.39	1097.50	1106.85	N
219.03	18" City of Phoenix sewer siphon	1112.90	-2.51	-2.51	1110.39	1110.39	1099.00	1106.85	N
219.03	12" Southwest Gas gas pipeline	1112.90	-2.51	-2.51	1110.39	1110.39	1096.00	1105.35	N
219.03	SR-143 Hohokam Freeway Bridge	1112.90	-2.51	-2.51	1110.39	1110.39	1045.00	1078.95	N
219.03	48" City of Phoenix sewer siphon	1112.90	-2.51	-2.51	1110.39	1110.39	1097.00	1105.85	N
219.51		1117.30	-3.00	-3.00	1114.30	1114.30			
220.04		1122.90	-4.00	-4.00	1118.90	1118.90			
220.06	69 KV SRP transmission line	1122.90	-3.52	-3.52	1119.38	1119.38	no poles		
220.06	69 KV APS transmission line	1122.90	-3.52	-3.52	1119.38	1119.38	no poles		
220.06	36" City of Tempe water line	1122.90	-3.52	-3.52	1119.38	1119.38	1116.00	1121.00	Y
220.06	Priest Drive Bridge	1122.90	-3.52	-3.52	1119.38	1119.38	1100.00	1107.90	N
220.06	48" City of Tempe sewer siphon	1122.90	-3.52	-3.52	1119.38	1119.38	1116.00	1121.00	Y
220.88	6" Southwest Gas gas pipeline	1126.00	-2.06	-2.06	1123.94	1123.94	1124.00	1129.00	Y
220.92	GCS downstream of Southern Pacific Railroad	1129.40	-1.02	-0.97	1128.38	1128.43	1101.00	1101.00	N
220.96	Southern Pacific Transportation Company line	1126.00	-0.85	-0.81	1125.15	1125.19	attached to bridge		
220.96	12 KV APS distribution line	1126.00	-0.85	-0.81	1125.15	1125.19	no poles		
220.96	MCI Communications line	1126.00	-0.85	-0.81	1125.15	1125.19	attached to bridge		
220.96	Southern Pacific Railroad Bridge	1126.00	-0.85	-0.81	1125.15	1125.19	1100.00	1111.00	N
221.19	APS distribution duct	1126.00	-1.35	-1.30	1124.65	1124.70	attached to bridge		
221.19	230 KV SRP transmission line	1126.00	-1.35	-1.30	1124.65	1124.70	no poles		
221.19	Old Mill Avenue Bridge	1126.00	-1.35	-1.30	1124.65	1124.70	1100.00	1113.00	N
221.19	12" City of Tempe reclaimed water line	1126.00	-1.35	-1.30	1124.65	1124.70	attached to bridge		
221.19	US WEST telephone duct	1126.00	-1.35	-1.30	1124.65	1124.70	attached to bridge		

Salt River Sediment Trend Analysis 26-Dec-96

Table 4 - Results With Additional Mining (20 ft Average Depth) wmine.wk4

Approx. River Mile	Description	Minimum Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
221.26	8" Southwest Gas gas line	1130.00	-1.56	-1.56	1128.44	1128.44	attached to bridge		
221.26	New Mill Avenue Bridge	1130.00	-1.56	-1.56	1128.44	1128.44	1114.00	1115.00	N
221.26	US WEST telephone duct	1130.00	-1.56	-1.56	1128.44	1128.44	attached to bridge		
221.26	6" AP&C Nitrogen Gas line	1130.00	-1.56	-1.56	1128.44	1128.44	attached to bridge		
221.26	12" City of Tempe water main	1130.00	-1.56	-1.56	1128.44	1128.44	attached to bridge		
221.70		1134.00	-2.58	-2.30	1131.42	1131.70			
222.09	Rural Road Bridge	1136.00	-2.89	-2.50	1133.11	1133.50	1085.00	1110.50	N
222.09	US WEST telephone cable	1136.00	-2.89	-2.50	1133.11	1133.50	attached to bridge		
222.09	21"/18" City of Tempe sewer siphon	1136.00	-2.89	-2.50	1133.11	1133.50	1126.00	1131.00	N
222.09	30" City of Tempe water line	1136.00	-2.89	-2.50	1133.11	1133.50	1125.00	1130.50	N
222.55	230 KV and 69KV SRP transmission lines	1139.00	-5.07	-5.07	1133.93	1133.93	no poles		
222.93	69 KV APS transmission line	1140.00	-4.15	-4.15	1135.85	1135.85	1046.00	1095	N
223.07	12" Southwest Gas gas pipeline	1150.00	-3.46	-3.46	1146.54	1146.54	1126.00	1137.00	N
223.07	36" City of Tempe water line	1146.30	-3.46	-3.46	1142.84	1142.84	1141.50	1146.50	Y
223.07	18" City of Mesa sewer siphon	1150.00	-3.46	-3.46	1146.54	1146.54	1126.50	1137.25	N
223.07	21" City of Mesa sewer siphon	1150.00	-3.46	-3.46	1146.54	1146.54	1127.00	1137.50	N
223.07	10" Southwest Gas gas pipeline	1150.00	-3.46	-3.46	1146.54	1146.54	1126.00	1137.00	N
223.09	GCS downstream of McClintock Drive	1146.30	-0.50	-0.50	1145.80	1145.80	1131.20	1131.20	N
223.11	McClintock Drive Bridge	1150.00	0.00	2.49	1150.00	1152.49	1046.00	1096.15	N
223.67	Loop 202, Red Mountain Freeway Bridge	1132.70	0.00	4.33	1132.70	1137.03	1010.00	1073.15	N
224.09	Loop 101, Pima Freeway Bridge	1152.00	0.00	6.39	1152.00	1158.39	1038.00	1095.00	N
224.25		1152.00	-0.45	3.38	1151.55	1155.38			
224.43		1158.40	-4.34	1.66	1154.06	1160.06			
224.81		1162.10	-6.81	-0.75	1155.29	1161.35			
225.28		1163.00	-8.22	-0.76	1154.78	1162.24			
225.66		1158.80	-9.32	-2.76	1149.48	1156.04			
226.04		1173.10	-20.97	-14.37	1152.13	1158.73			
226.23		1177.60	-17.82	-14.37	1159.78	1163.23			
226.48		1180.50	-13.58	-12.49	1166.92	1168.01			
226.52	GCS downstream of Alma School Road	1186.00	-0.14	-0.11	1185.86	1185.89	1161.00	1161.00	N
226.52		1186.00	-0.14	-0.11	1185.86	1185.89			
226.56	12 KV SRP distribution line	1180.50	-1.64	-1.64	1178.86	1178.86	no poles		
226.56	Alma School Road Bridges	1180.50	-1.64	-1.64	1178.86	1178.86	1148.00	1164.25	N
226.80	McKellips Road At Grade Crossing	1191.70	-3.57	-3.48	1188.13	1188.22	1191.70	1189.70	Y

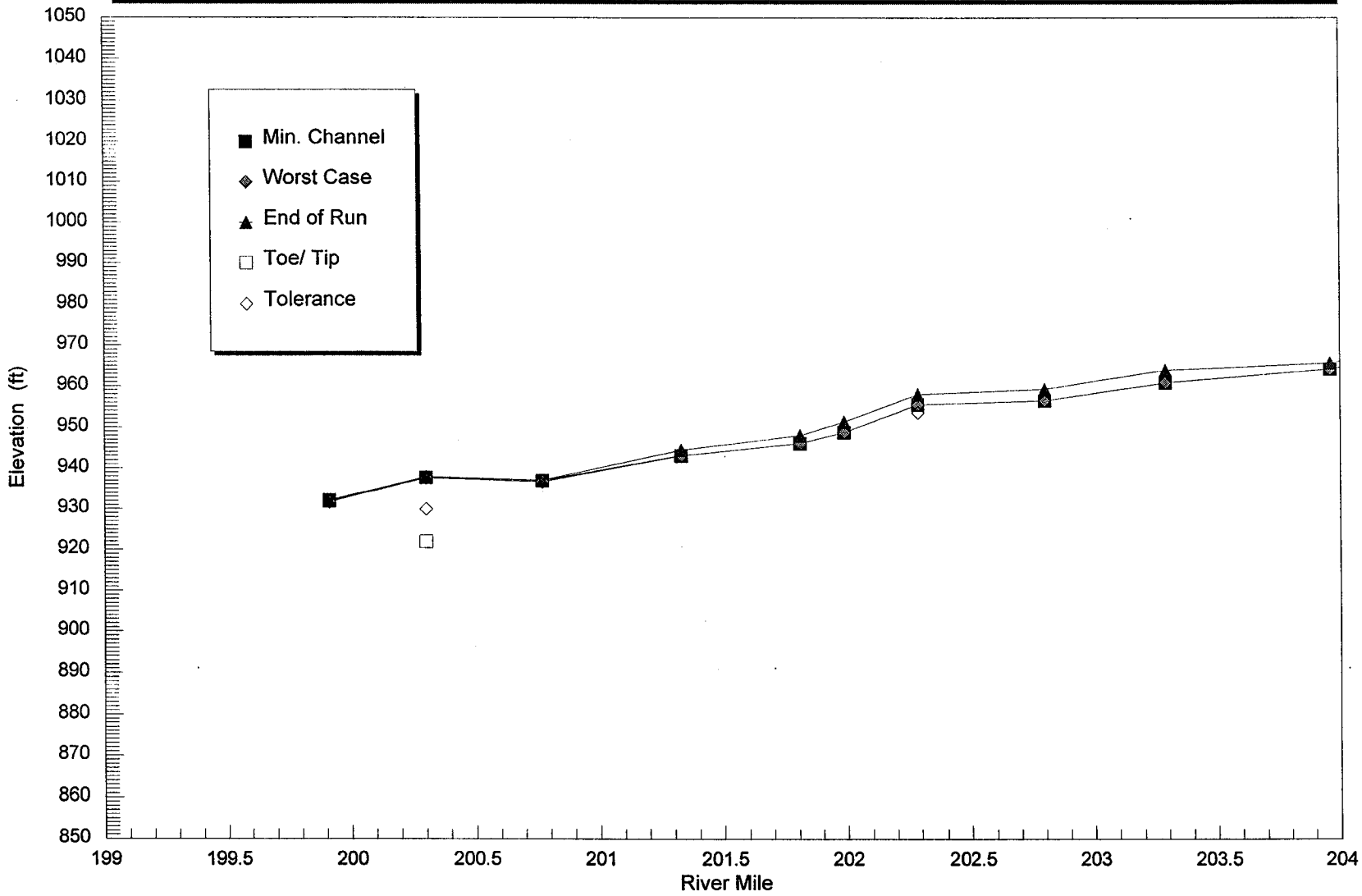
Salt River Sediment Trend Analysis 26-Dec-96

Table 4 - Results With Additional Mining (20 ft Average Depth) wmine.wk4

Approx. River Mile	Description	Minimum Channel Elevation	Bed Change Worst Case (ft)	Bed Change End of Run (ft)	Worst Case Elevation	End of Run Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	At Risk? (Y/N)
227.08		1194.10	-5.64	-4.72	1188.46	1189.38			
227.46		1194.10	-4.78	-3.87	1189.32	1190.23			
227.63	4" City of Mesa gas pipeline	1194.90	-4.50	-3.13	1190.40	1191.77	1175.20	1185.05	N
227.63	Country Club Drive Bridge	1194.90	-4.50	-3.13	1190.40	1191.77	1111.00	1152.95	N
227.88		1196.80	-4.11	-2.16	1192.69	1194.64			
228.17		1197.20	-3.52	-1.54	1193.68	1195.66			
228.64		1201.30	-4.31	-2.25	1196.99	1199.05			
229.12		1206.10	-5.52	-3.56	1200.58	1202.54			
229.40		1207.70	-8.30	-6.18	1199.40	1201.53			
229.68		1215.40	-11.41	-8.23	1203.99	1207.17			
230.09		1219.00	-12.69	-10.35	1206.31	1208.65			
230.47		1227.40	-14.41	-11.93	1212.99	1215.47			
230.94		1232.00	-16.33	-14.66	1215.67	1217.35			
231.32		1236.00	-17.03	-16.02	1218.97	1219.98			
231.56	Gilbert Road Bridge	1239.90	-17.33	-17.33	1222.57	1222.57	1159.00	1199.45	N
231.56	Two 230 KV WAPA transmission lines	1239.90	-17.33	-17.33	1222.57	1222.57	1230.50	1235.50	Y
231.89		1246.10	-17.93	-17.93	1228.17	1228.17			
232.45		1247.80	-15.06	-15.06	1232.74	1232.74			
232.74		1249.10	-12.47	-12.47	1236.63	1236.63			
233.03		1253.70	-8.40	-8.40	1245.30	1245.30			
233.51		1256.20	-9.18	-9.18	1247.02	1247.02			
233.95	Grusp canal crossing	1258.50	-9.48	-9.48	1249.02	1249.02	at grade		
234.53		1265.80	-10.43	-10.43	1255.37	1255.37			
235.01		1266.70	-12.20	-12.20	1254.50	1254.50			
235.38		1271.50	-13.28	-13.28	1258.22	1258.22			
235.67		1271.90	-14.06	-14.06	1257.84	1257.84			
236.05		1274.80	-12.96	-12.96	1261.84	1261.84			
236.43		1276.80	-13.40	-13.13	1263.40	1263.67			
236.81		1278.30	-13.97	-13.36	1264.33	1264.94			
237.19		1282.50	-15.62	-13.66	1266.88	1268.84			
237.59	69 KV SRP transmission line	1288.40	-16.19	-13.66	1272.21	1274.74	no poles		
237.59	21' CAP Canal siphon	1288.40	-16.19	-13.66	1272.21	1274.74	1258.40	1275.40	Y

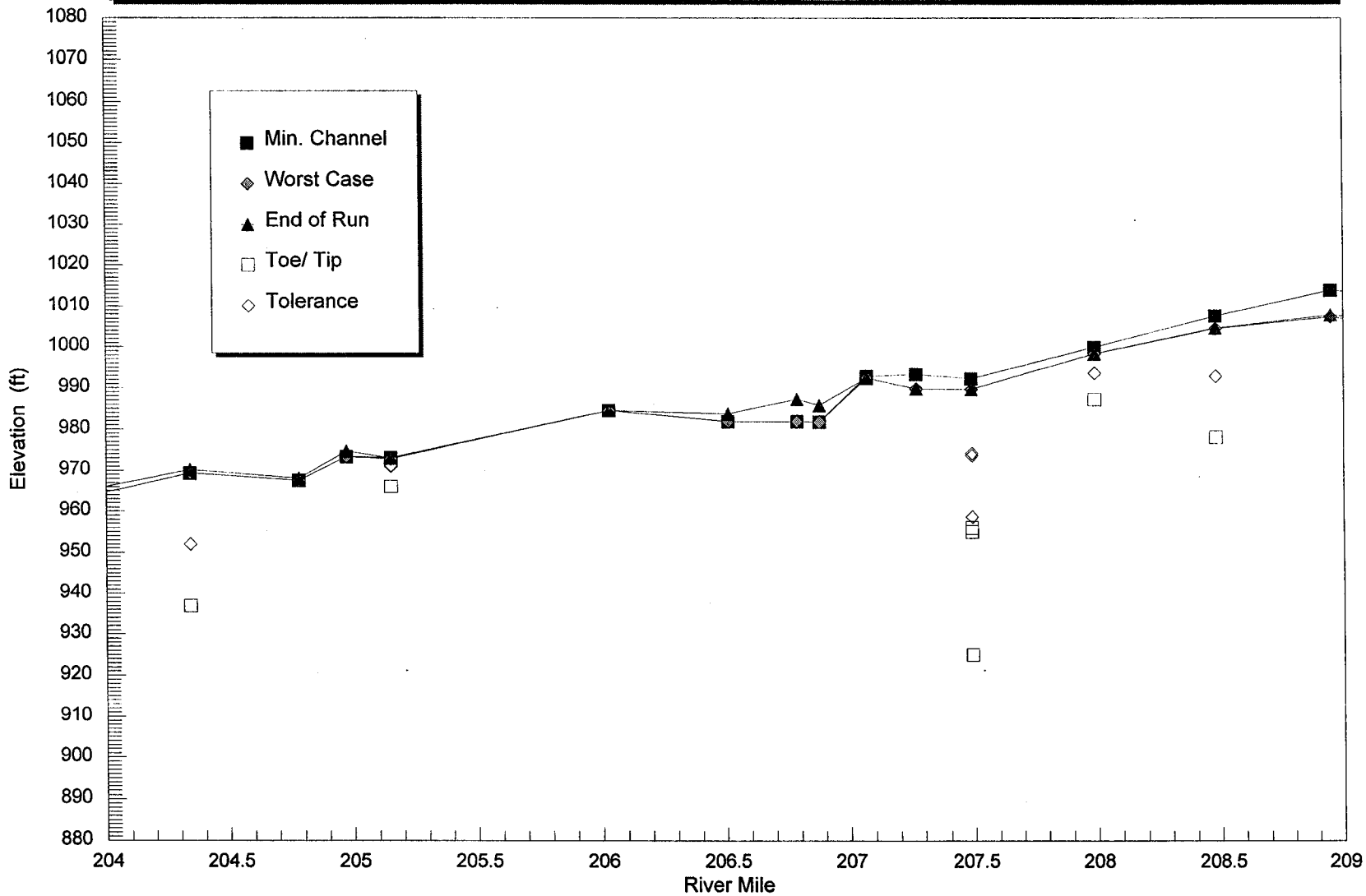
Salt River Sediment Trend Analysis

Figure 16 - Without Additional Mining: River Mile 199-204



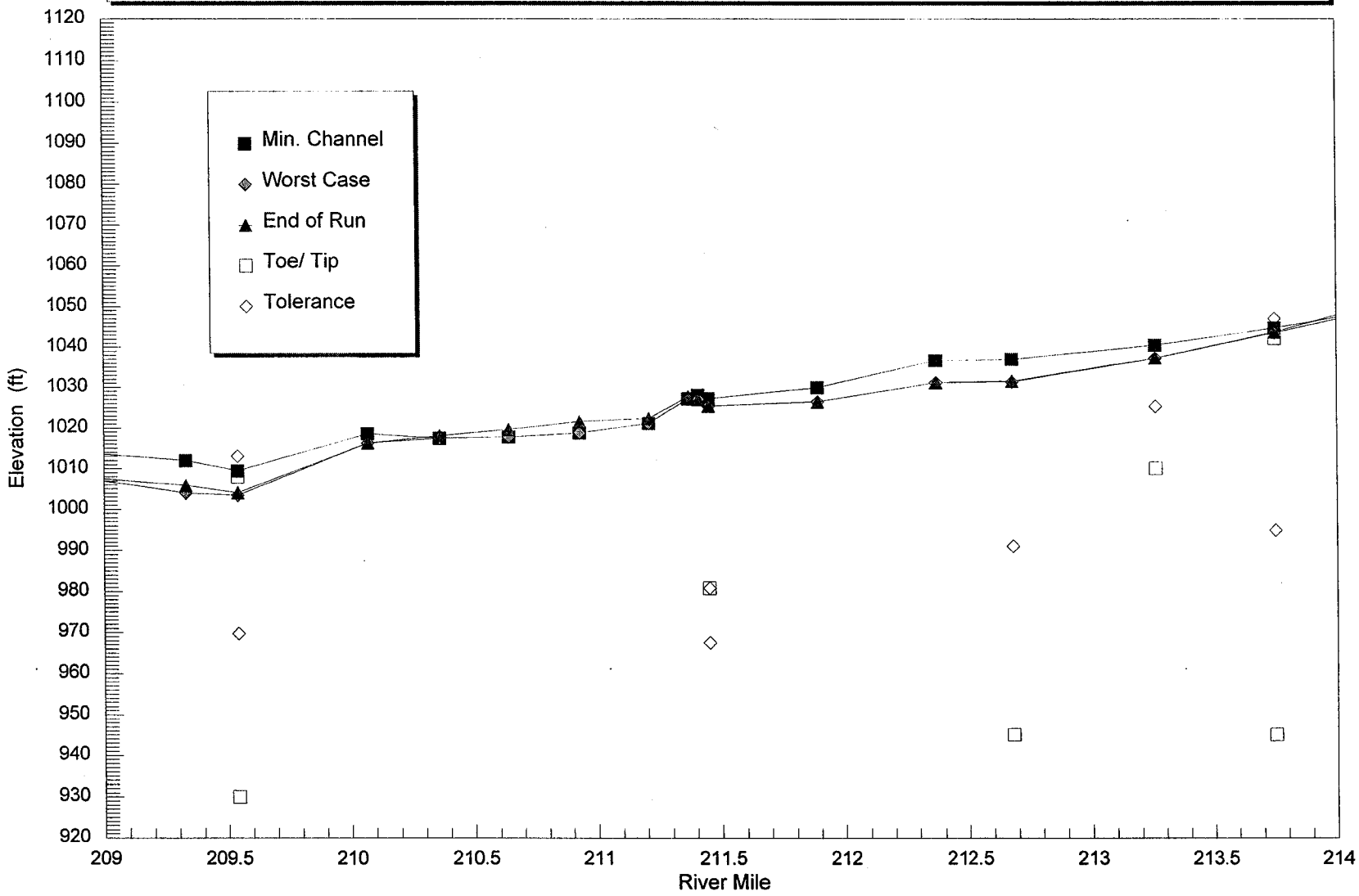
Salt River Sediment Trend Analysis

Figure 17 - Without Additional Mining: River Mile 204-209



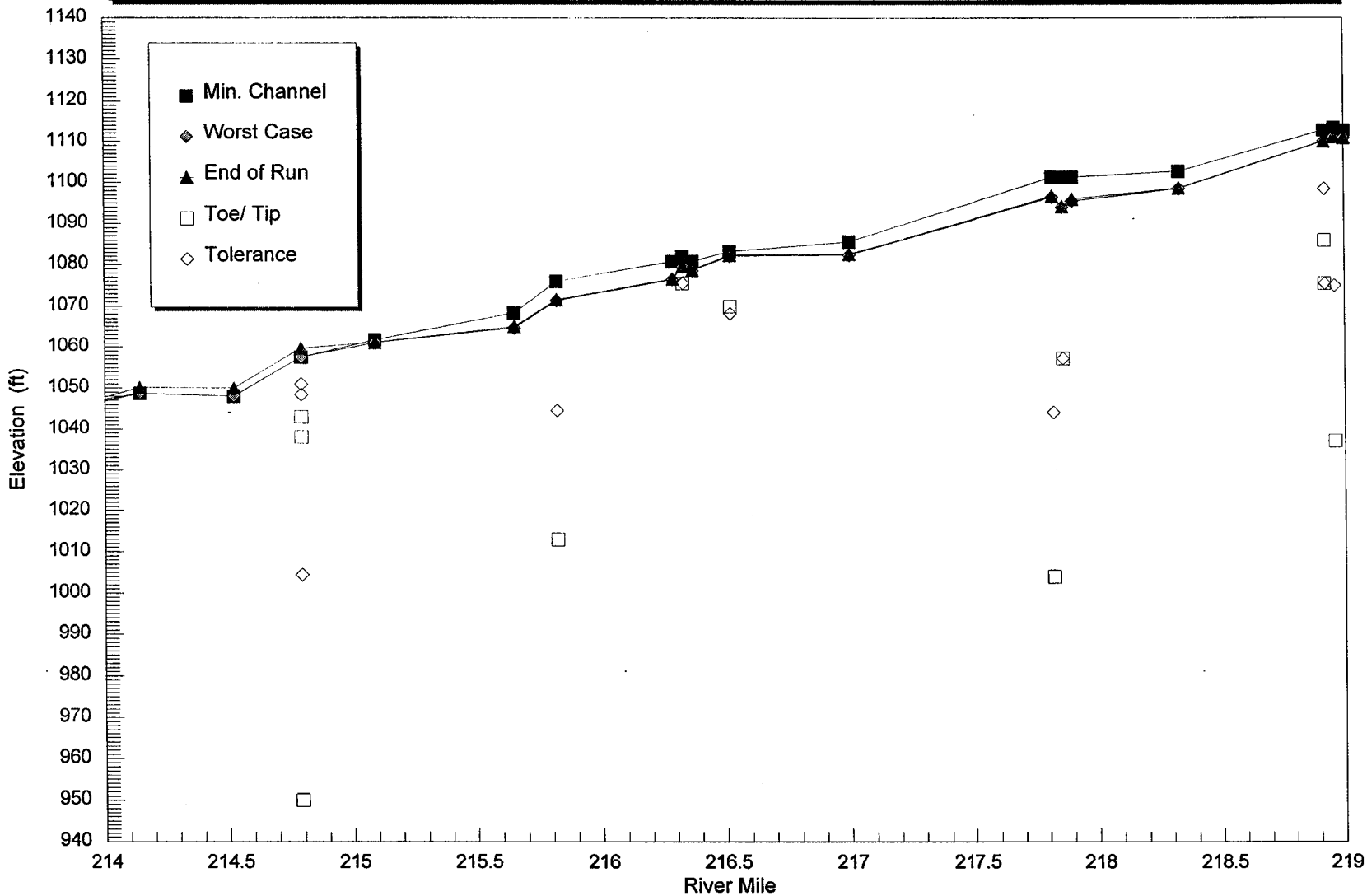
Salt River Sediment Trend Analysis

Figure 18 - Without Additional Mining: River Mile 209-214



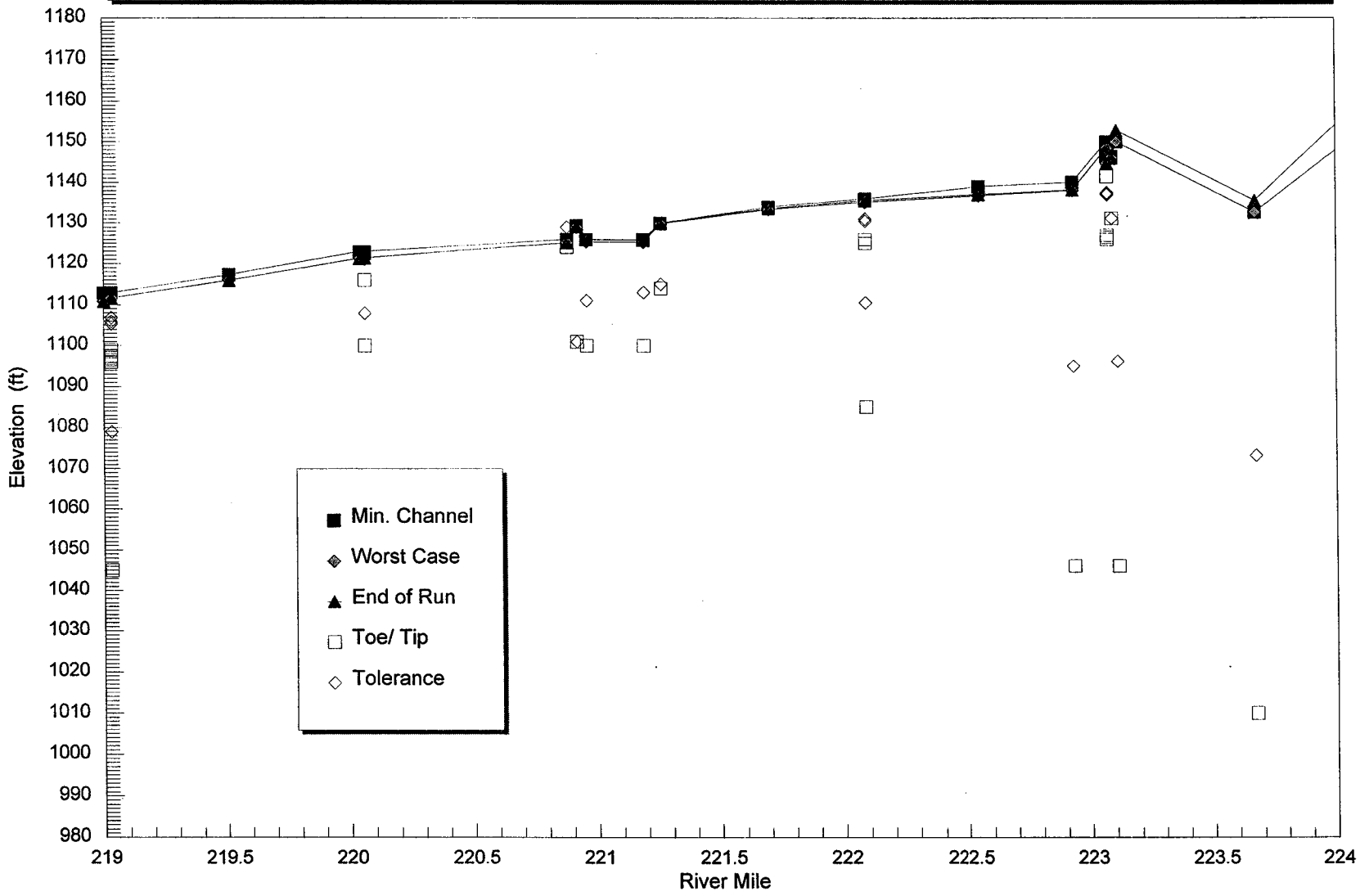
Salt River Sediment Trend Analysis

Figure 19 - Without Additional Mining: River Mile 214-219



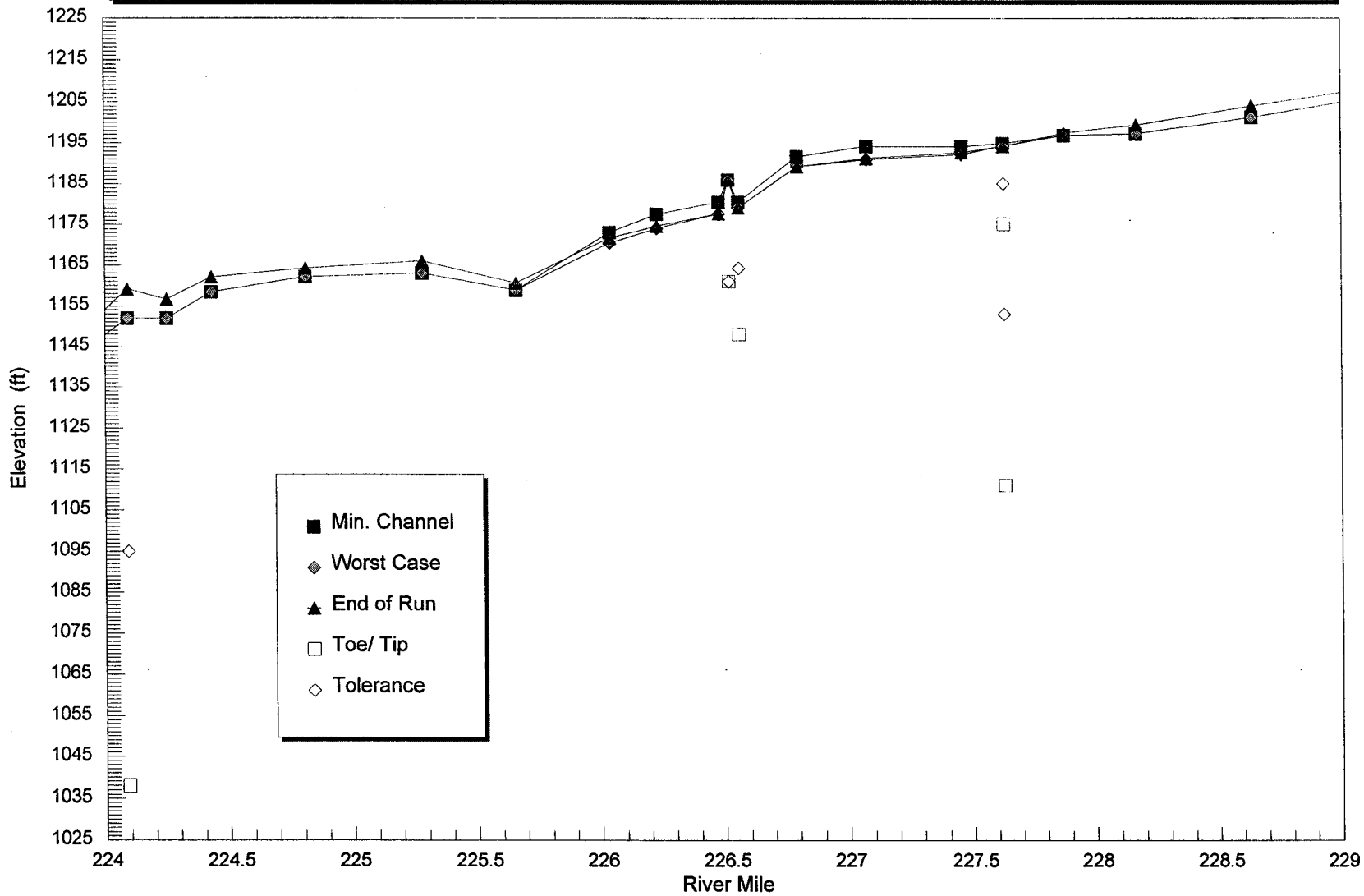
Salt River Sediment Trend Analysis

Figure 20 - Without Additional Mining: River Mile 219-224



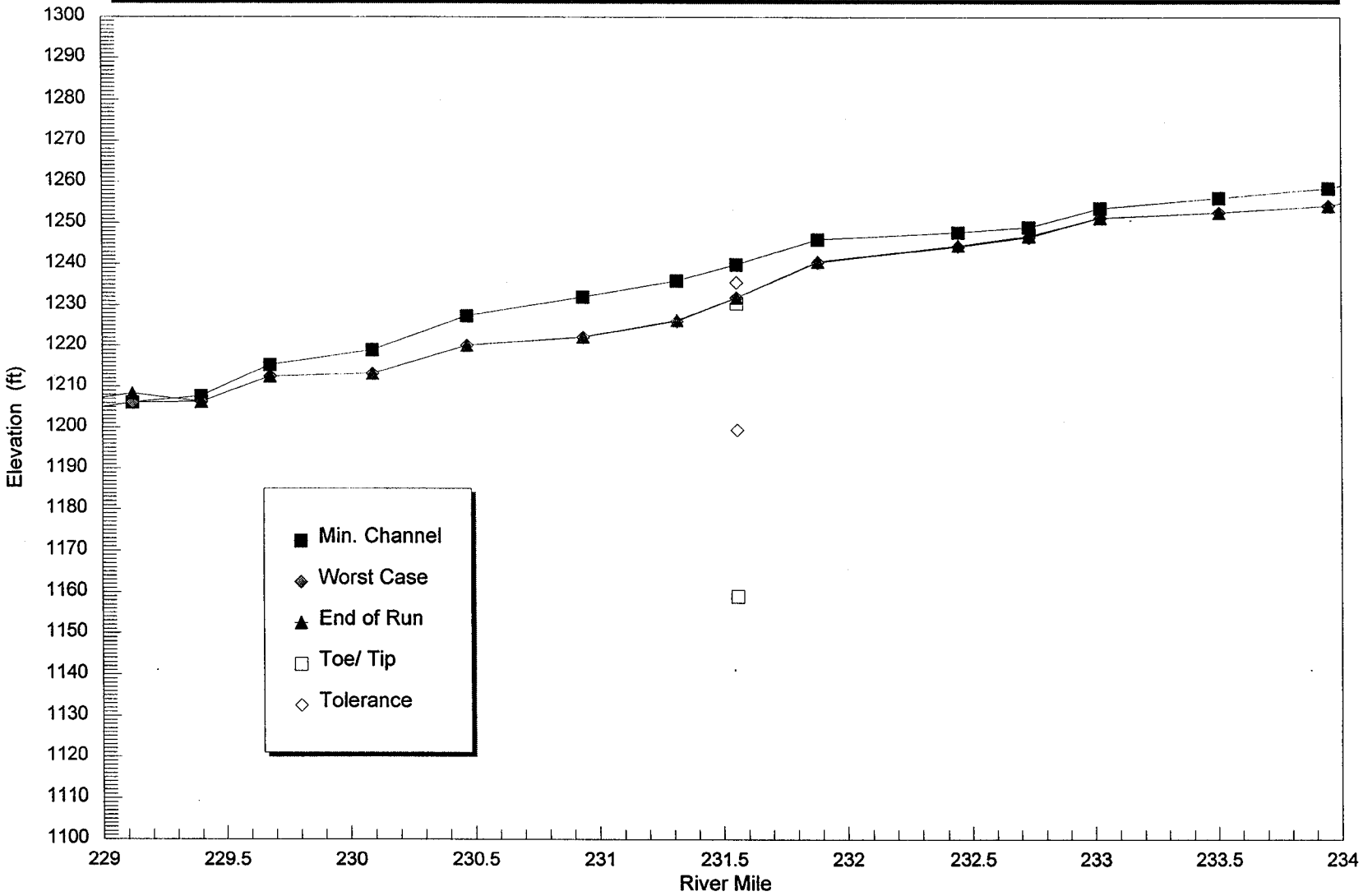
Salt River Sediment Trend Analysis

Figure 21 - Without Additional Mining: River Mile 224-229



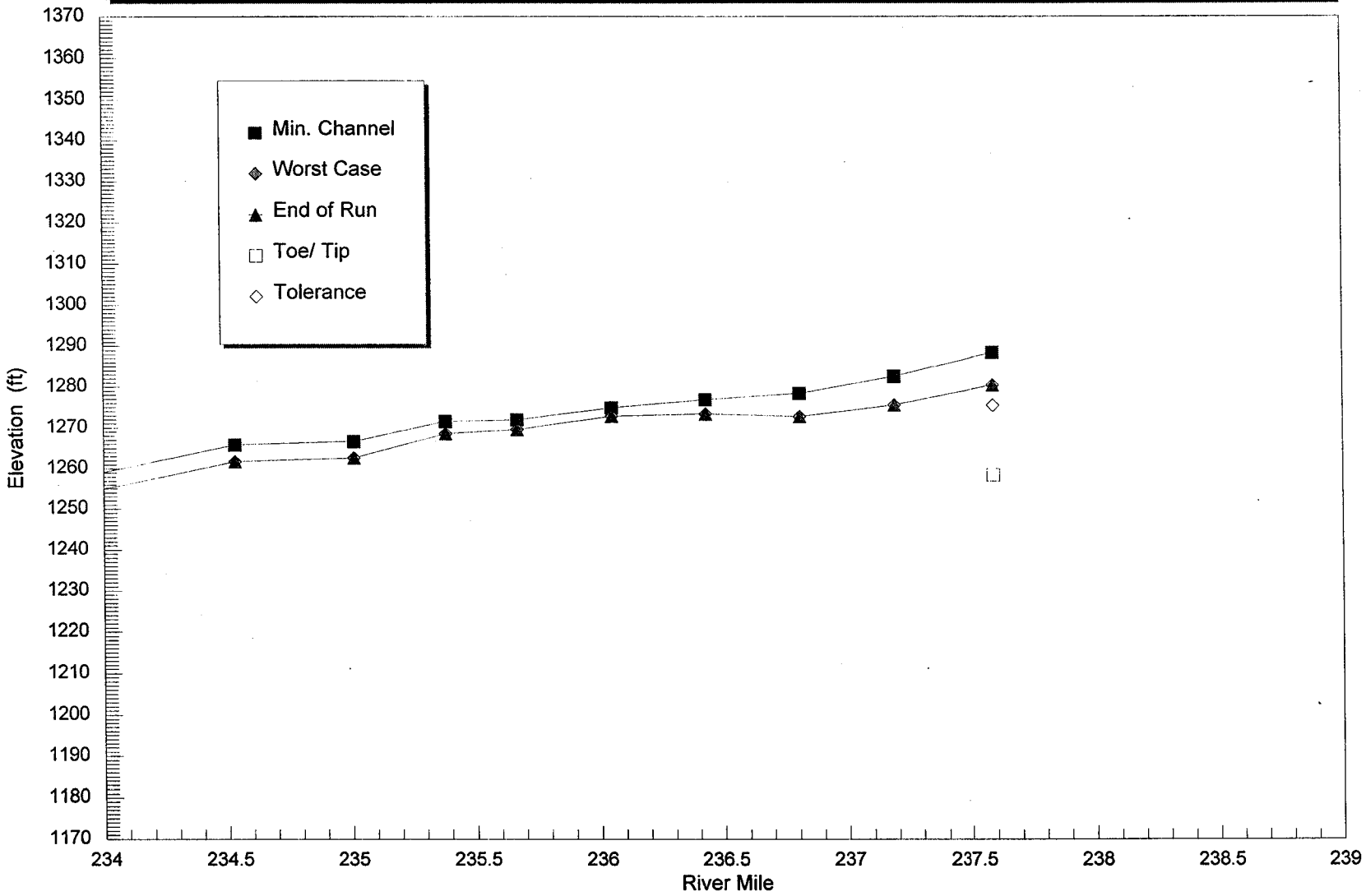
Salt River Sediment Trend Analysis

Figure 22 - Without Additional Mining: River Mile 229-234



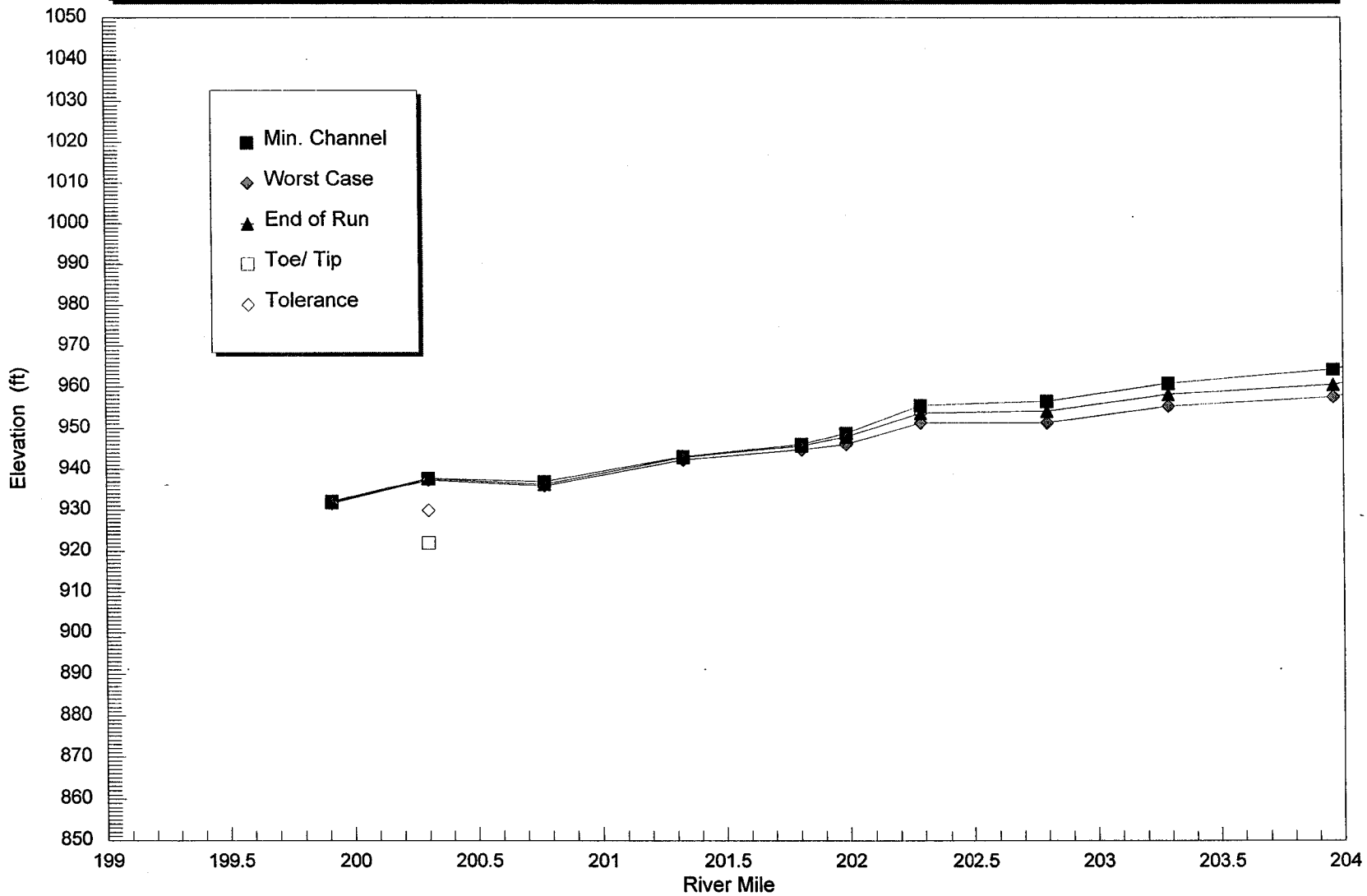
Salt River Sediment Trend Analysis

Figure 23 - Without Additional Mining: River Mile 234-239



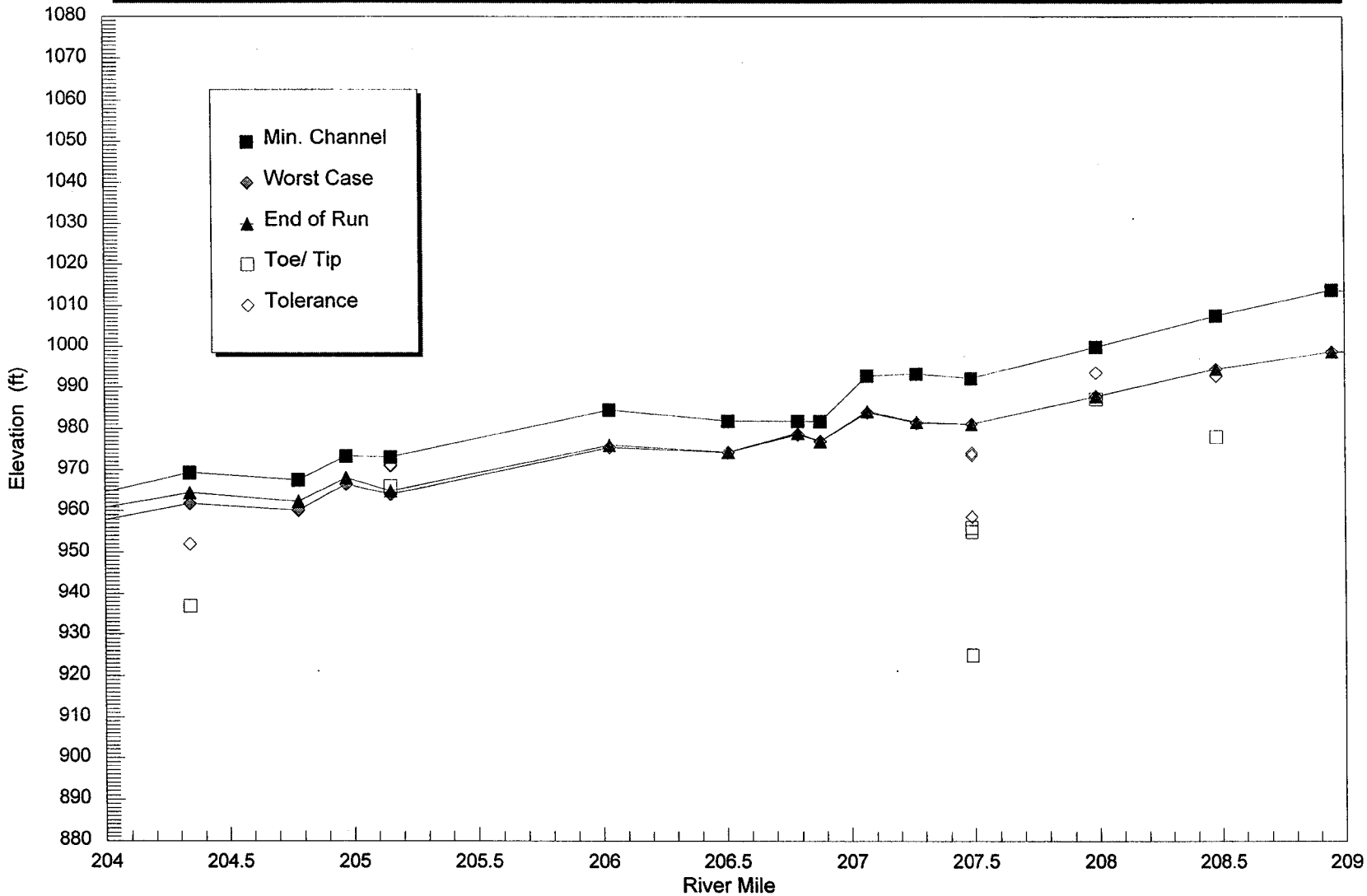
Salt River Sediment Trend Analysis

Figure 24 - With Additional Mining: River Mile 199-204



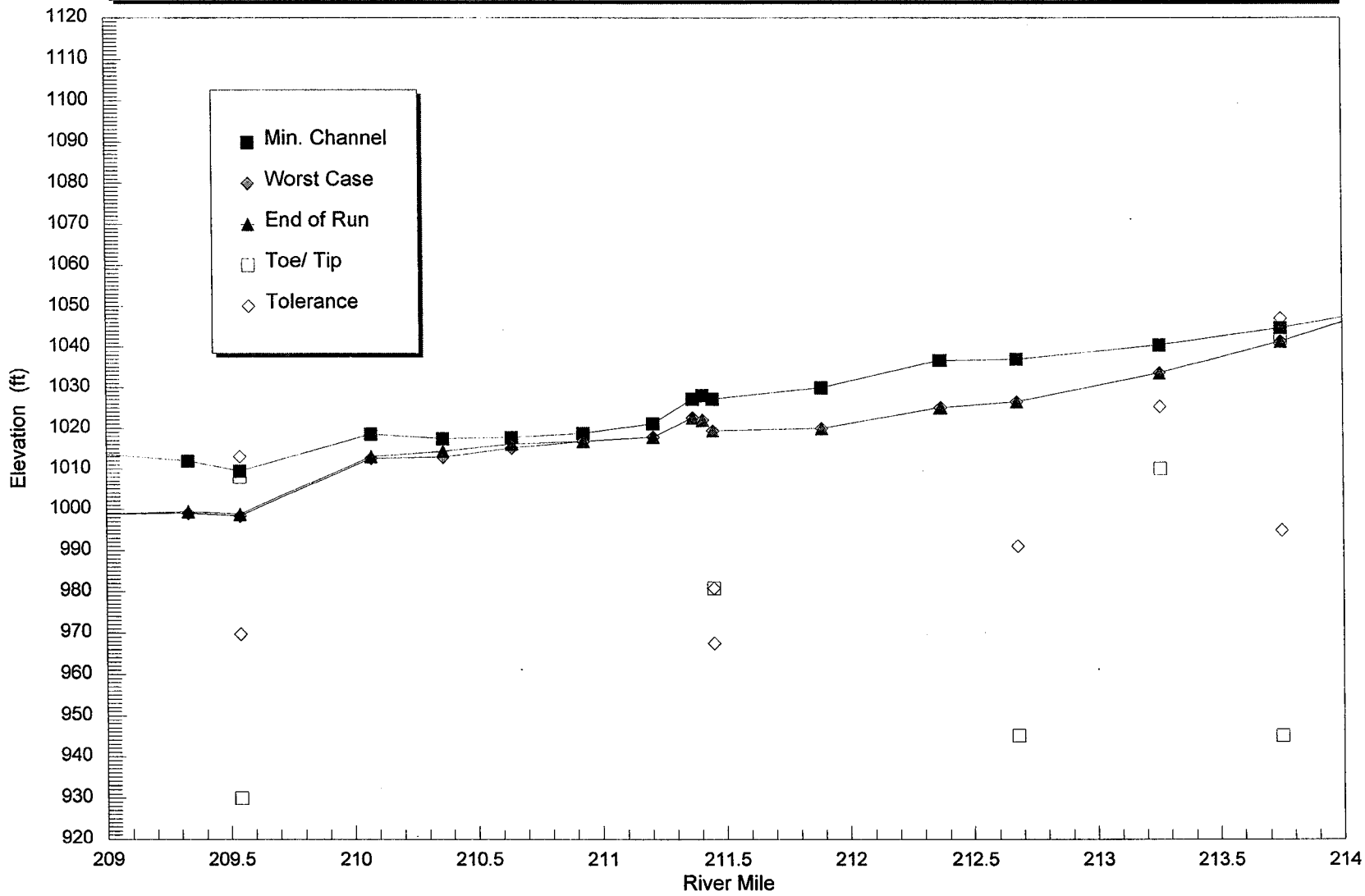
Salt River Sediment Trend Analysis

Figure 25 - With Additional Mining: River Mile 204-209



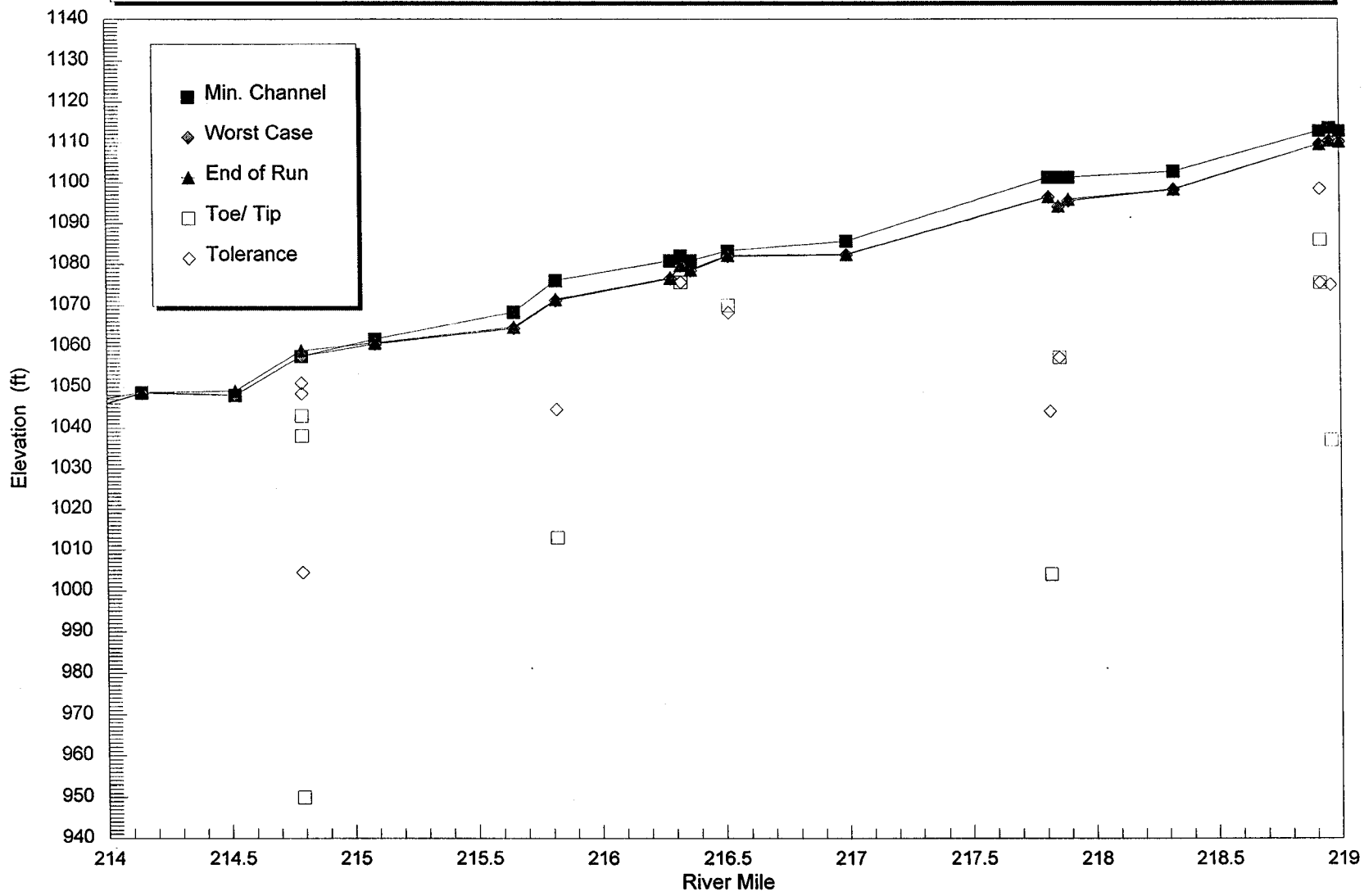
Salt River Sediment Trend Analysis

Figure 26 - With Additional Mining: River Mile 209-214



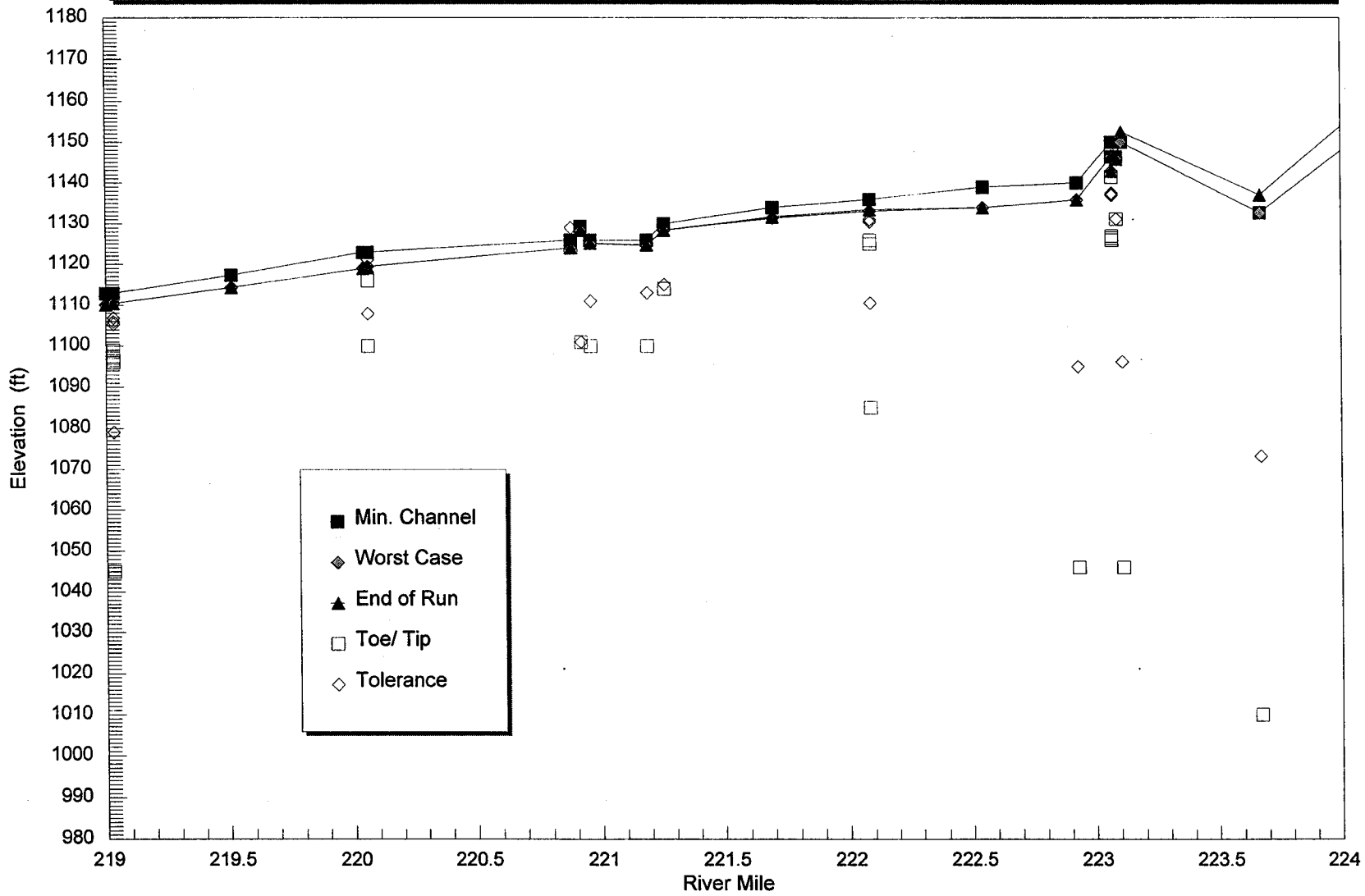
Salt River Sediment Trend Analysis

Figure 27 - With Additional Mining: River Mile 214-219



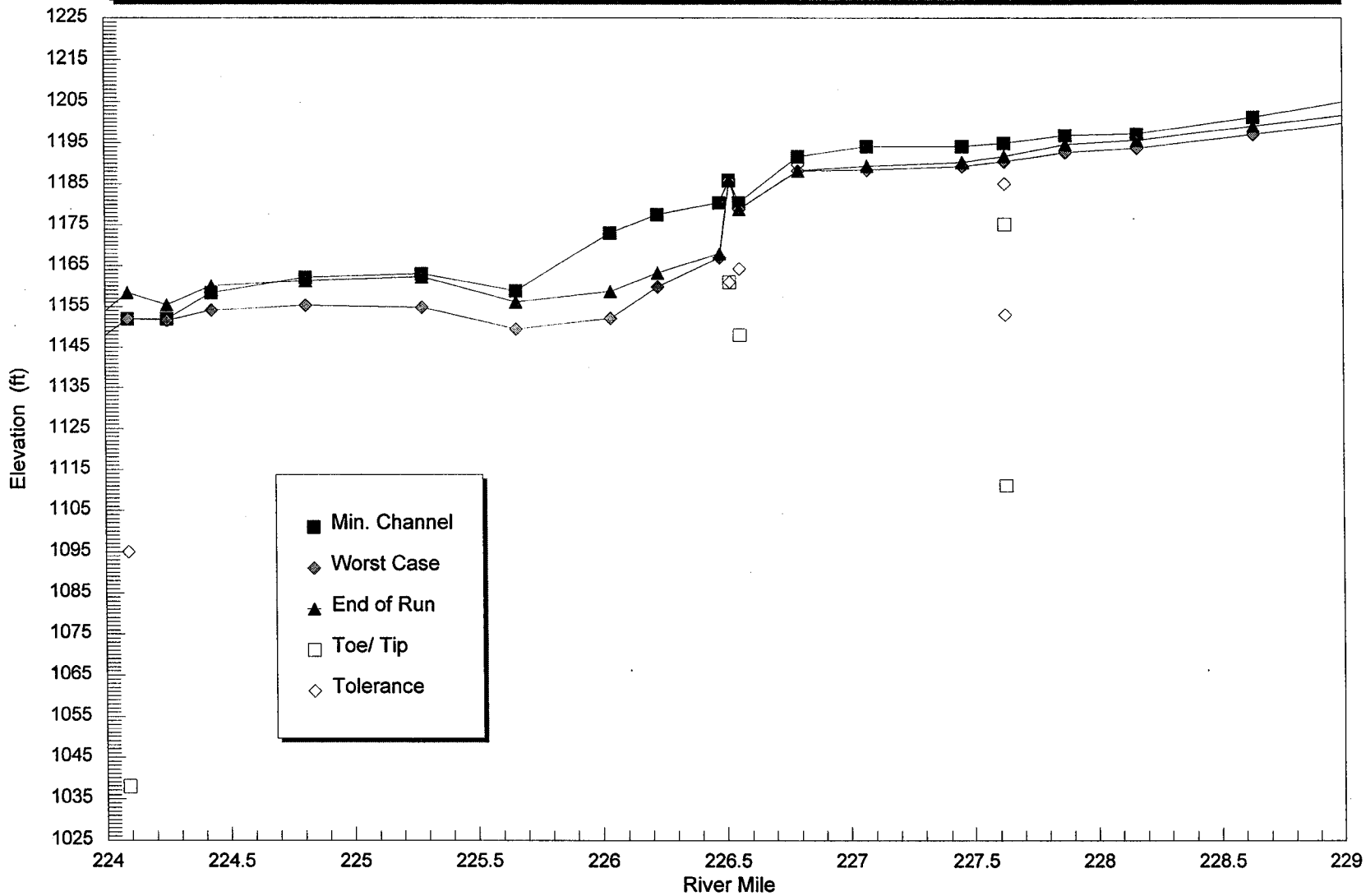
Salt River Sediment Trend Analysis

Figure 28 - With Additional Mining: River Mile 219-224



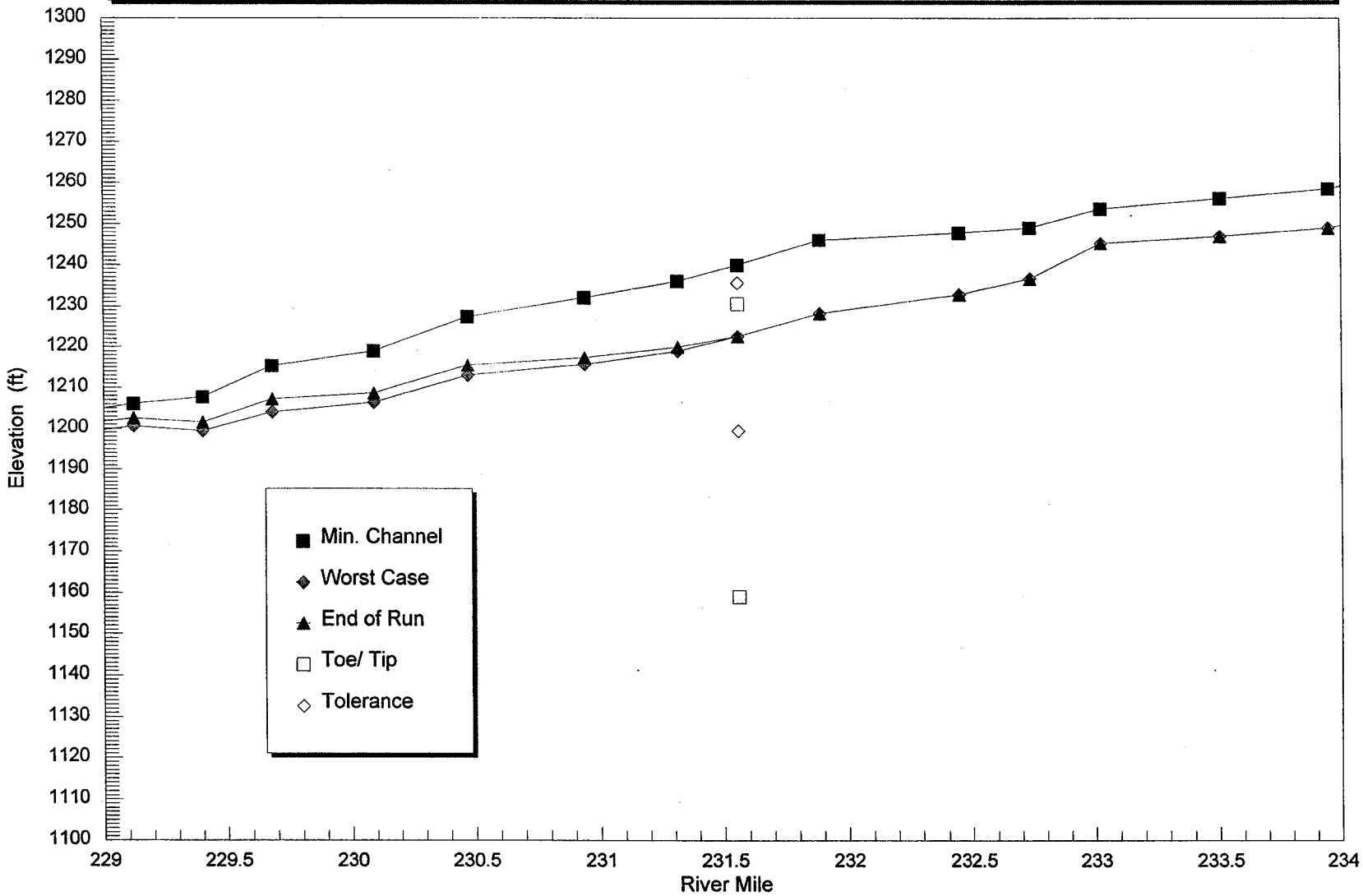
Salt River Sediment Trend Analysis

Figure 29 - With Additional Mining: River Mile 224-229



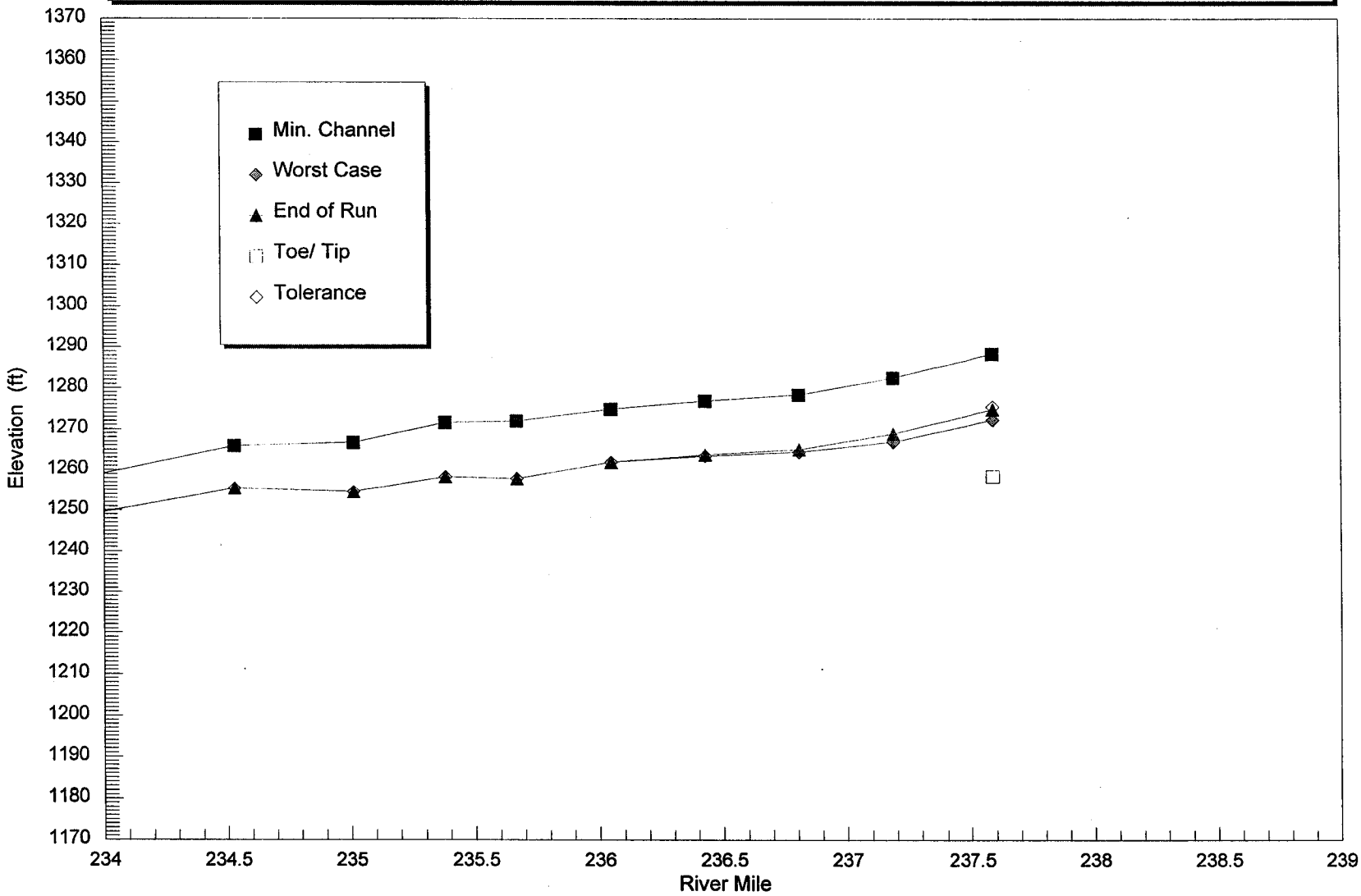
Salt River Sediment Trend Analysis

Figure 30 - With Additional Mining: River Mile 229-234



Salt River Sediment Trend Analysis

Figure 31 - With Additional Mining: River Mile 234-239



Salt River Sediment Trend Analysis
Table 5 - Infrastructure Potentially at Risk: Without Additional Mining

26-Dec-96
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Approx. River Mile	Description	Starting Channel Elev.	Worst Case Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	Calculated Starting Embedment	Calculated Remaining Embedment
209.54	48" City of Phoenix water line	1009.40	1003.36	1008.00	1013.00	1.40	0.00
213.75	10" Southwest Gas gas pipeline	1044.60	1043.39	1042.00	1047.00	2.60	0.00
220.88	6" Southwest Gas gas pipeline	1126.00	1125.20	1124.00	1129.00	2.00	0.00
223.07	36" City of Tempe water line	1146.30	1144.65	1141.50	1146.50	4.80	3.15
226.80	McKellips Road At Grade Crossing	1191.70	1189.16	1191.70	1189.70	0.00	0.00
231.56	Two 230 KV WAPA transmission lines	1239.90	1231.89	1230.50	1235.50	9.40	0.00

Salt River Sediment Trend Analysis
Table 6 - Infrastructure Potentially at Risk: With Additional Mining

Approx. River Mile	Description	Starting Channel Elev.	Worst Case Elevation	Toe or Tip Elevation	Comparative Tolerance Elevation	Calculated Starting Embedment	Calculated Remaining Embedment
202.29	91st Avenue At GradeCrossing	955.50	951.18	955.50	953.50	0.00	0.00
205.15	67th Avenue At Grade Crossing	973.10	963.98	973.10	971.10	0.00	0.00
205.15	12" City of Phoenix water line	973.10	963.98	966.00	971.00	7.10	0.00
207.99	16" El Paso Natural Gas pipeline	999.90	987.80	987.20	993.55	12.70	0.60
209.54	48" City of Phoenix water line	1009.40	998.36	1008.00	1013.00	1.40	0.00
213.75	10" Southwest Gas gas pipeline	1044.60	1041.30	1042.00	1047.00	2.60	0.00
220.06	36" City of Tempe water line	1122.90	1119.38	1116.00	1121.00	6.90	3.38
220.06	48" City of Tempe sewer siphon	1122.90	1119.38	1116.00	1121.00	6.90	3.38
220.88	6" Southwest Gas gas pipeline	1126.00	1123.94	1124.00	1129.00	2.00	0.00
223.07	36" City of Tempe water line	1146.30	1142.84	1141.50	1146.50	4.80	1.34
226.80	McKellips Road At Grade Crossing	1191.70	1188.13	1191.70	1189.70	0.00	0.00
231.56	Two 230 KV WAPA transmission lines	1239.90	1222.57	1230.50	1235.50	9.40	0.00
237.59	21' CAP Canal siphon	1288.40	1272.21	1258.40	1275.40	30.00	13.81

6.0 Conclusions and Recommendations

The purpose of this study was to evaluate the channel bed profile changes in the Salt River system due to additional sand and gravel mining activities and to determine the impacts these channel bed profile changes would have on infrastructure.

The results show that the Salt River system will continue to degrade with or without additional mining activities. Five utility crossings and one at grade crossing were determined to be potentially at risk without continued mining in the Salt River system.

Initial additional mining volumes resulted in significant levels of degradation and mining depths were limited to an average depth of up to 20 feet across the sites. This reduction in mining depth helped to reduce the degradation in the model with additional mining to an acceptable level. As a result, only five additional utility crossings and two additional at grade crossings were determined to be potentially at risk due to the impacts of additional mining. No bridges were determined to be potentially at risk due to the impacts of additional mining. The net impact of additional mining as compared to no additional mining was 5.4 feet of degradation in the lower section, 1.7 feet of degradation in the central section, and 6.9 feet of degradation in the upper section.

Based on the ongoing degradation of the Salt River system and our results indicating that degradation will occur with or without additional mining activities, we conclude that this level of additional degradation will be manageable. We also conclude that the additional degradation can be properly accounted for through a program of monitoring and the development of specific countermeasures for infrastructure potentially at risk as appropriate.

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