RIO SALADO CHANNEL IMPROVEMENT

MILL AVENUE TO HAYDEN ROAD

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FINAL REPORT

Submitted to:

City of Tempe
115 East Fifth Street
Tempe, Arizona 85281

Submitted by:

Simons, Li & Associates, Inc.
4600 South Mill Avenue, Suite 280
Tempe, Arizona 85282

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Registered Professional Engineer (Civil)
CERTIFICATE NO.
21560
DENNIS
RICHARDS
Date Signed 3/9/87
ARIZONA, U.S.A.

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I. INTRODUCTION

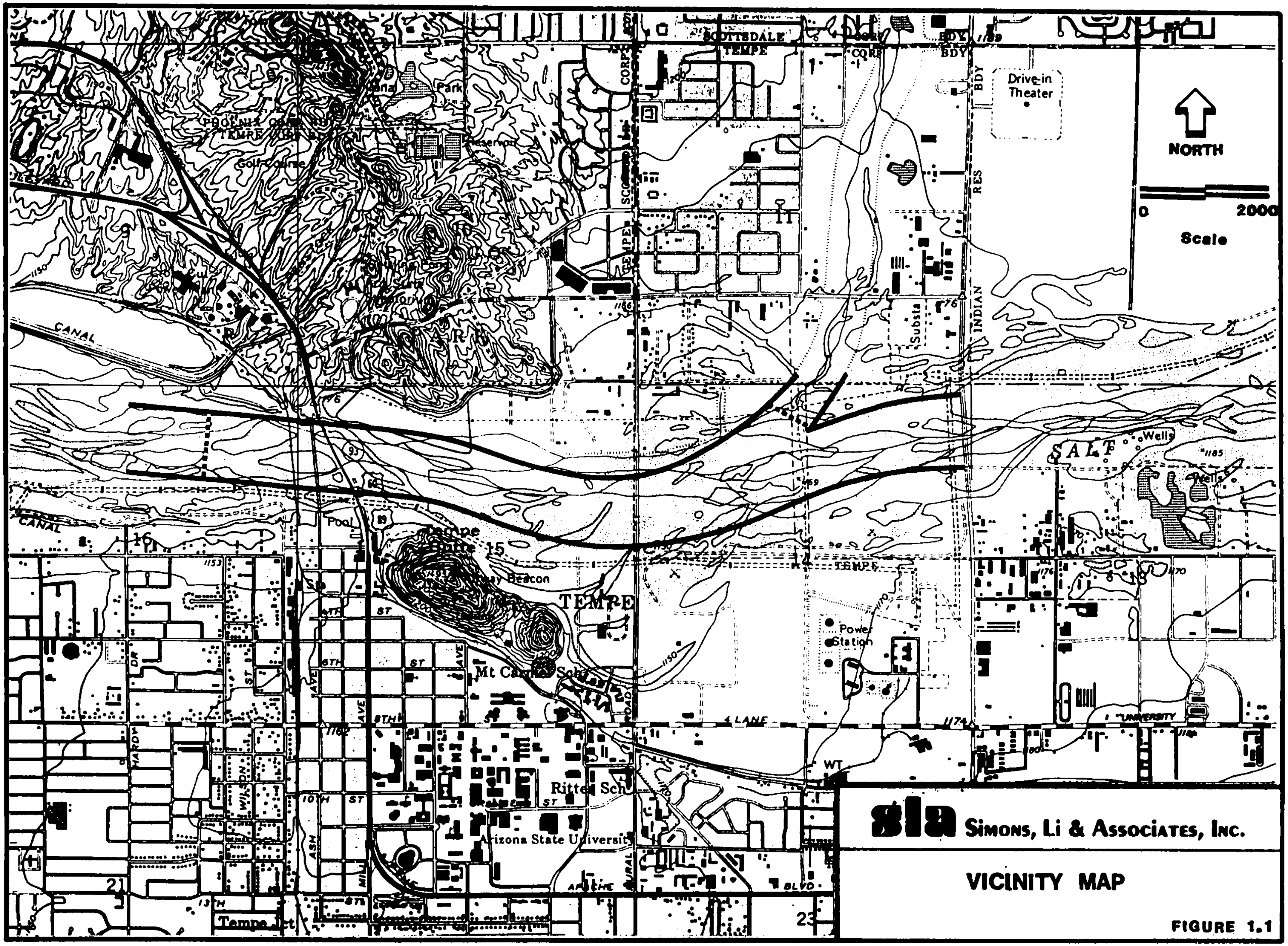
The development of the Rio Salado Park within the City of Tempe offers a unique opportunity to upgrade approximately six miles of the Salt River (Figure 1.1). The Salt River channel has undergone a significant change in its form during the rapid urban expansion of metropolitan Phoenix since the mid-1950s. Factors that have been particularly important in the alteration of the channel include modification of the hydrologic regime by dam construction, in-stream sand and gravel mining, placement of landfills in the main channel and overbank areas, and construction of river-control structures and levees. Up until this time, the factors altering river form have been introduced in a piecemeal manner, without comprehensive planning.

This study is part of a comprehensive planning effort undertaken by the City of Tempe's Rio Salado Task Force. The Task Force is addressing a broad set of issues including land use, water use, and channel design. This report addresses issues related to channel design, and has received substantial input from other members of the Task Force through coordination on related issues.

The purpose of this initial study is to identify the appropriate hydraulic design criteria to be used during development of the Rio Salado Park, and to put forward several alternative design concepts. Several goals were identified for the project which included:

1. Reduction of flood elevations in the Salt River floodplain through the City of Tempe.
2. Establishment of a stable channel section and profile.
3. Creation of an attractive and usable floodway during non-flow and low-flow periods.
4. Provision for off-channel storage of floodwaters.
5. Creation of riparian habitat for wildlife species.

In developing alternative design concepts, it was found that the planned channelization had effects on development adjacent to the river environment. For example, the proposed channel profile and channel section will require the excavation of river bed material, which in-turn is in demand as a source of embankment material for the East Papago freeway. There are a number of developments planned adjacent to the south bank of the Salt River that would benefit from a more integrated channel development plan.



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VICINITY MAP

FIGURE 1.1

This report contains a preliminary evaluation of the conceptual design of the Salt River channel. The initial engineering analysis of design alternatives is presented, which includes the evaluation of alternative river sections, alignments, and profiles. In addition, the report identifies potential impacts due to the proposed changes. Also evaluated are bank-protection measures to provide lateral stability, and grade-control structures to provide vertical stability of the Salt River.

II. DATA BASE

The formulation of a reliable data base was a primary objective of this study. Information gathered during this phase of planning presently provides the factual basis for formulation of alternative concepts; and, in the future, will provide the necessary data for more detailed design. This section describes the various data sets that were compiled and reviewed. The source of the data, and their accuracy, are discussed.

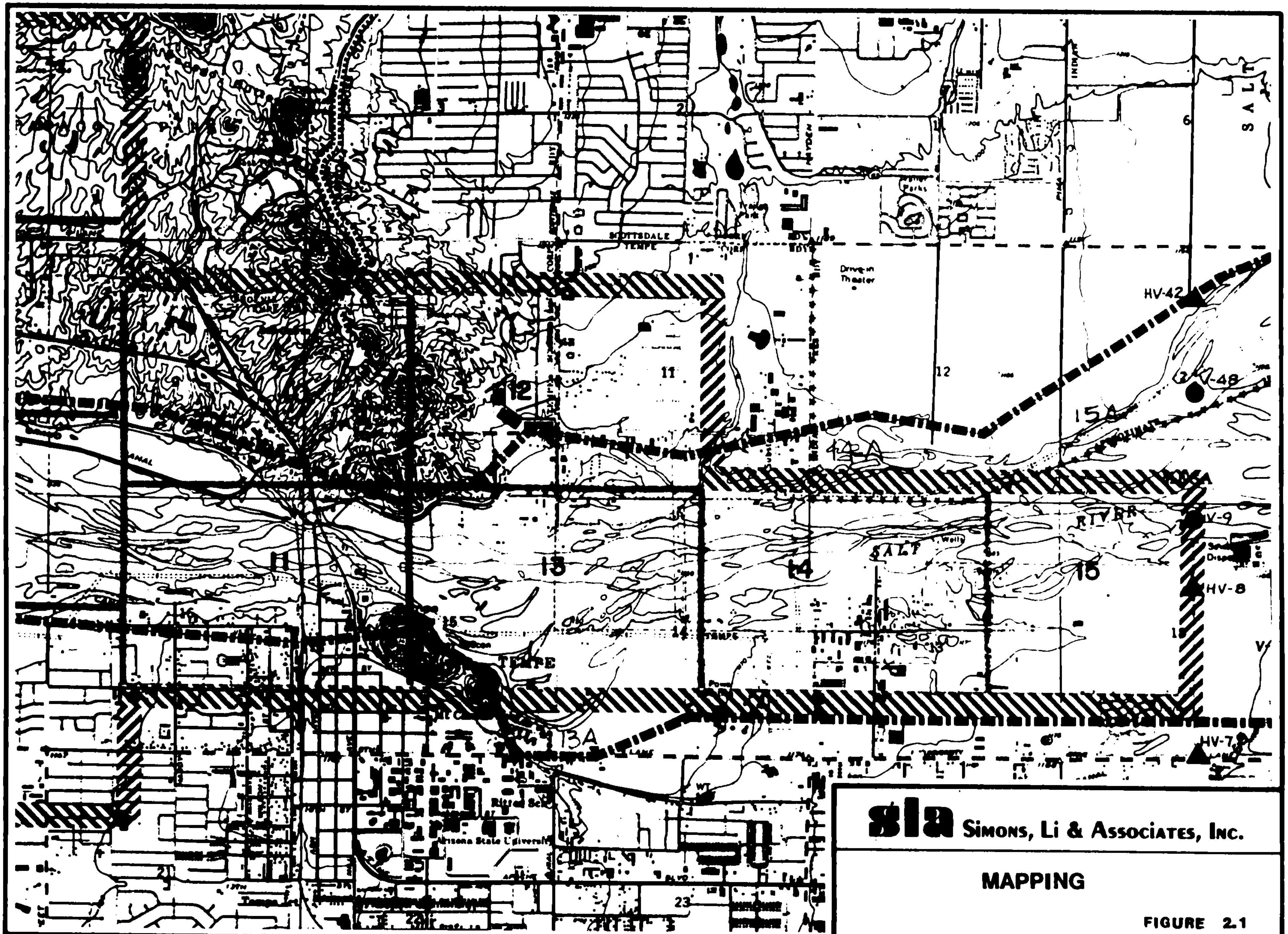
2.1 Mapping

The most recent mapping available for the Rio Salado Project area was conducted by ADOT for the East Papago Freeway Location and Design Concept Study (John Carollo Engineers, 1987) (Figure 2.1). The control survey was conducted by DNA Inc. (1987), and the aerial photography was conducted by Kenny Aerial Mapping. The photos are dated November, 1986. Contour maps were produced for ADOT at both a 200-scale and a 50-scale, with 2-foot contour intervals.

All control surveys and mapping was done in accordance with ADOT standards for horizontal and vertical control. The grid used is the state plane coordinate system, and the datum is based on ADOT benchmarks. The majority of the survey network established for the East Papago project is north of University Avenue, along the Salt River and the East Papago Highway corridor from 40th Street to Price Road.

Based on discussions with the engineering staff at the City of Tempe and their consultant Mapping Automation, it is our understanding that the horizontal control for ADOT and Tempe coincide. A consistent system of vertical control has not yet been established in Tempe, and ADOT's vertical control would be acceptable for this purpose. Because of the availability of ADOT's survey and the quality of the control survey, it was decided to use this mapping as the topographic data set for this study. Base maps at 400-scale were developed from 200-scale maps used by ADOT for the East Papago Freeway Study.

Looking to the future for topographic data, it is desirable that a digital version of the topography be developed, and then integrated with the Integraph CAD system supported by the engineering staff at the City of Tempe. This would permit the mapping information to be combined with other data sets contained in this system, and would expedite future planning and design work undertaken in the Rio Salado corridor. The development of a digital terrain model would require that the aerial photographs from the Kenney survey be reprocessed in a digital format. Because the control and



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MAPPING

FIGURE 2.1

aerial survey work have already been completed, the digital terrain model can be developed at a lower cost. It is recommended that during the next phase of Rio Salado planning the City of Tempe contract to complete digital terrain modeling of the Rio Salado corridor.

2.2 Hydrology

Discharges used in the hydraulic analyses were based on values presented in the May 1982 Central Arizona Water Control Study (CAWCS (I), 1982). For the channelized conditions, only the upstream discharge for each frequency was used throughout the entire reach, under the assumption that there would be little attenuation of the flood wave. This assumption represents the worst-case condition for floodwave propagation in the channel, and provides a conservative assessment of downstream impacts. It is assumed that if changes in the river stage are small, given this worst-case approach, it can be reasonably concluded that the downstream effect is negligible. Frequency and Peak Discharges are listed in Table 2.1. The CAWCS (I) values were used for the study.

TABLE 2.1

Frequency and Peak Discharges

Frequency	CAWCS (I) (cfs)	CAWCS (II) (cfs)
5	40,000	44,000
10	93,000	84,000
20	135,000	110,000
50	160,000	135,000
100	215,000	160,000
200	275,000	190,000
500	330,000	235,000

The Corps of Engineers is currently revising the hydrology of the Salt River to account for the planned modification to the Roosevelt Dam. The Roosevelt Dam modification will raise the spillway elevation by 51.7 feet, increasing the volume of the reservoir by 795,420 acre-feet. The revised study, CAWCS (II), is to be completed by the end of the year. The discharges listed in Table 2.1 under CAWCS (II) are preliminary values that are subject to revision.

2.3 Utilities

A base map consisting of utilities in the area of the Salt River within the City of Tempe was compiled by Tempe City Planners. A profile of the utilities with the channelization was obtained from Tempe Engineering Department to determine conflicts between new channel inverts and existing profiles, and if relocation of any utilities was necessary. The known utilities involved are as follows:

- Mill Avenue Crossing:

The Mill Avenue crossing has a water main and a gas (nitrogen) line; however, these are both located on the bridge itself.

- Rural Road Crossing:

The Rural Road Crossing has three utilities: water, gas, and sewer. The water is a 30"-diameter transmission main, and exists on the east side of the bridge. The gas line is located on the bridge. The sewer line is a 36"-diameter main located on west side of the bridge, and has very little cover at present. Regardless of what modifications occur in the channel, it will probably have to be relocated.

- Hayden Road Crossing:

The Hayden Road Crossing has an electrical line overhead and a 36"-diameter water transmission main.

- Tri-City Sewer Line:

The Tri-City sewer line is a 54"-diameter main located along the north bank of the channel in the area of Mill Avenue.

2.4 Land Use

Most of the land within or near the channel is presently used for commercial or recreational purposes. Some of the recreational uses include parks, golf courses, and equestrian trails.

2.5 Landfills

The Rio Salado Development District retained Dames & Moore (1987) to conduct a preliminary examination into the scope of the problem presented by waste sites within the boundaries of the Rio Salado Development District, and to develop a plan of action for dealing with the waste sites in an environmentally sound manner. This study identified 11 sites in the Tempe reach of the Salt River (48th Street to Price Road). Table 2.2 summarizes the landfill locations in the City of Tempe identified by that study. The Dames and Moore report was used during the location study to preliminarily identify the location of landfills that were adjacent to the Salt River channel.

Concurrent with the design of the channelization for the East Papago Freeway, ADOT conducted a more detailed investigation of the landfills located in the Salt River floodplain from 40th Street to the Southern Pacific Railroad bridge, west of Mill Avenue (SH&B, 1988). There is also another investigation of landfill location and contaminant levels underway by EPA from Rural Road to Dobson Road associated with the Superfund site at this location. The investigation to date has concentrated on areas east of Hayden Road.

Comparing the preliminary Rio Salado District Study to the more detailed ADOT and EPA studies, it is clear that the Rio Salado District Study provides a very rough assessment of the location of landfill material adjacent to the Salt River channel. The two detailed studies cover approximately 60 percent of the Salt River reach through Tempe. A gap in detailed coverage exists from the Southern Pacific Railroad bridge to Hayden Road. Significant disturbance of the land is evident in this area, which includes both small and large landfills. During the East Papago Freeway location study, the landfills located on both sides of Rural Road on the south bank of the river were identified as rubble and earth fill. However, no investigation of the character of these landfills was made. The landfill east of Rural Road will eventually be tested in conjunction with the investigation of the Superfund site. This leaves an unstudied portion of the Tempe Rio Salado District from the SPRR bridge to Rural Road.

While previous studies do not indicate any contamination problems in these landfills, these findings should not be accepted without confirmation tests. The data base for landfill location and character is therefore incomplete at this time, and Tempe should undertake a subsurface investigation to map existing landfills in the river reach from the SPRR bridge to Rural Road, prior to more detailed design of the channel.

Table 2.2

LANDFILLS

Site No. (*)	Location	Owner	Size (Acres)	Contents
41	Tempe So. Bank Salt River west of Pima Rd.	Private	40	R,D
47	SRP5 No. of University west of 56th St.	SRP	55	L/T,D
48	RS60 Rio Salado Road & Hardy Rd.	unknown	85	D,F,G,S&G
49	JD'S SPR73 No. Bank of Salt River east of Scottsdale Rd. and So. of Gilbert Rd.	SRP	5	S&G
50	JD'S SPR75 No. Bank of Salt River Between Scottsdale Rd. and Hayden Road	SRP	10	S&G
51	SRP78 No. Bank of Salt River West of Hayden Road	SRP	20	R,L/T,D
52	RS82 (part of Tempe Landfill) So. Bank of Salt River East of Hayden Rd.	Private	35	R,D,G,COM W,MW
59	RS72 So. Bank of Salt River at Hayden Rd.	A.S.U.	70	unknown
60	SRP 48th St. Middle of Salt River west of Rural Rd.	SRP	10	L/T,D
61	RS68 So. Bank of Salt River west of Rural Rd.	A.S.U.	40	unknown
63	First St. & Perry Ln. So. Bank of Salt River east of Hayden Rd.	City of Tempe	50	UCW (**)

Contents Legend

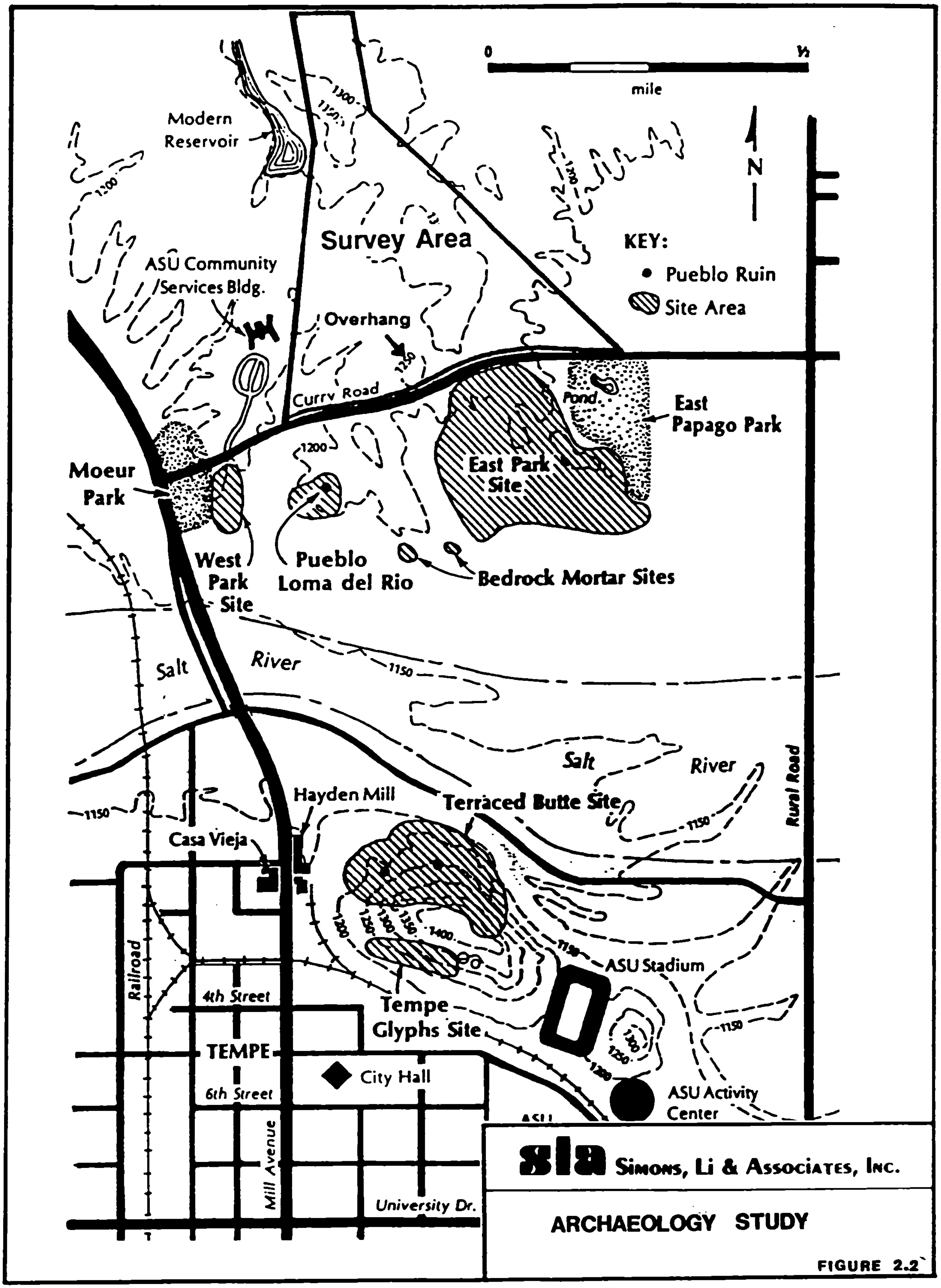
D	- Debris, Misc.
F	- Furniture, Home Appliances, Fixtures, TVs
G	- Household Garbage
R	- Rubble (Construction Site Waste)
L/T	- Lawn & Tree Trimmings
S&G	- Sand & Gravel
Com W	- Commercial Waste (paper, office supples)
MW	- Municipal Waste
UCW	- Unknown Chemical Waste, Industrial & Other

* Corresponds to Dames & Moore Report.
** At part of site only

2.6 Archaeology

Archaeologic investigation has recently been conducted around the area of Tempe Butte and Mill Avenue, and south of Curry Road (ASU, 1988). Figure 2.2 shows areas of study conducted by the Arizona State University, Department of Anthropology, in 1988. The archaeological sites are relatively small, representing both the Indian and Anglo occupations of the Salt River valley. Evidence of occupation spans more than one thousand years of history (A.D. 800 to late 1800s and early 1900s), as indicated by the discovery of the following types of artifacts: stone masonry structures, pottery/ceramic shards, stone/lithic tools, glycymeris shell, and petroglyphs.

Channelization will occur within the river bed between existing banklines of the Salt River. No known archaeology sites occur in this area. The nearby known sites, however, may add to the recreation/tourism value of the park, if incorporated in the overall Rio Salado Plan.



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ARCHAEOLOGY STUDY

FIGURE 2.2

III. DESIGN CRITERIA

The hydraulic design criteria are based on the design goals for the study that were introduced at the beginning of this report. The design criteria address the following areas:

1. Design discharge.
2. River form--including alignment, profile and section.
3. River stabilization--including lateral and longitudinal control structures.
4. In-channel features--including low-flow channel and lakes.
5. Off-channel features--including overbank storage.
6. Reclamation of channel and floodplain areas.

A more detailed discussion of each design area, and the corresponding design criteria, is presented in the following sections.

3.1 Design Discharge

The 100-year flood was selected as the appropriate flood-hazard level. The risk to life, property, and natural floodplain values for this project were considered typical of urbanized areas for which the base flood hazard is set at the 100-year return period (i.e., that return period which has a one-percent chance of being exceeded in a given year). No activities are planned in the flood-hazard zone that have a critical value, such that a lower risk of flooding would be necessary. No development of land in remnant sections of the channel will be undertaken until the land surface is raised to the elevation of the 100-year flood, plus a level of freeboard commensurate with the land use. The exception to this action will be in areas developed to provide floodplain storage, or in areas restored to provide a natural riparian setting outside of the floodway boundary.

The actual discharge used for design is based on the current hydrology for the Salt River given in the CAWCS report of 1982. The 100-year design discharge is 215,000 cfs at the confluence with Indian Bend Wash. This discharge is considered to be characteristic of the entire project area which covers the Salt River reach from 48th Street to Hayden Road. When construction money is authorized and work begins on the Roosevelt Dam improvement, the hydrology for the project should be revised. This could result in a 25-percent reduction in the 100-year flood discharge for the project. However, this reduction in flood levels could be offset in the future by the continued loss of floodplain storage in the upper reaches of the Salt River. At the present time, the upper Salt River channel is being actively mined for sand and gravel. The long-term effect of this mining is both an entrenchment of the main channel and a reduction in the floodplain width, resulting in a reduction in floodplain storage.

Since the actual time frame for construction of the Roosevelt Dam modifications is uncertain, it is prudent to continue to use the Salt River hydrology that has been established for existing conditions, until such time that the dam modifications are in place and the condition of the Salt River floodplain can be reevaluated.

3.2 River Form

3.2.1 River Alignment

A broad objective for design of the river alignment is to select a plan form for the main channel that conforms with general geomorphic features of the natural Salt River channel. In addition, the channel alignment should conform to the location of various structures and facilities that presently exist in the Salt River channel. Some of these facilities would be extremely expensive to relocate, and therefore are considered fixed constraints on the channel alignment. Because of the large size of the Salt River, rates of curvature must be small. For the planned channel width, the radius of curvature for the main channel cannot be less than approximately one mile, or greater than a one-degree curve.

Historically, the Salt River through Tempe was a braided, gravel bed channel that was wide and relatively shallow. Today, the upper reaches of the Salt River, east of Country Club Road, provide a good example of the basic form of the Salt River channel. In a braided channel, the individual braids are more sinuous and tend to meander and intertwine. The reach of the Salt River through Tempe had several unique geomorphic features that resulted from the geologic control that exists in the river channel at the buttes near Mill Avenue. The river had a meandering form upstream of the buttes, which was referred to as the Indian Bends. Downstream of the buttes, the river accelerated in a relatively narrow, straight reach that widened substantially below Priest Drive.

In addition to the natural channel form, there are also a number of constraints that must be dealt with in the existing river channel. There are five existing bridges crossing the Salt River in the Tempe reach, including: the Southern Pacific Railroad bridge, Ash Avenue, Mill Avenue, Rural Road, and Hayden Road. As part of the East

Papago Freeway construction and related transportation work, two additional bridges will be constructed in the Tempe reach, one for the Hohokam Freeway and another for Priest Drive. Both of these bridges will cross a channelized reach of the Salt River that ends 1500 feet downstream of the Southern Pacific Railroad bridge. These bridges and the planned channel were assumed to be fixed constraints that could not be moved.

Less rigorous constraints on the alignment occur due to the existing location of Rio Salado Parkway, the at-grade crossing near Mill Avenue, the Indian Bend Wash confluence, existing utilities, and current development in the floodplain. The intersection of the Rio Salado Parkway and the Mill Avenue at-grade crossings are presently located in the river floodway, and may have to be modified to accommodate further channelization. The Indian Bend Wash confluence will shift laterally, depending on the specific alignment of the Salt River channel selected. The only significant development occurring in the channel floodway is the ASU/Sun Angel Foundation golf course, located west of Hayden Road on the south bank of the river. Several of the golf-links are in the main channel, and they will impose a significant constraint to the channel alignment.

3.2.2 River Profile

The design criteria for the channel profile are intended to meet three main objectives: (1) reduce flood elevations; (2) provide a stable channel invert that is not subject to substantial aggradation or degradation; and (3) provide borrow material that can be used by ADOT for construction of segments of the East Papago Freeway. The three objectives compliment one another, and are largely a consequence of borrow requirements for the East Papago Freeway project. Approximately seven to ten million cubic yards of fill material is required by this project. The location of the Tempe channelization project offers a convenient source of material for that project. It also creates the opportunity to incorporate several desired recreational features into the channelization project.

The lowering of the channel invert will permit the narrowing of the floodway, with the result that land can be reclaimed from the adjacent floodplain. In many cases, land reclamation will not require that land be raised above the 100-year flood elevation, but simply that a more usable floodplain area be created that can accommodate a larger range of recreational activities and facilities.

The deepening of the channel will result in a flatter channel gradient, or a level grade through part of the reach. This will permit the formation of lake areas within the channel bed. A flatter channel gradient will permit the circulation of water from a series of lakes along the channel bed with a minimum of pumping.

Since the prevailing grade of the Salt River through the City of Tempe is 0.002 ft/ft (about ten feet per mile), a potential consequence of a reduced channel gradient is deposition of sediment. The chance of significant deposition in the Tempe reach is considered low because of the large volume of sand and gravel production that is occurring in the upper reaches of the Salt River at this time. Previous studies for the channelization west of Mill Avenue indicate that the river reach east of Mill Avenue is degrading. Lowering the river gradient in this reach should arrest this process, and provide a more stable river reach.

3.2.3 River Section

The design objective for the river cross-section is to provide a section that conveys the design flood discharge through the site with approximately the same hydraulic characteristics as the existing channel. Locally, the section should include stable channel banks that will not permit any lateral erosion by major flood flows. Hydraulic features of the cross-section include a low-flow channel capable of conveying mean Salt River Project (SRP) spills up to approximately 5000 cfs, a main floodway with the capacity for the 100-year discharge, and a floodway terrace set near the elevation of the 10-year discharge. At some locations, the section will include off-channel storage areas that are non-conveying.

There are substantial opportunities for variation in channel section in the reach from Mill Avenue to Hayden Road. Once the basic requirements of hydraulic capacity and channel stability have been met, enhancements can be made that are geared toward the planned recreational and land-use development for the district. The addition of floodway terraces and off-channel storage can be used to mitigate the loss of floodplain storage.

3.3 River Stabilization

The objective of river-stabilization measures is to control the lateral and longitudinal migration potential of the river channel. Because of the value of adjacent property, lateral migration of the main channel bankline will not be permitted. Within the main channel, features such as the low-flow channel will be permitted to shift in response to flood events. Design of any in-channel features must consider both the effects of severe flooding and potential shifts of in-channel form.

The vertical profile will be permitted to adjust within a range typified by the movement of channel bedforms and local scour. A prevailing trend of general degradation will not be permitted, and will be controlled at sufficient intervals to prevent any loss or damage to existing or planned in-stream structures. The bank stabilization will be set to an elevation below the combined effect of general degradation and bed form movement, with a factor of safety of 1.3 also provided (i.e., 1.3 times the total scour estimate). All grade-control structures will be set to an elevation below the effect of local scour at the downstream limit of the structure.

3.4 <u>In-Channel Features</u>

In-channel features such as a low-flow channel, lakes, or dunes will be designed to provide controlled passage of an SRP spill of up to 5000 cfs, but so as not to obstruct the passage of the design flood event. The addition of plant materials into the channel is desired to provide a landscaped visual quality that integrates the river environment with the adjacent Rio Salado Park and development. The in-channel landscaping will be evaluated from both the standpoint of hydraulic roughness and potential of debris creation. The hydraulic roughness will vary with the size and density of plants placed in the channel. Debris creation results from the erosion of plants by flood flows. The risk of damage from debris is greater the larger the size of the vegetation and the more vegetation that is scoured from channel.

3.5 <u>Off-Channel Features</u>

Channelization will result in a decrease in floodplain volume during major floods. To off-set this loss, opportunities will be sought to create floodwater storage areas adjacent to the river floodway. The objective will be to establish locations of dynamic flood storage that can be used for multiple purposes such as recreation or riparian habitat.

3.6 <u>Reclamation of Channel and Floodplain Areas</u>

The channelization of the Salt River in the Tempe reach will permit the use of land that is currently in the river floodplain. The type of land use will vary throughout the Rio Salado District; and, as such, the level of flood protection will also vary accordingly. For lands that are in the new channel, the level of flood protection will be set at a discharge of 5000 cfs. No hard protection will be provided in the channel, but consideration will be given to properly aligning the in-channel features with the prevailing flow direction and minimizing potential debris formation. The primary recreational features of the park will be placed above the elevation of the 10-year flood. Because these areas may also be in the floodway, consideration will also be given to proper alignment of in-channel features and minimization of debris formation. All land reclaimed for commercial development will be set above the design flood elevation, plus three feet of freeboard.

IV. CHANNELIZATION ALTERNATIVES

4.1 Alignment

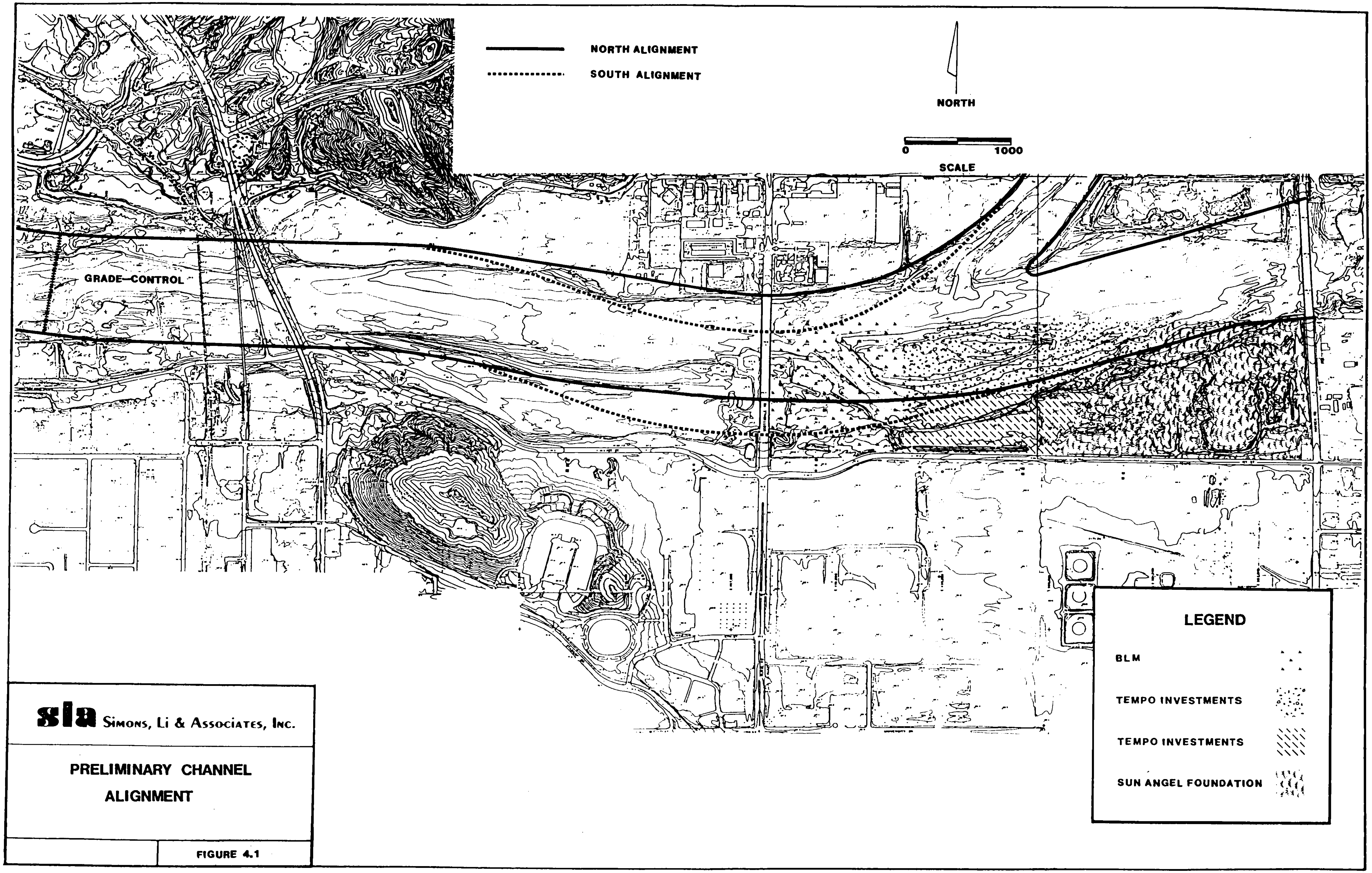
The alignment of the 1,000-foot-wide channel is defined to a large extent by the location of the three bridges (Mill Avenue, Rural Road, and Hayden Road) and ADOT's planned channelization and grade-control structure located west of Mill Avenue. Early in the study, two preliminary channel-alignment alternatives were developed for the reach from the ADOT grade control (1500 feet downstream of the Southern Pacific Railroad bridge) to Hayden Road.

The first alternative aligned the channel with the north abutment of the Rural Road bridge, thereby maximizing the amount of land reclaimed from the south bank (Figure 4.1). As criteria for channel form were developed in more detail, this alignment was found to have several disadvantages. The most important, from a hydraulic standpoint, is the straightening of the natural meander form in this reach of the channel. This becomes a potential problem due to the presence of the Indian Bend Wash confluence, between Rural Road and Hayden Road, which tends to force a channel curvature (as illustrated in Figure 4.2). Flood flows from Indian Bend Wash will tend to erode the Salt River channel downstream and opposite of the confluence and deposit sediment downstream of the confluence; thus creating a channel bend.

The second alternative maintains the natural curvature by aligning the channel with the southern abutment of Rural Road, which conforms more closely to natural conditions. This results in more reclaimable land on the north bank of the channel.

During the initial development of alignment alternatives, the Task Force adopted the southern channel alignment as a working alternative, and then searched to further refine that alternative by soliciting comment from land owners adjacent to the proposed alignment. The southern alternative was selected, because it provided correct river-hydraulics conditions and good opportunities for river-park development. The two basic alternatives were reviewed by a number of interested parties, and comments were solicited on the potential impact of the alignments on development plans.

Three land owners provided comment on the proposed channel alignment, including: Arizona State University, Sun Angel Foundation, and Tempo Investments. The University owns a substantial amount of land on the south bank of the Salt River from Mill Avenue to Rural Road, and has expressed interest in other public lands adjacent to their property. The Sun Angel Foundation is currently completing work on a golf course that is located west of Hayden Road in the Salt River floodway and



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PRELIMINARY CHANNEL ALIGNMENT

FIGURE 4.1

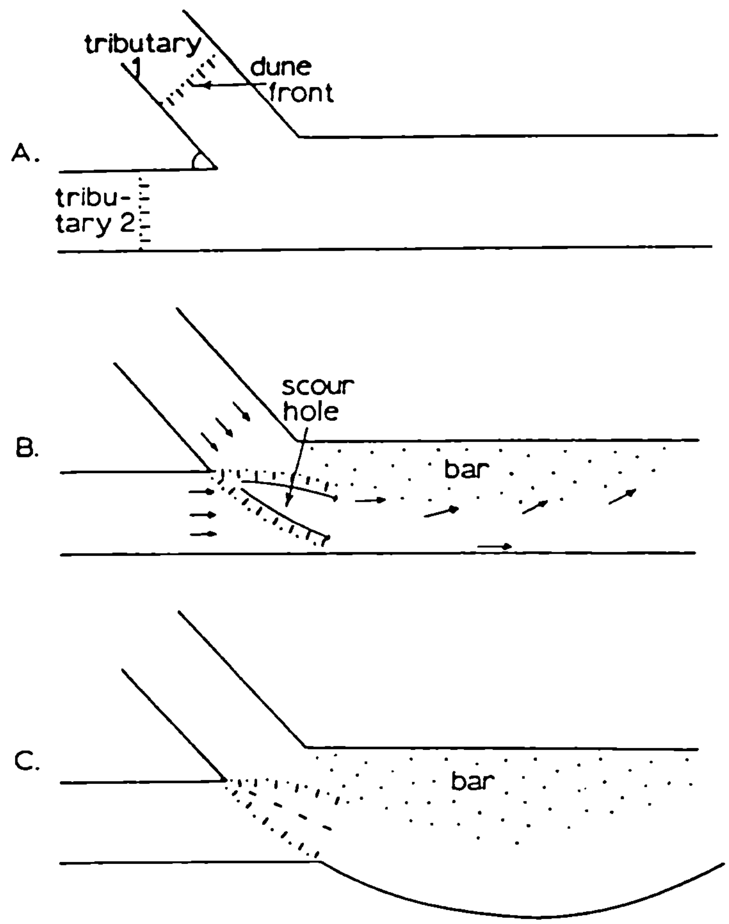


Figure 4.2

Channel Confluence

floodplain. Once the course is completed, it will be deeded to ASU by the foundation. Tempo Investments owns a section of the south bank of the Salt River, from Rural Road east to the Sun Angel Foundation golf course.

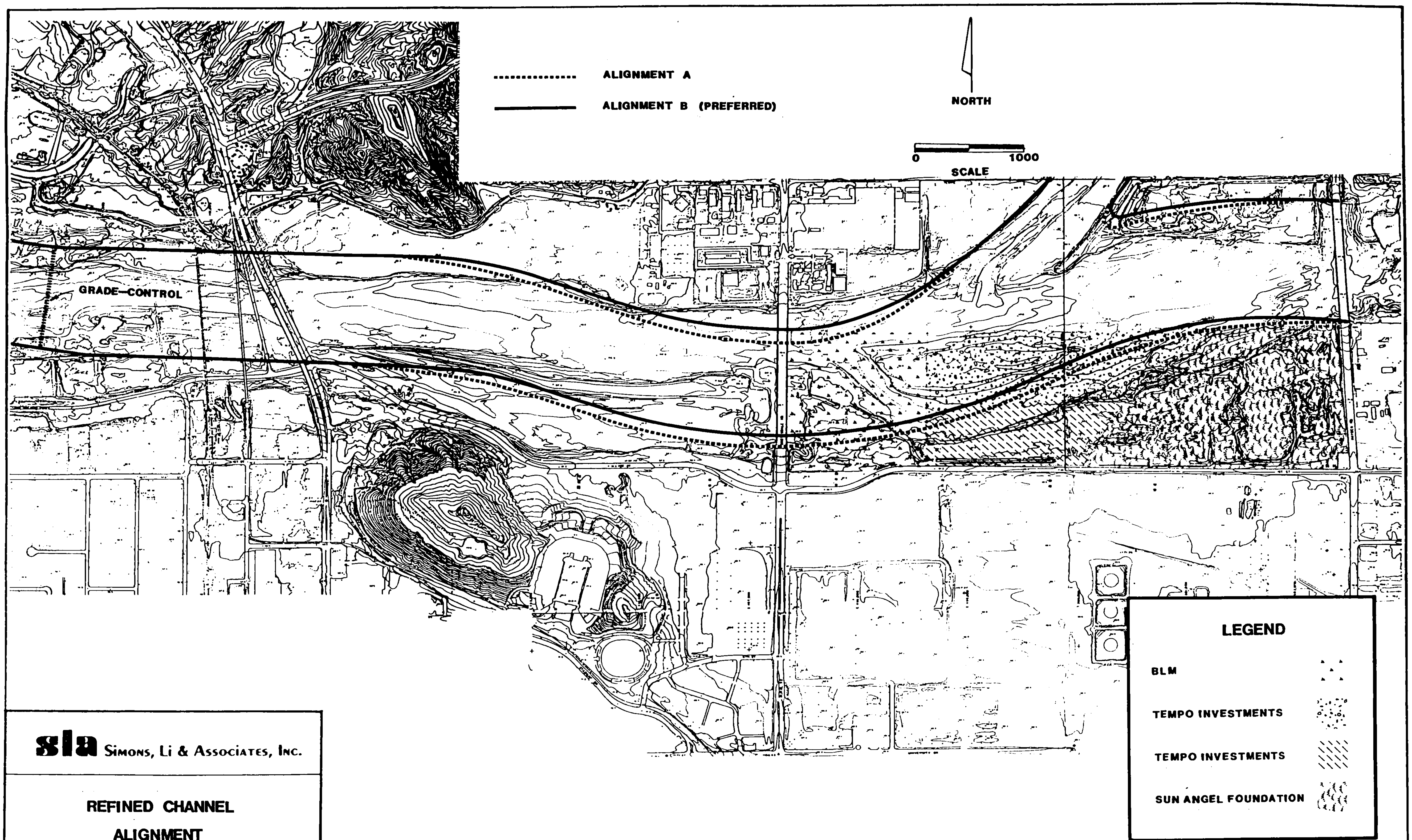
The location of the Sun Angel Foundation golf course created a problem for either proposed channel alignment. The difficulty occurs because a portion of the course is being constructed within the floodway, and the entire course north of First Street is in the floodplain. This constrains the channel alignment to head due west, beginning at Hayden Road. There is no solution for completely protecting the course from flooding. However, the main objective is to find an alternative that would protect the in-stream portions of the course from scour damage. Two alternatives were formulated based on the preferred southern channel alignment (see Figure 4.3).

Alignment A was set using the south abutment at Rural Road as a control, and directing the channel alignment due west through the Hayden Road bridge. In addition, a minimum bend radius of 5000 feet was used. With these adjustments, a portion of the golf course remains in the channel floodway, and would be subjected to scour damage during high flows.

Alignment B was set by offsetting the south channel bank 100 feet to the north at Rural Road, while keeping the channel bend radius at a minimum. This provides sufficient area on the south bank so that a guidebank could be constructed to protect the golf course. The golf course would continue to be subject to flood inundation, but would be protected from scour damage.

Compared to the original southern alignment, both alternatives have one distinct disadvantage in that they do not complete the channel bend before reaching the Indian Bend Wash confluence. This means that the flow will detach from the north channel when it reaches the confluence, and that the remainder of the redirection of the flow will be affected by the west bank of Indian Bend Wash. This will require significant bank stabilization to effectively control the flow at this location and to prevent scour. In the case of Alternative A, this bank stabilization will extend approximately 650 feet along the west bank of Indian Bend Wash. For Alternative B, bank stabilization would extend approximately 1000 feet.

Because of the many advantages for planned development on the south bank of the Salt River channel, Alternative B was selected as the preferred alignment alternative.



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REFINED CHANNEL ALIGNMENT

FIGURE 4.3

4.2 Profile

A baseline water-surface profile was determined for the existing channel conditions from the ADOT grade control to Price Road (Figure 4.4). An analysis was then conducted to determine the effect of a narrowed channel on the water-surface profile for the existing channel gradient (0.0015 ft/ft). For a 1000-foot-wide channel, this analysis showed that the resulting restriction in the waterway at the Rural Road bridge would create unacceptably poor hydraulic conditions, and an overall increase in flood elevations in the reach. Alternative profiles were investigated that would maintain an adequate distance between the water surface and the bridge superstructure at Rural Road, for a channel width of 1000 feet.

An alternative channel profile was developed by reducing the channel gradient through the reach. The downstream profile elevation is fixed by the elevation of the ADOT grade-control structure. It was found that by pivoting from that control point to a channel gradient of approximately half that of the existing gradient (i.e., 0.00073) that hydraulic conditions would improve substantially. This channel profile was extended east of Hayden Road, until it intercepted existing mining excavation upstream of the bridge. Figure 4.5 shows the existing and proposed profiles for the second alternative along the channel centerline.

A third profile alternative was developed by further reducing the channel gradient in the reach from the ADOT grade control to Rural Road to one-tenth that of the original gradient. This creates a nearly level reach suitable for water bodies, and results in a grade displacement at Rural Road of five feet. The reduced gradient improved hydraulic conditions at the Mill Avenue bridges, and results in a lowered water-surface profile in the reach below Rural Road. Figure 4.6 shows the existing and proposed profiles for the third alternative along the channel centerline.

A fourth profile alternative, similar to the third, was developed which reduces the entire section from Rural Road to Hayden Road by five feet. Figure 4.7 shows the existing and proposed profiles for the fourth alternative along the channel centerline. One disadvantage of this fourth alternative is that as the slope in the channel is decreased, the relative water-surface elevation is decreased but the depth of flow in the channel increases--thus making the channel larger and more expensive. Another disadvantage is that with the invert of the channel lowered, a drop of about fifteen feet exists between the invert of Indian Bend Wash and the Salt River invert at the confluence.

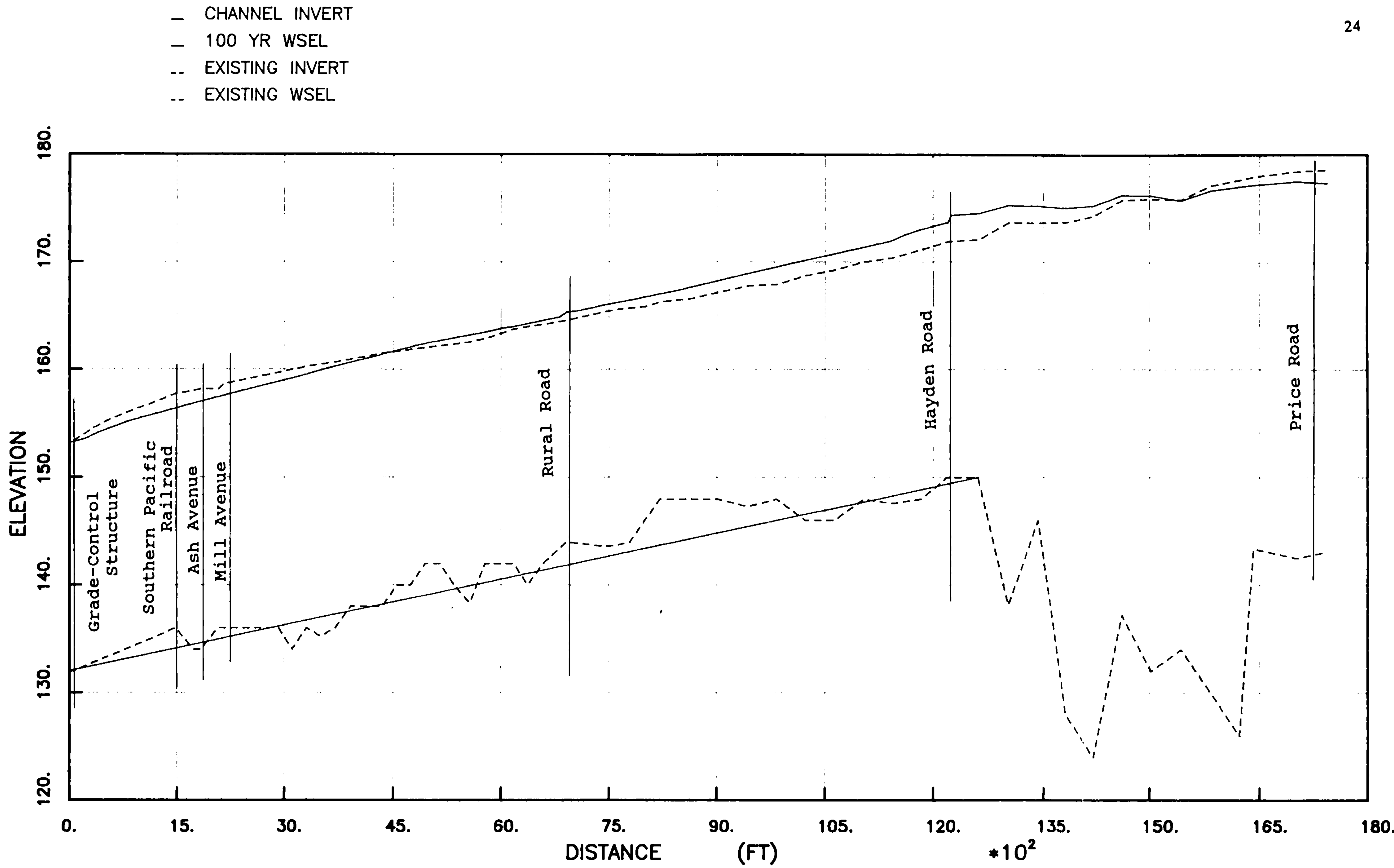


Figure 4.4 Baseline Water-Surface Profile

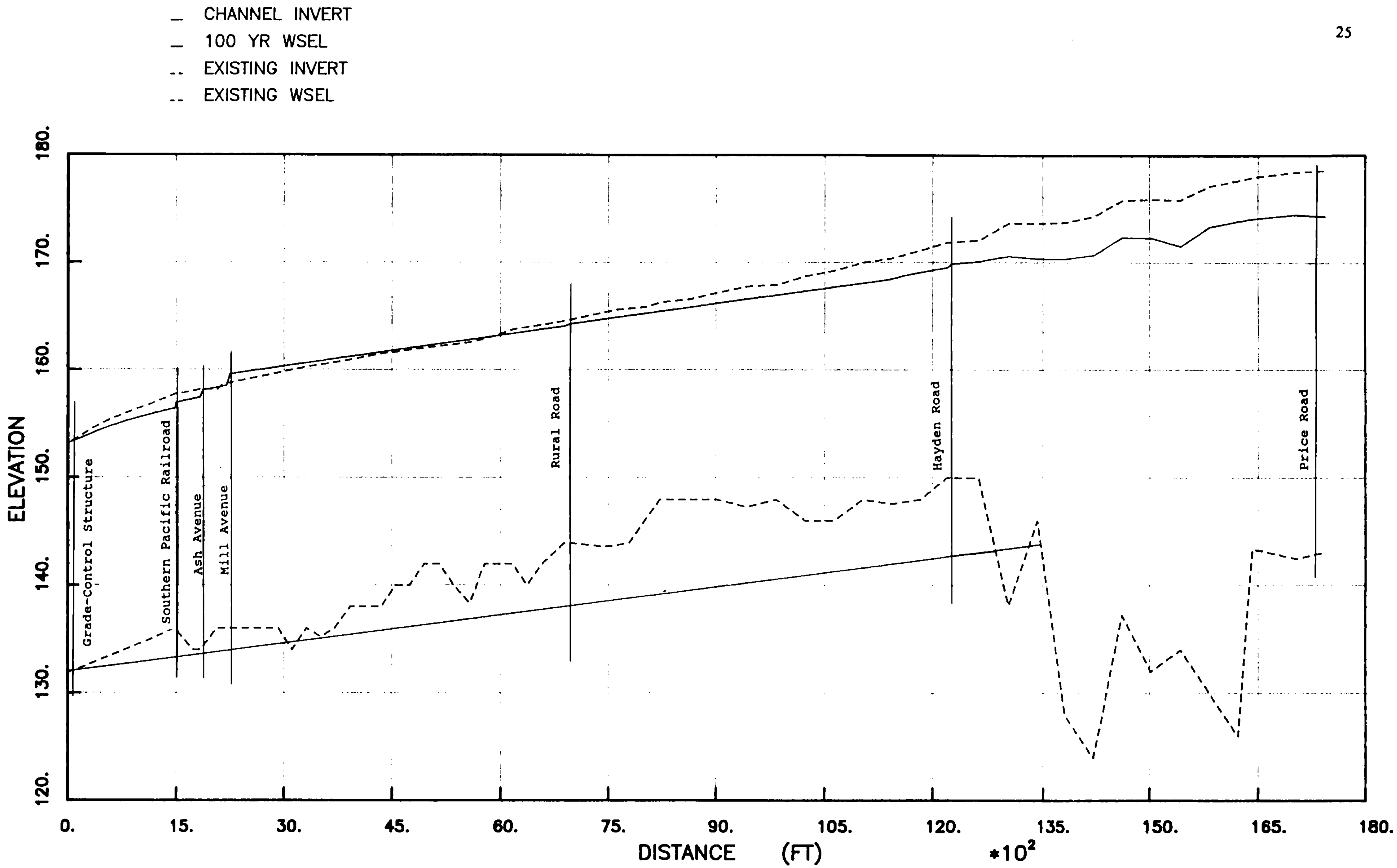


Figure 4.5 Second Alternative Profile

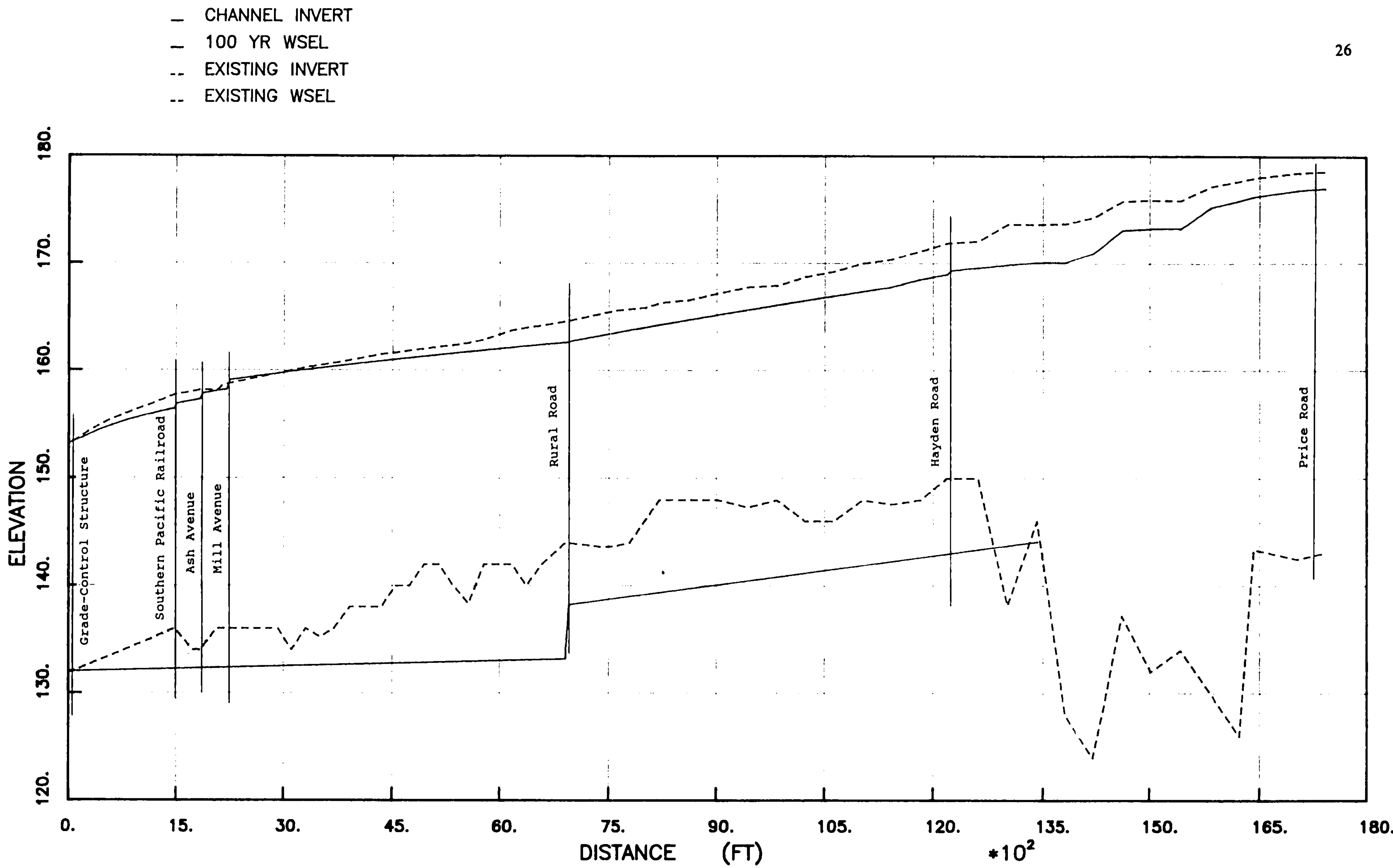


Figure 4.6 Third Alternative Profile

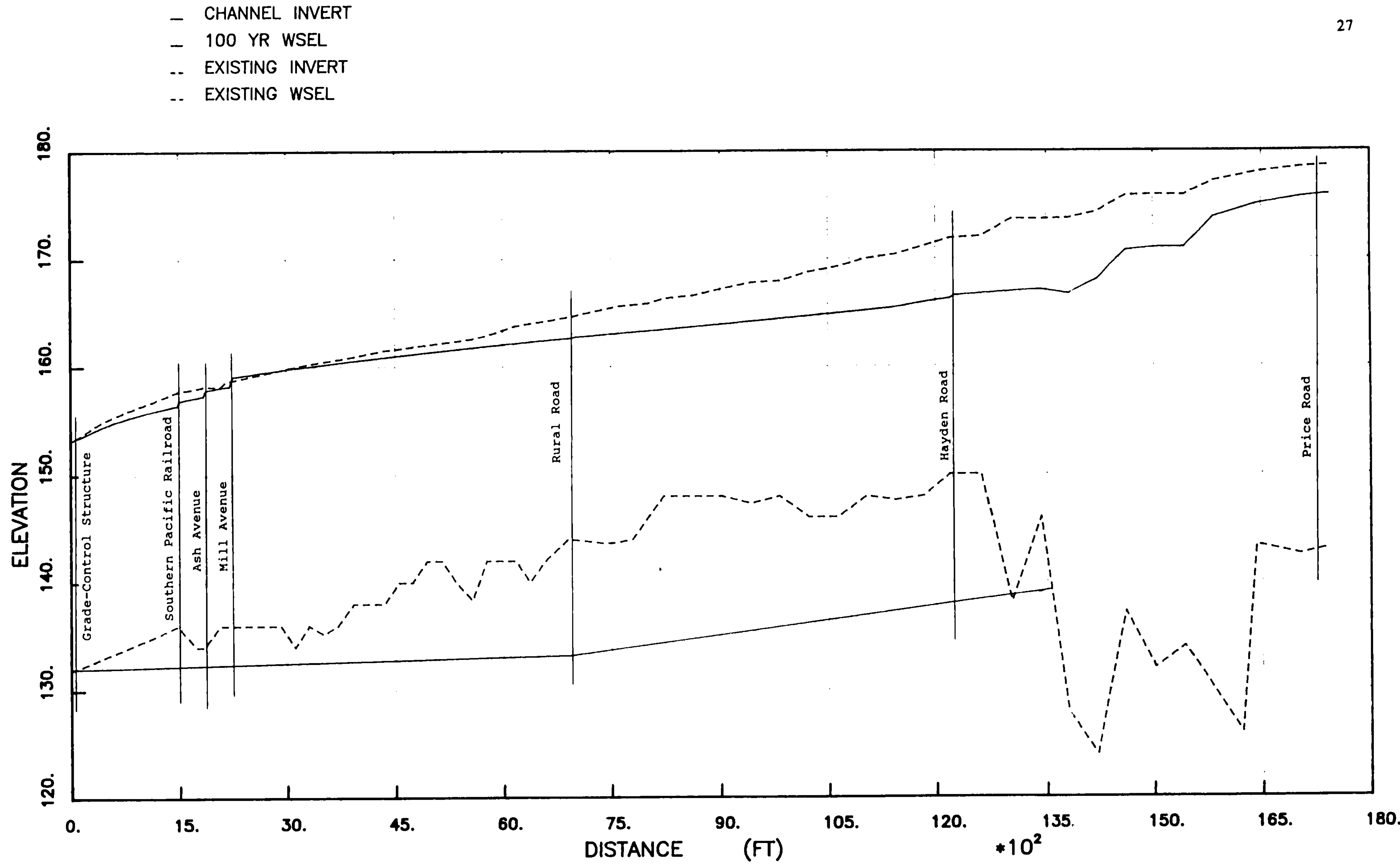


Figure 4.7 Fourth Alternative Profile

The third and fourth alternatives are the most feasible, because of the following three advantages: (1) they allow the 100-year discharge to free flow at the Rural Road Bridge; (2) they lower the water-surface elevation, thereby lowering the elevation of the top of the levees needed to contain the flows and reduce the amount of fill needed outside the channel to develop the land previously in the floodplain; and (3) they provide a borrow source for the construction facilities adjacent to the new channel.

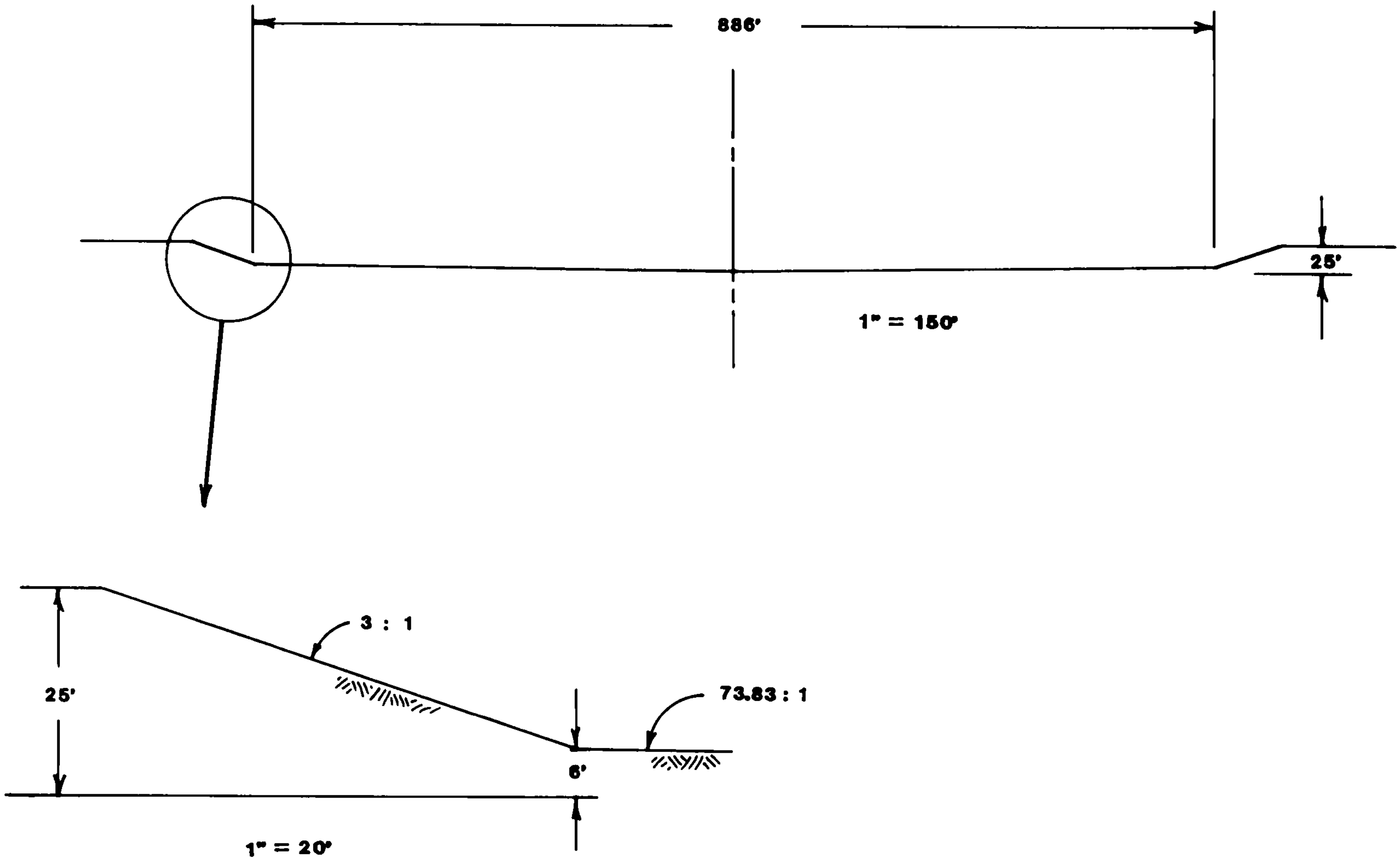
The lowering of the channel invert lowers the water-surface profile up to four feet in some locations. The water-surface elevation, however, is still above the elevation of First Street. This means that during large flows, most of First Street will be inundated.

4.3 Channel Cross-Section

The general channel cross-section proposed for the Tempe Rio Salado Park is a five-point cross-section, as shown in Figure 4.8. Banks for the channel are set at an average slope of 3:1 (horizontal to vertical), which provides for adequate room for bank-stabilization measures and landscaping features. The channel bed slopes toward the center of the channel at a cross slope of 1.4 percent. The overall channel depth from top-of-bank to channel invert is approximately 28 feet. This provides capacity for the 100-year flood discharge with 3.0 feet of freeboard. The thalweg (channel invert) is six feet below the toe-of-bank, which results in a 22-foot-high channel bank.

The basic channel section lends itself to a variety of modifications, and can be adapted to provide diverse features both on the channel banks and within the channel section. These include, but are not limited to, a low-flow channel, water bodies, varying bank slopes from vertical to flatter than 3:1, and varying bank form along the reach alignment. The general hydraulic considerations for these channel-section elements are discussed in this section. Other studies are being conducted as part of the overall master plan which address the landscape design of the channel section.

For low-flow conditions, meandering will occur within the main channel. This can be confirmed by the existence of a low-flow channel through the Tempe reach of the Salt River at the present time. The geometry of meandering rivers is quantitatively measured in terms of: (1) low-flow channel width W; (2) meander amplitude A; and (3) meander wavelength (see Figure 4.9). The existing low-flow channel is 300 to 400 feet in width, with a meander amplitude of 1300 feet and a meander wavelength of about



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TYPICAL CROSS SECTION

FIGURE 4.8

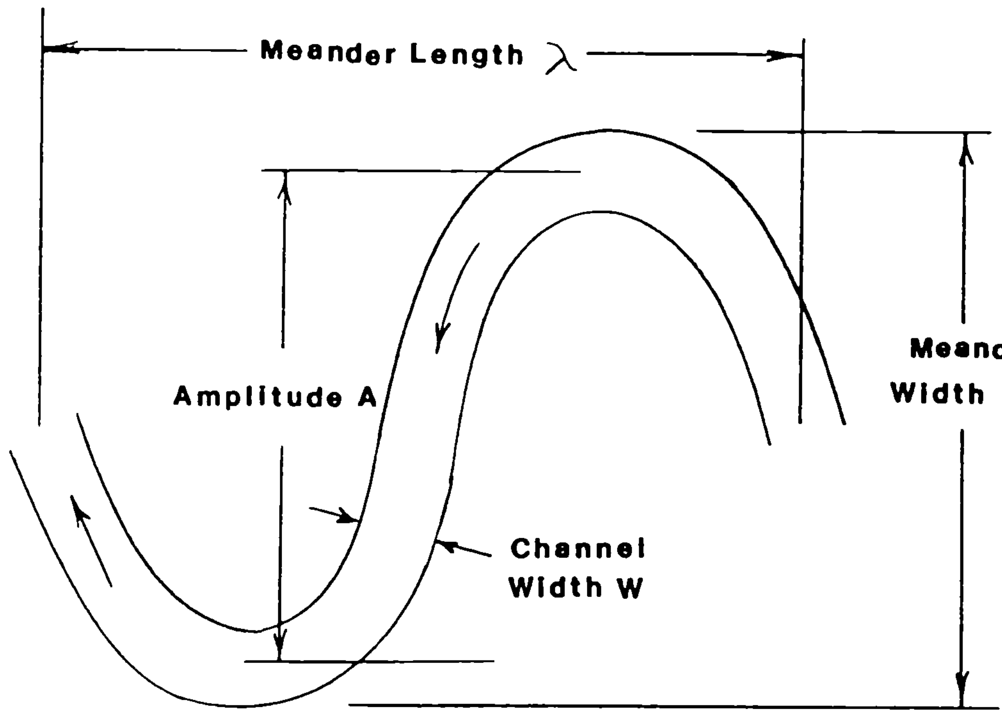


Figure 4.9 Low-Flow Channel Geometry

4000 feet. For a low-flow channel with a 5000 cfs discharge capacity, the channel top-width is estimated to be 225 feet (see calculations in Appendix B). The amplitude and wavelength of the low-flow meander are functions of the low-flow channel width (Leopold and Wolman, 1960). The amplitude and wavelength are given by the following empirical equations:

$$A = 2.7\ W^{1.10}$$
$$L = 10.9\ W^{1.01}$$

which gives a low-flow meander amplitude of 1044 feet and a wavelength of 2590 feet. The total meander path width is equal to the sum of the low-flow channel width and the meander amplitude, or Wm = A + W, which gives a meander-path width of 1270 feet.

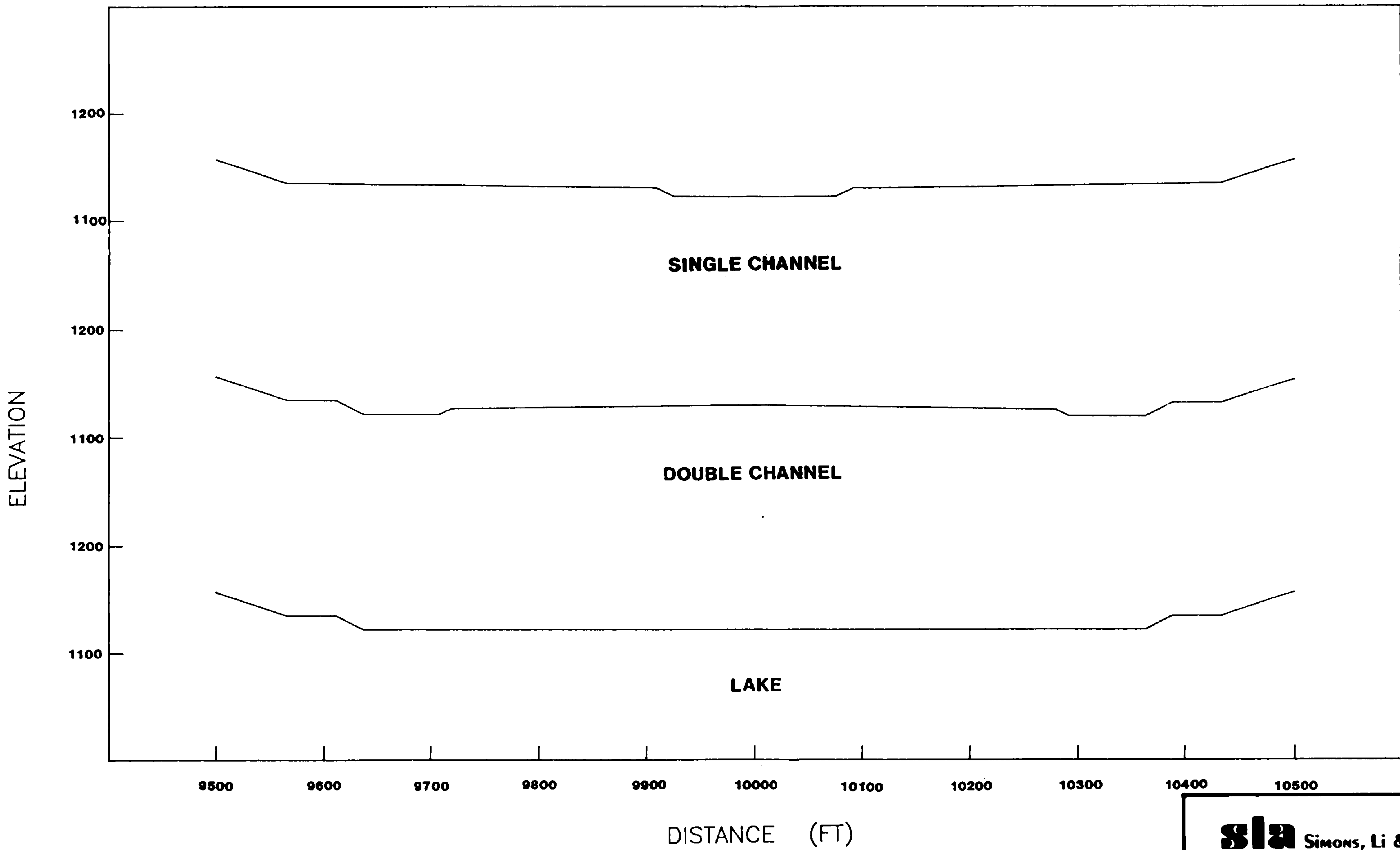
The resulting meander-path width is greater than the width of the main channel. However, given the approximate nature of these estimates, it is not anticipated that constraining the low-flow meander-path width will result in any significant problems. The low-flow channel will have a sinuosity of about 1.34 within the bounds of the main channel. As the low-flow channel meanders, it will tend to vary in width, with the bend areas tending to be wider and the crossing areas narrower. Three typical low-flow cross-sections are shown in Figure 4.10.

In the reach from the ADOT grade-control structure to Rural Road, the channel width needed to convey the low-flow discharge is almost equal to the main-channel bottom width. This is due to the flat channel gradient selected to provide for waterbodies. The channel conditions would be as follows:

Discharge	= 5,000 cfs
Bottom Width	= 700 feet
Slope	= 0.00013 ft./ft.
Depth	= 5 feet
Side Slope	= 2:1
Roughness	= 0.035

4.4 River Stabilization

River-stabilization measures consist of structures for protection of the river banks



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TYPICAL LOW-FLOW CROSS-SECTIONS

FIGURE 4.10

and structures that control the vertical profile of the channel. This section provides a preliminary overview of the alternative types of river stabilization measures that will be required for the Tempe Rio Salado channelization. For bank stabilization, three alternative types of protection measures are available that are adequate for the range of hydraulic conditions found in the Tempe reach of the Salt River, these include: rock riprap, wire-tied rock, and cement-stabilized alluvium. Each of these bank-protection alternatives can be used in landscape design in a flexible manner. In general, the bank protection needs to conform to the main-channel alignment, and not have any abrupt discontinuities in its form.

The advantages and disadvantages of the bank-protection types are primarily in their relative cost, durability, appearance, and habitat value. Table 4.1 summarizes the relative cost difference among the three bank-protection types, assuming a mean riprap stone size of 18-inches.

TABLE 4.1

Relative Cost of Bank Protection Types

Type	Unit Cost	Volume	Total Cost
Rock Riprap	1.0	1.0	1.0
Wire-tied Rock	2.0	0.33	0.66
Cement-Stabilized Alluvium	0.8	0.56	0.45

This shows that cement-stabilized alluvium is the least costly of the three alternatives, and that conventional rock riprap will cost roughly twice as much. Wire-tied rock falls between the other two alternatives.

From the standpoint of durability, conventional riprap and cement-stabilized alluvium (in the form of soil cement) have proven to be very durable at numerous locations throughout Arizona. Wire-tied rock can suffer abrasion problems in channels with a large bed load. Because of the large bed load in the Salt River, the durability of wire-tied rock is considered to be less than that of the two other bank-protection alternatives examined.

The appearance of bank protection is often considered to detract from the natural appearance of a river channel. Rock riprap has the most natural appearance, although when placed in large quantities in a uniform manner it can loose this quality. Wired-tied rock tends to accumulate trash and debris in the wires, which are a maintenance problem. Both rock riprap and wire-tied rock have sufficient voids to permit vegetation to grow through them, which helps hide the bank protection. Excessive vegetative growth can be a maintenance problem. Cement-stabilized alluvium is most stable when placed at the angle of repose of the alluvial material from which it is derived. This results in a steep, monolithic bankline that has an unnatural appearance. However, there is little long-term maintenance with cement-stabilized alluvium. In general, the appearance of bank protection can be enhanced by effective landscaping at the base and top of the bank slope, or even over the protection. A composite section of bank protection can be developed to combine the best features of different types of bank protection.

The habitat value of rock riprap and wire-tied rock are considered to be good, because vegetation can establish in the voids in the rock blanket. The voids also provide cover and shelter for small mammals. Cement-stabilized alluvium is considered to be poor habitat because vegetation cannot establish, and the surface of the bank is smooth and free of voids.

Two major profile stabilization areas in the channel bed are located at: (1) the Rural Road bridge, and (2) the mouth of the Indian Bend Wash channel.

4.5 Floodplain Storage

Another important aspect of concern with channelization is its effect upon the change in floodplain storage. For a non-channelized section during high flows, the existing channel has an inundated condition, and the water spreads out over the banks. Overbank areas have very little conveyance, if any, and provide floodplain storage. The channelization process confines flows within the channel. The flows no longer spread out at high-discharge conditions, and the floodplain storage capacity is reduced. This storage has a great effect upon the attenuation of the peak discharge. Reducing the storage capacity could have a tremendous effect on conditions downstream.

The floodplain storage was analyzed using two reach lengths: (1) the reach from the grade-control structure west of Mill Avenue to Hayden Road, and (2) the total channelized reach within the City of Tempe (from 48th Street to Hayden Road).

There is very little, if any, change in storage for low flows (e.g., 10-year or less) for the channel reach from the grade-control structure to Hayden Road, as shown in

Figure 4.11. This figure shows that as flows increase, channel capacities are inundated and the volume of storage increases. The cumulative floodplain storage lost by channelization between the grade-control structure and Hayden Road is about 1070 acre-feet. A majority of this lost volume/storage can be recovered by incorporating storage areas within the channel. One area of consideration is the Sun Angel Foundation Golf Course. Since the links are not completely protected by the channel, high-stage flows would cause flooding on the course up to a volume of about 528 acre-feet, assuming inundation depths are approximately nine feet. Another area of consideration for possible floodplain-storage recovery is between Mill Avenue and Rural Road. By increasing the channel width above the 10-year flows, a volume of 394 acre-feet could be recovered. These two areas provide a total of 922 acre-feet of recovered storage, leaving a deficit of about 148 acre-feet.

Similar conditions exist for the entire reach from 48th Street to Hayden Road (Figure 4.12). This area has additional storage capacity loss due to a bend in the existing channel. This bend influences both the high and low flows. For the 10-year conditions, the total difference in volume is approximately 1100 acre-feet with no recovery. The 100-year condition has a total volume difference of 2970 acre-feet. With the storage added to the system; that is, 48th Street to the grade-control (900 acre-feet), bench area between Mill Avenue and Hayden Road (394 acre-feet), and the golf course (528 acre-feet), the total remaining deficit is approximately 1148 acre-feet.

4.6 Excavation/Fill Quantities

The lowering of the channel invert and the flattening of the channel slope between the ADOT grade-control structure and Hayden Road, a length of approximately 2.4 miles, will require excavation of the channel bed. The quantity of excavation in this reach is approximately 3.0 million cubic yards, not including any excavation for water bodies, such as streams and lakes. The quantity of material needed for the levees and adjacent to the channel to fill up to the 100-year-flood level is approximately 5.2 million cubic yards, a deficit of 2.2 million cubic yards.

By filling up to the 100-year water-surface elevation, the floodplain is reduced and the land can be developed. Using FEMA Floodplain Maps (April 1988), the approximate land removed from the floodplain was planimetered. The channelization would increase the amount of usable land within Tempe by about 838 acres (1.3 square miles) between 48th Street and Price Road.

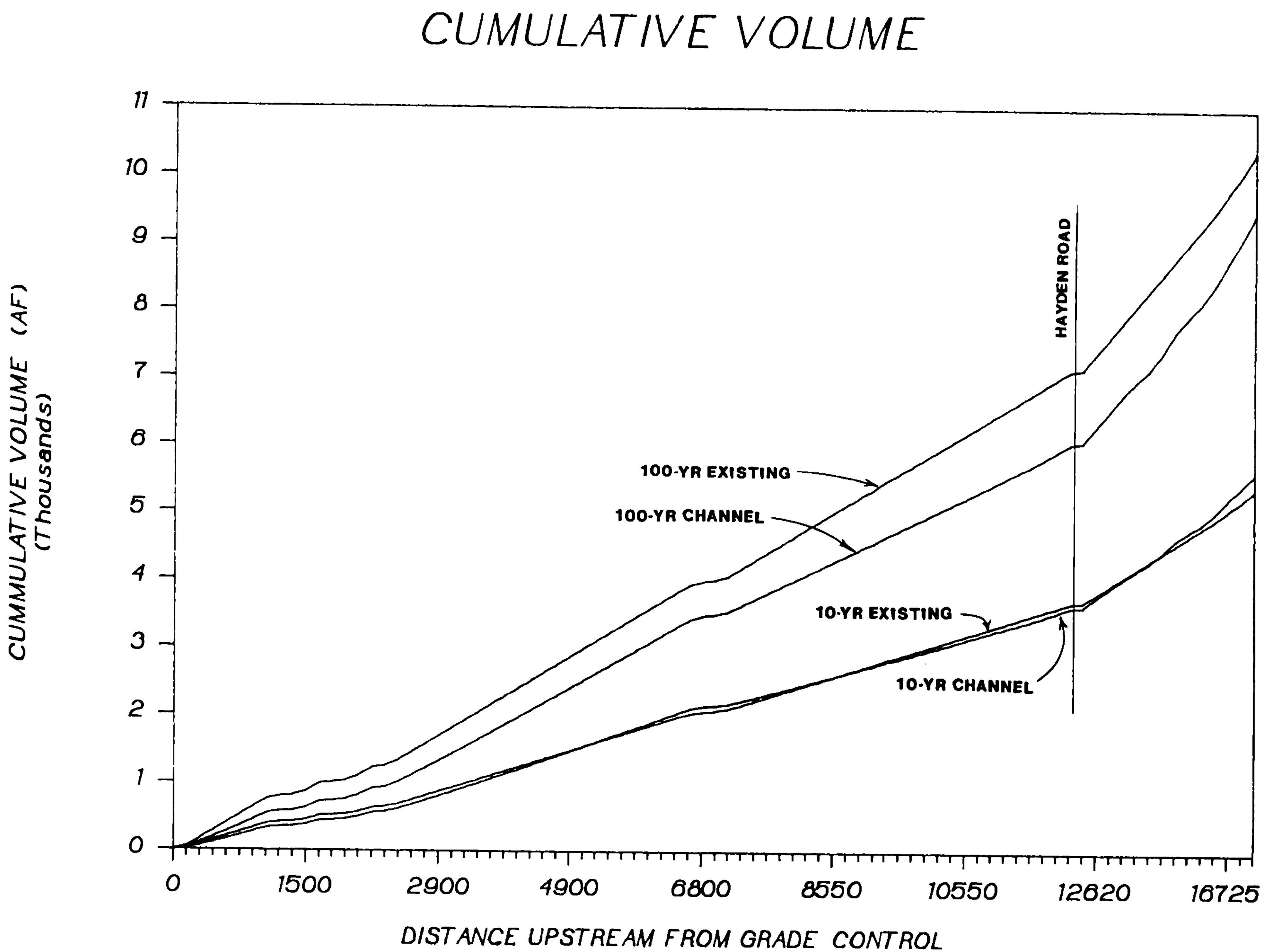

Figure 4.11 Storage Capacity Grade Control to Hayden Road

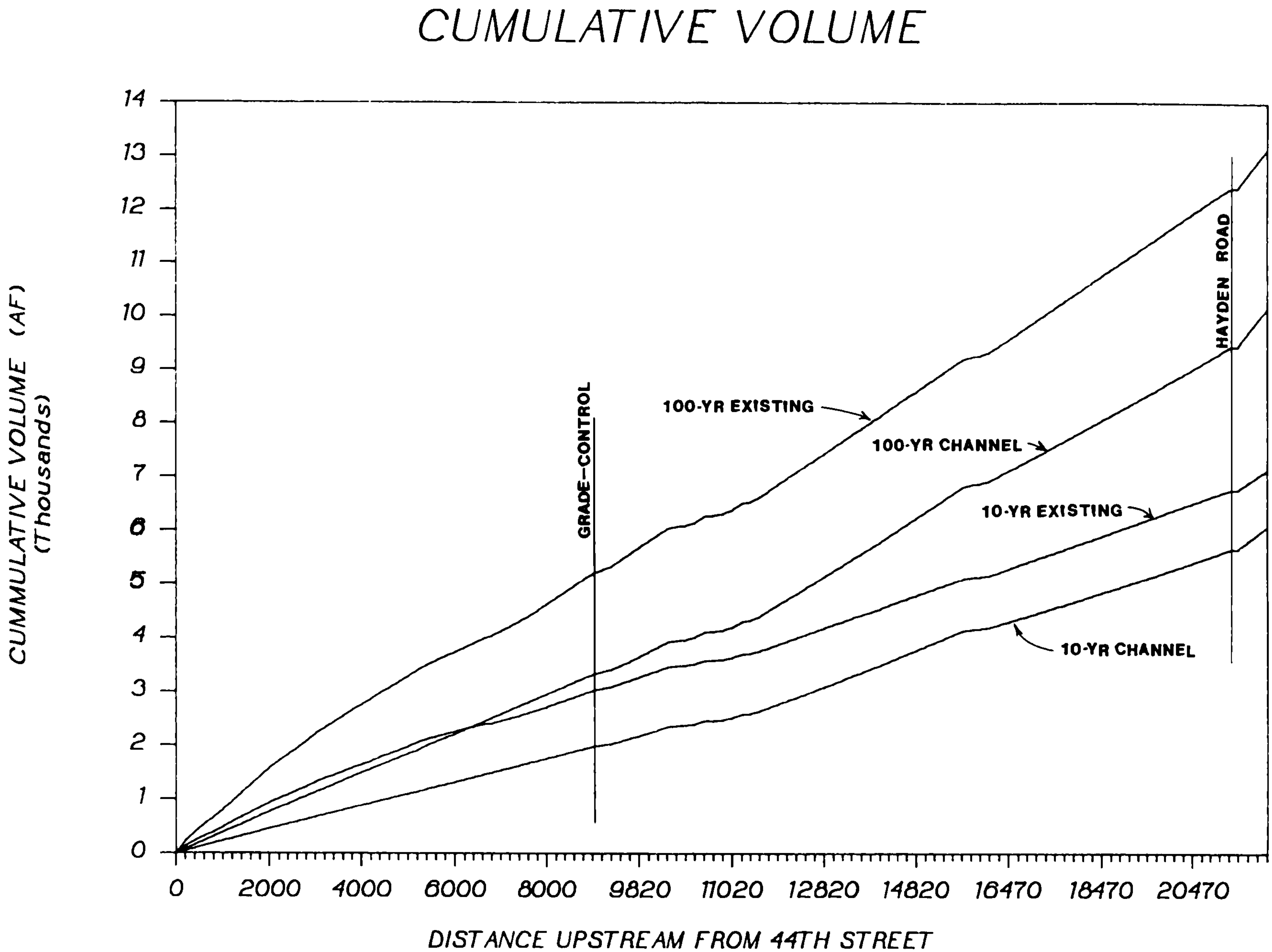

Figure 4.12 Storage Capacity 48th Street to Hayden Road

V. ENVIRONMENTAL/PERMITTING REQUIREMENTS

Permit applications will need to be prepared and submitted to the appropriate agencies at appropriate times during the project. The number of permits required depends on the use to which the project will be put. At a minimum, a Section-404 Permit will need to be submitted to the U.S. Army Corps of Engineers (COE) for compliance with the Clean Water Act. In addition, application will need to be made to the Federal Emergency Management Agency (FEMA) for a Letter of Map Revision (LOMR).

Technical information required for a Section-404 Permit Application is limited and can be analyzed early in the project, after the Design Concept is completed. This permit addresses various factors. Among those factors are: general environmental concerns, aquatic and wildlife habitat, recreation, and water quality. The permit application package provides a general overview of the project. The application package should include reference to any detailed documents on the project, such as concept reports, technical memorandums, inter-governmental agreements, and mitigation plans. Liaison and coordination will be required with State and Federal agencies during the permit review process in order to answer questions and to prepare supplemental or explanatory materials.

A wildlife-habitat resource investigation will be required. This involves the classification and quantification of habitat resources in the project area. This information will be used by the U.S. Fish and Wildlife Service and the Arizona Game and Fish Department when commenting on the Section-404 Permit application. Their intent will be to ensure that there is adequate mitigation for wildlife. Early coordination on wildlife-habitat issues will be important, and agreements for mitigation plans should be worked out in detail prior to submitting the permit application.

Application for the LOMR will need to be initiated during the construction of the channel improvements. Design plans and other engineering data will need to be submitted to request that revisions be made to the Flood Insurance Rate Maps (FIRM).

VI. IMPACTS ON EXISTING UTILITIES AND ROADS

The channelization of the Salt River has an impact on all existing utilities and roads within the channel bed and at the bridge locations.

For channelized conditions, the at-grade road crossings become a problem in the area of Mill Avenue. If channelization occurs at the north abutment of the Mill Avenue bridge, the road grade required to connect with the existing road would be greater than seven percent (see Figures 6.1 and 6.2). In order to avoid this problem, the road should be realigned.

At the crossing of Mill Avenue, the Rio Salado Parkway/First Street is in the bottom of the channel. The road and traffic can either be moved and redirected to a neighboring arterial to avoid associated impacts; or, rather than trying to reroute the road, it can be left within the channel. However, once the road is out of the channel, it should remain above the 100-year water-surface elevation.

The profile of the utilities located within the channelized section was analyzed to determine if any conflicts existed. The Mill Avenue crossing has a water main and a gas (nitrogen) line, both located on the bridge. Rural Road has a 30"-diameter water-transmission main on the east side of the bridge and a 36"-diameter sewer line on the west side of the bridge. Hayden Road has an electrical line overhead and a 36"-diameter water transmission main. With the lowering of the channel invert and the anticipated waterbodies occurring under the bridges, all underground utilities at the bridges will need to be relocated. The Tri-City sewer line parallels the north channelized bank for a distance of about a half mile. At the grade-control structure west of Mill Avenue, this utility is located about eight feet below the channel invert, but is only about 0.3 feet below the channel invert where it leaves the channel, which is about 2,100 feet east of Mill Avenue. This utility line will probably need to be encased in some areas and will define a boundary for the low-flow channel. All other utilities are considered to be non-affected by the Salt River channelization.

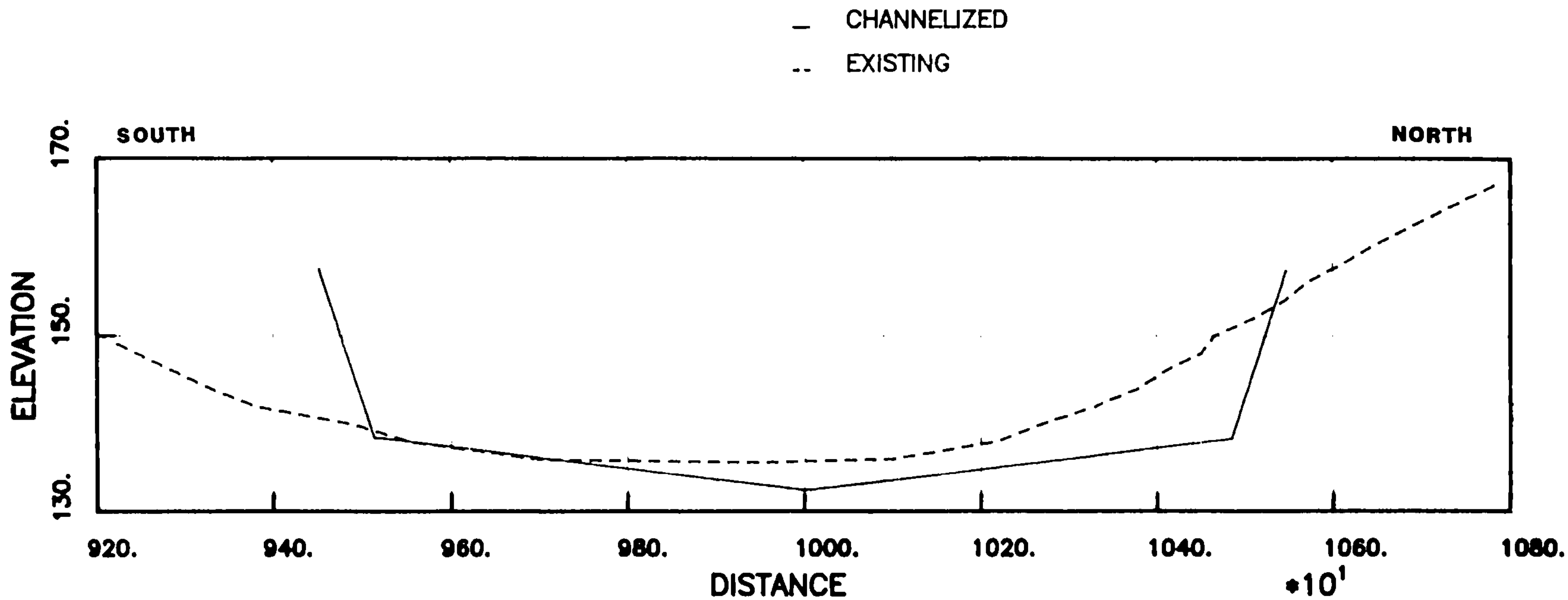

Figure 6.1 Road Crossing East of Mill Avenue

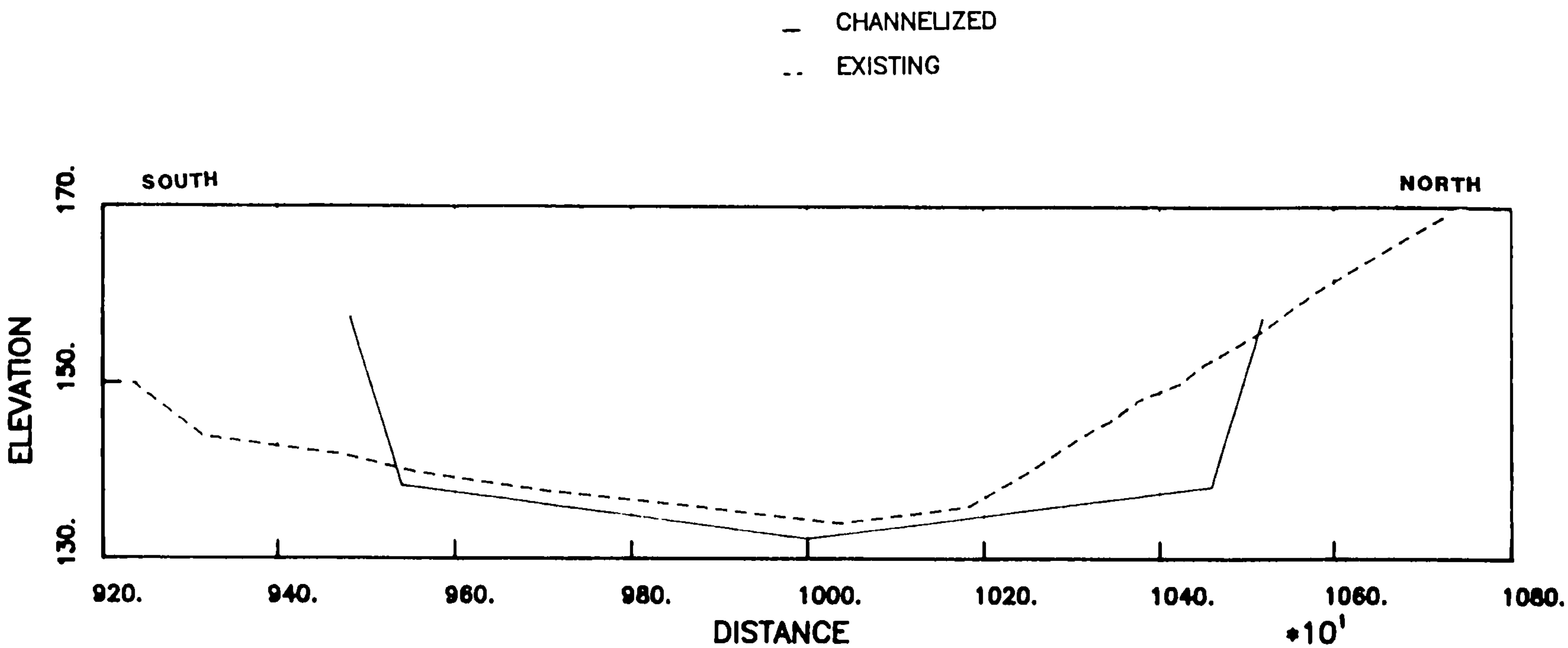

Figure 6.2 Road Crossing West of Mill Avenue

VII. COORDINATION

During this initial phase of the Salt River channelization study, close coordination has been ongoing with the Rio Salado/City planners through attendance at Rio Salado Task Force meetings and other periodic staff meetings. Information concerning channelization alternatives, permitting requirements, and related issues has been presented and substantial input received from city staff.

Coordination has also been maintained with interested governmental agencies and neighboring parties. Various meetings concerning the Salt River channelization study have been held with representatives from the Arizona Department of Transportation, the Flood Control District of Maricopa County, Arizona State University, the Sun Angel Foundation, and Tempo Investments as well as others. Through this coordination effort additional alignment alternatives have been developed due to conflicts encountered between the original alignment alternatives and current projects or planned development of neighboring land owners.

Throughout the concept design process continued coordination will be required with the Arizona Department of Transportation, U.S. Fish and Wildlife Service, Arizona Game and Fish Department, the Flood Control District of Maricopa County, Arizona State University, the Salt River Project, and other affected agencies and groups. This liaison and coordination activity is particularly important in conjunction with permit applications to insure all issues have been addressed and satisfactorily resolved. Supplemental or explanatory materials may need to be prepared during the permit review process.

Channelization of this reach of the Salt River will involve close coordination with ADOT on the East Papago Freeway design. During the design phase of the channelization, coordination for right-of-way, utilities, and the possible use of excess excavation by ADOT will be required.

VIII. RECOMMENDATION FOR CONTINUED WORK

The initial phase of the Salt River channelization concept design identified appropriate hydraulic design criteria and developed alternative design concepts. Channel alignment, channel profile, and channel cross section were factors considered in developing the channelization alternatives. Each of the alternatives developed during this initial phase have advantages and disadvantages, and will require additional evaluation and engineering analysis before a preferred design is selected.

There are a number of issues and development factors that need to be considered in the next phase of the concept design. The preferred channel alignment, channel profile, channel section, bank-protection measures and special channel features must be selected. This will involve a multi-disciplined effort with input from both engineering and planning areas. A detailed river mechanics and floodplain analysis must be conducted for the selected design alternative. These analyses will establish water-surface elevations, flow velocities, and other hydraulic design parameters to be used in determining the preliminary design dimensions of hydraulic structures. The height, depth, and type of bank protection must be designed to provide lateral stability, and also be aesthetically pleasing. Bank protection measures will be determined based on the hydraulic conditions and overall design requirements of the project. The size and location of grade-control structures must be designed to provide long-term vertical stability of the Salt River.

The permit application package to be submitted to the U.S. Army Corps of Engineers for compliance with Section-404 needs to be prepared during the next phase of the concept design. In addition, a detailed floodplain analysis must be completed for requesting revisions to the Flood Insurance Rate Maps.

A geotechnical investigation and analysis will be required prior to any detailed design for the channelization project. The full details of the geotechnical work would be developed in consultation with the geotechnical consultant, but should include the following services: subsurface investigation plan (borings and test pit layout); test pits and borings for material sampling; laboratory analysis; and engineering-data analysis and preliminary design report. The investigation should map existing landfills in the river reach from the SPRR bridge to Rural Road.

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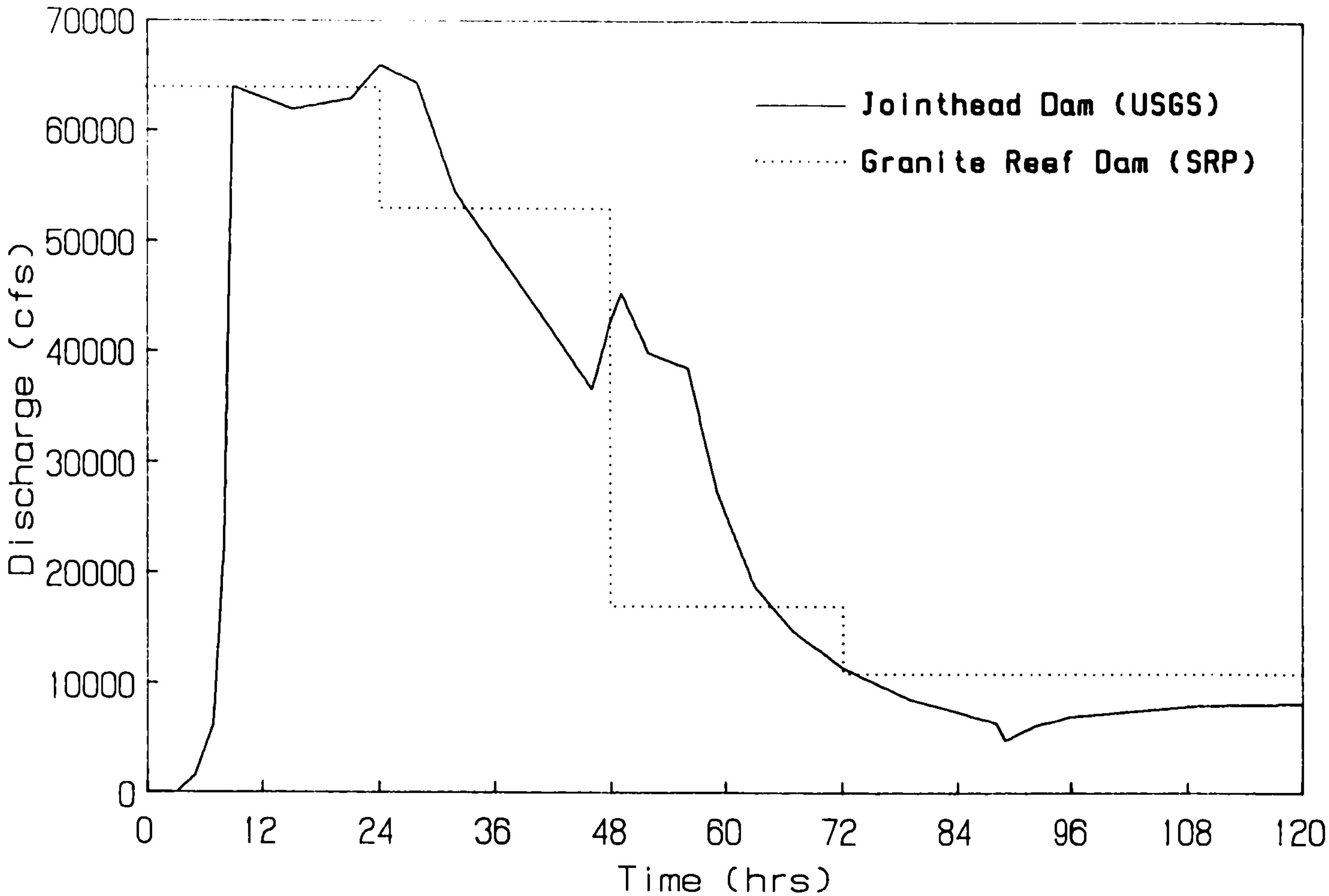
APPENDIX A

Historical Salt River Data

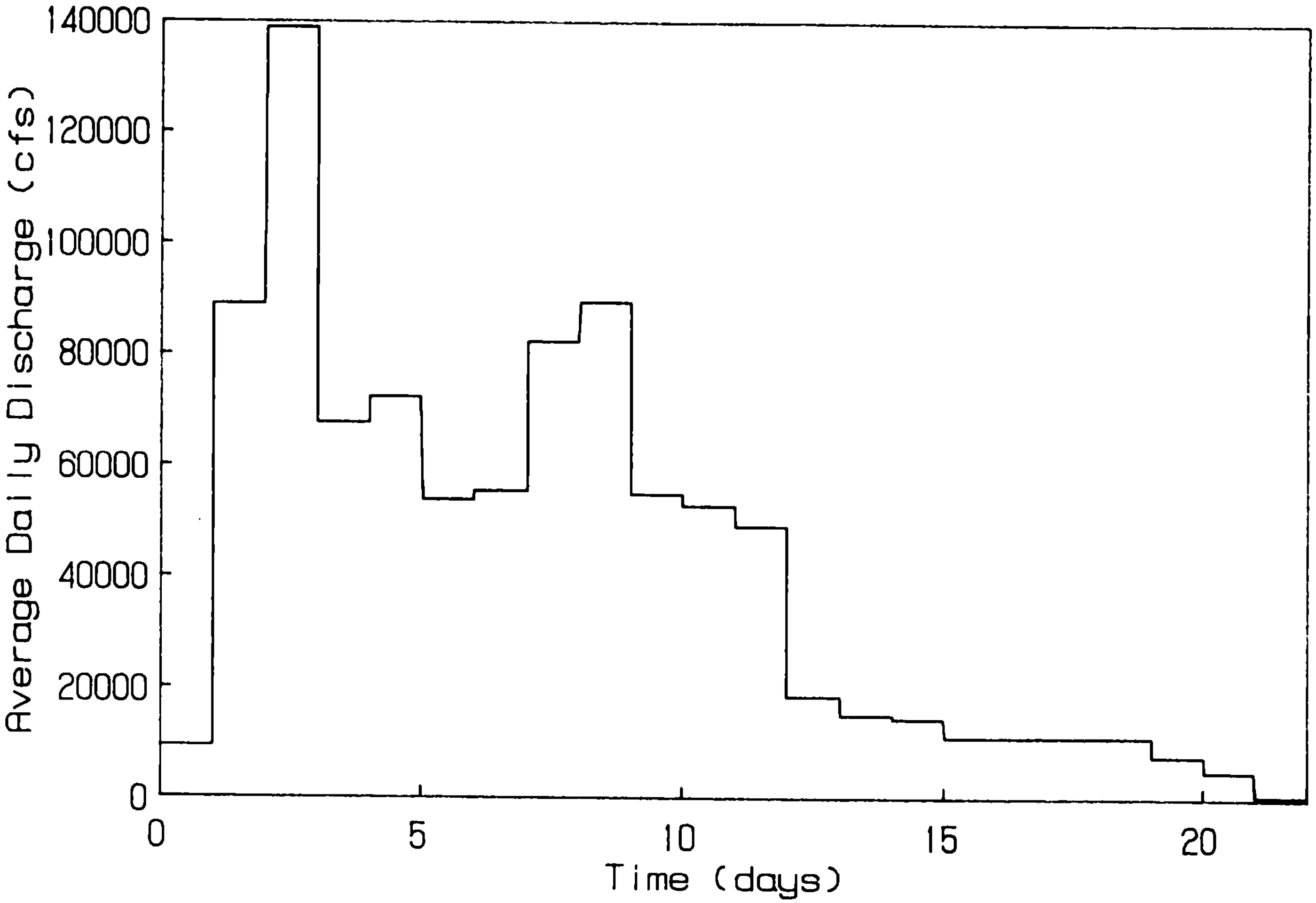
Salt River

Dec. 30, 1965 to Jan. 4, 1966

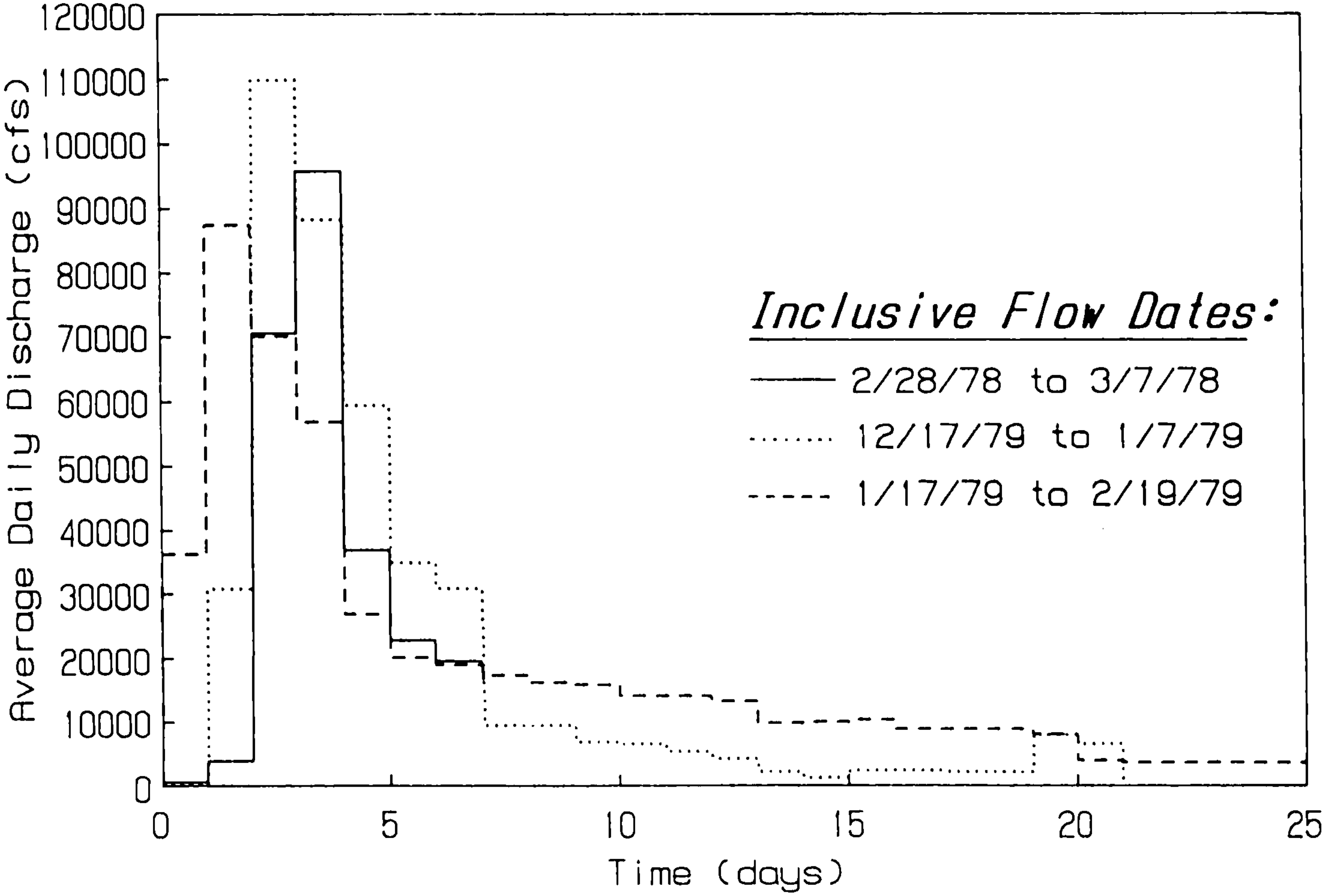


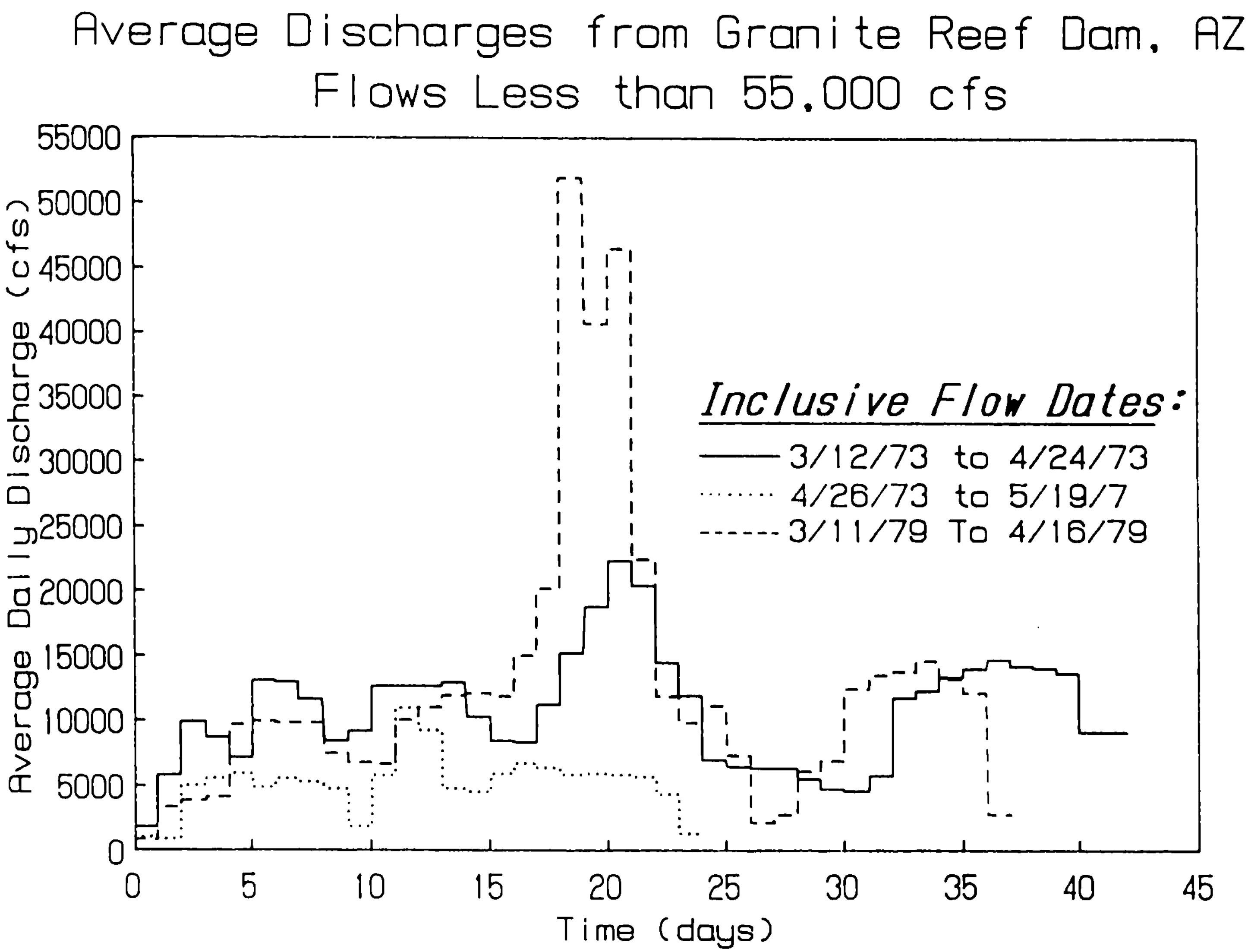
A.1

Average Discharges at Granite Reef Dam, Az
Feb. 14 to Mar. 6, 1980



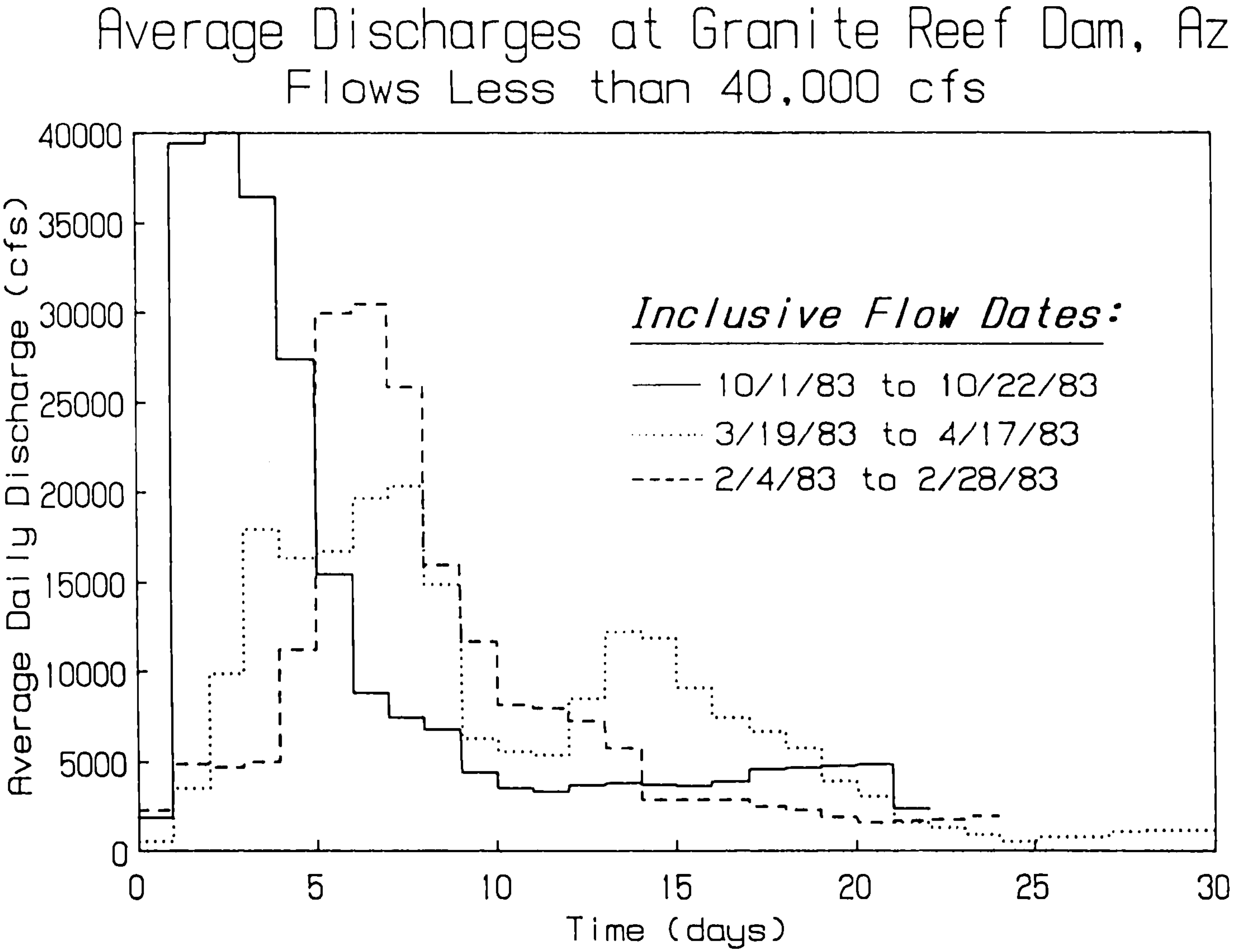
Average Discharges from Granite Reef Dam, Az
Flows Less than 110,000 cfs

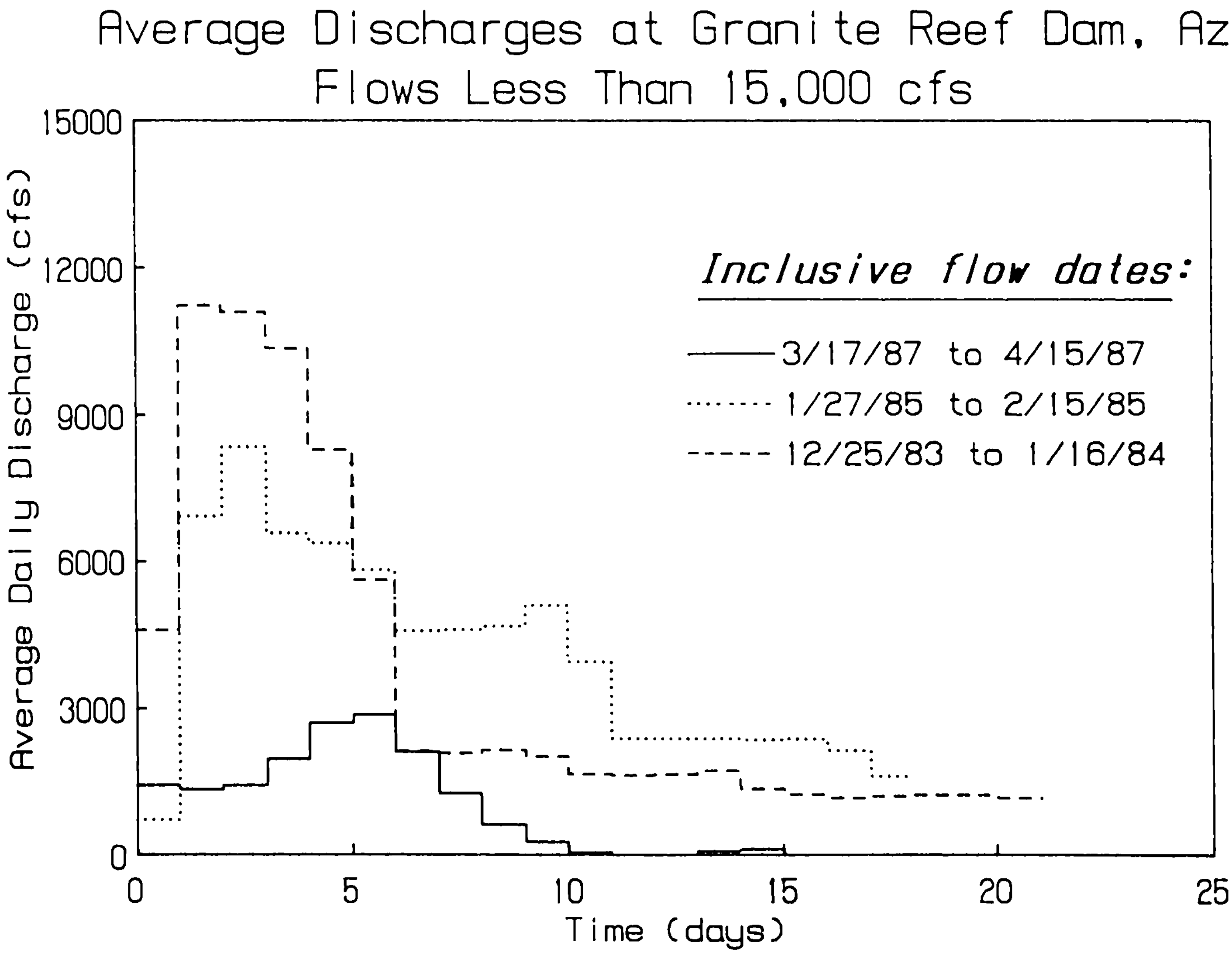


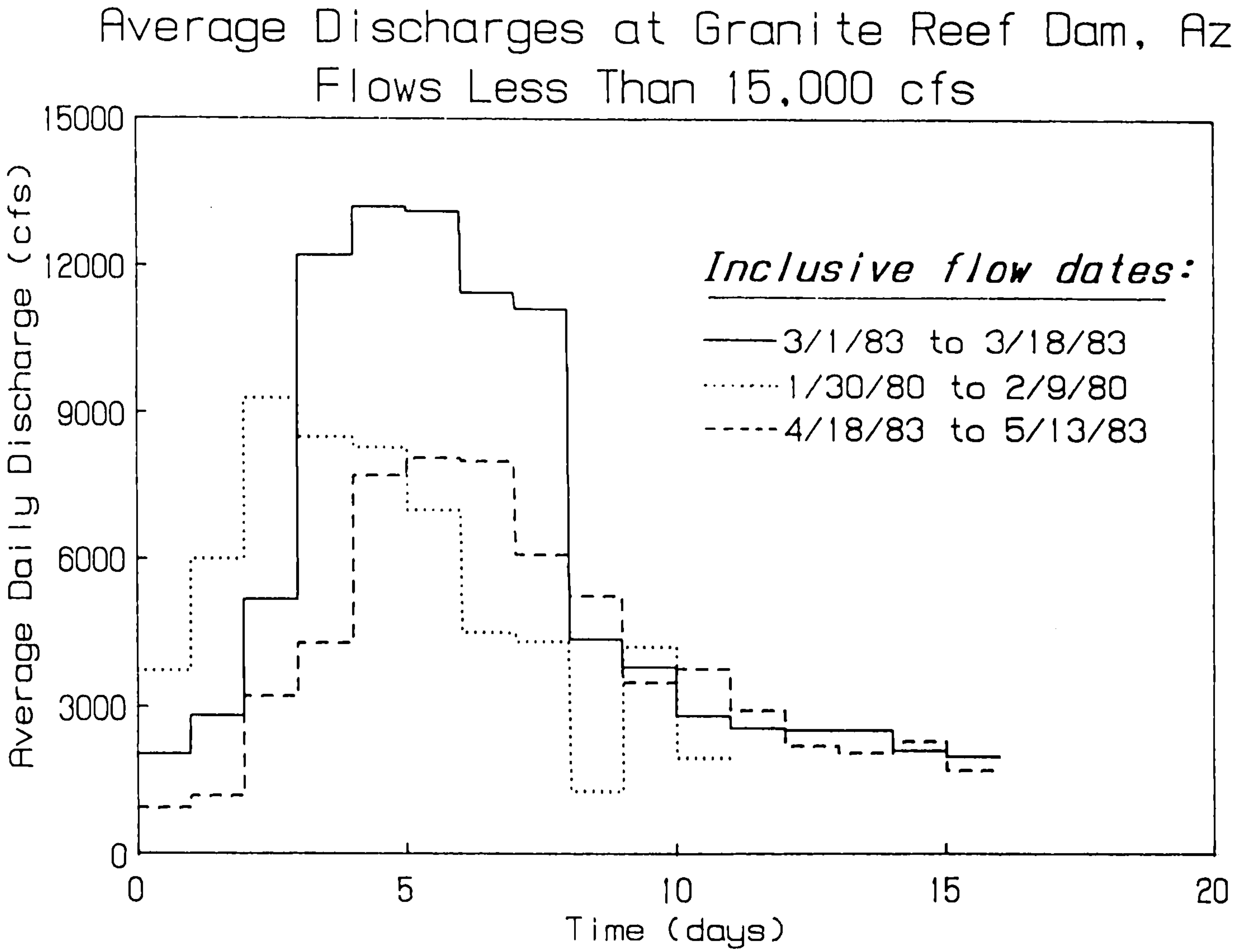


Average Discharges from Granite Reef Dam, AZ
Flows Less than 55,000 cfs
Average Daily Discharge (cfs)
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
30
35
40
45
Time (days)
Inclusive Flow Dates:
3/12/73 to 4/24/73
4/26/73 to 5/19/7
3/11/79 To 4/16/79

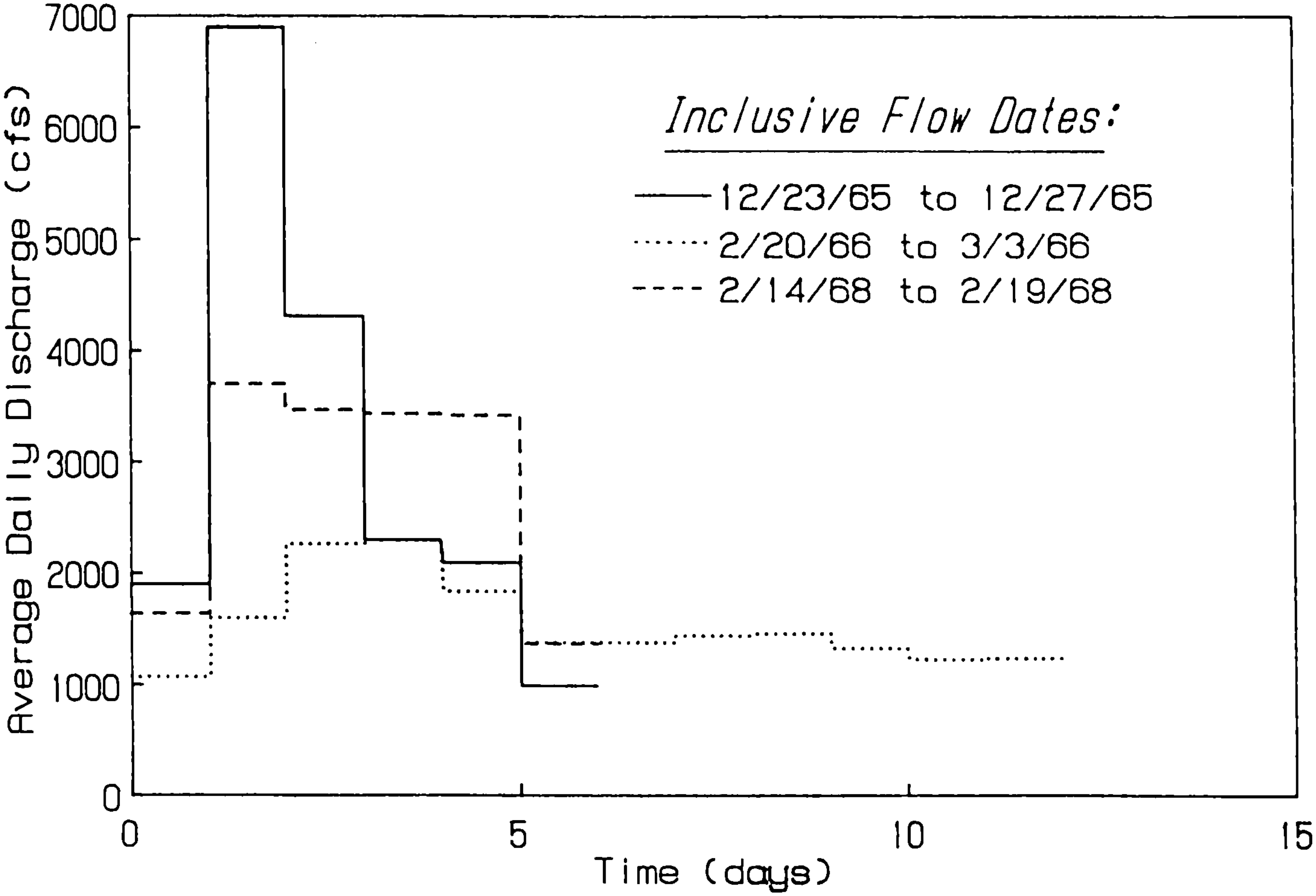
A.4

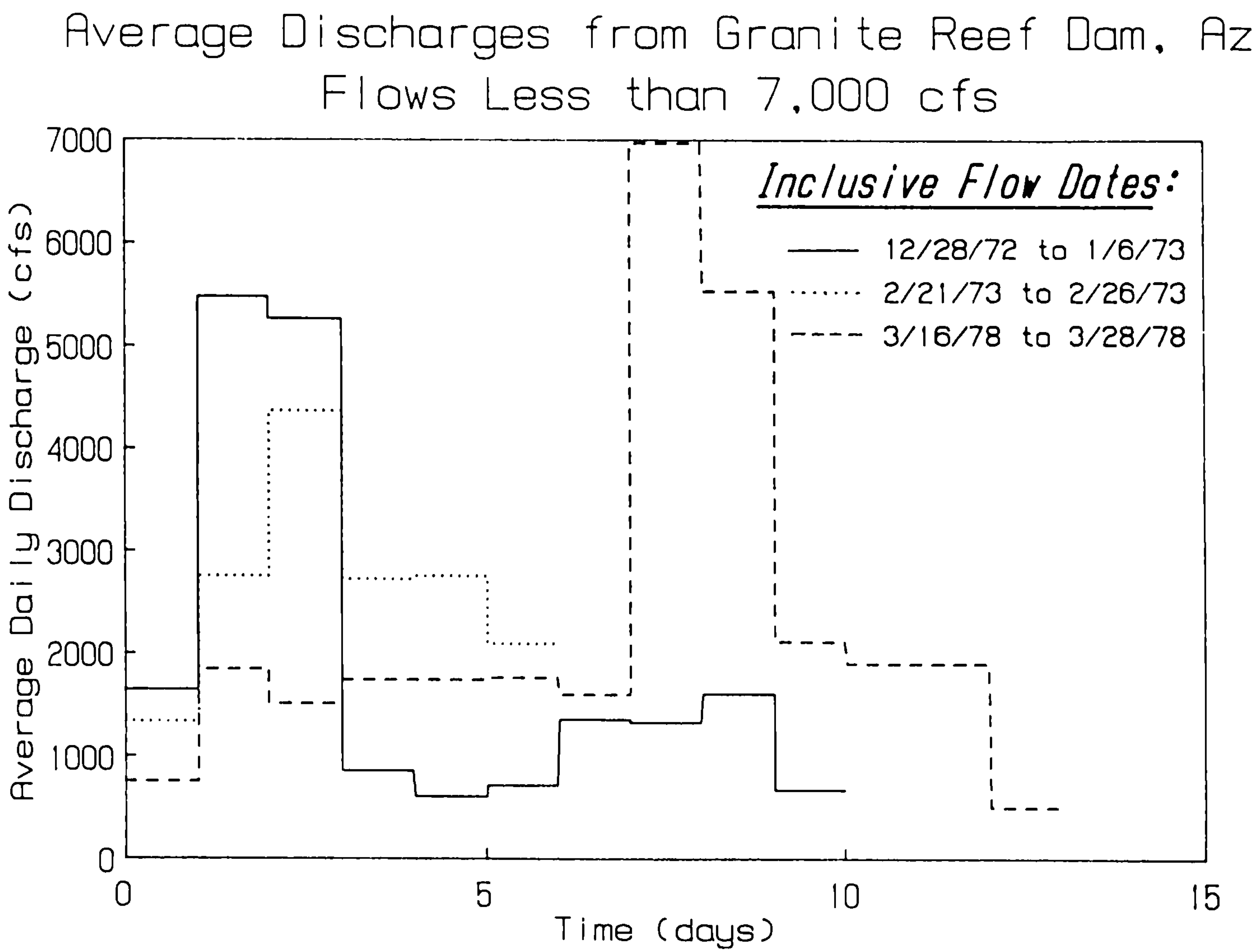

Average Discharges at Granite Reef Dam, Az
Flows Less than 40,000 cfs
Average Daily Discharge (cfs)
0
5000
10000
15000
20000
25000
30000
35000
40000
0
5
10
15
20
25
30
Time (days)
Inclusive Flow Dates:
10/1/83 to 10/22/83
3/19/83 to 4/17/83
2/4/83 to 2/28/83


Average Discharges at Granite Reef Dam, Az
Flows Less Than 15,000 cfs
Average Daily Discharge (cfs)
15000
12000
9000
6000
3000
0
Inclusive flow dates:
3/17/87 to 4/15/87
1/27/85 to 2/15/85
12/25/83 to 1/16/84
0
5
10
15
20
25
Time (days)


Average Discharges at Granite Reef Dam, Az
Flows Less Than 15,000 cfs
Average Daily Discharge (cfs)
Time (days)
0
3000
6000
9000
12000
15000
0
5
10
15
20
Inclusive flow dates:
3/1/83 to 3/18/83
1/30/80 to 2/9/80
4/18/83 to 5/13/83

Average Discharges from Granite Reef Dam, Az
Flows Less than 7,000 cfs




Average Discharges from Granite Reef Dam, Az
Flows Less than 7,000 cfs
Inclusive Flow Dates:
12/28/72 to 1/6/73
2/21/73 to 2/26/73
3/16/78 to 3/28/78
Average Daily Discharge (cfs)
Time (days)
0
1000
2000
3000
4000
5000
6000
7000
0
5
10
15

APPENDIX B

Low-Flow Channel Calculations

Low Flow Channel

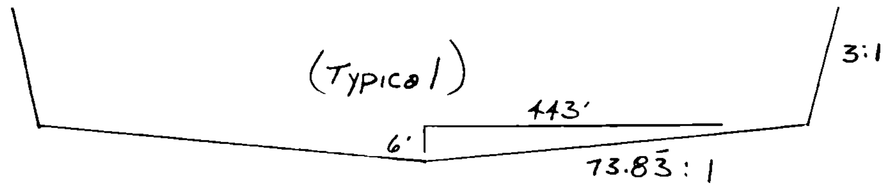
Slope = 0.0022   For reach from about 40th street to grade-control structure near Mill Ave.

Sinuosity = 1.33   ∴ S = 0.001654

n = 0.035

Q = 5,000 cfs

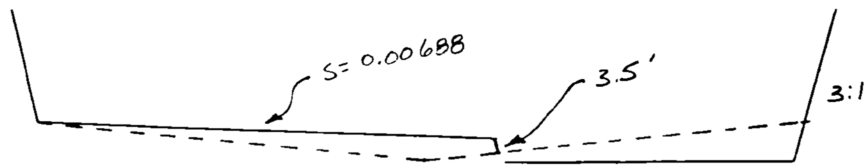
①



D = 4.70'
V = 3.06 ft/s
Fr = 0.25
TW = 694.0'

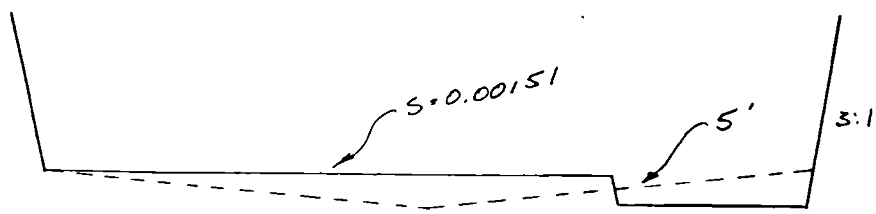
(Bottom width = 0)

②



D = 3.49'
V = 3.90 ft/s
Fr = 0.37
Bw = 356'
TW = 377'

③



D = 4.97'
V = 4.79 ft/s
Fr = 0.38
Bw = 195'
Tw = 225'

@ Q = 215,000 cfs
S = 0.0022 (No Sinuosity)

Section	Area
1	16,460 ft²
2	16,461 "
3	16,521 "