CITY OF PHOENIX, ARIZONA

MASTER DRAINAGE STUDY
INDIAN BEND WASH

Project No. ST-73140.00

YOST AND GARDNER ENGINEERS

Phoenix, Arizona

April 1975

Nº 124

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April, 1975

James E. Attebery, City Engineer
700 Municipal Building
251 West Washington Street
Phoenix, Arizona 85003

Re: City of Phoenix Project No. ST-73140
Contract No. 14715

Dear Sir:

With this letter, we respectfully submit our report and recommendations for the Master Drainage Study for Indian Bend Wash, within the City of Phoenix.

Pursuant to the contract and preceding discussions, the report presents four alternative approaches for the handling of 100-year flows in the main channel of Indian Bend Wash. The typical sections, plans and profiles given are schematic in nature. The final channel configuration and design will depend upon the secondary use to which the channel will be put by the City or property developers.

Our recommendation is that the main channel be designed as a wide shallow greenbelt with a small grassed low flow channel. This type of construction, with a meandering low flow channel, would be most adaptable to multiple uses.

The report also includes a study of a typical tributary channel with recommendations for its treatment, utilizing a variety of channel configurations.

Registered Professional Engineer (Civil)
CERTIFICATE EXPIRES
F. ROBERT STEVENS
DEC. 31, 1975
ARIZONA, U.S.A.

Very truly yours,

YOST AND GARDNER ENGINEERS

By F. Robert Stevens
F. Robert Stevens

FRS:fp

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Appendices appear in order following the text.

List of Figures

Plate

1. Purpose

The purpose of this report is to give city officials, responsible for the preparation or review of development plans a comparison of alternatives and a standard by which to evaluate proposals submitted by developers interested in the area.

The studies leading up to this report considered various alternatives for the treatment of that portion of Indian Bend Wash, in the City of Phoenix, which would stabilize its location, minimize the area subject to flooding, permit maximum utilization of the present floodplain area and would have the best appearance consistent with reasonable costs of construction and maintenance. The studies also gave a similar consideration to one of the principal tributaries of Indian Bend Wash in the City, an unnamed drainageway running north to south in the vicinity of 56th Street.

The presentation in this report should be regarded as schematic, and are not intended to be the final statement of channel configuration. Other alternatives approaches are possible and may relate better to the development of adjacent property. In any event surveys to establish the construction centerline and right-of-way limits on the ground, as well as definitive plans and specifications must be developed before contracts can be let for construction.

2. <u>Methods</u>

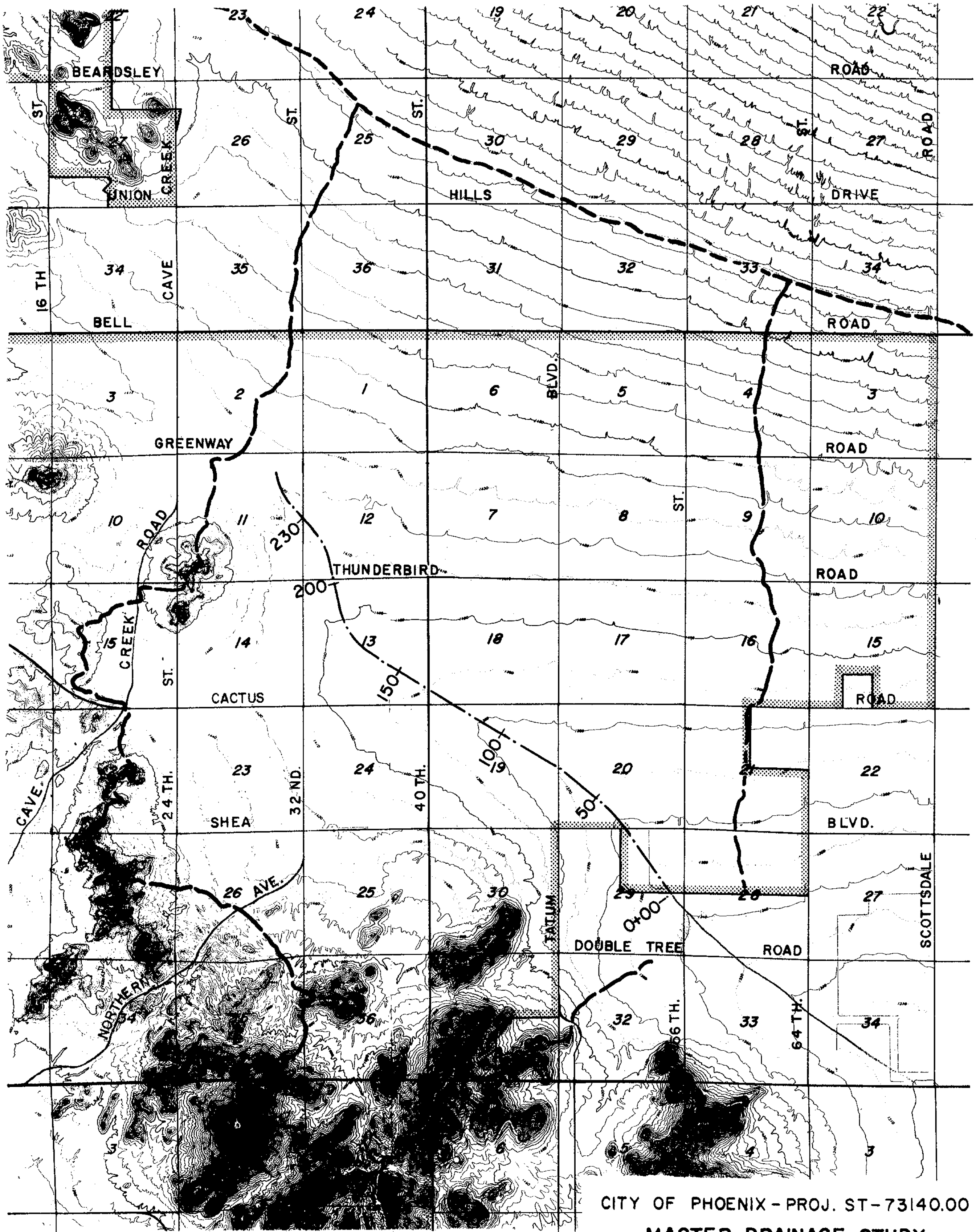
The first step in pursuing these studies was to assemble and examine all relevant and available previous work. The City's 1 inch to 100 foot contour maps, where such existed within the study area, were assembled. Areas contributing runoff and not yet covered by contour maps were surveyed, photographed, and mapped to City standards at 1 inch to 100 foot scale with a 2 foot contour interval. Thirty-three quarter sections were mapped in this way. Design discharges for various recurrence intervals up to the 100-year event were computed for numerous points along Indian Bend Wash from the Paradise Valley town limits to its head near Greenway Road, utilizing the cummulative drainage area to each such point and peak runoff rate/area correlations obtained from the Corps of Engineers (Ref's. 1 and 7). A profile was drawn for the main channel using ground surface elevations from contour maps for points along an arbitrarily established control line which corresponded closely with the natural thalweg. Various channel cross-sections (types of construction) were investigated and four were chosen as meriting further consideration. Water surface profiles were computed for each type using a computer program developed by the Corps of Engineers (Ref. 2). The results were evaluated giving consideration primarily to hydraulic capacity, flow velocity, and water surface elevation. Numerous trials were made in arriving at a suitable channel profile for each typical cross-section through the length of the wash. Large scale sections were drawn for each type and the cost of each was estimated using currently prevailing prices. One of the four types (greenbelt with grass lined low flow channel) was selected as the recommended type and this was mapped in plan and profile throughout the studied length of Indian Bend Wash.

A similar approach was used in studying the 56th Street tributary, but here existing developments limit the alternatives. Runoff quantities are smaller however, and it is possible to utilize a 40 acre park site as a detention basin to reduce peak rates - a measure that is not practical in the main channel of Indian Bend Wash.

While discharges for main channel flows were obtained by use of the Corps of Engineers' data and equations, it was not practical to use the same method for the much smaller drainage areas in the tributary basins. The resulting peak discharges are unreasonably large when the formula is applied to areas of one to three square miles such as we have in the tributaries. Consequently we have used the modified rational method in computing peak flows in the 56th Street drainage. This is the same method that has been used in designing City of Phoenix storm drains for many years. The results are reasonable. The methods of computing peak flows are discussed in Sections 6 and 7 of this report.

3. Location and Boundaries

The area covered by this study includes about 30 square miles located in northeast Phoenix which contributes drainage to the Indian Bend Wash. Fig. 1, pg. 4, shows its location and extent. The basin in which the area lies is popularly known as Paradise Valley. Indian Bend Wash continues southeasterly and south from the area, passing through the Town of Paradise Valley and the City of Scottsdale, ultimately discharging into the Salt River eleven miles below the area, in the City of Tempe.



CITY OF PHOENIX - PROJ. ST-73140.00

MASTER DRAINAGE STUDY

INDIAN BEND WASH

SITE PLAN

FIGURE 1

CONTOUR INTERVAL - 10' U.S.G.S. QUAD.

PHOENIX CITY LIMITS

NORTH

Area boundaries on the south and west are the ridges of the Phoenix Mountains of which Squaw Peak is the principal feature. The north boundary is assumed to be the Granite Reef Aqueduct which is presently under construction by the Bureau of Reclamation. The east boundary is delineated by the natural drainage divide that runs north and south at about 60th Street. Drainage east of this line reaches Indian Bend Wash beyond the city limits of Phoenix.

4. Natural Features

The area is underlain mostly by Quaternary and Tertiary alluvial deposits of intermediate thickness. Elevations range from 1345 feet above mean sea level where the Indian Bend Wash intersects Mountain View Road, to 2600 feet on Squaw Peak. Ground slopes in this portion vary from about 20 feet per mile along Indian Bend Wash to 40 to 50 feet per mile for tributary washes as they approach the foothill region.

The Phoenix Mountains lying on the southwesterly boundary of the drainage area are mostly older Precambrian schist and consist of many rugged peaks with steep slopes and canyons.

Soils in the southern portion of the area are loamy, becoming shallower and increasingly stony nearer the Phoenix Mountains. Toward the north they become more clay-like, with increasing lime content (Ref. 4).

Native vegetation is that of the Sonoran Zone, with creosote bush, saguaro, and palo verde on the flats. Mesquite and ironwood are found along the washes. Brittle bush, bur sage, and similar shrubby plants occur in the foothills and mountainous portions.

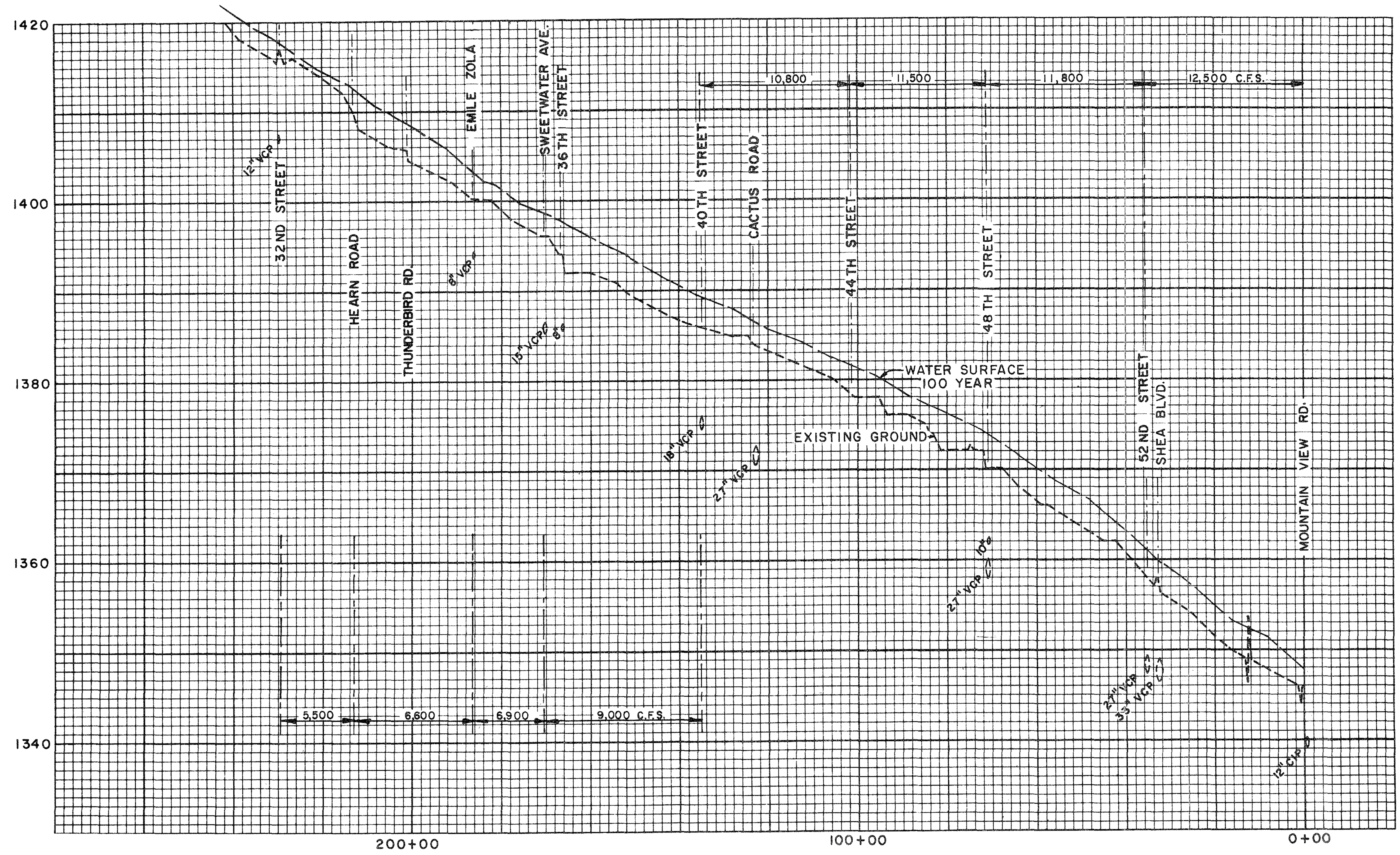
Indian Bend Wash is a wide shallow swale that heads in the vicinity of 32nd Street and Acoma Drive. It trends southeasterly through Paradise Valley, crossing Shea Boulevard in the vicinity of 52nd Street. Except for the denser vegetation along its course it is not readily discernbile to the untrained eye when seen from the ground. There is at present no defined channel except where easements have been dedicated through subdivisions.

The drainage divide on the southwest is roughly parallel to Indian Bend Wash and about two and half miles away. The slopes from this side are steep, the tributary drainage areas are bulbous with well-defined, deeply entrenched channels. The tributaries entering from the other side are more numerous with small, relatively indistinct channels. Before they were cut off by the Central Arizona Project canal, some of these washes extended northeasterly as much as 15 to 18 miles from Indian Bend Wash but these long drainage areas averaged less than a mile in width. The slopes to the north are also much flatter than those to the south.

This situation has a pronounced effect on the pattern of runoff from the two sides. Flows arriving from the north tend to be slow moving sheet flows that flood wide areas to shallow depths. The land to the south is not so subject to flooding because the water runs off more rapidly in its steep, deeply entrenched channels.

Figure 2, pg. 7, shows the 100 year flood limits for flows in Indian Bend Wash proper under present conditions. Figure 3, pg. 8, shows the water surface profile for this 100 year flood. It happens occasionally that heavy flows occur in the tributaries while the main wash is relatively unaffected. This can change the picture from that shown in Fig. 2. Aerial photographs

CITY OF PHOENIX - PROJ. ST-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
100 YR. FLOOD LIMITS
PRESENT CONDITIONS
FIGURE 2



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MASTER DRAINAGE STUDY

INDIAN BEND WASH

PROFILE

100 YEAR FLOOD

PRESENT CONDITIONS

FIGURE 3

taken during the June 22, 1972 storm (Ref. 3) show extensive sheet flooding north of Indian Bend Wash but in the wash itself is lower than shown in Fig. 2.

5. Cultural Features

About forty percent of the area has been urbanized at the present time. Development has consisted almost exclusively of single family residences with very little commercial, multi-family or mobile home park construction.

Urbanization will change the drainage flow characteristics radically. The streets will provide new artificial channels to conduct storm water run-off at a faster rate. Buildings and paving will render large areas impervious which will reduce infiltration. For a given storm, flows will arrive sooner, reach higher peaks, and subside more quickly. Future urbanization as projected from planning and zoning maps, is assumed to develop as shown in the Maricopa Association of Governments 1970 Storm Drainage Report (Ref. 5).

At Mountain View Road the drainage leaves the City of Phoenix and enters the Town of Paradise Valley. Channel improvements within the City of Phoenix require coordination with any planned work by the municipalities downstream.

The Granite Reef Aqueduct is presently under construction by the Bureau of Reclamation across the northern portion of Indian Bend Wash drainage area. Flood control dikes and detentions basins will be built on the north side of the aqueduct and will effectively intercept any water from the north.

There are several other projects currently being planned that have a bearing on what is done in the Indian Bend Wash channel. The purposes of these projects are not inconsistent with the improvement of the wash, however, it is important that all the work is coordinated. Projects in progress during these studies include those listed below. We know of no others at this writing.

A) Town of Paradise Valley Channel

A greenbelt is planned by Paradise Valley along the thalweg of Indian Bend Wash. As presently conceived, the project would be a shallow swale about 8 feet deep and 800 feet wide with grass lining and a small grass lined low flow channel. The Town plans to schedule design of the channel this fiscal year.

B) Shea Boulevard Bridge

A reinforced concrete bridge is being designed to cross Indian Bend Wash on Shea Boulevard. It will be constructed by the City of Phoenix. Total length will be 260 feet, skew 40° left. Centerline of the bridge will be approximately 253 feet east of 52nd Street. August 1975 has been tentatively set for the bid call.

C) Village of Paradise Valley

Westcor, Inc., Developers are promoting a planned community on land between 40th and 52nd Streets on Indian Bend Wash which presently contains no development. This is known as the Village of Paradise Valley. Their preliminary plans are to use the wash area for greenbelt parks and golf courses.

The planned channel will be designed to accommodate a 100-year return frequency storm. The work is in the early planning stages and apparently no dates have been set for the project.

D) Desert Lake Country Club.

Desert Lake Country Club is a Planned Area Development of approximately 140 acres between Wescor's land and Shea Blvd., with a portion extending south of Shea. The development will be similar to Wescor in that their plans also use the wash area for recreation and golf course.

6. Flows - Indian Bend Wash

The basis for flow in Indian Bend Wash is the Corps of Engineers' Phase 1 Design Memorandum dated October 1973 (Ref. 1). Flows for Indian Bend Wash from the Salt River to Shea Boulevard are given for various points on the stream, assuming certain conditions such as the existence of the Central Arizona Project canal. Separate flow figures are given in the memorandum assuming present conditions or future urbanization of the floodplain. For this report we have taken the value of 21,000 c.f.s. which is the predicted 100 year peak flow at Shea Boulevard assuming that the Central Arizona Project canal is built, that Indian Bend Wash has been developed as a greenbelt channel, and that the tributary areas has been completely urbanized. Refer to Table 9 of the Corps Design Memorandum.

For this report, our area of concern is the upper end of Indian Bend Wash extending downstream to a point one-half mile below Shea Boulevard. Only one of the Corps' projected flows falls into this area, the one for Shea Boulevard. Consequently it became necessary to develop consistent values for other points along Indian Bend Wash above and below Shea Boulevard. This was done using the regression equation in Ref. 1. This gives a relationship between drainage area and peak runoff for areas smaller than 30 square miles.

In Appendix I, Hydrology, of Ref. 1, a regression analysis of existing data was made. Table 13 gives the equation developed as:

$$Q = C1 (\log DA) + C5 (\log S) + C9 (\log 5R24) + \text{Constant}$$

Where: DA = drainage area in square miles
5R24 = 5 year - 24 hour rainfall in inches
S = basin slope in ft/mile
C1 = DA regression coefficient
C5 = S regression coefficient
C9 = 5R24 regression coefficient
Constant = regression constant
Q = return period peak discharge in c.f.s.

For small drainage areas the constants are as follow:

Return Period (Years)	C1	C5	C9	Constant
100	6580.04	0	20226.14	-3922.32
50	4539.83	0	13523.12	-2461.47
25	2987.84	0	7889.85	-1179.13
10	1541.98	0	2793.95	-85.86
5	815.86	0	643.13	+283.51
2	-	-	-	-

Using a value of 2.2 inches of rainfall for a five year, 24-hour storm, discharge rates for a 100-year storm were calculated and are plotted against drainage area on Fig. 4, pg. 14. The plot shows how the rates stand in a consistent relationship with the values given in the Design Memorandum for Shea Boulevard and points downstream. The value used for the 1974 Flood Insurance Study is also noted.

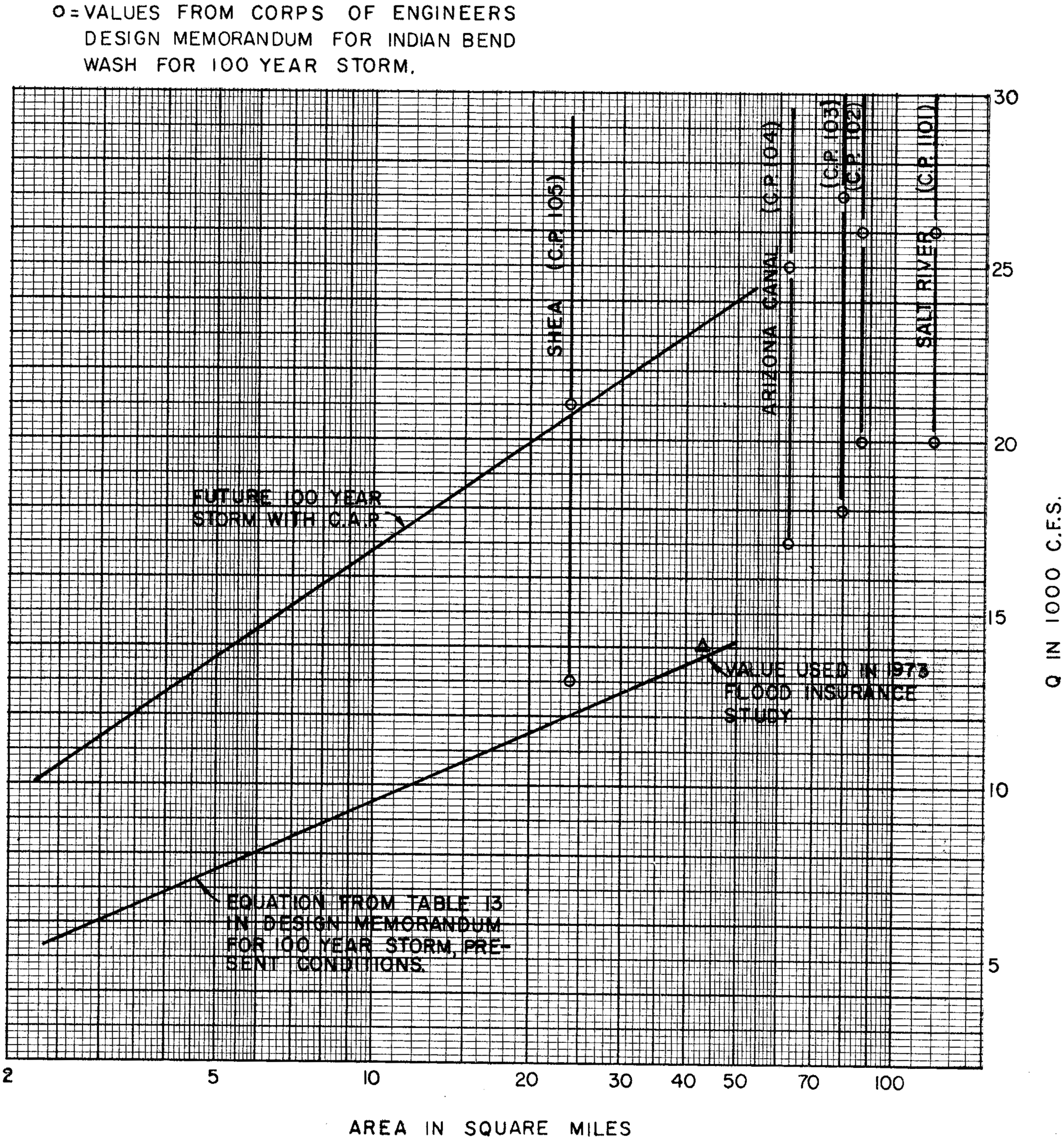
The relation between flow and drainage area for future conditions with the Central Arizona Project canal are also plotted on Fig. 4 for Shea Boulevard and points downstream as given in the Design Memorandum. Using these points as a reference, the future 100 year storm above Shea Boulevard has been plotted.

Figure 5, pg. 15, shows values for 100, 50, 25 and 10-year storms that were calculated from the 100-year curve in Fig. 4 using a percentage of the Standard Project Flood as follows:

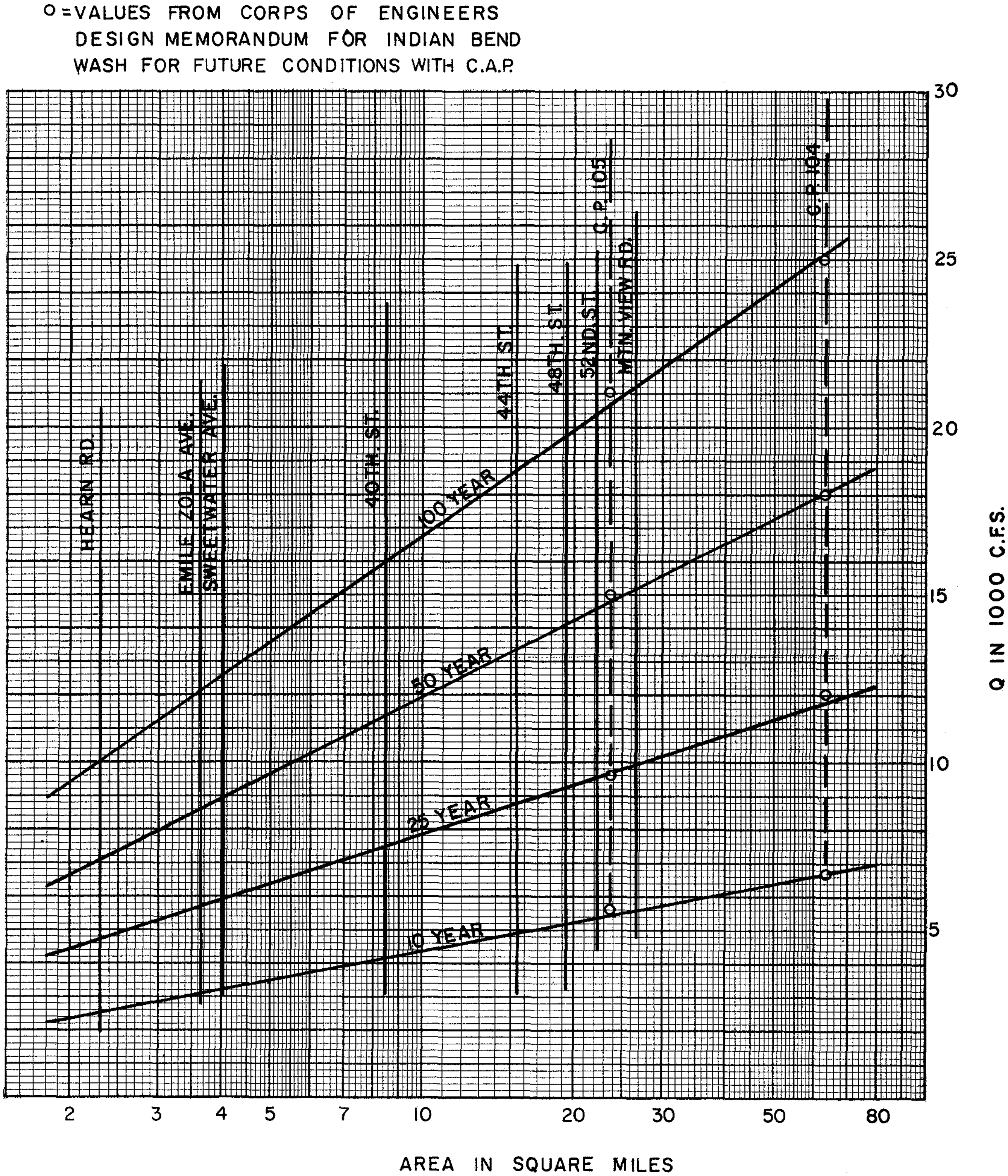
Return Period (Years)	Percent of S.P.F.
100	45
50	32
25	21
10	12

These ratios were obtained from the Corps of Engineer's District Office in Los Angeles.

Values given in the Corps' Design Memorandum (Ref. 1) for flows in Indian Bend Wash at Shea Boulevard (CP 105) and Arizona Canal (CP 104) are plotted to show their relationship to the calculated values. Future flows that were used to calculate the channel size were computed using the cumulative drainage area contributing for points approximately one-half mile apart on the existing thalweg of Indian Bend Wash.



CORPS OF ENGINEERS
100 YEAR DESIGN STORM
FIGURE 4



INDIAN BEND WASH
DESIGN FLOWS
FIGURE 5

The contributing drainages were delineated on contour maps and are shown in Plate A superimposed on an aerial photograph of the study area. The cumulative drainage area in square miles is indicated by italic figures along the course of Indian Bend Wash. Each tributary area has been given an identifying number on Plate A. The characteristics for each are tabulated in Appendix I.

7. Flows - 56th Street Drainage Area

Runoff from the drainage area that contributes to 56th Street is computed by a modified rational method as set forth in Ref. 5. For a complete and detailed explanation the reader is referred to this report. A quote from pages 25 and 26 with minor editing to refer to correct figure numbers is made in the following paragraphs to explain development of the formula.

"If the rate of runoff were equal to the rate of supply, that is if there were no losses or storage, the relation between runoff and supply could be expressed by the formula:

$$Q = CIA$$

Where Q is the rate of runoff in cubic feet per second
I is the rate of rainfall in inches per hour
A is the contributing area in acres
and C is the constant of proportionality, nearly equal to 1 (difference neglected) with the above stated units. In order to account for losses the sustained infiltration rate of soils, called for is deducted from the supply in case of pervious areas and a loss rate of 0.2 inches per hour is deducted in impervious areas such as street paving. It is further observed that such things as channel storage, depression storage, evaporation, and surface detention work toward reducing the peak flow rate. These latter effects are accounted for by setting C equal to 0.8 for the portion of runoff originating in pervious areas and 0.9 for that coming from impervious areas. Therefore the runoff-rainfall relationship is expressed as:

$$Q = 0.8\ A_p\ (I_a - f_c) + 0.9\ A_i\ (I_a - 0.20)$$ where

Q = design runoff rate in cubic feet per second

A_p = pervious portion of the drainage area in acres

A_i = impervious portion of the drainage area in acres

I_a = average rainfall intensity over the area in inches per hour

f_c = final or sustained infiltration capacity of the soil in the pervious area in inches per hour

In any location the pervious and impervious area (present or future conditions of development) contributing in a given time can be determined. The rainfall rate during that time period is determined for any design recurrence interval or frequency from the rainfall-intensity-duration curves (see Fig. 6) and adjusted downward (minor) to correct for area coverage versus the point intensity obtained from the rainfall curves using the area-depth-design curve. (see Fig. 7).

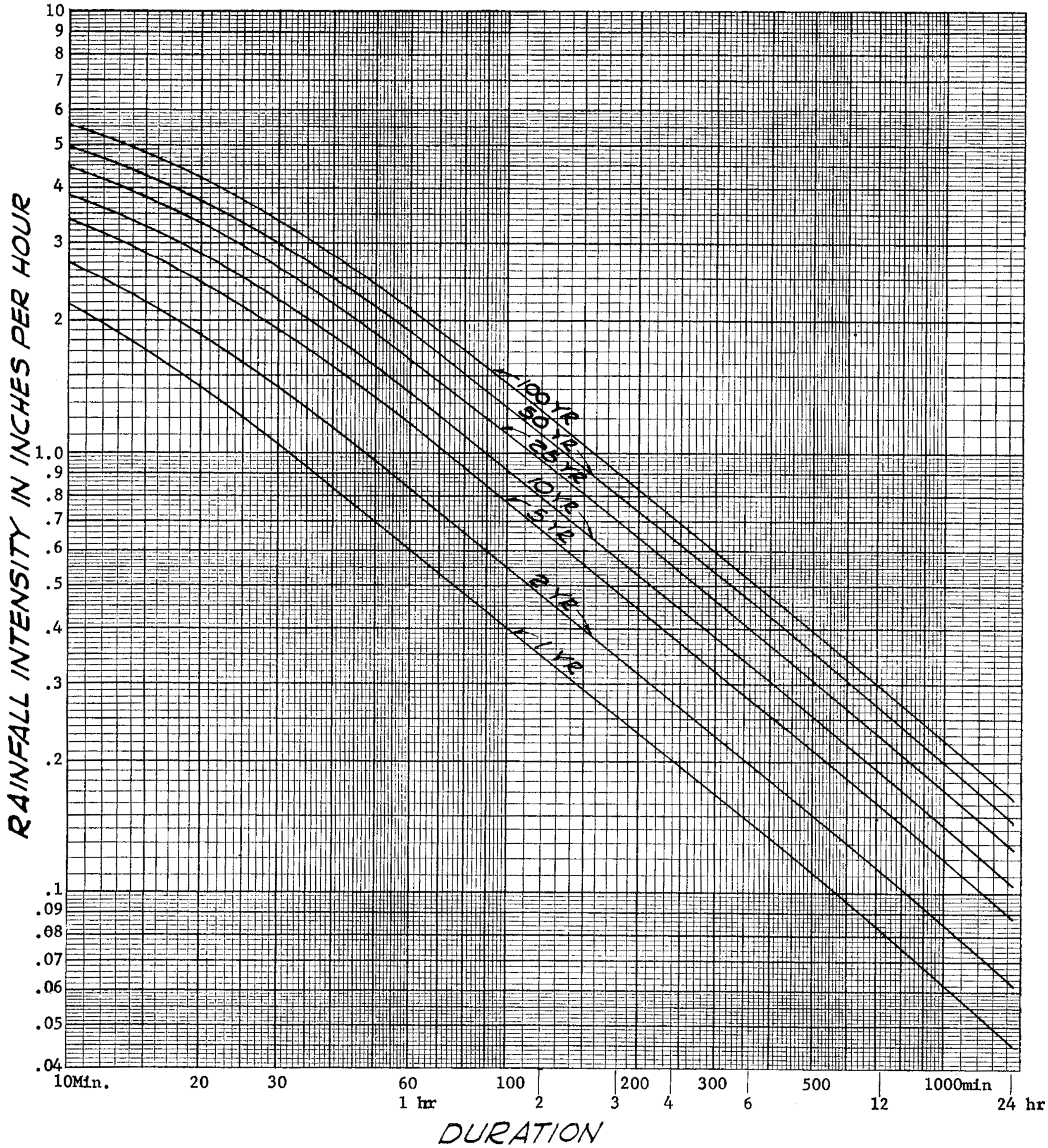
The storm duration or time period essential to reading the rainfall curves is that least period required for all increments of the area to contribute flow. In many cases portions of an area being studied will produce greater flows than the total because water can be collected from the partial area in a shorter 'time of concentration' and the partial area should therefore be considered with its appropriately greater rainfall intensity. The designer must seek out such areas and this is similar to hydrograph methods of centering the hypothetical design storm where it will produce the greatest rate of outflow.

This collecting period, critical storm duration, or time above referred to is usually called 'time of concentration' in this report and can be calculated for natural drainage basins from formulas given by the Corps of Engineers, Soil Conservation Service and others. Various means are given in the literature but in the case of urban areas we estimate the time of concentration as follows:

At any point under consideration the means of flow to the point are considered. If travel is over streets or in man-made channels and conduits the velocity therein is estimated and the associated time of concentration arrived at. Future improvements in an area are apt to change flow travel time and thereby time of concentration. Obviously travel in streets and conduits is faster than overland flows. The tabular calculations reflect these considerations and show the final chosen times.

Infiltration rates are determined from soil maps, comparison with other soils, or by other means.

On storms of high intensity, such as 2 inches per hour, the choice of a pervious area infiltration rate varying between 0.6 and 0.7 inches per hour could make only 8 percent difference in the result while the same choice of loss rates could make an infinite difference (on the pervious area flows) if the storm being considered was one of 0.6 inches per hour intensity. Indicated loss rate of soils is approximately 1/2 inch per hour and of paving less than 0.2 inches perhour but our formula allows for the use of substantial loss rates in the determination of peak flows while we would be more conservative in calculating storage requirements (or the net total outflow)."

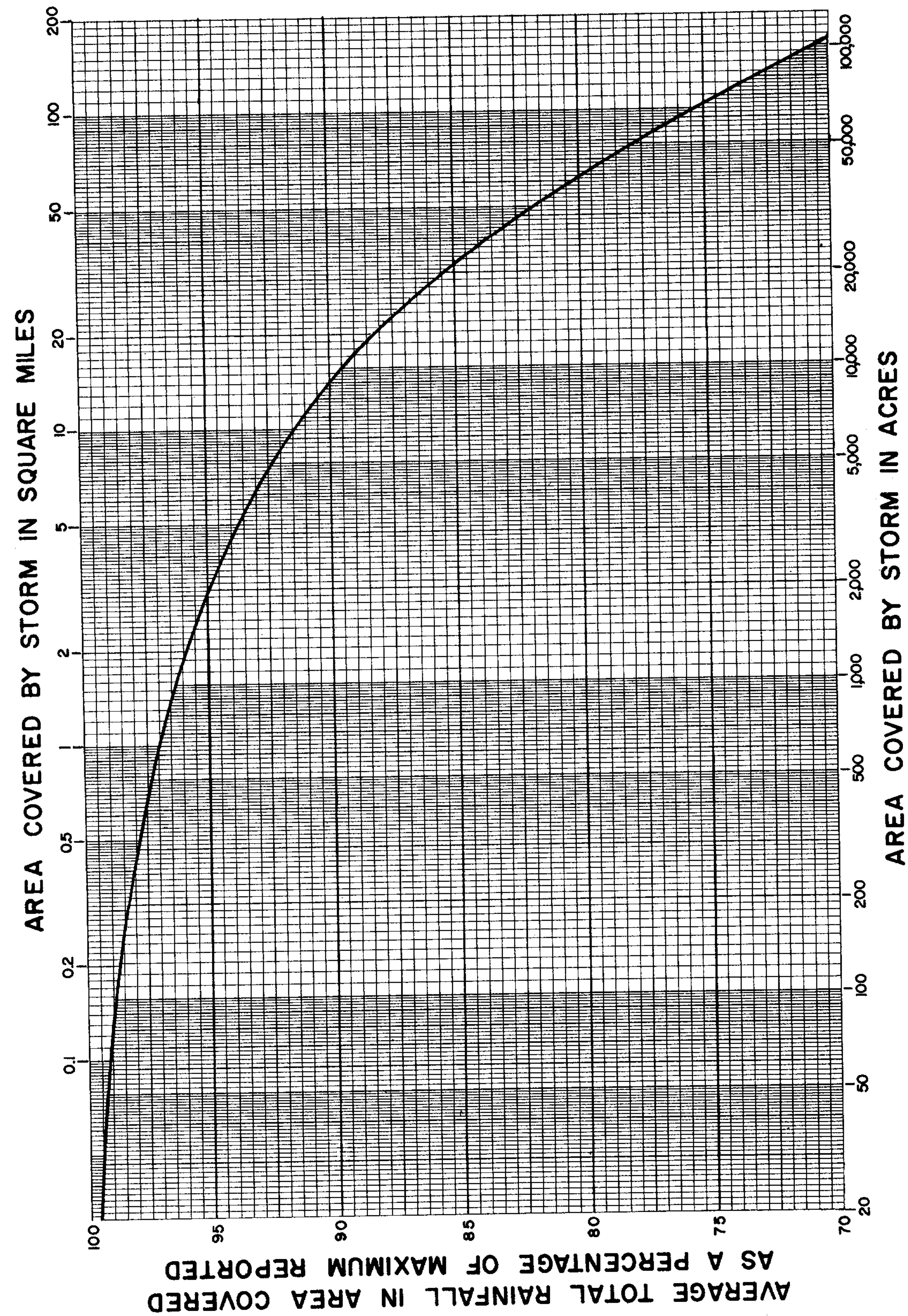


RAINFALL INTENSITY-DURATION-FREQUENCY RELATION
FOR PHOENIX, ARIZONA
(Partial Duration Series)

Curves are based on methods of U.S. Weather Bureau Technical Papers Nos. 28 and 40 and rainfall data prepared by U.S. Weather Bureau Office of Hydrology for the Soil Conservation Service, March 1967

YOST AND GARDNER ENGINEERS
PHOENIX, ARIZONA

FIGURE 6



DESIGN AREA-DEPTH CURVE

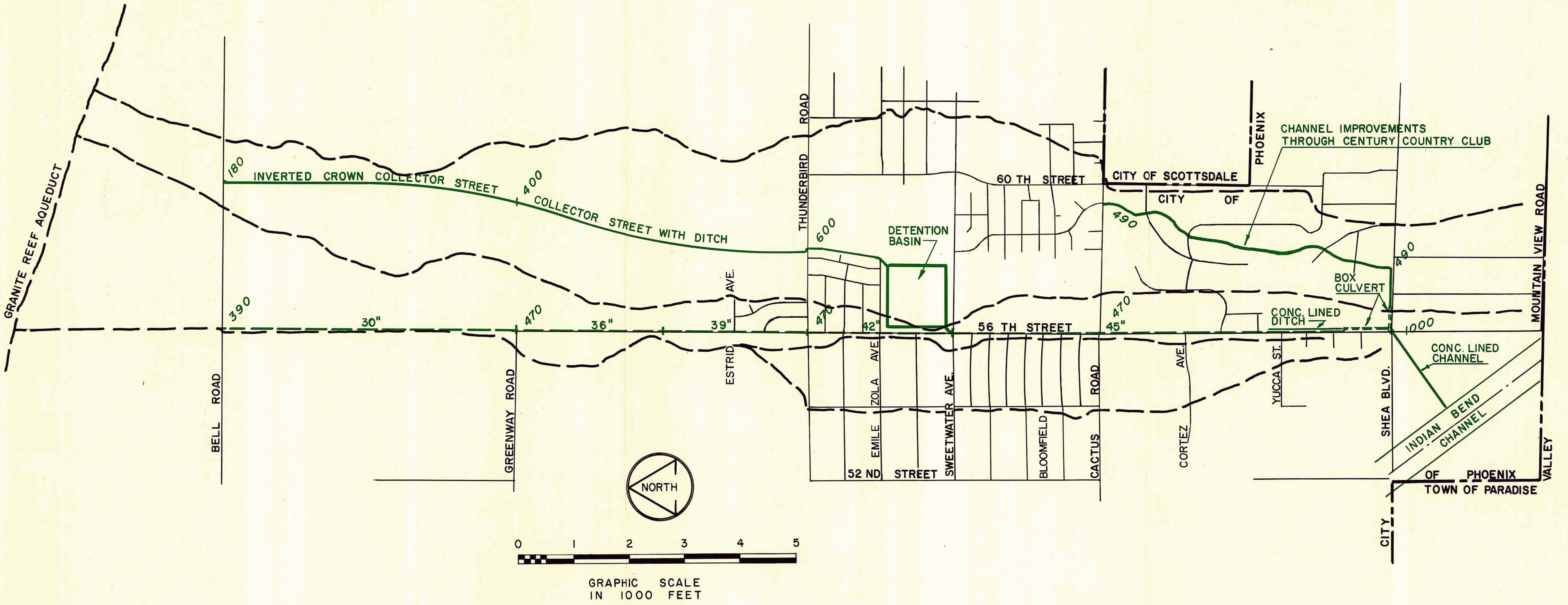
FIGURE 7

The rainfall-intensity-duration curve, Fig. 6, pg. 18, and area-depth design curve, Fig. 7, pg. 19 are reproduced herein from Ref. 5.

The tributary area that was selected as representative of north side drainage and studied for this report is the one that enters Indian Bend Wash from the north at 56th Street. At 56th Street and Shea Boulevard this wash splits into two separate but parallel drainages. These two drainage areas are shown in Fig. 8, pg. 21. The first is the area lying to the east of 56th Street and south of the new Granite Reef Aqueduct. Flow from this area will be concentrated by future paving of 56th Street and conducted to 56th Street and Shea Boulevard. The second area lies immediately east of the first and begins at the new aqueduct at approximately 60th Street and runs southerly along what will be the future alignment of 60th, 59th and 58th Streets. The drainage will enter the present street system at Sweetwater Avenue and 59th Street. At Cactus Road the drainage enters a channel that meanders through the golf course of Century Country Club and crosses Shea Boulevard approximately 1000 feet east of 56th Street.

Runoff calculations for these areas are included in Appendix II of this report. At present very little development has occurred above Sweetwater Avenue. These runoff calculations assume however, that urbanization has occurred throughout the areas in conformance with the present zoning.

After calculating a peak flow of 712 c.f.s. at 59th Street and Cactus Road and through Century Country Club, an alternative was calculated assuming a retention basin in Sereno Park located at the northeast corner of Sweetwater



LEGEND

DRAINAGE AREA BOUNDARY

36" PROPOSED STORM DRAIN

390 FLOW IN C.F.S. FOR 100 YEAR STORM, FUTURE CONDITIONS

CITY OF PHOENIX– PROJ. ST–73140.00

MASTER DRAINAGE STUDY
INDIAN BEND WASH
56TH. ST. AND 59TH. ST.
DRAINAGE AREAS
FIGURE 8

Avenue and 56th Street. This basin would reduce the calculated flow through Century Country Club to 487 c.f.s. This is discussed later in this report.

Flows were calculated for a 100-year return period storm. Peak rates occurring at various points along the drainageways are indicated by italic numerals in Fig. 8.

8. Channel Sections for Indian Bend Wash

Four alternative channel sections were considered: 1) a completely lined trapezoidal concrete channel, 2) a deep grass lined earth channel of trapezoidal section, 3) a shallow grass lined and landscaped swale or "greenbelt" with a deep concrete lined low flow channel, and 4) a greenbelt with a 50:1 transverse slope. These sections are shown in Figures 9, 11, 13, and 15. All sections shown are at the same channel station (Sta. 60+00) and will handle the same design 'Q', 20,600 c.f.s. The roads at the edges of the channel are shown to give an indication of the horizontal and vertical scale of the drawing only and it should not be inferred that they are an essential part of the improvement.

A fifth solution, that of doing nothing at all, was studied but is not given serious consideration as a viable alternative. While the "do nothing alternate" has worked in the past, urbanization of the Paradise Valley area has progressed to the point (Ref. 6) that land values make utilization of flood plains economically desirable. Adequate all weather arterial crossings of Indian Bend Wash are becoming imperative. These requirements dictate a compact, efficient waterway for Indian Bend Wash, preferably one that has secondary utility and is an esthetic asset to the community. Flooding of the unimproved channel by the 100-year storm under present conditions is indicated in Fig. 2, already referred to. Under future conditions of development, with a higher ratio of impervious to pervious area and more rapid runoff, the 100-year situation will be considerably worse. Fig. 3, a profile of the present channel, shows water surface elevations for the 100-year storm under present conditions with flows in the range of 5,500 to 12,500 c.f.s. Under future conditions, the range will be from 10,000 to 21,200 c.f.s. for the 100-year storm and the inundated band under a do-nothing policy would be considerably wider than shown in Fig. 2.

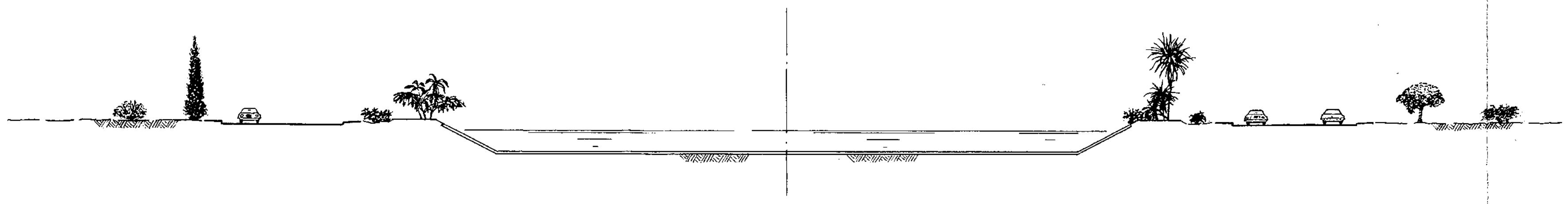
8.1 Concrete lined channel

Figure 9, pg. 24, shows a typical cross section of the proposed concrete lined channel. Depth to flow line of the channel is approximately 9 feet. Width of bottom varies from 100 to 170 feet. Side slopes are 2:1. Longitudinal channel slope follows the existing grade of the wash which is about 3.5 per 1000 feet.

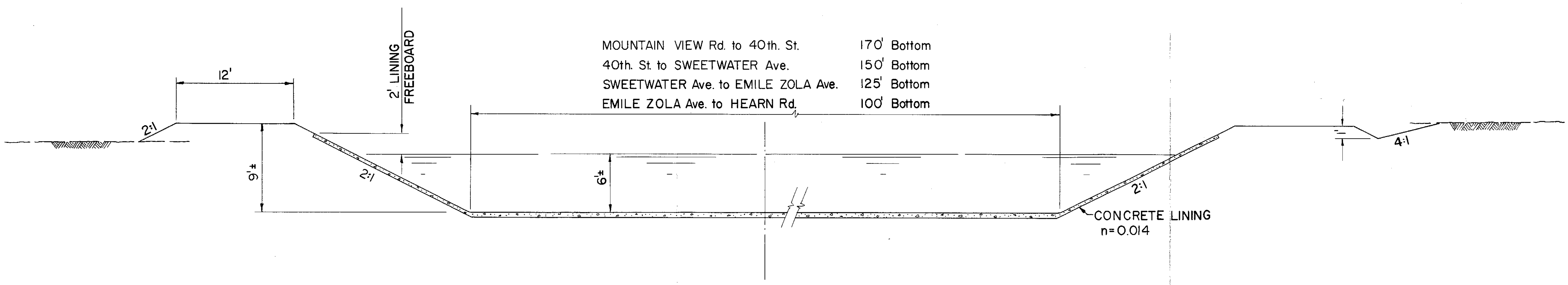
An overall profile of the concrete lined channel is shown on Fig. 10, pg. 25. Water depth is about 6 feet. Velocities are in the range of 14 to 21 feet per second.

The slope of this channel gives high velocities and unstable conditions which are considered undesirable. The energy gradient is three to six feet above the water surface which means that some small channel blockage could cause a hydraulic jump. For this reason it is necessary that this design have ample freeboard to prevent the water from breaking over the banks.

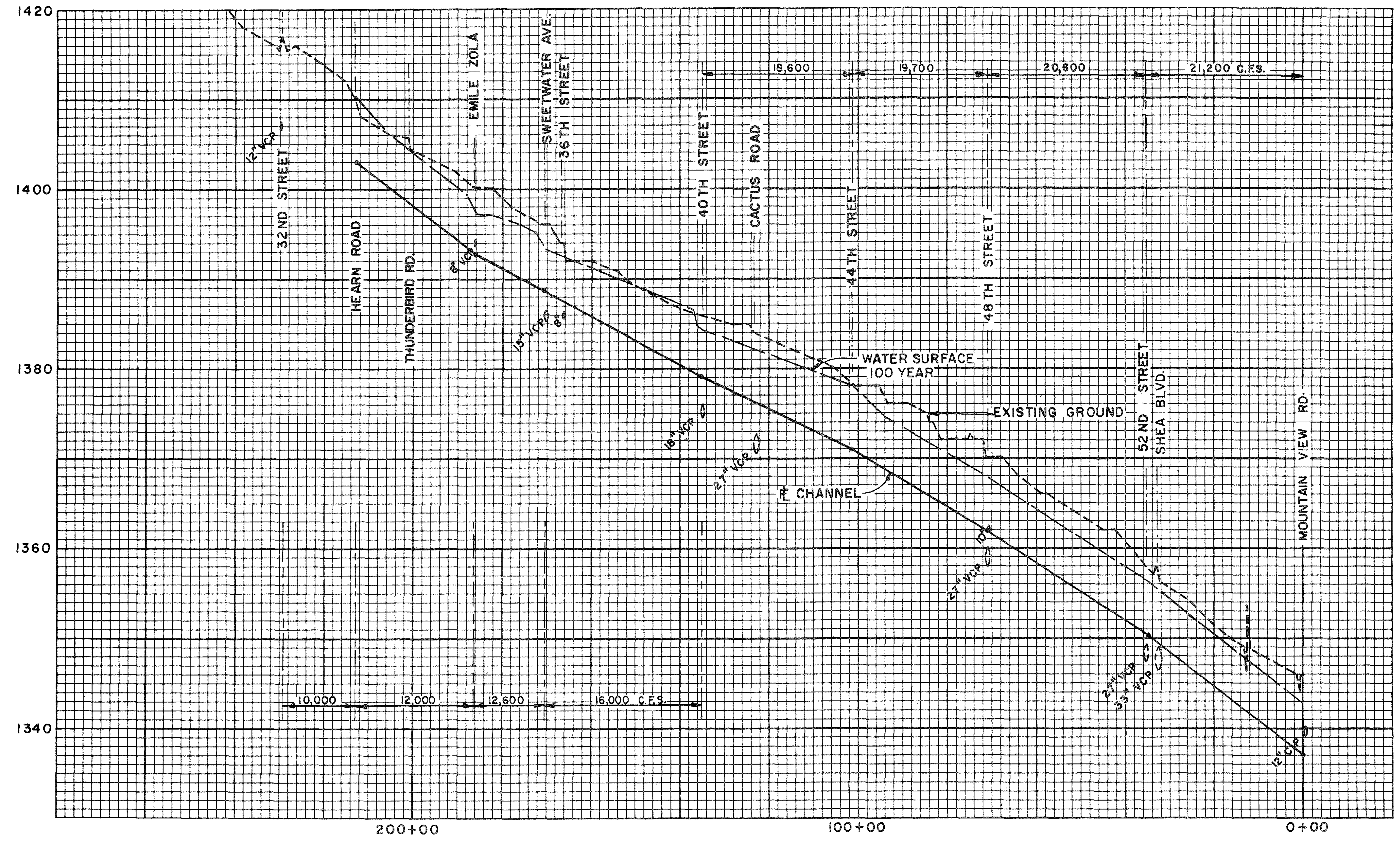
A concrete lined channel is compact. Right-of-way requirements are lower than for any other type, but construction costs are higher. Maintenance costs are low. Connections to incoming storm drains are simple. Esthetically, a concrete channel is no asset and it is difficult to think of



CROSS SECTION — STA. 60+00
Scale - 1" = 50'



CITY OF PHOENIX — PROJ. ST-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
TYPICAL SECTION
CONCRETE LINED CHANNEL
FIGURE 9



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MASTER DRAINAGE STUDY

INDIAN BEND WASH

PROFILE

CONCRETE LINED CHANNEL

FIGURE 10

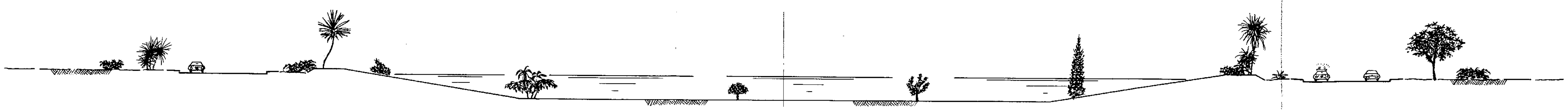
any beneficial secondary uses. Utility crossing problems are not bad but street crossings would best be made on bridges.

8.2 Deep grass lined channel

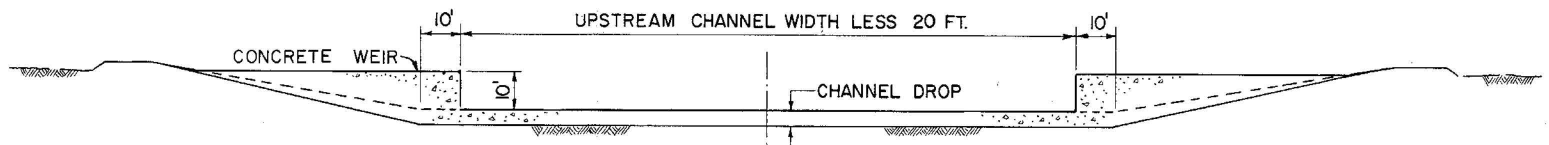
A typical section of the deep grass lined channel is shown in Fig. 11, pg. 27. Water depth for this channel would be up to 14 feet. Bottom width would be 220 feet at the lower end and narrow to 70 feet at 32nd Street. Side slopes are 6 horizontal to 1 vertical.

Velocity in the channel at the design frequency should be held to about 7 feet per second to prevent erosion. Maximum velocities for short reaches should be less than 9 feet per second. Slope of the channel would be 0.60 feet per 1,000 feet to hold the velocities to this range. This design would incorporate a 4-foot drop about every 1800 feet. A typical weir elevation at the channel drops is shown on Fig. 11. Overall channel profile is shown on Fig. 12, pg. 28.

The deep grass lined channel produces the greatest conflict with existing utilities. Right-of-way widths are greater than for the concrete channel but still moderate. Major street crossings would require bridges. Maintenance costs would be high. Special structures would be necessary at storm drain entrances. Landscaping would make it more attractive than the concrete channel and some secondary uses are possible although these are limited.

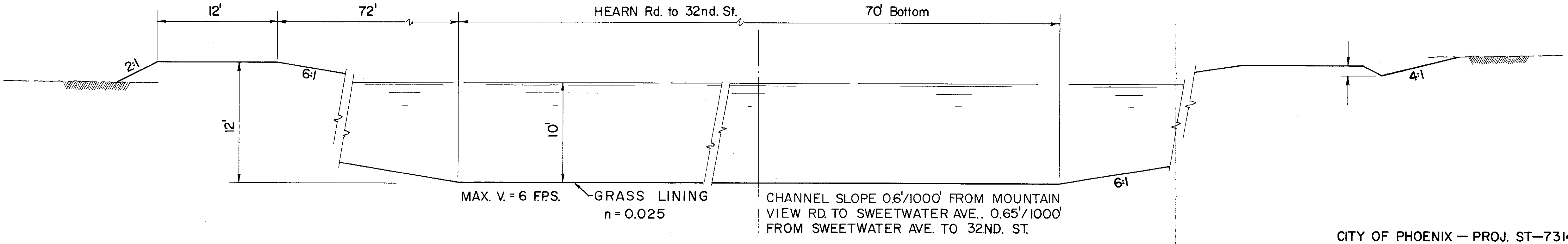


CROSS SECTION – STA. 60+00
Scale – 1" = 50'



TYPICAL WIER ELEV. AT CHANNEL DROP

MOUNTAIN VIEW Rd. to 48th. St.	220' Bottom
48th. St. to 44th. St.	200' Bottom
44th. St. to 40th. St.	180' Bottom
40th. St. to SWEETWATER Ave.	160' Bottom
SWEETWATER Ave. to EMILE ZOLA Ave.	110' Bottom
EMILE ZOLA Ave. to HEARN Rd.	100' Bottom
HEARN Rd. to 32nd. St.	70' Bottom



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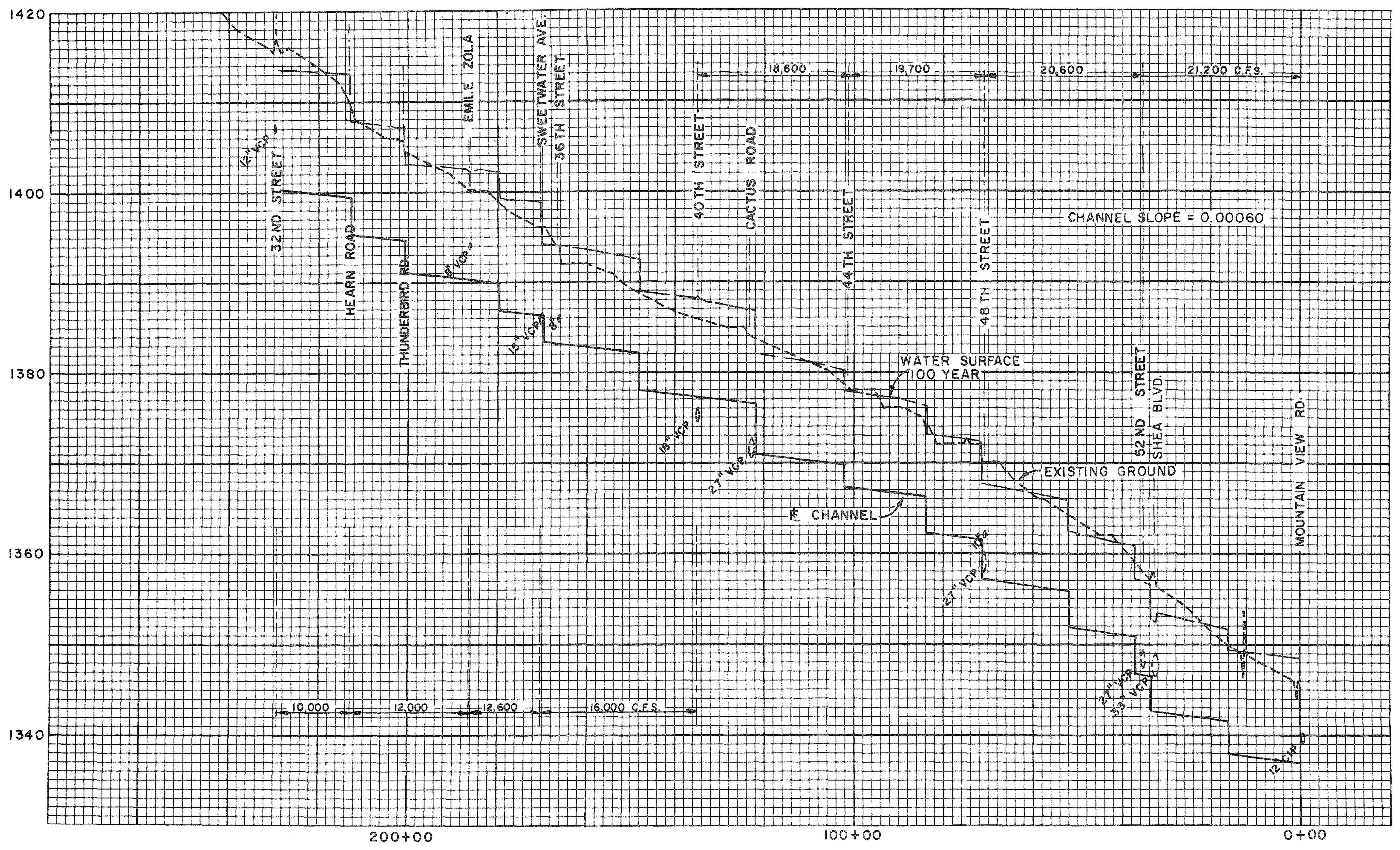
MASTER DRAINAGE STUDY
INDIAN BEND WASH
TYPICAL SECTION
GRASS LINED CHANNEL
FIGURE 11



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MASTER DRAINAGE STUDY

INDIAN BEND WASH

PROFILE

GRASS LINED CHANNEL

FIGURE 12

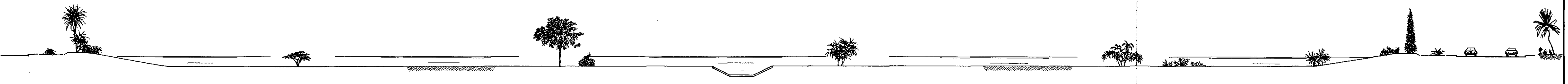
8.3 Shallow grass lined greenbelt with deep concrete lined low flow channel

Figure 13, pg. 30, shows the typical section for the grass lined greenbelt with a concrete low flow channel.

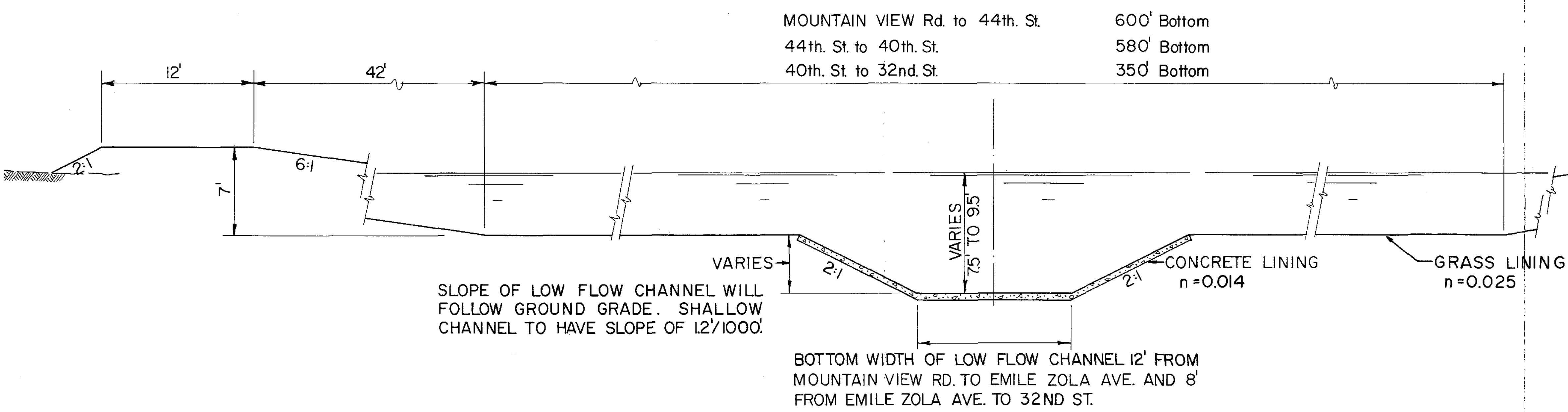
The concrete low flow channel has an 8 and 12 foot bottom with two horizontal to one vertical side slope. Profile slopes will follow the existing ground. Depth of the concrete channel will be 4 to 6 feet. Hydraulic capacity of the low flow channel is calculated to be approximately a two year return frequency storm flow.

The shallow greenbelt portion has a 350 foot to 600 foot bottom with six to one side slopes. A nominal velocity of six feet per second will require a profile slope of 1.2 feet per 1000 feet. To accomplish this slope a 2-foot drop will be required about every 1000 feet. Refer to Fig. 14, pg. 31, for the overall profile.

This channel section requires considerably more right-of-way than the previous alternates. Street crossings by means of dips could more readily be made than for the others. Appearance and secondary use possibilities are good. The paved low flow channel facilitates storm drain entries. Utility interferences are moderate.



CROSS SECTION — STA. 60+00
Scale – 1" = 50'



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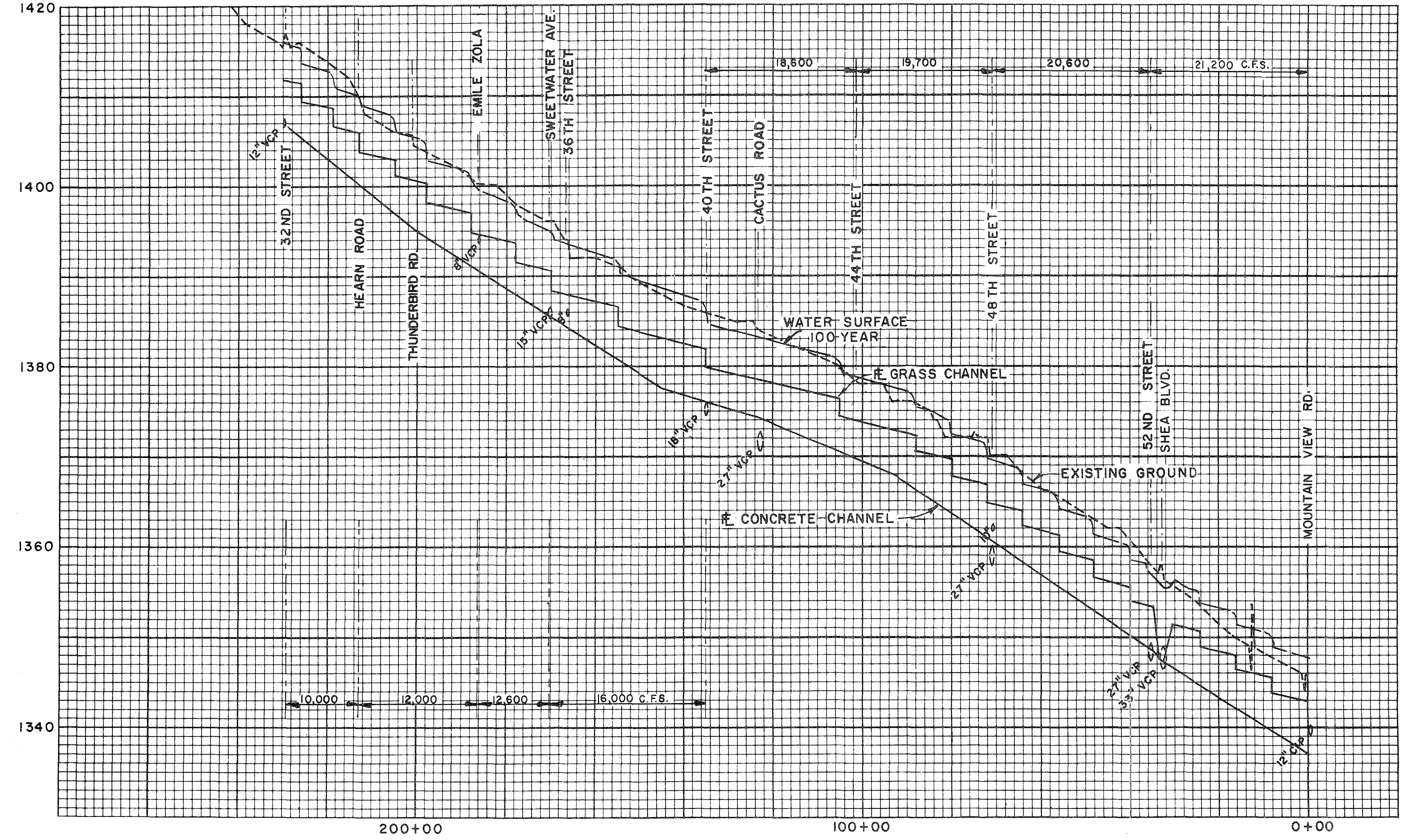
INDIAN BEND WASH

TYPICAL SECTION

SHALLOW GREENBELT WITH CONCRETE LOW FLOW CHANNEL

FIGURE 13



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MASTER DRAINAGE STUDY

INDIAN BEND WASH

PROFILE

SHALLOW GREEN BELT WITH CONCRETE LOW FLOW CHANNEL

FIGURE 14

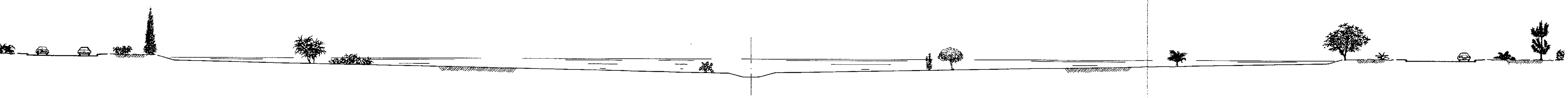
8.4 Greenbelt with 50:1 bottom

Refer to Fig. 15, pg. 33, for the greenbelt typical section. Width of channel varies from 350 feet to 600 feet. An eight foot bottom low flow channel for small flows is shown. Bottom transverse slope of the section from Mountain View to 44th Street is 50 horizontal to 1 vertical. Above 40th Street the existing right-of-way will not accommodate the channel width required so the bottom slope was changed to 100 horizontal to 1 vertical. By making this modification the present right-of-way, that which has been obtained above 40th Street, can be utilized.

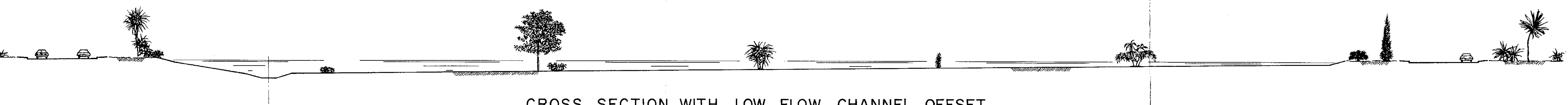
Longitudinal channel slope is 2.2 feet per 1000 feet at the lower end and 1.8 feet per 1000 feet at the upper end. Two foot drops at one to two thousand foot intervals will be required to maintain stability. Refer to Fig. 16, pg. 34, for the overall profile.

The low flow channel will carry only minor nuisance flows. The capacity of the grassed low flow channel is about 100 c.f.s. The low flow channel can be lined or given a paved bottom, as shown in the alternate section, Fig. 15, to facilitate cleaning and maintenance. The low flow channel would then have a capacity of about 230 c.f.s. Such pavement should of course be sufficiently strong for heavy trucks and loaders.

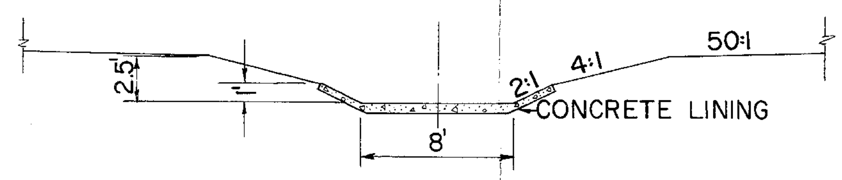
Additional capacity for nuisance flow can be achieved by widening and deepening the low flow channel. The channel should not be deepened more than about 1 foot or additional conflict with utilities may be a problem. A concrete lined channel 3 feet deep with 16 foot bottom and 2:1 side slopes can carry about 550 c.f.s.



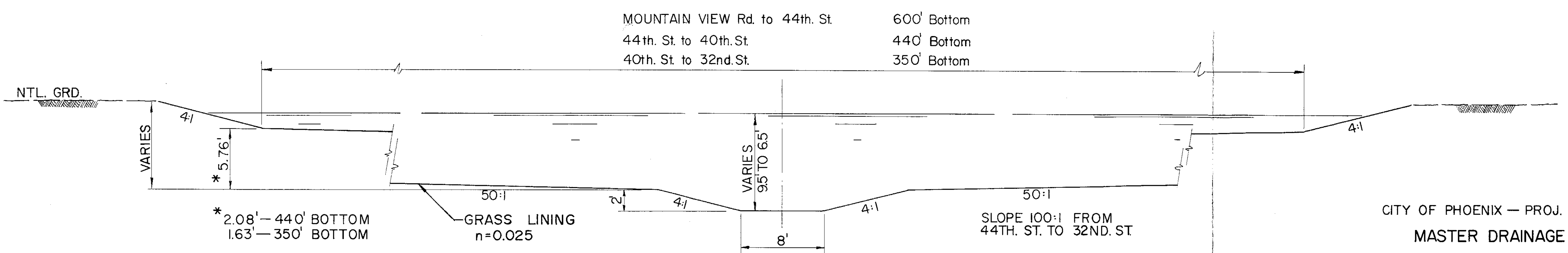
CROSS SECTION — STA. 60+00
Scale — 1"=50'



CROSS SECTION WITH LOW FLOW CHANNEL OFFSET
Scale — 1"=50'



ALTERNATE CONCRETE LINED LOW FLOW CHANNEL



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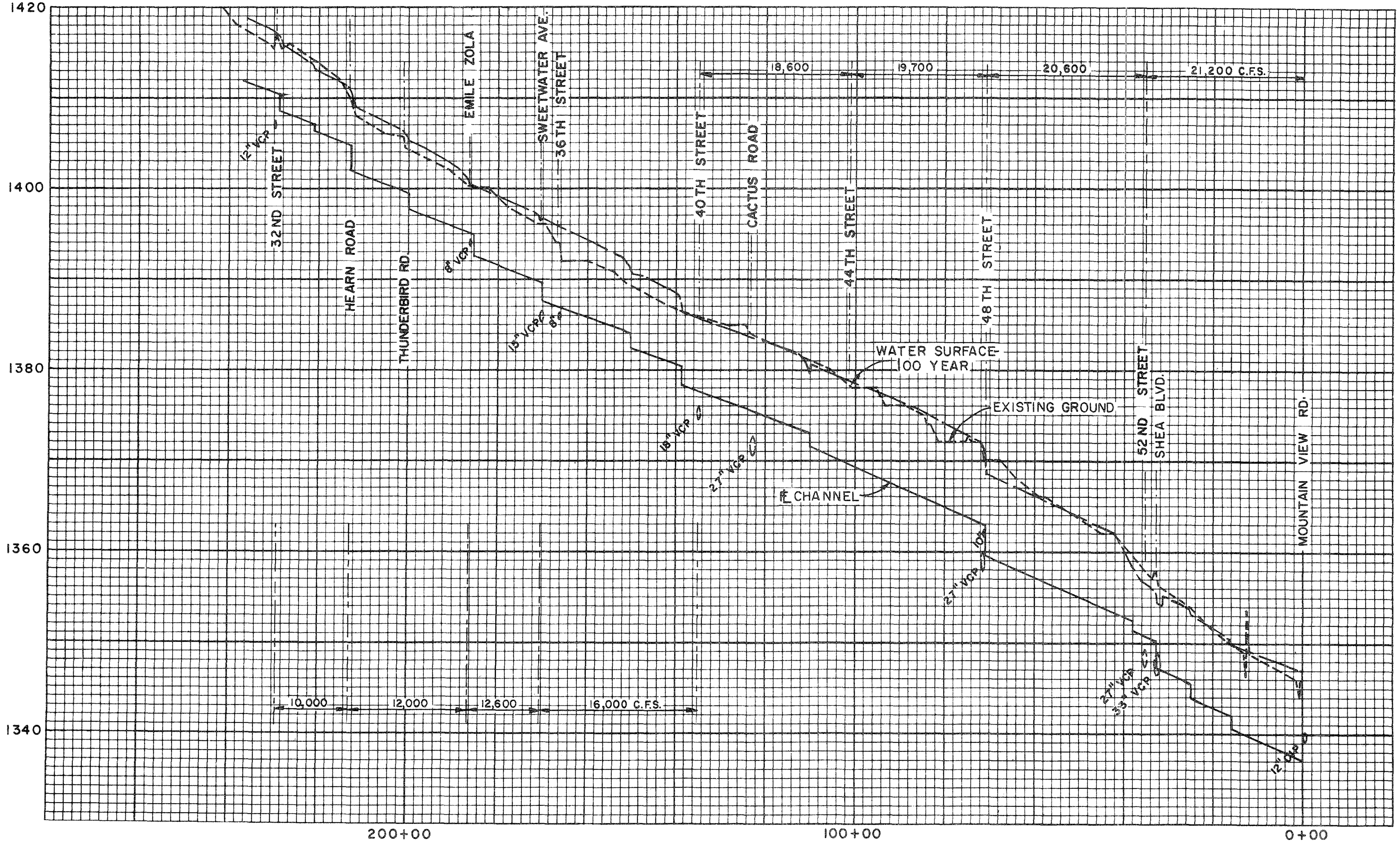
MASTER DRAINAGE STUDY

INDIAN BEND WASH

TYPICAL SECTION

GREENBELT WITH 50:1 BOTTOM

FIGURE 15



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MASTER DRAINAGE STUDY

INDIAN BEND WASH

PROFILE

GREENBELT WITH 50:1 BOTTOM

FIGURE 16

The low flow channel, shown in Fig. 15 as centered in the main channel or offset to one side, may be meandered anywhere within the main channel bottom providing proper flow lines are maintained.

Right-of-way requirements for this section are less than those for the previous one. Utility interferences are minimal and street crossings are readily made with paved dips. This section is more readily adaptable for parkways, golf courses, or similar secondary uses than any other. Entry of lateral storm drains will require special structures. Maintenance costs will be highest for this section unless they are allocated to the secondary use.

8.5 Alternative Sections

The following table summarizes dimensional properties of the four alternate channels.

Table 1. Comparative Physical Data

Concept	Bottom Width Feet	Channel Depth Feet	Water Depth Feet	Velocity Ft./Sec.	R/W Width Feet
Concrete lined channel	100 - 170	7 - 11	4.6 - 7.6	14 - 21	170 - 240
Deep grass lined channel	70 - 220	10 - 17	10.5 - 13.5	5 - 7.7	260 - 410
Greenbelt with conc. low flow channel	350 - 600	10 - 12	8.5 - 11	8.5 - 15	440 - 700
Greenbelt with 50:1 bottom	350 - 600	7 - 11	6.5 - 9.5	7 - 7.5	400 - 650

8.6 Sedimentation

Grass lined channels are designed to have low flow velocity under the 100-year flow to prevent erosion under those conditions. The greenbelt with 50:1 bottom has velocities that vary from 6.5 to 7.5 feet per second at the design freqeuncy. This velocity will keep sands and silt in suspension. When flow in the channel decreases and velocities decrease to 2 feet per second or less the material will settle out and be deposited in the grass lining. This will also occur at the outer fringes of the channel where velocities are low. As storm drains are built and discharge into the channel with low flows but at relatively high velocities, the suspended material will tend to drop out where these drains enter the channel. Trash will also be deposited on the outer fringes of the channel as storm flow recedes. This requires periodic maintenance of the channels to keep them clean and, more important, to keep the channel at the original elevation and cross-section so that it will perform properly during the next runoff period.

The need for such maintenance is not obvious, particularly if the channel is irregular and devoted to some secondary use such as a park or golf course. It is nevertheless essential that the maintenance be provided. This means periodic re-surveys, at least in reaches known to be troublesome, and periodic reshaping of the channel. Agreements for channel easements or rights-of-way should recognize this fact. Responsibility for surveillance and maintenance of channels should be clearly defined.

The problem of channel sedimentation should diminish as upper portions of the drainage basins are urbanized and erosion is controlled by paving, planting, and otherwise stabilizing the ground surface.

9. Street and Utility Interferences

A channel as wide and deep as the one envisioned in this report inevitably requires extensive relocation of existing streets and utility lines. The threat of floods has kept development back from Indian Bend Wash, except in the upper portion, so there is less of this than would otherwise be the case. Streets do need to be moved, however, and some bridges and culverts will have to be built . Utilities requiring relocation include water, sewer and gas lines and telephone ducts and cables. Aerial power and telephone lines will also be affected by construction but the problems here appear to be much simpler.

Because they must be laid on a continuously falling gradient, sanitary sewers present the greatest difficulty. All known sanitary lines affected have been plotted in the plans and profiles of this report. Where interferences occur the suggested solution is shown and usually consists of relocating a portion of the sewer. In some cases, notably that of the 12-inch sanitary sewer in Mountain View Road, it will be necessary to make an elevated crossing with the line supported on piers at its present gradient. In other cases, refinement of the channel design to provide a shallower and wider waterway in the vicinity of the crossing may make relocation of the sewer unnecessary.

Water lines, since they are pressurized, may be lowered at channel crossings without impairing their function. All crossing lines will need to be lowered but they are all of small diameter pipe. There are five 12-inch lines, the rest are of 6 and 8-inch pipe.

Gas lines that cross the channel will likewise need to be lowered but as in the case of the water mains there will be no particular difficulty. The same is true of telephone cables. Telephone ducts are laid to gradient so they will drain toward adjacent manholes. The only duct bank presently in place that will be affected is the one in Shea Boulevard and this will have to be reconstructed in any event when the bridge is built.

The channel section that requires least relocation of sanitary sewers is the greenbelt with 50:1 bottom slopes. The average depths of this section is in the 7 to 8 foot range. Except for the 12-inch sewer in Mountain View Road and those shown on the plan sheets, all other sewer crossings could be made without disturbing the mains by judicious placement of the required drop structures.

The concrete lined channel averages 8 to 8.5 feet in depth and involves a little more sewer interference. The conflicts at 48th Street and at Emile Zola Avenue could be resolved by raising and widening the channel. At Emile Zola Avenue it would also be possible to reroute the sewer.

The shallow greenbelt with the concrete low flow channel averages a foot deeper than the fully concrete lined channel. In this case, the 48th Street and Emile Zona Avenue sanitary sewer crossings could be made with cast iron pipe on concrete piers. At 36th Street and Sweetwater Avenue raising the channel slightly from the gradient shown on the profile would resolve the problem.

The fully grass lined channel, because of the flat gradient and numerous drop structures, has more sewer interferences than any other section. The depth averages 10½ to 11 feet. Some raising of the gradient would be possible at 48th and 36th Streets to clear the 10-inch and 15-inch lines on those streets, providing the channel is widened to compensate. Other crossings would have to be made with cast iron pipe on piers, or the sewers relocated.

Street crossings are simplest in the case of the greenbelt with 50:1 slopes or the greenbelt with the concrete low flow channel. Crossings may be made with paved dips using box culverts or pipes to carry low flows. These would not be "all weather" crossings, of course, and at major arterials such as 32nd and 48th Streets bridges or large box culverts may be justified.

Street crossings of the concrete and deep grass lined channels are not so readily made with dips because there is no separate low flow channel. If a separate low flow channel were provided, the already serious sewer conflicts would be worsened. The flat longitudinal slope of the grass lined channels results in low velocities, consequently flows will be one foot or more in depth even for the one year storm. For these reasons bridges are better suited for street crossings of these channel sections.

Streets that will have to be relocated or provided with some type of crossings are as follows:

Approximate Station	Street	Remarks
32	Shea Boulevard	Bridge under design
36	52nd Street	Relocate to northeast
70	48th Street	
70	Cholla Road	Relocate to southeast
123	Cactus Road	
135	40th Street	
165	36th Street at Sweetwater Ave.	To be abandoned?
170	Sweetwater Avenue	Culvert crossing under design
200	Thunderbird Road	
213	Hearn Road	
230	32nd Street	Suggest bridge
230	Acoma Drive	Relocate to northeast and southwest

10. Conduits for Tributary Drainage

At the outset of our studies for this report we had intended to consider alternative means of conveying flows in the washes tributary to Indian Bend Wash in the same manner as has been done for the main stream. While this would have been possible for tributaries in unimproved areas, it would have been pointless to do so in the case of the tributary that was selected for study, the wash entering Indian Bend Wash from the north at 56th Street.

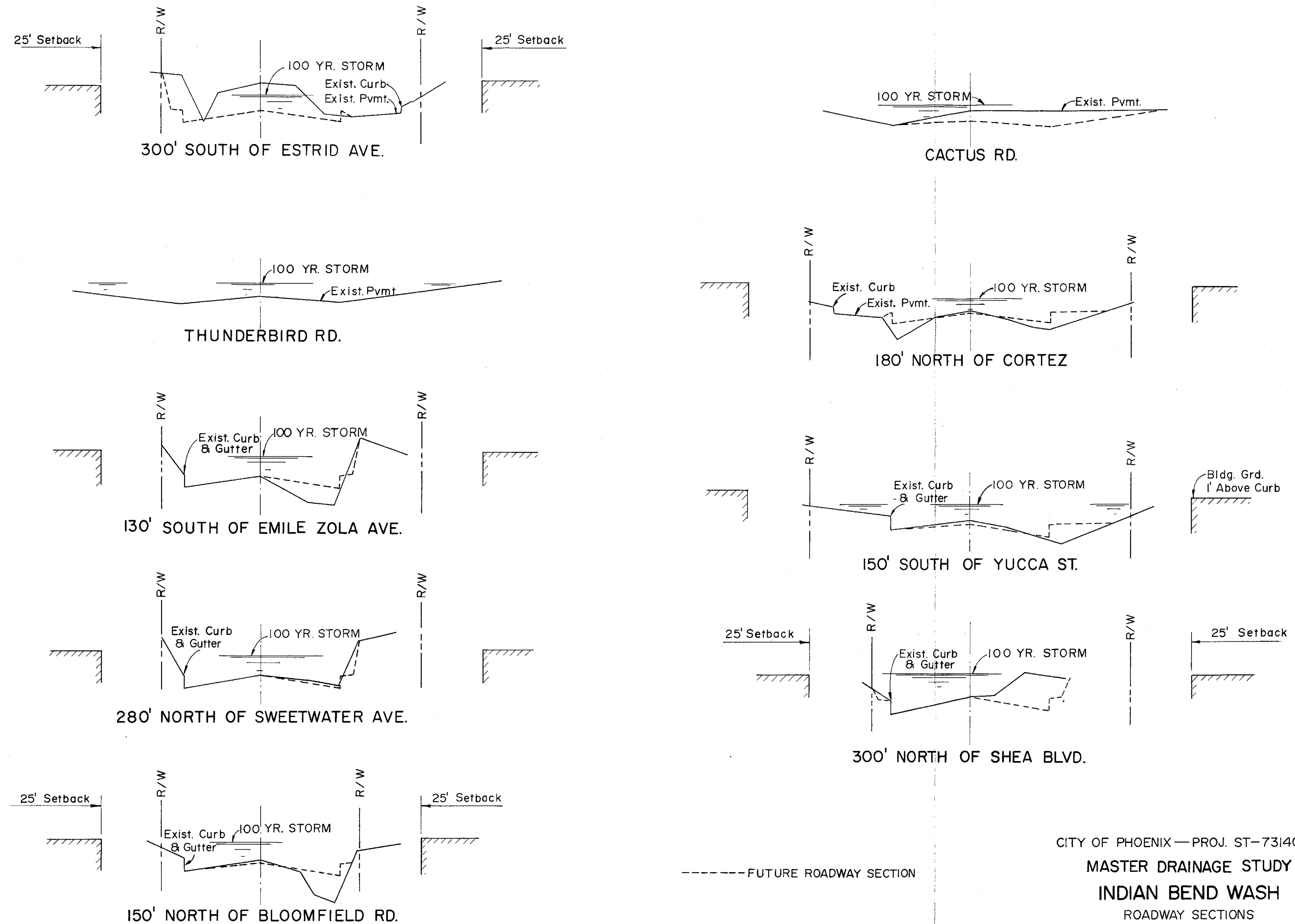
So much development has already taken place in the lower portions of the two branches of this wash (the portion south of Thunderbird Road) that few options remain. The problem becomes that of finding means of providing adequate hydraulic capacity while making the best use of what has already been built.

Conditions along the drainage path are so varied, however, and there is such a range of discharge rates, that the best conduit selections embrace quite a variety of types. There are normal streets, inverted crown streets, streets with auxiliary channels, grass lined swales, concrete flumes, box culverts, and lined trapezoidal channels among the recommendations that follow:

10.1 56th Street

Figure 17, page 42, shows selected sections on 56th Street between Shea Boulevard and Estrid Avenue one quarter mile north of Thunderbird Road. Partial improvements have been made to the roadway in this area. We assume these will control the grade on any future paving installed to complete the street. The future street sections, shown by dashed lines on Fig. 17 were used in calculating the water surface elevations shown in the figure for a 100-year storm. It was also assumed that a pipe drain capable of handling a one year storm (as recommended in the MAG report) had been installed and was surcharged to full capacity. Water depth is generally 0.5 to 0.7 ft. over the street crown. Building floor levels that are at least one foot above curb grade would be above the water surface.

The pipe drain could be increased in size to carry a five year storm or greater. The construction cost for the 5-year frequency would be about 40% more than the one year frequency and would reduce the depth of water over



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MASTER DRAINAGE STUDY

INDIAN BEND WASH

ROADWAY SECTIONS

56TH. ST.

FIGURE 17

the street crown approximately 0.1 ft. The majority of the 100-year flow would still have to be carried on the surface.

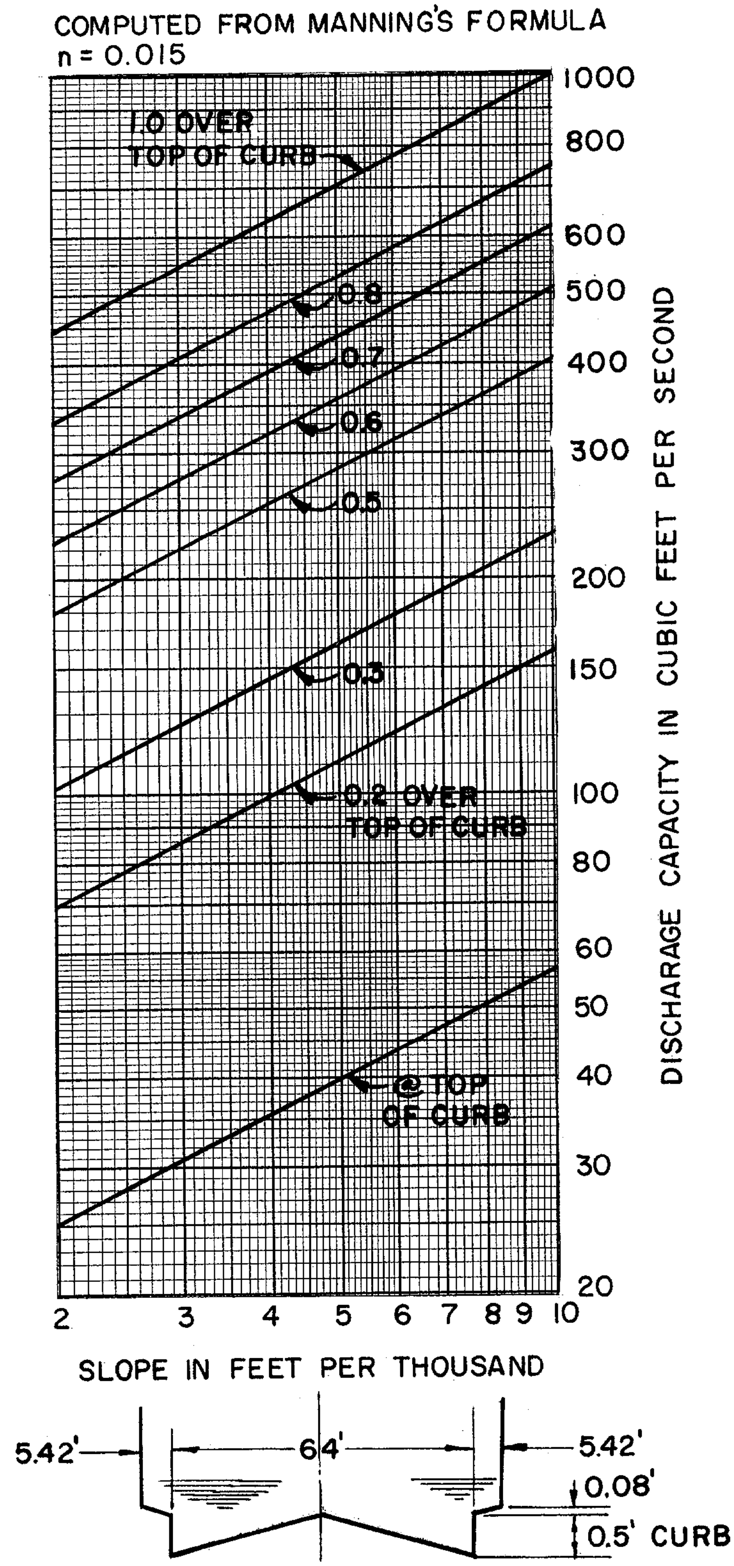
For 56th Street above Estrid Avenue it is recommended that the Street be designed with adjacent building grades at least one foot above the centerline street grade. See Fig. 18, pg. 44, for capacity of such streets flowing 1 foot above grade. Storm drain should be sizes as recommended in Ref. 5. Figure 8 shows sizes recommended.

Additional channel work is recommended on the east side of 56th Street north from Shea Boulevard. This work is covered in the section on recommended improvements through Century Country Club.

10.2 Future 60th and 59th Streets

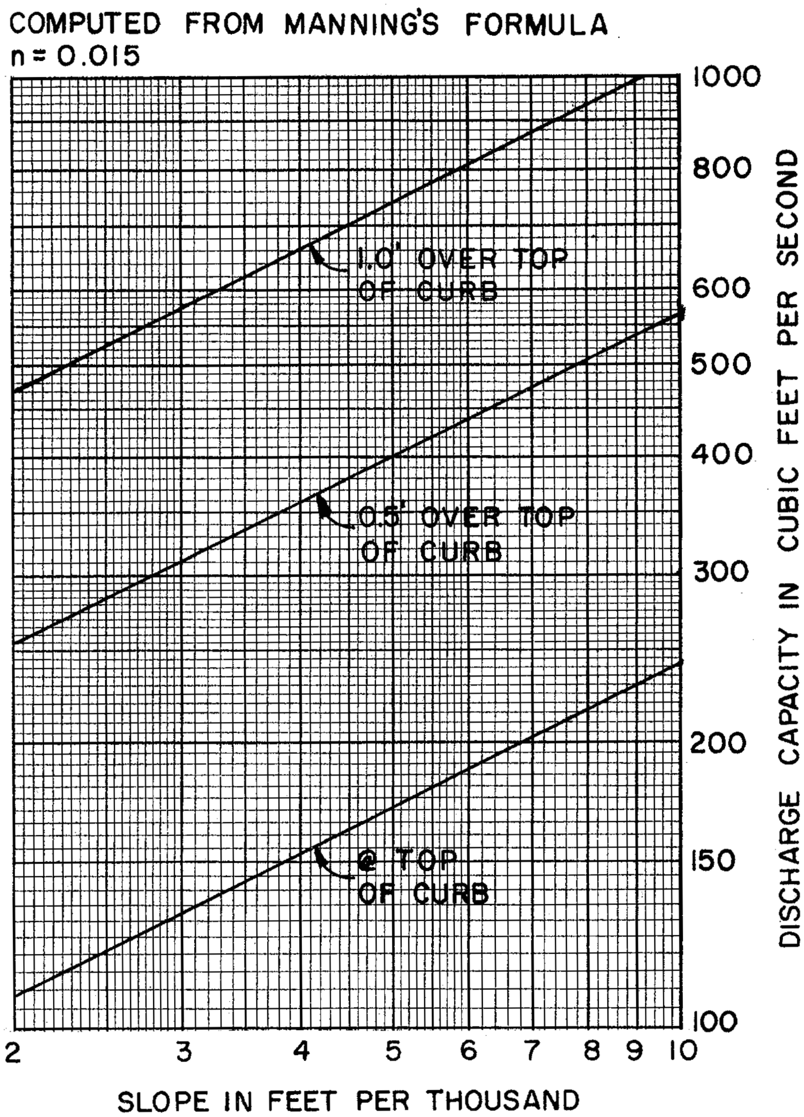
Figure 8 shows the drainage area below the Granite Reef Aqueduct that will drain to the south along the alignment of future 60th and 59th Streets. Flow calculations were made and are included in Appendix II. Calculations were made based on full development as presently zoned. The design storm has a 100-year return frequency.

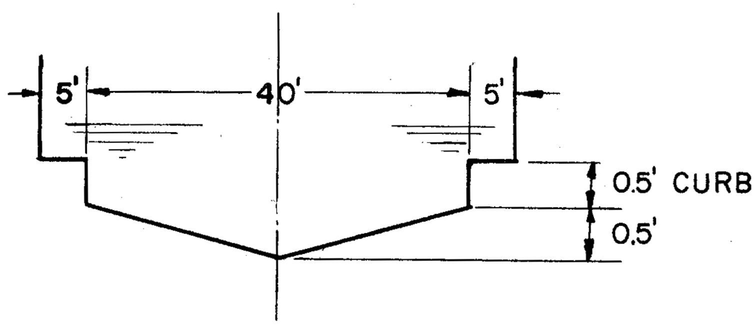
A forty foot wide collector street with inverted crown is recommended for the first mile from Bell Road to Greenway Road. See Fig. 19, pg. 45, for the capacity of such streets. From Greenway Road to Thunderbird Road an inverted crown collector street alone is inadequate to carry the calculated flow. For this portion a shallow median ditch should be added at the center of the street. See Fig. 20, pg. 46, for flow calculations of the recommended section. Fig. 21, pg. 47, shows typical street sections. Street location shown on Fig. 8 are schematic only and in the general location of future streets.



CAPACITY
ARTERIAL SECTION
FLOWING OVER TOP OF CURB

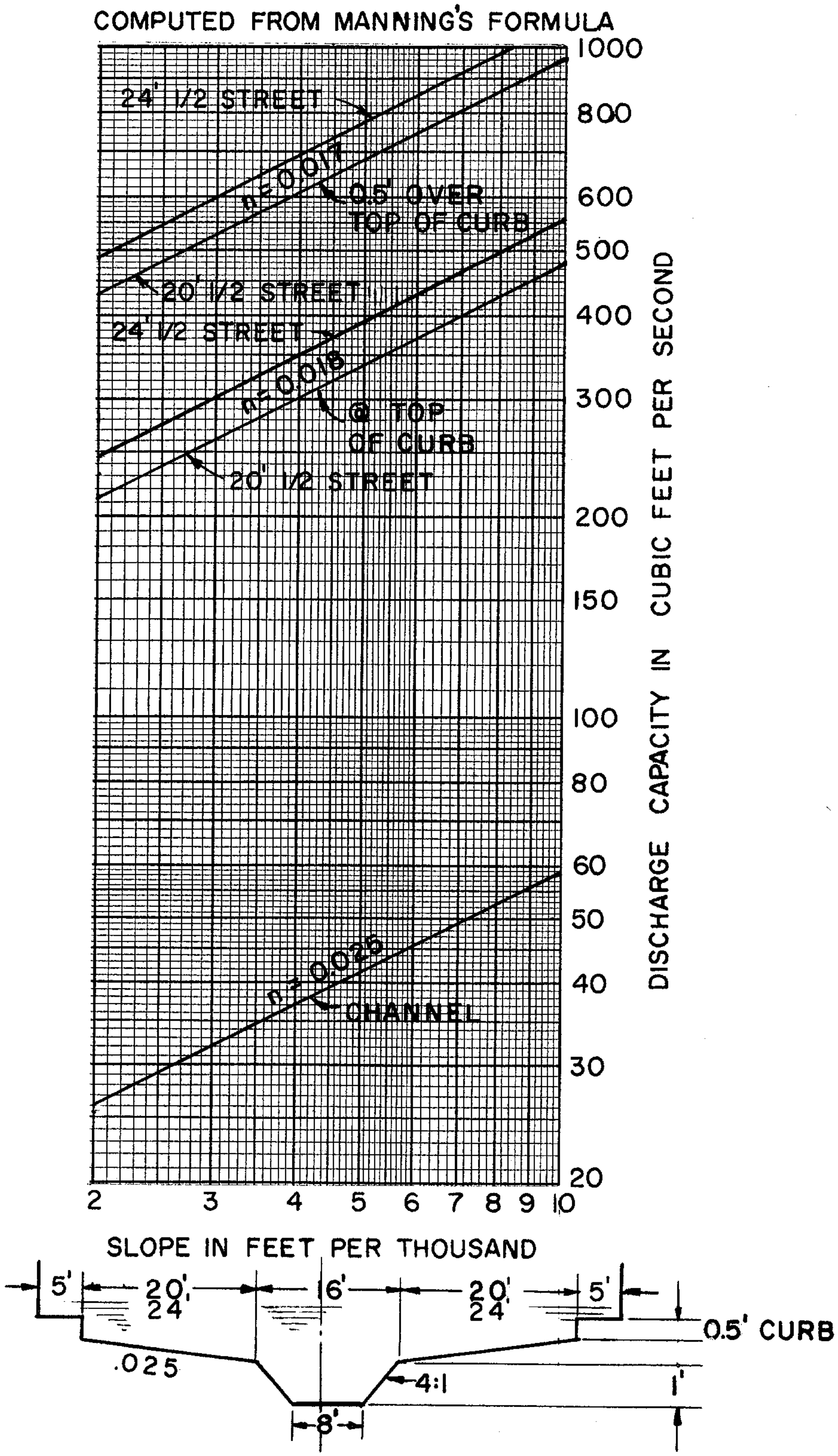
FIGURE 18





CAPACITY
INVERTED CROWN COLLECTOR STREET FLOWING OVER TOP OF CURB

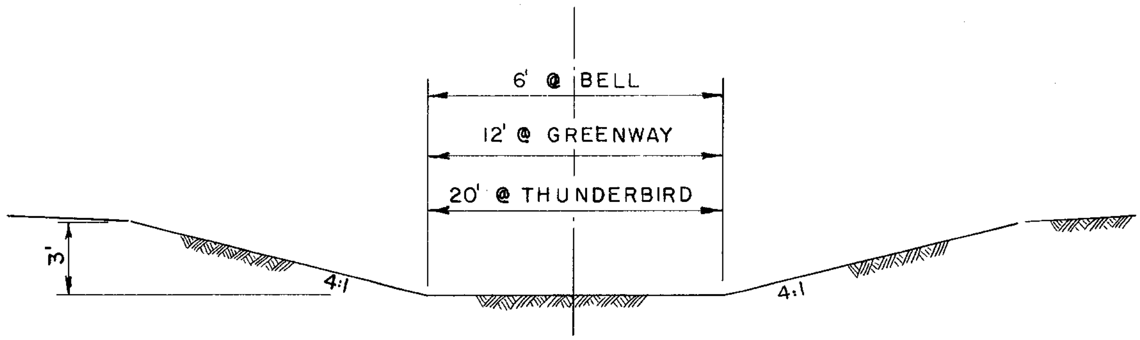
FIGURE 19



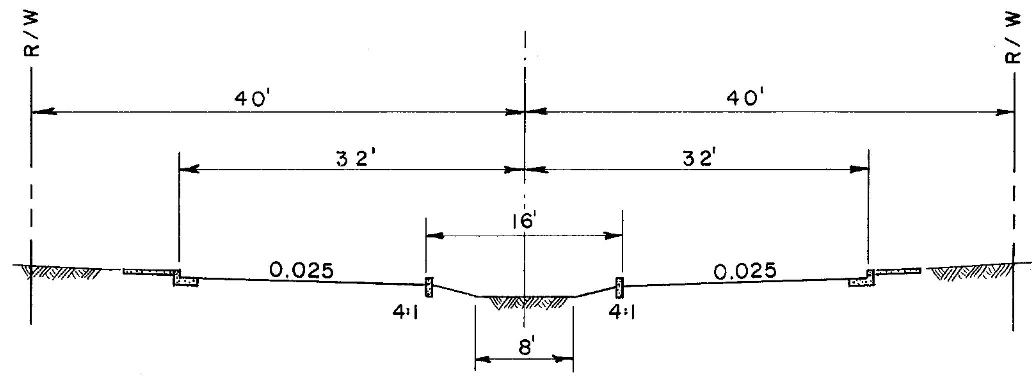
CAPACITY

COLLECTOR STREET WITH MEDIAN CHANNEL FLOWING OVER TOP OF CURB

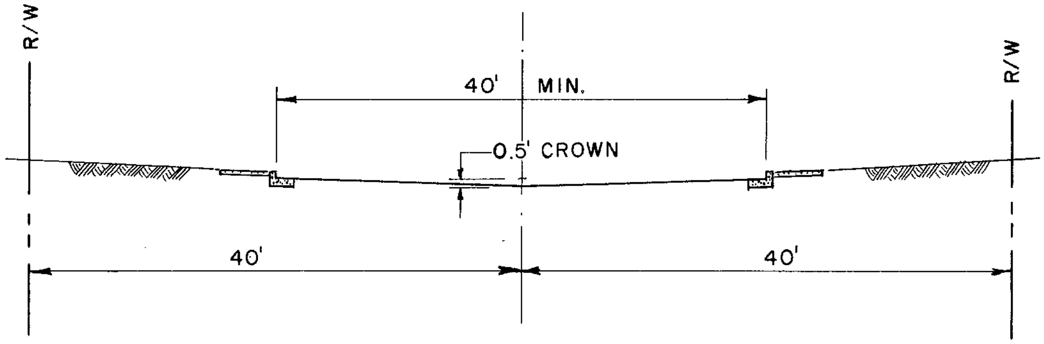
FIGURE 20



DITCH ALTERNATE



STREET WITH MEDIAN DITCH
58TH. ST. OR 59TH. ST. GREENWAY TO THUNDERBIRD



INVERTED CROWN STREET
60TH. ST. GREENWAY TO BELL

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MASTER DRAINAGE STUDY

INDIAN BEND WASH

PROPOSED SECTIONS

DRAINAGE EAST OF 56TH ST.

FIGURE 21

One half mile south of Thunderbird Road at Sweetwater Avenue the drainage enters 59th Street, which has an existing inverted crown pavement. The present capacity of this street was computed. The design storm will have a water surface about 1.5 feet over the top of curb. Proposed building grades, as shown on the subdivision plat and plotted, are higher than the calculated water surface. No modification to this inverted crown section is required.

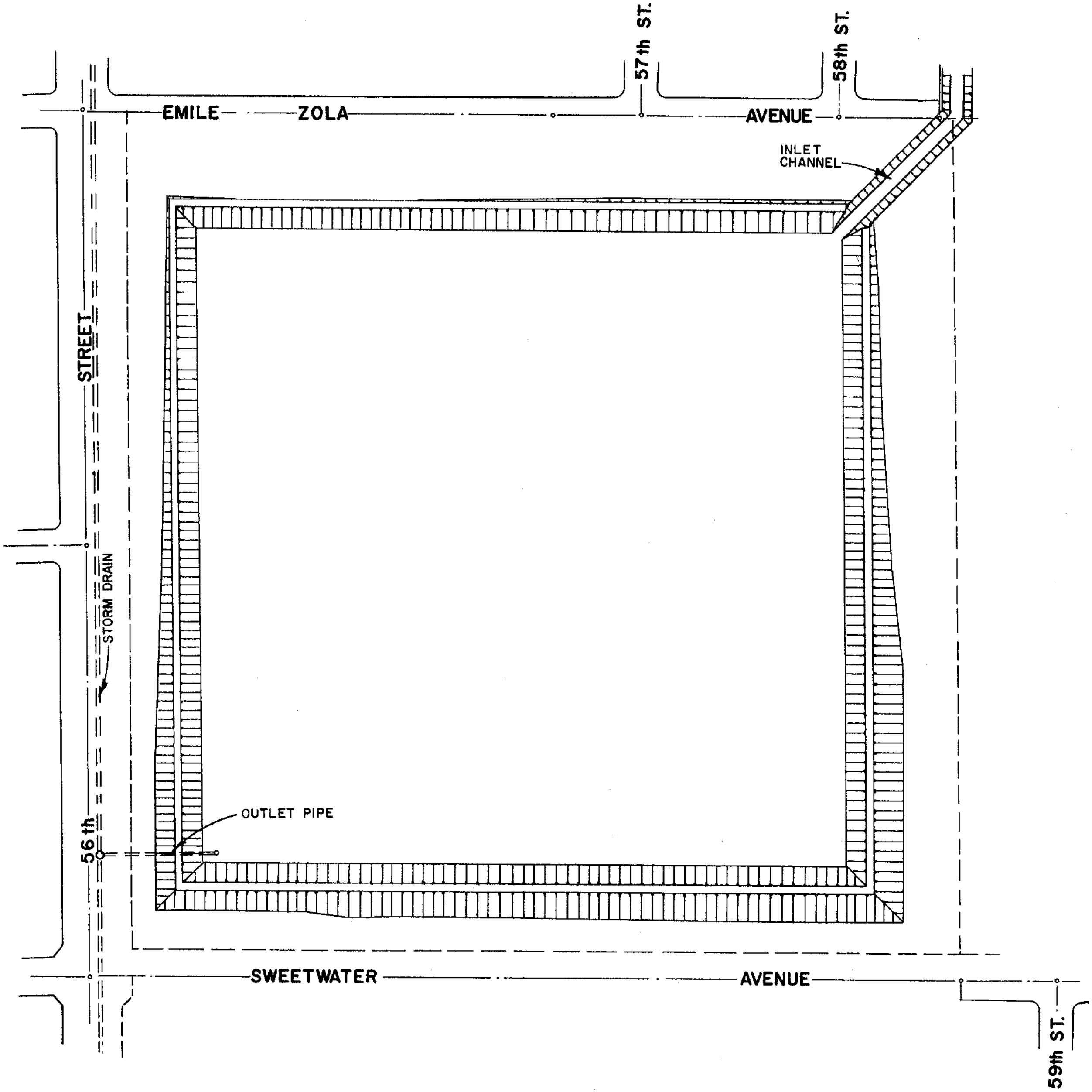
At 59th Street and Cactus Road the inverted crown street dumps the flow into a drainage easement that connects to a shallow swale meandering through Century Country Club golf course to Shea Boulevard. The water crosses Shea Boulevard in a shallow dip and finally meaders southerly along 58th Street to Indian Bend Wash.

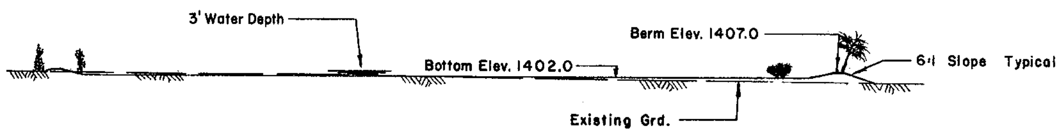
The recommended improvements for the connection to Indian Bend Wash and through Century Country Club are shown on Figs. 31, pg. 62, through 34, pg. 65. A ditch with capacity for 1000 c.f.s. is shown to connect the Indian Bend Wash channel with the intersection of 56th Street and Shea Boulevard. The ditch alignment could be run south on 56th Street a few hundred feet and then directed west in order to avoid spoiling a possibly valuable business corner southwest of the intersection. Water in the 56th Street storm drain and roadway would be picked up by a culvert and ditch extending 2200 feet north of Shea Boulevard along the east side on 56th Street. A culvert would run east from 56th Street along the north side of Shea Boulevard 1100 feet and turn north through an existing drainageway to Century Country Club golf course. The existing ditch through the golf course can be improved by constructing a ten foot bottom with 10 to 1 side slope ditch along its present alignment. The bottom of the improved ditch would be about one foot lower than the flow line of the existing ditch. The channel cuts through several residential building site areas by means of a 30-foot wide drainageway. This could be improved with a paved flume 28 feet wide with 3 foot high side walls. Additional drainageway width could be obtained for a channel as an alternate. Box culverts should be constructed on roadway crossings.

10.3 Detention Basin for 59th Street Drainage

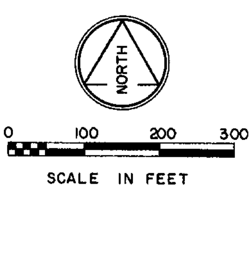
Sereno Park is a presently undeveloped 40 acre site at the northeast corner of 56th Street and Sweetwater Avenue. Drainage courses through undeveloped land along the east side of the park site. A portion of this park could be developed to function as a landscaped, multi use, detention basin. Fig. 22, pg. 50, schematically shows a 24 acre basin within the park site. This will receive the peak flow from the area above the park and release it at a slow rate into the proposed 56th Street storm drain. Picnic areas and ball fields could be designed to also function as basins. Other areas adjacent to the 59th Street drainage could also be used. The size of the basin could be reduced using a higher discharge rate provided storm drains were designed for this rate.

Bottom and berm elevations shown on Fig. 22 were used only for computing storage available. Final design would show a basin bottom with flat slopes, 0.1% plus or minus draining to a shallow collection channel. The basin could be constructed in a 'cut-fill' manner with the bottom only one to two feet below natural ground. Since the basin would be shallow, discharge could be accomplished by gravity into the storm drain.





NORTH-SOUTH SECTION THROUGH BASIN



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MASTER DRAINAGE STUDY

INDIAN BEND WASH
SERENO PARK DETENTION BASIN

FIGURE 22

Calculations in Appendix II - 11 show the benefit derived from use of the detention basin concept. Without the basin a 100-year storm has a calculated peak flow at 59th Street and Cactus Road of 712 c.f.s. With the basin the peak flow at the same point will be 487 c.f.s.

11. Comparative Costs

The first question that comes to mind in comparing alternatives is: "What are the costs?" Since this study was intended to be conceptual in nature, the drawings that were made are not sufficiently detailed to make highly accurate quantity estimates, nor are solutions given for all the design problems such as street and utility crossings. For the purpose of comparing alternatives, and not to establish budget estimates, quantity takeoffs were made for the lower 7,600 feet of the Indian Bend Wash channel, exclusive of the Shea Boulevard crossing.

Quantities of work for this reach (major construction items only) are given in Table 2, pg. 52, for each of the four alternative channel designs. The unit costs are based largely on actual bids for the recently awarded Central Arizona Project canal and dike in Paradise Valley, but were adjusted somewhat to reflect differing conditions and requirements.

The cost of right-of-way, although shown in Table 2, as $5,000 per acre, is a much more uncertain item than the structural items, consequently we have shown costs with and without right-of-way.

Table 2. - COMPARATIVE COSTS - 6,800 L.F. OF CHANNEL
Sta. 0+00 to 30+00 and Sta. 38+00 to 76+00

	GREENBELT WITH GRASS LOW FLOW			GREENBELT WITH CONC. LOW FLOW			DEEP GRASS LINED			CONCRETE LINED		
	Est. Quant.	Unit Cost	Total Cost	Est. Quant.	Unit Cost	Total Cost	Est. Quant.	Unit Cost	Total Cost	Est. Quant.	Unit Cost	Total Cost
Cut - C. Y.	672,000	$1.00	$ 672,000	759,800	$1.00	$759,800	742,700	$1.05	$779,800	414,500	$1.05	$435,200
Concrete Drop Structures - C.Y.	275	160	44,000	750	160	120,000	310	200	62,000	-		-
Concrete Lining 4" & 8" Thick - S. Y.	-		*(75,000)	26,600	9.00	239,400	-		-	155,500	7.00	1,088,500
Concrete Aprons - S. Y.	2,280	10.00	22,800	6,380	10.00	63,800	2,420	10.00	24,200	-		-
Grass Lining - Acres	93	3200	297,600	100	3300	330,000	56	3500	196,000	(1) 5	3600	18,000
Minimum R/W - Acres	95	5000	475,000	105	5000	525,000	61	5000	305,000	37	5000	185,000
TOTAL ESTIMATED COST			$1,511,400			$2,038,000			$1,367,000			$1,726,700
Total Cost excluding R/W			$1,036,400			$1,513,000			$1,062,000			$1,541,700
*Cost of Alternate Concrete Low Flow Channel												
Total Cost Including Alt. Channel			$1,111,400									

(1) Grass sodding above concrete lining

1. Unit Costs - Central Arizona Project and local contractors adjusted to be current spring 1975.
2. Grass Lining costs include sprinkler system costs.
3. Excavation costs higher for Concrete Lined and Deep Grass Lined channels due to steeper side slopes and deep drops.

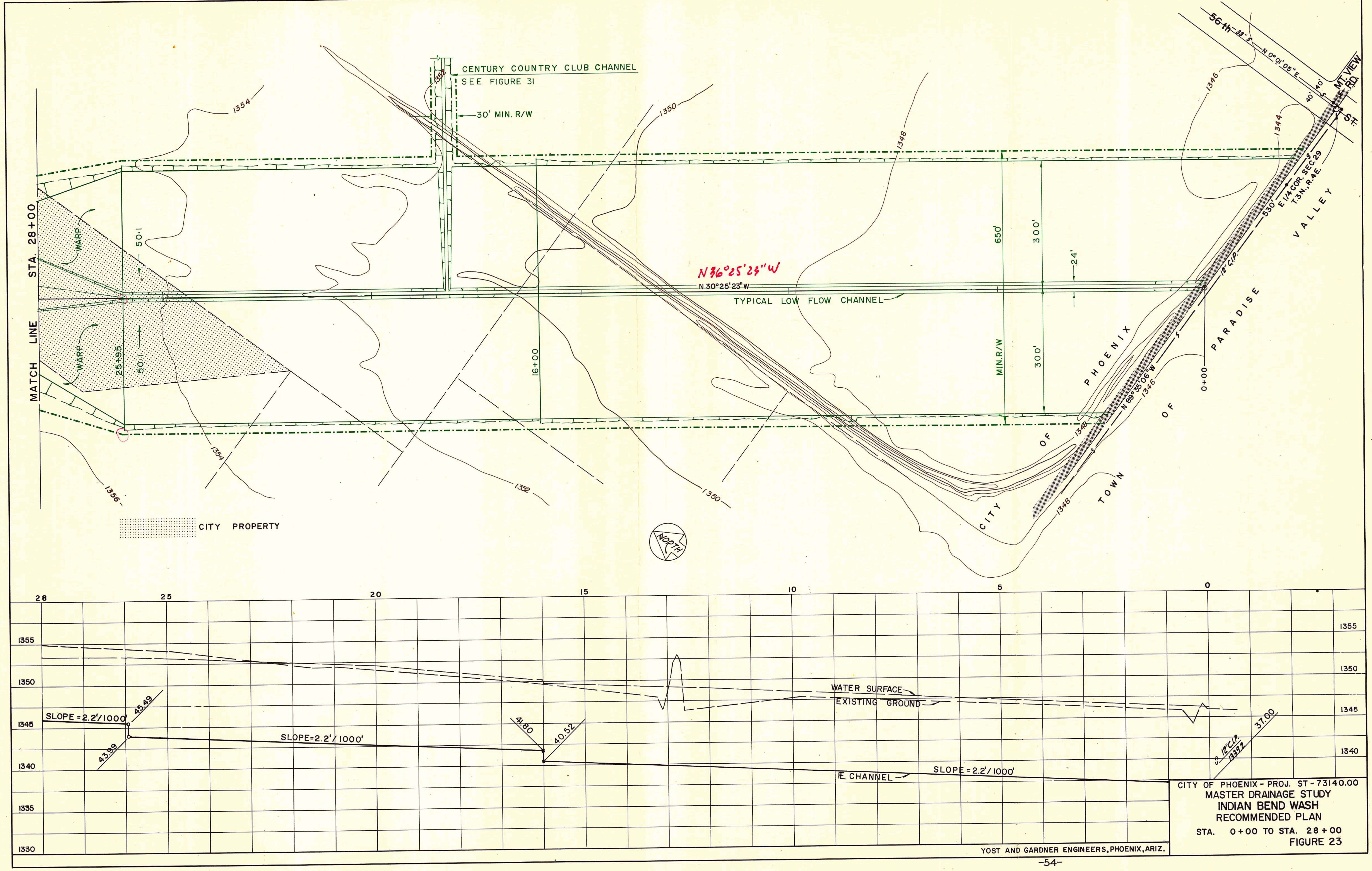
12. Recommendations

It has been mentioned that options remain for the treatment of the Indian Bend Wash channel whereas present development has already limited what can be done with the 56th Street drainage. Our studies lead us to recommend:

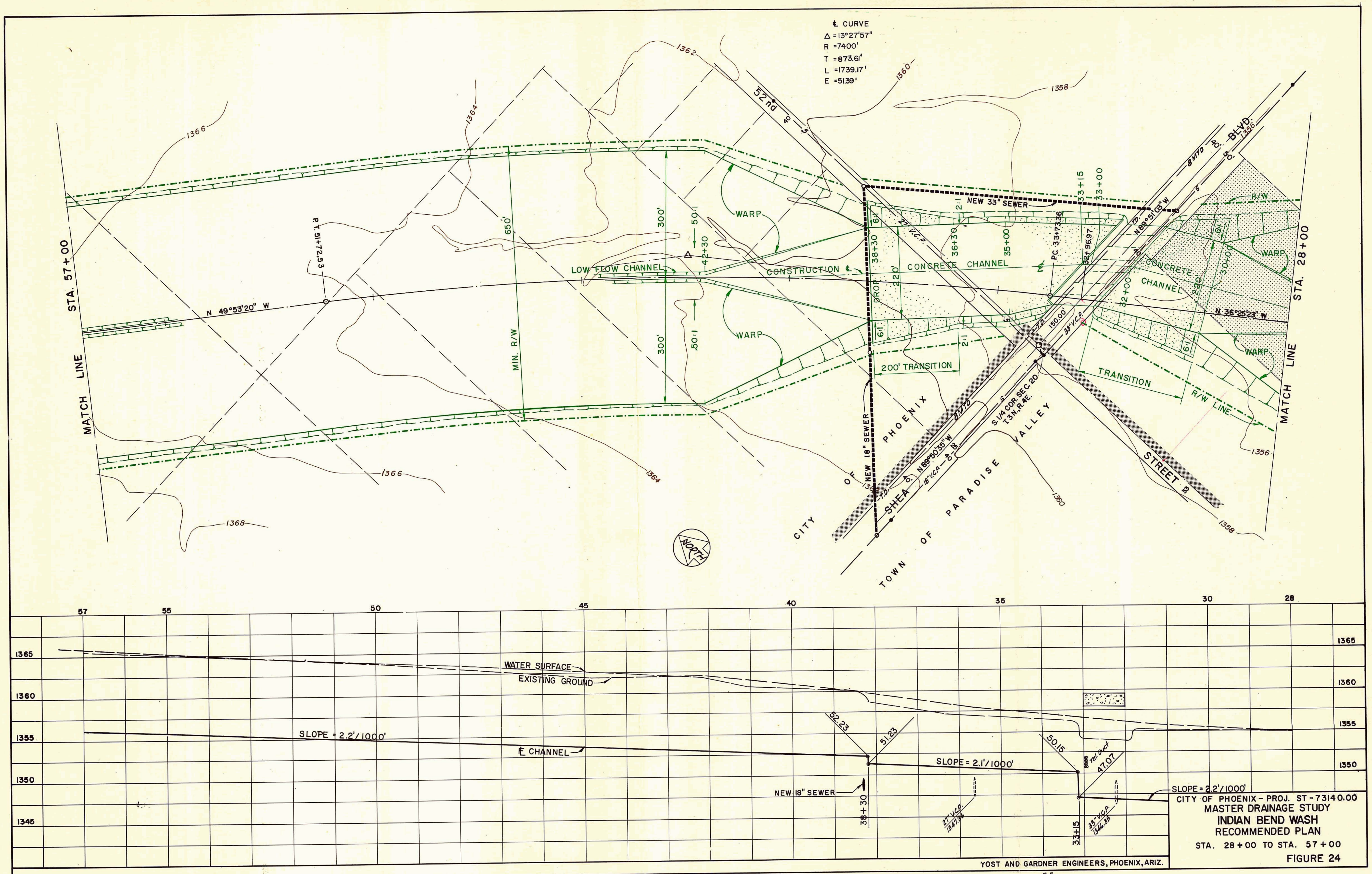
1. That the Indian Bend Wash be improved by construction of a greenbelt with a 50:1 bottom and slope and with either a grass lined or cunette-type low flow channel. A typical section for such a channel is given in Fig. 15, although many variations of this type are possible. A profile which also shows the design hydraulic gradient or 100-year water surface follows in Fig. 16. Figs. 23, pg. 54 through 61, show such a channel in plan throughout its entire length in the City of Phoenix.

2. That the 56th Street drainageway consist of a variety of channels and conduits as shown in Fig. 8 and in more detail in Figures 31 through 34. Again, variations are possible, especially for the open channel sections, and some rerouting may be expedient in order to obtain right-of-way or to conserve arterial business frontage.

3. That streets similar to 56th Street be designed to carry a 100-year storm in the roadway without incurring water damage to the adjacent property. This can generally be accomplished by designing the roadway grade below existing ground. Adjacent building floor grades should be set a minimum of one foot above top of curb.

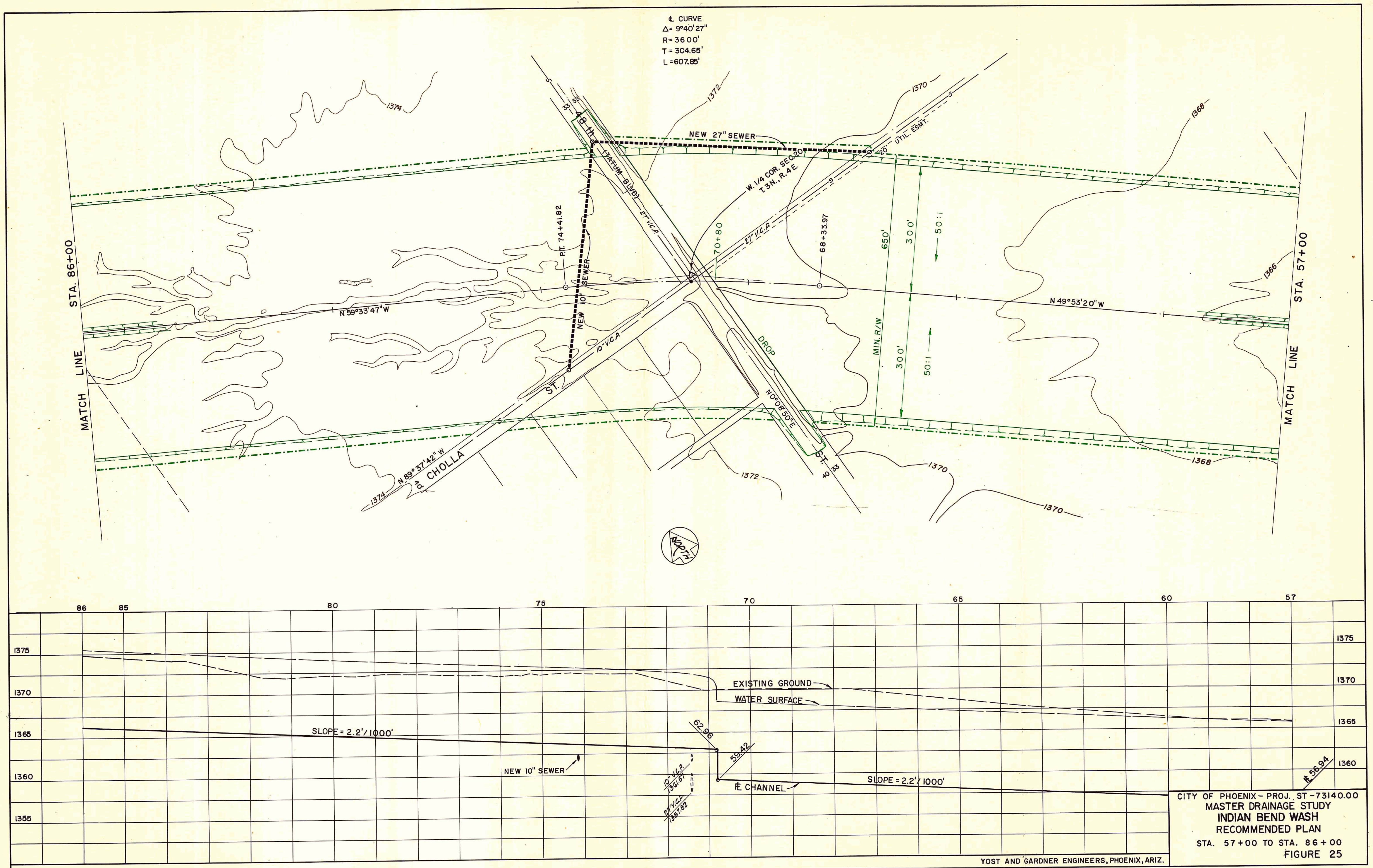


CITY OF PHOENIX - PROJ. ST-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 0+00 TO STA. 28+00
FIGURE 23

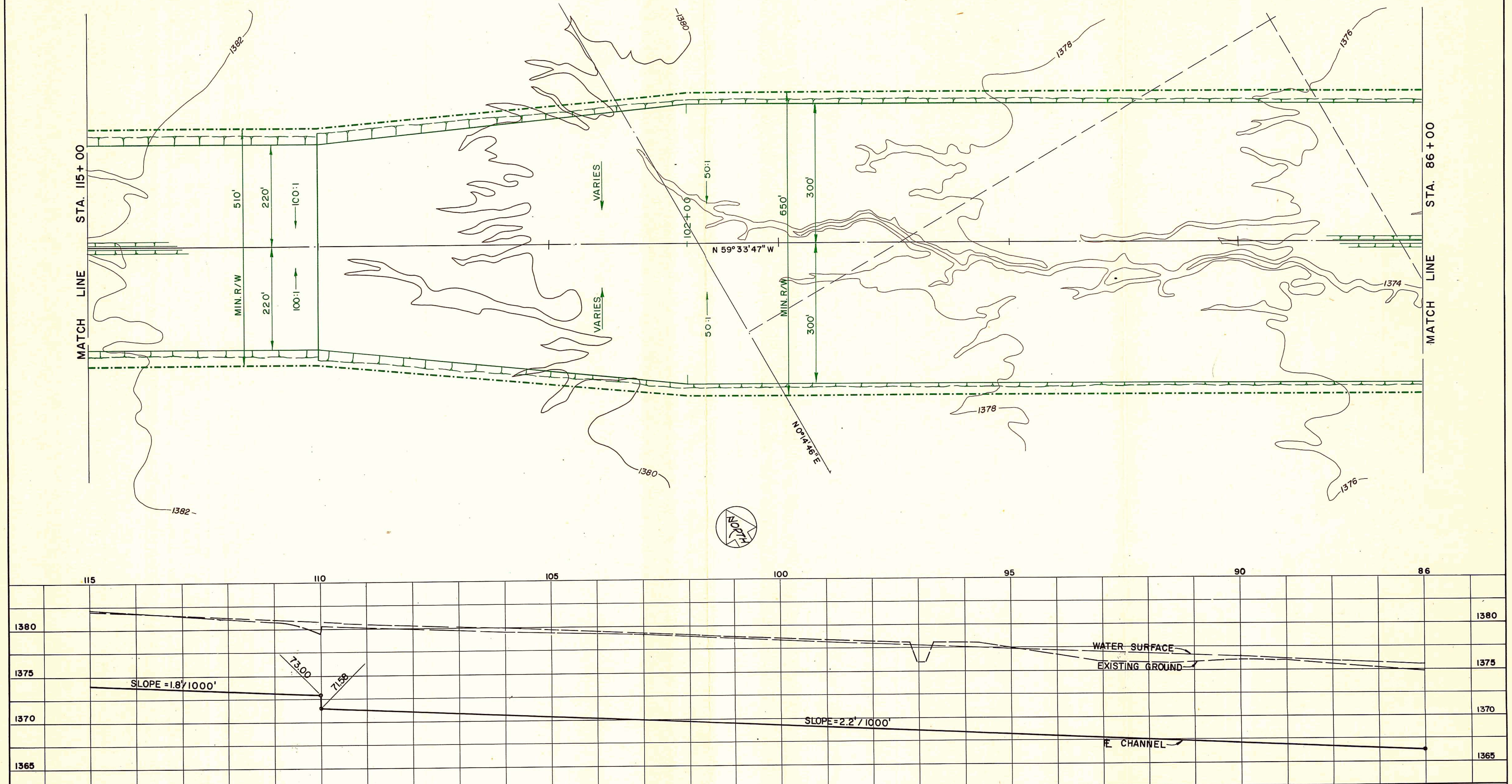


CITY OF PHOENIX - PROJ. ST-7314 0.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 28+00 TO STA. 57+00
FIGURE 24

YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.

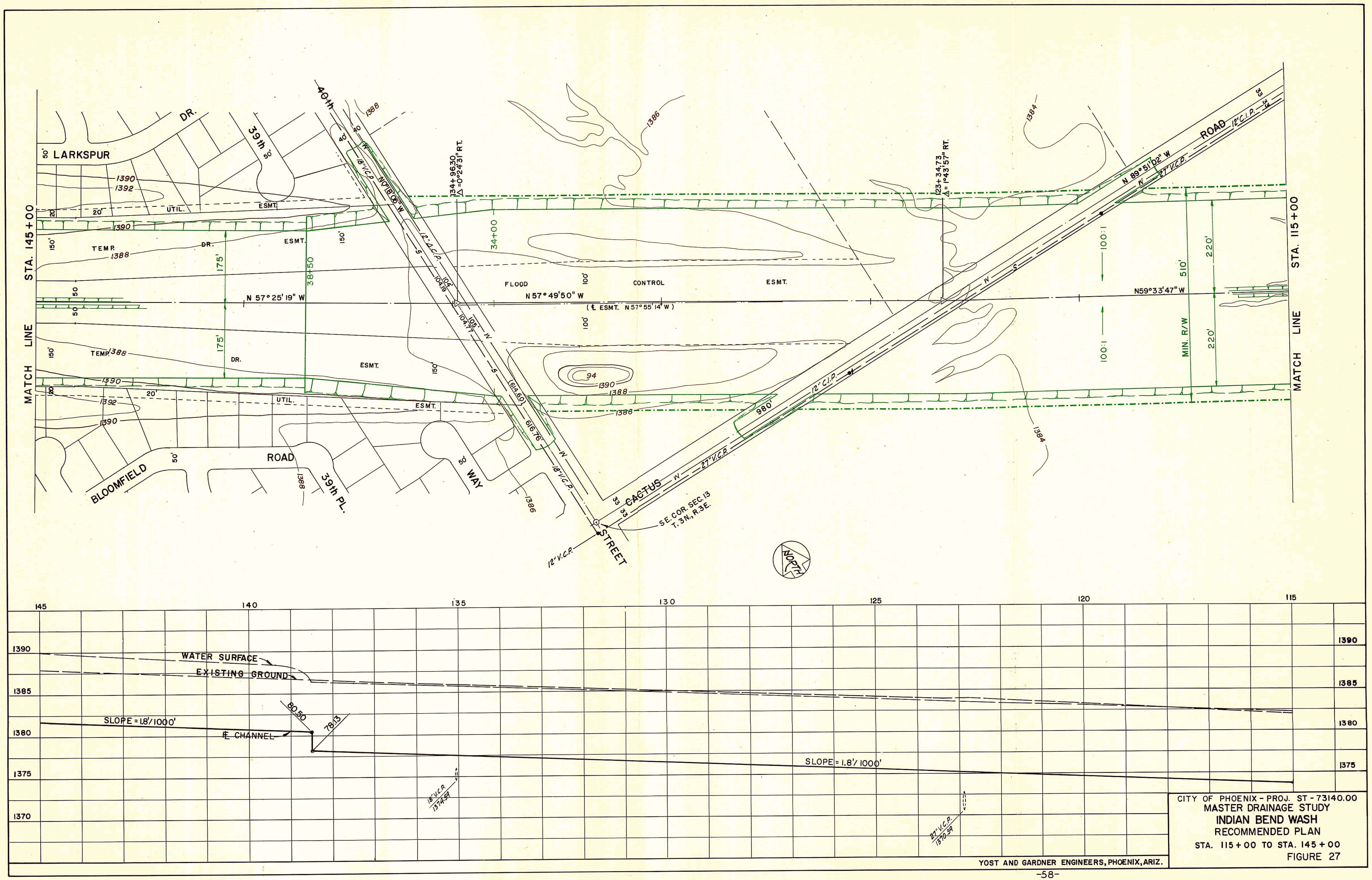


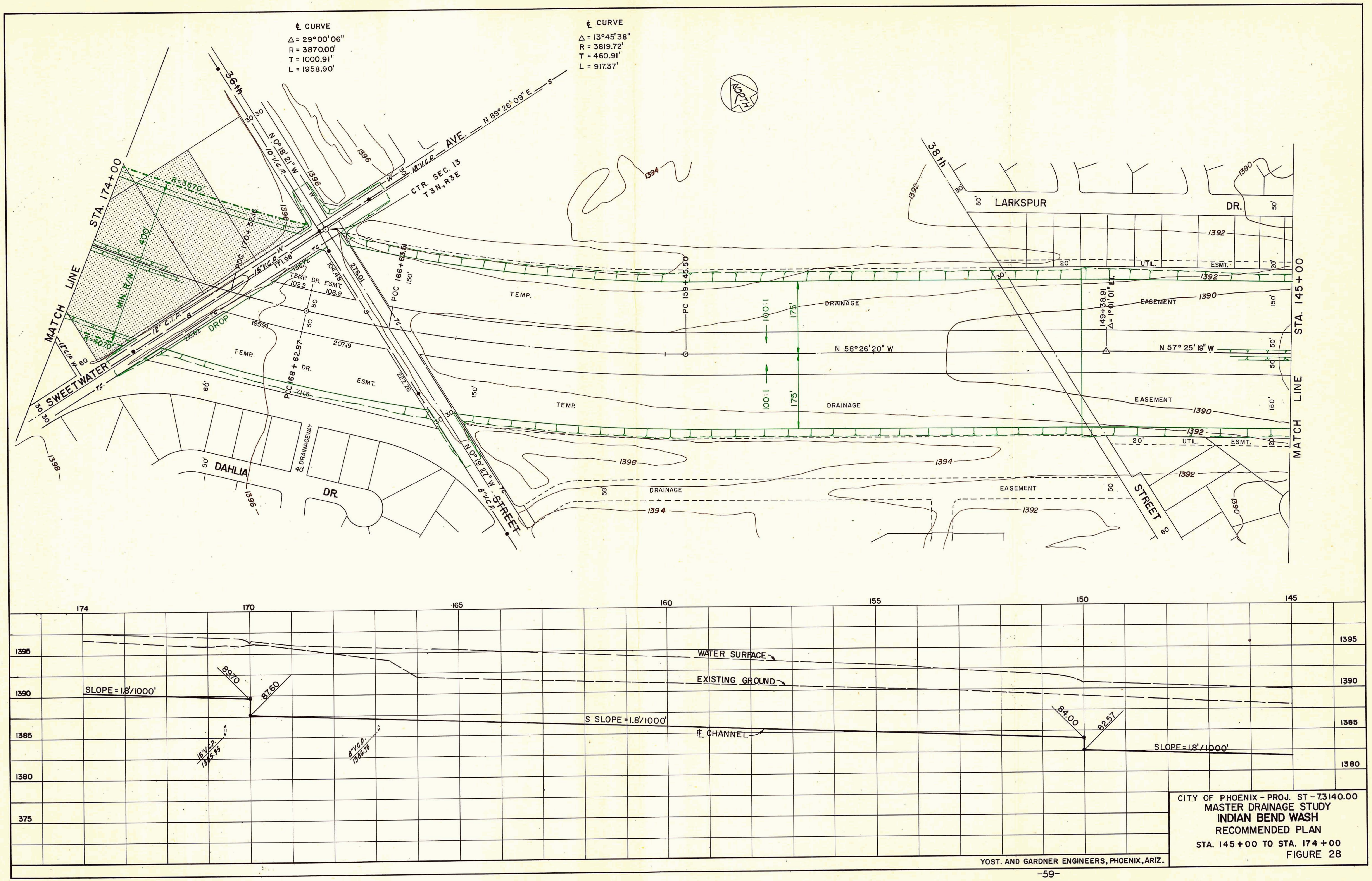
CITY OF PHOENIX – PROJ. ST-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 57+00 TO STA. 86+00
FIGURE 25



CITY OF PHOENIX - PROJ. ST-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 86+00 TO STA. 115+00
FIGURE 26

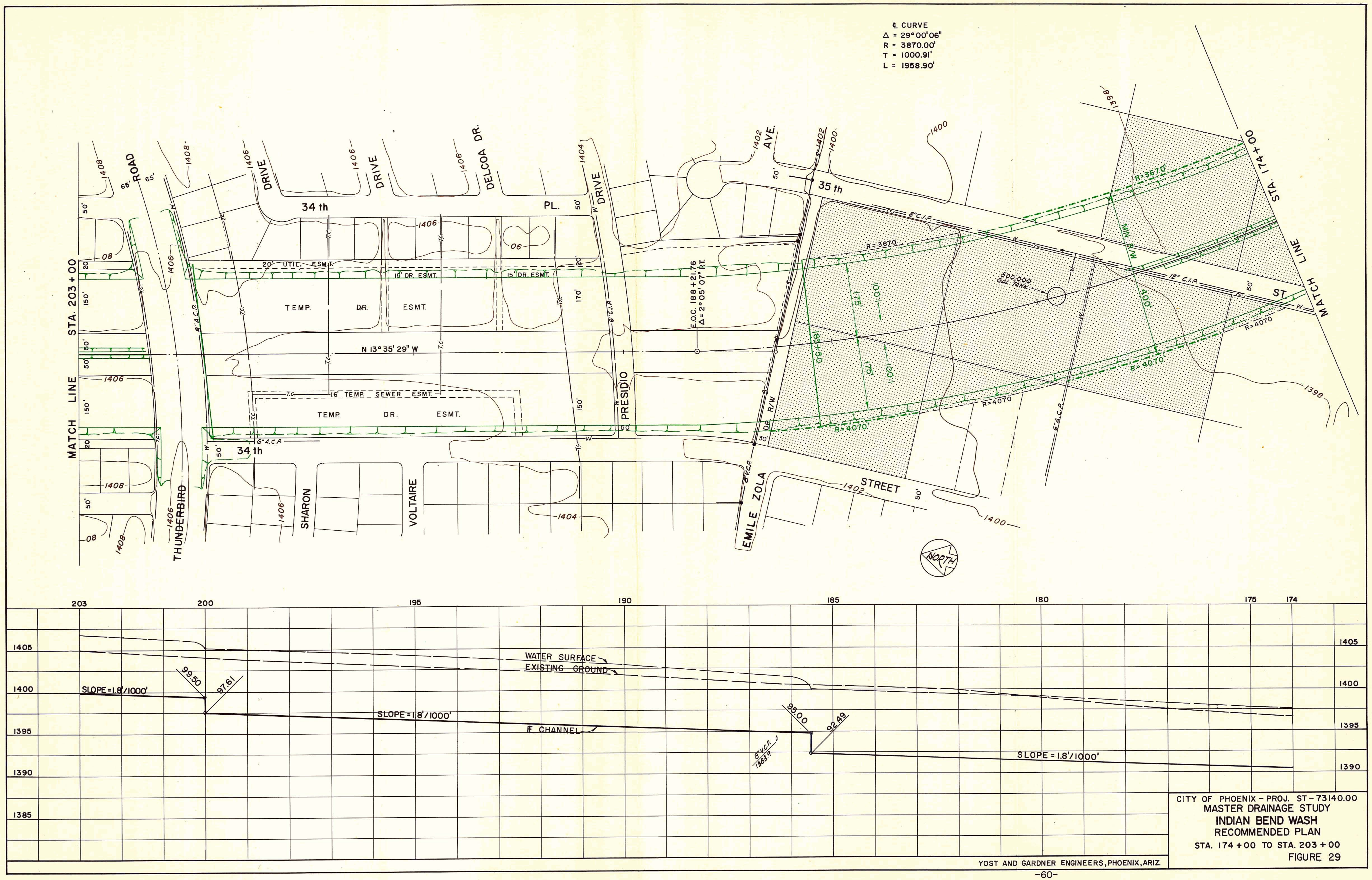
YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.


LARKSPUR DR.
39th
40th
STREET
CACTUS ROAD
BLOOMFIELD ROAD
39th PL.
WAY
MATCH LINE STA. 145+00
MATCH LINE STA. 115+00
FLOOD CONTROL ESMT.
N 57°25'19" W
N 57°49'50" W
(℄ ESMT. N 57°55'14" W)
N59°33'47"W
N 89°51'02" W
134+96.30 Δ=0°24'31" RT.
123+34.73 Δ=1°43'57" RT.
MIN. R/W
510'
220'
175'
100:1
980'
12" C.I.P.
27" V.C.P.
18" V.C.P.
12" A.C.P.
12" V.C.P.
SE. COR. SEC. 13 T. 3N., R. 3E.
NORTH
WATER SURFACE
EXISTING GROUND
SLOPE = 1.8'/1000'
℄ CHANNEL
80.50
78.13
18" V.C.P. 1374.59
27" V.C.P. 1370.59
CITY OF PHOENIX - PROJ. ST - 73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 115+00 TO STA. 145+00
FIGURE 27
YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.

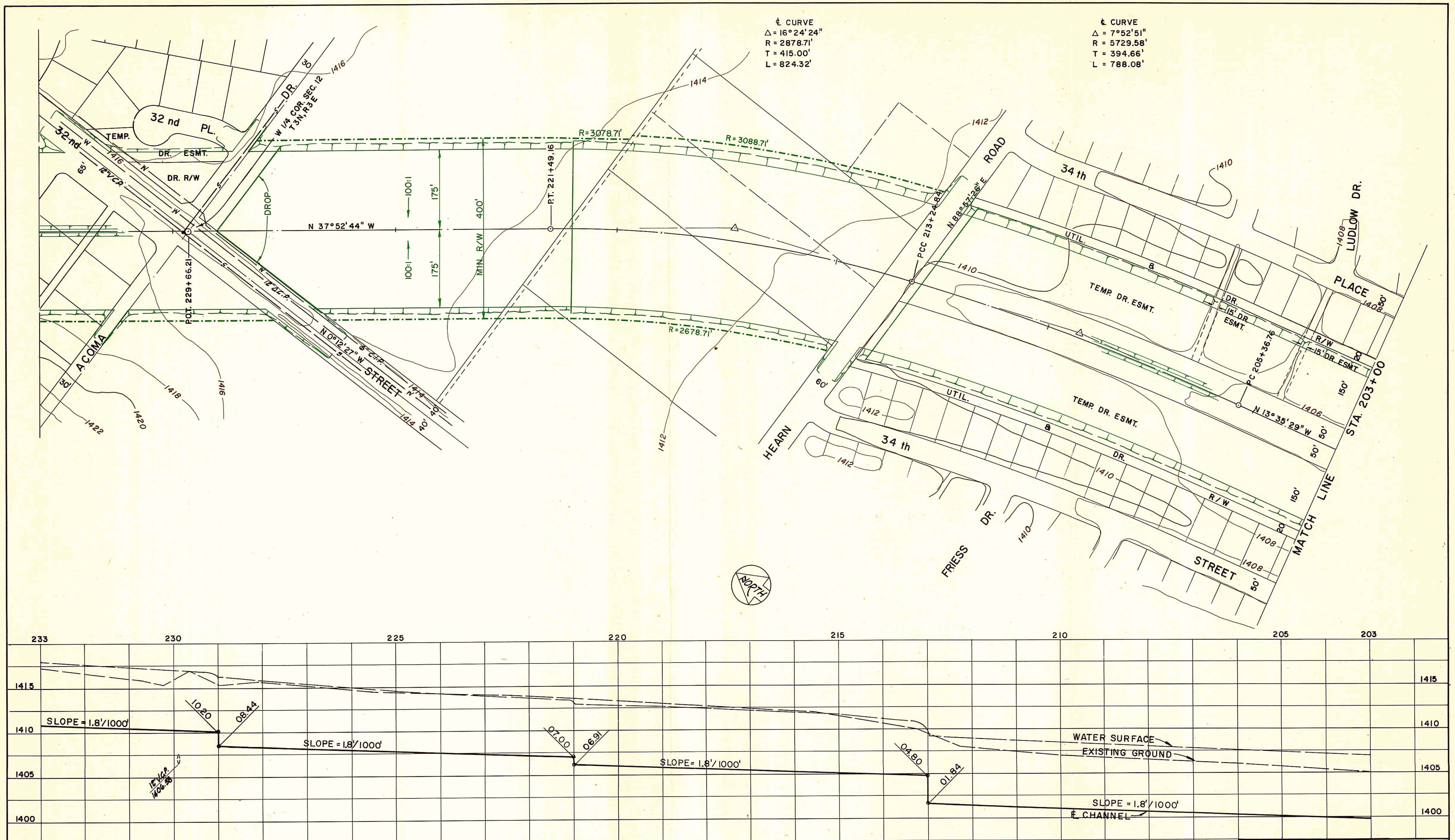


CITY OF PHOENIX - PROJ. ST - 73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 145+00 TO STA. 174+00
FIGURE 28

YOST. AND GARDNER ENGINEERS, PHOENIX, ARIZ.

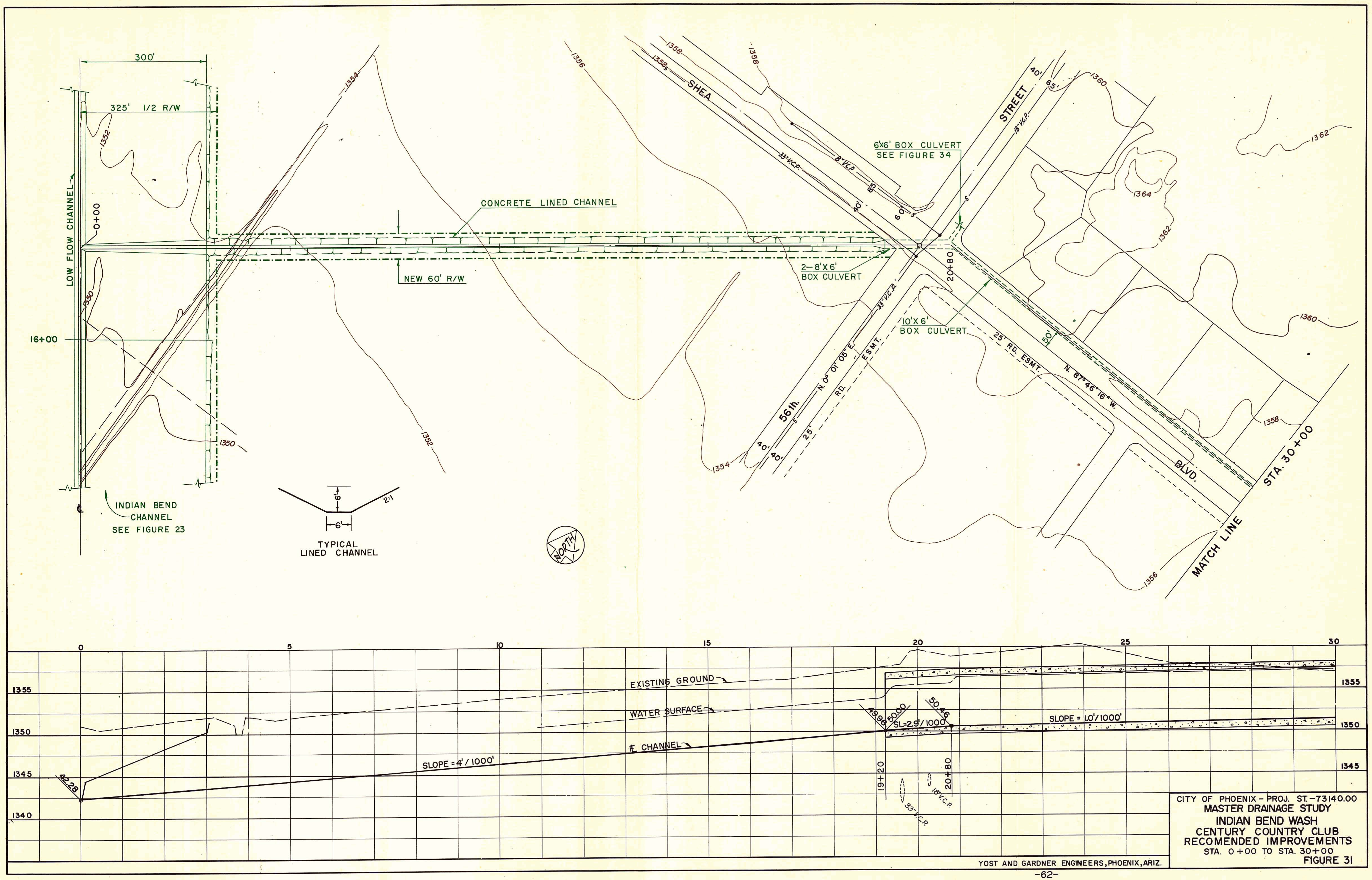


℄ CURVE
Δ = 29°00'06"
R = 3870.00'
T = 1000.91'
L = 1958.90'
STA. 203 + 00
MATCH LINE
STA. 174 + 00
MATCH LINE
ROAD
THUNDERBIRD
34 th DRIVE
34 th PL.
34 th DRIVE
DELCOA DR.
DRIVE
PRESIDIO
AVE.
35 th ST.
EMILE ZOLA
STREET
SHARON
VOLTAIRE
20' UTIL. ESMT.
15' DR. ESMT.
TEMP. DR. ESMT.
16' TEMP. SEWER ESMT.
TEMP. DR. ESMT.
N 13° 35' 29" W
E.O.C. 188 + 21.76
Δ = 2°05'07" RT.
500,000 GAL. TANK
12" C.I.P.
8" C.I.P.
R = 3670
R = 4070
NORTH
WATER SURFACE
EXISTING GROUND
℄ CHANNEL
SLOPE = 1.8'/1000'
SLOPE = 1.8'/1000'
SLOPE = 1.8'/1000'
CITY OF PHOENIX - PROJ. ST - 73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 174 + 00 TO STA. 203 + 00
FIGURE 29
YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.



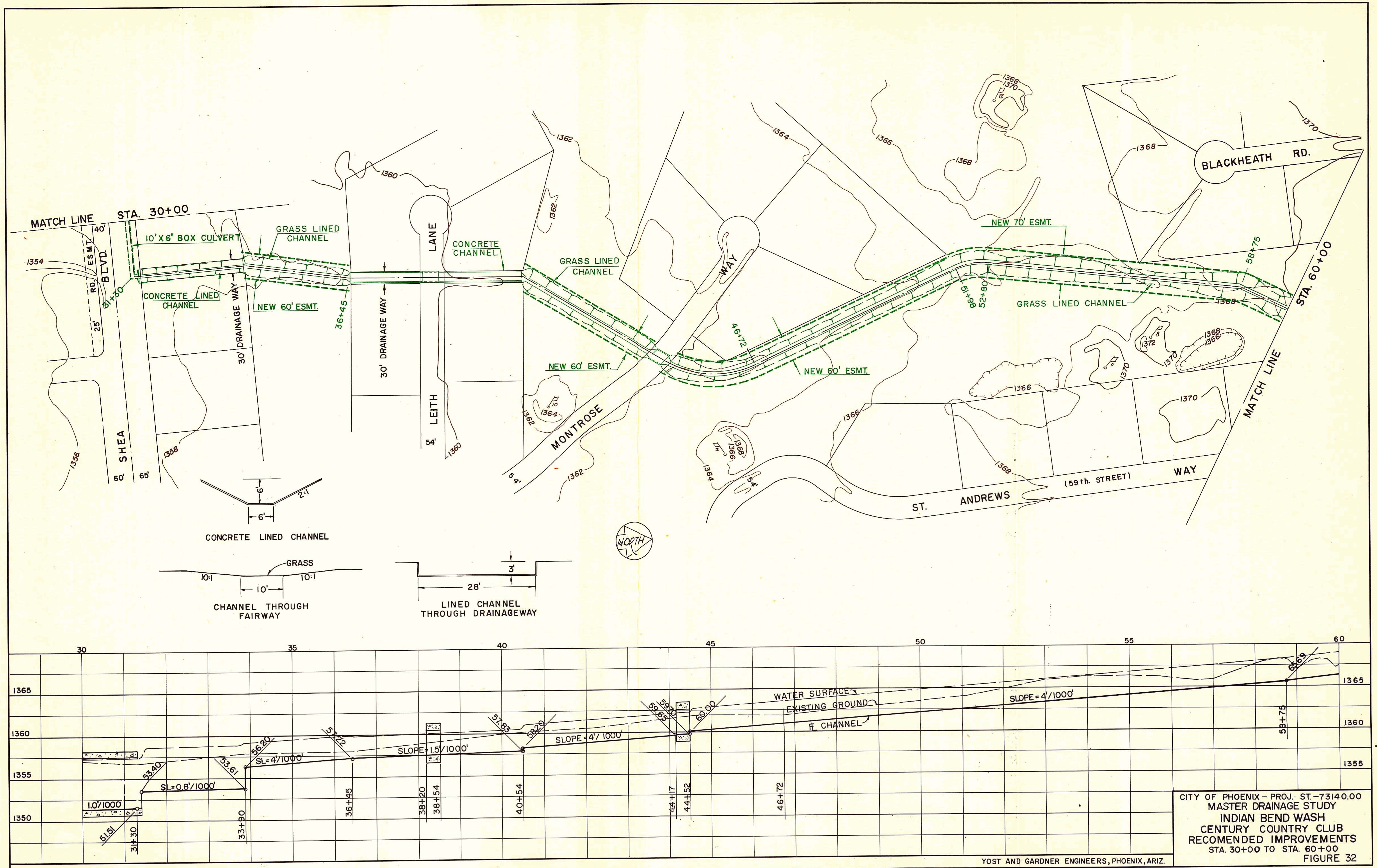
CITY OF PHOENIX - PROJ. ST - 73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
RECOMMENDED PLAN
STA. 203+00 TO STA. 233+00
FIGURE 30

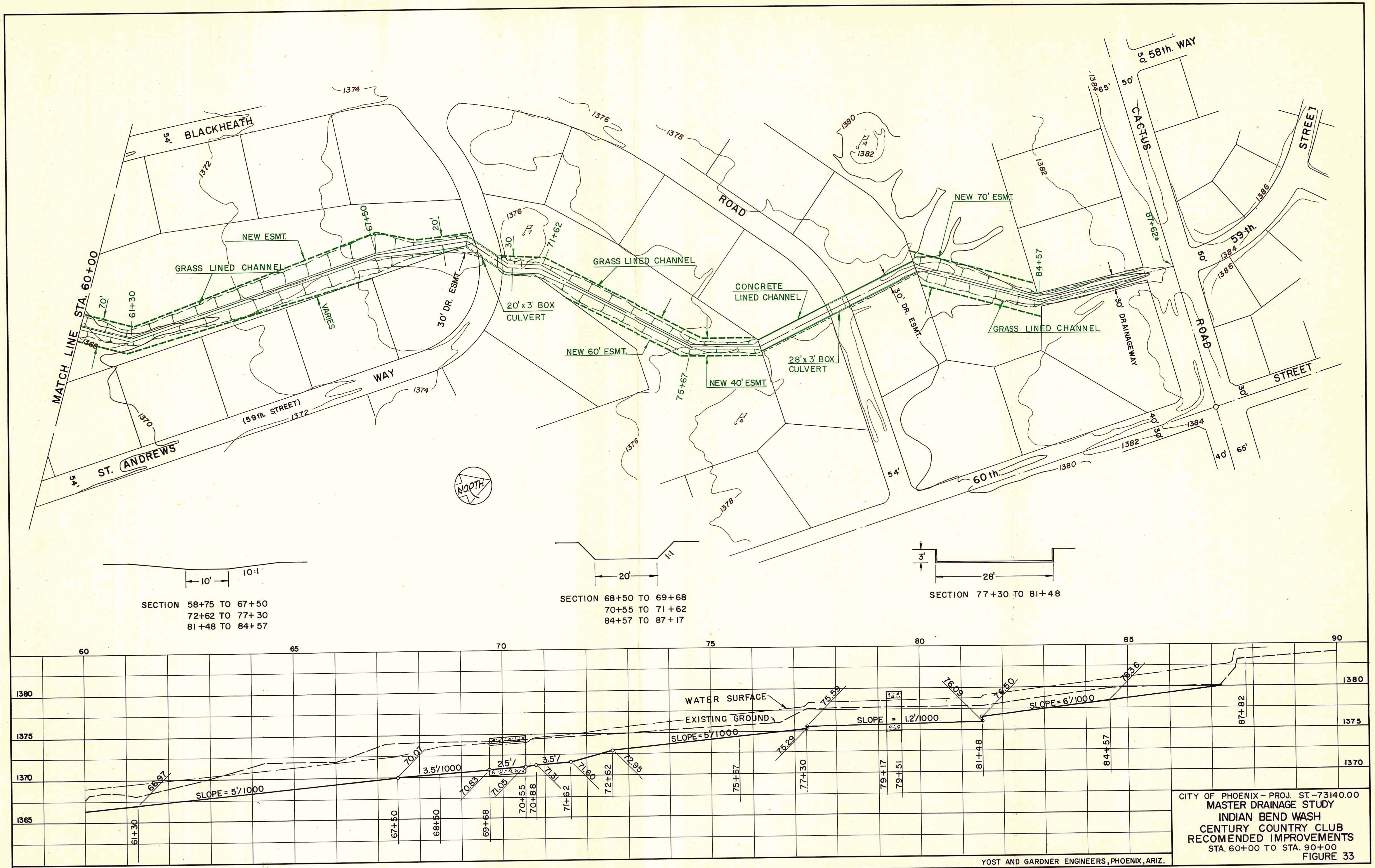
YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.



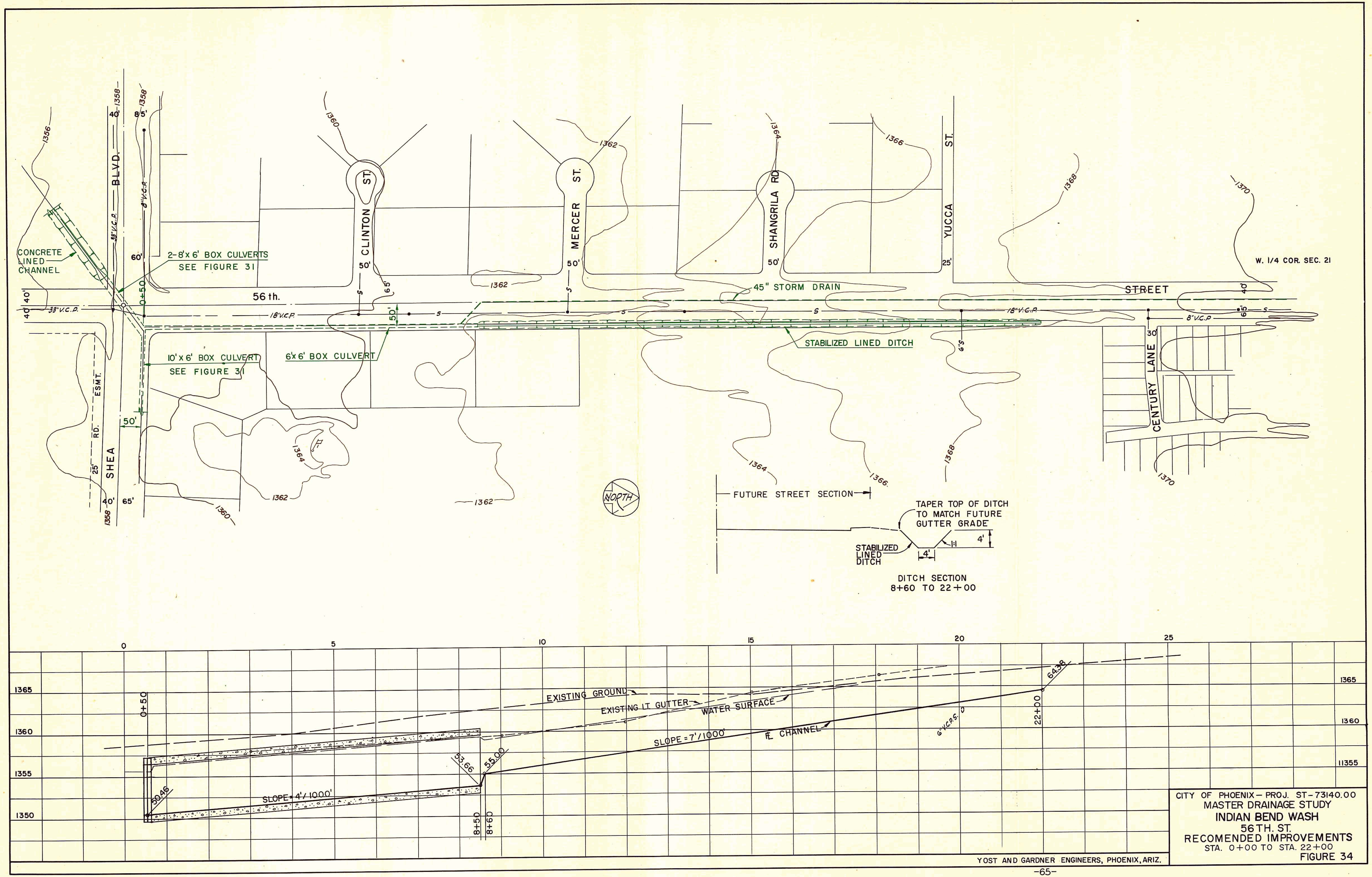
CITY OF PHOENIX - PROJ. ST.-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
CENTURY COUNTRY CLUB
RECOMENDED IMPROVEMENTS
STA. 0+00 TO STA. 30+00
FIGURE 31

YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.


MATCH LINE STA. 30+00
10'X6' BOX CULVERT
GRASS LINED CHANNEL
CONCRETE CHANNEL
CONCRETE LINED CHANNEL
NEW 60' ESMT.
30' DRAINAGE WAY
SHEA BLVD.
RD. ESMT.
LEITH LANE
MONTROSE WAY
NEW 70' ESMT.
GRASS LINED CHANNEL
BLACKHEATH RD.
STA. 60+00
MATCH LINE
ST. ANDREWS WAY (59th. STREET)
NORTH
CONCRETE LINED CHANNEL
CHANNEL THROUGH FAIRWAY
LINED CHANNEL THROUGH DRAINAGEWAY
WATER SURFACE
EXISTING GROUND
℄ CHANNEL
SLOPE = 4'/1000'
SLOPE = 1.5'/1000'
SL = 4'/1000'
SL = 0.8'/1000'
1.0'/1000
CITY OF PHOENIX - PROJ. ST.-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
CENTURY COUNTRY CLUB
RECOMENDED IMPROVEMENTS
STA. 30+00 TO STA. 60+00
FIGURE 32
YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.



CITY OF PHOENIX – PROJ. ST.–73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
CENTURY COUNTRY CLUB
RECOMENDED IMPROVEMENTS
STA. 60+00 TO STA. 90+00
FIGURE 33
YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.
MATCH LINE STA. 60+00
54' BLACKHEATH
ST. ANDREWS WAY
(59th. STREET)
ROAD
CACTUS ROAD
50' 58th. WAY
59th. STREET
60th. STREET
NORTH
NEW ESMT.
GRASS LINED CHANNEL
VARIES
30' DR. ESMT.
20'x3' BOX CULVERT
NEW 60' ESMT.
NEW 40' ESMT.
CONCRETE LINED CHANNEL
28'x3' BOX CULVERT
NEW 70' ESMT.
30' DR. ESMT.
30' DRAINAGEWAY
SECTION 58+75 TO 67+50
72+62 TO 77+30
81+48 TO 84+57
SECTION 68+50 TO 69+68
70+55 TO 71+62
84+57 TO 87+17
SECTION 77+30 TO 81+48
WATER SURFACE
EXISTING GROUND
SLOPE = 5'/1000
3.5'/1000
SLOPE = 1.2'/1000
SLOPE = 6'/1000


CONCRETE LINED CHANNEL
2-8'x 6' BOX CULVERTS
SEE FIGURE 31
10'x 6' BOX CULVERT
SEE FIGURE 31
6'x 6' BOX CULVERT
45" STORM DRAIN
STABILIZED LINED DITCH
56 th.
STREET
SHEA
BLVD.
RD.
ESMT.
CLINTON ST.
MERCER ST.
SHANGRILA RD.
YUCCA ST.
CENTURY LANE
W. 1/4 COR. SEC. 21
33" V.C.P.
18" V.C.P.
8" V.C.P.
0+50
NORTH
FUTURE STREET SECTION
TAPER TOP OF DITCH
TO MATCH FUTURE
GUTTER GRADE
STABILIZED
LINED
DITCH
DITCH SECTION
8+60 TO 22+00
EXISTING GROUND
EXISTING LT. GUTTER
WATER SURFACE
SLOPE = 7'/1000'
℄ CHANNEL
SLOPE = 4'/1000'
53.66
55.00
50.46
64.38
8+50
8+60
22+00
CITY OF PHOENIX – PROJ. ST-73140.00
MASTER DRAINAGE STUDY
INDIAN BEND WASH
56TH. ST.
RECOMENDED IMPROVEMENTS
STA. 0+00 TO STA. 22+00
FIGURE 34
YOST AND GARDNER ENGINEERS, PHOENIX, ARIZ.

There are many factors that affected the decision to make these recommendations. Some of these are quantifiable, such as construction and right-of-way costs. Others more intangible, such as good appearance and the adaptability for secondary uses. Another factor could be maintenance costs, however these are very illusive costs, in that they can vary so greatly dependent on the type of construction chosen. The concrete channel would require little maintenance in comparison to other alternates but would still require considerable clean up of trash and debris. The grassed channels would require the most maintenance in that they must be watered and mowed as well as maintained to repair wash sections etc. Maintenance of a grassed channel, not put to secondary uses, may run as high as $500 per acre per year. Channels with park areas including base ball diamonds, picnic areas etc. would cost approximately $1500 to $1600 per acre per year based on city park costs. Golf courses maintenance, from 1974 City Golf Course costs, would vary from $1550 to $1820 per acre per year. However these costs are offset by green fees and other fees which more than compensate for the maintenance costs. At the present time developers of the lower portions of the wash are proposing the use of golf courses in a wide greenbelt channel.

In order to deal with all these considerations in a systematic way, we have listed criteria in Table 3, pg. 67, along with an arbitrarily selected weighting factor for each, and applied them to each of the four alternative channel types that were considered for Indian Bend Wash. The procedure was simply to rank each section on a scale of one to four in

Table 3. Comparison of alternative channel types - Indian Bend Wash

	Right of Way Cost	Structural Costs	Maintenance Costs	Utility Crossing Costs	Street Crossing Costs	Accessibility for Maintenance	Ease of Lateral Drain Entry	Good Appearance	Multiple Use Possibilities	Measure of Merit*
Weighting Factor	0.10	0.30	0.10	0.05	0.05	0.05	0.05	0.10	0.20	
<u>Alternative</u>										
Greenbelt with Grass Low Flow Channel	3	2	3	1	1	1	4	1	1	1.85
Greenbelt with Concrete Low Flow Channel	4	3	2	3	2	2	3	2	2	2.60
Deep Grass Lined Channel	2	1	4	4	3	4	2	3	3	2.45
Concrete Lined Channel	1	4	1	2	4	3	1	4	4	3.10

*On a scale of 1 to 4 with the lower value the more desirable.

order of desirability in the light of each criterion in turn. The assigned rating is given vertically under the criterion in Table 3. These ratings were then summed horizontally across the table for each channel after each value had been multiplied by its appropriate weighting factor, shown in the table directly above the alternative types of channel. By this method the channel with the lowest aggregate rating, or "measure of merit", is the best selection.

The procedure outlined is admittedly highly subjective. The relative weight assigned each criterion is pre-eminent in determining the outcome. We know there are other factors not listed, such as the desires of residents in the area, which may be more weighty than those that do occur in the table. We have made no attempt to evaluate such sociological or political factors. Neither have we considered how the various channel types would fit into a future freeway pattern in the area.

Our recommendations relate to the engineering aspects of the problem of Indian Bend Wash and its tributaries. They are of a general nature and will need a considerable degree of refinement in the actual design. We have tried to show how we have arrived at them. We hope this report will be a useful contribution to the ultimate solution to the problem of Indian Bend Wash.

References

1. Design Memorandum, Phase 1, Indian Bend Wash, Maricopa County, Arizona, October 1973 - Los Angeles District Office, Corps of Engineers, US Army.

2. Generalized Computer Program 723-X6-L202A, HEC 2 Water Surface Profiles, Users Manual, Feb. 1972, Hydrologic Engineering Center, U. S. Army Corps of Engineers, Davis, California 95616.

3. Aerial Photographs of the Indian Bend Wash and Cave Creek drainages at 10:30 a.m. and 12:00 noon on June 22, 1972 by Landis Aerial Surveys, Phoenix, Arizona.

4. General Soil Map, Maricopa County, Arizona, U.S. Department of Agriculture, Soil Conservation Service, June 1969.

5. Storm Drainage Report for Maricopa Association of Governments, 1970, Yost and Gardner Engineers, Phoenix, Arizona.

6. Paradise Valley Design Study, Phoenix, Arizona, June, 1974, prepared by the City of Phoenix Planning Department.

Indian Bend Wash Drainage Areas

Area No.	Area in Square Miles
1	2.18
2	1.16
3	2.60
4	1.21
5	1.77
6	3.03
7	1.86
8	0.39
9	0.71
10	1.58
11	1.31
12	2.65
13	3.10
14	0.66
15	1.13
16	0.24
17	2.52
18	0.36
19	0.18
20	0.22
21	1.36

Refer to Plate A for area locations.

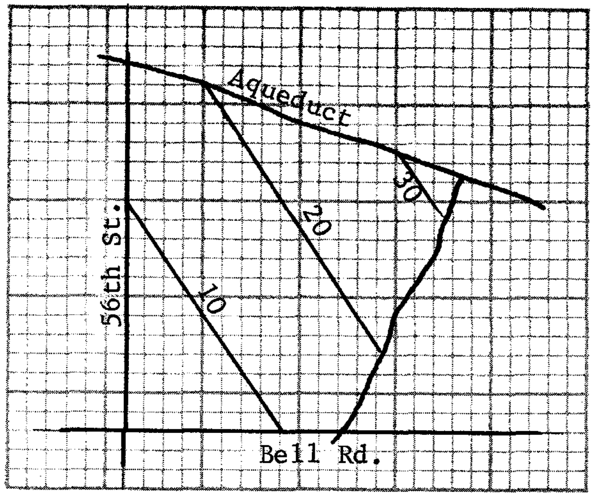
Done by W.H.F.

Date 6/3/74

Drainage Area Sec. 33

URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval



Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	187	80	150	20	37		
M.D. Residential							
H.D. Residential							
Parks & park-like	21	5	1	5	1		19
Farmlands, groves							
Commercial							
Industrial							
Total Acres	208		151		38		19

Mean land slope N-S 9.5'/1000' E-W 4.3'/1000'

Flow conveyance Street (Local)

Flow velocity N-S 3.9 ft./sec. 23 min./mile 234 ft./min.

E-W 2.6 ft./sec. 24 min./mile 156 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	0.8 $I_a - f_c$	Q_p cfs	0.9 $I_a - 0.2$	Q_i cfs	Q_t cfs	
10	42	30	8	5.5	.99	5.4	0.80	4.6	3.7	111	4.6	37	148	
20	154	111	28	4.2	.983	4.13	0.80	3.33	2.66	296	3.5	98	394	← Peak
30	204	147	37	3.3	.98	3.2	0.80	2.4	1.9	280	2.7	100	380	
32	208	151	38	3.2	.98	3.1	0.80	2.3	1.85	279	2.6	99	378	

Yost and Gardner Engineers

56th St.

Aqueduct to Bell Rd.

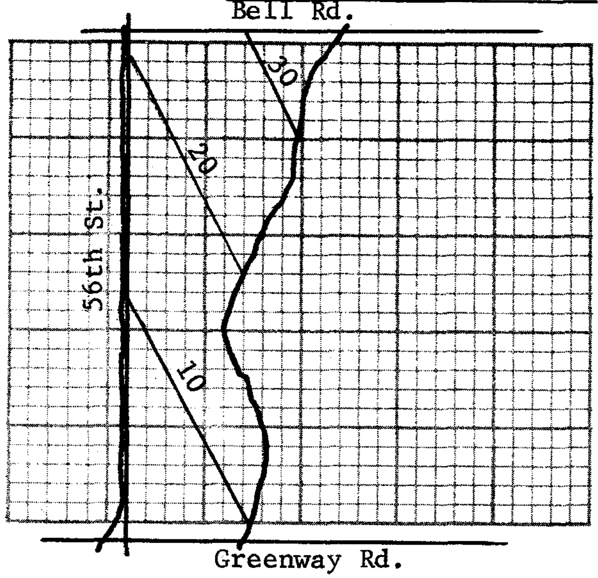
Done by W.H.F.

Date 6/3/74

Drainage Area Sec. 4

URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year Rec. Interval



Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	138	80	110	20	28		
M.D. Residential							
H.D. Residential							
Parks & park-like							
Farmlands, groves	38	10	3.8	5	1.9	85	32.3
Commercial							
Industrial							
Total Acres	176		113.8		29.9		32.3

Mean land slope N-S 8.0'/1000 E-W 3'/1000'

Flow conveyance Street (Arterial)

Flow velocity N-S 4.2 ft./sec. 21 min./mile 252 ft./min.

E-W 2.1 ft./sec. 42 min./mile 126 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	0.8 $I_a - f_c$	Q_p cfs	0.9 $I_a - 0.2$	Q_i cfs	Q_t cfs
10	36	24	6	5.5	.98	5.4	0.80	4.6	3.7	89	4.7	22	111
20	102	56	15	4.2	.97	4.1	0.80	3.3	2.6	145	3.5	52	197
30	164	104	28	3.4	.97	3.3	0.80	2.5	2.0	208	2.8	78	286
38	176	114	30	2.9	.97	2.8	0.80	2.0	1.6	182	2.3	69	261
				ADD PREVIOUS AREA (t_c = 20 + 21 = 41 min.)									
41	330	225	58	2.8	.965	2.7	0.80	1.9	1.52	342	2.25	130	472 ← Peak

Yost and Gardner Engineers

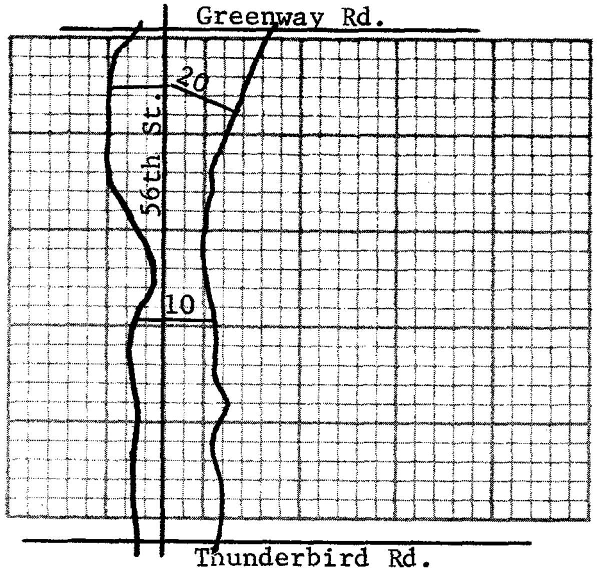
56th St.

Bell Rd. to Greenway Rd.

Done by W.H.F.

Date 6/3/74

Drainage Area Sec. 8 & Sec. 9



URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval

Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	120	80	96	20	24		
M.D. Residential							
H.D. Residential							
Parks & park-like							
Farmlands, groves							
Commercial							
Industrial							
Total Acres	120		96		24		

Mean land slope N-S 6.8'/1000' E-W ______

Flow conveyance Street (Arterial)

Flow velocity N-S 3.9 ft./sec. 23 min./mile 234 ft./min.

E-W - ft./sec. - min./mile - - ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	___yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	0.8 $I_a - f_c$	Q_p cfs	0.9 $I_a - 0.2$	Q_i cfs	Q_t cfs
10	54	43	11	5.5	.98	5.4	0.80	4.6	3.7	159	4.7	52	211
20	96	77	19	4.2	.97	4.1	0.80	3.3	2.6	200	3.5	66	266
23	120	96	24	3.9	.97	3.8	0.80	3.0	2.4	230	3.2	77	307
				ADD PEAK FROM PREVIOUS AREAS (t_c = 41 + 23 = 64 min.)									
64	450	321	82	1.9	.94	1.8	0.80	1.0	0.80	257	1.45	119	376
								USE PEAK FROM GREENWAY RD.					472

Yost and Gardner Engineers

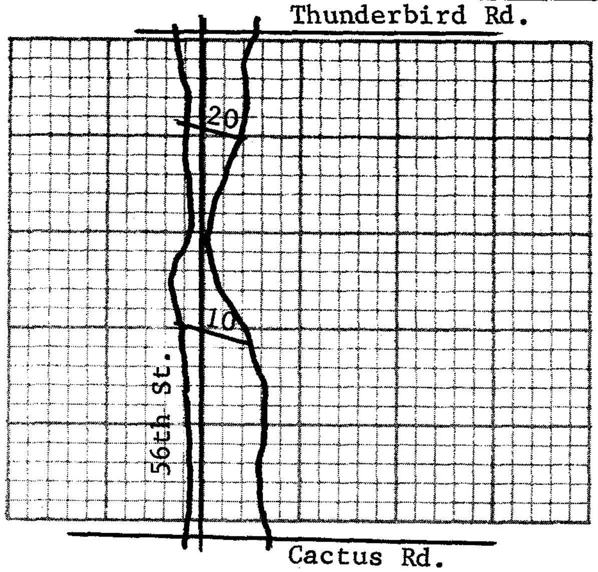
56th St.

Greenway Rd. to Thunderbird Rd.

Done by W.H.F.

Date 6/3/74

Drainage Area Sec. 17 & Sec. 16



URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year Rec. Interval

Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	57.5	80	46	20	11.5		
M.D. Residential							
H.D. Residential							
Parks & park-like							
Farmlands, groves							
Commercial							
Industrial							
Total Acres							

Mean land slope N-S 5.7'/1000' E-W - - -

Flow conveyance Street (Arterial)

Flow velocity N-S 3.5 ft./sec. 25 min./mile 210 ft./min.

E-W - ft./sec. - min./mile - ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	$0.8\ I_a - f_c$	Q_p cfs	$0.9\ I_a - 0.2$	Q_i cfs	Q_t cfs
10	32	26	6	5.5	.98	5.4	0.80	4.6	3.7	96	4.7	28	124
20	43	34	8	4.2	.97	4.1	0.80	3.3	2.6	90	3.5	28	118
25	57.5	46	11.5	3.8	.97	3.7	0.80	2.9	2.3	107	3.1	36	143
				ADD PEAK TO PREVIOUS AREAS (t_c = 64 + 25 = 89 min.)									
89	507.5	367	93.5	1.6	.92	1.47	0.80	0.67	0.54	198	1.14	107	205
								USE PEAK FROM GREENWAY RD.					472

Yost and Gardner Engineers

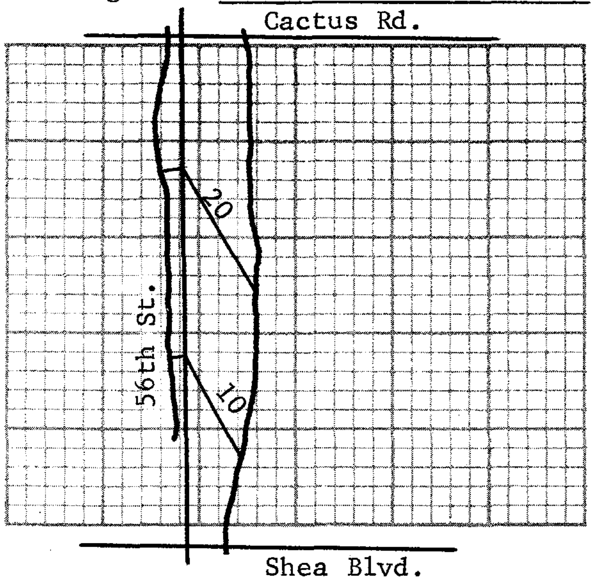
56th St.

Thunderbird Rd. to Cactus Rd.

Done by W.H.F.

Date 6/7/74

Drainage Area Sec. 21



URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval

Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential							
M.D. Residential							
H.D. Residential							
Parks & park-like	94	50	47	10	9		38
Farmlands, groves							
Commercial							
Industrial							
Total Acres			47		9		38

Mean land slope N-S 4.8'/1000' E-W - - -

Flow conveyance Street (Arterial)

Flow velocity N-S 3.2 ft./sec. 28 min./mile 192 ft./min.

E-W - ft./sec. - min./mile - ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	0.8 $I_a - f_c$	Q_p cfs	0.9 $I_a - 0.2$	Q_i cfs	Q_t cfs
10	20	10	2	5.5	.99	5.4	0.80	4.6	3.7	37	4.7	9	46
20	57	28.5	6	4.2	.97	4.1	0.80	3.3	2.6	74	3.5	21	95
30	94	47	9	3.4	.97	3.3	0.80	2.5	2.0	94	2.8	25	119
ADD PEAK TO PREVIOUS AREAS (t_c = 89 + 28 = 117 min.)													
117	602	414	103	1.26	.90	1.14	0.80	0.34	.27	113	85	88	201
USE PEAK FROM GREENWAY RD.													472

Yost and Gardner Engineers

56th St.

Cactus Rd. to Shea Blvd.

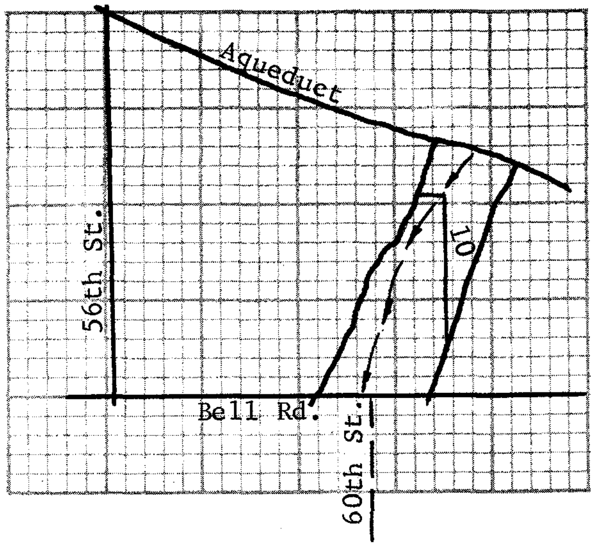
Done by W.H.F.

Date 6/3/74

Drainage Area Sec. 33

URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval



Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	57	80	45.6	20	11.4		
M.D. Residential							
H.D. Residential							
Parks & park-like							
Farmlands, groves							
Commercial							
Industrial							
Total Acres							

Mean land slope N-S 11'/1000' E-W 2'/1000'

Flow conveyance Streets (Local)

Flow velocity N-S 3.7 ft./sec. 24 min./mile 222 ft./min.

E-W 1.8 ft./sec. 49 min./mile 108 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	0.8 $I_a - f_c$	Q_p cfs	0.9 $I_a - 0.2$	Q_i cfs	Q_t cfs	
10	37	30	7	5.5	.99	5.4	0.80	4.6	3.7	118	4.7	33	151	
20	57	45.6	11.4	4.7	.99	4.6	0.80	3.8	3.0	137	4.0	45	182	← Peak

Yost and Gardner Engineers

60th St.

Aqueduct to Bell Rd.

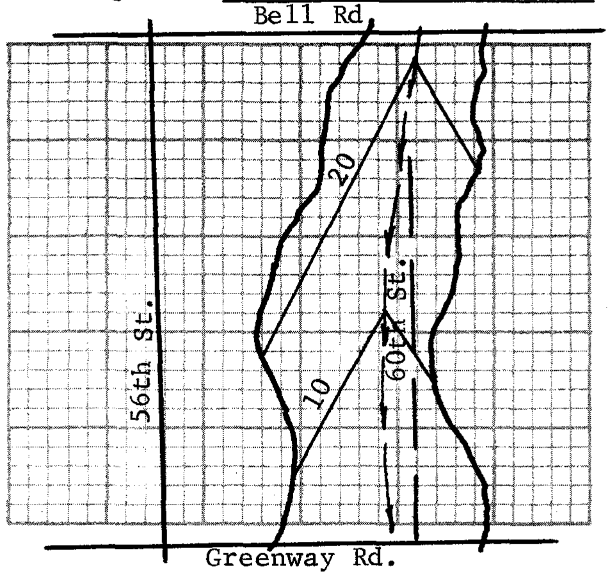
Done by W.H.F.

Date 6/4/74

Drainage Area Sec. 4

URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval



Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	161.6	80	130	20	32		
M.D. Residential							
H.D. Residential							
Parks & park-like							
Farmlands, groves	45.4	10	4.5	5	2.3		38.6
Commercial							
Industrial							
Total Acres	207.0		134.5		34.3		38.6

Mean land slope N-S 8.3'/1000' E-W 2.0'/1000'

Flow conveyance Assume Street (Local)

Flow velocity N-S 4.2 ft./sec. 21 min./mile 250 ft./min.

E-W 2.2 ft./sec. 40 min./mile 132 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	0.8 $I_a - f_c$	Q_p cfs	0.9 $I_a - 0.2$	Q_i cfs	Q_t cfs	
10	68	44	11	5.5	.99	5.4	0.80	4.6	3.7	163	4.7	52	215	
20	150	88	21	4.2	.97	4.1	0.80	3.3	2.6	230	3.5	74	304	
26	207	135	34	3.6	.97	3.5	0.80	2.7	2.2	297	3.0	102	399	← Peak
					ADD PREVIOUS AREA (t_c = 20 + 21 = 41 min.)									
41	264	181	45	2.8	.96	2.7	0.80	1.9	1.52	275	2.25	101	376	

Yost and Gardner Engineers

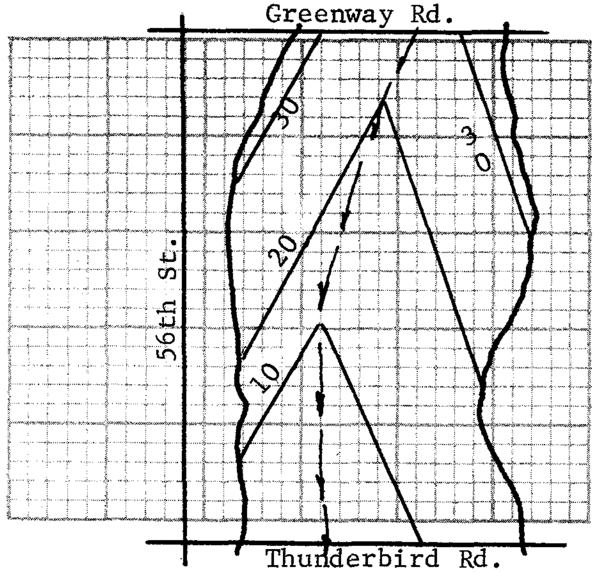
60th St.

Bell Rd. to Greenway Rd.

Done by W.H.F.

Date 6/4/74

Drainage Area Sec. 9



URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval

Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	303	80	242	20	61		
M.D. Residential							
H.D. Residential							
Parks & park-like	34	5	2	5	2		30
Farmlands, groves							
Commercial							
Industrial							
Total Acres	337		244		63		30

Mean land slope N-S 7.7'/1000' E-W 2'/1000'

Flow conveyance Assume Street (Local)

Flow velocity N-S 4.0 ft./sec. 22.0 min./mile 240 ft./min.

E-W 2.0 ft./sec. 44.0 min./mile 120 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	$0.8\ I_a - f_c$	Q_p cfs	$0.9\ I_a - 0.2$	Q_i cfs	Q_t cfs
10	53	38	10	5.5	.99	5.4	0.80	4.6	3.7	141	4.7	47	188
20	183	132	34	4.2	.97	4.1	0.80	3.3	2.6	344	3.5	119	463
30	301	218	56	3.4	.97	3.3	0.80	2.5	2.0	435	2.8	157	592
33	337	244	63	3.2	.97	3.1	0.80	2.3	1.8	440	2.6	164	604 ← Peak
				ADD PREVIOUS AREAS (t_c = 41 + 24 = 65 min.)									
65	601	425	108	2.0	.93	1.86	0.80	1.06	0.85	362	1.49	162	524

Yost and Gardner Engineers

58th - 59th St.

Greenway Rd. to Thunderbird Rd.

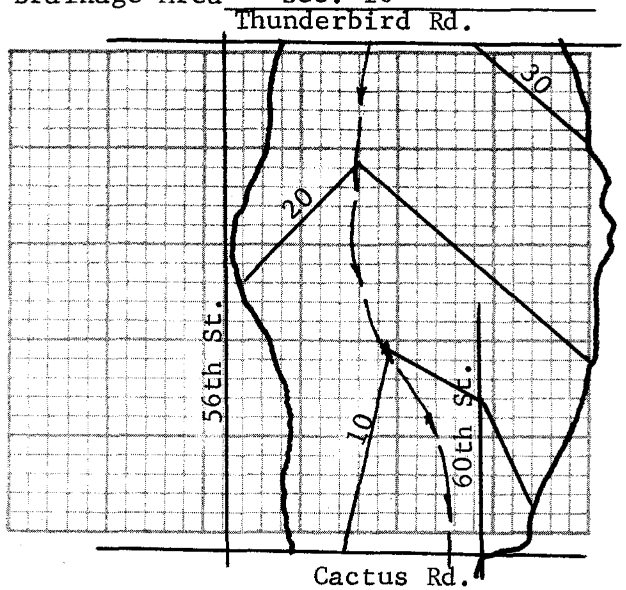
Done by W.H.F.

Date 6/4/74

Drainage Area Sec. 16

URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval



Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	328	80	262	20	66		
M.D. Residential							
H.D. Residential							
Parks & park-like	68	5	3.4	12	8.2		56.4
Farmlands, groves							
Commercial							
Industrial							
Total Acres	396		265.4		74.2		56.4

Mean land slope N-S 5.7 E-W 1.5

Flow conveyance Assume Street (Local)

Flow velocity N-S 3.6 ft./sec. 24.5 min./mile 216 ft./min.

E-W 1.7 ft./sec. 52 min./mile 102 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	0.8 $I_a - f_c$	Q_p cfs	0.9 $I_a - 0.2$	Q_i cfs	Q_t cfs	
10	59	47	12	5.5	.99	5.4	0.80	4.6	3.7	184	4.7	56	240	
20	213	137	37	4.2	.97	4.1	0.80	3.3	2.6	356	3.7	137	493	
30	385	256	72	3.4	.97	3.3	0.80	2.5	2.0	510	2.8	202	712	← Peak
33	396	265	74	3.2	.97	3.1	0.80	2.3	1.8	477	2.6	192	669	
				ADD	PREVIOUS AREAS (t_c = 65 +	26 = 91 min.)								
91	997	690	137	1.55	.92	1.43	0.80	0.63	0.505	348	1.11	1.52	500	

Yost and Gardner Engineers

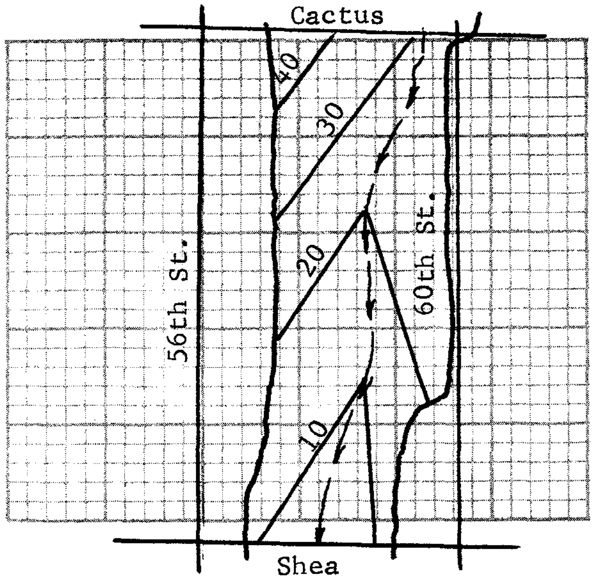
58th - 59th St.

Thunderbird Rd. to Cactus Rd.

Done by W.H.F.

Date 6/5/74

Drainage Area Sec. 21



URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval

Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential							
M.D. Residential							
H.D. Residential							
Parks & park-like	210	50	105	10	21		84
Farmlands, groves							
Commercial							
Industrial							
Total Acres	210		105		21		84

Mean land slope N-S 4.5'/1000' E-W 1'/1000'

Flow conveyance Grass Channel

Flow velocity N-S 3.0 ft./sec. 29 min./mile 180 ft./min.

E-W 1.0 ft./sec. 88 min./mile 60 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100 yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	$0.8 (I_a - f_c)$	Q_p cfs	$0.9 (I_a - 0.2)$	Q_i cfs	Q_t cfs
10	24	12	2.4	5.5	.99	5.4	0.80	4.6	3.7	44	4.7	11	55
20	90	45	9	4.2	.98	4.1	0.80	3.3	2.6	117	3.5	31	148
30	167	84	17	3.4	.97	3.3	0.80	2.5	2.0	168	2.8	48	216
40	203	101	20	2.8	.97	2.7	0.80	1.9	1.5	151	2.2	44	195
45	210	105	21	2.6	.97	2.5	0.80	1.7	1.36	143	2.1	44	187
				ADD PREVIOUS AREAS (t_c = 91 + 30 = 121 min.)									
121	1207	795	158	1.25	.90	1.13	0.80	0.33	0.264	210	0.84	133	343

Yost and Gardner Engineers

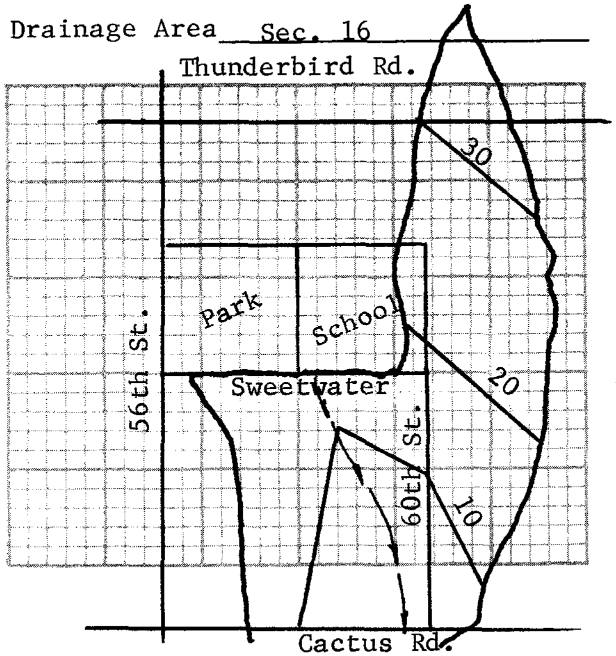
CHANNEL THROUGH CENTURY COUNTRY CLUB

Cactus Rd. to Shea Blvd.

Done by W.H.F.

Date 6/14/74

Drainage Area Sec. 16



URBAN RUNOFF COMPUTATION
(Modified Rational Method)

100 -Year
Rec. Interval

Land Use	Gross Acres	Pervious %	Pervious Acres	Impervious %	Impervious Acres	Non-contrib. %	Non-contrib. Acres
L.D. Residential	264	80	211	20	53		
M.D. Residential							
H.D. Residential							
Parks & park-like							
Farmlands, groves							
Commercial							
Industrial							
Total Acres	264		211		53		

Mean land slope N-S 5.7 E-W 1.5

Flow conveyance Assume Street

Flow velocity N-S 3.6 ft./sec. 24.5 min./mile 216 ft./min.

E-W 1.7 ft./sec. 52 min./mile 102 ft./min.

Hydrologic soil group ______ Assumed infiltration cap. 0.80 in./hr.

Time Min.	Total area ac.	Perv. area ac.	Imp. area ac.	100yr. intens. "/hr.	Area red. factor	I_a "/hr.	Infil. f_c "/hr.	$I_a - f_c$	$0.8\ I_a - f_c$	Q_p cfs	$0.9\ I_a - 0.2$	Q_i cfs	Q_t cfs	
10	59	47	12	5.5	.99	5.4	0.80	4.6	3.7	174	4.7	56	230	
20	167	134	33	4.2	.97	4.1	0.80	3.3	2.6	350	3.5	116	466	
30	241	193	48	3.4	.97	3.3	0.80	2.5	2.0	386	2.1	101	487	← Peak
35	264	211	53	3.1	.96	3.0	0.80	2.2	1.8	380	1.8	95	475	

Yost and Gardner Engineers

59th St. and Cactus Rd.

With Detention Basin in Sereno Park

LEGEND

WASH AREA BOUNDRY

SUB AREA BOUNDRIES

GRANITE REEF AQUEDUCT

26.7— AREA CONTRIBUTING IN SQ. MILES

⑫ DRAINAGE AREA NUMBER

NORTH

GRAPHIC SCALE IN 1000 FEET

0 1 2 3 4 5

CITY OF PHOENIX — PROJ. ST-7314000

MASTER DRAINAGE STUDY

INDIAN BEND WASH

STUDY AREA

CONTRIBUTING DRAINAGES

PLATE A