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ARIZONA HIGHWAY DEPT.
Drainage Study of Ehrenberg-Phoenix Highway
Project I-10-2 (1) PE

Yost and Gardner Engineers
7/12/67 Job #4459

I-10 between AF River and I-17

August 7, 1967

Mr. Ed Koehm
U. S. Army Engineer District
Corps of Engineers
300 North Los Angeles Street
Box 2711
Los Angeles, California 90053

Subject: Drainage facilities - Interstate Route 10
between Agua Fria River and I-17

Dear Ed:

Forwarded herewith is a copy of a letter received this date from the State Highway Engineer, State of Arizona, which is selfexplanatory.

It will be noted that this I-10 freeway running west from Black Canyon Highway is about one-quarter of a mile south of McDowell Road. It is also approximately one mile south of one of the flood control channels running west, south of the Grand Canal. This matter has been referred to your office in the past as a matter of information. It might be possible that the two channels, both of which are proposed, could be combined into one combination flood control channel and storm drainage channel. This is for such as you might wish to take of it.

Sincerely,

John C. Lowry
Chief Engineer and General Manager

JCL/mft
attachment - letter

cc: L. E. Thompson
Assistant State Engineer

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JUSTIN HERMAN
STATE HIGHWAY DIRECTOR

WM. N. PRICE
STATE HIGHWAY ENGINEER

ARIZONA HIGHWAY DEPARTMENT
206 South 17th Avenue
Phoenix, Arizona 85007

August 2, 1967

Col. John C. Lowry
Chief Engineer and General Manager
Maricopa County Flood Control District
4701 East Washington Street
Phoenix, Arizona 85034

Dear Colonel Lowry:

Transmitted herewith are two copies of a report dealing with theproblem of providing drainage facilities for Interstate Route 10 between the Agua Fria River and I-17 (Black Canyon Freeway), prepared by Yost & Gardner, Engineers.

This report is concerned with the problem created by the intersection of a generally north-south drainage flow with an east-west freeway in the absence of adequate natural channels. A 50 year storm is used together with the Consultant's estimates of land use development and water absorption characteristics. Various freeway characteristics are presented as they influence the problem; similarly the extent to which the City of Phoenix facilities are affected is analyzed.

This report is submitted for your review and comment. Following resolution of any differences that may arise, the State will proceed with incorporation of runoff facilities into the overall design of I-10.

Would you please forward one copy to the District Engineer, U.S. Army Engineering District, Los Angeles. I discussed this report briefly with Mr. Thomas L. Davis by telephone recently. We would appreciate comments from the Army Engineers as would be appropriate.

✓	LOWRY	
✓	OHSIEK	
✓	BREWSTER	8/7
	FILE	
	COMMENT:	

Very truly yours,

WM. N. PRICE
State Highway Engineer

L. E. THOMPSON
Assistant State Engineer

LET:fh
Enclosures (2)

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M E M O

August 21, 1967

TO: Col. Lowry

FROM: L. E. Ohsiek

SUBJECT: Glendale-Maryvale Project

During the period 10-14 August, I visited the office of the District Engineer in Los Angeles to discuss the report made by Yost & Gardner for the State Highway Department concerning drainage for the freeway south of Maryvale. I carried your letter and a copy of the report with me.

I initially presented the report and gave a digest of its contents. They were somewhat familiar with the matter which I presented because Mr. Gardner had been in their office previously to discuss aspects of his report. I suggested that they have someone familiar with their report examine the Gardner report and then I would discuss it more fully.

When I called again, Mr. Cramer referred me to Mr. Tom Davis for additional discussion. Mr. Davis has been working on the Glendale-Maryvale report along with three other major reports in the District Office. He has just completed the analysis of land enhancement for the Glendale-Maryvale area; this analysis has caused some delay in submission of the District's report. With the introduction of this new information into the situation, the Glendale-Maryvale report will be further delayed.

It was Mr. Davis' (also Mr. Cramer's) tentative opinion that it is entirely feasible to move the location of the east-west channel southwardly one mile to coincide with the channel planned for the freeway. They pointed out, as did Mr. Gardner, that the Corps of Engineers' peak flows are generally much higher than those presented in the Gardner report. This is no particular problem insofar as a joint project is concerned because provision for a greater flood than anticipated by the State Highway Department will give them additional protection. It appears that the Flood Control District would benefit greatly by having the State Highway Department assist in obtaining the necessary right of way for a flood control channel.

Mr. Davis stated that the next action will be that the District Engineer will write a letter to Mr. Thompson of the State Highway Department suggesting that an inter-agency meeting be held to discuss a joint project. This letter from the District Engineer will probably be sent the latter part of September or early October when they have fully analyzed the problem and are prepared for discussions.

I raised the question as to whether a federal flood control project could be constructed in time to provide the protection needed for the freeway, which is now understood to be planned in the next several years. Mr. Davis informally gave the opinion that it would be approximately four years before the Corps of Engineers could complete the General Design Memorandum phase. It was our opinion, however, that even though a federal flood control project could not be started for several years after the freeway was built, there is no reason that the freeway construction could not include an open unlined channel within the necessary right of way to provide interim protection against a storm of less frequency than that which would be included in the federal flood control project.

L. E. Ohsiek

L. E. Ohsiek

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AUG 1967
RECEIVED
FLOOD CONTROL
DISTRICT

Yost and Gardner Engineers
2619 North Third Street
Phoenix, Arizona 85004
July 12, 1967

William Price, State Highway Engineer
State Highway Department
1739 West Jackson Street
Phoenix, Arizona 85007

Our Job #4459

Dear Mr. Price:

In accordance with Contract #67-3, Project I-10-2 (1) PE, herewith our report on Drainage Studies of the Ehrenberg-Phoenix Highway from 27th Avenue to 115th Avenue west of Phoenix, Arizona.

The report discusses hydrology, estimates flows resulting from the storm of 50 year recurrence interval, summarizes flow conditions at the Freeway and presents recommendations concerning the drainage program. A preliminary report dated April 28th was given you based upon the '10 year' storm and the Bureau of Public Roads made comments by letter of June 5 concerning criteria and points to be covered in this report.

Construction of the Freeway will to a varying degree change the surface flow pattern of the area. A lined channel paralleling the Freeway and extending from 27th Avenue on the East to the Agua Fria River on the West is recommended as the basic plan to adopt for further detail investigation.

More particular description is given in the report concerning cost estimates of the recommended plan for which $6,291,400 should be budgeted pending more detail as to Freeway design, possibilities of earth channel, right-of-way requirements and other factors.

It is understood the report will be submitted to other interested agencies for their comments and possible participation in a drainage program of mutual scope and effort.

Summary and recommendations are set forth at the end of the report text. Table of contents and lists of maps, tables and appendices follow. Aerial photographs and other material and work sheets not included in the report are available in our office for reference.

It is hoped the report gives you the information upon which you may base the future drainage program for the I-10 Freeway between the I-17 Freeway on the east and the Agua Fria River on the west.

Respectfully submitted

YOST AND GARDNER ENGINEERS

By Leigh O Gardner
Leigh O. Gardner

LOG:fp

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Maps, Charts, and Tables

Appendices

Contract #67-3
Project I-10-2 (1) PE
Our Job #4459 - 50

Storm Drainage Study
Ehrenberg-Phoenix Highway
115th to 27th Avenues

Purpose - This report discusses flood water drainage along the Ehrenberg-Phoenix Highway from the Agua Fria River to the Black Canyon Highway. The drainage area encompasses parts of Phoenix and Glendale and the I-10 alignment is generally 1/4 mile south of McDowell Road.

The extent to which construction of the I-10 Freeway affects the drainage pattern in the area, and methods of handling drainage under various choices of Freeway vertical alignment, are given comment.

Scope - The work consisted of:

(1) Field reconnaissance - along with presently available aerial and other maps furnished by the State - to define the existing drainage areas

(2) General hydrologic studies

(3) Office mapping and calculations to determine the magnitude and recurrence of flows that would reach the Freeway under conditions both with or without the Maricopa County Flood Control District's proposed Glendale-Maryvale Drainage Channel.

(4) Description of means of handling the above flows

(5) Estimates of cost of drainage construction work described, and

(6) General, and/or specific recommendations for drainage works which should be undertaken.

The results of the work of items (1) to (3) above are incorporated in the first portions of the report.

HYDROLOGY

General.

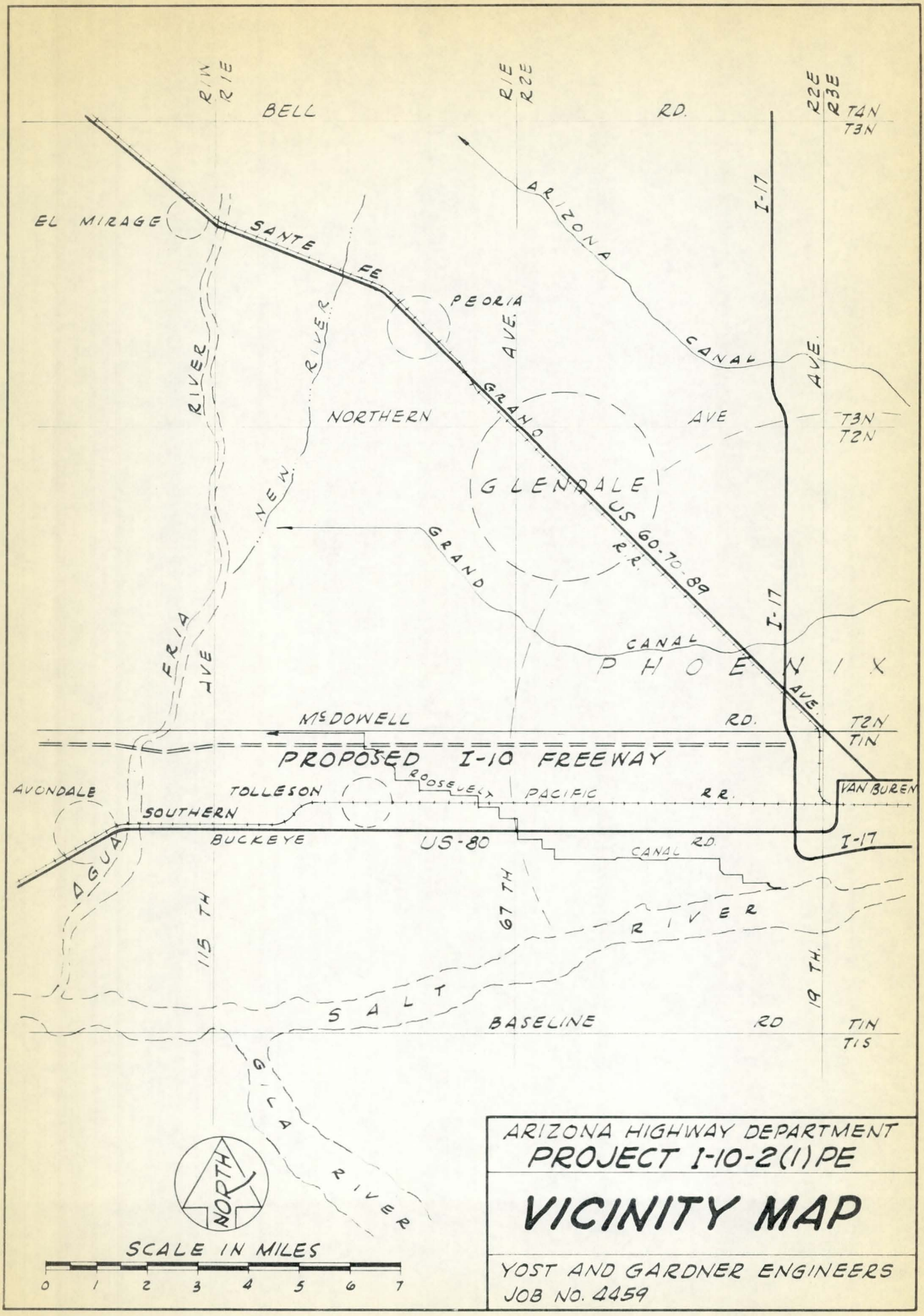
The area studied is about 12 miles long along the proposed Freeway and extends from the Agua Fria River on the west to the I-17 Freeway on the east. The northwestern boundary of the drainage area is a poorly defined ridge coursing from the Agua Fria northeasterly through the center of Glendale. The drainage boundary is applicable only to the proposed I-10 alignment south of McDowell Road and may be altered by future road or drainage construction near the boundary but such variations will not materially affect the results of this study.

Elevations are in the 1,000 to 1,100 feet above sea level range and land slopes are flat ranging from almost level to near 4 feet per thousand. Farm land prevails to the west but urban development is taking over and moving westward from Phoenix in irregular patterns. A vicinity map follows. Other maps of the report utilize the U.S.G.S. quadrangle sheets, with subdivisions and other facilities in and near the drainage area added, to provide a general picture of conditions.

Soils are predominantly clay loam of low infiltration capacity.

Subdivision, commercial, and industrial development has been rapid over the past 15 years and such developments will continue.

Such documents as the "Interim Report on Survey for Flood Control - Phoenix, Arizona and Vicinity (including New River)" prepared by the U.S. Army Engineer district, Los Angeles, Corps of Engineers dated January 15, 1964, and our own "Flood Control Survey Report for Northeastern Maricopa County - Area III" prepared for the Maricopa County Flood Control District in September, 1962 should be referred to for discussion of the surrounding areas.



ARIZONA HIGHWAY DEPARTMENT

PROJECT I-10-2(1)PE

VICINITY MAP

YOST AND GARDNER ENGINEERS

JOB NO. 4459

At the request of the M.C.F.C.D. the U.S.E.D. is currently preparing a report on the Glendale-Maryvale area and their preliminary plan of proposed structures is shown later in this report.

The above reports also give detail concerning climatology, infiltration in soils, and other hydrologic data. This report will usually discuss such matters only in general.

Rainfall.

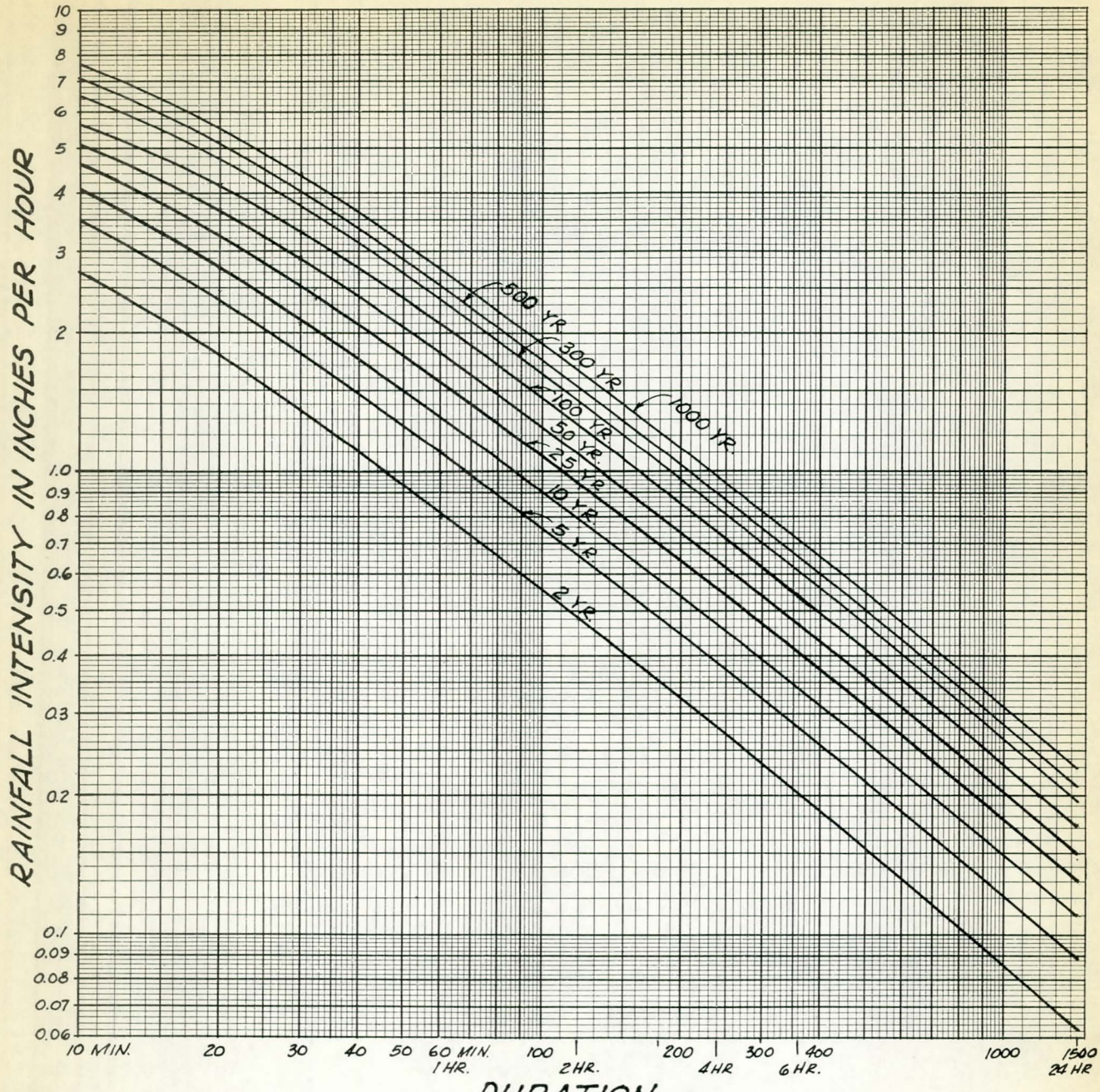
A rainfall intensity - duration - frequency chart is attached applicable to Phoenix, Arizona. Primarily this is from U. S. Weather Bureau Technical Paper No. 28 which also gives data for other areas of the state.

The Arizona Highway Departments "Drainage Table" includes "Isohyetal" charts prepared from the same weather bureau paper and yields essentially the same rainfall results.

In the use of the attached rainfall intensity - duration - frequency chart two points should be noted, first that this is for a point intensity and rainfall would be somewhat less over larger areas and second, that the chart applies to Phoenix and intensities are different at other locations and elevations. The first point is minor as shown by curve 1 on the attached chart showing area depth curves for central Arizona storms. The second point is also minor for this location and the Phoenix curves were adopted.

Estimates of Flow.

While the U. S. Army Corps of Engineers, in their report previously mentioned, usually applies standard project flood isohyetals (a Queen Creek storm of August 19, 1954) to each area under consideration and develops hydrographs considering net rainfall (rain less infiltration), time of travel,

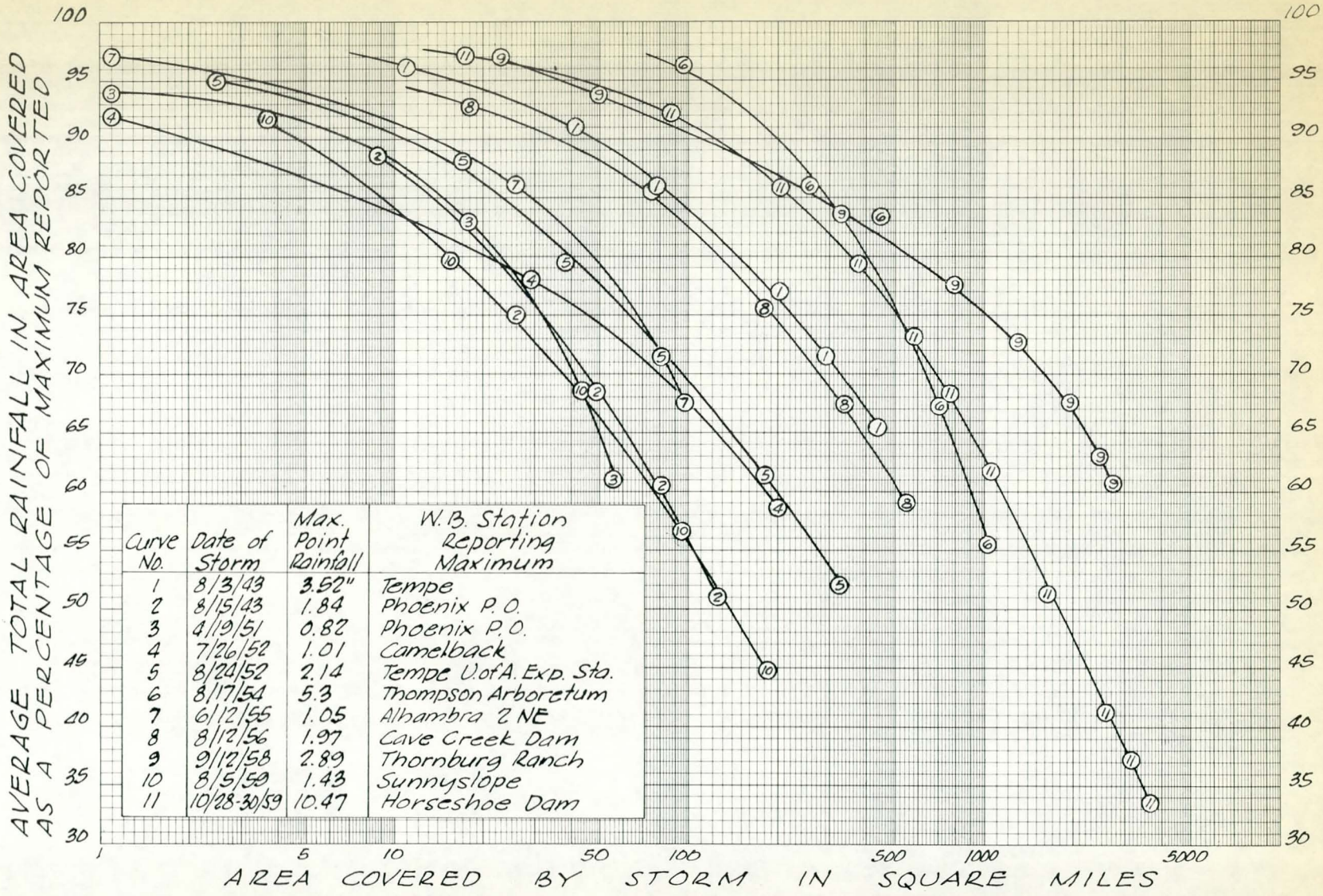


RAINFALL INTENSITY-DURATION-FREQUENCY RELATION FOR PHOENIX, ARIZONA

(Partial Duration Series)

Curves for recurrence intervals of 100 years and less are based on data and methods of U.S. Weather Bureau Technical Paper No. 28. The 300, 500 and 1000 year curves are plotted for Gumbel extreme value distributions after Chow (Transactions, American Geophysical Union Vol. 32, No.2, p 231 ff.)

YOST AND GARDNER ENGINEERS
PHOENIX, ARIZONA



Curve No.	Date of Storm	Max. Point Rainfall	W.B. Station Reporting Maximum
1	8/3/43	3.52"	Tempe
2	8/15/43	1.84	Phoenix P.O.
3	4/19/51	0.82	Phoenix P.O.
4	7/26/52	1.01	Camelback
5	8/24/52	2.14	Tempe U. of A. Exp. Sta.
6	8/17/54	5.3	Thompson Arboretum
7	6/12/55	1.05	Alhambra 2 NE
8	8/12/56	1.97	Cave Creek Dam
9	9/12/58	2.89	Thornburg Ranch
10	8/5/59	1.43	Sunnyslope
11	10/28-30/59	10.47	Horseshoe Dam

AREA-DEPTH CURVES FOR CENTRAL ARIZONA STORMS

Computed from isohyetal maps plotted using Climatological Data for Arizona by U.S. Weather Bureau, supplemented by unofficial data from Louis R. Jurwitz, Phoenix, Arizona.

YOST AND GARDNER ENGINEERS Phoenix, Arizona

channel storage and other factors we have developed a formula method of estimating run-off.

This formula yields results comparable (usually less) with the Army methods and comparable with the formula included in the Arizona Highway Department "Drainage Table" if appropriate constants are selected from such table. A comparison of the results of applying our formula with that of the "Drainage Table" is shown later in the appendices. An explanation of our formula and methods follows:

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.

$$Q = IA$$

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 the constant of proportionality is nearly equal to 1 (difference neglected) with the above stated units. In order to account for losses the sustained infiltration rate of soils, called f_c, is deducted from the supply in the 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. Therefore the runoff - rainfall relationship is expressed as:

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

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

Ia = 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 types) contributing in a 'time' can be determined. The rainfall rate during the 'time' period is determined for any design recurrence interval or frequency from the Rainfall-Intensity-Duration curves and adjusted downward (minor) to correct for area coverage versus the point intensity obtained from the rainfall curves.

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

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 a total area being studied will produce greater flows because water can be collected in a shorter 'time of concentration' and the partial area therefore receives greater rainfall intensities. The designer must seek out such areas and this is similar to hydrograph methods of centering the storm where it will produce the greatest rate of outflow.

This collecting period, storm duration, or 'time' above referred to is usually called 'time of concentration' in this report and can be calculated

in natural drainage basins from formulas given by the U.S.E.D., Soil Conservation Service and others. Various means are given in the literature but in the case of urban areas we estimate such '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.

For this report it was usually assumed (1) that future conditions would range from over 30% impervious area on the east to less than 20% impervious on the west (2) that the pervious areas would have a higher rate of infiltration (0.6 inches per hour) than they have in nature (0.4$\pm$ inches per hour) (3) and that flow paths west and south of the Freeway alignment would collect at the time rate of 40 minutes per mile. Observations and estimates made for this and other drainage problems suggest these assumptions to be reasonable.

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 only make 8% 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 the soils is less than 1/2 inch per hour and of paving less than 0.2 inches per hour 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).

Reference is made to our "Phoenix Storm Drainage Report" for a more detailed description and the studies and observations leading to use of the formula method.

Storage requirements, such as that in an underpass, should be computed from the entire areas net runoff (total rainfall less total minimum infiltration) without the further reductions to peak flow rates deemed applicable and indicated by the formula. It should be also noted that maximum flow rate might result from one intense period of the storm but maximum quantity (volume) results from all periods of the storm where intensity of rainfall is greater than the loss rate.

Appendix I through V are estimates of flow for each area for 50 year frequency rainfall intensities under conditions of Freeway construction as later discussed. Such tables also show, in a few instances, calculations for other frequencies of occurrence. Calculations were also made for present conditions (with higher or lower infiltration rates) shorter or longer times of concentration, etc. to assist in our studies but these are not included in the report. A preliminary report was submitted to the State based upon 10 year recurrence rainfall. Amount shown in the appendices, and other figures of the report, are only estimates although as they are carried forward or presented for bookkeeping purposes they may indicate some refinement.

Appendix VI shows a comparison of estimated flows using the highway departments drainage table and our formula method - they at least are in the same order of magnitude.

In passing it is noted that ratio of flow estimates for various periods of recurrence are about as follows:

Flood Recurrence - Ratio of Flow Estimates to 50 Year Storm Flows

Source	100 Yr.	50 Yr. (Base)	25 Yr.	10 Yr.	5 Yr.	2 Yr.
Preliminary report of Corps of Engineers (Some North Phoenix Mountaineous Areas)	1.35±	1.0	0.70±	0.45±	0.30-	
Highway Table		1.0	0.90+	0.75+		
Appendices and other calculations (Y&G)	1.25±	1.0	0.8±	0.5±	0.4-	0.2-

Note: 50 Year Bases of 1.0 do not necessarily correlate with each other. Estimates by the U.S.E.D. are usually higher - and the Highway Department's are usually lower - than ours.

FLOW CONDITIONS AND FLOWS

General. Conditions of construction of the Freeway - and this effect on the flow to be expected at any point - are discussed in this section. Flows were estimated for construction conditions deemed pertinent (Appendix I through V) and summaries are given near the end of this section of the report.

Freeway Construction.

(1) All elevated on structure.

If rain water is put back on the ground (kept receptive) at sufficient intervals the total effect of the Freeway is negligible.

(2) All at or near ground level like a city street.

The change of pervious area to paving would add some flow but could be partially offset by increased attention to infiltration and storage in unpaved areas within the Freeway right-of-way. Major storm flows would simply pass over the roadway.

It is not expected that either of the above methods will be totally used. The first is expensive and the second brings inconvenience to traffic so that even in the case of city thoroughfares the necessity is felt to collect and handle flows thereby offsetting the original advantages of low cost and least change in runoff patterns. Grade separations - other than by open elevated structure - create an immediate and local variation to the 'at ground level' construction method.

(3) Freeway depressed.

This is an effective barrier to (or collector of) any flows reaching the Freeway - usually requires pumps to handle rainfall in the depressed areas - and is particularly successful in interrupting all surface flows. It is also a major interruption to drainage crossings by conduits, or open channels including streets.

(4) Freeway elevated on fill.

This is a barrier to any flows reaching the Freeway and requires some works to handle rain falling on the Freeway. Water crossing in conduits and channels, or on the streets, can be more easily handled than in (3). If this Freeway elevation is only done at arterial crossings the local characteristics are similar.

(5) Arterial crossings at grade and Freeway depressed follow the characteristics of (3) while arterial crossings at grade and Freeway elevated follow the characteristics of (4).

(6) Arterial crossings depressed, or elevated, have local characteristics on the arterial like (3) and (4).

(7) Combinations of the above.

Flows Reaching the Freeway.

While the total water reaching the north side of the Freeway location is the same for any condition of Freeway construction there is a major difference in amounts reaching any one point along the Freeway depending on how such water is handled after it reaches the Freeway - for example:

(1) If the Freeway is an effective barrier, or dyked on the north, (either elevated on fill or depressed construction) water will come against the Freeway, and pond, and travel downstream (usually westward) in a wide and shallow cross section. More water will reach any point west (downstream) than would have occurred naturally without such barrier.

(2) For conditions as above but carrying water westward in a man-made channel the time of concentration is shortened and greater flow rates will therefore be experienced, at all points west of the eastern terminus of the man-made channel, than would be the case in (1) above.

Flows reaching the Freeway location can be materially reduced by the proposed construction of the Glendale-Maryvale drain. The Corps of Engineers (U.S.E.D.) at the request of the Maricopa County Flood Control District, proposes a channel along or south of Thomas Road. Unfortunately the peak flow rates along the Freeway are usually generated from a storm falling in the area within 1-1/2 miles north and therefore the Glendale-Maryvale drain would not greatly reduce design flow rates (See Appendix V). It would consistently reduce by one-half the total quantity of flow reaching the Freeway (see Appendix VII) and therefore damage potential would be reduced. Any plan of Freeway drainage incorporating storage would be helped

considerably by the M.C.F.C.D. plan. We have made flow estimates in Appendix V as if the proposed M.C.F.C.D. channel (and Thomas Road to the east of 43rd Avenue) were the northern drainage boundary limits and the comparison ranges from little or no change in peaks for culverts crossing the Freeway up to 30 - 35% for various paralleling channel alternates.

Flows reaching the Freeway can be carried south across the right-of-way on each mile road (or greater spacing). A nearly unlimited number of closely spaced crossings could also be used. Calculations have been made based upon typical mile, 1/2 mile, etc. down to 1/16 mile spacings and also for some actual locations such as 51st and 75th Avenues. The effect of the proposed Glendale-Maryvale drain on estimated peak flow rates is minor at the closer spacings since rainfall near the point under consideration becomes increasingly important for the closer spacings or smaller areas.

The appendices, summarized in Appendix VIII and also on the following pages, give a picture of flows to be expected.

(a) If drainage works (a concrete channel) were built paralleling the Freeway.

(b) If drainage works were built paralleling the Freeway utilizing a concrete channel east of 43rd Avenue and an earth channel west of 43rd Avenue.

(c) If drainage works crossing the Freeway north to south are undertaken at various east-west intervals or locations.

If combinations of the above plans are used the following summaries are helpful as a guide but it would be better to evaluate flows appropriate to the final method chosen to handle such flows if detail consideration or

comparison is required. In cases (a) and (b), or a constructed paralleling channel, the effect of depressing the Freeway from east of 31st to west of 39th is shown - also the effect of building the Freeway on elevated open structure east of 43rd Avenue is tabulated.

Summary of Suggested Design Flows

Condition (a)

Concrete lined channel along Freeway. See Appendix VIII

Fifty year recurrence, suggested design flows in c.f.s.

Location	Calculated flow reaching	(1) Freeway on fill	(2) Freeway depressed	(3) Freeway Open
27th Ave.	0	0	0	
29th Ave.	251	260	260	
31st Ave.	485	500	510	
33rd Ave.	688	700	710	
35th Ave.	887	900	920	
39th Ave.	1263	1280	1310	
43rd Ave.	1587	1600	1630	0
47th Ave.				490
51st Ave.	2040	2050	2080	920
59th Ave.	2660	2670	2700	1730
67th Ave.	3200	3210	3240	2410
75th Ave.	3630	3640	3660	3000
83rd Ave.	3900	3910	3930	3440
91st Ave.	4100	4110	4130	3760
99th Ave.	4150	4160	4180	3800
107th Ave.	4200	4210	4230	3850
115th Ave.	4250	4260	4280	3900
El Mirage	4300	4310	4330	3950
To Agua Fria	4300	4310	4330	3950

(1) Freeway on fill but elevated on open structure east of 27th Ave.
(3) Freeway on fill but elevated on open structure east of 43rdAve.
(2) Freeway depressed from east of 31st Ave. to west of 39th Ave.

Summary of Suggested Design Flows

Condition (b)

Channel along Freeway. Concrete lined east of 43rd Ave. and earth channel west of 43rd Ave. Fifty year recurrence suggested design flows in c.f.s. See Appendix VIII.

Location	Calculated flow reaching	(1) Freeway on fill	(2) Freeway depressed	(3) Freeway open
27th Ave.	0	0	0	
29th Ave.	251	260	260	
31stAve.	485	500	510	
33rd Ave.	688	700	710	
35th Ave.	887	900	920	
39th Ave.	1263	1280	1310	
43rd Ave.	1587	1600	1630	0
47th Ave.				460
51st Ave.	1850	1860	1890	850
59th Ave.	1960	1970	2000	1400
67th Ave.	2040	2050	2080	1700
75th Ave.	2100	2100	2120	1900
83rd Ave.	2150	2150	2170	1950
91st Ave.	2200	2200	2220	2000
99th Ave.	2250	2250	2270	2050
107th Ave.	2300	2300	2320	2100
115th Ave.	2350	2350	2370	2150
El Mirage	2400	2400	2420	2200
To Agua Fria	2400	2400	2420	2200

(1) Freeway on fill but elevated on open structure east of 27th Ave.
(3) Freeway on fill but elevated on open structure east of 43rd Ave.
(2) Freeway depressed from east of 31st Ave. to west of 39th Ave.

Summary of Flows Reaching Freeway and Suggested Design Flows

Condition (c)

Surface crossings at intervals shown.

Applicable for culverts, inverted crown roads, or storm drain lines to Salt River. See Appendix IV.

Spacing or Interval	50 Year Flow c.f.s.	Remarks
1 mile - Typical (or 51st Ave.)	770	Typical is for 25% impervious and 40 minute travel along Freeway
1 mile - 75th Ave.	878	20 minute travel along Freeway
1/2 mile - Typical	448	
1/4 mile - Typical	240	
1/8 mile - Typical	124	For 25% impervious and 5 minute (40 min/mi) travel along Freeway
1/16 mile - Typical	64	For 25% impervious and 2-1/2 minute (40 min/mi) travel along Freeway

Conclusions to be reached from the flow estimates.

Certain observations, conclusions, and assumptions, as to means of handling storm flow are made at this stage of the report for simplification.

(1) The Freeway will not all be elevated on structure (which would virtually eliminate the drainage problem).

(2) The irrigation canal system can at the best only provide minor flow capacities or assistance.

(3) The City of Phoenix storm sewers designed only for the 1 to 2 year storm are helpful but in the near future, only from 43rd Avenue eastward. The City 27th Avenue line, due to proximity of I-17 and other factors, will handle bigger storms than their normal 1 to 2 year design frequency.

(4) The Glendale Maryvale drain as proposed by the U.S.E.D. and M.C.F.C.D. will be helpful but its final location is not absolute and its construction may be many years in the future. Design capacity probably will be on the order of 100 year frequency and such channel would materially reduce major storm quantities reaching the Freeway. It is possible that the Freeway drainage plan can become a joint project doing portions of the job planned for the Glendale-Maryvale drain - if it does not it seems entirely feasible to choose the 10 year frequency proposed in our preliminary report looking foward to future additional protection from the works of others.

(5) Near 81st Avenue the distance from a point on the Freeway to the Agua Fria River becomes less than the distance to the Salt River.

(6) Local low points and ridges bring out difference not thoroughly shown by the estimates of this report. The U.S.G.S. quadrangle sheets and the State Highway topographic maps (planimetric) clearly indicate the

swale extending from 31st to 39th Avenues. This area is going to collect and pond water (it does now) and must be more adequately drained.

(7) With urban development expected west of 43rd Avenue, adjacent to the Freeway, it is assumed Freeway drainage works will be accomplished and that capacities must be adequate for at least the 10 year recurrence storm.

(8) While our preliminary report suggested a 10 year recurrence storm and utilized higher infiltration or loss rates, the Bureau of Public Roads has suggested the '50 year design flood' and submittal of this report to other agencies for their comment and possible participation. It is realized that other criteria, deeper channel, etc., might be more appropriate to the requirements of others - or a joint effort plan.

With these observations, and from discussions of our preliminary report, it seems best to propose one method of flow handling with remarks as to changes in costs, etc. associated with other alternatives. A concrete lined channel - north of and paralleling the main roadway - from near 27th Avenue to the Agua Fria is set forth as a basic plan for comparison purposes.

A map of the area with proposed drainage works by others shown thereon is attached. The City of Phoenix proposes lines on 43rd Avenue and other mile roads west thereof (terminating at the Salt River) as development and the need warrants.

In passing it should be noted that 'flow reaching' the Freeway, and 'design flow', are different by allowances for added flows due to the Freeway construction itself and decreased flows due to allowances for City storm sewers and street crossing flows as explained in Appendix IX. The total of the differences are minor but allowance is made as can be seen in the previous tables.

METHODS OF HANDLING FLOWS - AND COSTS

General.

Possible plans of flow handling are discussed in this section. First cost and annual cost of plans that appeared feasible are also presented.

Flows resulting from the storm of 50 year recurrence period were selected as the design criteria.

Possible Plans of Flow Handling.

1. Lined Channel paralleling the Freeway.

   This plan most readily fits any type of roadway construction undertaken at both the normal roadway and at grade separations or crossings. Present and future urban development adjacent to the Freeway will best be served by a project of this type.

2. Lined and unlined channel paralleling the Freeway.

   This plan compares favorably with 1, if at least the portion from 27th Avenue to 43rd Avenue is lined. If velocity is controlled with flat slopes and drop structures an earth channel could be used. Maintenance and operation costs will of course be considerably greater for unlined portions.

Both above plans do constitute a diversion to the Agua Fria of flows that would normally trend toward the Salt River. From preliminary sections and reconnaissance we do not think, with the quantities involved, that any special clearing, flowage easements in the Agua Fria, or major work is required but the fact remains. It would be best to work with the M.C.F.C. District on this problem and at least allot some funds for study purposes.

The District and U.S.E.D. propose Agua Fria channelization and improvement - see the Corps' January 15, 1964 Interim Report for Phoenix, Arizona and Vicinity.

3. Storm drain lines to the Salt River.

   Pipe lines, and in some cases open channels, can be carried from the north side of the Freeway south to the Salt River. This system would also require collection facilities along the Freeway. This would be an extension of the plan being carried forward by the City of Phoenix within the city limits (east of 67th Avenue) and should be done in close cooperation with them.

4. Conduits crossing the Freeway.

   It is possible to carry flows reaching the Freeway across in pipes, culverts, or wasteways of wide and limited depth section. Much difficulty is going to be experienced through the 27th Avenue to 43rd Avenue area. Structures located west of 43rd Avenue will in the future bring on trouble from downstream (south of Freeway) property owners at every outlet. Good maintenance is essential - no upstream property owner should see a plugged inlet during heavy flow. Water generated by Freeway impervious areas must be well taken care of because now not only concentration at a location but added quantity will both be points of contention to any downstream owner affected.

5. Storage along the Freeway.

This plan could be accomplished west of 43rd Avenue. To be effective it should be designed for quantities resulting from storms of the approximate 100 year frequency of recurrence. Provision for draining the storage areas in about a one day period is recommended since many summer storms occur nightly for two or more days. Combinations of the above plans can also be utilized and the alternative of doing nothing (or very little) and taking the risk of damages should also be considered.

Lined Channel Paralleling the Freeway (1.)

A cost estimate was made in our preliminary report of a project to handle the 10 year flows. Herewith are estimates based upon the flow resulting from the storm of 50 year recurrence interval.

Appendix X sets forth the hydraulic properties and construction quantities of a lined channel of trapezoidal section with 2:1 side slopes. The sections used are not themselves the most economical since shallow depths were used to keep conflict with other present and future utilities (principally sewers) to a minimum. If this project becomes a joint project with the M.C.F.C.D. and others, it will be an advantage to deepen the channel to better receive connecting closed conduits.

Appendix XI shows the quantities estimated for the box culverts on the channel required to cross the mile or 1/2 mile roads.

Appendix XII estimates the cost of excavation and concrete for both the lined channel and box culverts required.

Appendix XIII shows the cost estimate for right-of-way. In this regard two categories of land acquisition are estimated.

The preliminary alignment and typical cross sections furnished by the State provided a general picture upon which the right-of-way for the channel could be superimposed. Estimates were made of what additional right-of-way would actually be required to accommodate the channel. In general - west of 43rd Avenue - it was assumed that 25 feet of required channel right-of-way was available within the north one-half width of 154 feet presently contemplated. An estimate is also shown for the hypothetical condition that the channel would have to stand on its own - e.g. there is not 25 feet width available in the contemplated 154 feet road right-of-way west of 43rd Avenue. The hypothetical right-of-way figure could be kept in mind for comparison with other projects requiring no right-of-way.

An estimate of the lined channel follows: Two points should be noted, first - there may be small reaches between 27th and 43rd Avenues in the final design where rectangular cross section channel, or even closed conduit, could be used to save individual costly right-of-way requirements, and second - we have allowed for guard rail south of the channel and part of this could possibly be simplified or eliminated.

Typical roadway and channel cross-sections are included with the maps of the appendix.

Maps to be referred to are:

A. Location Map (showing existing conditions in the drainage area)

B. Proposed M.C.F.C.D. - U.S.E.D. Projects

C. Lined Channel along Freeway (with design flow and channel sizes shown thereon)

D. Profiles (along the I-10 Freeway and other locations)

E. Profile (along the I-10 Freeway)

F. Sections (showing relationship of channel to roadway)

G. Sections (showing possible culverts crossing the Freeway)

Appendices XX through XXVI show the hydraulic properties of various channels and conduits used in our selection of sizes appropriate to the lined channel as well as for other possible projects.

In the State's consideration of possible vertical alignment it is necessary to compare costs of plans (a) building the Freeway near grade, or on fill, and the Freeway elevated at crossings with (b) depressing the Freeway so that 31st, 35th and 39th Avenues cross at grade, and with (c) elevating the Freeway on open structure east of 43rd Avenue.

First cost of the lined channel follows and later in the report comparisons are given of both first cost and annual costs for alternate Freeway vertical alignments.

Cost Estimate - Lined Channel Along Freeway
See Appendices X through XIII

Item	Description	Unit Cost	Total Cost
Land & Right-of-Way			
East of 43rd Ave.	Mostly subdivisions		$ 575,000
43rd Ave. to Agua Fria	63.3 acres		215,900
Subtotal R/W			$ 790,900
Construction Costs			
Lined Channel			
East of 43rd Ave.	10,020 l.f.		253,800
43rd Ave. to 75th Ave.	20,700 l.f.		1,054,300
75th Ave. to Agua Fria	33,680 l.f.		2,112,200
Subtotal Lined Channel			($3,420,300)
Guard Rail			
East of 43d Ave.	10,020 l.f.	3.50	35,100
West of 43rd Ave.	52,980 l.f.	3.50	185,400
Collectors, paved inverts, etc.			
East of 43rd Ave.	20 each	500.00	10,000
West of 43rd Ave.	70 each	200.00	14,000
Irrigation Crossings			
East of 43rd Ave.	Neglect	- -	- -
Make R.I.D. a Siphon	1 each		40,000
West of 43rd Ave.	88 each		116,600
Utility Crossings			
East of 43rd Ave.	Allow	- -	8,000
East of 43rd Ave. - San Sewer	Allow	- -	20,000
West of 43rd Ave.	Neglect	- -	- - -
Box Culverts			
43rd Ave. and East	4 each		96,800
West of 43rd Avenue	10 each		293,700
Appurtenances & Miscl. @ 5%			212,000
Subtotal construction			$4,451,900
Subtotal Construction & R/W			$5,242,800
Contingencies - 10%			524,300
Engineering, administration, and overheads			524,300
TOTAL			$6,291,400

East of 27th Ave. - Elevated on open structure.
East of 43rd Ave. - Freeway on low fill except elevated at 1/2 mi. crossings.
West of 43rd Ave. - As above but mile crossings.
Guard rail - Between Freeway, or on-off ramps, and lined channel.

Lined and Unlined Channel Paralleling the Freeway (2)

A cost estimate was made similar to the lined channel of (1) but utilizing an unlined channel west of 43rd Avenue. Design flows are given in previous flow summaries. Earth channel for 6 feet water depth and 3:1 side slopes was used and cost estimate of $4,720,400 is derived in Appendix XV and XVIII.

This project is less expensive in both first and annual cost than the lining of the entire length.

Storm Drain Lines to the Salt River (3)

A cost estimate was made (see Appendix XVI for a few typical lines draining from the Freeway to the Salt River. The 51st Avenue and 75th Avenue lines handling the 50 year storm within only the first mile east of each line would cost over $2,300,000 and $3,100,000 respectively. This is without allowance for collection works north of the Freeway and assuming no right-of-way costs.

Obviously three of such lines, of themselves, would exceed cost estimated for a lined channel.

Cost of a line on 43rd Avenue (to receive flows collected from the east) would itself exceed $3,400,000 and this is also shown in Appendix XVI.

Closed conduits of the appropriate sizes are three times the cost of lined trapezoidal channels and if serious consideration were given this alternate (3) it would seek out right-of-way or alignment allowing the less expensive open channels. Again it should be noted that just a few lines to the Salt River will exceed the length, and costs, of the channel to the Agua Fria River.

There are good possibilities in working with the City of Phoenix to jointly build lines to the Salt River - however even with this mutual benefit it is doubtful that such co-operative projects would approach the cost or value of a lined channel to the Agua Fria.

We believe the more realistic view to be that if the State builds a channel along the north side of Freeway and the M.C.F.C.D. accomplishes some works in the Glendale-Maryvale area then the needs for storm drain lines to the Salt River are minimized - may be shortened to only a few miles north of the Salt River, or may be eliminated entirely. The City may go ahead with the planning for a line on 43rd Avenue which would serve (a) local drainage and (b) to relieve the Grand Canal and the Maryvale area drainage situation pending better plans or solutions offered by the MCFCD-USED Glendale-Maryvale project, or the I-10 Freeway drainage program.

Conduits Crossing the Freeway (4)

An estimate, Appendix XVII, was made of wide and shallow box culverts, or pipe clusters, crossing the Freeway. See also Appendix Map F and Appendix XXV for background. Such structures every 330 feet would cost $227,000 per mile.

A project of this type accentuates rather than allevaites the drainage problem. It is doubtful if this can be the only type of work done east of 43rd Avenue. This project would protect the Freeway itself but the State would soon be forced into additional work by downstream land owners and would, in the end, spend more money than for a lined channel. This alternate is not recommended.

Storage Along the Freeway (5)

This type of job can be accomplished west of 43rd Avenue. Provisions should be made for storage of 200 acre feet per mile (see Appendix VII and for drainage within a days period. It is doubtful that the Salt River Project canals and wasteways could accomplish even a small part of these discharges resulting in the continued need for a channel west to the Agua Fria or conduit south to the Salt River.

Storage basins would be limited to about 6 foot depths requiring 30 acres of basins per mile, heavy right-of-way costs (say over $100,000 per mile) and in the end would be more costly than a paralleling unlined channel plan.

If the MCFCD Glendale-Maryvale drain were built at its present proposed location (one mile north of the Freeway) storage requirements would drop at least 1/2 and the feasibility of storage increases considerably.

Combination of the Above Plans.

Various combinations either do not appear to give the protection afforded by the channel or will exceed it in first cost.

Joint Project with the MCFCD and Others

A joint project serving the entire area offers good possibilities. It is our understanding this report will be submitted for comment to the Maricopa County Flood Control District, Salt River Project, City of Phoenix, U. S. Corps of Engineers, Soil Conservation Service, U. S. Geological Survey, and others.

It should be reaffirmed here that this project:

(1) Is based on a 50 year storm recurrence and our estimate of factors such as infiltration loss and future area development.

(2) Does not contemplate large conduits being brought from the north into this channel i.e. - dumping the Grand Canal.

(3) Does contemplate normal street flow and minor drains of the contributing area being brought to the channel.

(4) Is appropriate to the Freeway itself and in fact we would recommend this job or preferably a smaller channel (10 year design flow) as submitted in our preliminary report.

(5) Must be reexamined in the light of other agencies needs should such joint participation be realized.

Project Summary

A channel paralleling the Freeway from west of 27th Avenue to the Agua Fria is deemed the best general plan for the State to adopt. Tabular data concerning first and annual costs follows. This analysis is made also to assist in your consideration of choices of Freeway vertical alignment. Although savings are indicated if an earth channel is utilized west of 43rd Avenue it is not recommended that you budget, or plan, for this type of construction at this time.

Summary
First and Annual Costs
Various Channels and
Alternate Freeway
Vertical Alignments
See Appendix XIX

1. Concrete lined channel, Freeway on low fill with elevated open structure east of 27th Avenue

2. As 1. but Freeway depressed from east of 31st Avenue to west of 39th Avenue

3. As 1. but Freeway on elevated open structure east of 43rd Avenue

4. Concrete lined channel east of 43rd Avenue and earth channel west of 43rd, Freeway on low fill with elevated open structure east of 27th Avenue

5. As 4. but Freeway depressed from east of 31st Avenue to west of 39th Avenue

6. As 4. but Freeway on elevated open structure east of 43rd Avenue.

	1.	2.	3.	4.	5.	6.
Flow at end, c.f.s.	4310	4330	3950	2400	2420	2200
Land and R/W						
E. of 43rd Ave.	$ 690,000	$ 690,000	$ - -	$ 690,000	$ 690,000	$ - -
W. of 43rd Ave.	259,100	259,100	214,200	666,700	666,700	541,700
Construction	5,342,300	5,506,500	4,275,800	3,363,700	3,527,800	2,514,600
TOTAL - FIRST COST	$6,291,400	$6,455,600	$4,490,000	$4,720,400	$4,884,500	$3,056,300
Annual Costs	372,158	389,425	270,574	307,653	324,851	211,355
Indicated difference in first cost from 1.	0	345,340 more	2,031,680 less	1,290,000 less		
Indicated difference in first cost from 4.				0	343,960 more	1,925,960 less

The depressed highway (31st to 39th) will cost the State about $345,000 more than one on low fill. If the Highway is built on open elevated structure east of 43rd Avenue such added work should be credited $2,000,000 for the saving in drainage works required for the low fill.

DAMAGES

Projects (such as the lined channel) should justify themselves as to saving in direct costs due to damages and in other indirect benefits.

Such direct items as farm, road and utility, commercial and subdivision damage are more readily apparent than indirect damages such as flood fighting and rescue work, business losses and loss of wages, rerouting of traffic and transportation losses. Intangibles such as personal injury, loss of life, etc. are of major consequence but not susceptible to monetary evaluation.

A concrete channel along the Freeway is estimated to cost $6,291,400 with the portion east of 43rd Avenue assigned $1,223,900 of this.

Assuming 50 year rainfall amounts fell in the 43rd Avenue to 27th Avenue reach and the boundaries of drainage were the Grand Canal and Grand Avenue - then over 200 acre feet would pond north of any Freeway obstruction or dyke. Much more than this is probable even with outflow westerly over 43rd Avenue and the 35th Avenue storm drain performing. If the pond averaged 1 foot in depth there would be a width of 825 feet under water. There are about 269 homes in the first block (300') north of the Freeway right-of-way as proposed. Very easily a storm of less than the 50 year intensity could cause far in excess of 1 million dollars in damages.

Definite discussion of damages, or benefit cost ratio, is beyond the scope of this report. The above discussion of the 27th to 43rd Avenue area is only a hypothesis or rough reconnaissance figure in that we do not have sufficient levels to define ponding areas, flowout sections, house floors etc. but there is every indication that detail study would greatly increase the estimated benefits accruing to adequate methods of storm water disposal.

Also note that if the roadway is built near ground level the water would sweep across and not bring about the back-up or ponding assumed here.

SUMMARY AND RECOMMENDATIONS

General.

While it is felt this report is in sufficient detail for the State to reach its general planning decisions, your review and discussion with other agencies including municipalities may indicate further study is desirable.

Summary.

The report has evaluated the magnitude and recurrence of storm flows reaching the Freeway.

Hydrologic data, information, and assumptions relating to future conditions of the terrain (infiltration, pervious vs impervious area ratio, etc.) have been set forth.

Design flows based upon the storm of 50 year recurrence interval was chosen by the Bureau of Public Roads for the basis of project comparison. While this is appropriate it is not inviolate. Design flows from lesser storms might well be chosen if this project does not become a joint effort with other agencies.

The Freeway elevation in relation to the ground and possible methods of storm flow handling produce an almost unlimited number of alternative projects for consideration.

The only alternative possibly not given the consideration it merits is that of building the Freeway at grade (with crossing roads similarly unobstructive to surface flow) so that all storms of more than a few years recurrence interval would flow across the land or Freeway, where it would have flowed naturally, and also without material upstream ponding. There would still be problems of varying degree at any grade separations.

A lined channel paralleling the Freeway was investigated and its cost estimated.

Sufficient cost estimating was done on other possible projects to relate them to, or compare them with, the lined channel.

A cost comparison was made of drainage for depressed versus elevated Freeway at the 31st, 35th and 39th Avenue crossings to show both the increase in first cost and the further increase in annual cost for the depressed section. A cost comparison (drainage only) was made assuming that the Freeway might be elevated on open structure east of 43rd Avenue.

Conclusions and Recommendations.

1. Submit this report to other interested agencies as suggested by the Bureau of Public Roads.

2. In the meantime select a lined channel paralleling the Freeway as the project to be accomplished and allot $6,291,400 for this work.

(a) Detail design, or at least some further decisions, should be made as to how much of the channel should remain the preferred trapezoidal lined section rather than earth channel, and also how much open rectangular concrete section should be used east of 43rd Avenue etc. These considerations change costs and right-of-way requirements and proper choice should result in reduction of the allotment. We do not think the earth channel is going to be an appropriate choice even though the estimates indicate lower than annual costs.

(b) Work with M.C.F.C.D. on Agua Fria channel improvements or flowage easement requirements. We do not think this problem could materially affect costs or conclusions of this report.

3. As far as drainage is concerned it is always best to keep the Freeway elevation near grade for overflow under extreme storm conditions. Crown or cross slope, of both the Freeway and frontage roads should also be considered along this line. For example, with a lined channel we would recommend both frontage roads slope south (falling with the ground) and only the west bound Freeway lanes slope north, or opposite the ground slope.

(a) One mile and other road crossings should go through at grade if the Freeway is not at grade.

(b) Hold depressed sections of the Freeway to a minimum to eliminate pumping stations which add both first cost and increased operational and annual costs.

(c) With the lined channel, drainage from the south one-half of the Freeway can be absorbed as much as possible, sent over the land to the south, and only returned north to the proposed channel at points of major concentration (pumping stations, or unusal collection of Freeway drainage).

4. Other points that should be kept in mind are

(a) Salt River Project canals and wasteways crossing the Freeway should be replaced in capacity more than such units surcharged flow rate, to provide for storm conditions.

5. If other agencies do not participate, or this job does not become a joint effort for the area, then we recommend serious consideration be given our preliminary report and the design flows resulting from storms of lesser magnitude.

INDEX

XXI	Hydraulic Properties - Box Culverts
XXII	Hydraulic Properties - Rectangular Channel
XXIII	Hydraulic Properties - Swale along Freeway
XXIV	Hydraulic Properties - Streets
XXV	Hydraulic Properties - Culverts Crossing the Freeway
XXVI	Hydraulic Properties - Pipe

Maps

A	Location Map
B	Proposed MCFCD-USED Projects
C	Lined Channel Along Freeway
D & E	Profiles
F & G	Sections through Freeway

Future conditions
Infiltration fc = 0.6
Impervious Area
Near 35th - 30% ±
West of 67th - 20% ±
Streets gather of 40 min/mile

EXPECTED FLOWS 50 year rainfall intensity and duration unless noted

LOCATION	AREA IN ACRES: Total Area A	Pervious Area A_p	Imperv's Area A_i	Infiltr'n (final) in/hr f_c	Concentration Time: Street Slope	Min. t_c	RAIN: Point Intensity I	Average Intensity Ia	RUNOFF: Pervious $(Ia-f_c)0.8$ = Inches	$InxA_p$ = CFS	Impervious $(Ia-0.2)0.9$ = Inches	$InxA_i$ = CFS	Total Flow CFS	DESIGN FLOW AND REMARKS
Assume concrete lined channel along Freeway. Flow 20 min/mile east of 51st and 10 min/mile west														
27th Ave. Freeway elevated to east on structure													0	
29th Ave.	220	154	66	0.6		60	1.81	1.80	0.96	148	1.44	95	243	Not max.
	193	135	58	0.6		50	2.05	2.04	1.15	155	1.66	96	251	
31st Ave.	440	311	129	0.6		60	1.81	1.80	0.96	299	1.44	186	485	
33rd Ave	630	445	185	0.6		60	1.81	1.79	0.95	423	1.43	265	688	
35th Ave.	800	560	240	0.6		60	1.81	1.78	0.94	526	1.42	341	867	Not max.
	960	680	280	0.6		70	1.62	1.59	0.79	537	1.25	350	887	
39th Ave	1560	1100	460	0.6		80	1.48	1.45	0.68	748	1.12	515	1263	
43rd Ave	1920	1350	570	0.6		80	1.48	1.45	0.68	918	1.12	638	1556	Not Max.
	2240	1570	670	0.6		90	1.35	1.32	0.58	910	1.01	677	1587	
51st Ave	2880	2020	860	0.6		90	1.35	1.32	0.58	1171	1.01	869	2040	
59th Ave	3760	2750	1010	0.6		90	1.35	1.31	0.57	1570	1.00	1010	2580	Not max.
	4400	3200	1200	0.6		100	1.25	1.21	0.49	1570	0.91	1090	2660	
67th Ave	5280	3910	1370	0.6		100	1.25	1.21	0.49	1915	0.91	1245	3160	Not max.
	6080	4500	1580	0.6		110	1.17	1.12	0.42	1890	0.83	1310	3200	
75th Ave	6960	5220	1740	0.6		110	1.17	1.12	0.42	2190	0.83	1440	3630	
83rd Ave	6560	4980	1580	0.6		100	1.25	1.20	0.48	2390	0.90	1420	3810	Not max.
	7680	5840	1840	0.6		110	1.17	1.11	0.41	2390	0.82	1510	3900	
91st Ave	8120	6250	1870	0.6		110	1.17	1.11	0.41	2570	0.82	1530	4100	
	6950	5300	1650	0.6		100	1.25	1.20	0.48	2550	0.90	1490	4040	Not max.
99th Ave	8000	6200	1800	0.6		110	1.17	1.11	0.41		0.82			see 91st
107th Ave & West														Add to 91st Ave

ADD I 50YR

Future Conditions
Infiltration f_c = 0.6
Impervious Area
Near 35th - 30% ±
West of 67th - 20% ±
Streets gather at 40 min/mile

EXPECTED FLOWS 50 year rainfall intensity and duration unless noted

LOCATION	AREA IN ACRES Total Area A	Pervious Area A_p	Imperv's Area A_i	Infiltr'n (final) in/hr f_c	Concentration Time Street Slope	Min. t_c	RAIN Point Intensity I	Average Intensity Ia	RUNOFF Pervious $(Ia-f_c)0.8$ = Inches	$InxA_p$ = CFS	Impervious $(Ia-0.2)0.9$ = Inches	$InxA_i$ = CFS	Total Flow CFS	DESIGN FLOW AND REMARKS
Assume earth channel along Freeway west of 43rd Ave - 30 min. per mile														
East of 43rd Ave. is concrete lined - See Appendix I														
27th to 43rd Ave - See App. I													0 to 1587	See Appendix I
51st Ave.	2960	2080	880	0.6		100	1.25	1.22	0.50	1040	0.92	810	1850	
59th Ave.	2880	2060	820	0.6		100	1.25	1.22	0.50	1030	0.92	753	1783	Not max.
	4160	3000	1160	0.6		120	1.08	1.05	0.36	1080	0.76	880	1960	
67th Ave.	3960	2850	1110	0.6		120	1.08	1.05	0.36	1030	0.76	840	1870	Not max - Add to 59th
75th Ave	3840	2840	1000	0.6		140	1.08	1.05	0.36	1020	0.76	760	1780	Not max - Add to 59th
83rd Ave. & West														Add to 59th Ave flow
ASSUME FREEWAY ON OPEN STRUCTURE EAST OF 43RD AVE. — Earth channel west of 43RD Ave														
43rd Ave.													0	
51st Ave.	1040	750	290	0.6		80	1.48	1.45	0.68	510	1.12	320	830	Not max.
	1360	980	380	0.6		100	1.25	1.22	0.50	490	0.92	350	840	
59th Ave.	2240	1610	630	0.6		100	1.25	1.22	0.50	805	0.92	580	1385	
67th Ave.	2640	1920	720	0.6		100	1.25	1.22	0.50	960	0.92	663	1623	Not max.
	3600	2620	980	0.6		120	1.08	1.05	0.36	943	0.76	745	1688	
75th Ave.	3840	2880	960	0.6		120	1.08	1.05	0.36	1040	0.76	730	1770	Not max.
	5120	3860	1260	0.6		140	0.97	0.94	0.27	1040	0.67	843	1883	
83rd Ave.	5100													Add to 75th
91st Ave. & West														Add to 75th

APP II 50 YR.

Future Conditions
Infiltration fc = 0.6
Impervious Area
Near 35th - 30% ±
West of 67th - 20% ±
Streets gather of 40min/mile

EXPECTED FLOWS 50 year rainfall intensity and duration unless noted

LOCATION	AREA IN ACRES: Total Area A	Pervious Area A_p	Imperv's Area A_i	Infiltr'n (final) in/hr f_c	Concentration Time: Street Slope	Min. t_c	RAIN: Point Intensity I	Average Intensity Ia	RUNOFF: Pervious $(Ia-f_c)0.8$ = Inches	Pervious $InxA_p$ = CFS	Impervious $(Ia-0.2)0.9$ = Inches	Impervious $InxA_i$ = CFS	Total Flow CFS	DESIGN FLOW AND REMARKS
Assume concrete lined channel and other criteria as Appendix I														
Freeway on open structure east of 43rd Ave.														
43rd Ave. - no flow													0	
47th Ave.	440	320	120	0.6		60	1.81	1.80	0.96	307	1.44	173	480	
51st Ave	800	580	220	0.6		60	1.81	1.79	0.95	552	1.43	315	867	Not max.
	1120	810	310	0.6		80	1.48	1.46	0.69	558	1.13	351	909	
59th Ave	2160	1600	560	0.6		80	1.48	1.45	0.68	1088	1.12	628	1716	
	2800	2080	720	0.6		100	1.25	1.22	0.50	1040	0.92	663	1703	Not max.
67th Ave	4000	2950	1050	0.6		100	1.25	1.21	0.49	1445	0.91	955	2400	
	4960	3720	1240	0.6		120	1.08	1.05	0.36	1340	0.76	940	2280	Not max
75th Ave.	5040	3800	1240	0.6		100	1.25	1.21	0.49	1860	0.91	1130	2990	
83rd Ave.	5920	4520	1400	0.6		100	1.25	1.20	0.48	2170	0.90	1260	3430	
91st Ave	6500	5000	1500	0.6		100	1.25	1.20	0.48	2400	0.90	1350	3750	
99th Ave	6240					100								Less than 91st Ave.
	8800	6850	1950	0.6		120	1.08	1.03	0.34	2330	0.75	1460	3790	
107th Ave. & West														Add to 99th Ave.

App III 50YR.

EXPECTED FLOWS 50 year rainfall intensity and duration unless noted

LOCATION	AREA IN ACRES Total Area A	Pervious Area A_p	Imperv's Area A_i	Infiltr'n (final) in/hr f_c	Concentration Time Street Slope	Min. t_c	RAIN Point Intensity I	Average Intensity Ia	RUNOFF Pervious $(Ia-f_c)0.8$ = Inches	$InxA_p$ = CFS	Impervious $(Ia-0.2)0.9$ = Inches	$InxA_i$ = CFS	Total Flow CFS	DESIGN FLOW AND REMARKS
If drainage is across Freeway at intervals shown. Other criteria as per Appendix I - Flow Time 40 Min/mile ea. way. Typical Areas - 25% impervious.														
1 mile	640	480	160	0.6		60	1.81	1.80	0.96	461	1.44	230	691	
	960	720	240			80	1.48	1.46	0.69	496	1.13	271	767	
	1280	960	320			100	1.25	1.22	0.49+	476	0.92	294	770	Max. 100 min.
	1600	1200	400			120	1.08	1.05	0.36	432	0.76	303	735	
1/2 mile	400	300	100	0.6		60	1.81	1.80	0.96	288	1.44	144	432	
	560	420	140			80	1.48	1.46	0.69	290	1.13	158	448	Max. 80 min.
	720	540	180			100	1.25	1.22	0.49	265	0.92	165	430	
1/4 mile	220	165	55	0.6		60	1.81	1.80	0.96	158	1.44	76	234	
	300	225	75			80	1.48	1.46	0.69	155	1.13	85	240	Max. 80 min.
	380	285	95			100	1.25	1.23	0.50	142	0.93	88	230	
1/8 mile	115	86	29	0.6		60	1.81	1.80	0.96	82	1.44	42	124	
	155	116	39			80	1.48	1.46	0.69	80	1.13	44	124	Max. 80 min.
	195	146	49			100	1.25	1.23	0.50	73	0.93	45	118	
1/16 mile	39	29	10	0.6		40	2.39	2.37	1.42	41	1.95	20	61	
	59	44	15			60	1.81	1.80	0.96	42	1.44	22	64	
	71	59	20			80	1.48	1.46	0.69	41	1.13	23	64	Max. 80 min.
	99	74	25			100	1.25	1.24	0.51	38	0.91	24	62	
51ST Ave - Collect 1 mile east, near same as typical 1 mile above, 40 min. time along Freeway													770	Use typical mile although % impervious is greater
75TH Ave - (20 min/mi. along Freeway)	1120	880	240	0.6		80	1.48	1.46	0.69	607	1.13	271	878	

Criteria -
As previous Appendices but M.C.F.C.D. channel in place and no flow contribution from North of Thomas Road.

EXPECTED FLOWS 50 **year rainfall intensity and duration unless noted**

LOCATION	AREA IN ACRES Total Area A	Pervious Area A_p	Imperv's Area A_i	Infiltr'n (final) in/hr f_c	Concentration Time Street Slope	Min. t_c	RAIN Point Intensity I	Average Intensity Ia	RUNOFF Pervious $(Ia-f_c)0.8$ = Inches	$InxA_p$ = CFS	Impervious $(Ia-0.2)0.9$ = Inches	$InxA_i$ = CFS	Total Flow CFS	DESIGN FLOW AND REMARKS
TYPICAL FLOWS ASSUMING M.C.F.C.D. CHANNEL CONSTRUCTED														
APP. I - Concrete Channel along Freeway														
27th to 35th Ave.														Minor change in area
43rd Ave.	1600	1120	480	0.6		90	1.35	1.32	0.58	650	1.01	485	1135	1587 w/o MCFCD or 71%
59th Ave.	3120	2240	880	0.6		100	1.25	1.21	0.49	1100	0.91	800	1900	2660 w/o MCFCD or 72%
75th Ave.	4440	3300	1140	0.6		110	1.17	1.13	0.42	1385	0.84	955	2340	3630 w/o MCFCD or 65%
83rd Ave. and west														Greater change than 75th
APP. II - Earth channel west of 43rd Ave.														
27th to 35th Ave.														Minor change in area
43rd Ave.	1600	1120	480	0.6		90	1.35	1.32	0.58	650	1.01	485	1135	1587 w/o MCFCD or 71%
59th Ave.	3050	2200	850	0.6		120	1.08	1.05	0.36	795	0.76	645	1440	Not max.
	2400	1740	660	0.6		100	1.25	1.22	0.50	870	0.92	606	1476	1960 w/o MCFCD or 75%
APP. II - Earth Channel West of 43rd Ave. Freeway on open structure east of 43rd Ave.														
51st Ave	800	580	220	0.6		80	1.48	1.45	0.68	395	1.12	245	640	830 w/o MCFCD or 77%
67th Ave.	1900	1370	530	0.6		100	1.25	1.22	0.50	685	0.92	485	1170	1688 w/o MCFCD or 69%
75th Ave and west														Greater change than 67th
APP. III - Concrete channel. Freeway on open structure east of 43rd Ave.														
51st Ave.	800	580	220	0.6		70	1.62	1.59	0.74	460	1.28	280	740	867 w/o MCFCD or 85%
59th Ave.	1440	1080	360	0.6		80	1.48	1.45	0.68	732	1.12	403	1135	1716 w/o MCFCD or 66%
75th Ave	2720	2070	650	0.6		100	1.25	1.22	0.50	1035	0.92	595	1630	2400 w/o MCFCD or 68%
APP. IV - Culverts or pipe crossing the Freeway at various intervals														Near same with MCFCD
Typical 1/4 mile spacing	180	135	45	0.6		50	2.06	2.05	1.16	157	1.66	75	232	240 w/o MCFCD
Typical 1/8 mile spacing	95	71	24	0.6		50	2.06	2.05	1.16	82	1.66	40	122	124 w/o MCFCD

APP II 50YR

Some Flow Calculations Using
Arizona Highway Dept. "Drainage Table"
dated 3-61

c_1 = 0.20 for little vegative cover

c_2 = 0.10 for flat slopes

c_3 = 0.10 for poor shape factor

"C" = 0.40 (could use the single factor 0.20 - page 8 of Table)

For the 50 year storm the 'K' factor to be applied to "C" is 1.15 for a resultant

C = 0.46 to be used in the formula

A = $C \sqrt[4]{M^3}$ or $Q = 10\ C \sqrt[4]{M^3}$

Where A = Opening area required at velocity 10'/second
Q = c.f.s. flow rate
C = Coefficient, see above
M = Area in acres

Location or Description	Area Draining Acres	From Formula cfs	
1 mile culvert or crossing spacing - 100 min. collection time	1280	975	Y & G typical is 770 cfs
51st Ave - 90 min. collection time. Concrete channel along Freeway	2880	1805	Y & G = 2040 cfs
35th Ave - 70 min. as above	960	792	Y & G = 887 cfs
91st Ave - 110 min. collection time channel along Freeway	8120	3950	Y & G = 4100 cfs

In the examples the State might choose smaller drainage areas (collection in less time) or might use the single coefficient "C" = 0.20 and in either or both cases obtain a much smaller cfs flow rate.

Storage Requirements

Quantities expected
from rain of frequency shown

Assumptions. Infiltration pervious = 0.6"
Infiltration impervious = 0.2"
Impervious area = 25% of Total

Figures in inches per hour except last column

10 Year

Duration	Intensity Inches/hr	Net Rate Pervious (0.6)	Net Rate Impervious (0.2)	Net Rate 25% Imperv.	Total Runoff Inches
30 min.	2.13	1.53	1.93	1.63	0.82
1 hr.	1.32	0.72	1.12	0.82	0.82
1½ hr.	0.97	0.37	0.77	0.47	0.70
2 hr.	0.79	0.19	0.59	0.29	0.58
2½ hr.	0.67	0.07	0.47	0.17	0.43
3 hr.	0.58	- -	0.38	0.10	0.10

50 Year

30 min.	2.88	2.28	2.68	2.38	1.19
1 hr.	1.82	1.22	1.62	1.32	1.32
1½ hr.	1.34	0.74	1.14	0.84	1.26
2 hr.	1.08	0.48	0.88	0.58	1.16
2½ hr.	0.92	0.32	0.72	0.42	1.05
3 hr.	0.80	0.20	0.60	0.30	0.90
4 hr.	0.64	0.04	0.44	0.14	0.56

100 Year

30 min.	3.30	2.7	3.1	2.8	1.4
1 hr.	2.10	1.5	1.9	1.6	1.6
1½ hr.	1.57	0.97	1.37	1.07	1.61
2 hr.	1.27	0.67	1.07	0.77	1.54
2½ hr.	1.07	0.47	0.87	0.57	1.42
3 hr.	0.93	0.33	0.73	0.43	1.29
4 hr.	0.74	0.14	0.54	0.25	1.00
6 hr.	0.53	0.0	0.33	0.08	0.48

Storage Requirements
Typical locations

Location	Area Draining In Time	Acres	Inches Runoff	100 Yr. Storm Quantities or as noted
75th Ave.	12 mi^2 - 3 hrs.	7,680	1.29	825 a.f.
75th with MCFCD Channel (USED)	4-3/4 mi^2 - 100 min.	3,040	1.6	405 a.f.
99th Ave.	24 mi^2 - 4 hrs. +	15,360	1.00	1,280 a.f.
99th Ave. with MCFCD Channel	7-3/4 mi^2 - 130 min.	4,960	1.53	632 a.f.
75th Ave. if bounded by 1 mile east	4 mi^2 - 170 min.	2,560	1.33	284 af 100 yr.
50 year	4 mi^2 - 170 min.	2,560	0.95	203 af 50 yr.
10 year	4 mi^2 - 170 min.	2,560	0.2	43 af 10 yr.
As above with MCFCD Channel	1 mi^2 - 50 min.	640	1.61	86 af 100 yr.
50 year	1 mi^2 - 50 min.	640	1.32	70 af 50 yr.
10 year	1 mi^2 - 50 min.	640	0.82	44 af 10 yr.
43rd Ave. (If bounded by Grand Ave. & Grand Canal & 27th Ave.)	3-1/2 mi^2 - 130 min. (Flow out westerly)	2,200	1.13	208 af 50 yr.

Notes: There are no storage sites available east of 43rd Avenue. If storage is used releases should be at average daily rate (i.e. - 825 a.f. is 416 c.f.s. flowing for 24 hours).

DESIGN FLOWS - VARIOUS ALTERNATES OF CHANNEL OR FREEWAY CONSTRUCTION

LOCATION	Calcul. Flow	DESIGN FLOWS CONCRETE CHANNEL 1. Freeway on fill	2. Freeway Depressed	3. Open East of 43rd Ave.	DESIGN WITH EARTH CHANNEL WEST OF 43RD AVE. 4. Freeway on fill	5. Freeway Depressed	6. Open East of 43rd Ave.
Flows West of location							
27th	0						
29th	251	260	260		260	260	
31st	485	500	510		500	510	
33rd	688	700	710		700	710	
35th	887	900	920		900	920	
39th	1263	1280	1310		1280	1310	
43rd	1587	1600	1630	0	1600	1630	0
47th				490			460
51st	2040	2050	2080	920	1860	1890	850
59th	2660	2670	2700	1730	1970	2000	1400
67th	3200	3210	3240	2410	2050	2080	1700
75th	3630	3640	3660	3000	2100	2120	1900
83rd	3900	3910	3930	3440	2150	2170	1950
91st	4100	4110	4130	3760	2200	2220	2000
99th	4150	4160	4180	3800	2250	2270	2050
107th	4200	4210	4230	3850	2300	2320	2100
115th	4250	4260	4280	3900	2350	2370	2150
El Mirage	4300	4310	4330	3950	2400	2420	2200
To Aqua Fria	4300	4310	4330	3950	2400	2420	2200

1. Concrete channel, Freeway on fill, elevated east of 27th Ave, APP. I
2. As 1. but Freeway depressed from east of 31ST to west of 39th Ave.
3. As 1. but Freeway on open structure east of 43rd Ave. See APP. III
4. Like 1. but earth west of 43rd. Ave., APP. II
5. Like 2. but earth west of 43rd Ave.
6. Like 3. but earth west of 43rd Ave. APP. II

APP. VIII 50 YR

Additions or Subtractions to Flow Reaching Freeway

Freeway

Assume unpaved portions can be maintained at infiltration rate near 50 year storm rate and therefore outflow negligible.

Assume for many years the Freeway paved portions will aggregate as follows:

Location	Freeway Elevated	Freeway Depressed
55th Ave. east	17 acres/mile	27 acres/mile
87th Ave. to 55th Ave.	12 acres/mile	not likely
87th Ave. west	10 acres/mile	not likely

Irrigation Ditches and Storm Drains

The irrigation and waste ditches can be helpful but are apt to be surcharged during bigger storms. No additions or subtractions are assumed.

City storm drain lines such as 27th, 35th and 43rd are designed only for the two year flow at a future onehalf mile spacing of drains. Under any event the increment of flow contribution in the average mile north of the Freeway is usually less than 20 c.f.s. In other words although any one city drain may have capacity in the 150 c.f.s. range - facilities for handling water reaching the Freeway should not credit, or utilize, as much as 20 c.f.s. of the drains capacity. No allowances were made for the City Storm Drains in this report.

Streets and Other Freeway Crossings

All crossings at or near ground level provide some leak-out or relief to water reaching the Freeway. If the streets cross at grade (Freeway elevated or depressed) they can provide 10 c.f.s. or more capacity.

Obviously if the Freeway is elevated more water can pass through on the crossing street without particular damage (or special design of the street crossing as a viaduct).

Pipe crossings even if built to take water from south to north across the Freeway (for Freeway drainage) will provide some leak-out (reverse flow) during larger storms.

PROPOSED LINED CHANNEL
Trapezoidal 2:1 Side Slopes
50 Yr. Flows

	Location	Length Feet	Design Q - Cfs	Design Slope	Size Bott. Depth	Area Sq. - Ft.	Velocity F.P.S.	Street Crossing Culverts	Freeboard Allowed	Lining Sq ft./ft.	Exc. C.Y./ft.	R/W Width Ft.
			HYDRAULIC PROPERTIES						ESTIMATING QUANTITIES			
1	27TH Ave to 28TH Ave.	400	125	10'/1000'	4' x 2'½	22.5	5.8		0.5	17.5	1.4	21
2	28TH to 29TH	660	150	0.4 "	6' x 3'	36.0	4.2		0.5	21.7	2.2	25
3	29TH to 30TH	660	260	0.4 "	6' x 4'	56	4.8		0.5	26.2	2.8	29
4	30TH to 31ST	620	380	0.4 "	8' x 4.5'	77	5.2		0.5	30.3	3.9	33
5	31ST to 33rd	1280	500	0.4 "	11' x 4.5'	90	5.6	2-10' x 4.5'	0.5	33.3	4.5	36
6	33rd to 35TH	1280	700	0.4 "	14' x 5'	120	6.0		1.0	40.8	6.5	43
7	35th to 37th	1280	900	0.4 "	19' x 5'	145	6.3	3-9' x 5'	1.0	45.8	7.7	48
8	37th to 39th	1280	1090	0.4 "	24' x 5'	170	6.5		1.0	50.8	8.9	53
9	39th to 41ST	1280	1280	0.4 "	29' x 5'	195	6.6	3-10' x 5.5'	1.0	55.8	10.0	58
10	41st to 43rd	1280	1440	0.2 "	34' x 6'	276	5.2		1.5	67.5	14.8	69
11	Subtotal	(10,020)										
12	43rd to 45th	1280	1600	0.2 "	35' x 6.3'	299	5.4	4-12' x 6'	2.0	72.0	17.2	73.2
13	45th to 47th	1320	1710	0.2 "	35' x 6.5'	312	5.5		2.0	73.0	17.8	74
14	47th to 49th	1320	1820	0.2 "	35' x 6.7'	324	5.6		3.0	78.3	20.9	78.8
15	49th to 51ST	1280	1930	0.2 "	35' x 7'	343	5.7		3.5	82.0	23.2	82
16	51ST to 53rd	1280	2050	0.6 "	24' x 6.5'	241	9.0	4-8' x 7'	3.5	68.7	17.5	69
17	53rd to 55th	1320	2205	0.8 "	24' x 6'	216	10.2		2.5	62.0	14.2	63
18	55th to 59th	2600	2360	1.0 "	24' x 6'	216	11.4		2.0	59.7	13.0	61
19	59th to 63rd	2600	2670	1.2 "	24' x 6'	216	12.5	4-8' x 6.5'	2.0	59.7	13.0	61
20	63rd to 67th	2500	2990	1.2 "	26' x 6.2'	238	12.7		2.0	62.6	14.1	63.8
21	67th to 71ST	2600	3210	1.2 "	26' x 6.5'	254	12.9	4-9' x 6.5'	2.5	66.2	15.9	67
22	71ST to 75th	2600	3425	1.2 "	28' x 6.5'	267	13.0		2.5	68.2	16.7	69
23	75th to 79th	2600	3640	1.2 "	30' x 6.5'	279	13.0	4-9' x 7'	5.5	83.7	25.6	83
24	79th to 83rd	2600	3775	1.2 "	32' x 6.5'	292	13.1		3.0	74.5	19.4	75
25	83rd to 87th	2600	3910	1.6 "	27' x 6.5'	260	15.0	4-11' x 6.5'	2.0	65.0	15.1	66
26	87th to 91ST	2600	3960	1.6 "	28' x 6.5'	267	15.0		2.0	66.0	15.5	67
27	91ST to 95th	2600	4110	0.6 "	40' x 7.5'	412	10.1	4-10' x 7'	1.5	80.2	20.9	81
28	95th to 99th	2600	4135	0.6 "	40' x 7.5'	412	10.1		1.5	80.2	20.9	81
29	99th to 105TH	3920	4160	0.6 "	40' x 7.5'	412	10.1	4-11' x 8'	2.5	84.7	23.9	85
30	105th to 107th	1280	4190	1.0 "	29' x 7.5'	330	12.7		2.5	73.7	19.6	74
31	107th to 111th	2600	4210	1.4 "	28' x 7.0'	294	14.5	4-10' x 7.5'	3.0	72.7	19.2	73
32	111th to 115TH	2400	4235	2.0 "	32' x 6.0'	264	16.3		2.0	67.8	15.6	69
33	115th to El Mirage	5200	4260	1.4 "	46' x 5.5'	313	13.7	4-10' x 6.5'	2.0	79.5	18.5	81
34	El Mirage to Transition	1280	4310	1.4 "	46' x 5.5'	313	13.7	4-12.5' x 6'	2.0	79.5	18.5	81
35	Transition	500	4310		46' x 5.5' TO 131' x 5.0'				2.0	136.5	31.0	122.5
36	Earth Channel	900	4310	0.49 "	131' x 5.0'	860	5.0		2.0		38.0	164
37	Total	64,400										
38												
39	NOTE: R/W width is the top width of channel (including freeboard) plus 5 ft.											
40												

APP. X 50 YR

Proposed Culvert Crossings
Estimating Quantities
For Lined Channel Along Freeway

Location	Size Width-Height	Excavation in C.Y. per l' Length	Concrete C.Y. per l' Length
31st Ave.	Two 10x4.5	6.8	2.3
35th Ave.	Three 9x5	9.7	2.9+
39th Ave.	Three 10x5.5	11	3.5
43rd Ave.	Four 12x6	21	5.9+
51st Ave.	Four 8x7	18	4.0
59th Ave.	Four 8x6.5	15.4	3.8
67th Ave.	Four 9x6.5	17.5	4.2
75th Ave.	Four 9x7	18	4.3
83rd Ave.	Four 11x6.5	21	5.5+
91st Ave.	Four 10x7	17.5	4.8
99th Ave.	Four 11x8	25	5.9
107th Ave.	Four 10x7.5	21	5.1
115th Ave.	Four 10x6.5	17.5	4.8
El Mirage	Four 12.5x6	21	5.9+

Culvert height as posted in water height.

LINED CHANNEL COSTS

Cost includes joints, cut off walls etc.

	LOCATION		1 TRAPEZOIDAL BOTT. x HGT. INCL. FREEBOARD	2 LENGTH FT.	3 EXCAVATION AT $0.50/C.Y.	4 LINING $/S.F. 0.50 east of 55th	0.70 west of 55th	5 UNIT COST PER FOOT	6 TOTAL
1	27th Ave	to 28th Ave.	4'x3'	400	$ 0.70	$ 8.75		$ 9.45	$ 3780
2	28	29	6'x3.5'	660	1.10	10.85		11.95	7890
3	29	30	6'x4.5'	660	1.40	13.10		14.40	9510
4	30	31	8'x5'	620	1.95	15.15		17.10	10610
5	31	33	11'x5'	1280	2.25	16.65		18.90	24200
6	33	35	14'x6'	1280	3.25	20.40		23.65	30300
7	35	37	19'x6'	1280	3.85	22.90		26.75	34300
8	37	39	24'x6	1280	4.45	25.40		29.85	38300
9	39	41	29'x6'	1280	5.00	27.90		32.90	42200
10	41	43	34'x7.5	1280	7.40	33.75		41.15	52710
11	Subtotal 27th to 43rd			(10,020)					(253,800)
12	43	45	35'x8.3'	1280	8.60	36.00		44.60	57100
13	45	47	35'x8.5'	1320	8.90	36.50		45.40	60000
14	47	49	35'x9.7'	1320	10.45	39.15		49.60	65500
15	49	51	35'x10.5'	1280	11.60	41.00	50¢	52.60	67300
16	51	53	24'x10'	1280	8.75	48.10	70¢	56.85	72800
17	53	55	24'x8.5	1320	7.10	43.40		50.50	66600
18	55	59	24'x8'	2600	6.50	41.80		48.30	125600
19	59	63	24'x8	2600	6.50	41.80		48.30	125600
20	63	67	24'x8.2	2500	7.05	43.80		50.85	127200
21	67	71	26'x9'	2600	7.95	46.30		54.25	141000
22	71	75	28'x9'	2600	8.35	47.65		56.00	145600
23	Subtotal 43rd to 75th			(20,700)					(1,054300)
24	75	79	30'x12'	2600	12.80	58.60		71.40	185,700
25	79	83	32'x9.5'	2600	9.70	52.15		61.85	161000
26	83	87	27'x8.5'	2600	7.55	45.50		53.05	137900
27	87	91	28'x8.5'	2600	7.75	46.20		53.95	140200
28	91	95	40'x9'	2600	10.45	56.15		66.60	173200
29	95	99	40'x9'	2600	10.45	56.15		66.60	173200
30	99	105	40'x10'	3920	11.95	59.30		71.25	279300
31	105	107	29'x10'	1280	9.80	51.60		61.90	78600
32	107	111	28'x10'	2600	9.60	50.90		60.50	157300
33	111	115	32'x8'	2400	7.80	47.45		55.25	132600
34	115	El Mirage	46'x7.5'	5200	9.25	55.65		64.90	337500
35	El Mirage to Transition		46'x7.5'	1280	9.25	55.65		64.90	83100
36	Transition		46'x7.5' to 131'x7.0'	500	15.50	95.50		111.00	55500
37	Earth Channel		131'x7.0'	900	19.00	0		19.00	17100
38	Subtotal 75th to end			(33,680)					(2,112,200)
39									
40	TOTAL			64,400					$ 3,420,300

CULVERTS

	LOCATION	LENGTH FT.	SIZE FT.	EXCAVATION AT $1.50/C.Y.	CONCRETE AT $70.00/C.Y.	UNIT COST PER FT.	TOTAL
1	31st Ave.	80'	Two 10'x4.5'	$ 10	$ 161	$ 171	$ 13680
2	35th	80'	Three 9'x5'	15	204	219	17520
3	39th	80'	Three 10'x5.5'	17	245	262	20960
4	43rd	100'	Four 12'x6'	32	414	446	44600
5	Subtotal						(96,760)
6	51st	80'	Four 8'x7'	27	280	307	24560
7	59th	80'	Four 8'x6.5'	23	266	289	23120
8	67th	80'	Four 9'x6.5'	26	294	320	25600
9	75th	80'	Four 9'x7'	27	301	328	26240
10	83rd	80'	Four 11'x6.5'	32	386	418	33440
11	91st	80'	Four 10'x7'	26	336	362	28960
12	99th	80'	Four 11'x8'	38	413	451	36080
13	107th	80'	Four 10'x7.5'	32	357	389	31120
14	115th	80'	Four 10'x6.5'	26	336	362	28960
15	El Mirage	80'	Four 12.5'x6'	32	413	445	35600
16	Subtotal West of 43rd						(293,680)
17							
18	TOTAL						$ 390,440
19							

NOTE: Culvert height shown is water
See APP. X for channel properties
See APP XI for culvert quantities

APP. XII 50 YR.

Right-of-Way Requirements & Costs
Lined Channel

	Location	Length In Feet	Actual Descr.	Actual Amount	Hypothetical Descr.	Hypothetical Amount
	East of 27th Ave.	- -	None			None
	27th to 28th Ave.	450		None	6 lots @ $14,000	$ 84,000
	28th to 30th Drive	1,450	Field	None	0.9 ac. @ 10,000	9,000
	30th Dr. to 31st	550	3 lots	$ 36,000	4 lots @ 12,000	48,000
	31st to 33rd Ave.	800	4 lots	48,000	8 lots @ 12,000	96,000
	33rd to 34th Ave.	950	3 lots	39,000	16 lots @ 13,000	208,000
	34th to 35th Ave.	800	5 lots	55,000	11 lots @ 11,000	121,000
	35th to 37th Ave.	1,200	4 lots	60,000	8 lots @ 15,000	120,000
	37th to 39th Ave.	1,200	9 lots	126,000	14 lots @ 14,000	196,000
(1)	39th to 41st Ave.	1,500	Field	16,000	2 ac. @ 8,000	16,000
			3 lots	45,000	3 lots @ 15,000	45,000
	41st to 43rd Ave.	1,100	10 lots	150,000	15 lots @ 15,000	225,000
	Subtotal			$575,000		$1,168,000
(2)	43rd to 51st Ave.	5,200	6.2 ac.	27,900	9.2 ac. @ 4,500	41,400
	51st to 59th Ave.	5,200	4.7 ac.	21,100	7.6 ac. @ 4,500	34,200
	59th to 67th Ave.	5,100	4.5 ac.	20,200	7.4 ac. @ 4,500	33,300
	67th to 75th Ave.	5,200	5.2 ac.	20,800	8.1 ac. @ 4,000	32,400
	75th to 83rd Ave.	5,200	6.5 ac.	22,800	9.4 ac. @ 3,500	32,900
	83rd to 91st Ave.	5,200	5.0 ac.	17,500	8.0 ac. @ 3,500	28,000
	91st to 99th Ave.	5,200	6.7 ac.	20,100	9.7 ac. @ 3,000	29,100
	99th to 107th Ave.	5,200	6.8 ac.	20,400	9.8 ac. @ 3,000	29,400
	107th to 115th Ave.	5,000	5.3 ac.	15,900	8.2 ac. @ 3,000	24,600
	115th to El Mirage	5,200	6.7 ac.	20,100	9.7 ac. @ 3,000	29,100
	El Mirage to)	1,280	1.7 ac.	5,100	2.4 ac. @ 3,000	7,200
	Agua Fria)	1,400	4.0 ac.	4,000	4.8 ac. @ 1,000	4,800
	Subtotal		63.3 ac.	$215,900		$326,400
	Total			$790,900		$1,494,400

(1) Assume alignment can be moved southerly into field here.
(2) Assume present right-of-way can accommodate 25' of the required channel right-of-way width for actual added acquisitions west of 43rd Ave.
(3) Contingencies and engineering and overheads totaling 20% are later added to above.

LINED CHANNEL COSTS
WITH 43RD AVE. EASTERN BOUNDARY
(Freeway elevated east of 43rd Ave. Compared to elevated east of 27th Ave.)

	1	2	3	4	5	6	7	8	9	10	11	12	13
	LINED CHANNEL 27TH AVE TO AGUA FRIA						LINED CHANNEL 43RD AVE. TO AGUA FRIA						
LOCATION	CHANNEL CAP. C.F.S.	LENGTH FT.	SIZE INCL. FREEBOARD	UNIT COST PER FT.	TOTAL (see APP. XII)	R/W WIDTH (See APP. X)	R/W COST (see APP. XIII)	CHANNEL CAP. C.F.S.	LENGTH FT.	SIZE INCL. FREEBOARD (Approx.)	UNIT COST PER FT.	TOTAL	R/W WIDTH	R/W COST (25' available)
27th Ave to 43rd Ave	0 to 1490	10020	To 34'x7.5'	To $41.15	$253800	to 69'	$575000	0	0			0		
43rd to 47th	1610	2600	35'x8.5'	45.10	117100	73.7		300	2600	6x7	$16.25	$42200	39	$3800
47th to 51st	1865	2600	35'x 10'	51.10	132800	80.4	27900	800	2600	16x9	50¢ 28.00	72800	57	8500
51st to 55th	2185	2600	24'x9.3'	53.60	139400	66		1100	2600	10x9	70¢ 38.00	98800	51	7000
55th to 59th	2460	2600	24'x8'	48.30	125600	61	21100	1500	2600	16x8	41.00	106500	53	7500
59th to 67th	2890	5100	24'x8.1	49.60	252800	62.3	20200	2070	5100	18x8	43.00	219000	55	15700
67th to 75th	3365	5200	27'x 9'	55.00	286600	68	20800	2700	5200	21x9	49.00	255000	62	17600
75th to 83rd	3720	5200	31'x10.5'	66.70	346700	79	22800	3220	5200	26x10.5	60.00	312000	73	20000
83rd to 91st	3950	5200	27'x8.5	53.50	278100	66.5	17500	3600	5200	24x8.5	51.00	265000	63	15900
91st to 99th	4170	5200	40'x 9'	66.60	346400	81	20100	3780	5200	36x9	63.00	327500	77	18600
99th to 105th	4170	3920	40'x10'	71.25	279300	85		3800	3920	36x10	68.00	267000	81	15200
105th to 107th	4200	1280	29'x10'	61.90	78600	74	20400	3830	1280	26x10	58.00	74200	71	4100
107th to 115th	4280	5000	30'x9'	58.00	289900	71	15900	3850	5000	27x9	56.00	280000	68	14800
115th to El Mirage	4300	5200	46'x7.5'	64.90	337500	81	20100	3900	5200	42x7.5	62.00	322000	77	18600
El Mirage to end Trans.	4300	1780	60'x7'	77.80	138600	100±		3950	1780	56x7	74.00	132000	90±	6000
Trans. to end (Earth)	4300	900	131'x7'	19.00	17100	164	9100	3950	900	120x7	17.50	15700	153	2600
Subtotal West of 43rd Ave.		54380			$3,166,500		$215900		54380			$2,789,700		$175,900
CULVERTS														
27th Ave to 43rd Ave.		Four-340'			96,760				0					
51st Ave	2050	80	Four 8'x10.5'	30.7	24560			920	80	Two 8X10	17.0	13600		
59th	2670	80	" 8'x8.5'	28.9	23120			1730	80	two 11X8.5	22.8	18240		
67th	3210	80	" 9'x9'	32.0	25600			2410	80	three 9x9	25.8	20640		
75th	3640	80	" 9'x9.5'	32.8	26240			3000	80	three 10X9.5	31.0	24800		
83rd	3910	80	" 11'x8.5'	41.8	33440			3490	80	Four 10X8.5	36.2	28960		
91st	4110	80	" 10'x8.5'	36.2	28960			3760	80	Four 9X8.5	33.0	26400		
99th	4160	80	" 11'x10.5'	45.1	36080			3800	80	Four 10X10.5	38.9	31120		
107th	4210	80	" 10'x10.5'	38.9	31120			3850	80	Four 9X10.5	36.3	29040		
115th	4235	80	" 10'x8.5'	36.2	28960			3900	80	Three 12X8.5	34.9	27920		
El Mirage	4310	80	" 12.5'x8'	44.5	35600			3950	80	Four 11.5X8	42.0	33600		
Subtotal West of 43rd Ave.					$293,680							$254,320		

NOTE: R/W COSTS from APP. XIII

APP. XIV 50 Yr.

QUANTITIES AND COSTS

UNLINED CHANNEL WEST OF 43RD AVENUE

(Earth, Trapezoidal. 3:1 side slope)

LOCATION	LENGTH Ft.	DESIGN Q - C.F.S.	AREA FOR AT 6' Depth V = 3'/Sec.	Bott.	Top	R/W WIDTH ADD 2' Freeb'd and 3' Width	EXCAVATION CY/LIN.FT.	EXCAVATION COSTS 60¢/C.Y.	ACRES OF R/W PURCHASE WIDTH 25 ft AVAILABLE	R/W COST
27th to 43rd Ave.										
Same as lined channel	10,020	to 1600								
UNLINED										
43rd Ave to 51st Ave.	5200	1600 to 1860	570	77'	113'	130	30	$ 93,100	12.5	$ 56300
51st 59th	5200	1860 to 1970	640	89'	125'	142	33.5	104.500	14	63000
59th 67th	5100	1970 to 2050	670	94	130'	147	35	107.000	14.3	64300
67th 75th	5200	2050 to 2100	690	97'	133	150	36	112.500	15	60000
75th 83rd	5200	2100 to 2150	710	100'	136	153	37	115500	15.3	53600
83rd 91st	5200	2150 to 2200	725	103'	139'	156	38	118500	15.7	54900
91st 99th	5200	2200 to 2250	740	105'	141'	158	38	118500	15.9	47.700
99th 107th	5200	2250 to 2300	755	108'	144'	161	39	122000	16.3	48900
107th 115th	5000	2300 to 2350	775	110'	146'	163	40	120000	15.9	47.700
115th to El Mirage	5200	2350 to 2400	790	113'	149'	166	41	128.000	16.8	50400
El Mirage to end	2680	2400	800	115'	151'	168	41	66000	8.8	8800
Subtotal	54,380							1,206,200	160.5	$ 555,600
							Allow. for drop structures (30)	150000		

AS ABOVE BUT FREEWAY ELEVATED ON OPEN STRUCTURE EAST OF 43RD AVENUE

27th Ave. to 43rd Ave.	None	0								
UNLINED										
43rd Ave. to 47th Ave.	2600	0 TO 460 say	120	2'	38'	55	7.7	$ 12000	1.8	$ 8100
47th 51st	2600	460 TO 850	220	19'	55'	72	12.8	20000	2.8	12600
51st 59th	5200	850 to 1400	375	45'	81'	98	20.4	63500	8.7	39100
59th 67th	5100	1400 to 1700	520	69'	105'	122	27.6	84500	11.4	51300
67th 75th	5200	1700 to 1900	600	82'	118	135	31.2	97500	13.1	52400
75th 83rd	5200	1900 to 1950	640	89'	125'	142	33.5	104500	14.0	49000
83rd 91st	5200	1950 to 2000	660	92'	128'	145	34.4	107500	14.3	50100
91st 99th	5200	2000 to 2050	680	95'	131'	148	35.3	110000	14.7	44100
99th 107th	5200	2050 to 2100	690	97'	133'	150	35.9	112000	15.0	45000
107th 115th	5000	2100 to 2150	710	100'	136'	153	36.8	110500	14.7	44100
115th to El Mirage	5200	2150 to 2200	730	104'	140'	157	37.9	118000	15.8	47400
El Mirage to end	2680	2200	740	105'	141'	158	38.2	61500	8.2	8200
Subtotal	54,380							$ 1,001,500	134.5	$ 451,400
							Allow. for drop structures (30)	135,000		

NOTE: Excavation cost estimated higher than for lined channel - may need haul-out.

APP. XV 50 Yr.

Approximate Cost Estimates
Storm Drain Lines to Salt River

51st Ave. - Say handle 770 c.f.s. for 50 year storm (Typical 1 mile spacings)

About 19,000 feet

12,000' at 3'/1000 - requires 108" Pipe or 8x8 Box
7,000' at 1.2/1000 - requires 126" Pipe or 9x9.5 Box

Approximate Cost				
8x8 Box	- 12,000'	@ $ 91.00	-	$1,092,000
9x9.5 Box	- 7,000'	@ 105.00		735,000
Crossings & appurtenances				100,000
	Subtotal			$1,927,000
	Contingencies			193,000
	Engineering & Overheads			193,000
	Total			$2,313,000

75th Ave. - Say handle 880 c.f.s. - 50 year storm on one mile east.

About 24,000 feet

12,000' at 2.3'/1000 - requires 120" Pipe or 9x8.5 Box.
12,000' at 1.4/1000 - requires 132" Pipe or 10x9.5 Box.

Approximate Cost			
9x8.5 Box	- 12,000'	@ $ 97.00	$1,164,000
10x9.5 Box	- 12,000'	@ 114.00	1,368,000
Crossings & appurtenances			120,000
	Subtotal		$2,652,000
	Contingencies		265,000
	Engineering & Overheads		265,000
	Total		$3,182,000

43rd Ave. - Say handle 1600 c.f.s. or 50 year storm collecting from 27th Ave.

About 18,100 feet

6,300' @ 1.3'/1000 requires 15.5x10 Box
11,800' @ 2.3'/1000 requires 12.5x10 Box

Approximate Cost				
12.5x10 Box	- 11,800 l.f.	@	$145.00	$1,711,000
15.5x10 Box	- 6,300 l.f.	@	175,000	1,102,500
Crossings & appurtenances				100,500
	Subtotal			$2,914,000
	Contingencies			291,000
	Engineering & Overheads			291,000
	Total			$3,496,000

Near 96" diameter pipe and above box culverts become less costly per foot.

Culverts Crossing the Freeway

Notes:

1. Assume shallow concrete culvert or series of small pipes would probably be less in first cost.

2. From flow calculations, Appendix XXV, can produce 65 c.f.s. in double 1.5'x7' waterway. Actual inside height of box 2' plus to suit roadway.

3. From flow reaching Freeway, Appendix IV we need 64 c.f.s. at 1/16 mile spacing for the 50 year flow.

Culverts

a. Double 1.5'x7' waterway with 10-inch walls and floors require 1.3 cubic yard per foot. Forming top slab expensive so may use precast or special methods.

b. Length required 168 feet east of 87th Avenue without frontage roads and 224 feet west of 87th Avenue with frontage roads, but use only the 168 foot length in this cost analysis.

Item	Unit Cost	Total
Excavation	Neglect	- -
Concrete - 168' length	$ 90.00	$ 15,120
Headwalls, transitions, miscl.		880
Subtotal		$ 16,000
Contingencies @ 10%		1,600
Engineering & Overheads @ 10%		1,600
Average Total Cost Per Crossing		$ 19,200

c. Need approximately 16 per mile

APPROXIMATE COST PER MILE = 16 x $19,200 = $307,200

Pipes

a. 24" pipe culverts would require cluster of 7 at each 1/16 mile, see Appendix IV, and as above.

Item	Unit Cost	Total
Excavation and pipe - each 168' long or total 1176'	$9.00	$10,584
Headwalls, transitions, miscl.		1,416
Subtotal		$12,000
Contingencies @ 10%		1,200
Engineering & Overheads @ 10%		1,200
Average Total Cost per Crossing		$14,200

APPROXIMATE COST PER MILE = 16 x $14,200 = $227,200

SUMMARY - FIRST COSTS OF CHANNELS
VARIOUS FREEWAY VERTICAL ALIGNMENTS
(R/W, channel and culvert costs developed in previous appendices - remaining items here)

	1	2	3	4	5	6	7	8	9	10	11	12	13
		LINED CHANNEL				EARTH CHANNEL WEST OF 43RD AVENUE							
		FREEWAY ON LOW FILL			FREEWAY DEPRESSED	OPEN STRUCTURE E. OF 43RD		FREEWAY ON LOW FILL		FREEWAY DEPRESSED		OPEN STRUCTURE E. OF 43RD	
	DESCRIPTION	UNIT PRICE	TOTAL	REMARKS	TOTAL	REMARKS	TOTAL	REMARKS	TOTAL	REMARKS	TOTAL	REMARKS	TOTAL
1	Land & Right of Way												
2	East of 43rd Ave.	Subdiv. See App XIII	$ 575,000	Say same	$ 575,000	None	-		$ 575000		$ 575,000		-
3	43rd to Aqua Fria	63.3 Acres	215900	Say same	215900		$ 175900		555600		555600		$ 451400
4	Construction Costs								-				
5	Pump Stations, Collect	-	-	3 ea @ 30,000	90000	-	-		-		90000		-
6	Pumping Equipment	-	-	3 Sets @ 20,000	60000	-	-		-		60000		-
7	Lined Channel								-				
8	East of 43rd Ave.	10020 l.f. See App. XII	253800	2% more	260000	None			253800		260000		-
9	43rd Ave. to 75th Ave.	20700 l.f.	1054300		1054300								
10	75th Ave to El Mirage	31000 l.f.	1956500	Say same	1956500	See XIV	2789700	Earth 43rd Ave to end and drop Structures	1,356,200	Say same	1,356,200	Channel & drop Structure	1,136,500
11	El Mirage to Transition	1280 l.f.	83100		83100								
12	Transition	500 l.f.	55500		55500								
13	Earth Channel	900 l.f.	17100		17100								
14	Subtotal Lined Channel	64,400 l.f.	(3,420,300)		(3,576,500)		(2,789,700)		(1,610,000)		(1,766,200)		(1,136,500)
15	Guard Rail												
16	East of 43rd Ave.	10020 l.f. 3.50	35100	Less	8000	None	-		35100		8000		-
17	West of 43rd Ave.	52980 l.f. 3.50	185400	Same	185400		185400		185400		185400		185400
18	Collectors, paved inverts												
19	East of 43rd Ave.	20 Ea. 500	10000	Same	10000	None	-		10000		10000		-
20	West of 43rd Ave	70 Ea. 200	14000	Same	14000		14000		28000		28000		28000
21	Irrigation Crossings												
22	Make R.I.D a siphon	1	40000	Same	40000	Less	38000		80000		80000		75000
23	43rd Ave to 75th Ave.	33 1200	39600	Same	39600	Less	37000		99000		99000	$ 2800 ea.	92800
24	75th Ave to end	55 1400	77000	Same	77000	Less	75000		203500		203500	3600 ea.	198000
25	Utility Crossing												
26	East of 43rd Ave.		8000	Say same	8000	None	-		8000		8000		-
27	East of 43rd - San. Sewer		20000	"	20000	"	-		20000		20000		-
28	West of 43rd Ave.	-	-		-	"	-		-				-
29	Box Culverts												
30	43rd Ave and East	4	96800	2% more	98000	None	-		96800		98000	None	-
31	West of 43rd Ave.	10	293700	Say same	293700	See XIV	254300	Smaller but need approach ea.	293700		293700		280000
32	Subtotal		(4,239,900)		(4,370,200)		(3,393,400)		(2,669,500)		(2,799800)		(1,995,700)
33	Appurt. & Miscl.	5%	212000		218500		169700		133500		140000		99800
34	Subtotal Construction		4,451,900		4,588,700		3563100		2,803,000		2,939,800		2,095,500
35	SUBTOTAL CONSTR. & R/W.		5,242,800		5,379,600		3739000		3,933,600		4,070,400		2,546,900
36	Contingencies - 10%		524300		538000		373900		393400		407000		254700
37	Engr., admin. - 10%		524300		538000		373900		393400		407100		254700
38	TOTAL - FIRST COST		$ 6,291,400		$ 6,455,600		4,486,800		4,720,400		4,884,500		3,056,300
39	Portion 43rd Ave. & east		(1,223,900)		(1388100)		-		(1,223,900)		(1,388,100)		-
40	Portion West of 43rd Ave.		(5,067,500)		(5,067500)		(4,486,800)		(3,496,500)		(3,496,400)		(3056300)

APP. XVIII 50 YR.

SUMMARY- ANNUAL COSTS OF CHANNELS
VARIOUS FREEWAY VERTICAL ALIGNMENTS

	1	2	3	4	5	6	7	8	9	10	11	12	13
	CONCRETE LINED CHANNEL					EARTH CHANNEL ON PORTION WEST OF 43RD AVE.							
	FREEWAY ON LOW FILL OPEN STRUCTURE EAST OF 27TH ①		FREEWAY DEPRESSED 31ST AVE. to 39TH AVE. ②		FREEWAY ON LOW FILL OPEN STRUCTURE EAST OF 43RD ③		FREEWAY ON LOW FILL OPEN STRUCTURE EAST OF 27TH ④		FREEWAY DEPRESSED 31ST AVE to 39TH AVE. ⑤		FREEWAY ON LOW FILL OPEN STRUCTURE EAST OF 43RD ⑥		
Land & Right of way													
East of 43rd Ave.	Subdiv.	$690000	Subdiv.	690000		-	Subdiv.	$690,000	Subdiv.	$690,000	none	0	
43rd Ave to Aqua Fria	63.3 Acres	259100	63.3 Acres	259100		$ 214200	160.5 Acres	666700	160.5 Acres	666700	134.5 Acres	541700	
Subtotal		949100		949100		214200		1,356,700		1,356,700		541700	
Construction Costs													
Pump Stations		-	3 ea.	113400		-			3 ea.	113400		-	
Pump Equipment		-	3 Sets	75600		-			3 Sets	75600		-	
Lined Channel E. of 43rd	10020 l.f.	533900	10020 l.f.	509100		-	10020 l.f.	533900	10,020 l.f.	509000		-	
Lined Channel 43rd to end	54380 l.f.	4,808400	53380 l.f.	4,808,400		4,275,800							
Earth Channel 43rd to end		-				-	54380 l.f.	2829800	54380 l.f.	2,829,800	54,380 l.f.	2514,600	
TOTAL - FIRST COST		$6.291400		$6,455,600		$4,490,000		$4,720,400		$4,884,500		$3,056,300	
Annual Costs													
Channel - 40 Yrs @ 5%	CRF 0.05828	311349	0.05828	309962		249194		196036		194585		146,551	
Pump Sta & collectors	0.05828	-	0.05828	6609		-		-		6,609		-	
Pumps 15 Yrs @ 5% Int.	CRF 0.09634	-	0.09634	7283		-		-		7,283		-	
Land	CRF 0.05	47455	0.05	47455		10710		67835		67835		27085	
M&O Channel, lined	0.0025	13354		13296		10670		1335		1272		-	
M&O Channel, earth		-		-		-		42447		42447		37719	
M&O Pumps Sta.	0.0025	-		284		-		-		284		-	
M&O Pumps	0.06	-		4536		-		-		4536		-	
Annual Costs		$372,158		389,425		270,574		307653		324,851		211,355	
Annual cost diff. from LINED CHANNEL ①		0		+ 17,267		- 101584		- 64505					
Indicated first cost difference at 5%				$ 345,340 more		$ 2,031,680 less		$ 1,290,100 less					
Annual diff. from ④								0		+ 17,198		- 96,298	
Indic. First Cost diff. from ④										$ 343,960 more		$ 1,925,960 less	

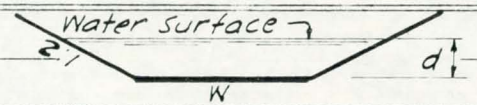
NOTE: Contingencies, engineering and overheads included with their respective items.
C. R.F. is capital recovery factor.

APP. XIX 50 Yr.

AREA DESCRIPTION I-10 FREEWAY 50 YR.

CONC. CHANNEL WEST OF 27TH AVE.

n=0.011 Big Concrete Culverts
n=0.012 Pipe Culverts 21" & Larger
n=0.015 Street Paving
n=0.020 Earth - Best
n=0.0225 Corr. Culverts
n=0.030 Earth - Brushy - Poor
n=0.050 Rocky Streams

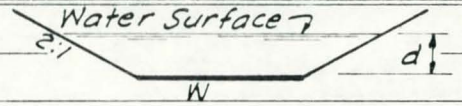
STA. OR LOCATION	WATERWAY DESCRIPTION			ROUGHNESS n	SLOPE FT. PER. 1000	AREA SQ.FT. A	p=WET. PER. $r=\frac{A}{p}$	VEL. FT./SEC. V	QUANT. C.F.S. Q
		W=4'	d=2.5'	0.011	1.0	22.5	1.5	5.8	130
		W=6'	d=3'	"	0.4	36	1.9	4.2	150
		W=6'	d=4'	"	0.4	56	2.3	4.8	268
		W=8'	d=4.5'	"	0.4	77	2.7	5.2	400
		W=11'	d=4.5	"	0.4	90	2.9	5.6	505
		W=14'	d=5'	"	0.4	120	3.3	6.0	720
		W=19'	d=5'	"	0.4	145	3.5	6.3	915
		W=24'	d=5'	"	0.4	170	3.7	6.5	1100
		W=29'	d=5'	"	0.4	195	3.8	6.6	1290
		W=34'	d=6'	"	0.2	276	4.5	5.2	1435
		W=35'	d=6.3'	"	0.2	299	4.8	5.4	1610
		W=35'	d=6.5'	"	0.2	312	4.9	5.6	1715
		W=35'	d=7'	"	0.2	343	5.2	5.7	1950
		W=24'	d=6.5'	"	0.6	241	4.5	9.0	2170
		W=24'	d=6'	"	0.8	216	4.3	10.2	2200
		W=24'	d=6'	"	1.0	216	4.3	11.4	2460
		W=24'	d=6'	"	1.2	216	4.3	12.5	2700
		W=26'	d=6.5'	"	1.2	254	4.6	12.9	3260
		W=28'	d=6.5'	"	1.2	267	4.7	13.0	3470
		W=30'	d=6.5'	0.011	1.2	279	4.7	13.0+	3630

APP XX 50 YR
1 of 2

AREA DESCRIPTION I-10 FREEWAY 50 YR

CONC. CHANNEL WEST OF 27TH AVE.

n=0.011 Big Concrete Culverts
n=0.012 Pipe Culverts 21" & Larger
n=0.015 Street Paving
n=0.020 Earth - Best
n=0.0225 Corr. Culverts
n=0.030 Earth - Brushy - Poor
n=0.050 Rocky Streams

STA. OR LOCATION	WATERWAY DESCRIPTION		ROUGHNESS n	SLOPE FT. PER. 1000	AREA SQ FT. A	p=WET. PER. r=A/p	VEL. FT./SEC. V	QUANT. C.F.S. Q
		W=32' d=6.5'	0.011	1.2	292	4.8	13.1	3810
		W=27' d=6.5'	"	1.6	260	4.7	15.0	3900
		W=28' d=6.5'	"	1.6	267	4.7	15.0	4000
		W=40' d=7.5'	"	0.6	412	5.5	10.1	4170
		W=29' d=7.5'	"	1.0	330	5.3	12.7	4200
		W=28' d=7'	"	1.4	294	5.0	14.5	4260
		W=32' d=6'	"	2.0	264	4.5	16.3	4300
		W=46' d=5.5'	0.011	1.4	313	4.4+	13.7	4300
EARTH	CHANNEL W. OF TRANS. 2:1 SIDE SLOPE							
		W=131' d=6'	0.020	0.49	860	5.4+	5.0	4300

App VII 50 YR
2 of 2

AREA DESCRIPTION I-10 FREEWAY 50 YR

BOX CULVERTS - As alternates to Pipe Culverts.

n=0.011 Big Concrete Culverts
n=0.012 Pipe Culverts 21" & Larger
n=0.015 Street Paving
n=0.020 Earth - Best
n=0.0225 Corr. Culverts
n=0.030 Earth - Brushy - Poor
n=0.050 Rocky Streams

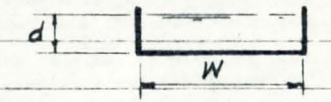
STA. OR LOCATION	WATERWAY DESCRIPTION		ROUGHNESS •n	SLOPE FT. PER. 1000	AREA SQ.FT. •A	p=WET. PER. $r = \frac{A}{p}$	VEL. FT./SEC. •V	QUANT. C.F.S. •Q
51st	To Salt River	8'x8'	0.011	3.0	64	2	12+	770
	(Typical draining for ea. 1 mile East)	9'x9.5'	"	1.3	85.5	2.3	9	770
75Th	To Salt River	9'x8.5'	0.011	2.3	76.5	2.2	11.5	880
	(Draining 1 mile East)	10'x9.5'	"	1.4	95	2.4+	9.25	880
43rd	To Salt River	12.5'x10'	0.011	2.3	1250	2.8-	12.8	1,600
	(Draining from 27th Ave.)	15.5'x10'	"	1.3	1550	3.0+	10.32	1,600

AREA DESCRIPTION I-10 FREEWAY

RECTANGULAR CHANNEL

n=0.011 Big Concrete Culverts
n=0.012 Pipe Culverts 21" & Larger
n=0.015 Street Paving

n=0.020 Earth - Best
n=0.030 Earth - Brushy - Poor

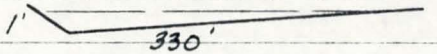
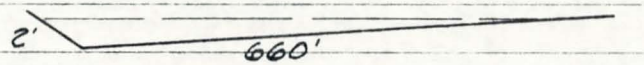
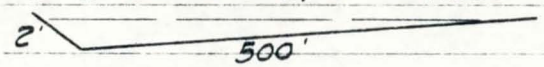
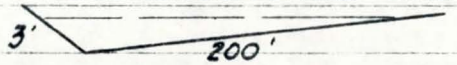
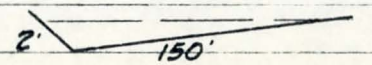
STA. OR LOCATION	WATERWAY DESCRIPTION			ROUGHNESS =n	SLOPE FT. PER. 1000	AREA SQ.FT. =A	p=WET. PER. $r=\frac{A}{p}$	VEL. FT./SEC. =V	QUANT. C.F.S. =Q
		W=8'	d=3'	0.011	1.0	24	1.7	6.2	149
		9'	4'	"	0.4	36	2.1	4.5	162
		12'	4'	"	0.4	48	2.4	4.9	235
		14'	5'	"	0.4	70	2.9	5.6	392
		16'	5'	"	0.4	80	3.1	5.8	464
		18'	5'	"	0.4	90	3.2	5.9	530
		20'	5'	"	0.4	100	3.3	6.0	600
		22'	5'	"	0.4	110	3.4	6.1	670
		28'	5'	"	0.2	140	3.5	4.5	630
		30'	5'	"	0.2	150	3.8	4.6	690

AREA DESCRIPTION I-10 FREEWAY

SWALE ALONG FREEWAY

n=0.011 Big Concrete Culverts
n=0.012 Pipe Culverts 21" & Larger
n=0.015 Street Paving

n=0.020 Earth-Best
n=0.030 Earth-Brushy-Poor

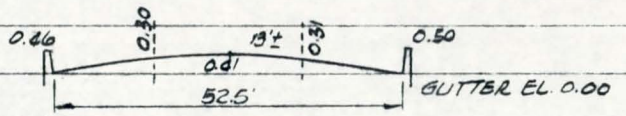
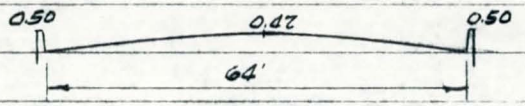
STA. OR LOCATION	WATERWAY DESCRIPTION	ROUGHNESS =n	SLOPE FT. PER. 1000	AREA SQ.FT. =A	p=WET. PER. $r=\frac{A}{p}$	VEL. FT/SEC. =V	QUANT. C.F.S. =Q
	N.-S. Ground Slope 3'/1000'						
		0.020	1.6	165	0.5	1.8	297
		"	1.2	"	"	1.5	208
		"	0.5	"	"	0.95	157
		0.020	1.6	660	1.0	2.8	1950
		"	1.2	"	"	2.4	1585
		"	0.5	"	"	1.45	957
		"	0.2	"	"	0.95	627
	N-S Ground Slope 4'/1000'						
		0.020	1.6	500	1.0	2.8	1400
		"	1.2	"	"	2.4	1200
		"	0.5	"	"	1.45	725
		"	0.2	"	"	0.95	475
	Shallow Excavated Channel						
		0.020	1.2	310	1.5	3.2	993
		"	0.5	"	"	2.1	651
		"	0.2	"	"	1.3	403
		0.020	1.2	150	1.0	2.4	360
			0.5	"	"	1.45	218
			0.2	"	"	0.95	143

AREA DESCRIPTION I-10 FREEWY

CONTRIBUTING STREETS

n=0.011 Big Concrete Culverts
n=0.012 Pipe Culverts 21" & Larger
n=0.015 Street Paving

n=0.020 Earth - Best
n=0.030 Earth - Brushy - Poor

STA. OR LOCATION	WATERWAY DESCRIPTION	ROUGHNESS n	SLOPE FT. PER. 1000	AREA SQ.FT. A	p=WET. PER. r=A/p	VEL. FT./SEC. V	QUANT. C.F.S. Q
31 ST. AVE.		0.015	3'	8	0.2	1.5	12
39TH AVE.		0.015	3'	10'	0.2	1.5	15
TYP 64 FT. - LOW CROWN		0.015	4'	15	0.23	2.1	31.5
		"	3'	"	"	1.8	27.0
		"	2'	"	"	1.5	22.5
		"	1'	"	"	1.1	16.5

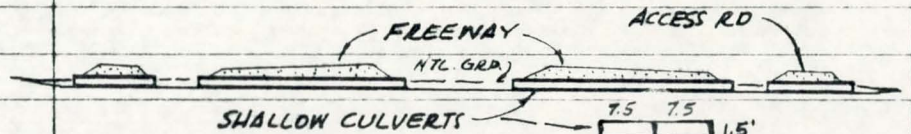
APP XXIV 50 YR

AREA DESCRIPTION I-10 FREEWAY 50 YR

POSSIBLE CULVERT OR PIPE CROSSINGS

n=0.011 Big Concrete Culverts
n=0.012 Pipe Culverts 21" & Larger
n=0.015 Street Paving

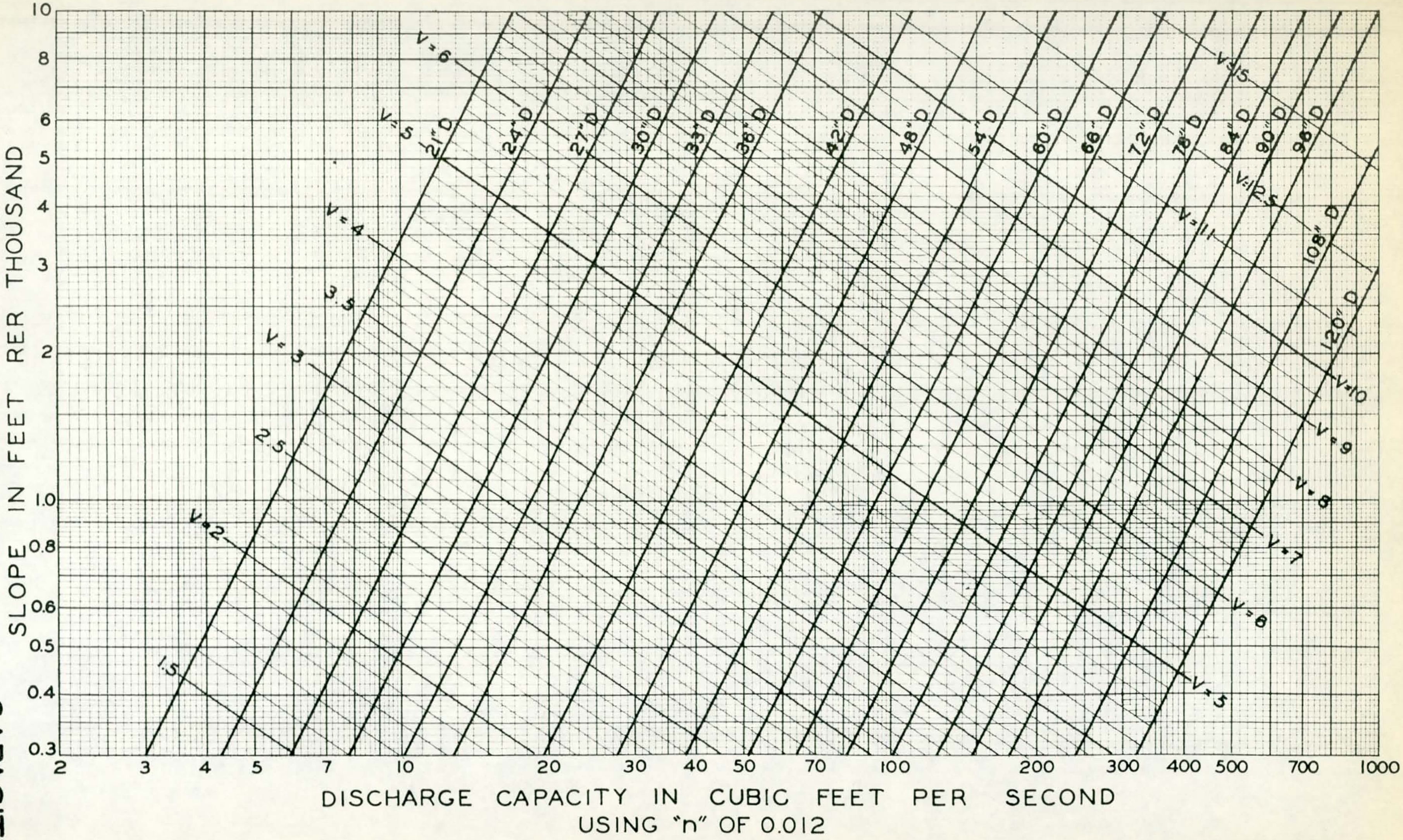
n=0.020 Earth-Best
n=0.030 Earth - Brushy - Poor

STA. OR LOCATION	WATERWAY DESCRIPTION	ROUGHNESS n	SLOPE FT. PER 1000	AREA SQ.FT. A	p=WET. PER. r=A/p	VEL. FT./SEC. V	QUANT. C.F.S. Q
		0.012	1.5	21	FULL 0.5	3.1	65
		0.012	1.0	21	0.5	2.5	53
	LAND SLOPE 2' TO 4' PER 1000' 1 FT. DROP ACROSS 308' R/W BUT TO GENERATE 3'/SEC. AND WITH LOSSES ONLY 0.5' AVAILABLE OR SLOPE = 1.5'/1000 or less						
	One culvert every 1/16 Mile - 64 C.F.S. required from Appendix IV 50 year flow						
	One 24" pipe at 1.5'/1000 (seven required for each 1/16 mile to develop over 64 c.f.s. or 50 yr. flow)	0.012	1.6	3.14	0.5	3+	9.5

APP XXV 50 YR

PIPE CULVERTS

CAPACITY



APP XXVI 50 YR

APPROX. DRAINAGE AREA BOUNDARY FOR FREEWAY

SUBDIVIDED AREAS

PROPOSED I-10 ALIGNMENT

GRAPHIC SCALE - FT.

ARIZONA HIGHWAY DEPARTMENT
PROJECT I-10-2(1)PE

LOCATION MAP

YOST AND GARDNER ENGINEERS

JOB NO. 4459 APPEND. MAP A

- LEGEND -
STORM DRAINS
24" PIPE
OPEN DITCH
48" FUTURE PIPE

NOTE:
CITY OF PHOENIX STORM DRAINS EAST OF I-17 NOT SHOWN.

NORTH UNIT

PROP. U.S.E.D. NEW RIVER CHANNEL

APPROX. DRAINAGE AREA BOUNDARY FOR FREEWAY

SUBDIVIDED AREAS

PROPOSED U.S.E.D. GLENDALE-MARYVALE DRAIN - SOUTH UNIT

PROPOSED I-10 ALIGNMENT

PROP. U.S.E.D. AGUA FRIA CHANNEL

PROP. U.S.E.D. SALT RIVER CHANNEL

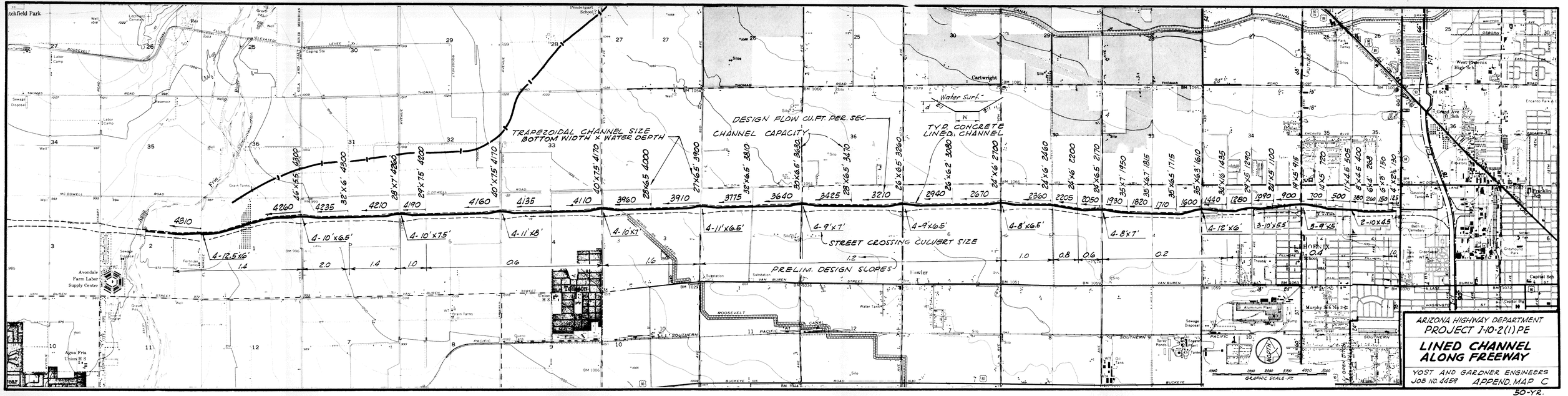
APPROX. FLOOD LIMIT

GRAPHIC SCALE - FT.

ARIZONA HIGHWAY DEPARTMENT
PROJECT I-10-2(1) PE

PROPOSED M.C.F.C.D. - U.S.E.D. PROJECTS

YOST AND GARDNER ENGINEERS
JOB NO. 4459 APPEND. MAP B

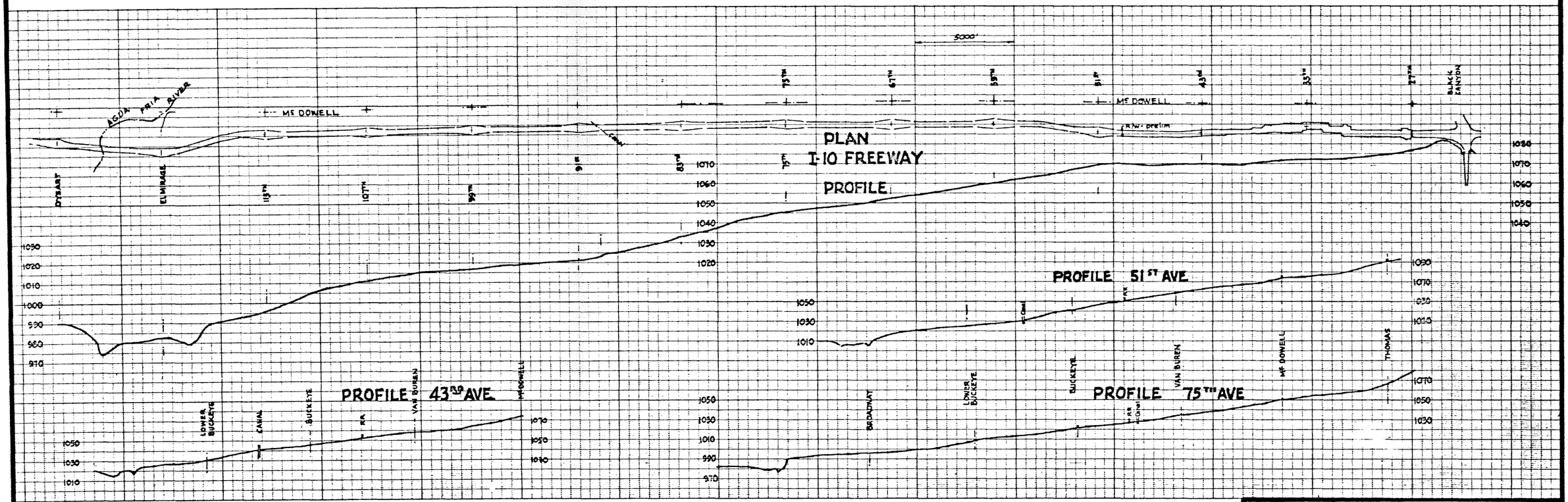


ARIZONA HIGHWAY DEPARTMENT
PROJECT I-10-2(1)PE

LINED CHANNEL ALONG FREEWAY

YOST AND GARDNER ENGINEERS
JOB NO. 4459 APPEND. MAP C

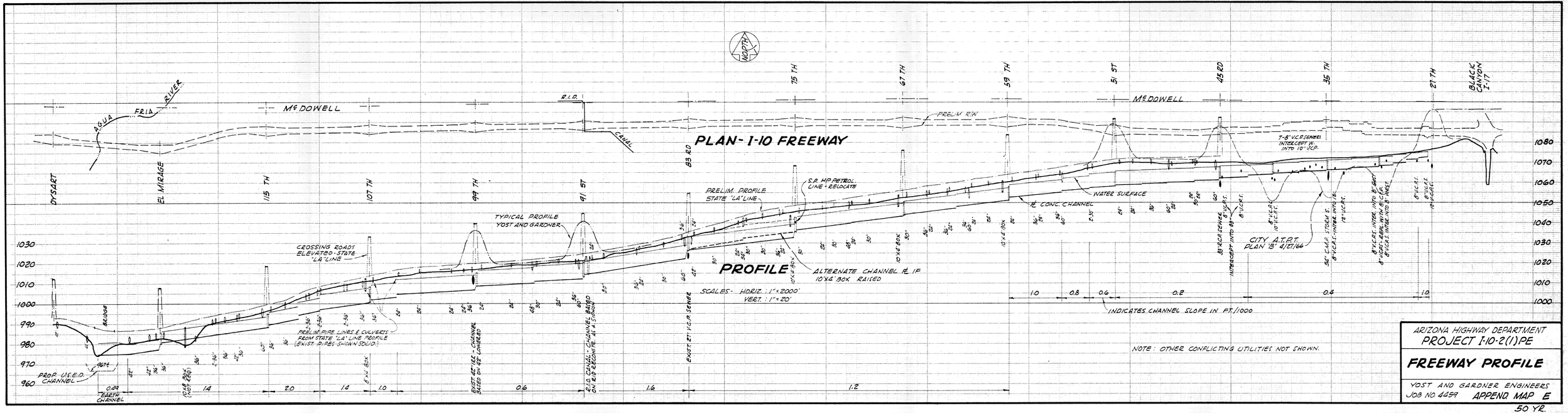
30-YR.



ARIZONA HIGHWAY DEPARTMENT
PROJECT I-10-2(1) PE

PROFILES

YOST AND GARDNER ENGINEERS
JOB NO. 4459 APPEND. MAP D

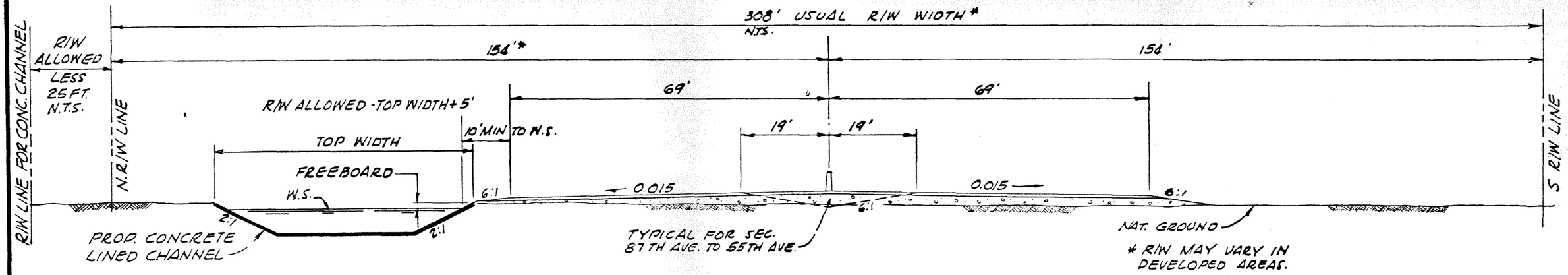


ARIZONA HIGHWAY DEPARTMENT
PROJECT I-10-2(1)PE

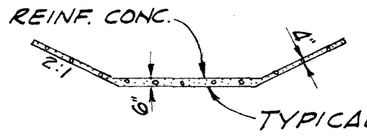
FREEWAY PROFILE

YOST AND GARDNER ENGINEERS
JOB NO. 4459 APPEND MAP E

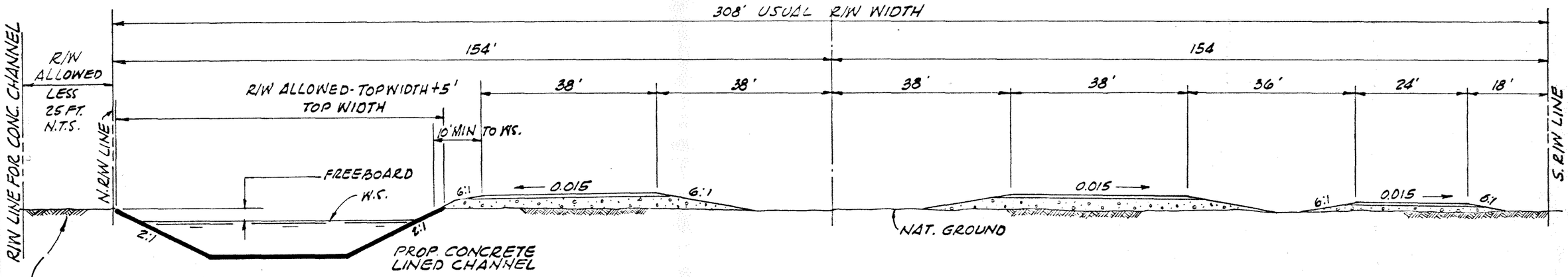
50 YR.



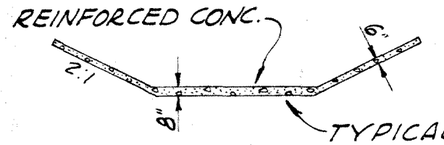
TYPICAL SECTION EAST OF 87TH AVENUE
(41ST AVE. SHOWN)



TYPICAL CHANNEL FOR EAST OF 51ST AVE.
AND VELOCITY LESS THAN 8 FT./SEC.



TYPICAL SECTION WEST OF 87TH AVENUE
(105TH AVE. SHOWN)
1" = 20'



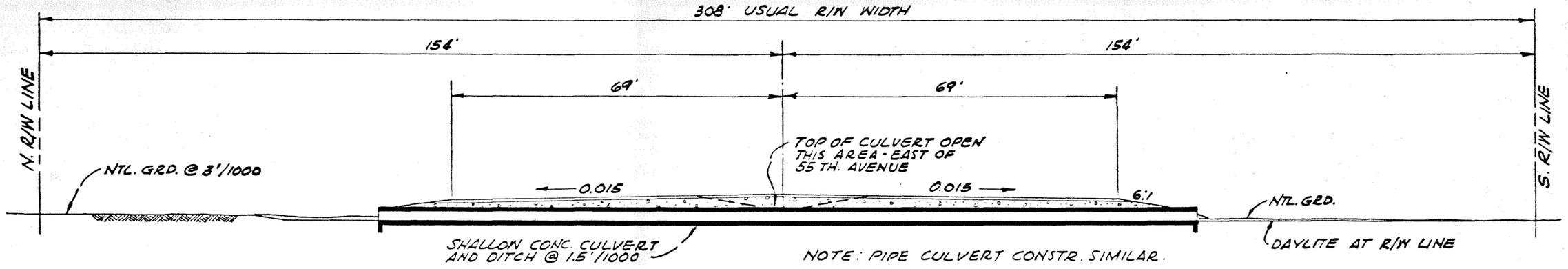
TYPICAL CHANNEL FOR WEST OF 51ST AVE.
AND VELOCITY LESS THAN 16' FT./SEC.

ARIZONA HIGHWAY DEPARTMENT
PROJECT I-10-2(1)PE

SECTIONS
FREEWAY & CHANNEL

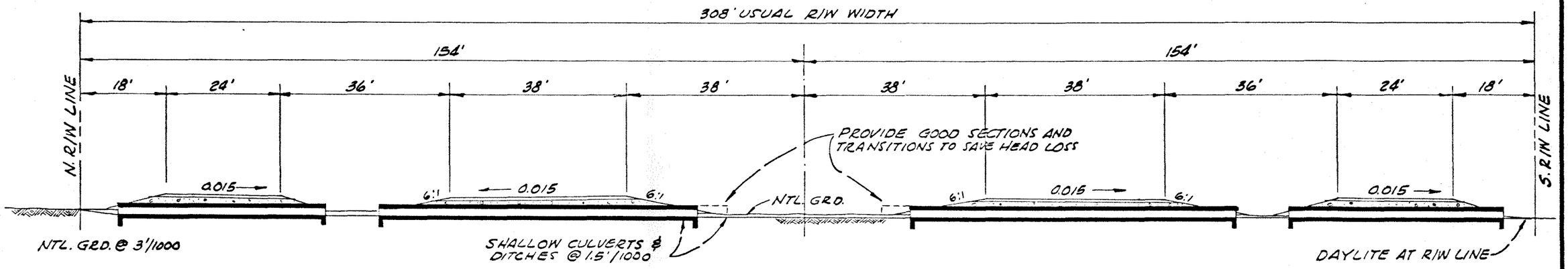
YOST AND GARDNER ENGINEERS
JOB NO. 4459 APPEND. MAP F

50 YR.



TYPICAL SECTION EAST OF 87TH AVENUE

1"= 20'



TYPICAL SECTION WEST OF 87TH AVENUE

(105TH AVE. SHOWN)

1"= 20'

NOTE: PIPE CULVERT CONSTR. SIMILAR - CULVERTS UNDER FRONTAGE ROADS NOT INCLUDED IN ESTIMATES.

ARIZONA HIGHWAY DEPARTMENT

PROJECT I-10-2(1)PE

SECTIONS

CULVERT CROSSING FREEWAY

YOST AND GARDNER ENGINEERS

JOB NO. 4459 APPEND. MAP G

50 YR.