INFORMAL REPORT

on

SIXTEENTH STREET STORM DRAIN

VAN BUREN TO GRAND CANAL

ST-66089

City of Phoenix Arizona

1967

ENGINEERING
ARCHITECTURE
PLANNING
RESEARCH

THE KEN R. WHITE COMPANY
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Study area between 16th and
24th Streets from Van Buren
Street to Grand Canal

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DEC. 31, 1967
ARIZONA, U.S.A.

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REFERENCES

* Informal Report On Sixteenth Street Storm Drain, The Ken R. White Company, 1964

** Soil Resistivity Survey For Proposed Storm Drain On 16th Street, Van Buren Street To Indian School, George W. Menzler, Corrosion Control Company Of Arizona, 1967

*** Soils Investigation Storm Sewer 16th Street From Van Buren To Grand Canal, Arizona Testing Laboratories, 1967

Phoenix Storm Drainage Report, Yost And Gardner Engineers, 1956

I INTRODUCTION

Under the terms of an agreement between the City of Phoenix and The Ken R. White Company dated June 9, 1964, this firm was commissioned to prepare an informal, preliminary storm drainage report, the objective of which was to ascertain the general requirements for a new storm drain on 16th Street from the Salt River Channel to Van Buren Street. Subsequently on May 24, 1967 a second agreement between the City of Phoenix and The Ken R. White Company was executed which commissioned this firm to amend the "Informal Report on Sixteenth Street Storm Drain, ST-61089". The objective of the following amended report is to set forth the general requirements for a new storm drain on 16th Street from Van Buren Street to the Grand Canal.

This report establishing basic criteria is preliminary to the development of detailed plans and specifications as further called for in the agreement. Also, this report is informal in that its treatment of the topics of discussion is not rigorous but abridged; its context is meant to guide rather than to instruct; and its length is intended to be brief.

By experiencing perhaps only four notable storms each year the Phoenix area receives most of its 7.43 inches of annual rainfall. A days inconvenience from the storm aftermath is soon dispelled by the long, succeeding periods of drought. The local historic approach to the immediate disposal of storm runoff is practical, and it is essentially this: serve areas definitely requiring drainage for safety and convenience, but design not to take water away from a large storm as fast as it comes, rather invest in designs for small storms which permit minor, acceptable ponding. It is hard to justify greater storm water protection in the desert than that. So long as little or no damage is done, the extensive ponding from large storms for a days time is generally tolerated by the public as a natural and expected part of the regimen of the southwest. We do not propose to alter these concepts in this report.

The construction of a storm sewer on 16th Street from the Salt River northward is in accord with the formulations for an overall drainage master plan of the valley as made by the consultants Yost and Gardner Engineers in their Phoenix Storm Drainage Report of 1956 (hereinafter termed the Y. & G. Report).

As given in the aforementioned agreement the study area of this report is to be generally between 15th and 24th Streets, as modified by construction of the 20th Street freeway, and from the Salt River channel to the Grand Canal. Allowance for periodic discharge from the Grand Canal and for runoff from areas north of the Grand Canal extending to the Arizona Canal are to be considered. Preliminary pipe sizing for relative comparison only are included for the eight plans that were considered in the 1964 report.

The City of Phoenix Division of Engineering has requested our adherance to the use of the 1-year return frequency storm, the rainfall intensities for that storm as given in the Y. & G. Report, the Phoenix standard inlets with 12" minimum connecting pipes, the value of 100 to 110 cfs discharge from the Grand Canal, the Manning roughness coefficient of n = 0.012, and the rational formula approach.

II BASIS OF STUDY

A. RATIONAL FORMULA APPROACH

1. Formula The basic approach to the determination of rainfall runoff in the various parts of the proposed drainage area has been by the use of the rational formula, Q=CiA. The rational formula relates rainfall and runoff directly by simultaneously accounting for time, retention, area, and rainfall intensity. While it is impracticable to attempt refinements in expressing runoff from so variable an occurrence as a thunderstorm, the selection of proper values for the variables in the formula should be given very careful attention. We feel the basic design assumptions and calculations used for this report are adequate for developing a satisfactorily designed system.

Other approaches to the determination of flows for storm sewers are being used in various places about the country to a limited extent. The Chicago Hydrograph Analysis and the Hicks Los Angeles Method are two of these; however, they are based on local experimental work and involve factors that require extensive engineering studies which few communities have felt offer a clear advantage to conduct.

The variables in the rational formula, Q=CiA, are:

a. "A" is the drainage area in acres tributary to the point under design.

b. "i" is the average rainfall intensity in inches per hour for the period of maximum rainfall of a given return frequency having a duration equal to the time of concentration—the time of concentration is defined as the time required for runoff originating during the period of maximum rainfall to flow from the most remote part of the drainage area to the point under design.

c. "C" is a runoff coefficient which is the ratio of the maximum rate of runoff from the area to the average rate of rainfall on the area during the time of concentration.

d. "Q" is the resultant runoff and because rainfall at one inch per hour uniformly applied over one acre equals a rate of 1.0083 cubic feet per second, "Q" is expressed for all practical purposes in cubic feet per second.

The use of the rational formula makes the following two basic assumptions: (1) the peak rate of rainfall occurs within the time of concentration, and (2) the rate of runoff to any point under design is a function of the average rainfall rate during the time of concentration.

Assumption (1) may become a near reality when the storm patterns of many storms are plotted and averaged and the time of concentration adjusted to contain the peak rate of rainfall. Assumption (2) presumes the rate of rainfall to be the same over a given time span which in the natural storm pattern is not uniform; however, it is necessary to make this assumption to express an erratic variable.

2. Areas For use in the rational formula the area under study between 16th and 24th Streets was divided into 160 gross acre quarter sections or lesser gross acreage as defined by canal and freeway locations. Much of the land in Phoenix is still served with irrigation water, and those lots which are served will not contribute runoff to the streets because irrigation dikes and/or depressions easily contain any rain water.

To determine how much acreage was isolated in this manner, we conducted a field reconnaissance, lot by lot, of 18 quarter sections south of the Grand Canal (100% of the area) and 3 quarter sections north of the Grand Canal. The remaining quarter sections north of the Grand Canal were observed in the field in a way which compared them to quarter sections previously covered in detail. The isolated areas were noted on a map and thereafter their dimensions were scaled for acreage determination.

The gross acreage less the isolated acreage is the net area, or, more descriptively, the acreage free to drain. On Plates 6 and 7 the acreage free to drain may be noted for each quarter section, and notwithstanding a wide variation such acreages are significantly smaller than the gross acreages and have a substantial reducing effect on the quantity of rainfall run-off to be expected.

3. Rainfall Intensities For design of any point in a storm drainage system three questions regarding rainfall must be simultaneously answered in order to select the proper value of "i" of the rational formula. These questions are: what is the general magnitude of the storm? how long has the storm been in progress? and at what rate is it raining? To graphically answer these questions rainfall intensity-duration-frequency curves derived from actual recorded rainfall data are employed.

Plate 3 is an abridged reproduction of the set of curves shown in the Y. & G. Report—only the 1 and 2-year return period curves are shown. These rainfall intensity-duration-frequency curves originate from Technical Paper No. 25, Weather Bureau, U.S. Department of Commerce and have been modified from the annual series in the Paper to the partial-duration series. The term annual series means that for every year considered, only the heaviest rainfall that occurred during the year is listed for analysis; rainfalls of nearly equal magnitude may have fallen during the same year but they are not considered even though some of those rainfalls may have been larger than the heaviest downpours of other years of record. The term partial-duration series means that, for every year considered, all the heavy rainfalls above a practical amount that have occurred during the year are listed for analysis. In our opinion the partial-duration series is better related to the probability of occurrence.

A return period curve is a series of probability points relating time and intensity for that period. Because they are merely probability points, any one actual storm need not have intensity rates following exactly or even approximately any single return curve.

Since Technical Paper No. 25 was published in 1955, another more comprehensive work known as Technical Paper No. 40 has been issued by the U.S. Weather Bureau in 1961. The rainfall intensity-duration-frequency curves of No. 40 are higher than those of No. 25; the 1-year curve of No. 40 is equivalent to the 2-year curve of No. 25—both being on the partial duration series. Because the City of Phoenix Division of Engineering uses the No. 25 curves and because of the approach to drainage mentioned earlier in the Introduction, the work of this report has been based on the No. 25 curves.

The Y. & G. Report recommends that initially constructed storm sewers below the Grand Canal be designed "...for storms such as occur no oftener than once a year on the average....". The City of Phoenix Division of Engineering has indicated a preference for a 1-year period of design. From an economical standpoint we concur; therefore, the "i" curve for the 1-year return period has been used throughout our calculations.

Knowledge of the storm pattern is of importance in that the peak rate of rainfall must occur during the time of concentration—a basic assumption of the rational formula approach. For this locality there is a meterological difference between summer rainstorms, the moisture of which originates from the Gulf of Mexico, and winter rainstorms, the moisture of which originates from the Pacific Ocean. To determine the two typical storm patterns for Phoenix, the original rainfall records for maximum annual summer storms and for maximum annual winter storms were analyzed and the intensities versus time plotted as shown on Plate 4. Since the peak rate of rainfall occurs within the first 5 minutes for either storm, the time of concentration may be considered as commencing practically at the start of the storm.

The curves for Phoenix of Technical Paper No. 25 were developed from the maximum annual storm, almost all of which were summer storms. The length of these storms as recorded by a tipping bucket device at the main Phoenix weather station is limited to 180 minutes from the present time back to 1939, and to 120 minutes from 1938 back to 1906. With the record it may be observed that 48 of 57 summer storms lasted at least 120 minutes. Virtually all the maximum annual winter storms lasted the 180-minute limit with some special observations noted for 6 to 9 hours of time. Of the 9 summer storms, which did not last 120 minutes, 7 of these had released 0.60 inches of rain or more—an indication that they were moderate to heavy in magnitude and not light.

To use the rational formula the duration of the storm must equal or exceed the length of the time of concentration. The plans studied with smaller areas require approximately an hours time of concentration, while the largest area studied required about two hours time of concentration. From the available rainfall records we have concluded that for the purposes of this report the 1-year return frequecy summer storm used for design calculations may be anticipated to last 60 minutes with confidence and 120 minutes with fair expectation.

Not only does the rational formula approach require continuous rainfall during the time of concentration, but it also is essential that the aerial extent of a storm cover the entire runoff area being investigated. Winter storms often extend well beyond the Salt River Valley. Summer storms, upon which our design factors are based, tend to be concentrated. There is sufficient evidence to show that the large maximum annual storms cover more than several townships (see Y. & G. Report Fig. 10, 14, 15, 16—also radar measurements of storms in The Ken R. White Company files). But to our knowledge no work has been done to correlate aerial extent of rainfall with low intensity-frequency storms such as occur at 1, 2, 3 or 5-year intervals. The 28 or so scattered weather observation stations in the Salt River Valley together with the data accumulated therefrom would make such a correlation possible, but the research expense and the considerable time required puts the knowledge from such a study well beyond the scope of this informal report. The largest area upon which rain is considered to continuously fall was under Plan 2-B, discussed later, which measures about 1 mile wide and 4 miles long. We believe it possible that a 1-year storm will cover the stated area although this remains an assumption for lack of supporting data.

4. Runoff Coefficients Included in the value of a runoff coefficient, "C" in the rational formula, are the effects of time, condition of turf or surface, infiltration into pervious soils, slope of ground, retention in local depressions, interception by vegetation, and evaporation.

For the purpose of determining runoff it has been assumed that all quarter sections will be developed with fully paved streets and sidewalks and with average density grassed surfaces or turf areas free to drain. A number of quarter sections already are so developed.

The effect of low initial runoff followed by gradually increasing runoff as surfaces begin to refuse water is recognized and shown on Plate 5 where coefficients are plotted against time. As previously pointed out the time of concentration begins near the first 5 minutes of the storm which contains the peak rate of rainfall according to the Phoenix storm pattern. Becuase of this, the time of concentration for the "C" curves of Plate 5 also begins near the first 5 minutes of the duration of rainfall. The upper curve is for flat impervious surfaces subject to local ponding. Runoff from a medium density soil with a pervious surface is represented in the lower curve. Both curves are approximations guided by the investigations of Hoad.

Concerning the study area below the Grand Canal, the contours of Plate 2 show that the general grade is 1 in 300 for the northerly half and 1 in 500 for the southerly half. Typical times of concentration for quarter section drainage were estimated to range between 50 and 90 minutes. Since application of the rational formula permits intelligent latitude, the use of constant runoff coefficients has been employed to represent design "C" values ("C" = 0.9 for impervious areas and "C" = 0.4 for pervious areas). Reference to Plate 5 will illustrate the reasonableness of this simplification.

The next step following the selection of constant runoff coefficents for pervious and impervious areas was the determination of a single design runoff coefficient for each quarter section of the study area. Only the acreage free to drain was considered. From measurements on aerial photos the acreage of roofs and concrete drives was ascertained; from measured lengths on maps the acreage of a 45-foot wide street-sidewalk unit was calculated; by combining these two acreages the total impervious area was obtained. Following this was the derivation of the percent of the area free to drain which was composed of the two types of surfaces. By multiplying the respective percentage of pervious or impervious surface times the corresponding constant runoff coefficient and adding the two products, a combined "C" value for each quarter section was calculated. The resultant "C" values are noted on Plates 6 and 7.

Because of the similarity of the calculated "C" values below the Grand Canal, we further simplified our design computations by using a single "C" value of 0.60 for all those quarter sections shown on Plate 6. But since certain areas north of the Grand Canal are quite variant from the average, they were treated individually, and the design "C" values are as given on Plate 7.

5. <u>Time of Concentration</u> The time of concentration is made up of three parts: (1) the time for the rainfall from the most remote point to reach a street gutter, (2) the time of travel in the gutter to an inlet, and (3) the time of travel in underground piping to the point under consideration. The first part is found by empirical means which relate the ground slope, the kind of turf, and the length of travel. For the most part we have used 200 feet of overland travel distance at 0.5% slope with an average grass surface giving 23 minutes of time; near the Arizona Canal where desert lands predominate, we used 200 feet of overland travel distance at 1.0% slope with a bare ground surface giving 13 minutes of time. The second and third parts are calculated from velocities determined by formula for channel flow and from the distances involved. Gutter velocities used were on the order of 1.5 to 2.0 feet per second (fps). Pipeline velocities varied with ground slope; on 16th Street velocities were approximated at 10 fps south of the Arizona Canal, 6 fps south of Indian School Road, and 4½ fps south of Harrison Street.

B. HYDRAULIC FACTORS

Pipes have been sized on the basis of the calculated storm runoff flowing in the existing sewers and in the proposed sewers at full depth under a few feet of water pressure depending upon the total head available for design. The roughness coefficient for use in the Manning flow formula was stipulated by the City of Phoenix Division of Engineering to be n = 0.012. Because the existing storm sewer on 16th Street is in quite good condition, this same coefficient was used for that and all other existing storm sewers. An "n" coefficient of 0.018 was used for calculating gutter flows by the Manning formula. Hydraulic calculations for existing and new inlets were based upon sump type conditions with gutters flowing full to the top of the curb. For design purposes the following capacities have been assigned to these City of Phoenix standard storm water inlets: 4 cfs for No. 212, 5 cfs for 3' -6" curb opening, and 8 cfs for 5' -6" curb opening.

The necessary studies and determinations concerning the use of various types of pipe and their respective hydraulic factors shall be examined during the project design period. Therefore, only the aforementioned hydraulic factors are of importance for this report.

III EXISTING STORM DRAINAGE

A. FACILITIES

In the study area storm drainage is handled in a pipe system separate from that used for sanitary sewage. Storm runoff appraoching the study area from the east is intercepted by a major drain line traversing 24th Street from the Salt River Channel to Camelback Road. Within the study area are a certain number of scattered laterals connecting to a relatively small drain line located on 16th Street from the bank of the Salt River to Indian School Road. West of 15th and 16th Streets storm runoff moves westerly away from the study area. The size and route of the existing storm drainage facilities which concern this report may be seen on Plate 2.

Plan 1-B, shown on Plate 10, was adopted in 1964, and subsequently the 57-inch storm drain from the Grand Canal to the north and the 60-inch storm drain from Van Buren Street to the south was constructed. To complete this plan the construction of a 60-inch storm drain is proposed from Van Buren Street to the Grand Canal which will conjoin the existing 60-inch pipe at Van Buren Street to the 57-inch pipe at the Grand Canal.

A field check on 16th Street (south of Indian School Road to Van Buren Street) revealed the following past choices for inlets:

Inlet Type	Van Buren to Grand Canal
Phoenix 212 combination	80
Phoenix 211 grate	5
Phoenix 210 grate	1
4" x 20" half-bar curb opening	2
4" x 24" curb opening	1

B. CAPACITY

The emphasis of study is not upon the capacity of existing laterals or future laterals, but upon the capacity of existing storm drains on 16th Street which will affect the sizing of any new storm drain. The existing 18-inch storm drain on 16th Street from Van Buren to the Grand Canal has a capacity under pressure of only 6 cfs —the hydraulic gradient being s = 0.0008. Under gravity flow, the existing 36-inch storm drain on 16th Street from Van Buren to the Salt River bank just flows full; under pressure flow, the hydraulic gradient is allowed to rise above the pipe to a height limited by the lowest swale of ground encountered. Capacities under these two conditions are:

Exist 36-inch	Gravity Flow	Pressure Flow
Q in cfs	19	24
V in fps	2.7	3.4
Hydraulic gradient	0.00070	0.00106

Existing connecting pipes from storm drains to inlets are assumed to be suited to the inlet capacity. Although every existing or new connecting pipe must be checked during alteration or original design, it is out of the ordinary to find one which is under-matched to its inlet.

The acreage of area served by each inlet must not be exceeded for adequate drainage design. As a matter of interest the following tabulation of capacities of existing Phoenix standard inlets is presented for conditions during a 1-year storm and a 30-minute time of concentration:

Inlet	Rated Q	Service Area
No. 212 combination	4 cfs	8 acres
3'-6" curb opening	5 cfs	10 acres
5'-6" curb opening	8 cfs	16 acres

About one percent of all inlets observed on 16th Street during dry weather had any appreciable amount of debris collected against the grate or curb openings. The cleanliness of the inlets results mainly from two factors, namely, the regular street sweeping done by the City on this arterial street, and the scattered occurrance of deciduous foliage in the area. As to design inlet capacities, we have derated curb openings 5 percent and grate openings 20 percent. However, it must be recognized that every inlet is different in regard to clogging because of the amount of floatable debris in its watershed. A single large piece of wrapping paper can nearly plug an inlet grate. Also, debris gradually collects on grates so that a grate which may be clear at the start of a storm will at the end of the storm be 90 percent clogged. The No. 212 inlet is especially vulnerable to clogging, but the two standard curb opening inlets will remain quite clear except under very unusual conditions.

To examine the existing inlets' suitability, their tributary watersheds were delineated and runoff flows computed for the 1-year return storm (see Plate 3). The runoff flow was compared with its respective inlet capacity, and this comparison revealed that the installation of approx. 12 new inlets is required if the overland flows are to be matched with the inlet capacities.

C. INSPECTION SUMMARY

On July 2, 1964, the existing 36-inch storm drain on 16th Street between the Salt River and Van Buren Street was inspected to determine its physical condition. The drain is of undetermined age. Fourteen manholes were entered, and by the use of a brilliant lamp the interiors were clearly visible for a distance of some 70 feet.

During the construction period for the larger diameter storm drain in 16th Street from the Salt River Channel to Van Buren Street concrete inverts, shaped to the pipe springline, were poured into manholes of the existing 36-inch storm drain. This will assist in reducing headloss under operation and reduce the catchment of sticks and boards.

On June 20, 1967, the existing 18-inch storm drain in 16th Street between Van Buren Street and the Grand Canal was inspected. This pipe was difficult to observe because of its small size; however, there was no visible evidence of structural deterioration at the manholes. The capacity of this small line, as previously mentioned, is only about 6 cfs, and therefore, should not be considered to influence the capacity of the proposed 60-inch storm drain.

IV PLANS OF POSSIBLE INFLUENCE

A. PURPOSE OF PLANS

The proposed storm drain lies at the lower end of a strip of land 1 mile wide and 8 miles long which eventually might all be served if the master planning of the Y. & G. Report is fully carried out. We feel that the influences of localized rainfall, possible freeway construction, and future discharge from the Grand Canal are important to consider, the result of such consideration being a fuller understanding of the conditions under which the proposed drain will be adequate. In the 1964 Report*, eight conditional plans were set up and briefly studied to determine their comparative influence on the lower five miles of storm drain. Because of the preliminary nature of the conditional plans, we caution the reader not to consider any part of a plan as fixed; final design will refine the calculations and fix pipe sizes and flows. The objective at hand is merely to ascertain the relative effect of the three mentioned influences. Plan 1-B as shown on Plates 10 and 11 was adopted for further development, and in 1966 the storm drains north of the Grand Canal and between Van Buren Street and the Salt River Channel were constructed.

B. CONDITIONS

1. Localized Rainfall As previously mentioned, there is a lack of supporting evidence as to the size of low intensity-frequency summer storms. Even though a 1-year storm may be of larger extent than the area under consideration in this report, the significant precipitation falling from such a storm may be positioned over only a portion of the study area. Plans A, B, C, and D are attempts to account for the influence of storm size and position.

Both the Arizona and Grand Canals are natural terminal boundaries since rainfall runoff north of either will, if permitted, flow into the waterway. Future laterals passing under the canals could bring water to 16th Street from east of the canals, but it seems reasonable to exclude this rather remote possibility except under Plan 2-D. As explained earlier, 24th Street is a man-made terminal boundary, and water drains away from the study area west of 16th Street and south of Magnolia Street. The boundary line for Plans A and C (Pates 9 and 10) between Van Buren and Roosevelt Streets follow a slight ridge which divides the runoff. This boundary is somewhat arbitrary because if the significant precipitation area overlaps the divide, the water from the overlap will be carried to 16th Street storm drains the same as though it had fallen on part of the area considered. For study purposes the boundary was used despite its want of exact difinition.

2. Freeways South of Durango Street the new east-west Maricopa Freeway construction is complete. On 20th Place the Squaw Peak Freeway has been constructed northward to Buckeye Road, and it is under design to Harrison Street. A possible routing for the Squaw Peak Freeway extending from Harrison Street to Bethany Home Road is sketched on Plate 10. Its location may be subject to some future shifting, and, indeed, it has not been determined whether the proposed freeway is to be elevated, ramped above ground, or excavated below ground.

Plans marked by the numeral 1 (1 quarter section wide) account in a general way for new freeway construction between Harrison Street and Bethany Home Road—it being assumed that such a freeway will intercept all runoff from the east as far as 24th Street. Whether future policy by governing agencies will permit or prohibit the interception of all runoff at the freeway is a matter for conjecture. But for this comparative study, we have assumed complete interception of all easterly runoff.

Interception of nearly all rainfall runoff is physically established at this time between the north-south ramped freeway and 24th Street from the east-west ramped freeway to Harrison Street; twin 48-inch pipes along the freeway are now installed to serve this area as well as the freeway surfaces. Only right-of-way drainage on Mohave Street goes under the freeway to 16th Street.

3. <u>Canal Discharge</u> Structures now exist on the Grand Canal at 7th Avenue, 7th Street, 24th Street, and other places which can divert water from the canal into the storm drains of the City. Arrangements were made in the past to do this as a partial relief from excess flood runoff entering upstream. The City of Phoenix Division of Engineering has requested a minimum flow of 100 to 110 cfs of canal discharge be accounted for in the design of any future storm drain line laid as far as the Grand Canal. The discharge of canal water is to occur only when no rain falls on 16th Street. The pipe sizes indicated on Plates 9 and 10 are sized for this flow or for a greater flow.

4. <u>Other Factors</u> Since the sizing of lateral storm drains connecting to the 16th Street drain is not relevant to this study, that work was left for another time. But the occurrence of east-west laterals has been assumed at every half-mile line if they did not already exist there. The existing intermediate laterals on Washington and Jefferson Streets were given special attention regarding their entering flows in the 1964 Report*.

For the calculation of peak rates of runoff, the study area was generally treated in units equal to a quarter section unless intermediate division lines needed to be considered. In the rational formula, when areas become large and times of concentration long, it is not uncommon for calculations to reach a maximum rate of runoff and then gradually diminish even though more increments of area are added. This is due to the probable rainfall intensity declining proportionately faster, as time goes on, than area is added. Whenever a maximum runoff was reached, the value of that maximum was carried to the Salt River outlet of the storm drain.

5. <u>Hydraulic Gradient</u> In order to use the proposed 16th Street storm drain to its fullest extent, the preliminary calculations in the 1964 Report* were based on the conduit passing the peak rate of runoff while under a few feet of pressure head (less than 8'). By reference to Plate 8 one may see a hydraulic gradient drawn for estimating purposes from the Salt River Channel to the Grand Canal; its slope is, of course, approximate since final design additions of minor head losses, velocity changes, and actual pipe friction have modifed the gradient somewhat. Also shown is another hydraulic gradient for the existing 36-inch storm drain.

As long as the top of the pipe lies below the hydraulic gradient the flow conditions will be satisfied. It matters not how far below the gradient the pipe crown lies except as excavation may be affected. The final design hydraulic gradient as drawn begins some ½ foot below the top of the highway box culvert at the Salt River Channel. That starting elevation will minimize excavation depth and tend to be more satisfactory to county flood control planners than if it were lower.

The approximate hydraulic gradient and velocity of flow for the adopted Plan 1-B between Van Buren and the Grand Canal may be seen on Plate 11. The storm drain pipe north of the Grand Canal and south of Van Buren Street are manifestly imposing controls at each end of this project. Final design will refine the hydraulic gradient somewhat; however, the latitude of variation is restricted somewhat by the above mentioned controls.

C. PLANS

For the conditions mentioned in Section B above, Plate 9 shows the influences of localized rain and canal discharge on storm runoff rates and storm drain sizes. Plate 10 shows the same things plus the influence of the future freeway. Plate 11 shows the adopted Plan 1-B and the storm drains north of the Grand Canal and south of Van Buren Street that were constructed during the year of 1966. Nomenclature on the plates is self-explanatory.

It may be noted that the effect of using the existing 36-inch storm drain in conjunction with a new conduit on 16th Street is to reduce the conduit diameter by one 6-inch increment except when the design flow is 300 cfs or more, in which case no reduction occurs. The effect of similarly using the existing 18-inch drain on 16th Street is nil.

V OUTLINE SPECIFICATIONS

A. GENERAL

The following specification outline is presented to indicate the major items on which the cost estimate is based. City of Phoenix Standard Specifications and Details are available and should be the specification guide for this project. The final construction specifications will consist of the City of Phoenix Standard Specifications with supplementary Special Provisions.

City of Phoenix Standard Details for manholes and inlets are quite adequate and are recommended for this project.

These outline specifications are for precast reinforced concrete pipe. Alternate materials should be allowed to insure competitive bidding; however, specifications covering alternate materials will not appear at this time so that further investigation may be allowed in the design stage which will maximize comparability.

B. SCHEDULING

Approximately sixty (60) days of lead time will be required for pipe fabrication prior to beginning excavation and pipe installation. The installation may progress at a rate of approximately 200 feet per day which will account for approximately 100 days. After allowing for the construction of inlets and connecting pipes, jacking and pavement replacement construction, a total period of 260 days may be estimated for construction.

C. REINFORCED CONCRETE PIPE

1. According to ASTM C-76, latest edition.
2. AASHO M-85, Type II or Type V, low alkali cement.
3. Class III or as depth and load requires.
4. Wall thickness per ASTM Tables.
5. Tongue and groove type joints or approved alternate.
6. Minimum length of 4 feet.

D. EARTHWORK

1. Open cut excavation except at arterial intersections.
2. Not more than 300 feet of trench open ahead of completed sewer unless authorized.
3. Existing utilities to be kept in service and repaired by the contractor if damaged.
4. Maximum trench width at top of pipe to be held to a practical minimum.
5. Pipe bedding to be imported granular material.
6. Backfill according to City of Phoenix Standard Specification No. 600.

E. MANHOLES

1. Shafts or Barrels shall be reinforced concrete pipe Class II.
2. Reinforced concrete for manhole boxes shall be according to City of Phoenix Standard Specification No. 751.
3. Castings shall conform to City of Phoenix Standard Specification No. 954.

F. PAVEMENT REPLACEMENT

1. Pavement replacement shall conform to City of Phoenix Standard Type A (Modified).

VI CONSTRUCTION COSTS

A. UNIT COSTS

Cost estimates have been based on unit prices which, it is believed, will reflect the prices bid by Contractors for the proposed work if the project is done during 1968 or 1969. Construction competition is so keen in the Phoenix area that contractual compensations have been uncommonly low compared to state and national averages. To reflect the condition we have been guided partly by bidding practices found on several recent large storm drain projects for the City of Phoenix.

The findings of the field test borings***(see Plate 12) indicate relatively similar underground conditions on 16th Street from Van Buren Street to the Grand Canal. The upper 20 feet of ground is composed of silty clays. Heavy earth handling equipment will be required to work the depth required.

Excavation costs were calculated on a trench section (1) whose sides are vertical from the surface to the bottom of the pipe, and (2) whose width equals 1.5 times the outside diameter of the conduit. Backfill was computed on the excavated volume less the volume occupied by the conduit and less the volume taken by pavement replacement. Depths for excavation and backfill varied with and account for the pipe diameter used and the ground profile as surveyed.

The pipe considered for cost analysis in this study was reinforced concrete pipe with tongue and groove ends, ASTM C-76 Class III for 60-inch size and smaller, 6' lengths thru 24-inch size, 8' lengths thru 60-inch size. Unit prices given per foot of pipeline in the tabulation of construction cost given later are composite prices which include the laid cost plus the cost of excavation and backfill.

B. PLAN COSTS

For each of the eight conditional plans set up and discussed in Section IV, a careful cost study was presented in the 1964 Report*. Construction costs for Plan 1-B are recapitulated below. Each plan was predicated on (1) a 1-year storm frequency, engineering data, and rational formula criteria previously developed, (2) the passing of 110 cfs released from the Grand Canal, (3) use of the existing 36-inch storm drain on 16th Street, and (4) a limit of 15,185 lineal feet of pipeline on 16th Street beginning at Van Buren Street and ending at the Grand Canal.

CONSTRUCTION COST FOR PLAN 1-B

From Van Buren Street to Grand Canal

1 - Year Storm Frequency

Item	Quantity		Unit Cost	Rounded Extension
15" RCP	1,530	L.F.	$ 10.50	16,100
18" RCP	90	L.F.	11.50	1,000
60" RCP	15,185	L.F.	39.50	599,800
Lateral Manholes	5	Each	1300.00	6,500
Thru Manholes	12	Each	900.00	10,800
Inlets	12	Each	450.00	5,400
Pavement Replacement	16,700	S.Y.	13.00	167,000
Obstructions and Jacking		L.S.	-	56,000
Spur Connections	53	Each	110.00	5,800
Removal of Concrete Pavement	11,500	S.Y.	2.00	33,000
Permanent Pipe Supports	14	Each	200.00	2,800
Reset Survey Monuments	44	Each	45.00	1,980
Misc. Relocations and Removals		L.S.	-	4,000
Sub-Total				910,200
+ 10% Construction Contingencies				89,800
TOTAL CONSTRUCTION COST				$ 1,000,000

NOTE: Pipe costs are for the RCP size listed or its equivalent alternate.

VII SUMMARY AND RECOMMENDATIONS

This informal, preliminary storm drainage report has been prepared to ascertain the general requirements for a new storm drain on 16th Street from Van Buren Street to the Grand Canal. The study area lies generally between 15th and 24th Streets, as modified by construction of the 20th Street freeway, and from the Salt River northward to the Grand Canal. Allowance for periodic discharge from the Grand Canal and for runoff from areas north of the Grand Canal extending to the Arizona Canal are included in the study.

The basic approach to the determination of rainfall runoff in the various parts of the proposed drainage area has been by use of the rational formula. The acreage free to drain was determined in the field; coefficients of runoff were developed; and rainfall intensities were taken for a 1-year storm frequency.

Of the existing storm drainage facilities in the study area only the 36-inch RCP drain on 16th Street from the Salt River to Van Buren Street is considered effective enough to supplement the new drain line; under pressure it will handle 24 cfs.

In the 1964 Report*, eight conditional plans were set up and studied to determine their comparative influence on the proposed lower two mile storm drain—the conditional influences being localized rainfall, possible freeway construction, and future discharge from the Grand Canal. Plan 1-B was adopted for further development and subsequent construction.

As a result of this study we make the following recommendations:

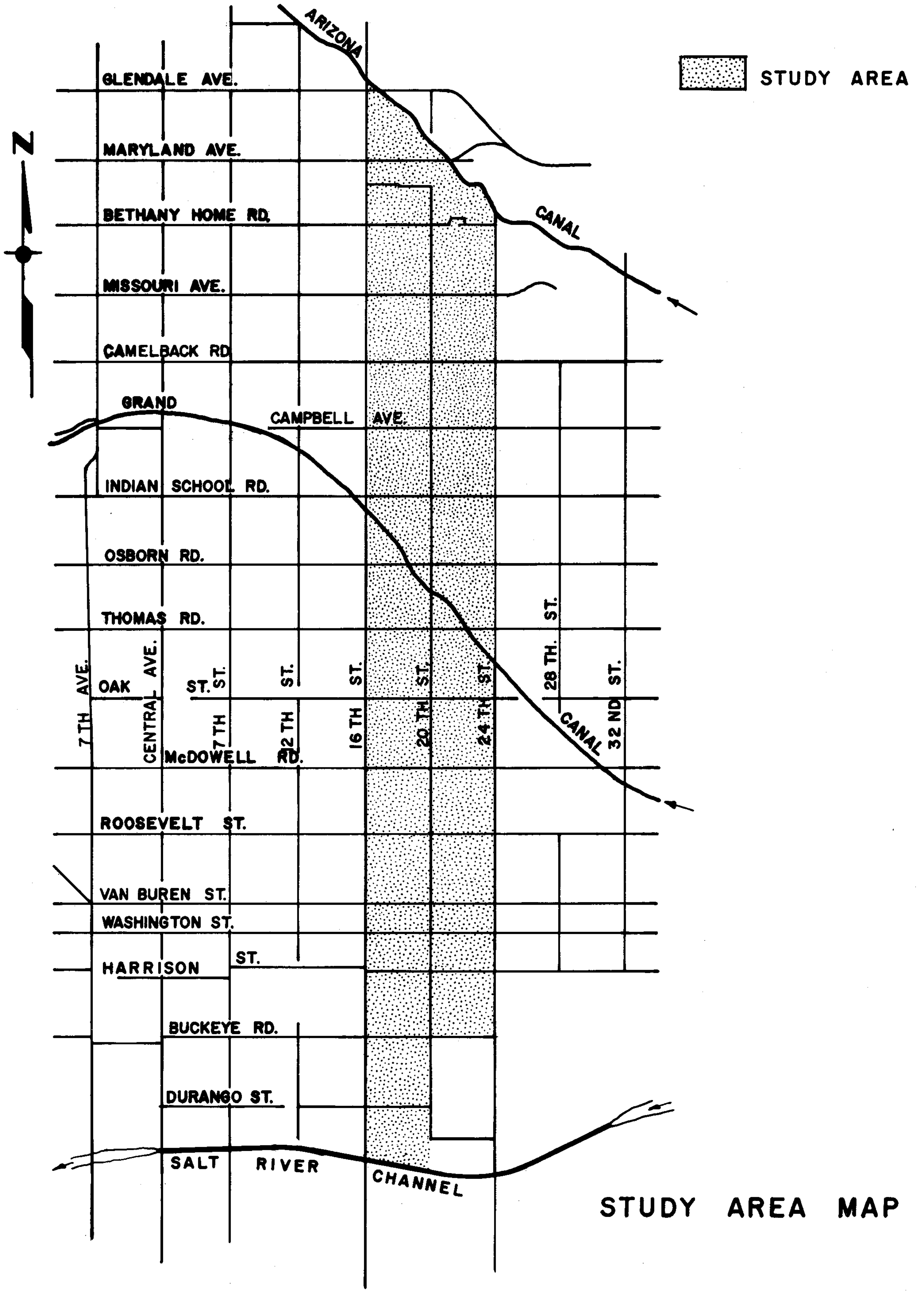
1) That the length of allowable open cut be minimized for three reasons: (1) 16th Street is a high traffic density arterial, and road user's costs increase as detours are extended, (2) construction of this magnitude certainly has an adverse effect on local business, and (3) the width of existing right-of-way for 16th Street is rather limited; therefore, accomodation of continuous lanes on 16th Street will be difficult.

2) That because of the moderately corrosive soil, as indicated by the Soil Resistivity Survey***, a cognizant appraisal concerning metal pipe longevity and comparability be performed during the design stage of this project. Conjectural determinations for a large project can be costly and should be minimized. Final specifications should attempt to simultaneously maximize longevity and comparability of all alternate materials.

3) That consideration be given to the last 1000 feet or so of the new 16th Street storm drain so as to be capable of carrying additional storm flows coming from State Highway drainage facilities to the east.

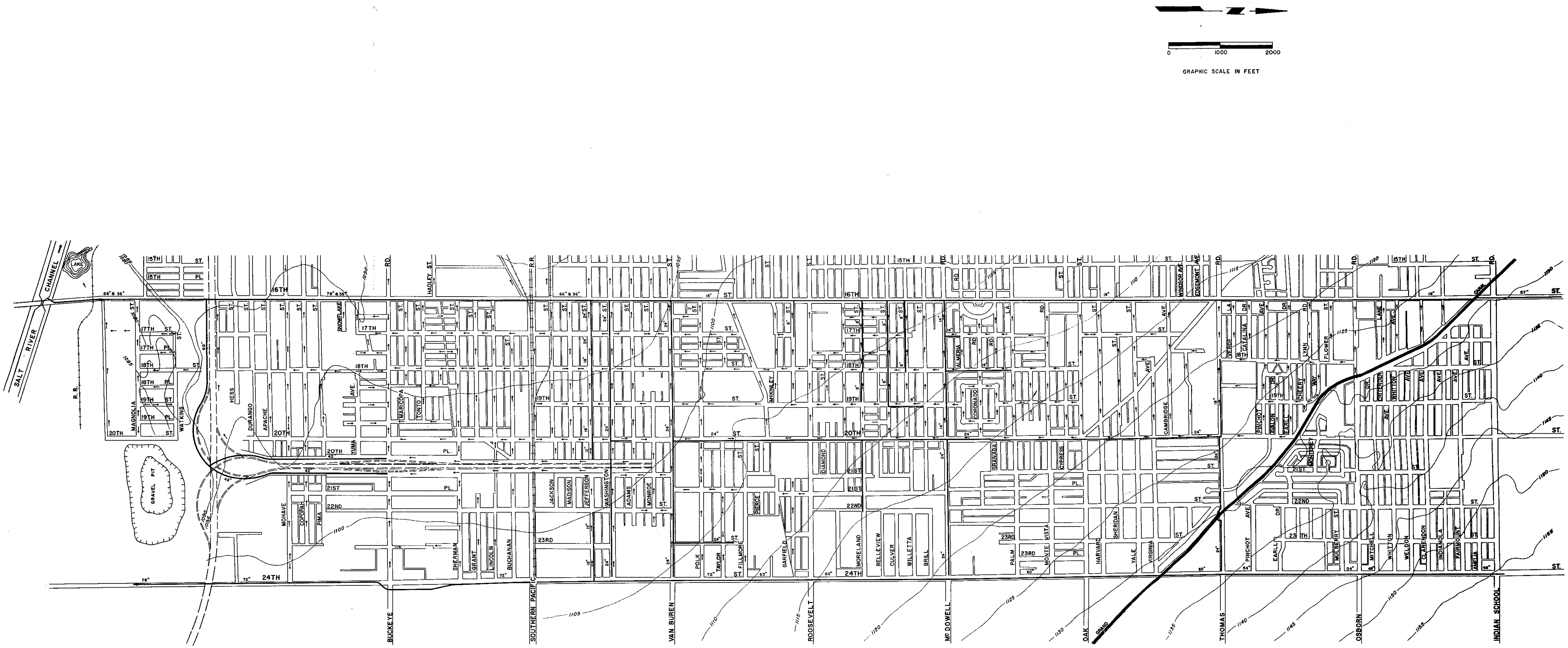
4) That since the existing 18-inch and 36-inch RCP storm drains are greatly overloaded at present, all new inlets and virtually every existing inlet on 16th Street should be connected to the proposed new storm drain.

5) That new inlets, as mentioned in Section III, be installed at those locations where existing inlets have inadequate capacity to carry local drainage.



STUDY AREA MAP

PLATE NO. 1



AREA SURFACE DRAINAGE

16TH STREET STORM DRAIN STUDY

THE KEN R. WHITE COMPANY
PHOENIX, ARIZONA

PLATE 2

RAINFALL INTENSITY CURVES

RAINFALL INTENSITY - DURATION - FREQUENCY
PARTIAL DURATION SERIES
FROM
1956 Y. & G. REPORT

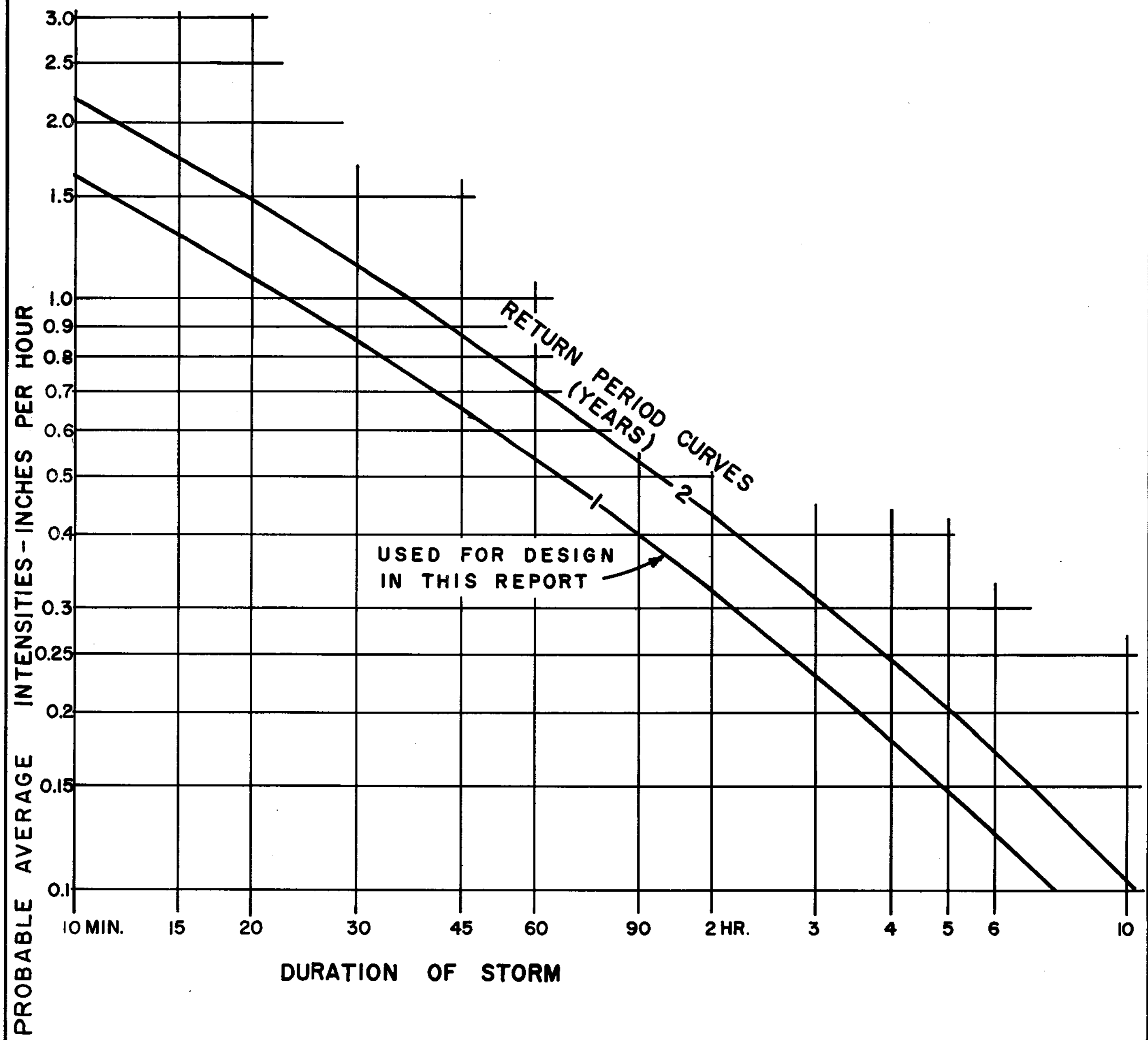
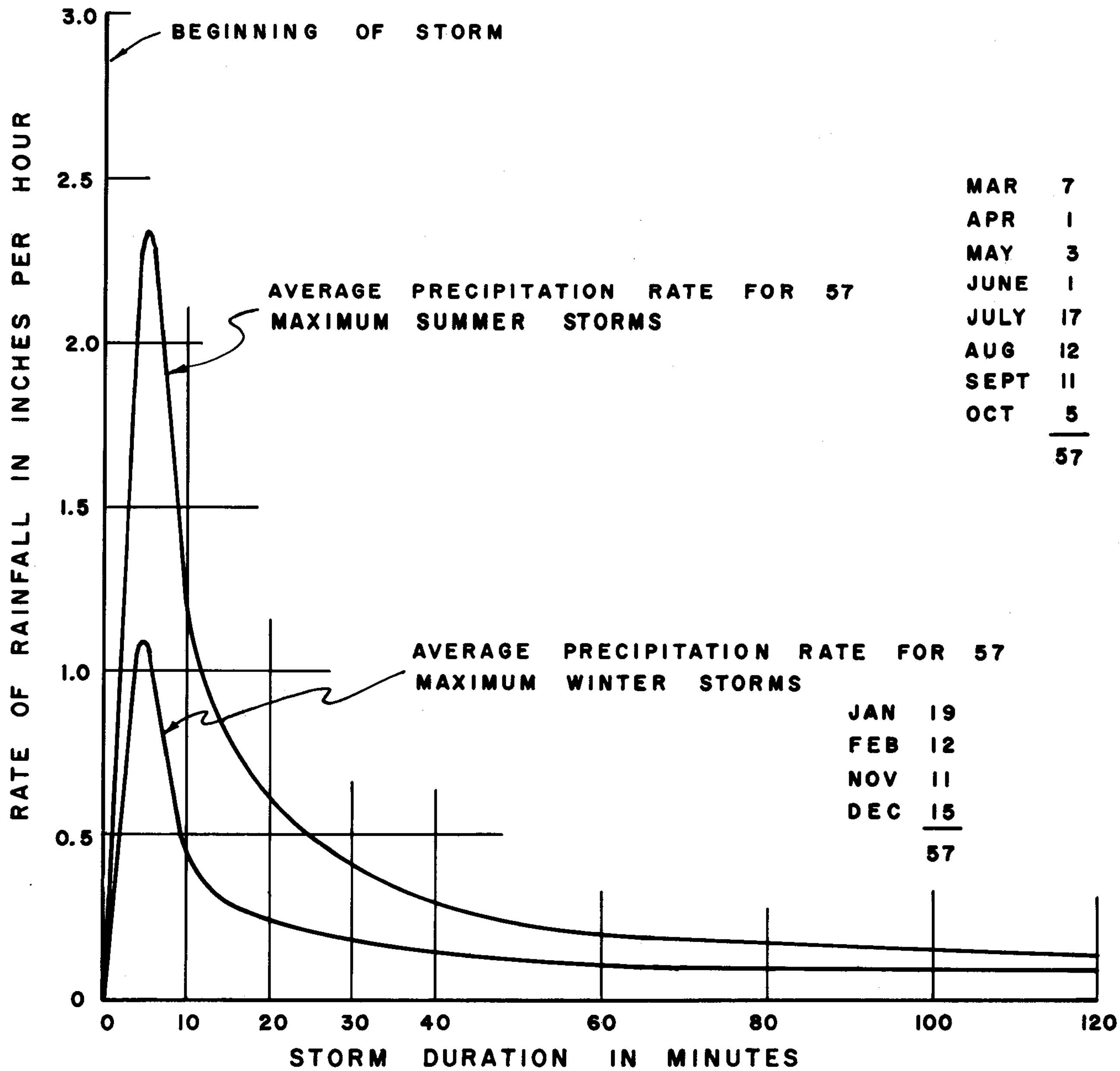


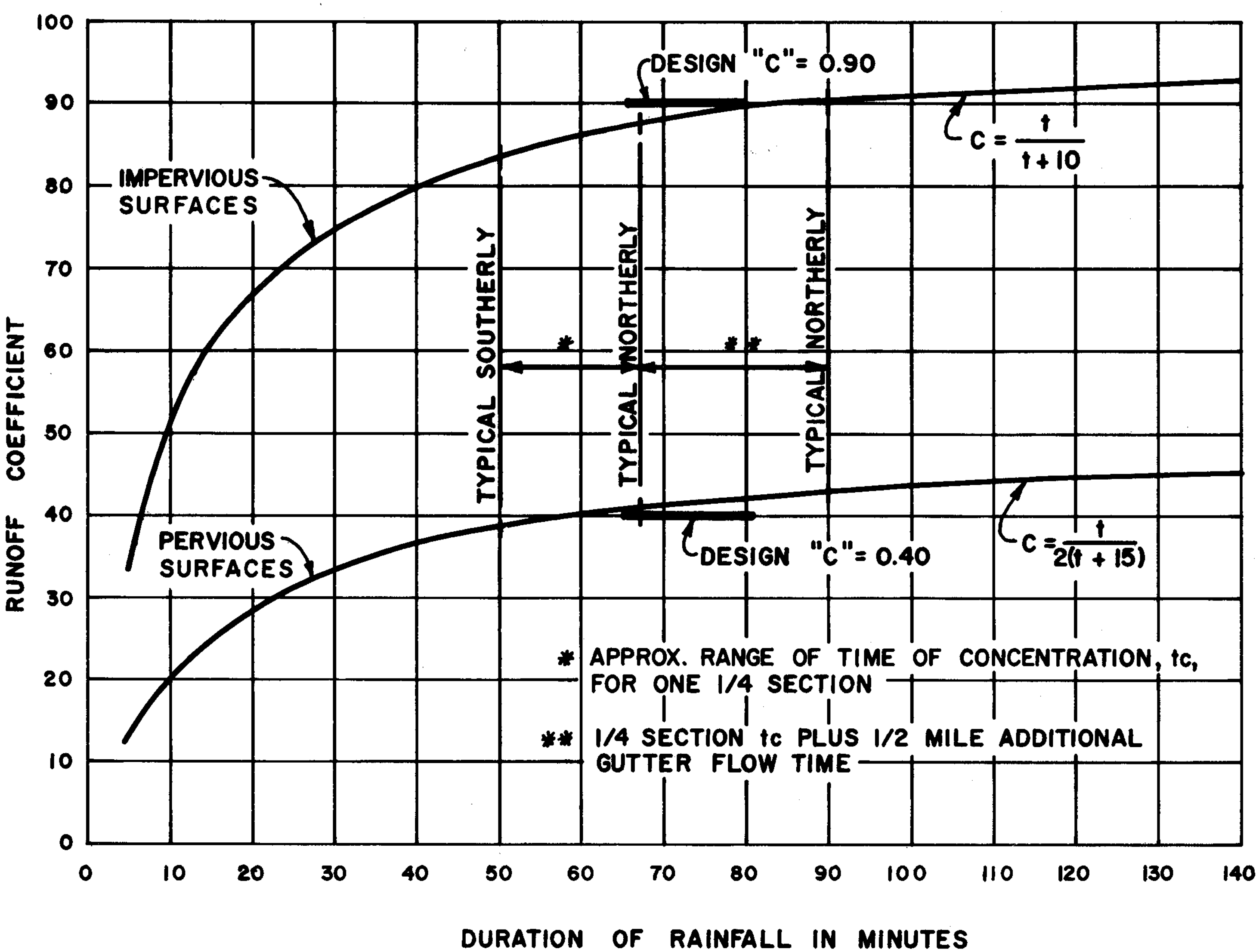
PLATE NO. 3



PHOENIX RAINFALL RATE PATTERN

PLATE NO. 4

RUNOFF COEFFICIENT CURVES



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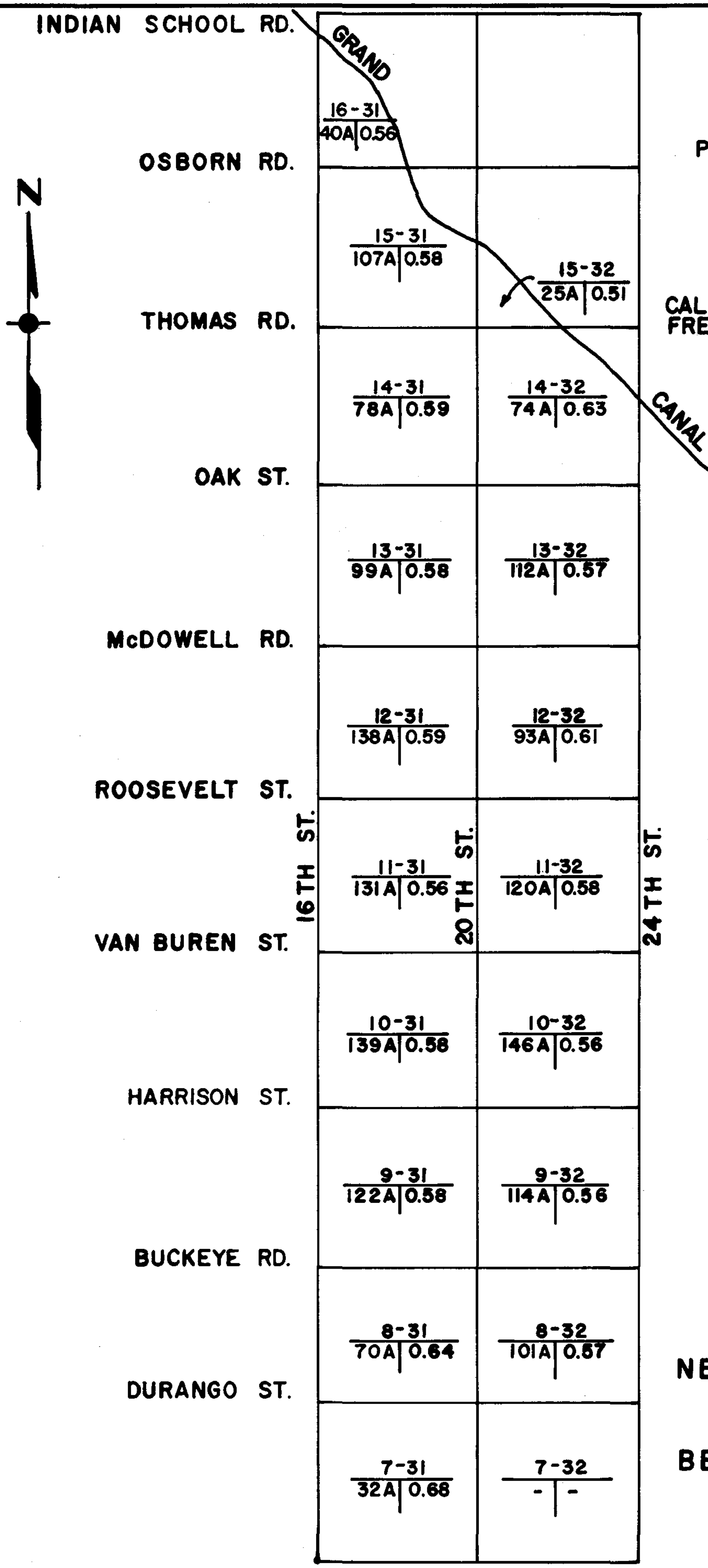
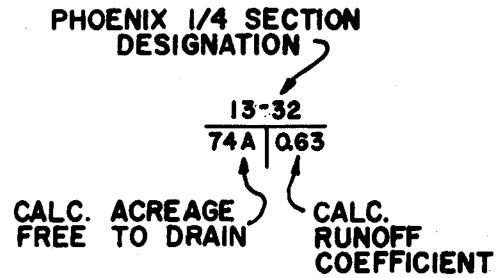


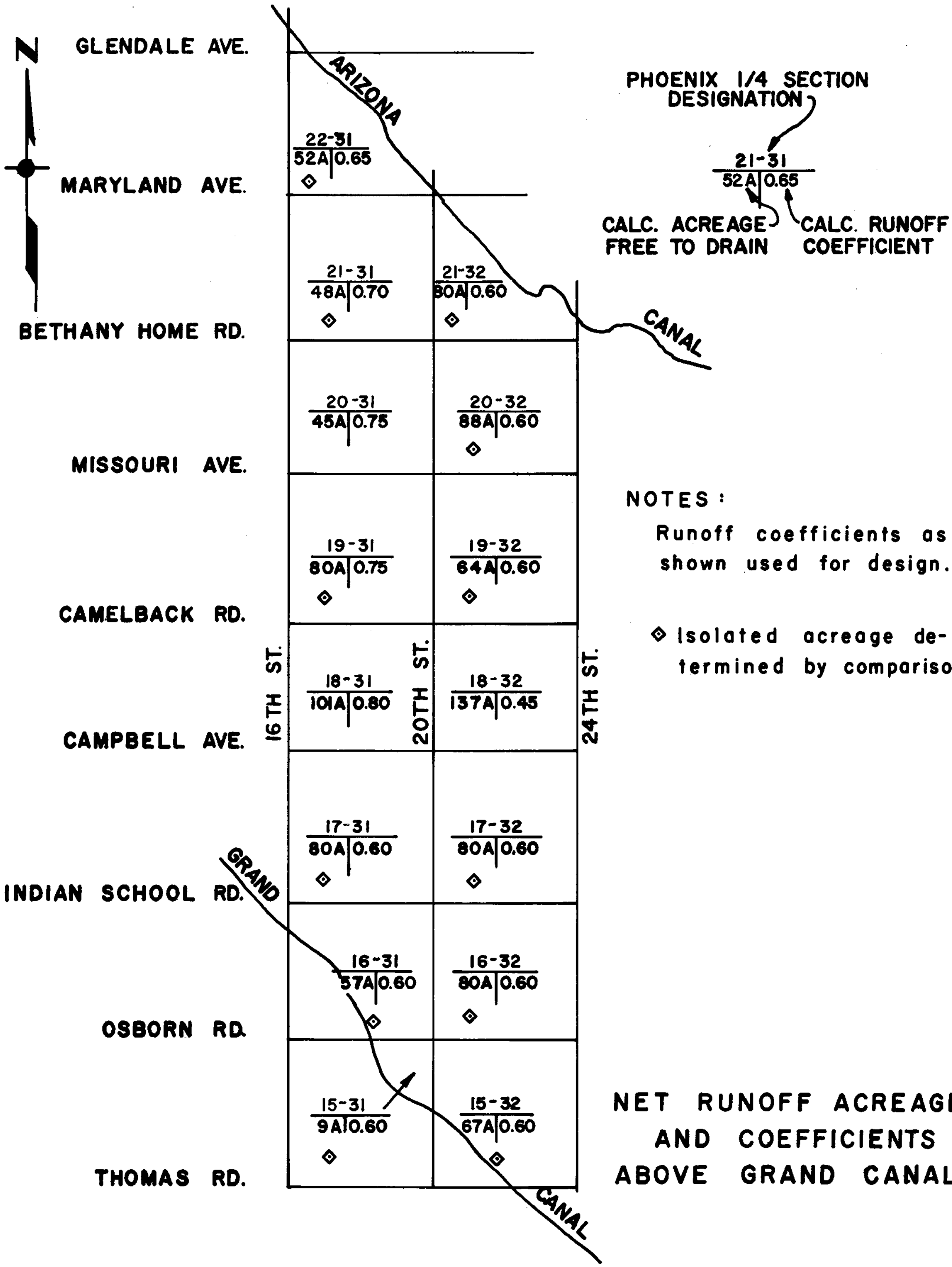


NOTE :

A rounded value of "C" = 0.60 used for design purposes.

NET RUNOFF ACREAGE AND COEFFICIENTS BELOW GRAND CANAL

PLATE NO. 6



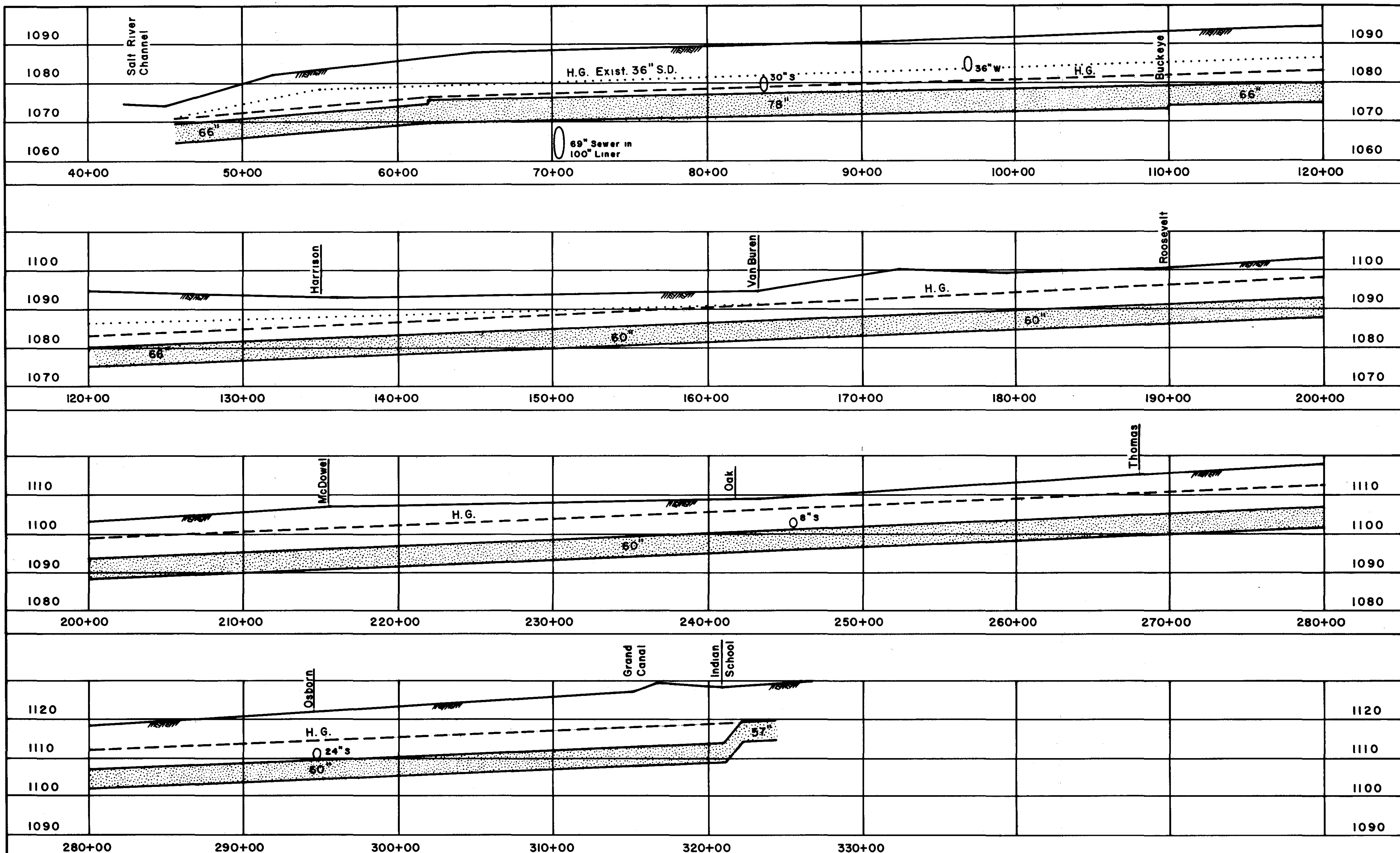
NOTES:

Runoff coefficients as shown used for design.

◇ Isolated acreage determined by comparison.

NET RUNOFF ACREAGE AND COEFFICIENTS ABOVE GRAND CANAL

PLATE NO. 7



APPROXIMATE PROFILE, SALT RIVER TO GRAND CANAL

PLATE NO. 8

PLANS OF POSSIBLE INFLUENCE — WITHOUT FREEWAY

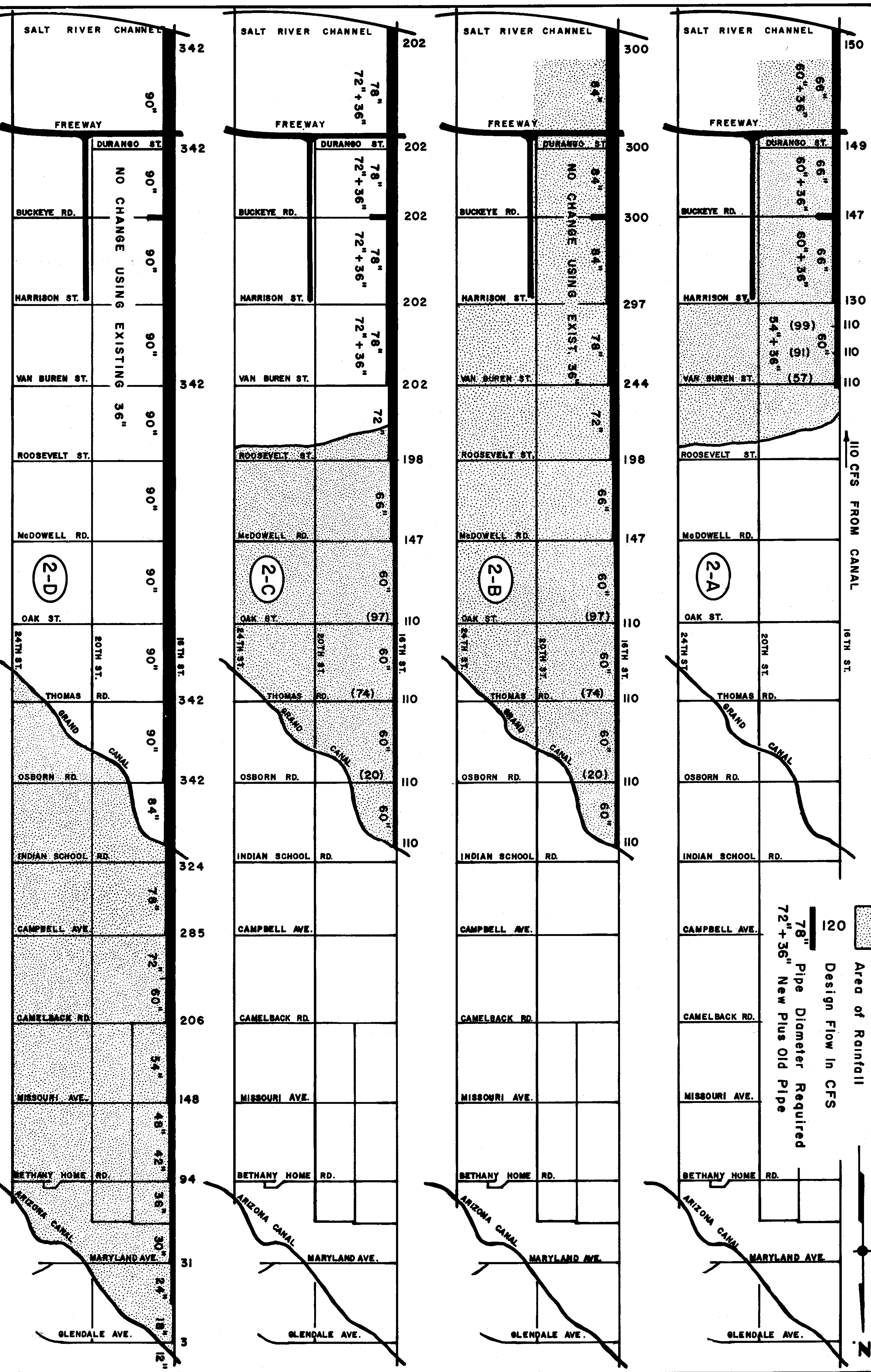


PLATE NO. 9

PLANS OF POSSIBLE INFLUENCE – WITH FREEWAY

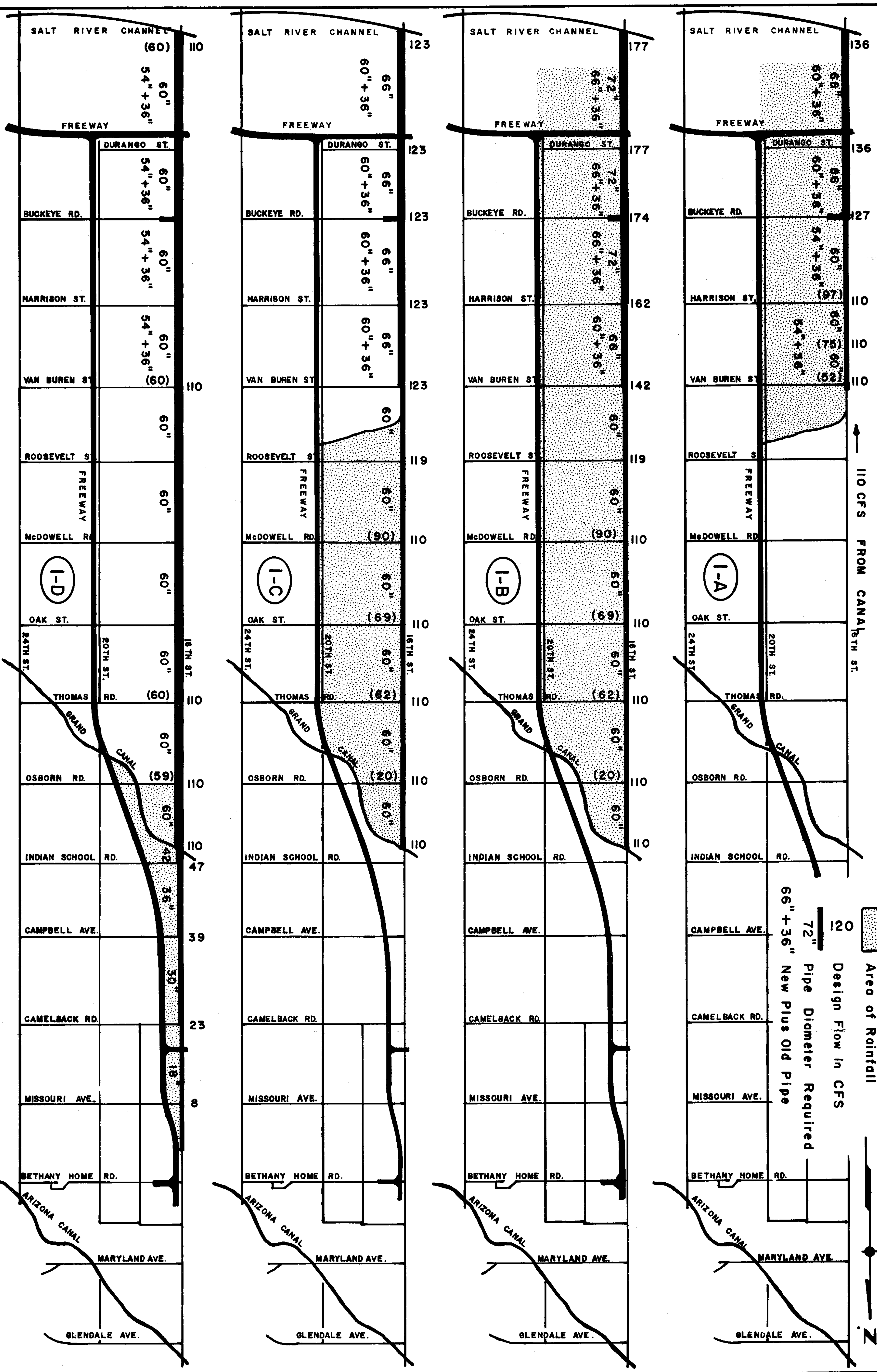
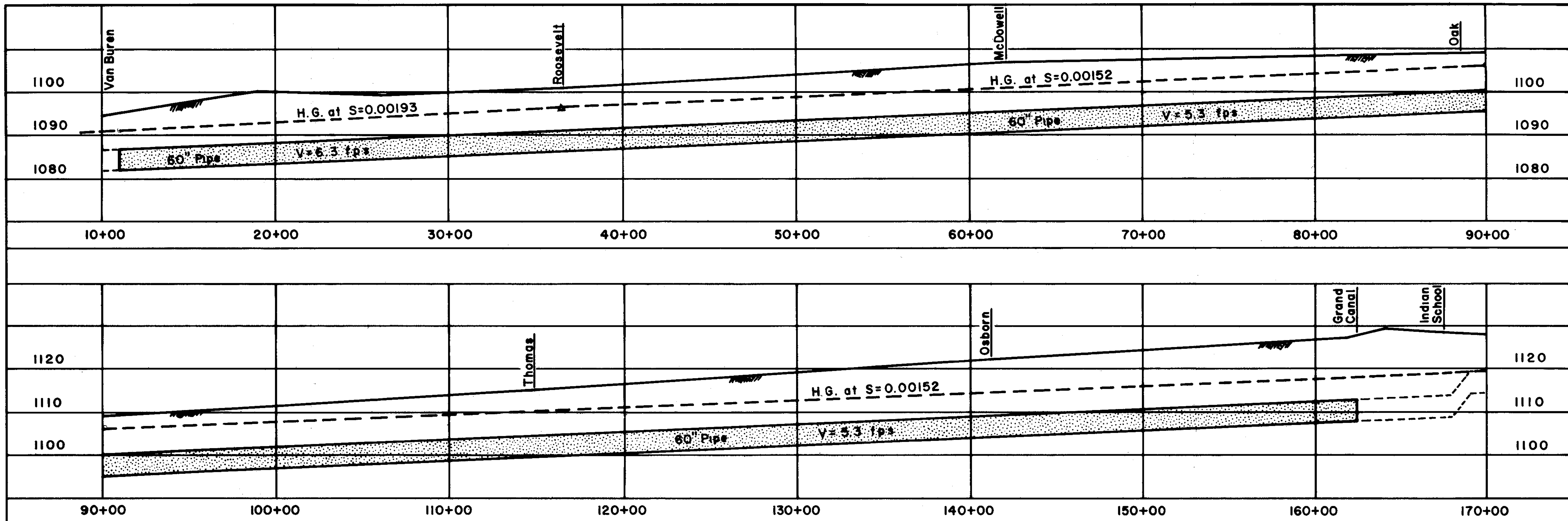
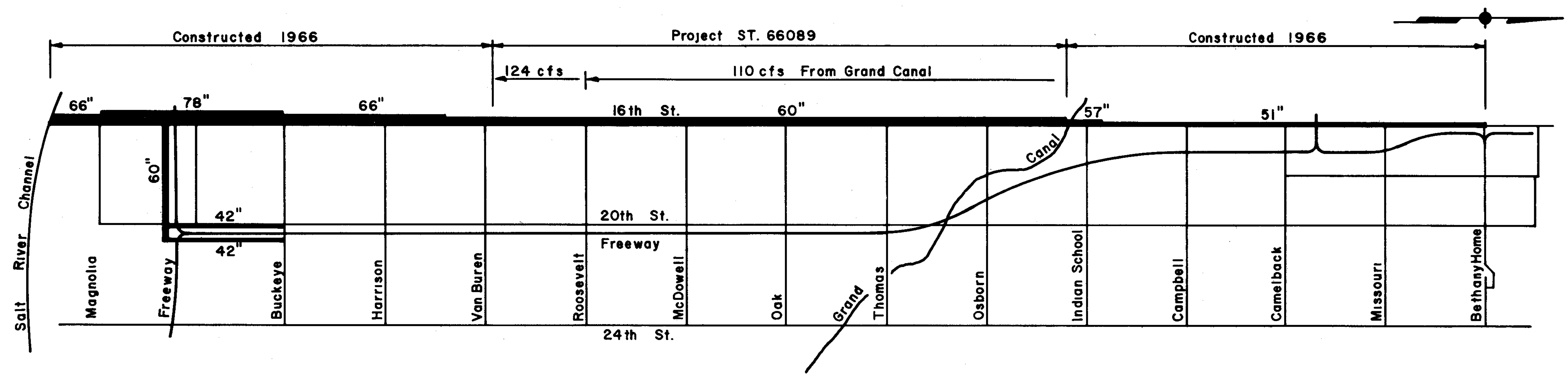


PLATE NO. 10

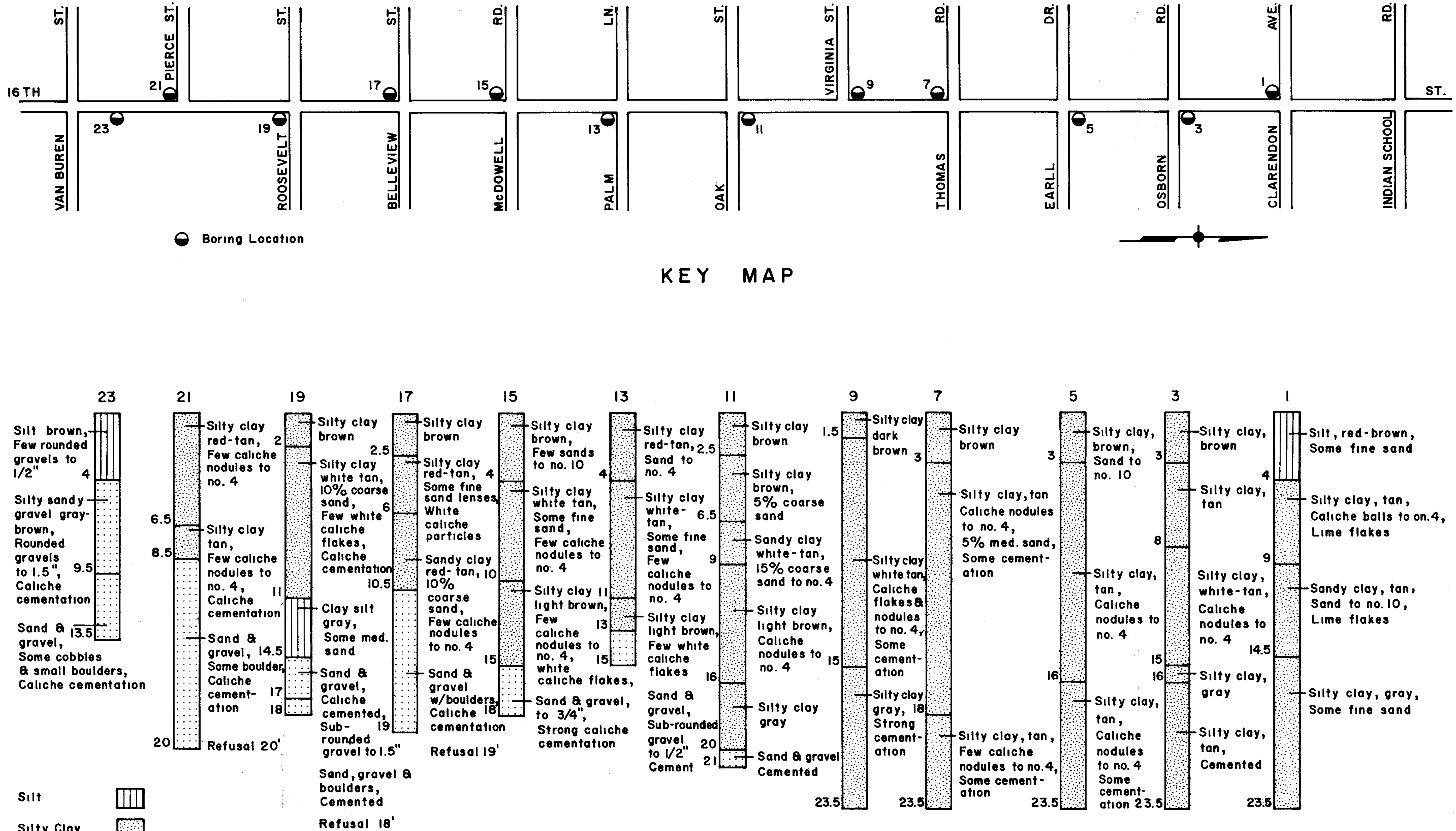


PRILIMINARY PROFILE, VAN BUREN TO GRAND CANAL



PLAN I-B

PLATE NO. 11



Source:
"Soils Investigation Storm Sewer, 16th Street from Van Buren to Grand Canal", Arizona Testing Laboratories, June 1967

SOIL BORINGS
(ABRIDGED)

PLATE NO. 12