MNR3K

MONARCH

DRAINAGE REPORT

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Revised
May, 1991

Prepared for:
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CVL

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1.0 INTRODUCTION

1.1 General Background

Continental Homes, Inc. is planning to develop a 38-acre parcel within the Master Planned Community of 48th Street and Chandler Blvd in the City of Phoenix. The site, known as Monarch, is of an irregular shape and is generally bounded by the undeveloped Marley Parcel to the north, Mountain Park Ranch (undeveloped) to the west and the SRP Highline canal to the south and east. More specifically, the site is located in the north half of the southeast quarter of section 30 (T1S,R4E). The overall project (48th Street and Chandler Blvd. Master Planned Community) is anticipated to develop over a 2-year span. The portion of the project known as Monarch is being developed at this time. Refer to Plate 1 for the vicinity and approximate boundary location.

1.2 Scope of Work

The scope of the report is to provide detailed hydraulic and hydrological analysis of the proposed Monarch Parcel of the 48th Street and Chandler Boulevard Master Planned Community. This report will address off-site drainage, on-site drainage, street flow, storm drain, and retention for the Monarch Parcel.

1.3 Previous Report

The hydrologic background is covered in the approved report *48th Street & Chandler Boulevard Master Drainage Report* (Reference 1). The methods proposed in this report for handling on-site and off-site storm runoff is based on the above referenced approved report.

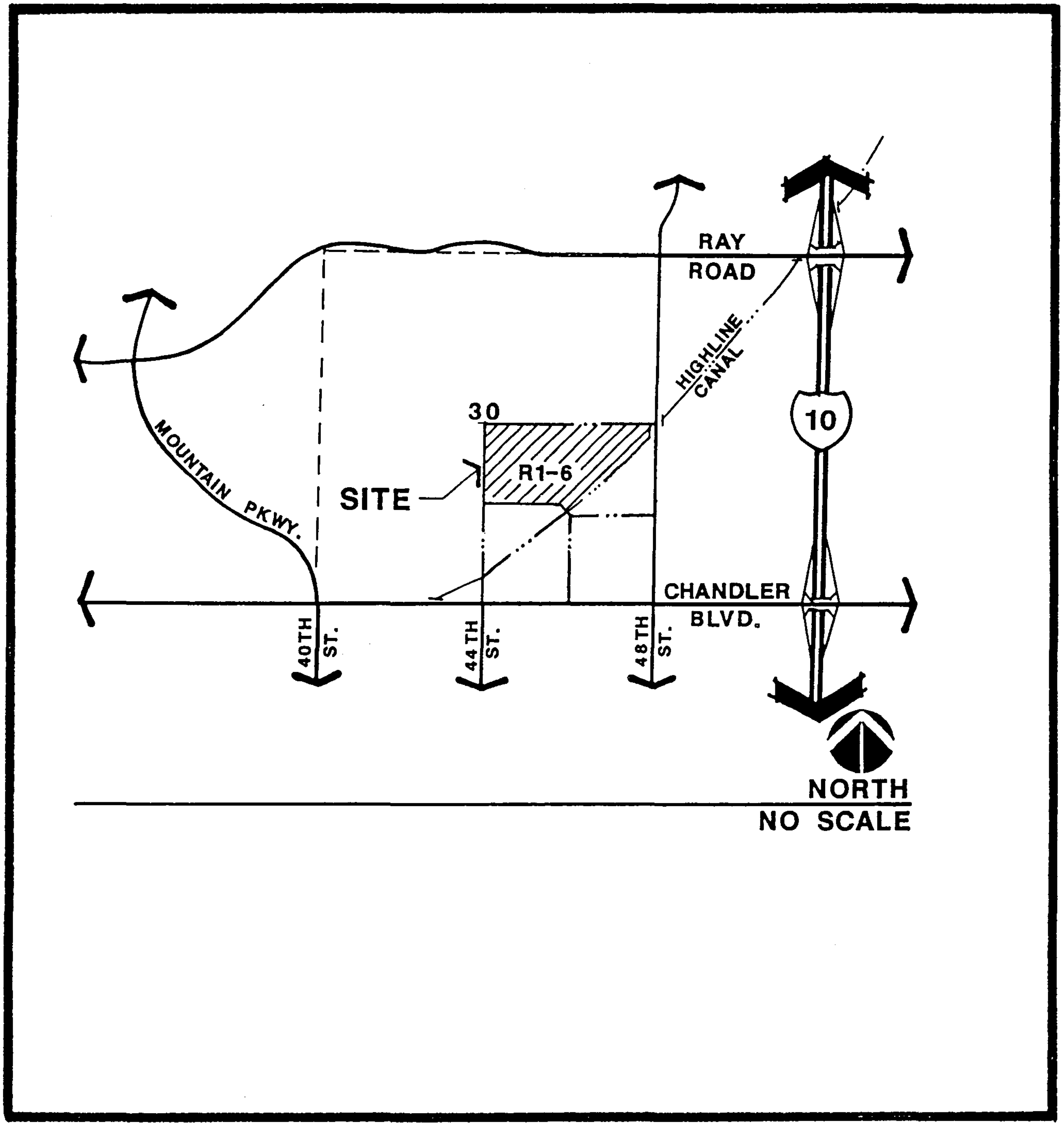


PLATE 1

VICINITY MAP

CYL

2.0 HYDROLOGY

The rational method was used for the Monarch Parcel drainage system, due to the small sub-basins required for the detailed design of this parcel. This method can be used to compute flows at concentration points, for the design of the street hydraulics. Therefore, it can be easily determined where storm drain is needed, and the minimum street slopes required to carry the design storm.

For the rational method, a coefficient of runoff (C-value) of 0.45 was used for residential areas based on the City of Phoenix *Storm Drain Design Manual Subdivision Drainage Design*, (Reference 2).

Times of concentration were based on street flow and lot flow where applicable, and the rainfall intensities were based on City of Phoenix standards. For the Monarch Parcel, rear yard retention will be used on all lots to reduce the runoff that would flow into the streets. Due to relatively steep driveway grades, front yard retention will not be provided except for lots 127-148 and 91-106. However, for the purposes of street flow calculations, on-lot retention was ignored, and it was assumed that the entire lot contributes runoff to the street. This is a very conservative assumption, therefore a 15 minute lot flow time was considered appropriate. Refer to Plate 2 for tributary areas and concentration point locations. Table 1 contains a summary of the hydrologic calculations.

3.0 EXISTING CONDITIONS

3.1 General

The terrain throughout this project is relatively flat, sloping southeast at an average slope of about 1.0 percent. The majority of the site consists of undeveloped desert. Currently, storm runoff enters the project site along the northern property line, and flows south in natural washes. Construction of a proposed drainage channel along the northern property line of the site will collect and convey this flow east around the site. This drainage channel is expected to be constructed prior to or concurrently with the Monarch Parcel. Therefore, offsite flow from the north will not impact the site.

Mountain Park Ranch (MPR) which borders the project site to the west is currently under development. The main drainage facilities within MPR will drain to the south when they are in place. Additionally, a common wall is proposed to be installed with the Monarch Parcel. Therefore, the project site is not impacted by storm runoff along the western property line. Consequently, the proposed parcel, Monarch, will not be subjected to offsite flows, except for the flow that will be contained in the proposed north channel.

3.2 Floodplain Maps

The Flood Insurance Rate Map (FIRM) for Maricopa County, Arizona and Incorporated Areas, Map number 04013C2640D, effective date April 15, 1988, as published by the Federal Emergency Management Agency (FEMA), indicates that this project is in either Zone A or Zone B.

> Zone "A" as defined by FEMA is: Special Flood Hazard Areas Inundated by 100-year flood, no base flood elevations determined.
>
> Zone "B" as defined by FEMA is: Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood.

The 100-year floodplain shown on the Flood Insurance Rate Map (FIRM) is caused by ponding of storm runoff behind the Highline Canal. This ponding will be alleviated in the future condition of the development by the proposed drainage channel at the north property line, and the construction of White Aster Street, and the proposed siphon at the Highline canal. Furthermore, finished pad elevations for lots adjacent to the canal will be set to a minimum elevation equal to one half foot above the bank elevations of the canal. When the parcels that are impacted by this floodplain are developed, a Letter of Maps Revision (LOMR) shall be obtained from FEMA.

4.0 POST-DEVELOPMENT CONDITION

4.1 Drainage Concept

The Monarch Parcel is part of the proposed drainage system for the 48th Street & Chandler Blvd. Master Planned Community as outlined in the MDR (Reference 1). Local flows are collected in street flow and storm drain to outlet at strategic locations per the MDR. Storm drain will be used on Thistle Landing Drive to intercept flows from the upper portion of the site. This flow will outlet into the proposed drainage channel per the *Hydrology & Hydraulics Report for 48th St. & Chandler Blvd. Infrastructure, Draft* by Clouse Engineers Reference 4. Local flows will also need to be conveyed through streets and possibly storm drain through a portion of Polygon Parcel southeast of the Monarch Parcel. This flow will then outlet to the southeast corner of the development, toward the intersection of 48th Street & Chandler Blvd., to maintain existing flow patterns per the MDR. Within the scope of this report, the design of the storm drain system on Thistle Landing Drive is included in the appendix. The drainage system of the Monarch Parcel is designed to conform to the MDR. The system is designed based on generally accepted engineering practices and in accordance with local requirements. Currently, the Shea and Polygon Parcels are being improved, therefore, final design is provided for the drainage system associated with the Monarch Parcel only.

4.2 Channels

A channel system is currently proposed for the north property line per the *Hydrology & Hydraulics Report for 48th St. & Chandler Blvd. Infrastructure, Draft,* reference 4. This channel will turn 90 degrees to the south along the west side 48th Street alignment and continue to the south toward the 48th Street and Chandler Blvd. intersection.

4.3 Culverts

A concrete box culvert is being used where the north channel (referenced previously) crosses Thistle Landing Drive. The design of this box culvert is being done in conjunction with the north channel per reference 4.

4.4 Street Hydraulics

The streets within the Monarch Parcel are designed to carry runoff from the 10-year storm to top of sidewalk, per the City of Phoenix requirements. Additionally, the designed finished floor elevations are above the 100-year storm, in accordance with the City of Phoenix requirements. Where possible, roll curb is used for the local streets. Vertical curb is used at locations where the 10-year flow exceeds the capacity of the street to the back of sidewalk.

Refer to Table 1 in the Appendix for a hydraulic summary of street flow. Additionally, refer to the Appendix for storm drain calculations.

5.0 RETENTION

Since the proposed development involves only single family residential lots, on-site retention for the 100-year, 2-hour event will be provided by rear yard on-lot retention, in accordance with the City of Phoenix requirements. Rear yard retention will be .4' deep and front yard retention will be .2' deep where applicable. This site will be developed based on the City of Phoenix requirement that not more than 45% of the lot is impervious. Calculations are based on information provided by Continental Homes using their 800 series model.

Impervious area = 2,377 S.F./Total Lot Area = 5,600 S.F.

Percent impervious = 42%

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis of this drainage report, the following conclusions are drawn:

A. This Drainage Report is prepared in accordance with the recommendations and design parameters from the Master Drainage Report (Ref. 1). Due to the change in land use, it updates hydrologic modeling for the Monarch Parcel and provides some conceptual design for other parcels in the 48th Street and Chandler Blvd. Master Planned Development. The concept design is included for information purposes only. It is not intended to build any drainage facility, other than those within the Monarch Parcel at this time.

B. The rational method has been used for street flow calculations within the parcel. These methods were also coordinated with the City.

C. The offsite flow that historically entered the site should be conveyed around the site in a channel system designed by Clouse Engineering and constructed prior to or concurrently with the Monarch Parcel.

D. A detailed drainage system, comprised of streets, storm drain, channels, and culverts, have been designed for the Monarch site based on generally accepted engineering practices and in accordance with local requirements. Refer to the Appendix for design calculations.

E. On-lot retention is being provided for the Monarch Parcel to reduce the flow from the development.

It is recommended that the results of this drainage report be used as the guidelines in implementing local drainage from further development within the Shea and Polygon Parcels. It is further recommended that:

A. Finished floor elevations be kept above the 100-year flood elevations and above the bank elevations of the SRP canal for those parcels that are adjacent to the canal.

B. Further development and individual parcels within this project conform to this drainage report and the MDR (reference 1).

C. When the parcels that are impacted by this floodplain are developed, a Letter of Maps Revision (LOMR) shall be obtained from FEMA.

7.0 REFERENCES

1. Coe & Van Loo Consulting Engineers, Inc., *48th Street & Chandler Blvd. Master Drainage Report*, prepared for CHI Construction, August 1990

2. City of Phoenix, *Storm Drain Design Manual, Subdivision Drainage Design*, September, 1985.

3. City of Phoenix, *Storm Drain Design Manual, Storm Drains with Paving of Major Streets*, July, 1987.

4. Clouse Engineering, Inc., *Hydrology & Hydraulics Report for 48th Street & Chandler Boulevard Infrastructure*, March, 1991. Draft.

5. Los Angeles County Flood Control District, *Hydraulic Design Manual*, August 1973.

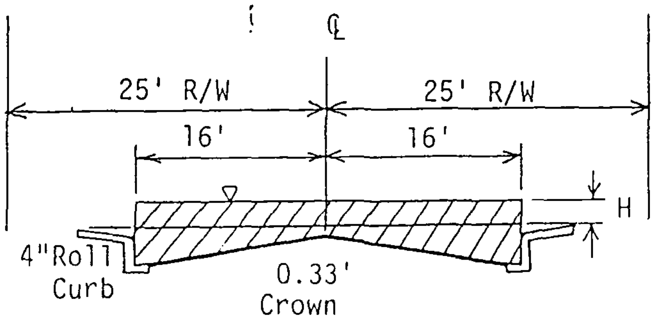
APPENDIX

HYDROLOGY
TABLE 1

CP	Area (ac)	Weighted C	Init. Flowtime (min)	Flow Length (ft)	Ave. Velocity (fps)	T_c min	i_{10}/i_{100} (in/hr)	Q_{10}/Q_{100} (cfs)	Street slope	Capacity[1] (cfs)
A	9.96	.45	15	1940	1.8	33	2.1/3.2	9/14	.30	14
B	(A+B) 12.53	.45	33	400	2.0	36	2.0/3.0	11/17	.15	26[2]
C	7.38	.45	15	1320	1.8	27	2.4/3.6	8/12	.50	18
D	(C+D) 9.59	.45	27	30	1.8	27	2.4/3.6	10/16	.36	15
E	(C+D+E) 11.21	.45	27	250	2.0	29	2.3/3.5	12/18	.20	30[2]
F	9.47	.45	15	1600	1.8	30	2.2/3.4	9/14	.50	18
G	(E+F+G) 20.90	.45	30	60	2.0	31	2.2/3.3	21/31	.60	51[2]
H[3]	11.05	.45	15	1200	2.0	25	2.5/3.8	12/19	.20	30[2]
I	(E+F+G+H+I) 32.24	.45	31	120	3.0	32	2.1/3.2	30/46	.60	51[2]
J	5.22	.45	15	930	1.4	26	2.4/3.6	6/8	.15	10
K	(I+J+K) 38.24	.45	32	230	3.0	33	2.1/3.2	36/55	.60	51[2]

[1] Capacity in street to top of sidewalk.
[2] Capacity calculated to top of sidewalk using vertical curb section.
[3] Contributing flow from Shea Parcel.

TABLE 2
RESIDENTIAL STREET CAPACITY
(50' RIGHT OF WAY)



SLOPE %	H = 0 A = 7.15		H = 0.1 A = 10.35		H = 0.17* A = 12.59		H = 0.3 A = 16.75		H = 0.4 A = 19.95		H = 0.5 A = 23.15	
	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
0.15	1.39	9.96	1.78	18.46	2.00	25.6	2.46	41.2	2.76	55.1	3.05	70.6
0.20	1.61	11.51	2.06	21.31	2.35	29.5	2.84	47.5	3.19	63.6	3.52	81.5
0.25	1.80	12.86	2.30	23.83	2.62	33.0	3.17	53.2	3.57	71.1	3.94	91.1
0.30	1.97	14.10	2.52	26.10	2.87	36.2	3.47	58.2	3.91	77.9	4.31	99.8
0.35	2.13	15.22	2.72	28.20	3.10	39.1	3.75	62.9	4.22	84.2	4.66	107.8
0.4	2.28	16.27	2.91	30.14	3.32	41.8	4.01	67.2	4.51	90.0	5.00	115.3
0.5	2.54	18.19	3.26	33.70	3.71	46.7	4.49	75.2	5.04	100.6	5.57	128.9
0.6	2.79	19.93	3.57	36.92	4.06	51.2	4.92	82.3	5.52	110.2	6.10	141.2
0.7	3.01	21.53	3.85	39.87	4.39	55.3	5.31	88.9	6.00	119.0	6.59	152.5
0.8	3.22	23.01	4.12	42.63	4.69	59.1	5.68	95.1	6.38	127.2	7.04	163.0
0.9	3.41	24.41	4.37	45.21	5.00	62.7	6.02	100.8	6.76	135.0	7.47	172.9
1.0	3.60	25.73	4.60	47.65	5.11	64.4	6.35	106.3	7.13	142.3	7.87	182.3
1.5	4.41	31.51	5.64	58.37	6.38	80.3						
2.0	5.09	36.39	6.51	67.40	7.37	92.8						
2.5	5.69	40.68	7.28	75.36	8.24	103.7						
3.0	6.23	44.56	8.00	82.55	9.03	113.6						

* = 6" vertical curb.
H = Height above top of sidewalk in feet.
A = Area in square feet.
V = Velocity in feet per second.
Q = Flow in cubic feet per second.

1/9/65

CATCH BASIN & STORM DRAIN CALCULATIONS
CB#2 CONCENTRATION POINT B

Thistle Landing Drive catch basins to intercept 10-year flow.
2-C.O.P. type M-1, L=3 (6' curb opening) in sump condition.

Q_{10} = 11 cfs (5.5 cfs each C.B.)

h = 0.5'
Y_o = 0.56'
Y_o/h = 0.56'/0.5' = 1.12
Q/L = 1.30 cfs/ft

Q (capacity) = 1.30 x L = 1.30 x 6 = 8 cfs each C.B.

Q intercepted in CB #1 = 5.5 cfs

5.5 cfs to be carried in 18" RGRCP @ S = 0.006 ft/ft

Q intercepted in CB #2 = 5.5 cfs

Total Q in Storm Drain = 11 cfs

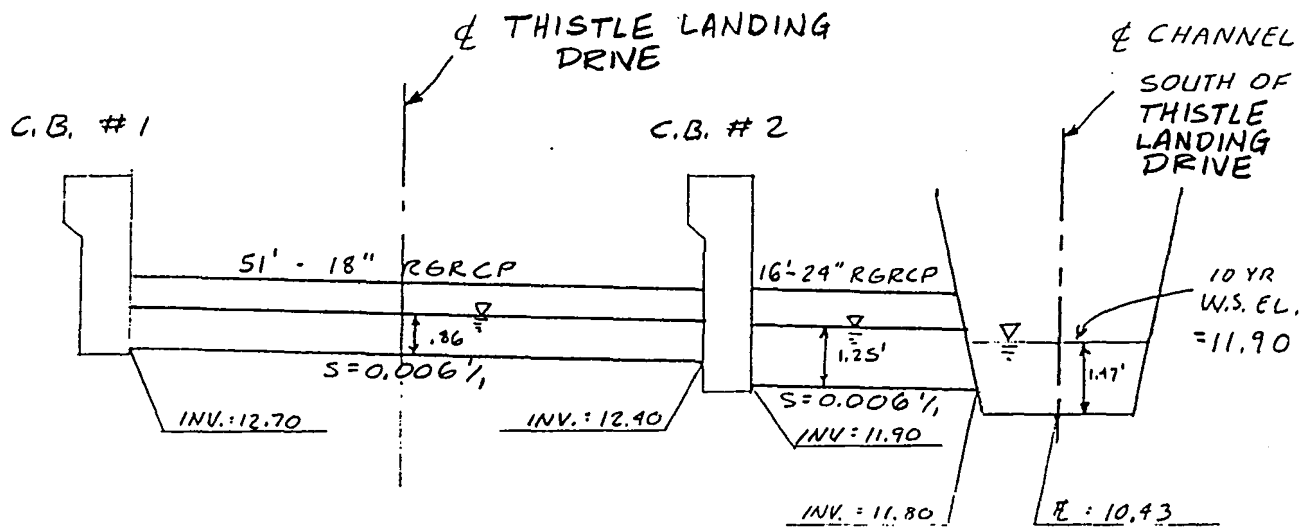
24" RGRCP @ S = 0.006 ft/ft can carry 19 cfs

Note: 10-yr flow remaining in street = 0

CVL

COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

Project MONARCH
Project No. 1782-56
Sheet No. ______ of ______
Calculated by DB Date 3-22-9
Checked by ______ Date ______



24" PIPE

Q_{10} = 11 cfs PIPE IS PARTIALLY FULL, NORMAL DEPTH = 1.25'
V = 5.35 fps

MANHOLE LOSS @ C.B. # 2

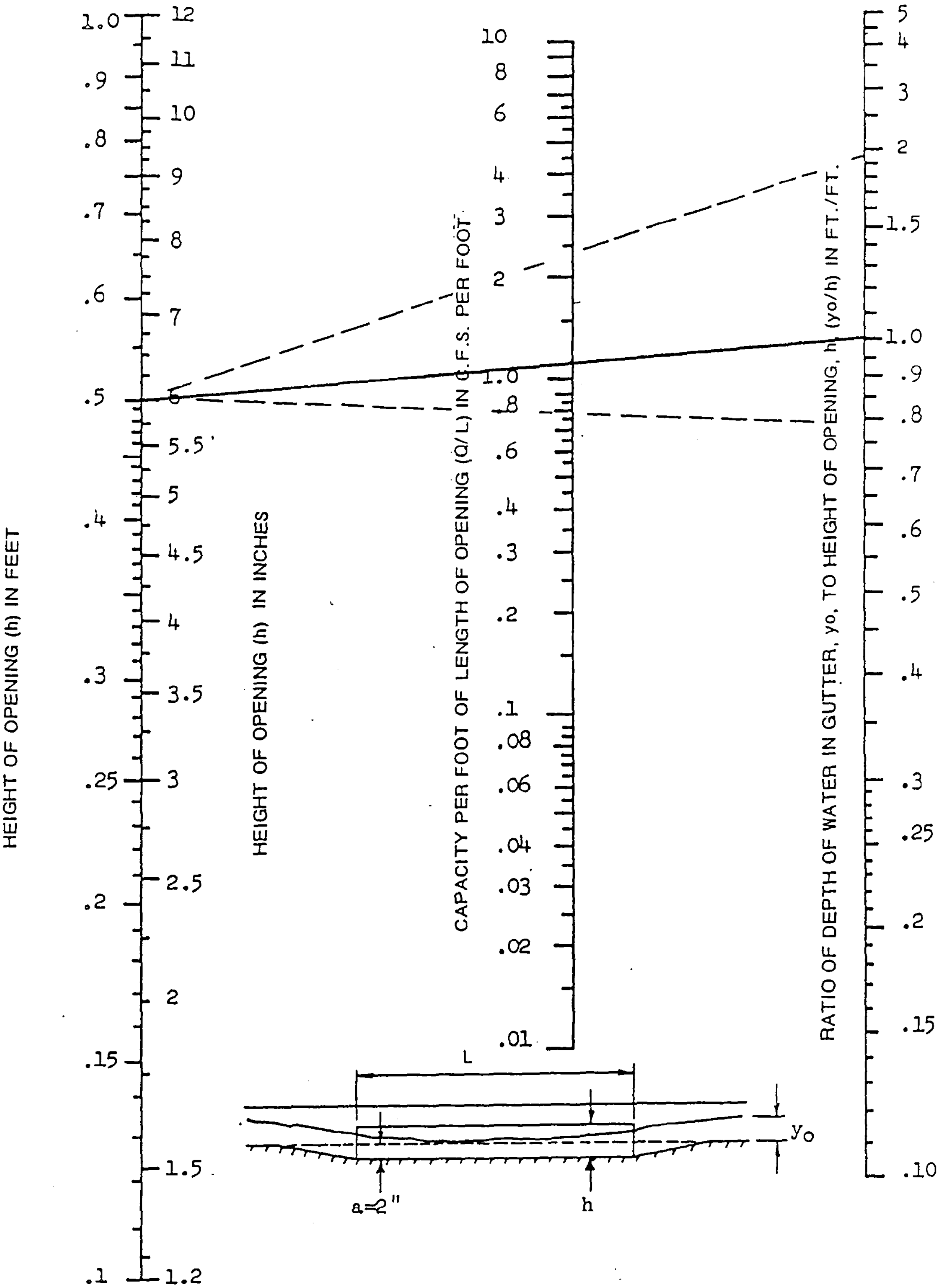
$$h = 0.05\left(\frac{V^2}{2g}\right)^{*} = 0.05\,(0.44) = 0.02$$

∴ THE 0.5' DROP AT THE C.B. WILL ACCOUNT FOR THE MANHOLE LOSS.

18" PIPE

Q_{10} = 5.5 cfs PIPE IS PARTIALLY FULL, NORMAL DEPTH = 0.86'
V = 5.27 fps

* FROM THE LOS ANGELES COUNTY FLOOD CONTROL DISTRICT HYDRAULIC MANUAL.



NOMOGRAPH FOR CAPACITY OF CURB OPENING INLETS IN SUMPS, DEPRESSION DEPTH 2"

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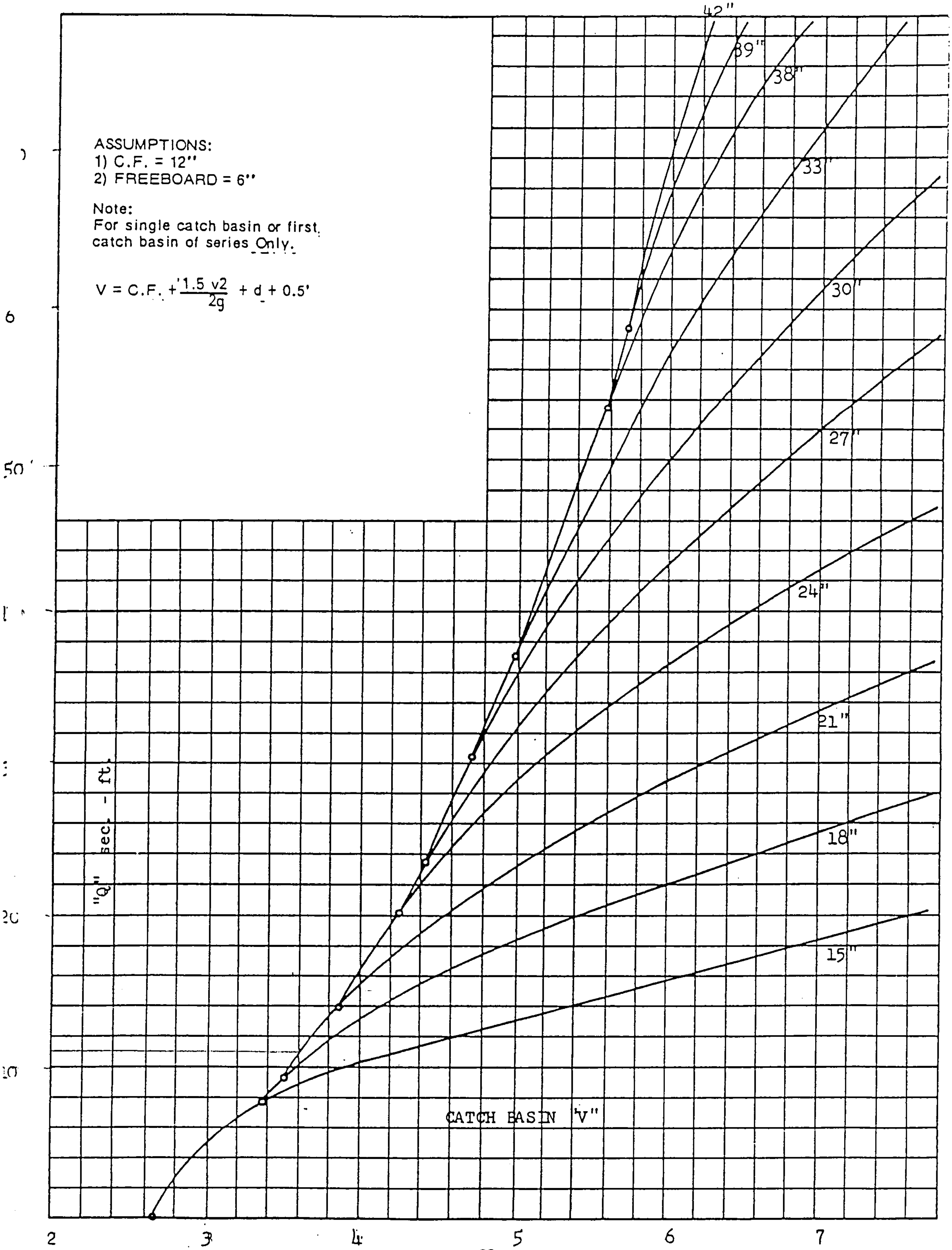

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APPROXIMATE SCALE IN FEET

1000 0 1000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

MARICOPA COUNTY,
ARIZONA AND
INCORPORATED AREAS

PANEL 2640 OF 4350

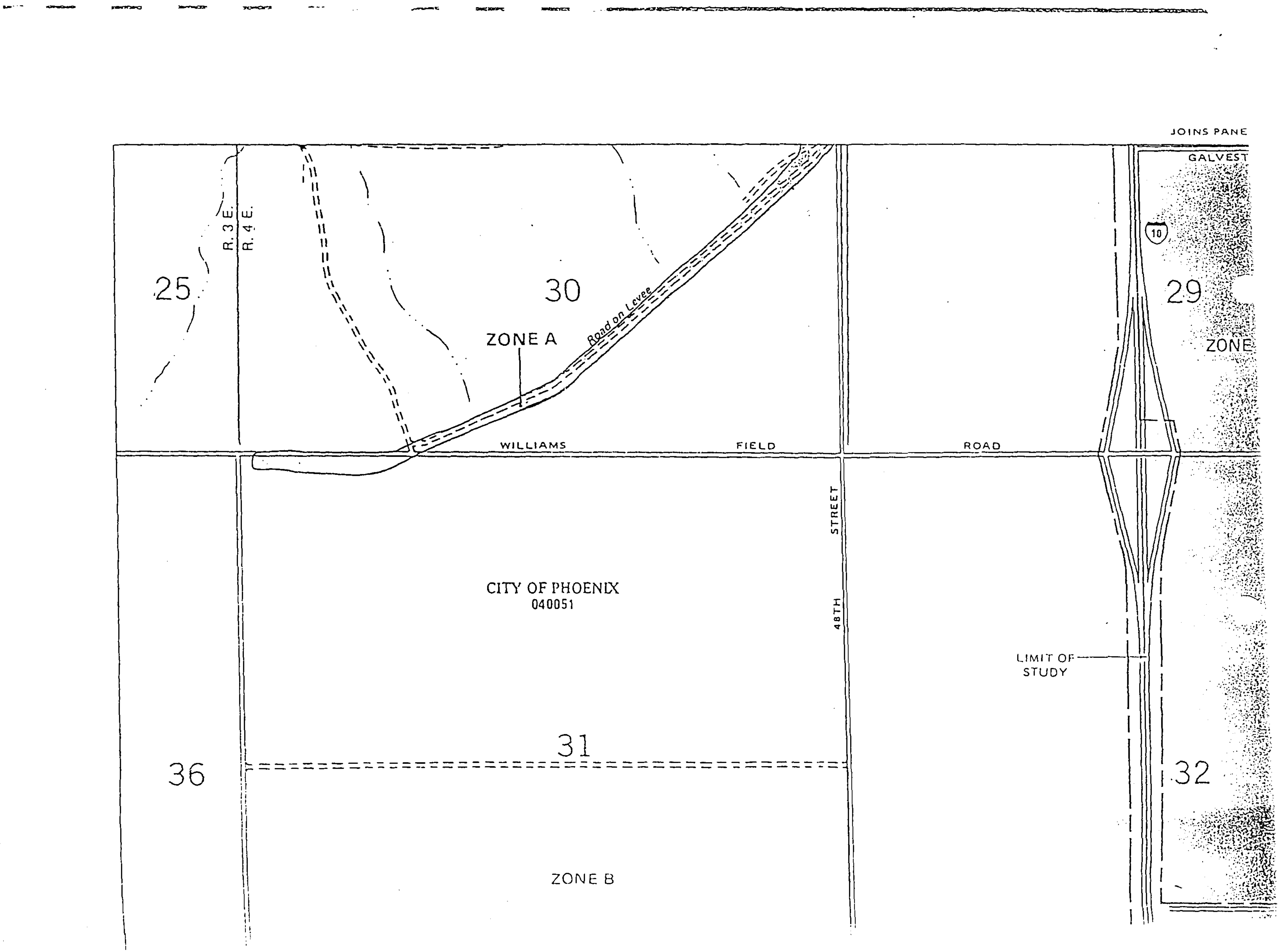
CONTAINS

COMMUNITY	NUMBER	PANEL	SUFFIX
CHANDLER, CITY OF	0400[illegible]	2640	0
MARICOPA COUNTY, UNINCORPORATED AREAS	0400[illegible]	2640	0
PHOENIX, CITY OF	0400[illegible]	2640	0

MAP NUMBER
04013C2640 D

EFFECTIVE DATE:
APRIL 15, 1988

Federal Emergency Management Agency



JOINS PANE
GALVEST
R. 3 E.
R. 4 E.
25
30
29
ZONE
ZONE A
Road on Levee
WILLIAMS
FIELD
ROAD
48TH
STREET
CITY OF PHOENIX
040051
LIMIT OF
STUDY
36
31
32
ZONE B
10

THE FOLLOWING PAGES ARE COPIED FROM THE LOS ANGELES COUNTY FLOOD CONTROL DISTRICT HYDRALIC MANUAL.

Section B

CRITERIA FOR HYDRAULIC DESIGN

CLOSED CONDUITS

B-1 General Hydraulic Criteria

Closed conduit sections (pipe, box, or arch sections) shall be designed as flowing full, whenever possible, and may be allowed to flow under pressure except when the following conditions exist:

a. In some areas of high debris potential, there is a possibility of stoppage occurring in drains. In situations where debris may be expected, the District's Hydraulic Division shall be consulted for a determination of the appropriate bulking factor.

b. In certain situations open channel sections upstream of the proposed closed conduit may be adversely affected by back pressure.

If the proposed conduit is to be designed for pressure conditions, the hydraulic grade line shall not be higher than the ground or street surface, or encroach on the same in a reach where interception of surface flow is necessary. However, in those reaches where no surface flow will be intercepted, a hydraulic grade line which encroaches on or is slightly higher than the ground or street surface will be acceptable.

B-2 Water Surface Profile Calculations

B-2.1 Determination of Controlling Water Surface Elevation

A conduit to be designed for pressure conditions may discharge into one of the following:

a. A body of water such as a reservoir or the ocean.

b. A natural watercourse or ravine.

c. An open channel, either improved or unimproved.

d. Another closed conduit.

B-2.1 Determination of Controlling Water Surface Elevation continued.

The controlling water surface elevation at the point of discharge is commonly referred to as the control and, for pressure flow, is generally located at the downstream end of the conduit. If flow becomes unsealed, the control may be at the first gradebreak upstream of the point where unsealing occurs or, under certain conditions, may be farther upstream.

Two general types of controls are possible for a conduit on a mild slope, which is a physical requirement for pressure flow in discharging conduits.

a. Control elevation above the soffit elevation. In such situations the control shall conform to the following criteria:

   (1) In the case of a conduit discharging into a reservoir, the control shall be the reservoir water surface elevation.

   (2) In the case of a conduit discharging into an open channel, the control shall be the design water surface elevation of the channel.

   (3) In the case of a conduit discharging into another conduit, the control shall be the hydraulic grade line elevation of the outlet conduit immediately upstream of the confluence.

   (4) In the case of a conduit discharging into the ocean, the control shall be approved by the District prior to preparation of hydraulic calculations.

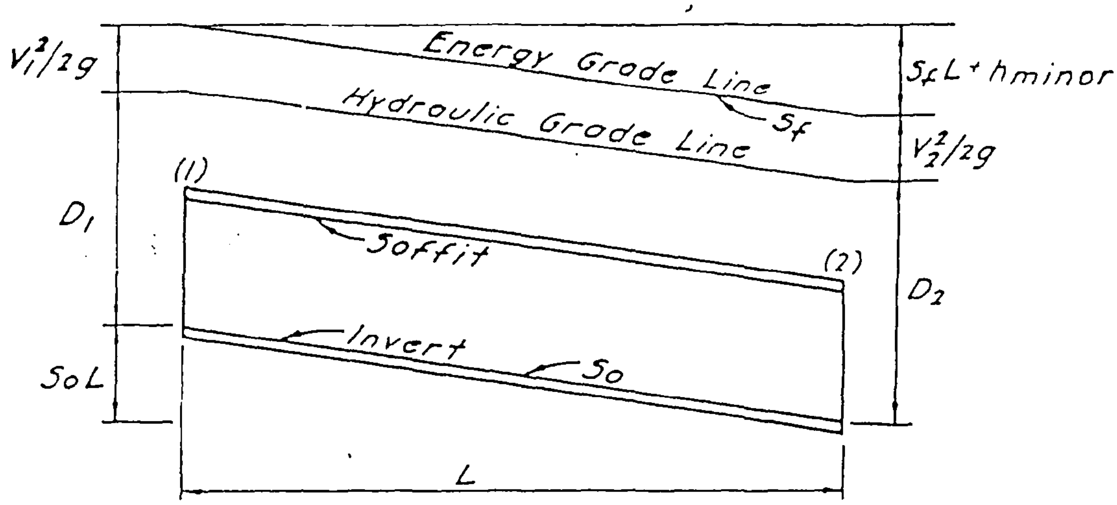
b. Control elevation at or below the soffit elevation. The control shall be the soffit elevation at the point of discharge. This condition may occur in any one of the four situations described on page B-1.

Hydraulic grade line elevations to be used as controls for bond issue projects in many cases may be obtained from the District's Design Division. Exceptions to the above policy must be approved by the District.

B-2.2 Instructions for Hydraulic Calculations

Most procedures for calculating hydraulic grade line profiles are based on the Bernoulli equation. This equation can be expressed as follows:

$$\frac{V_1^2}{2g} + D_1 + S_o L = \frac{V_2^2}{2g} + D_2 + S_f L + h_{minor}$$



In which D = Vertical distance from invert to H.G.L.
S_o = Invert slope
L = Horizontal projected length of conduit
S_f = Average friction slope between Sections 1 and 2
V = Average velocity (Q/A)
h_{minor} = Minor head losses

Minor losses have been included in the Bernoulli equation because of their importance in calculating hydraulic grade line profiles and are assumed to be uniformly distributed in the above figure.

B-2.2 Instructions for Hydraulic Calculations continued.

When specific energy (E) is substituted for the quantity $V^2/2g + D$ in the above equation and the result rearranged,

$$L = \frac{E_2 - E_1}{S_o - S_f}$$

The above is a simplification of a more complex equation and is convenient for locating the approximate point where pressure flow may become unsealed.

One format in use at the District for calculating hydraulic grade line profiles and considered acceptable for bond issue work is shown on Chart No. B-01. For use in expediting such calculations, a computer program is available with a separate instruction book and may be obtained upon request. (See page B-16.)

B-2.3 Head Losses

B-2.3.1 Friction Loss

Friction losses for closed conduits carrying storm water, including pump station discharge lines, shall be calculated from the Manning equation or a derivation thereof. The Manning equation is commonly expressed as follows:

$$Q = \frac{1.486}{n} A R^{2/3} S_f^{1/2}$$

in which Q = Discharge, in c.f.s.
n = Roughness coefficient
A = Area of water normal to flow in ft.^{2}
R = Hydraulic radius
S_f = Friction slope

When rearranged into a more useful form,

$$S_f = \left[\frac{Qn}{1.486 A R^{2/3}}\right]^2 = \left[\frac{Q}{K}\right]^2$$

In which

$$K = \frac{1.486 A R^{2/3}}{n}$$

B-2.3.1 Friction Loss continued.

The loss of head due to friction throughout the length of reach (L) is calculated by:

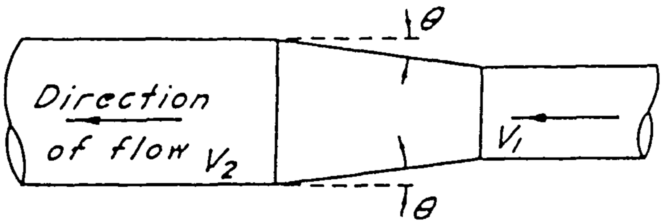
$$h_f = S_f L = \left[\frac{Q}{K}\right]^2 L$$

The value of K is dependent upon only two factors: the geometrical shape of the flow cross section as expressed by the quantity $AR^{2/3}$, and the roughness coefficient (n). The values of n shown in Chart No. F-04 shall be used for bond issue and District work.

Values of K corresponding to an n value of .013 for reinforced concrete pipe and equivalent reinforced concrete box sizes are shown on Chart No. F-01.

B-2.3.2 Transition Loss

Transition losses shall be calculated from the equations shown below. These equations are applicable when no change in Q occurs and where the horizontal angle of divergence or convergence (θ) between two sections does not exceed 5°45'.



For velocities which increase in the direction of flow ($V_2 > V_1$),

$$h_t = .1\left[\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right]$$

For velocities which decrease in the direction of flow ($V_2 < V_1$),

$$h_t = .2\left[\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right]$$

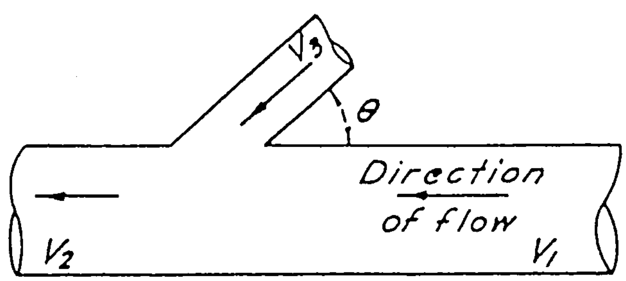
B-2.3.2 Transition Loss continued.

Deviations from the above criteria must be approved by the District. When such situations occur, the angle of divergence or convergence (θ) may be greater than 5°45'. However, when θ is increased beyond 5°45', the above equations will give results for h_t that are too small, and the use of more accurate methods, such as the Gibson method shown on Chart No. B-11, will be acceptable.

B-2.3.3 Junction Loss

In general, junction losses shall be calculated by equating pressure plus momentum through the confluences under consideration. This can be done by using either the District's P + M method or the City of Los Angeles' Thompson equation, both of which are shown in Section F. Both methods are applicable in all cases for pressure flow and will give the same results.

For the special case of pressure flow with $A_1 = A_2$ and friction neglected,



$$h_j = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} - \frac{2A_3}{A_2} \cdot \frac{V_3^2}{2g} \cdot \cos\theta$$

B-2.3.4 Manhole Loss

Manhole losses shall be calculated from the equation shown below and shall be used only for District Manhole Nos. 1 and 2. Where a change in pipe size and/or change in Q occurs, the head loss shall be calculated in accordance with Sections B-2.3.2 and B-2.3.3.

$$h_{m.h.} = .05\left[\frac{V^2}{2g}\right]$$

B-2.3.5 Bend Loss

Bend losses shall be calculated from the following equations:

$$h_b = K_b\left[\frac{V^2}{2g}\right]$$

in which

$$K_b = 0.20\sqrt{\frac{\Delta}{90^\circ}}$$

where Δ = Central angle of bend in degrees

K_b may be evaluated graphically from Chart No. B-10 for values of Δ not exceeding 90 degrees.

Bend losses should be included for all closed conduits, those flowing partially full as well as those flowing full.

B-2.3.6 Angle Point Loss

Angle point losses shall be calculated from the following equation:

$$h_{a.pt} = .0033\,\theta \left[\frac{V^2}{2g}\right]$$

in which θ = Deflection angle in degrees, not to exceed 6° without prior approval from the District.

B-3 Special Cases

B-3.1 Transition From Large to Small Conduit

As a general rule, storm drains shall be designed with sizes increasing in the downstream direction. However, when studies indicate it may be advisable to decrease the size of a downstream section, the conduit may be decreased in size in accordance with the following limitations:

a. For slopes of .0025 (.25 percent) or less, conduit sizes may be decreased to a minimum diameter of 72 inches. Each reduction is limited to a maximum of 6 inches.

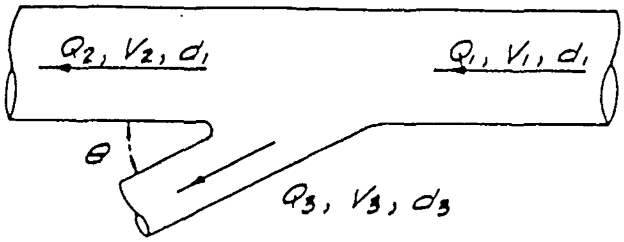
b. For slopes of more than .0025, conduit sizes may be decreased to a minimum diameter of 30 inches. Each reduction is limited to a maximum of 3 inches for pipe 48 inches in diameter or smaller, and to a maximum of 6 inches for pipe larger than 48 inches in diameter. Reductions exceeding the above criteria must have District approval.

In any case the reduction in size must result in a more economical system.

Where conduits are to be decreased in size due to a change in grade, the criteria for locating the transition shall be as shown on Chart No. B-20.

B-3.2 Branching of Flow in Pipe - Head Loss

The following equation may be used to determine the loss of head in cases where it may be necessary to split or branch the flow into another drain.



$$h_{br.} = C \frac{V_1^2}{2g}$$

Values for the coefficient C may be obtained from the table below and apply only to straight reaches of pipe of constant diameter. For angles of divergence (θ) and ratios of Q_3/Q_1 other than those shown, values of C may be interpolated.

Divergence Angle-θ	$\frac{Q_3}{Q_1} = 0.3$	$\frac{Q_3}{Q_1} = 0.5$	$\frac{Q_3}{Q_1} = 0.7$
90°	C = 0.76	C = 0.74	C = 0.80
60°	C = 0.59	C = 0.54	C = 0.52
45°	C = 0.35	C = 0.32	C = 0.30

B-4 Design Requirements for Maintenance and Access

B-4.1 Manholes

B-4.1.1 Spacing

a. Conduit diameter 30 inches or smaller:

Manholes shall be spaced at intervals of approximately 300 feet. Where the proposed conduit is less than 30 inches in diameter and the horizontal alignment has numerous bends or angle points, the manhole spacing shall be reduced to approximately 200 feet.