Civil & Municipal Engineering

UNITED WESTERN ENGINEERS & LAND SURVEYORS

Structural Design
Land Planning and Surveying

Phone
ME 2-9840

108 East Mill Street
Colorado Springs, Colorado

Director of Public Works
City of Colorado Springs
Colorado Springs, Colorado

Dear Sir:

Enclosed herewith is the Engineering Study of the Sand Creek Drainage Basin, authorized by the City Council of the City of Colorado Springs.

The report includes a study of the rainfall-runoff characteristics, and channel improvements for the entire basin. It also includes a study of storm sewer requirements, developed basin hydrographs, and required streets and grading in an area around the City.

If desired, the study may be used as a "master drainage plan" for the basin as it is developed in the future.

Respectfully submitted,

Registered Engineer
Colorado 2051

RETURN TO:
Land Development
101 West Costilla, Suite 122
Colorado Springs, CO 80903

HYDROLOGIC ENGINEERING STUDY

OF THE

SAND CREEK DRAINAGE BASIN

FOR THE

DEPARTMENT OF PUBLIC WORKS

COLORADO SPRINGS, COLORADO

JANUARY 25, 1962

UNITED WESTERN ENGINEERS

COLORADO SPRINGS, COLORADO

VOLUME I

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SCOPE & PURPOSE:

This report is intended to furnish the basis for an overall plan for placing storm sewers and drainage appurtenances in the Sand Creek basin, as subdivisions are developed. It should be a part of the overall plan for storm water control in the metropolitan area around Colorado Springs.

The intent of this study is not to establish the exact design of a storm sewer or channel in any definite area. It should, rather, establish the general location of required storm drainage structures and their required sizes. It should establish those natural channels which must remain as water carrying channels, and those which may be blocked or diverted.

Saving existing channels for drainage purposes, and not allowing any encroachments, is one of the major problems facing the City of Colorado Springs. Natural channels, blocked or diverted, can lead to flooding of major proportions. This in turn, leads to the installation of large quantities of storm sewer and other drainage works. If the natural channels can be saved, part, at least, of these installations can be avoided.

Studies of undeveloped basins provide the basis for logical overall storm drainage design prior to the time of subdivision development. In this manner, storm drainage structures may be constructed as subdivisions are developed, thus controlling costs and avoiding potential storm damage.

BASIN DESCRIPTION:

The Sand Creek basin is approximately 52 square miles in area and lies generally east and northeast of the City of Colorado Springs. It extends from Austin Bluffs on the West to the Town of Falcon on the East, and from the Vollmer Road, Black Forest on the North, to a point on Fountain Creek near the North boundary of Fort Carson on the South.

The basin is drained by Sand Creek, which has four major branches and many minor branches. Water can be found in the main stream and in some of the branches during years of high rainfall. Generally, however, the entire stream is dry, or nearly so.

The records indicate some very high flows in past years, and these flows have left their mark in eroded banks and sand deposits. Evidence of considerable erosion can be found along the entire reach of the stream and its branches. A large amount of soil conservation work has been done in this basin, and consequently, high flows of water have been very infrequent in recent years.

The basin has a rolling topography with only a small area of abrupt hills or bluffs. The valley is relatively narrow in the Northern 1/3, quite wide in the Middle 1/3, and narrows again in the Southern 1/3. Most of the creek channel is wide and flat, indicating relatively slow water movement even during flood flow.

Four general soil types are found in the basin. The Northern portion of the basin is nearly all of the Dawson formation, which is primarily sand and clayey sand. It is in this formation that the high, abrupt bluffs are found.

The central portion of the basin is composed primarily of the Fox Hills formation and some loess. Both materials are silty sands, but have strikingly different characteristics. Infiltration is reasonably high in both soils, but the Fox Hills formation is easily saturated and runoff can be high if the rainfall lasts for an extended time.

The most Southerly portion of the basin consists of the Pierre Shale covered by a thin layer of wind blown sand. This shale does not allow infiltration to any great extent, and run-off is therefore quite high.

RAINFALL PATTERNS:

Average annual rainfall in the Sand Creek basin is low, being about 14.8" per year. The major portions of this annual rainfall are in May, June, July and August. Both mountain type storms and plains type storms fall on this basin.

Snow storms can be severe, especially in the Northern portions of the basin. The amount of actual moisture in a snowfall however, is usually not high enough to lead to excessive runoff.

Storms of record in the basin fall into two categories.

1. Short, intense storms lasting up to two hours, and usually local in nature, and,

2. Long term storms lasting six hours or more, and being spread over a large area.

The long term storms last a relatively long period of time, allow high infiltration, produce a great volume of runoff, but has a relatively low flood peak.

The short duration storm produces less runoff water, but being intense, has a very high flood peak.

Four storm types were investigated. They were:

1. 30 minute duration, 0.8" intensity, 2 year frequency storm.
2. 1 hour duration, 2.0" intensity, 50 year frequency storm.
3. 6 hour duration, 3.0" intensity, 50 year frequency storm.
4. 6 hour duration, 3.5" intensity, 100 year frequency storm.

After applying these rainfall types to the basin, it was found that the storm shown as No. 2 above, has the highest reasonable design flood peak. This storm was then used in all computation.

The probability of occurrence was balanced with economic considerations, and the 50 year, 1 hour storm was confirmed for use in design. The hydrographs in the appendix of this report can be used to change the design storm if desired, but for the purposes of this report, all data is given for this design storm.

RUNOFF PATTERNS:

Actual, measured runoff data does not exist for this basin. This data would be very desireable, and should be obtained in the future. If the data were available, some refinement in design would be possible, and the work would be easier.

In the absence of measured data, the available data of other basins must be adapted to the soil conditions and topography of the Sank Creek basin. Runoff data was collected from Soil Conservation Service, from the Forest Service, the Weather Bureau, and the Bureau of Reclamation records. Several local basins have been studied to some extent, and some data is available from these studies.

The data was then adapted to the Sand Creek Basin by the use of the system developed by the Soil Conservation Service. An inventory of the land was made to determine the usable portions and that most likely to remain unsubdivided. Aerial photos and on the spot observations completed this general survey.

The Sand Creek Basin was then subdivided into five sub basins. These were divided into twenty area basins, and these were divided into 128 minor basins. An outfall point was assigned to each minor basin and a synthetic hydrograph constructed at these points.

The final hydrographs of each minor basin were combined on a time scale so that combined hydrographs could be constructed at each outfall point of the twenty area basins.

These combination hydrographs give a graphical picture of the flow down Sand Creek and its various tributaries. As it takes a certain amount of time for a flood crest to travel from point to point, and since the length of Sand Creek is relatively great, it was found that the peak of the combined hydrograph gradually increases in time interval and in width as the crest moves to the South.

In the Southern extremity of the basin, the peak is rather flat. This occurs since the majority of local runoff has already left the area by the time the crest of the upper basin runoff reaches it. For example, the flow crest at point I on Vollmer Road occurs about .8 hours after rainfall begins and lasts a short time only. The crest at point V on Highway 24, however, occurs about 2.4 hours after rainfall begins, and the period of high flow lasts over an hour.

All the hydrographs developed in this report are based on the assumption that the entire area has been developed into residential tracts. It was assumed for this purpose that land within 5 miles of the City of Colorado Springs will develop into City sized lots and blocks. A strip three miles in width around this was assumed to have developed into 1/2 acre tracts. The remainder of the basin was assumed to have developed into one acre tracts.

It was judged best to assume the entire basin to be developed due to the fact that the Southern basins will be developed first. This allows drainage design to be made so that structures in the Southern portion of the basin will be large enough to handle the water produced if the entire basin becomes fully developed.

These hydrographs are all synthetic graphs and some adjustments may be necessary if and when actual stream runoff measurement can be made. These adjustments will be minor, but may be desireable.

MAIN CHANNELS - GREENBELTS:

The most economical method of removing flood runoff from a developed area is a system of open ditches or drainage channels. First cost is lower, and the ditches are easier to maintain and clean than are pipes.

In developed areas, however, ditches have been impractical due to the fact that, usually, insufficient space has been left by the development for proper sized ditches or control works.

In this basin however, development is negligible at the present time, and sufficient right of way can be made available at a reasonable cost.

Previous studies commissioned by the City of Colorado Springs have recommended a "Greenbelt" drainage system in other areas. This basin lends itself to this system, and such a "Greenbelt" system is recommended for the Sand Creek basin.

The Greenbelt system consists of strips of land reserved for drainage flow and for certain drainage structures. This land should be maintained as a ditch, should be planted in grass where possible and rip rapped where necessary.

New subdivisions should be planned around these Greenbelts so that there is no interference with runoff, and so that road crossings are held to a minimum. Bridges, culverts and pedestrian crossings will be required along the stream bed, but care should be taken that stream flow is neither impeded nor diverted.

In the Sand Creek basin, the Greenbelts follow the natural stream bed for the most part, and do not interfere excessively with land fit for subdividing. Required channel widths and depths are shown in the Appendix, but the channel generally should be wide and shallow. This reduces the danger to children, and reduces water velocity, which decreases the amount of required channel stabilization.

Since actual water flow along these ditches would be periodic and not continuous, these strips could be used as parks. Wide points might be used as playgrounds or parks, if desired, making use of the land during periods of no flow.

RESERVOIRS:

A large number of medium to small reservoirs presently exist in the basin and have been responsible for the low incidence of flooding. With increasing subdivision development, however, these reservoirs will disappear, to be replaced with streets, paved parking lots, buildings, etc. The inevitable result of this will be increased runoff, and eventually, flooding.

It can be seen by examination of the hydrographs, that when the existing dams disappear, peak flows will become so high as to require very wide ditches, and large structures.

To avoid this situation, seven reservoirs have been planned at strategic points along the greenbelts to reduce flow.

These reservoirs are of the "flow through" variety, and are intended to control rate of flow only. By construction of larger dams, retention is possible. This may be very desireable for recreational or aesthetic reasons, but for the purposes of this report, it has been assumed that the reservoirs shall be flow control structures only, and will, consequently, usually be dry.

Water is allowed through these dams at a certain rate, only. Water in excess of this rate is temporarily stored. This allows smaller structures downstream from the reservoirs, and will greatly reduce the overall cost of drainage control.

The attempt was made to locate these reservoirs on land which is generally unsuitable for development. This should not be the sole criteria for location, but is desireable.

Along eastern Sand Creek, a series of good dam structures exist on the Banning-Lewis ranch at present. If this area is developed in the future, these dams should be saved. They are reasonably well built and very well located. Some renovation would be required, since they are designed to hold water at all times, but these reservoirs are in general, well suited to the purpose of flood control.

The other six reservoirs must be constructed. These reservoirs are long, but relatively low, and construction costs should not be large. The savings which can be made in the construction of smaller bridges and culverts easily repays the cost of retention reservoirs.

INDIVIDUAL IMPROVEMENTS:

Attention is directed to that portion of the Appendix which maps individual improvements recommended. These maps show the recommended improvements to greater advantage than any discussion.

After designing the main channel and reservoirs, the individual basins were studied, using the minor basin hydrographs previously described. Water flow at various points in the basin was compared to street capacity and distribution.

In some cases, it was found that the specification of location of a certain size street will be sufficient to distribute runoff properly. In other cases, this will not be sufficient, and storm sewers will be required.

Inlet problems can be very difficult, especially in the case of streets with steep grades. Such problems must be worked out as each area is designed, since street designs of the subdivisions will alter the sewer designs somewhat. These changes should be relatively minor in mature.

Individual basin improvements are shown only in the area within about a 5 mile radius of the City of Colorado Springs. This is the scope of this report since the development of areas outside this radius is, in all probability, some years in the future. This study includes all basic data needed for the design of individual basin improvements, however. Thus, any basin outside the area of logical city extension may be easily studied with the data developed.

SUMMARY & RECOMMENDATIONS:

Experience in and around the City of Colorado Springs has shown the futility of attempting to control storm runoff with street drainage alone. Streets will carry large quantities of water under favorable conditions, but will not contain the high flood peaks common during the intense local storms in the area.

A study such as this, and previous studies, should be made for each basin in the region in which subdivision development is contemplated. In this manner, drainage channels and reservoir sites can be preserved, and dangerious building locations avoided.

The location and sizes of required primary drainage streets and storm sewers will be known and may be constructed before residential and commercial density becomes so concentrated that drainage problems are acute. Substantial long term savings in construction costs can be made by using this system. It is much less expensive to control drainage by construction of structures before the area is developed.

The recommendation of this study is that the design features shown in Appendices A, B, and C be followed in general terms, and that the cost thereof be prorated among the subdivisions involved.

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APPENDIX A:

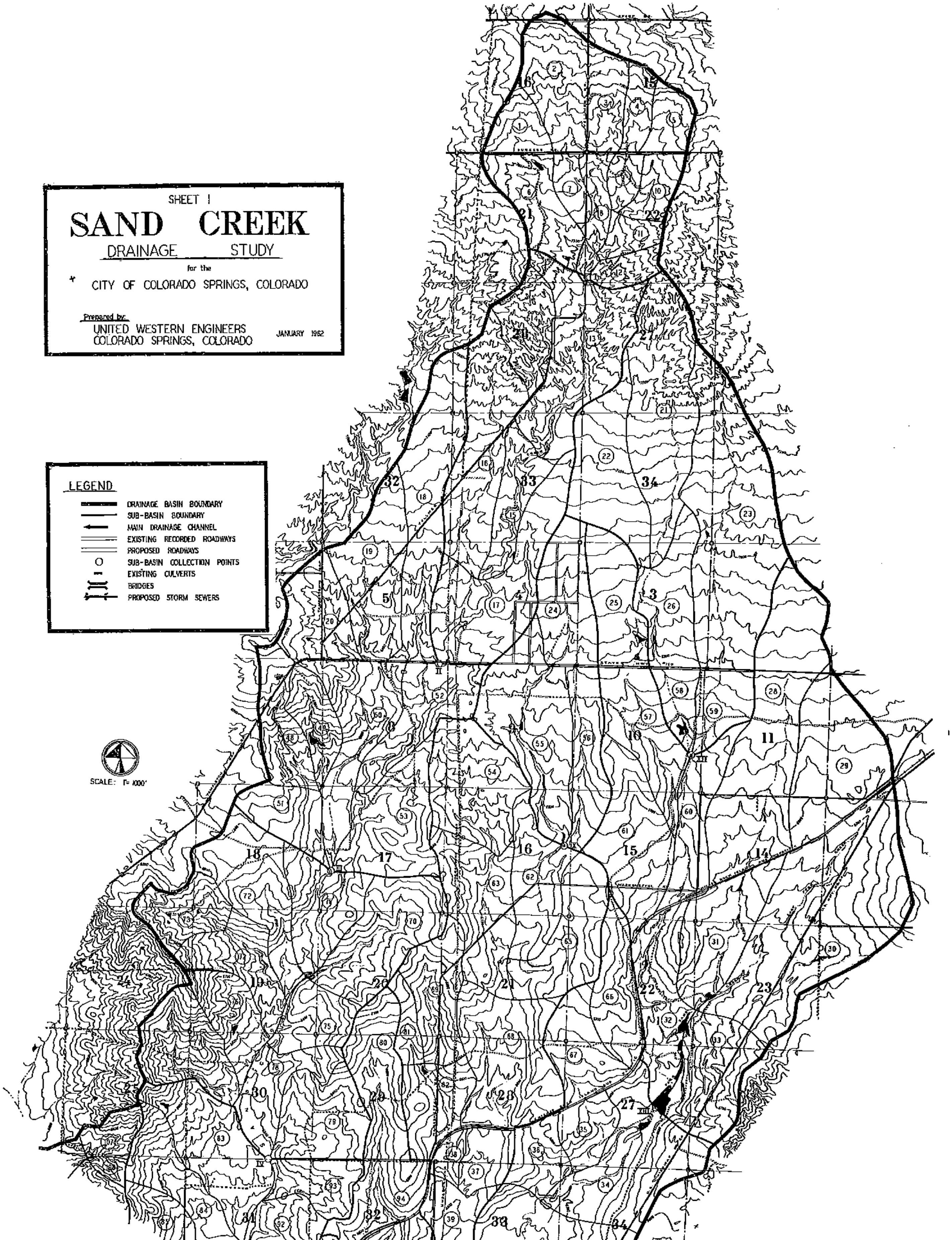
GENERAL MAP OF

SAND CREEK DRAINAGE BASIN

EL PASO COUNTY, COLORADO

AS IT EXISTS

January, 1962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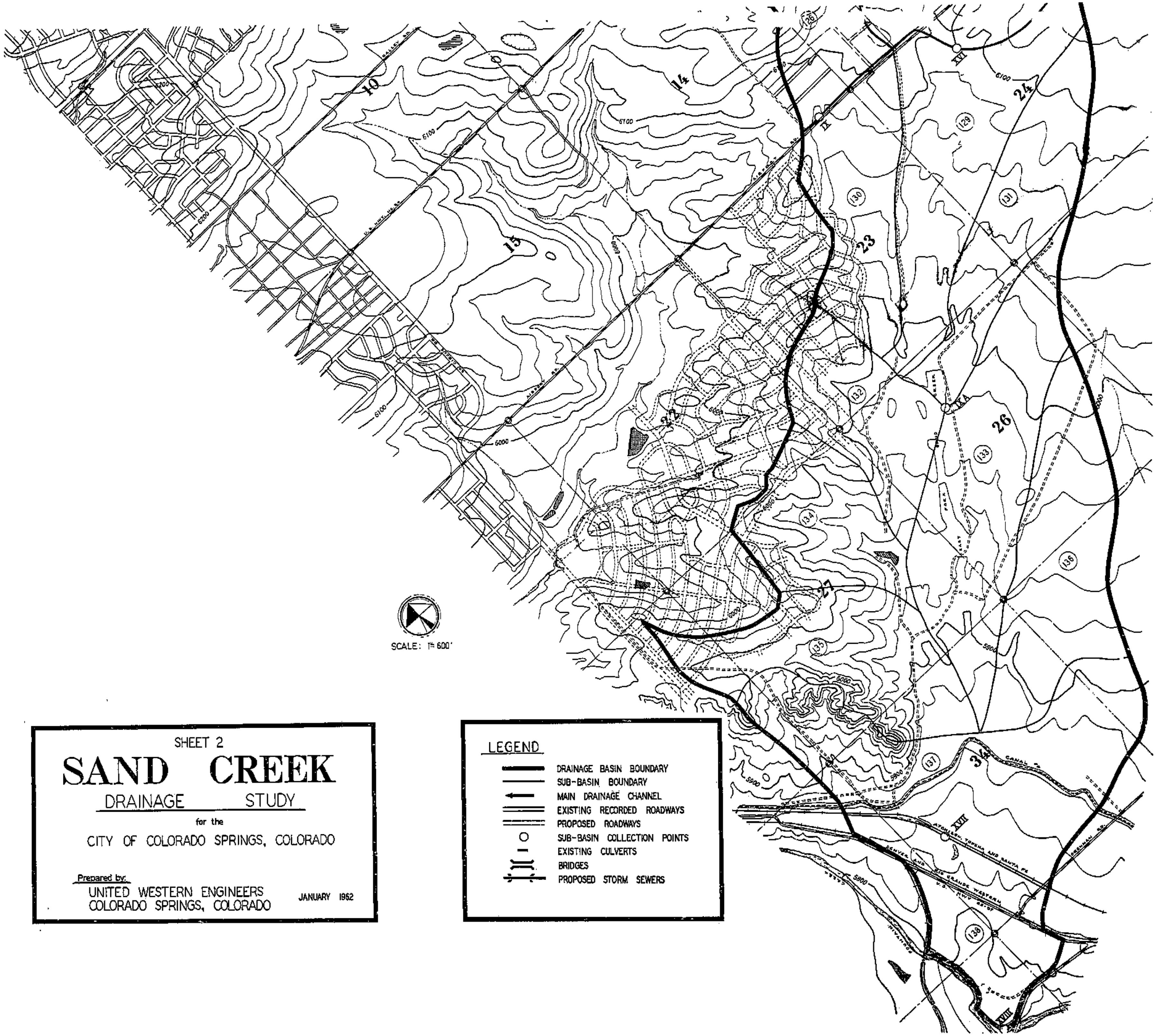
SAND CREEK
DRAINAGE STUDY
for the
CITY OF COLORADO SPRINGS, COLORADO
Prepared by:
UNITED WESTERN ENGINEERS
COLORADO SPRINGS, COLORADO
JANUARY 1962
LEGEND
DRAINAGE BASIN BOUNDARY
SUB-BASIN BOUNDARY
MAIN DRAINAGE CHANNEL
EXISTING RECORDED ROADWAYS
PROPOSED ROADWAYS
SUB-BASIN COLLECTION POINTS
EXISTING CULVERTS
BRIDGES
PROPOSED STORM SEWERS
SCALE: 1"= 1000'



SHEET 2

SAND CREEK

DRAINAGE STUDY

for the

CITY OF COLORADO SPRINGS, COLORADO

Prepared by:
UNITED WESTERN ENGINEERS
COLORADO SPRINGS, COLORADO

JANUARY 1962

LEGEND

- DRAINAGE BASIN BOUNDARY
- SUB-BASIN BOUNDARY
- MAIN DRAINAGE CHANNEL
- EXISTING RECORDED ROADWAYS
- PROPOSED ROADWAYS
- SUB-BASIN COLLECTION POINTS
- EXISTING CULVERTS
- BRIDGES
- PROPOSED STORM SEWERS

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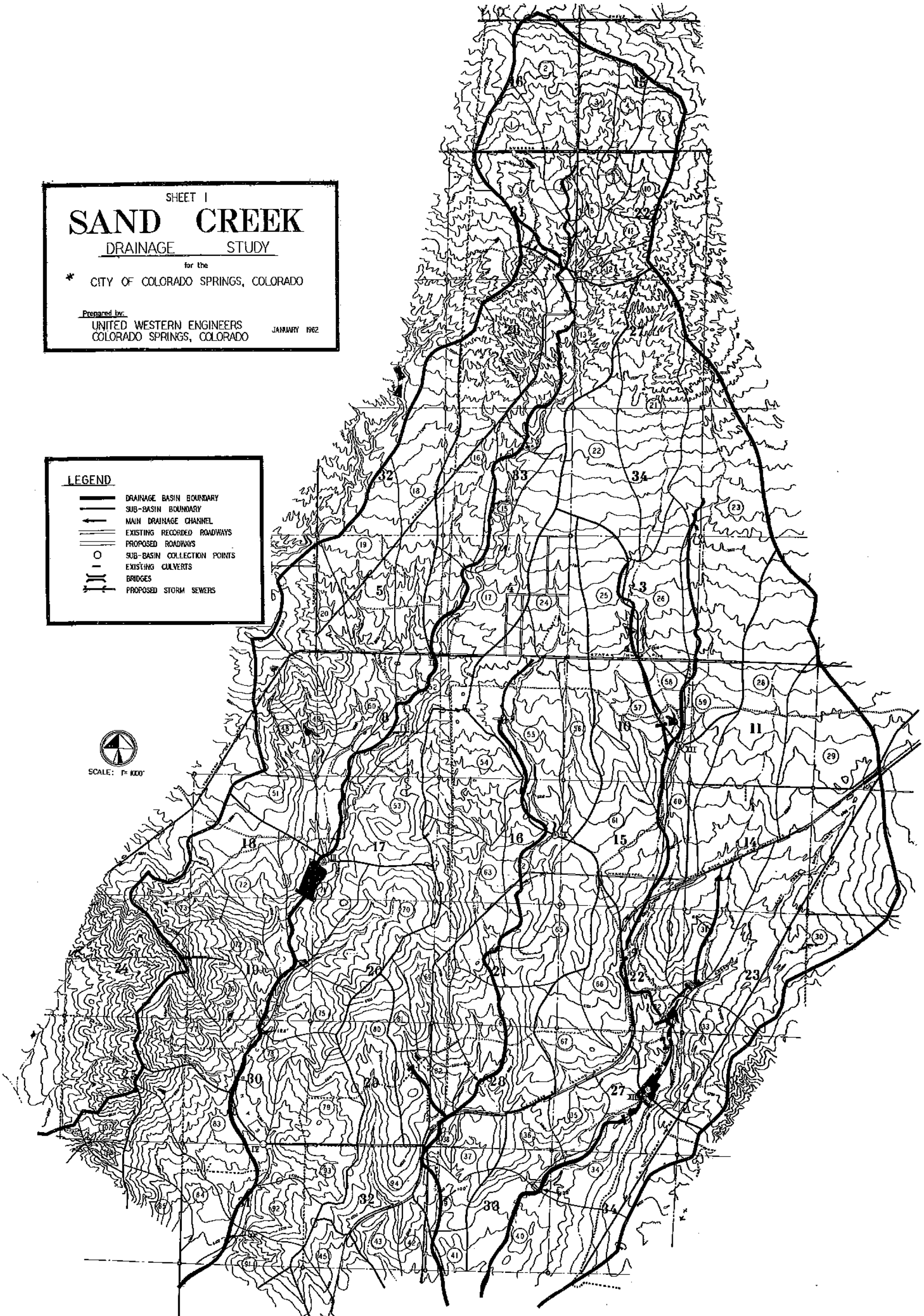
APPENDIX B:

GENERAL MAP OF

SAND CREEK DRAINAGE BASIN

EL PASO COUNTY, COLORADO

SHOWING OVERALL PROPOSED, REQUIRED IMPROVEMENTS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DRAINAGE STUDY
for the
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BRIDGES
PROPOSED STORM SEWERS
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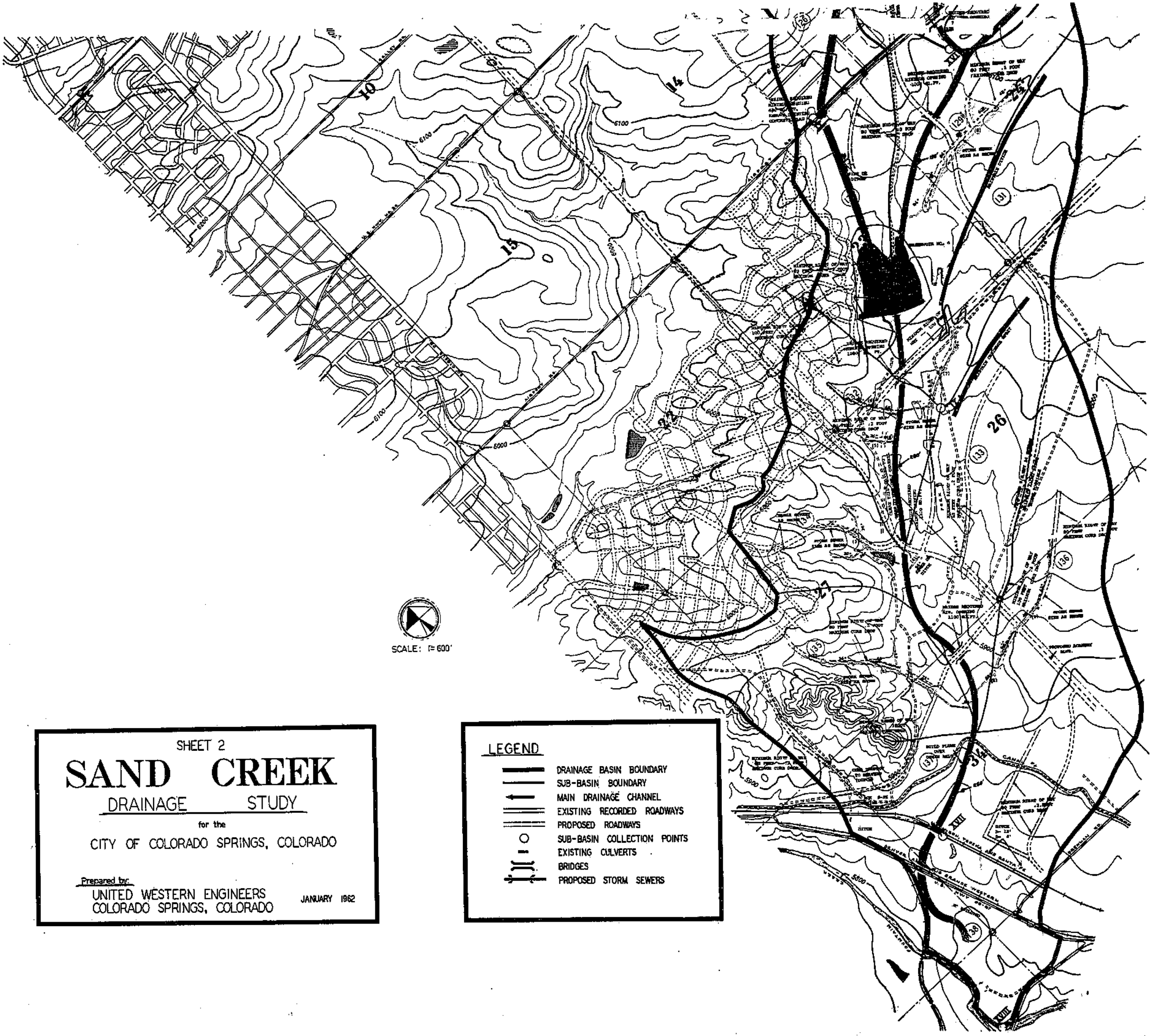

SHEET 2

SAND CREEK

DRAINAGE STUDY

for the

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Prepared by:

UNITED WESTERN ENGINEERS
COLORADO SPRINGS, COLORADO

JANUARY 1962

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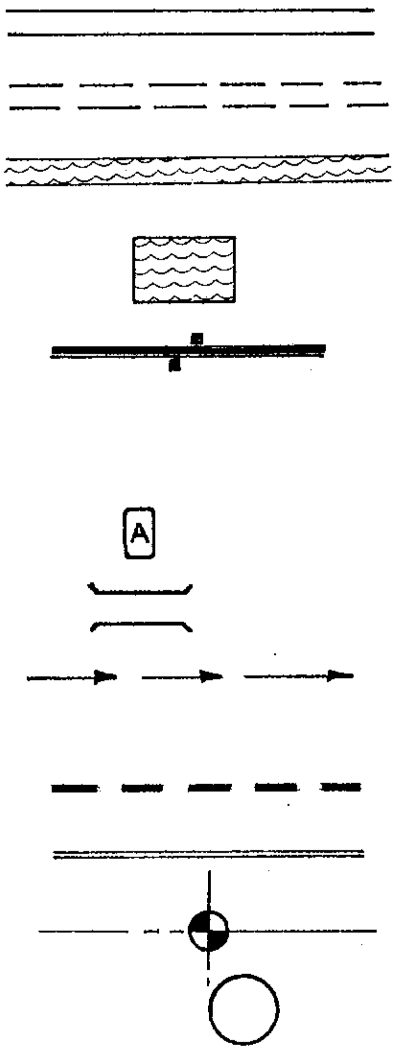
APPENDIX C:

DETAIL SHEETS - SOUTHERN SAND CREEK BASIN

AREA AROUND CITY LIMITS

OF THE

CITY OF COLORADO SPRINGS, COLORADO



EXISTING STREET

PROPOSED STREET

GREENBELT

DRAINAGE RESERVOIR

PROPOSED STORM SEWER

INTAKE BOX

SUB BASIN COLLECTION POINT

PROPOSED BRIDGE OR LARGE CULVERT

DIRECTION OF DRAINAGE FLOW

DRAINAGE BASIN BOUNDARY

ARTIFICIAL BLOCKING OF DRAINAGE

SECTION CORNER

SPECIAL DESIGN PROBLEM

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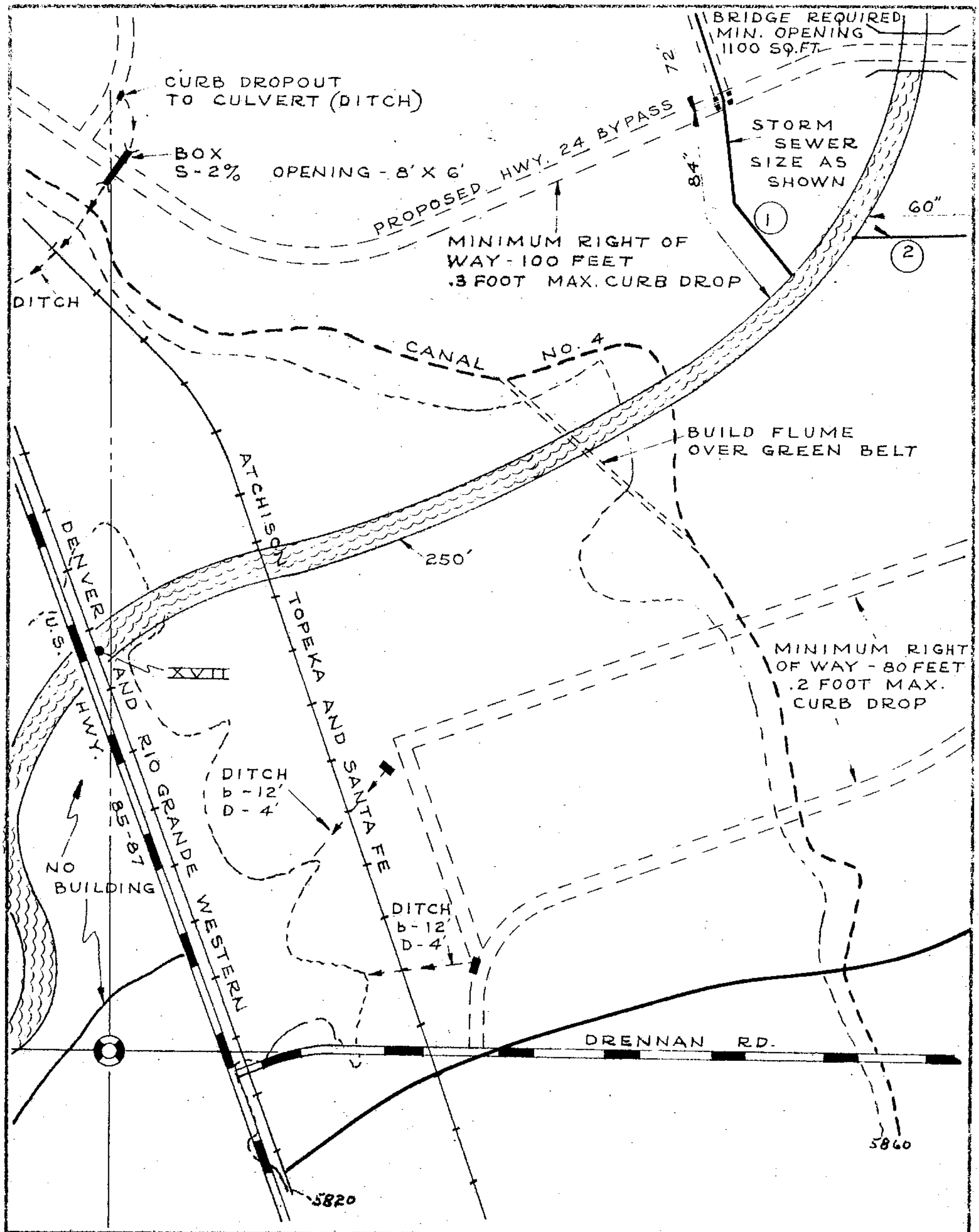

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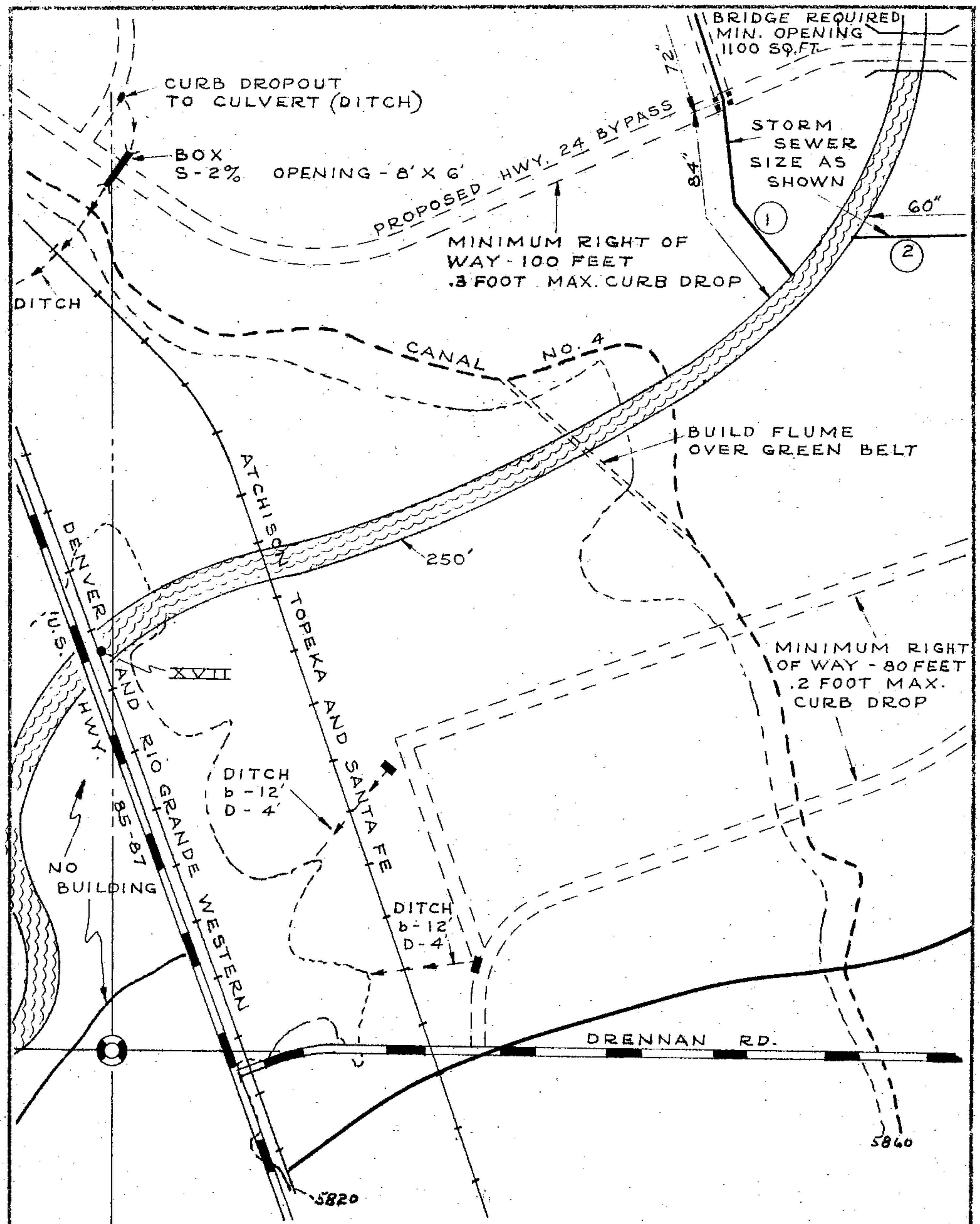

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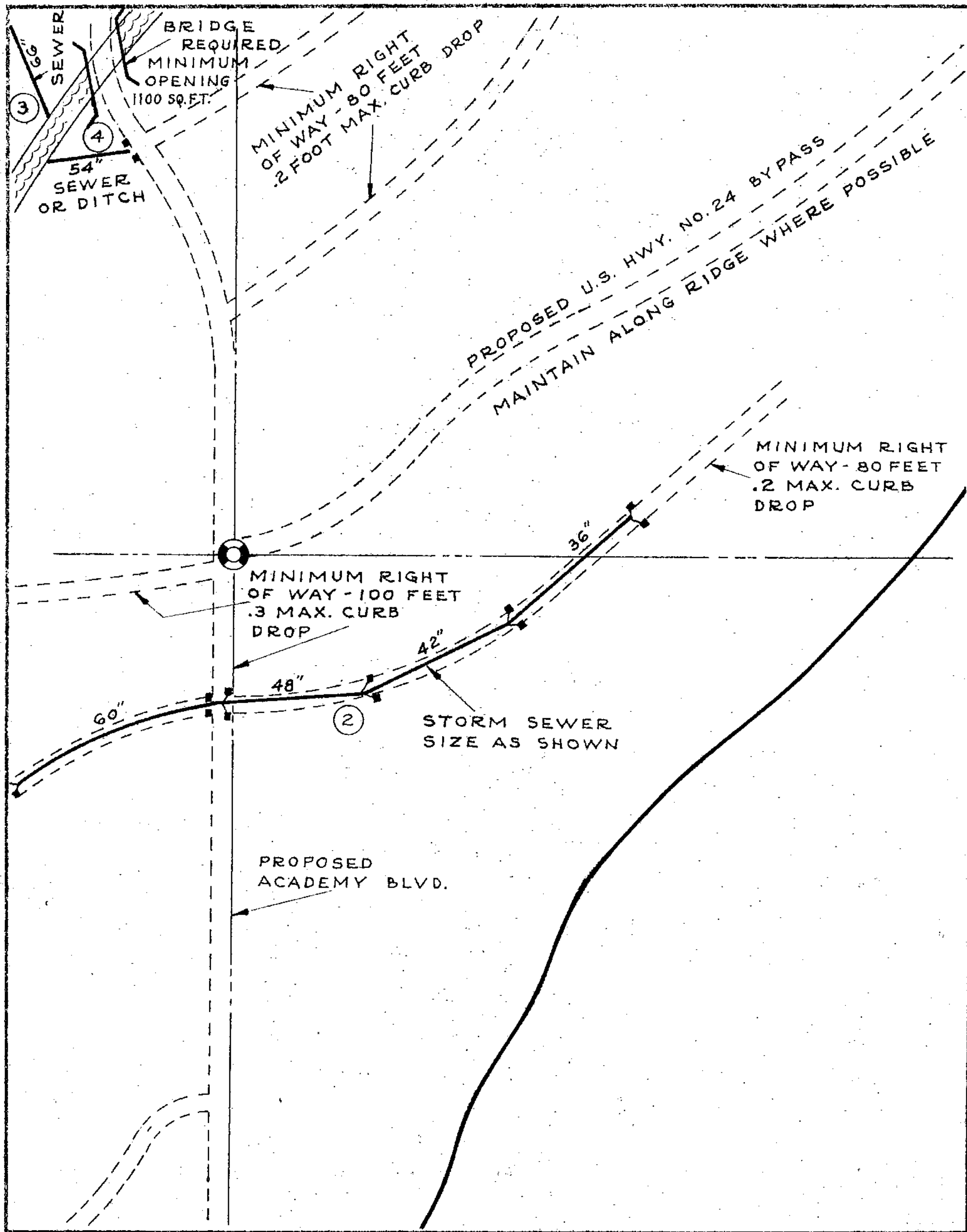

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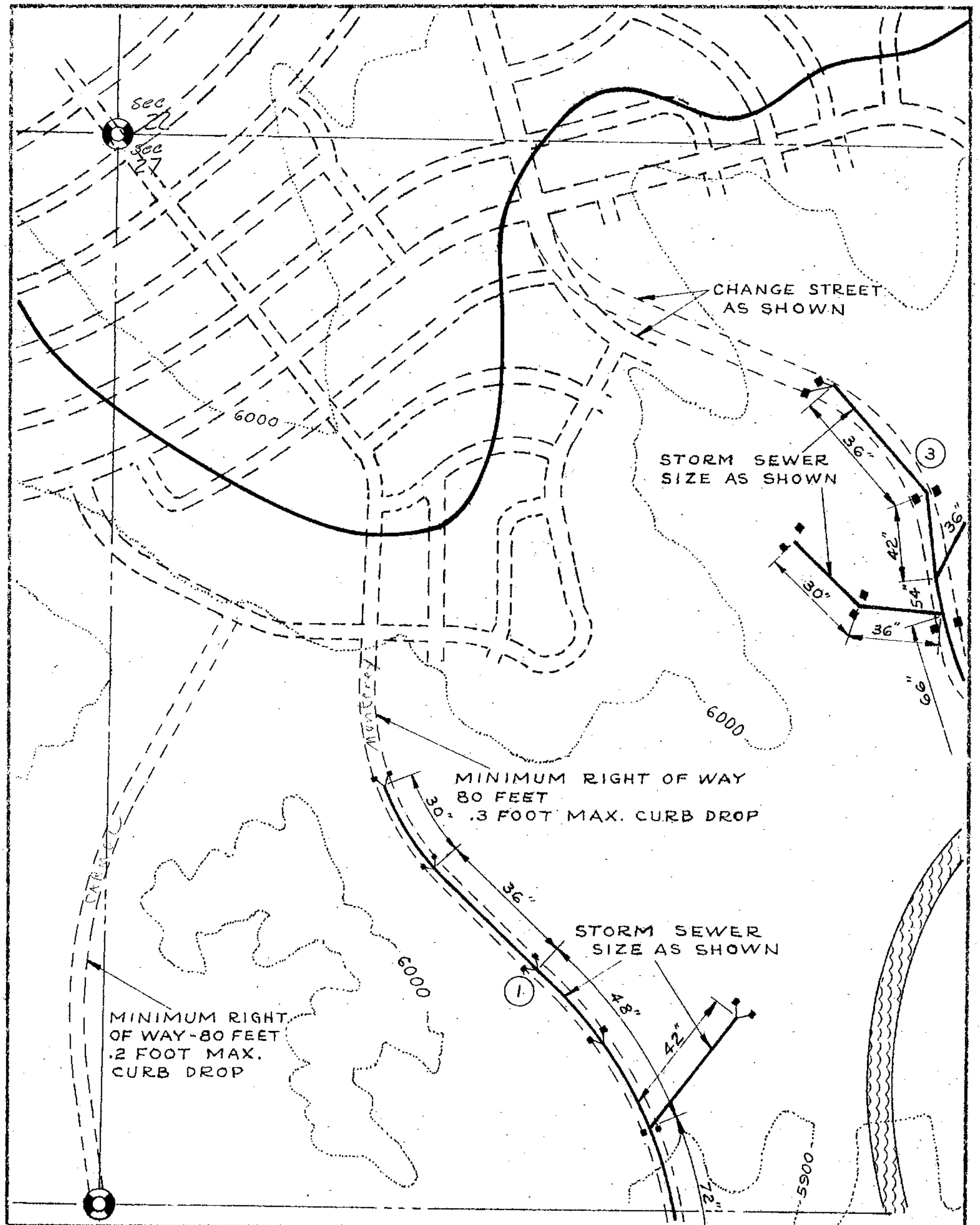

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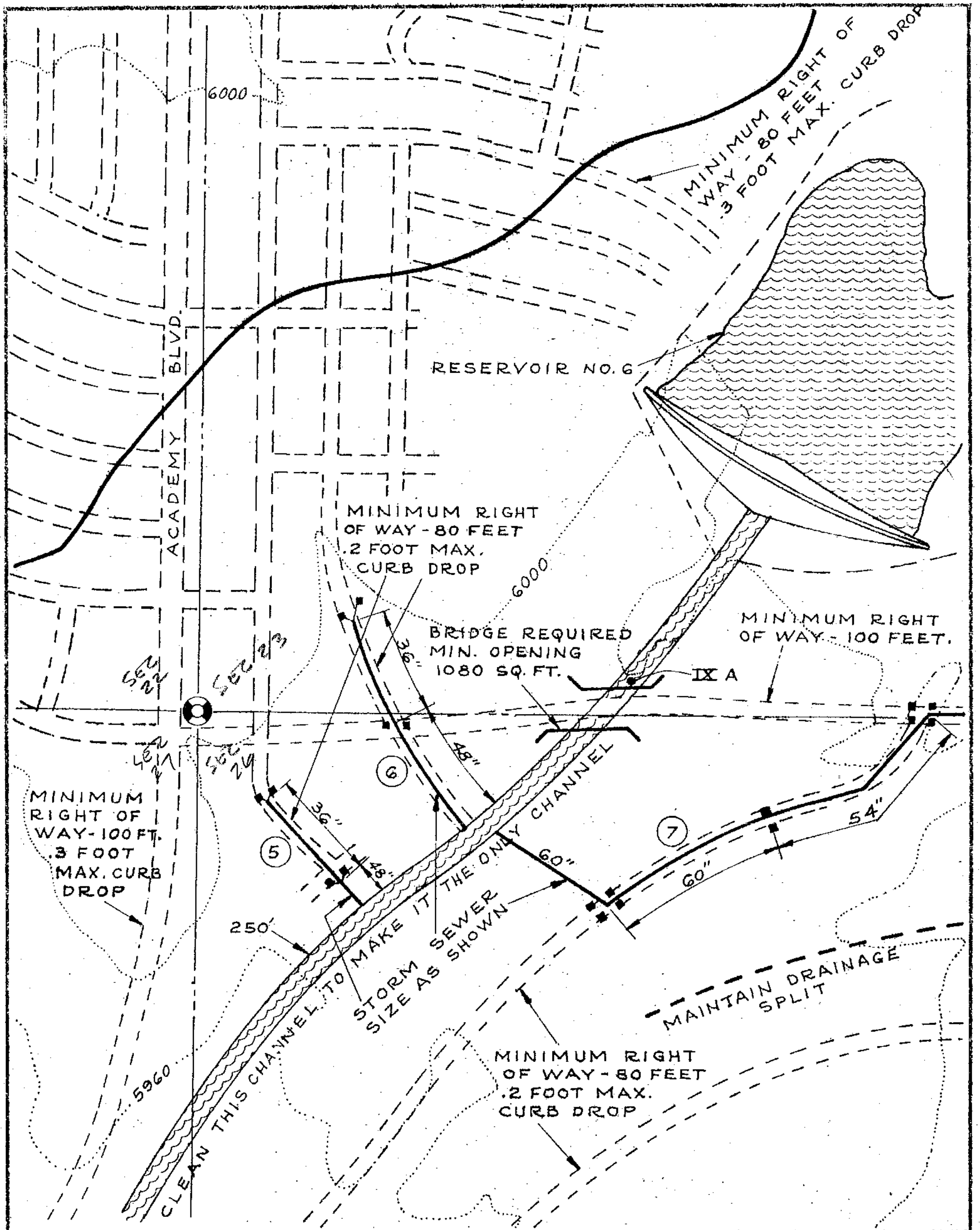

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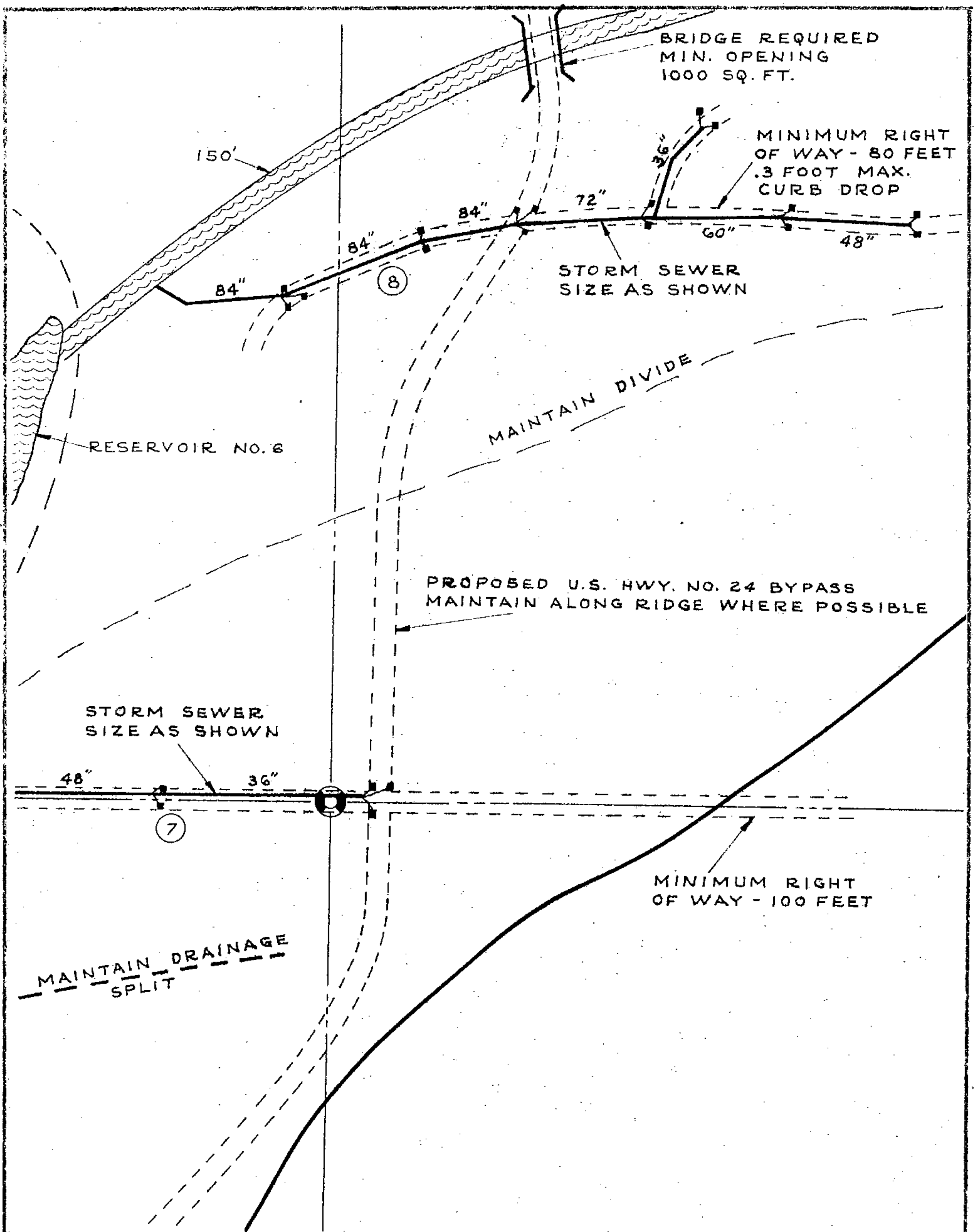

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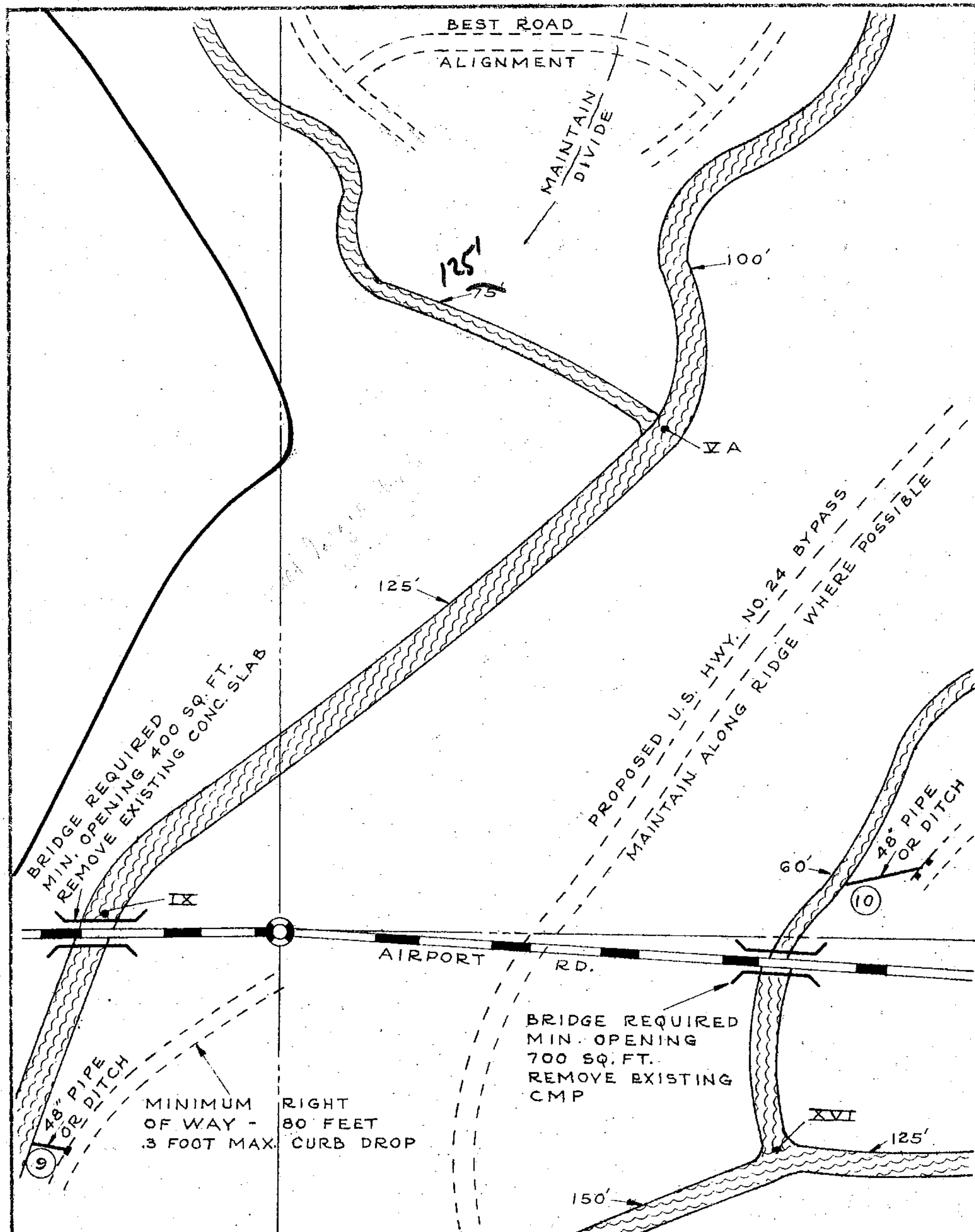

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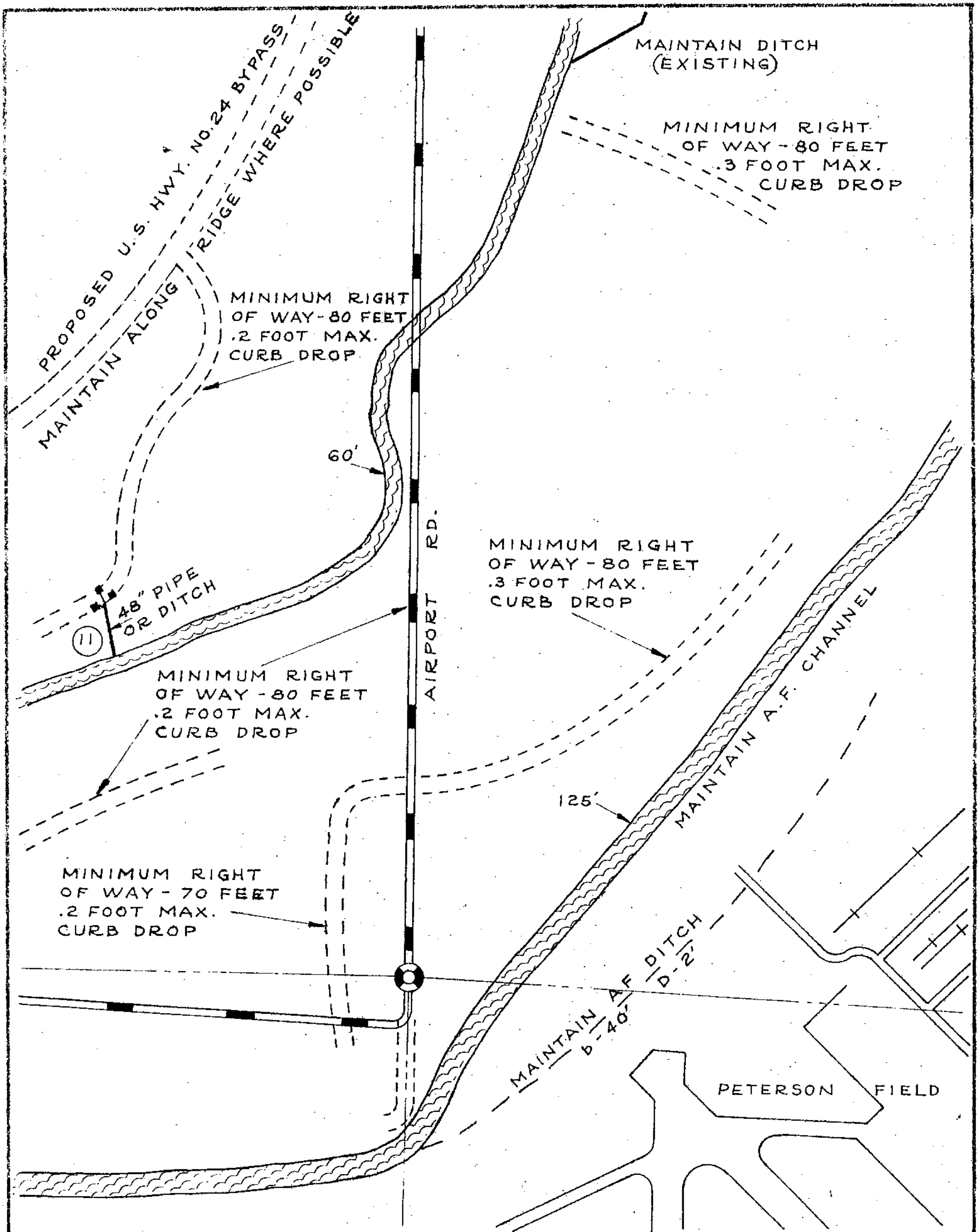

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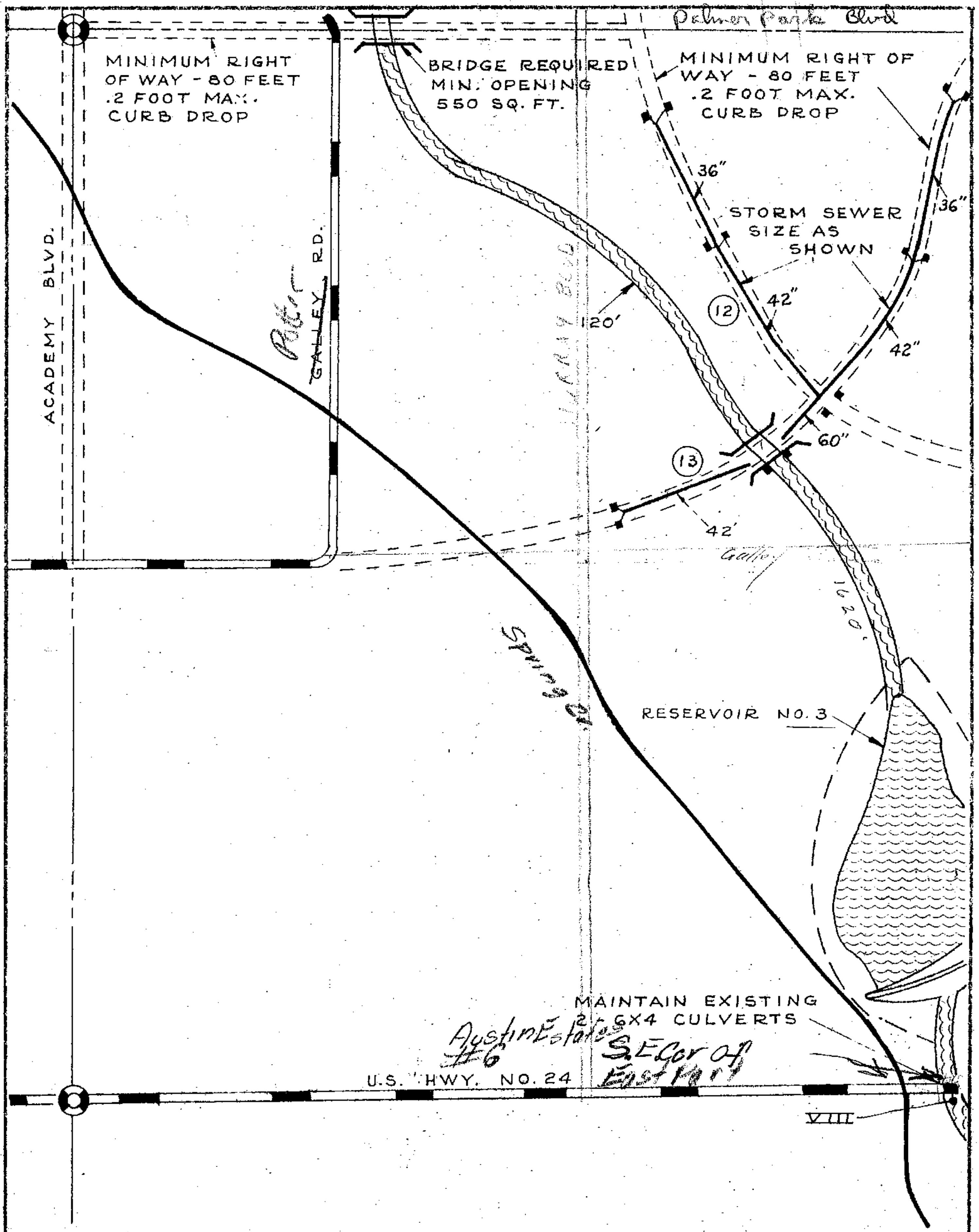

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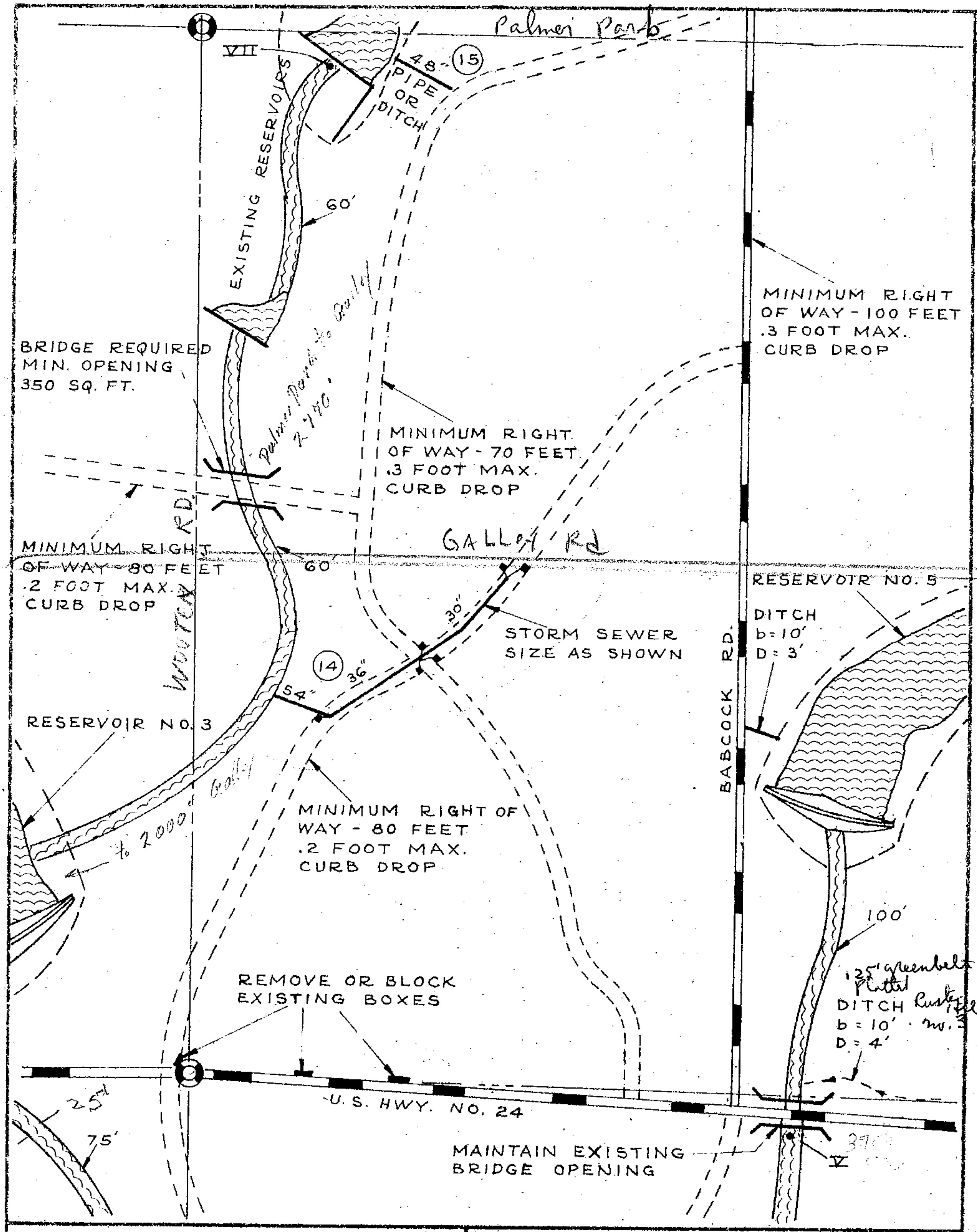

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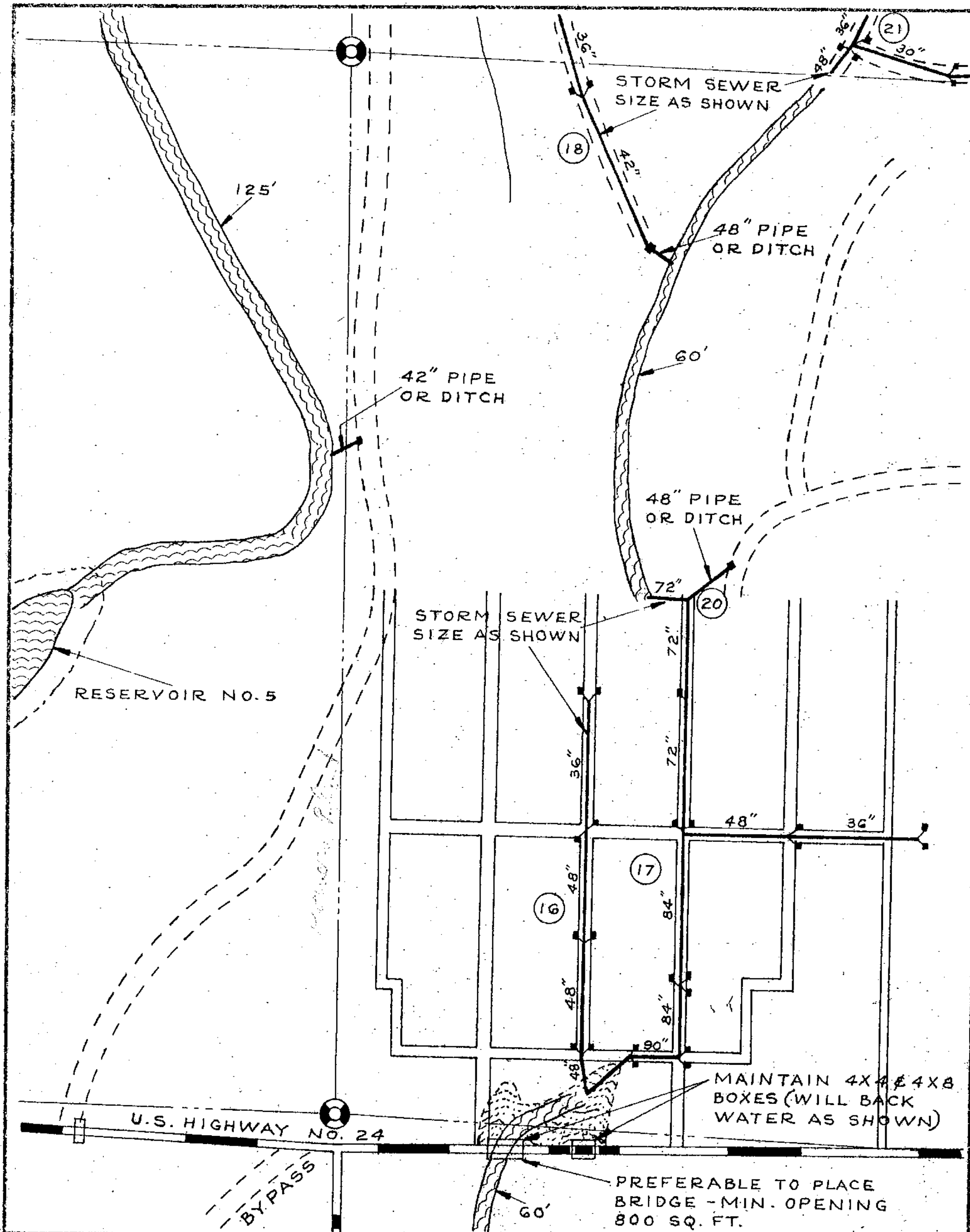

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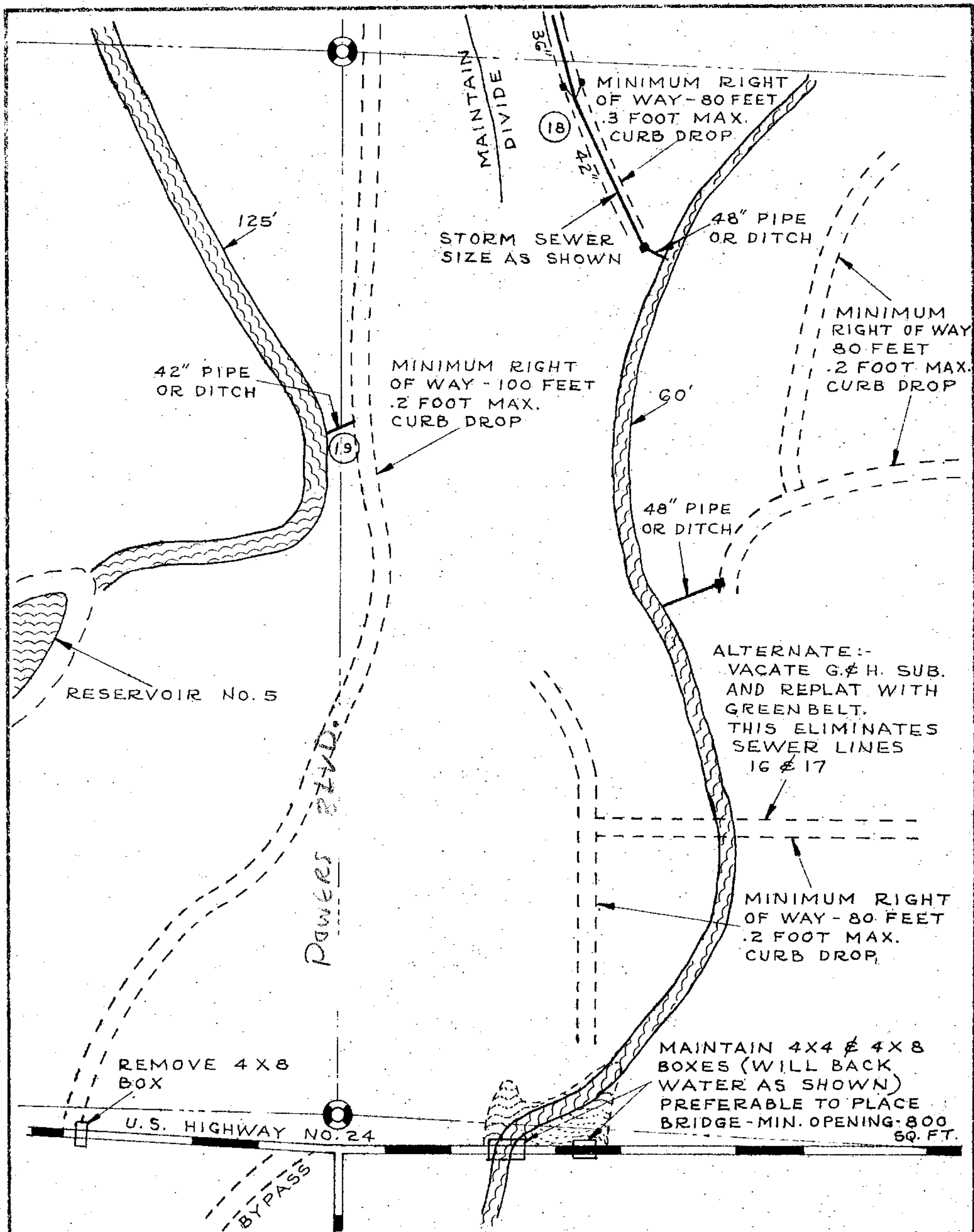

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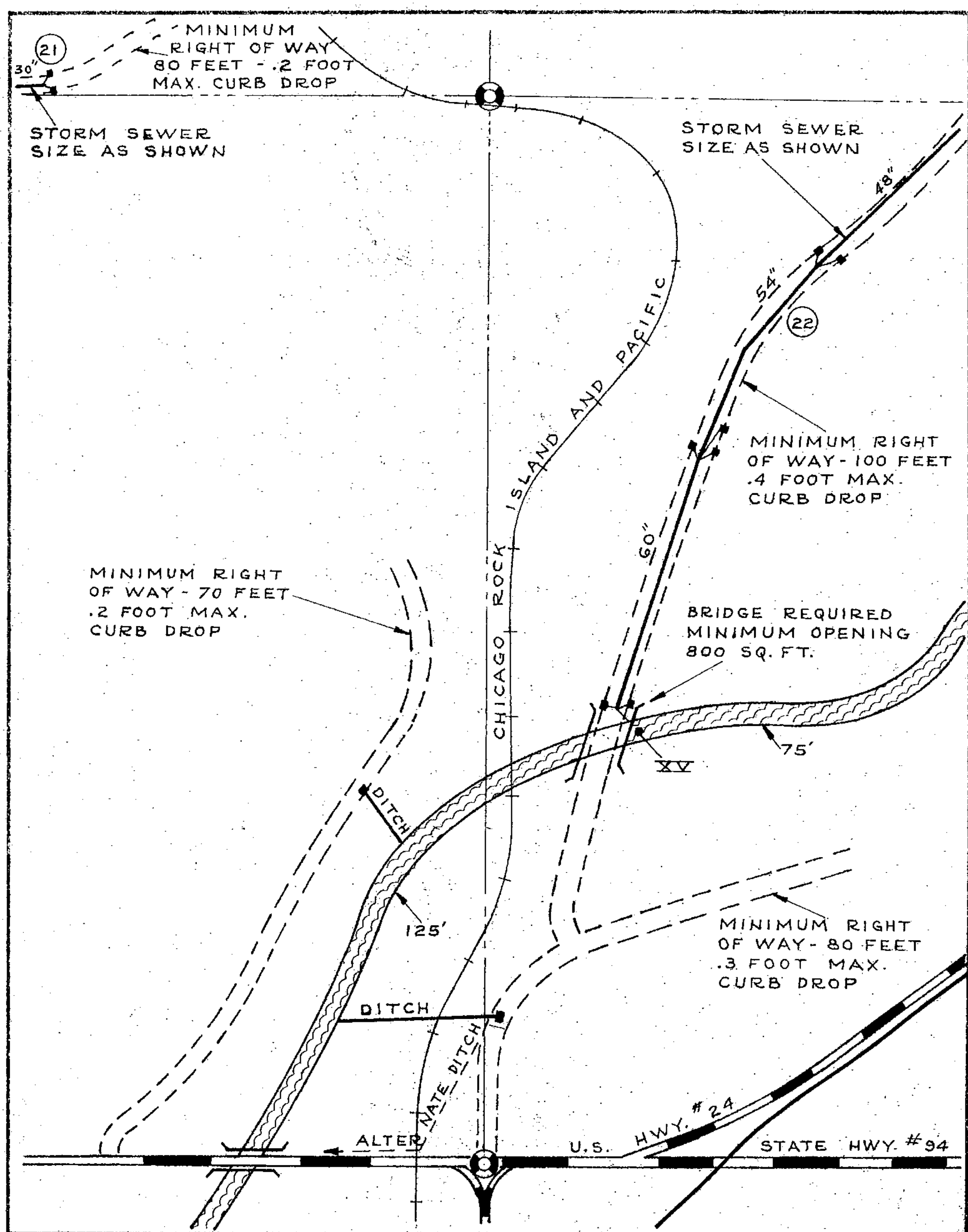

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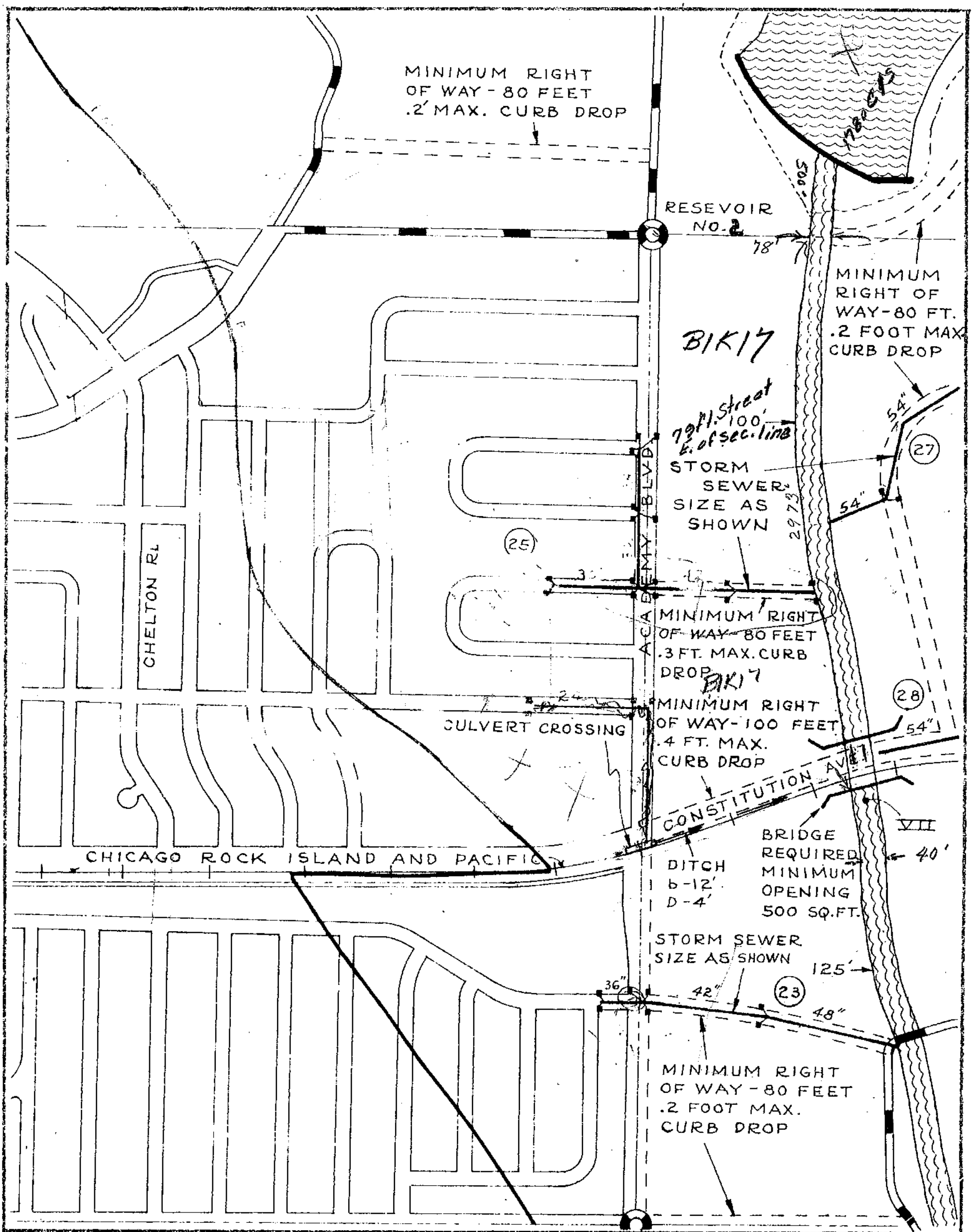

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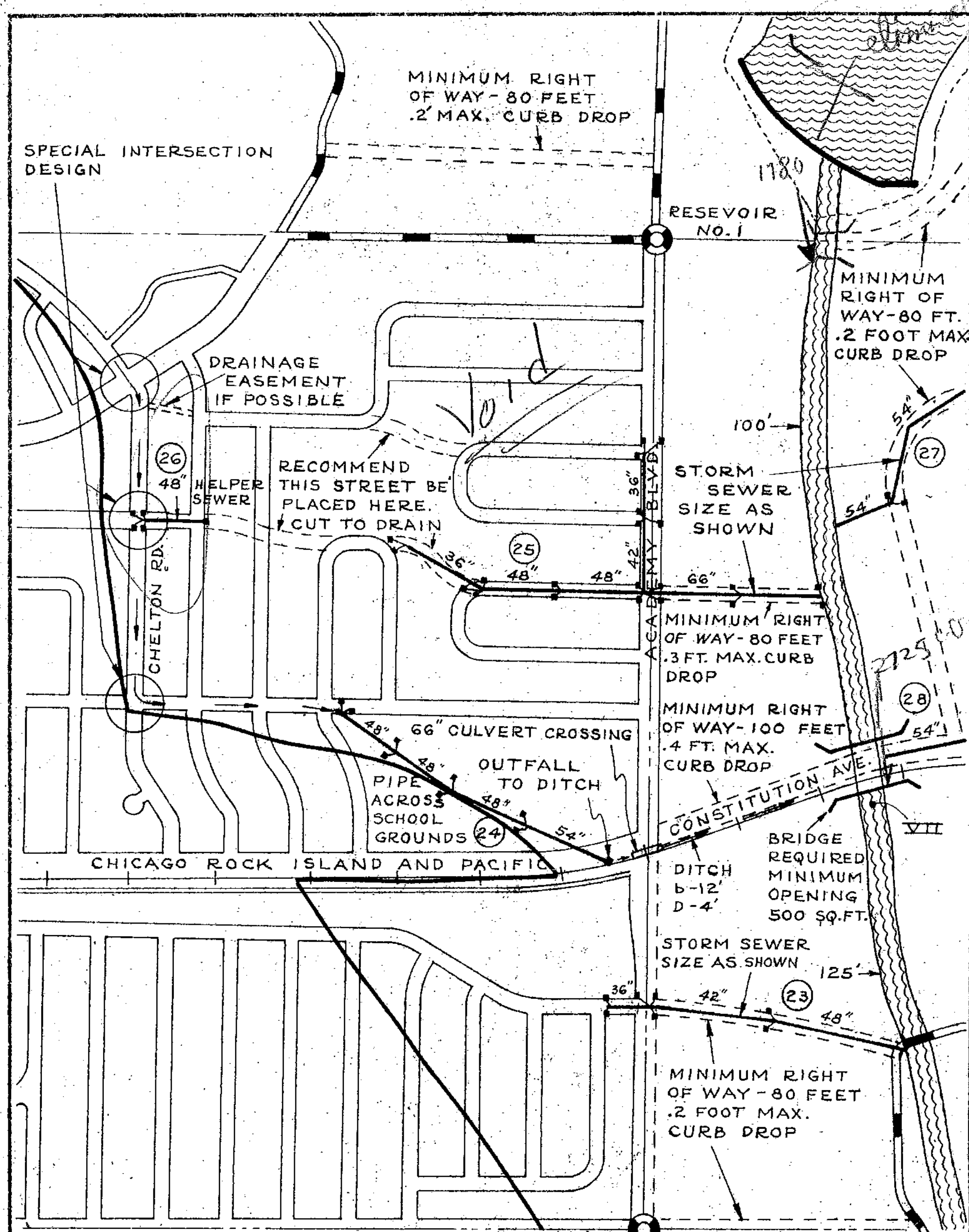

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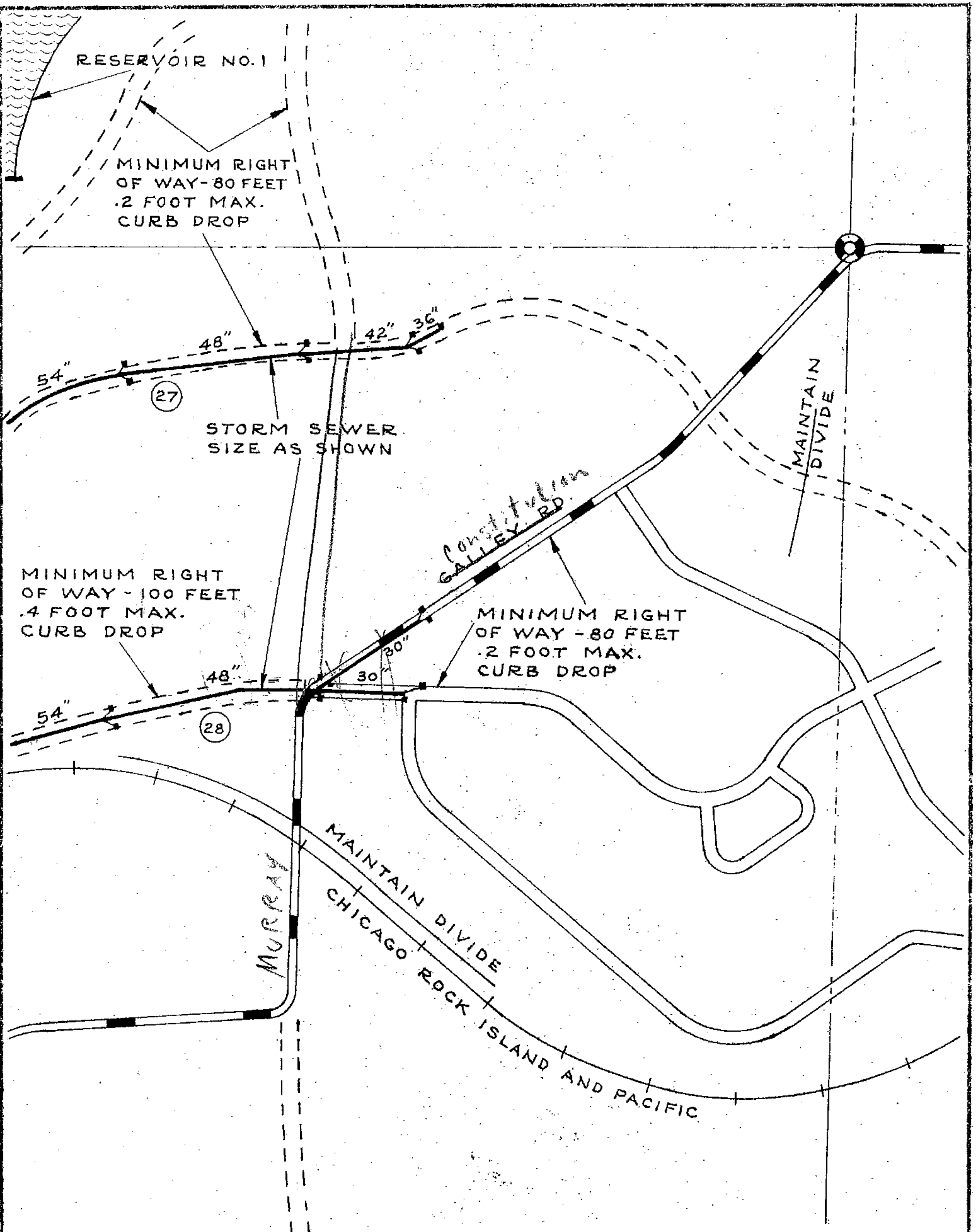

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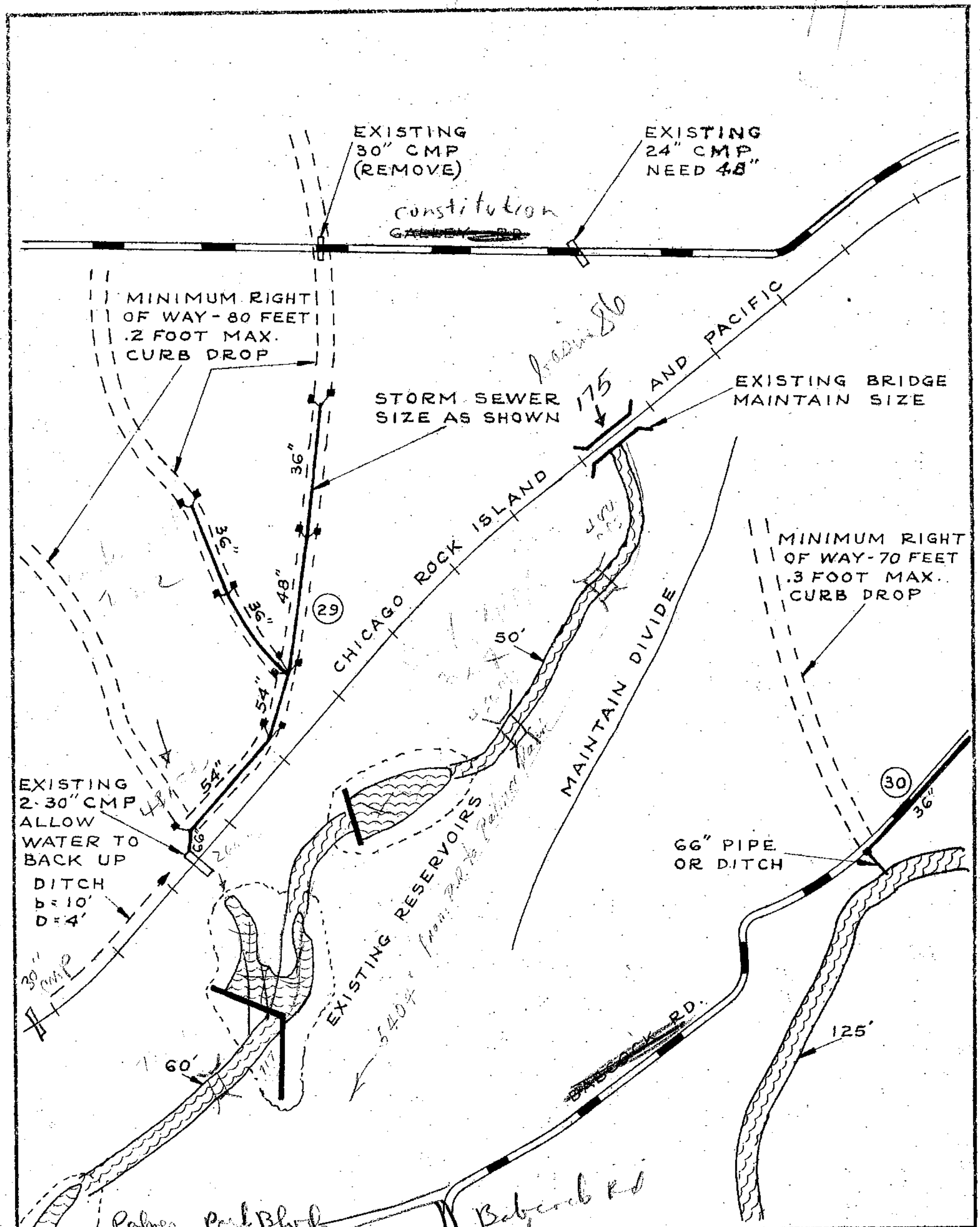

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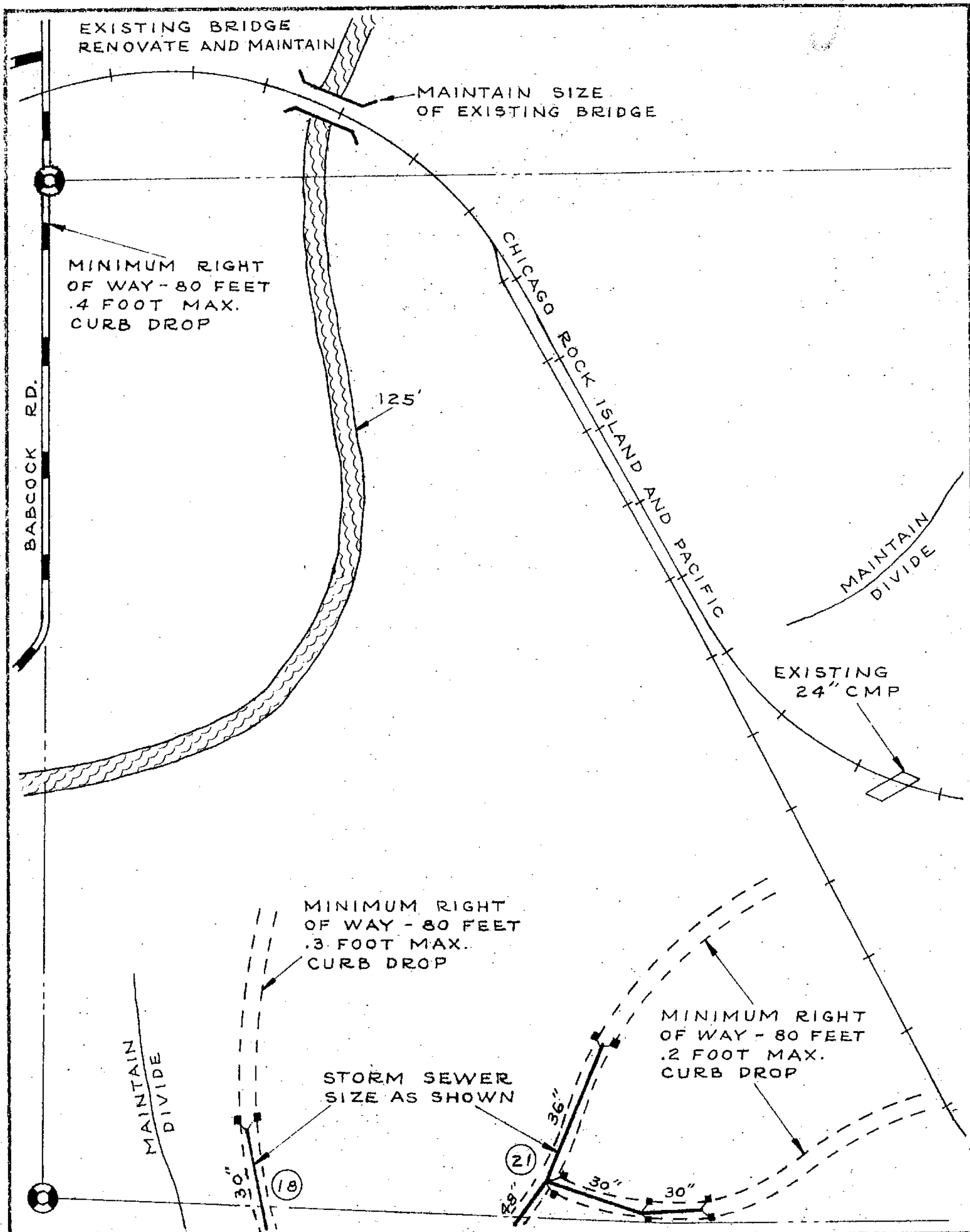

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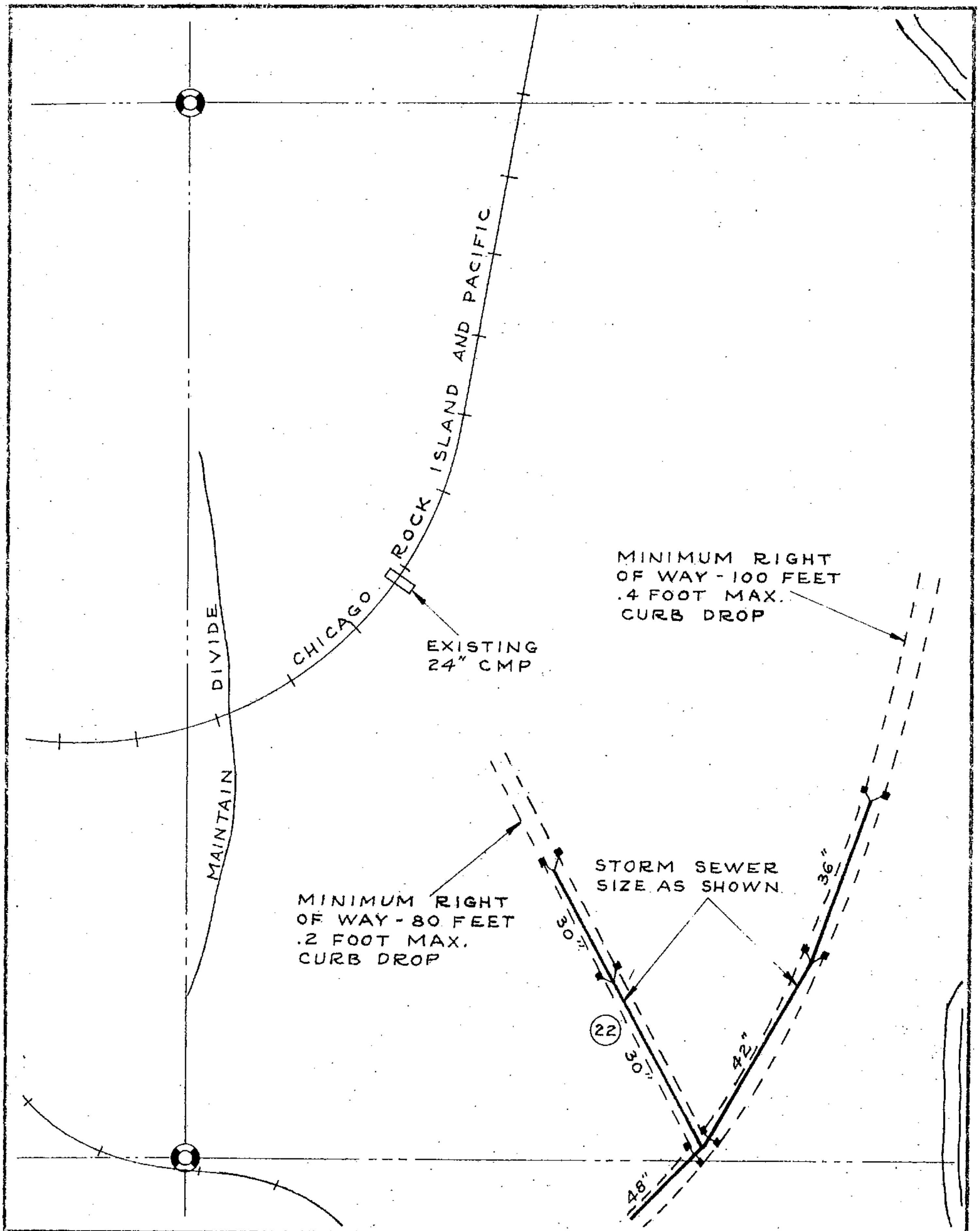

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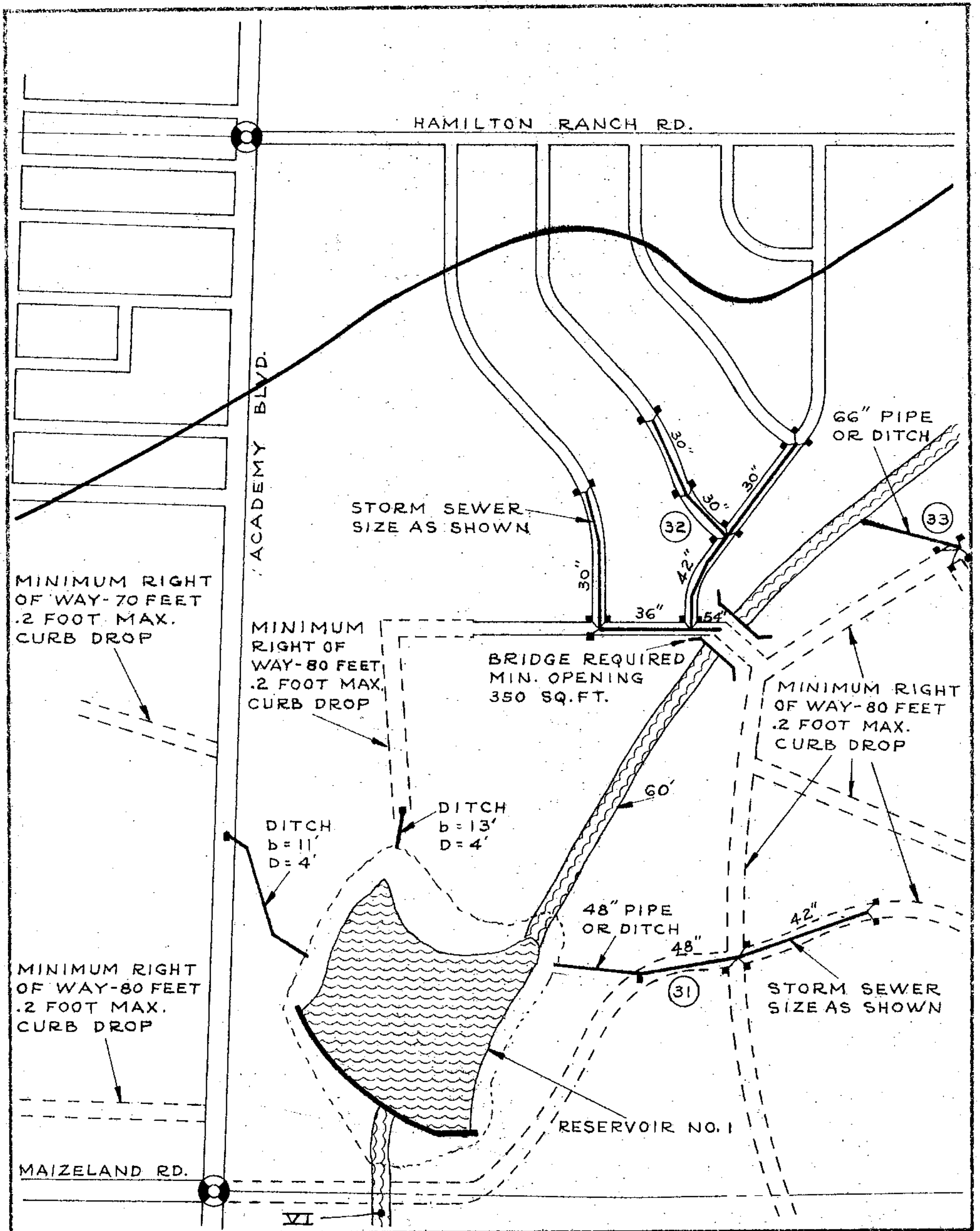

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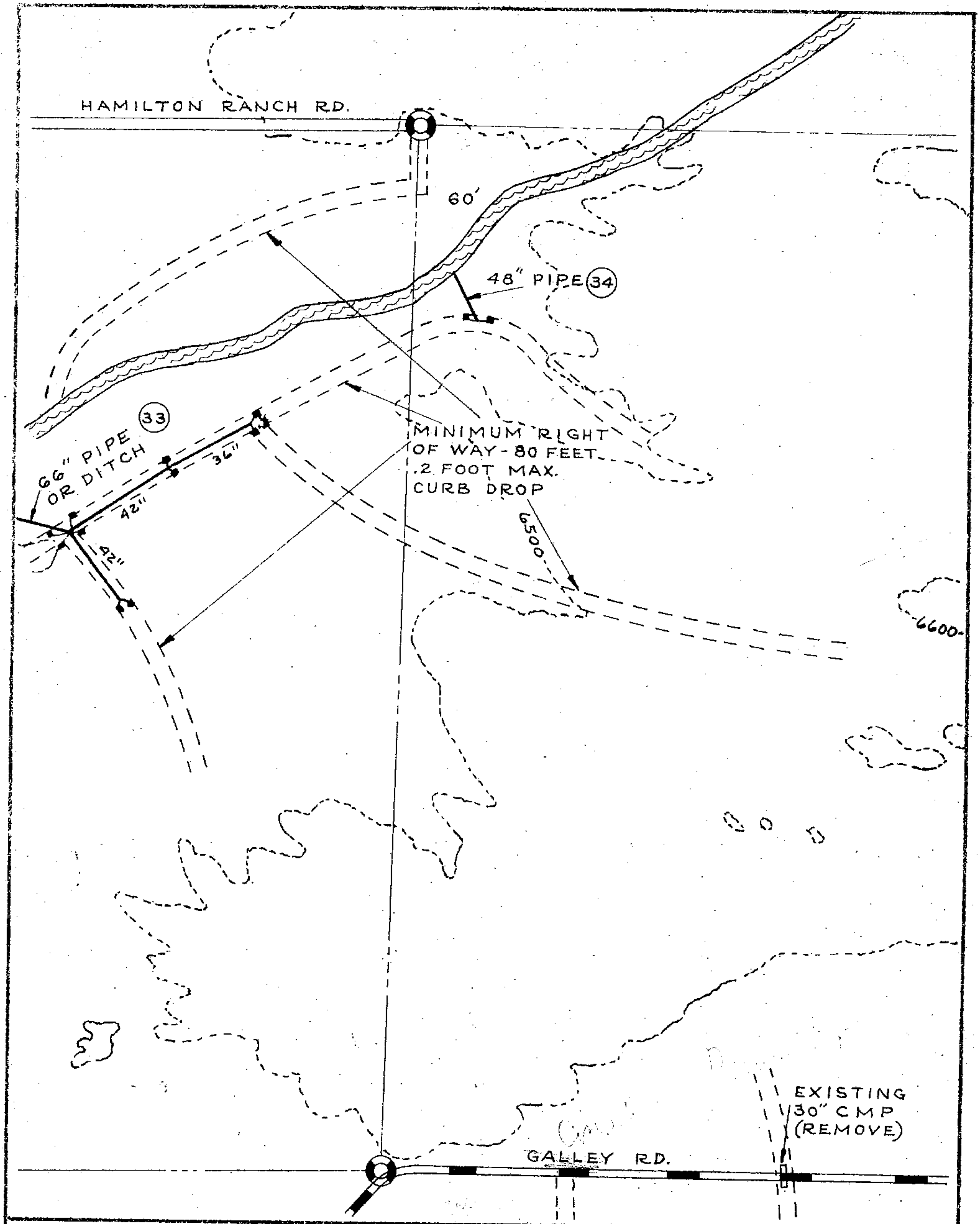

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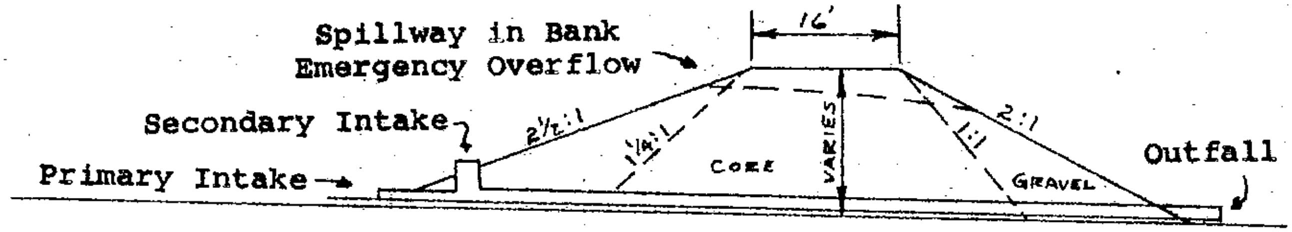
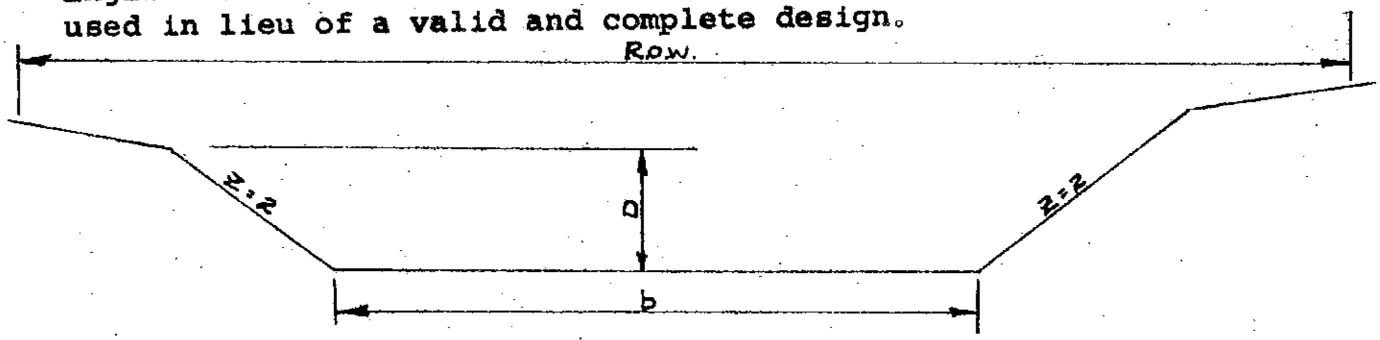
COLORADO SPRINGS, COLORADO

Intake Pipe to be on
Reservoir Grade so that
Stream does not pond.



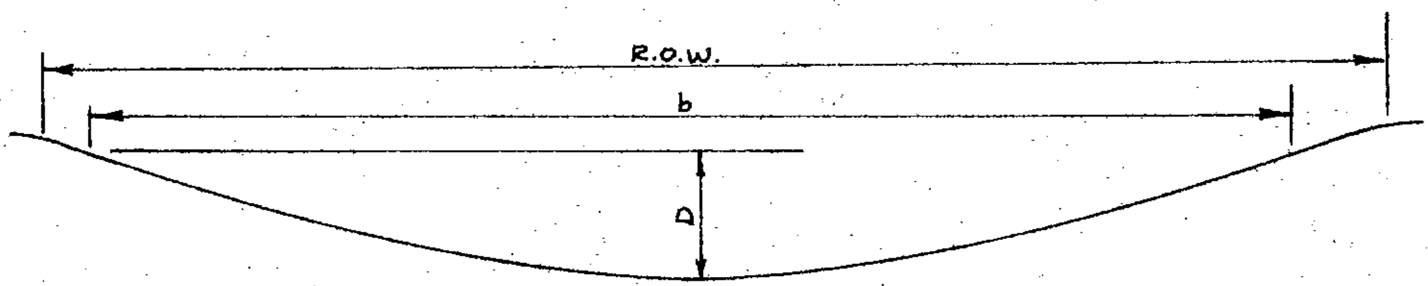
TYPICAL SECTION - "FLOW THROUGH" DAM

Each Dam must be individually designed and submitted to the State Engineer. The above sketch is for reference only and is not to be used in lieu of a valid and complete design.



DITCH TYPE NO. 1

For use as street divider or high capacity ditch.



DITCH TYPE NO. 2

For use as Park Strip, Playground Strip,
or low capacity residential ditch.

See Sheet C-21 For Dimensional Values.

CONSTRUCTION DETAILS	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO

MAJOR GREENBELT SYSTEM

REQUIRED CHANNEL SIZES

LOCATION FROM	TO	BOTTOM WIDTH FEET	FLOW DEPTH FEET	GREENBELT WIDTH-FEET
LINE 1:				
AREA 'A'	I	62'E.branch	2.0'	75'
		44'W.branch	2.0'	50'
I	II	110'	2.0'	125'
II	III	110'	2.5'	125'
	RESERVOIR NO. 1 - Required Acreage - 28 Acres			
III	IV	120'	2.5'	125'
IV	Reservoir	120'	2.5'	125'
	RESERVOIR NO. 5 - Required Acreage - 19 Acres			
Reservoir	V-A	84'	2.5'	100'
LINE 2:				
AREA 'F'	VI	48'	2.5'	60'
	RESERVOIR NO. 2 - Required Acreage - 7 Acres			
VI	VII	86'	2.5'	100'
VII	VIII	101'	3.0'	120'
	RESERVOIR NO. 3 - Required Acreage - 21 Acres			
Lines 1 & 2 combine at Point V-A				
VIII	V-A	61'	2.5'	75'
V-A	IX	112'	2.5'	125'
IX	IX-A	116'	2.5'	125'
	RESERVOIR NO. 6 - Required Acreage - 74 Acres			
All lines combine at Reservoir No. 6				
LINE 3:				
AREA'K'	X	37'	2.0'	50'
X	Basin 82+	43'	2.0'	50'
Basin 82	Basin 82+	46'	2.5'	60'
Basin 82+	XI	84'	2.5'	100'
LINE 4:				
AREA 'N'	XII	36'	2.0'	50'
XII	XIII	58'	2.0'	75'
AREA 'O'	XIII	42'	2.0'	50'
	EXISTING RESERVOIRS - EXISTING ACREAGE - 25 Acres			
XIII	XI	83'	2.5'	100'

MAJOR GREENBELT SYSTEM

REQUIRED CHANNEL SIZES

LOCATION FROM	TO	BOTTOM WIDTH FEET	FLOW DEPTH FEET	GREENBELT WIDTH-FEET

RESERVOIR NO. 4 - Required Acreage - 18 Acres

Lines 3 & 4 combine at Reservoir No. 4

FROM	TO	BOTTOM WIDTH FEET	FLOW DEPTH FEET	GREENBELT WIDTH-FEET
AREA 'M'	XIV	29'	1.5'	40'
XIV	Jct. Line 4	26'	2.0'	40'
Jct. Line 4	XV	63'	2.5'	75'
XV	XVI	103'	3.5'	125'
AREA 'S'	XVI	46'	2.5'	60'
XVI	IX-A	130'	3.5'	150'

All lines join at Reservoir No. 6 (See Sheet C-22)

FROM	TO	BOTTOM WIDTH FEET	FLOW DEPTH FEET	GREENBELT WIDTH-FEET
IX-A	XVII	182'	4.0'	200'
XVII	XVIII	236'	4.0'	250'

Outfall to Fountain Creek

LAND FOR GREENBELTS & RESERVOIRS:

Greenbelts as Recommended - 540 Ac.	....	$810,000.00
Reservoirs as Recommended - 192 Ac.	....	288,000.00
Total	....	$1,098,000.00

1500 per acre

Acreage in Sand Creek Basin (Total)...33,388

Cost per Acre Based on Total Acreage............$32.89

IMPROVEMENTS:

Reservoirs (Total Area)

Existing Reservoirs	-	Rehabilitation..	$14,300
Reservoir No. 1	-	Construction....	13,950
Reservoir No. 2	-	"	9,650
Reservoir No. 3	-	"	15,400
Reservoir No. 4	-	"	13,650
Reservoir No. 5	-	"	10,100
Reservoir No. 6	-	"	36,400
			$113,450

COST Per Acre Based on Total Acreage............$ 3.40

MISCELLANEOUS DITCHES: (South Area only)

C-1 A	..........Construction..........	$1,050
C-1 B	.... "	1,000
C-1 C	.... "	1,450
C-9 A	.... "	880
C-9 B	.... "	1,300
C-11 A	.... "	940
C-11 B	.... "	1,540
C-12	.... "	2,650
C-14	.... "	2,100
C-17 A	.... "	1,750
C-17 B	.... "	1,350
		$16,010

Cost Per Acre Based on South Acreage,only.......$ 0.002/Ac.
1.528

STORM SEWERS:

No. 1	$150,601	No. 18	$ 27,516
No. 2	104,364	No. 19	3,263
No. 3	79,953	No. 20	8,347
No. 4	10,725	No. 21	24,548
No. 5	11,266	No. 22	158,710
No. 6	21,848	No. 23	27,955
No. 7	117,110	No. 24	36,068
No. 8	194,706	No. 25	70,868
No. 9	4,068	No. 26	10,942
No. 10	8,562	No. 27	57,565
No. 11	5,995	No. 28	47,184
No. 12	6,447	No. 29	65,212
No. 13	14,957	No. 30	19,383
No. 14	20,950	No. 31	33,900
No. 15	7,706	No. 32	39,427
No. 16	36,962	No. 33	47,436
No. 17	175,394	No. 34	5,780
			$1,655,718

Cost Per Acre, Based on South Acreage, only.......$158.09

10,473.3 Acres

However, Lines 16 & 17 could be eliminated by replatting the G & H Subdivision, leaving a total of $1,443,362, or $137.82 per Acre.

Also, lines 4,9,10,11,13,15,19,20, & 34 could be ditches, leaving a total of $1,373,959, or $131.19 per Acre.
(+ a ditch cost of $12,600)

The total will thus be variable, depending on several decisions.

Using Maximum costs, however, the total cost per Acre in this basin will be..........................~~$194.38~~ 213.29

APPENDIX D:

BASIC DATA

SOIL TYPES:	WIND BLOWN SAND	- Group B
	FOX HILLS FORMATION	- Group B
	PIERRE SHALE	- Group D

RAINFALL TYPES USED IN COMPUTATION:

Duration	Intensity	Frequency
30 min.	0.8"	2 years
1 hour	2.0"	50 years
6 hour	2.75"	25 years
6 hour	3.00"	50 years
6 hour	3.50"	100 years

SOIL CONDITION:

Average - neither dry nor saturated. Average infiltration characteristics prevailing. Infiltration Rate, high during first 1/2 hour, and progressively lower.

RAINFALL CONDITION ASSUMED:

Rain of same intensity falls on basin. Start and end of rain same over entire basin.

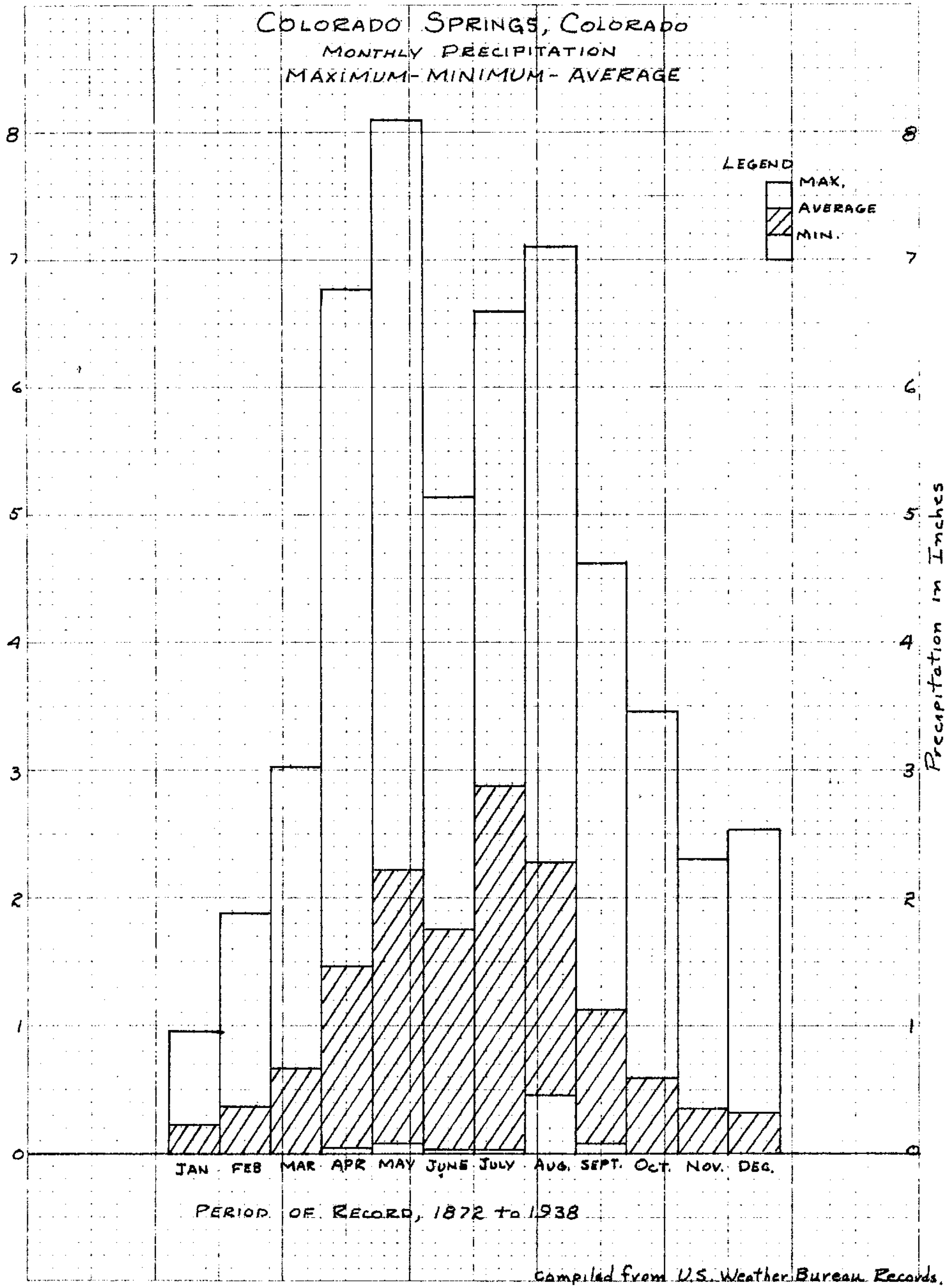

COLORADO SPRINGS, COLORADO
MONTHLY PRECIPITATION
MAXIMUM - MINIMUM - AVERAGE
LEGEND
MAX.
AVERAGE
MIN.
Precipitation in Inches
0
1
2
3
4
5
6
7
8
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
PERIOD OF RECORD, 1872 to 1938
compiled from U.S. Weather Bureau Records.

FIGURE 15 D-1

Infiltration Curves
Estimated From Rainmaker Tests By SCS Projects, 1936

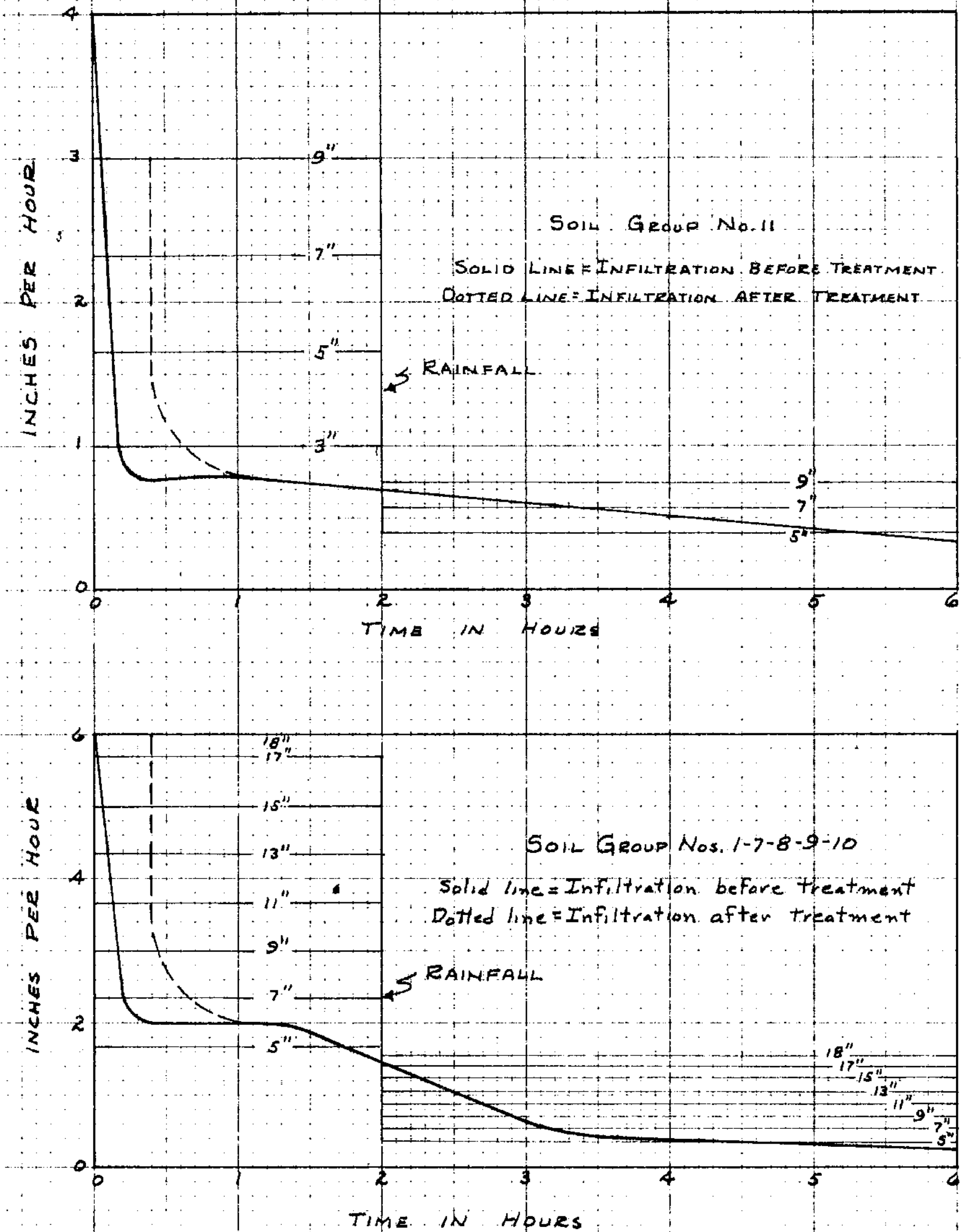


Figure 26

	EXISTING GROUND			SUBDIVIDED GROUND	
RUNOFF BASIN	AREA	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF
1	135	36.5	101.3	148.3	270.0
2	266	66.5	191.5	292.0	532.0
3	145	39.2	108.8	159.2	290.0
4	62	23.6	58.3	68.1	124.0
5	102	27.5	76.5	112.0	204.0
6	231	87.8	217.0	254.0	462.0
7	59	22.4	55.5	64.9	118.0
8	110	46.2	110.0	121.0	220.0
9	62	16.7	46.5	68.1	124.0
10	105	26.3	75.6	115.2	210.0
11	66	25.1	62.0	72.5	132.0
12	83	31.5	78.0	91.1	166.0
13	490	113.0	352.5	382.0	784.0
14	163	40.7	117.3	127.0	260.0
15	216	82.0	203.0	168.0	345.0
16	413	157.0	388.0	322.0	661.0
17	473	179.6	445.0	293.0	634.0
18	463	176.0	435.0	361.0	740.0
19	360	57.5	202.0	281.0	576.0
20	233	63.0	175.0	256.0	466.0
48	240	36.0	129.7	187.0	284.0
49	166	26.6	93.0	129.5	266.0
51	153	49.0	125.5	119.5	245.0
50	364	156.5	378.0	298.0	607.0
52	276	82.7	218.0	215.0	442.0
53	362	57.9	203.0	224.0	485.0
70	400	128.0	328.0	200.0	472.0
71	289	110.0	272.0	121.3	289.0
72	344	55.0	193.0	172.0	405.0
73	185	29.6	103.5	93.0	218.0
74	253	40.5	142.0	106.2	253.0
75	171	27.4	95.7	68.4	167.5
76	193	36.7	124.0	96.5	228.0
77	292	46.6	163.5	146.0	344.0
78	204	24.5	104.0	77.5	192.0
79	290	46.4	162.5	145.0	342.0

	EXISTING GROUND			SUBDIVIDED GROUND	
RUNOFF BASIN	AREA	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF
83	393	58.9	212.0	196.5	463.0
93	160	19.2	81.5	80.0	188.5
92	180	21.6	91.8	90.0	212.0
91	396	47.5	205.0	198.0	466.0
84	292	43.7	157.5	292.0	542.0
85	191	36.3	122.3	191.0	355.0
90	308	37.0	157.0	252.0	514.0
101	208	31.2	112.5	170.5	347.0
105	255	10.2	76.5	280.0	510.0
107	107	20.4	68.5	160.5	266.0
108	48	12.0	34.6	72.0	119.0
109	84	21.0	60.5	126.0	208.0
110	219	54.7	157.5	328.5	543.0
111	99	22.8	67.4	148.5	246.0
112	212	40.3	136.0	318.0	525.0
113	143	22.9	80.0	204.0	354.5
114	81	32.4	79.4	121.5	201.0
115	72	16.6	49.0	108.0	179.0
116	135	31.0	92.0	31.0	91.8
117	136	34.0	98.0	190.5	321.0
118	132	19.8	71.2	198.0	328.0
119	85	1.7	23.8	119.0	200.5
121	53	15.4	42.5	79.5	131.5
122	108	20.5	69.0	125.2	226.0
120	59	4.7	23.6	82.5	139.0
86	92	26.7	73.5	138.0	228.0
87	155	49.6	127.0	232.0	384.0
88	90	26.1	72.0	135.0	223.0
89	81	18.6	55.0	121.5	201.0
102	121	7.3	44.7	169.0	300.0
123	290	23.2	116.0	405.0	684.0
124	310	118.0	291.5	434.0	732.0
103	139	16.4	89.0	194.5	328.0
104	272	10.9	81.6	380.5	642.0
125	314	25.1	125.5	376.0	672.0
126	152	24.3	85.0	182.5	326.0

	EXISTING GROUND			SUBDIVIDED GROUND	
RUNOFF BASIN	AREA	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF
21	336	84.0	242.0	168.0	396.0
22	570	142.5	410.5	285.0	672.0
26	252	68.0	189.0	126.0	297.0
58	113	30.5	84.7	56.5	133.0
23	169	42.2	121.5	84.5	199.0
59	864	274.0	708.0	432.0	1020.0
25	211	52.7	152.0	105.5	249.0
57	268	77.7	214.0	134.0	316.0
60	223	60.2	167.0	111.5	263.0
61	404	109.0	303.0	202.0	475.0
32	375	93.7	270.0	187.5	442.0
28	715	193.0	536.0	357.5	844.0
29	306	82.5	229.0	153.0	361.0
30	830	266.0	680.0	415.0	979.0
31	314	84.8	235.5	157.0	370.0
33	332	89.6	249.0	166.0	392.0
34	482	120.5	347.0	241.0	569.0
35	143	27.2	91.5	71.5	168.5
36	140	22.4	78.4	70.0	165.0
40	680	129.2	435.0	286.0	680.0
66	293	67.4	199.2	146.5	345.7
67	222	51.1	151.0	111.0	262.0
24	292	46.6	164.0	146.0	344.0
55	496	124.0	357.0	248.0	585.0
56	278	41.7	150.0	139.0	328.0
54	389	58.3	210.0	303.5	621.0
62	276	69.0	199.0	160.0	342.0
63	366	54.8	197.5	270.0	548.0
65	318	79.5	229.0	159.0	375.0
68	461	106.0	314.0	230.5	544.0
69	272	103.5	256.0	202.0	407.0
81	104	16.6	58.3	60.3	129.0
82	189	28.4	104.0	140.0	284.0
38	66	9.9	35.6	41.0	88.5
37	121	30.2	87.0	60.5	143.0
39	123	30.8	88.5	51.6	123.0
41	102	38.8	96.0	25.5	73.5

		EXISTING GROUND		SUBDIVIDED GROUND	
RUNOFF BASIN	AREA	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF	ONE HOUR 50 YEAR RUNOFF	SIX HOUR 50 YEAR RUNOFF
80	262	42.0	147.0	152.0	324.0
94	221	26.5	113.0	128.0	274.0
43	138	16.5	70.4	69.0	163.0
42	84	11.0	42.8	42.0	99.0
45	309	46.3	167.0	154.5	364.0
46	342	51.2	184.5	171.0	402.0
44	551	127.0	375.0	232.0	551.0
97	282	33.8	144.0	231.0	471.0
99	296	25.5	151.0	243.0	495.0
106	199	4.0	55.7	239.0	426.0
47	296	80.0	222.0	296.0	551.0
127	391	46.9	199.5	430.0	782.0
128	477	76.4	267.0	477.0	887.0
129	381	7.6	107.0	533.0	899.0
130	245	4.9	68.5	343.0	578.0
131	257	5.1	72.0	360.0	606.0
132	169	32.1	108.0	267.0	436.0
134	213	109.0	243.0	362.0	575.0
135	281	143.0	320.0	477.0	758.0
133	410	209.0	466.0	615.0	1020.0
136	286	146.0	326.0	400.0	675.0
137	355	206.0	440.0	602.0	957.0
138	137	57.5	137.0	232.9	370.0

TOTAL

33,268 = 51.98 Sq.Mi.

650.5	1964.0	2203.4	4345.9

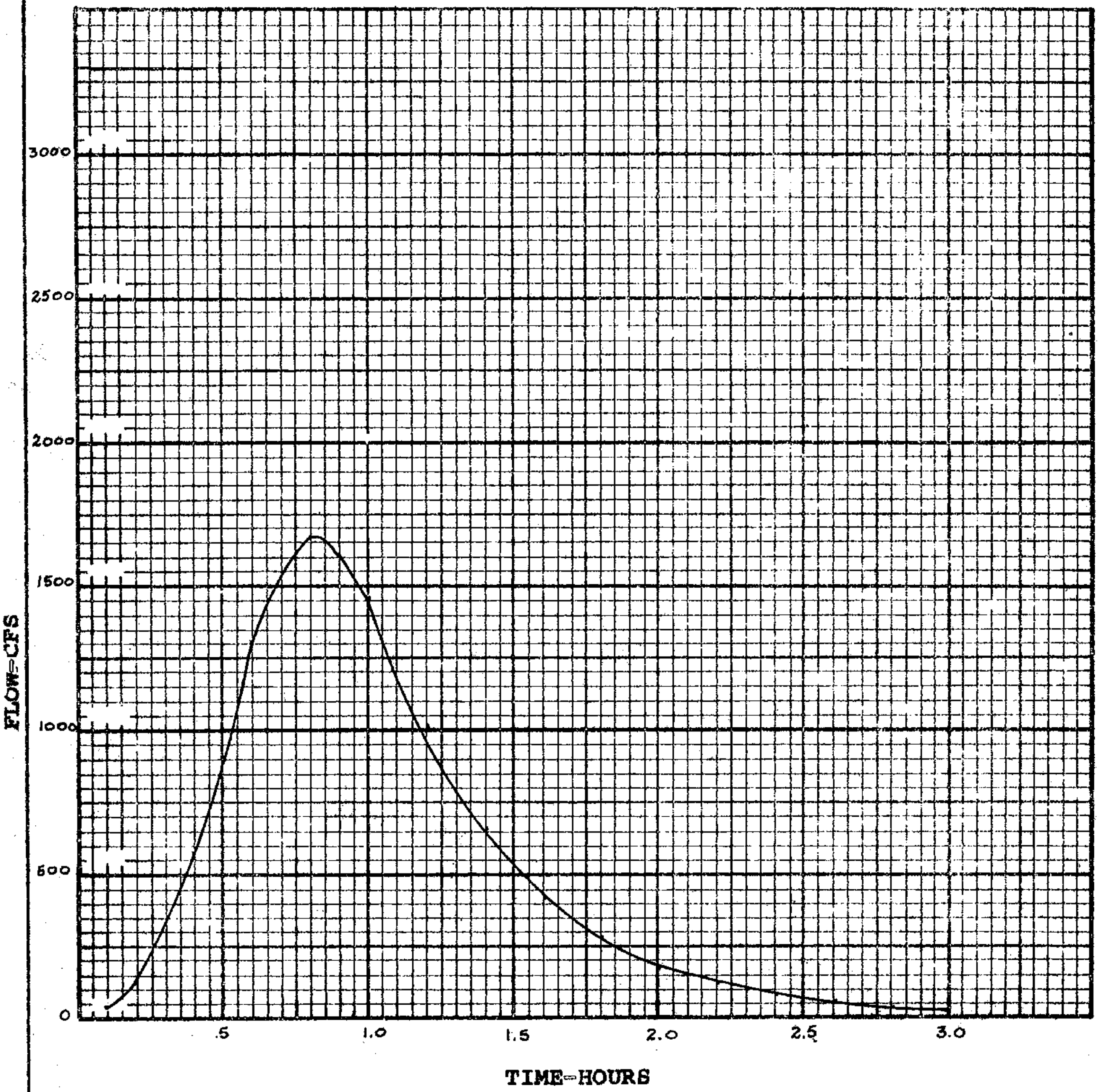
APPENDIX E:

HYDROGRAPH:

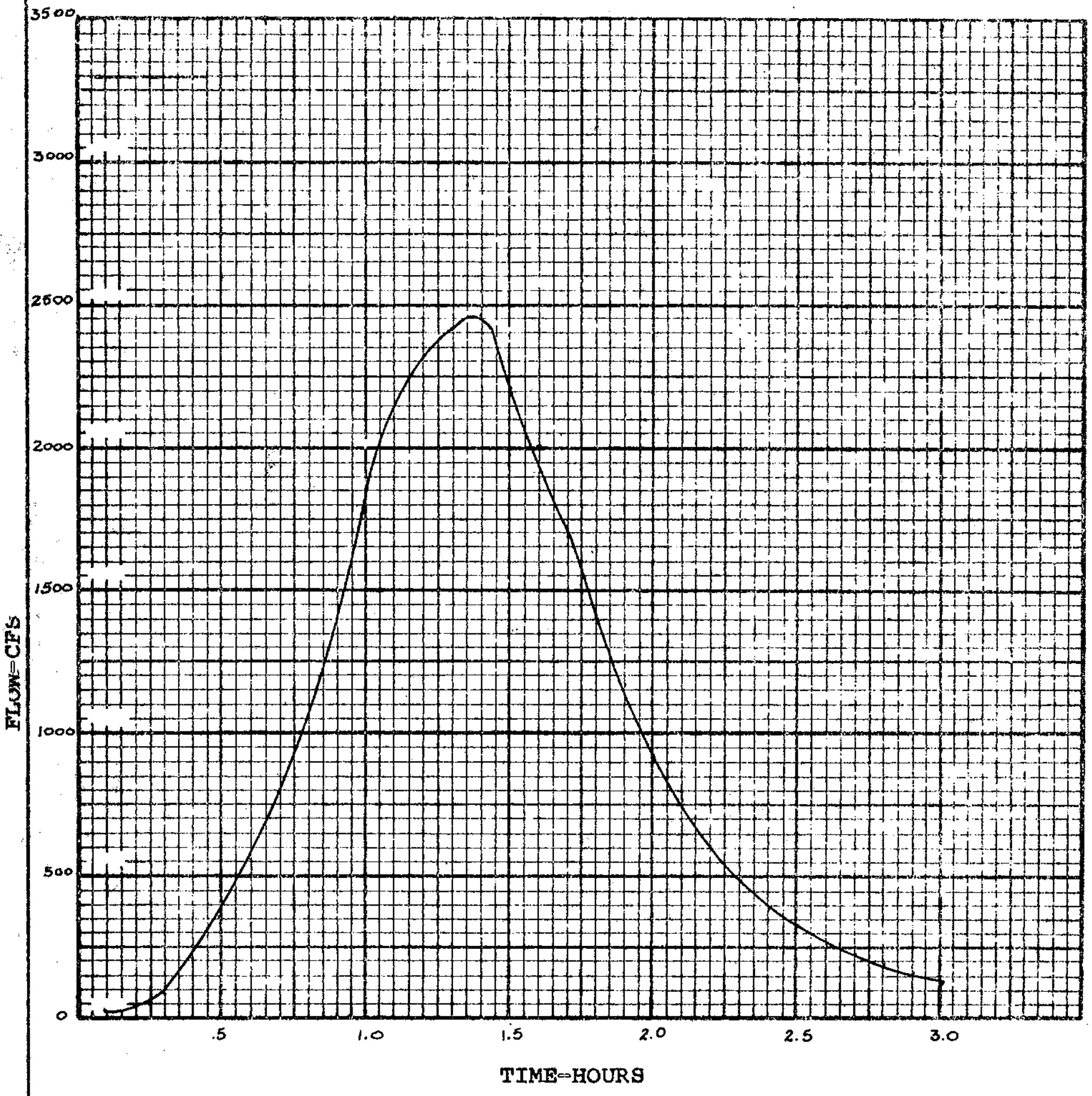
A hydrograph is a graphic "picture of run-off. The area of the graph equals the total amount of runoff in Acre Feet. The Peak and entire upper limit of the hydrograph represents the amount of runoff at any given instant of time. In the case of all the following hydrographs, the 0 point on the time scale represents the beginning of rainfall.

To be plotted and calculated, a point in the subject basin must be arbitrarily selected, and the hydrograph constructed in relation to that point.

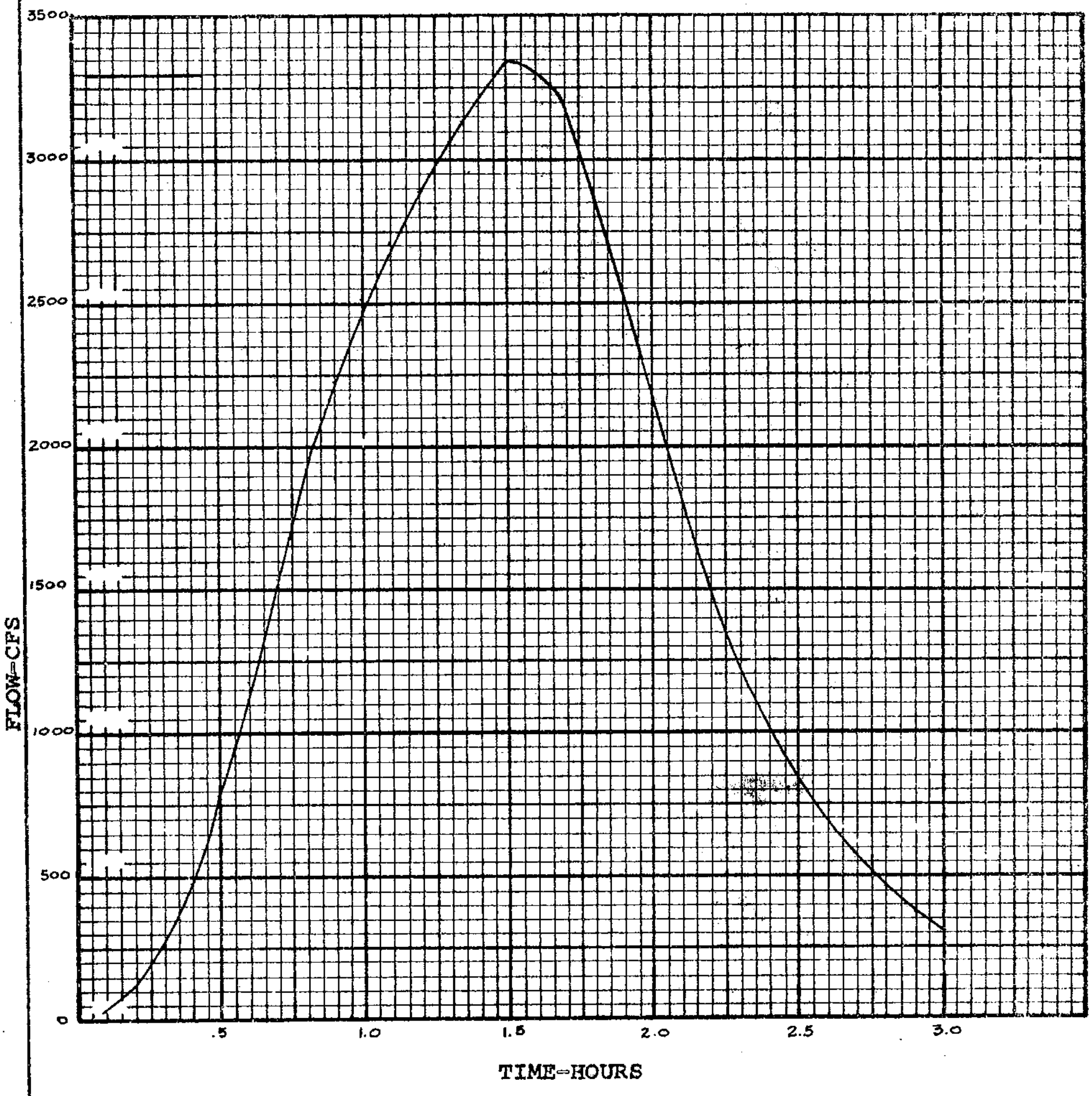
The numbered points on the following series of hydrographs can be matched to numbered points on the base maps, and represent those key points which have been selected along the Sand Creek Basin. The following group of hydrographs represent the flow at the selected points for the condition of the rainfall selected, and no control along the channel.



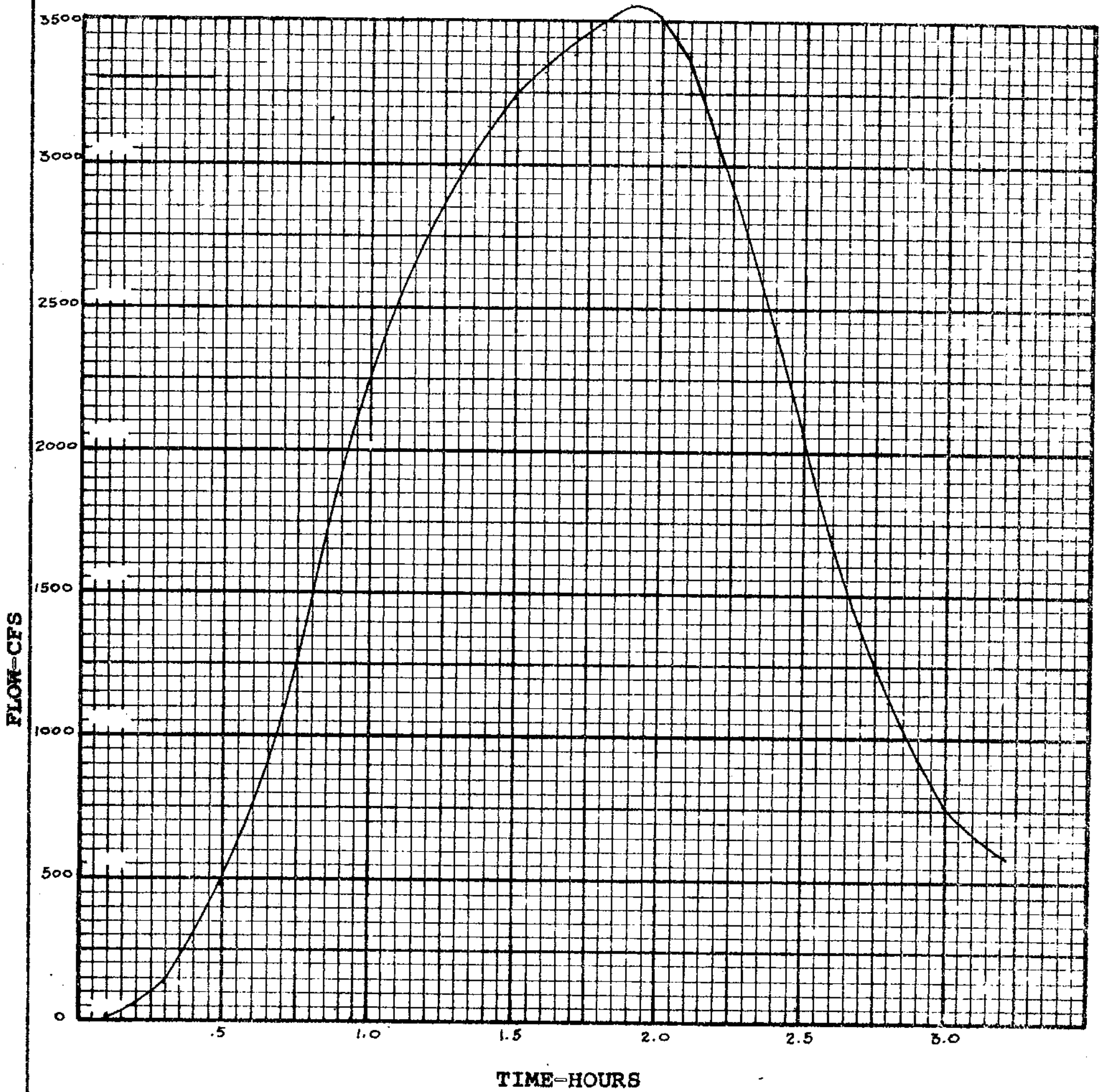
UNTREATED COMBINED HYDROGRAPH AT POINT I	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



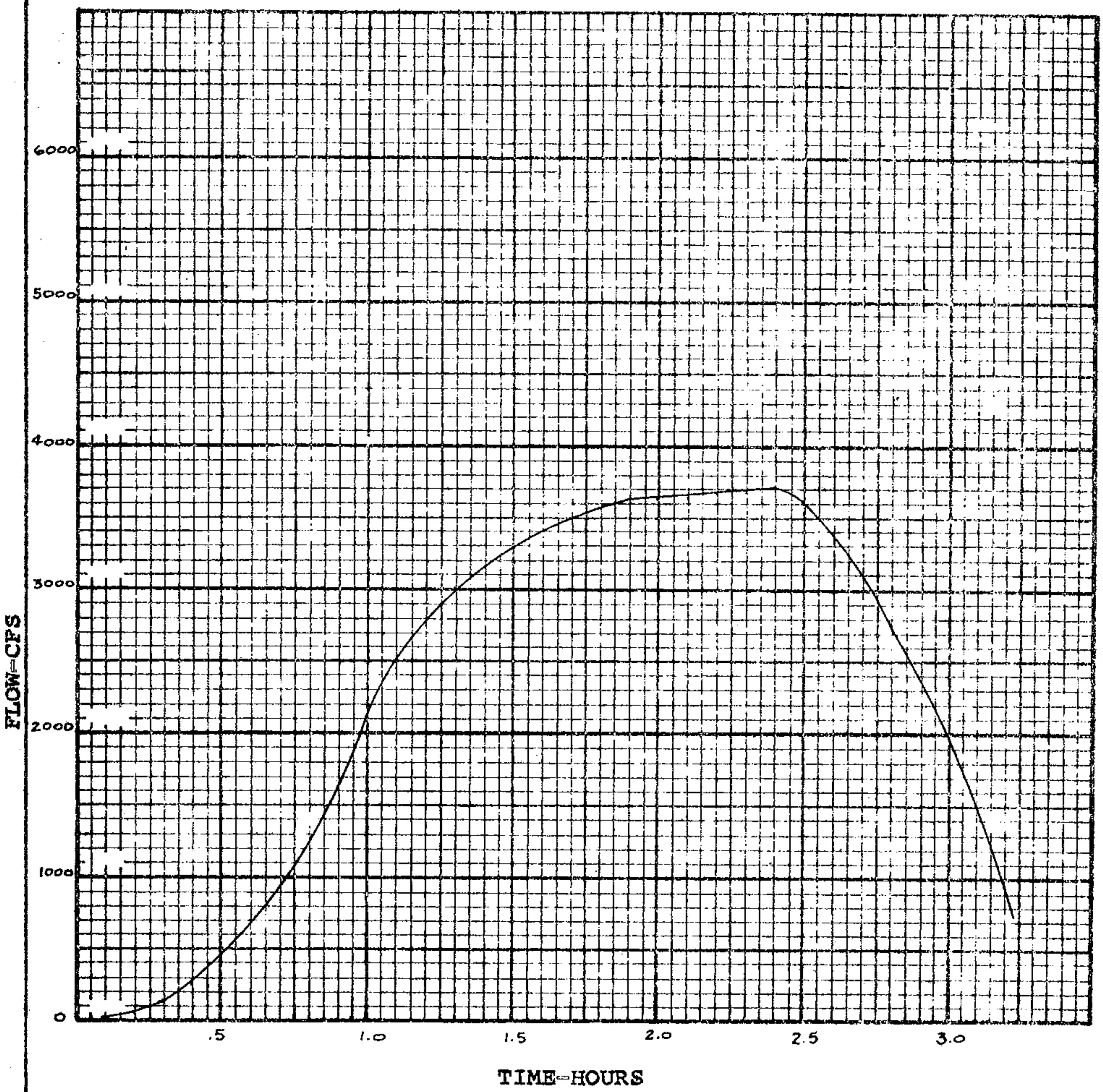
UNTREATED COMBINED HYDROGRAPH AT POINT II	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



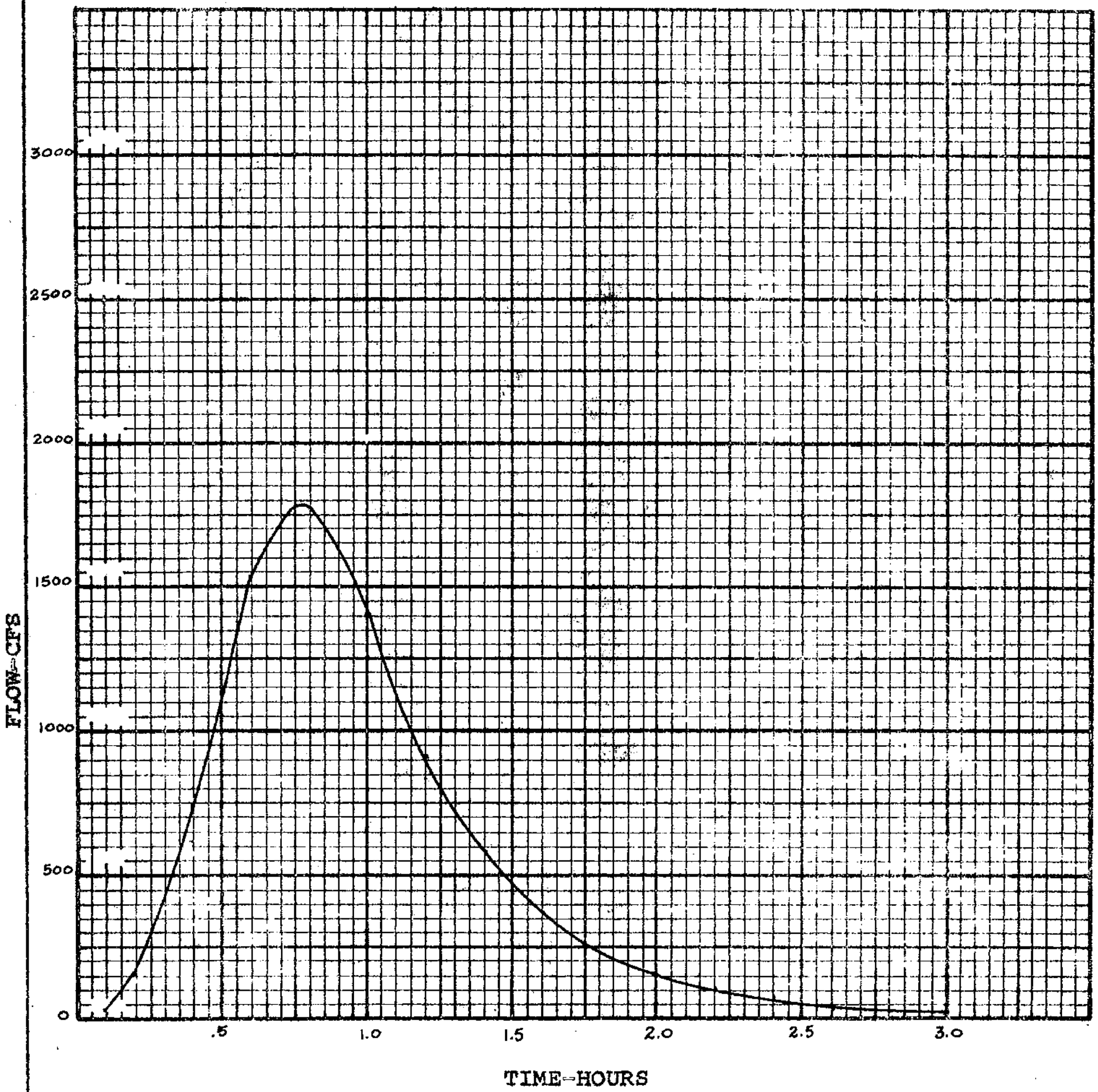
UNTREATED COMBINED HYDROGRAPH AT POINT III	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



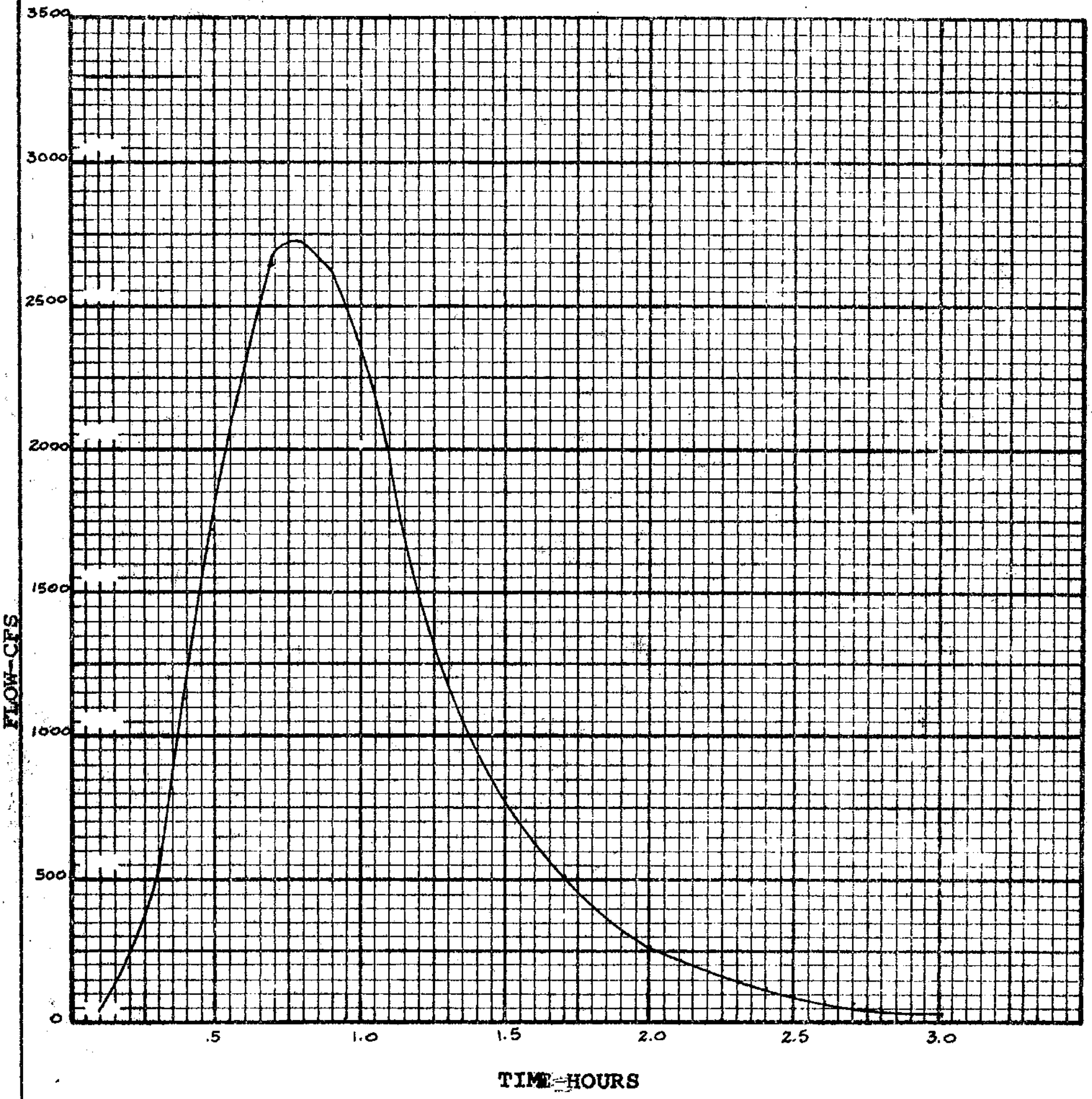
UNTREATED COMBINED HYDROGRAPH AT POINT IV	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



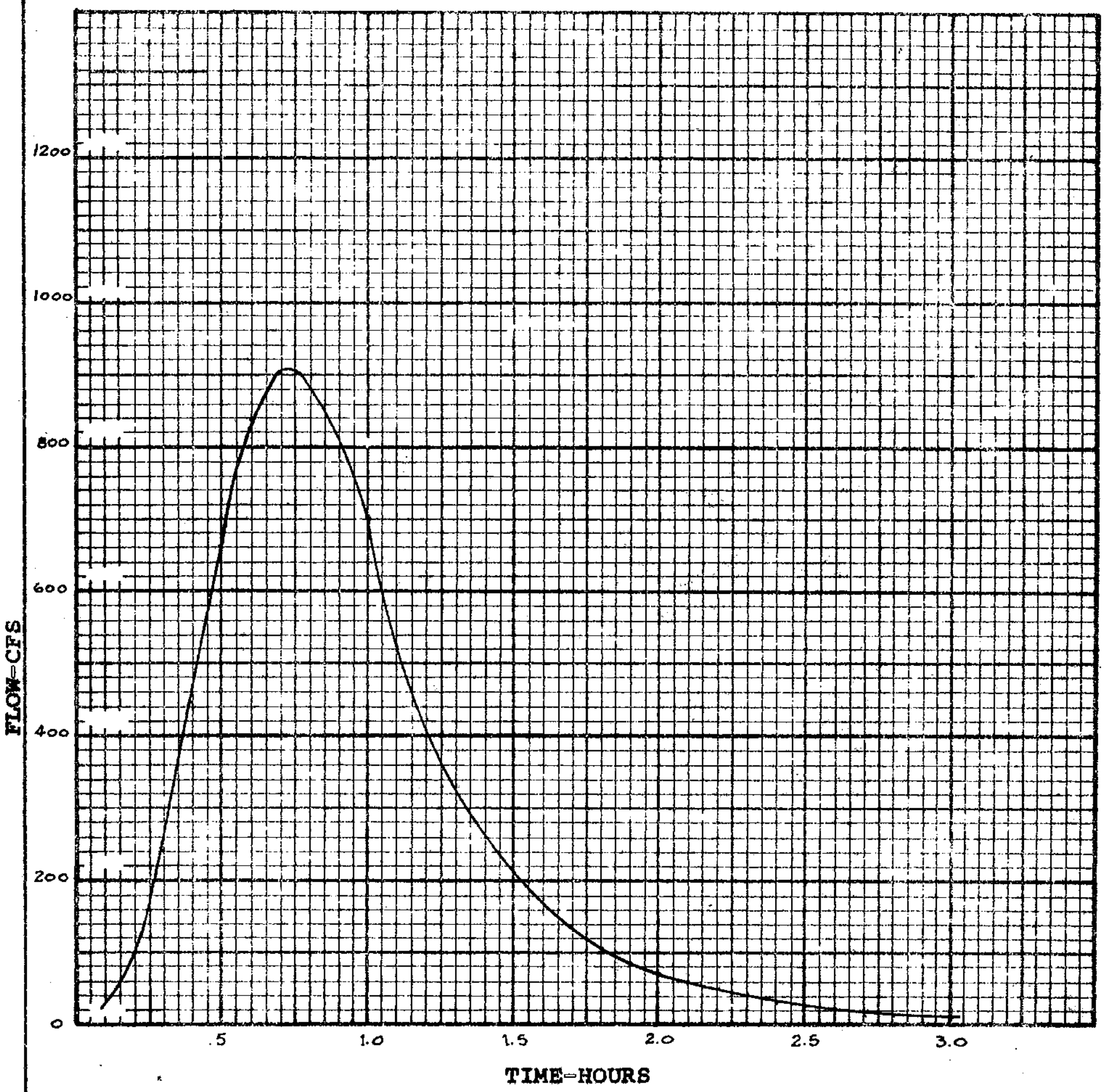
UNTREATED COMBINED HYDROGRAPH AT POINT V	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



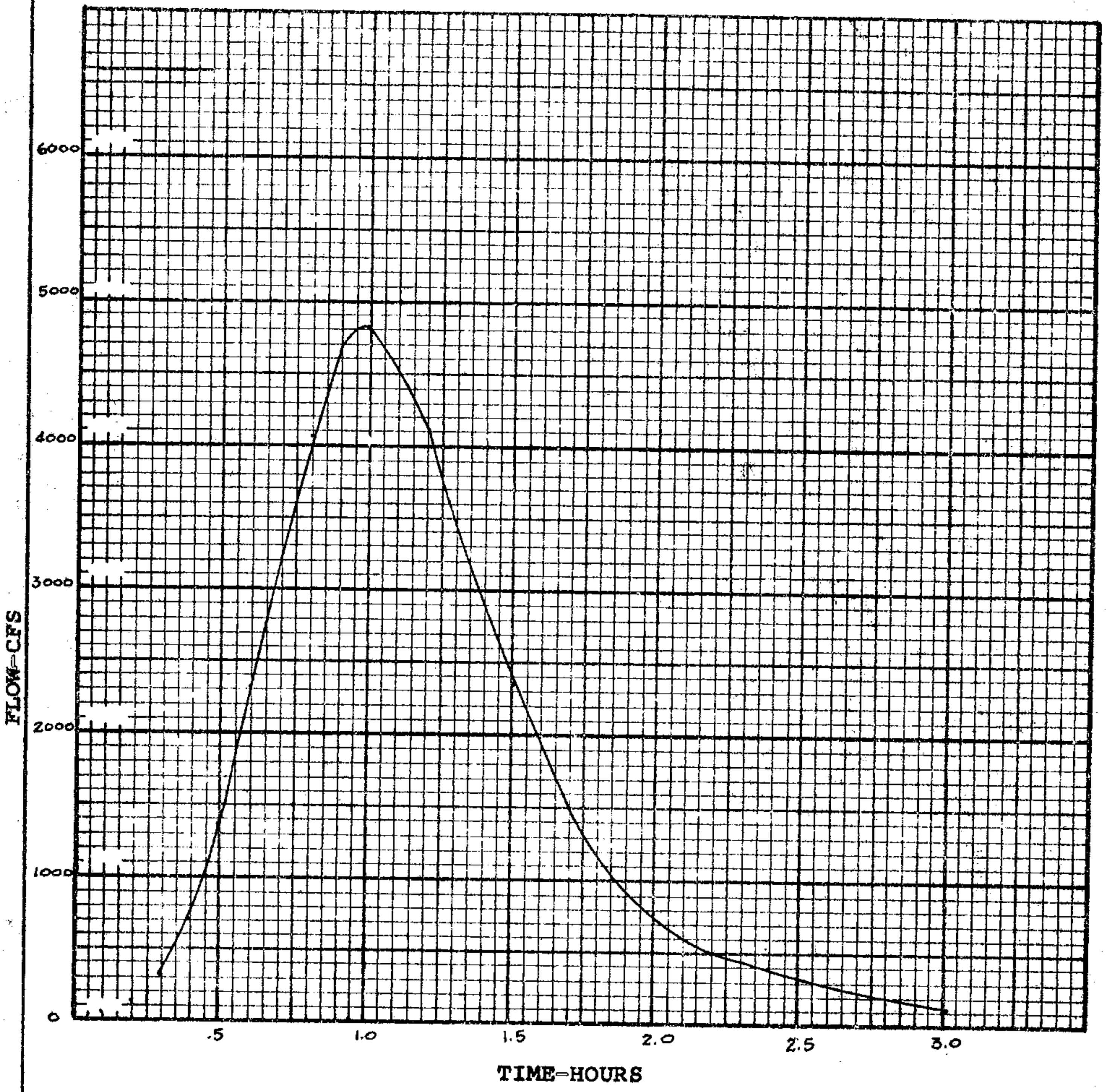
UNTREATED COMBINED HYDROGRAPH AT POINT VI	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



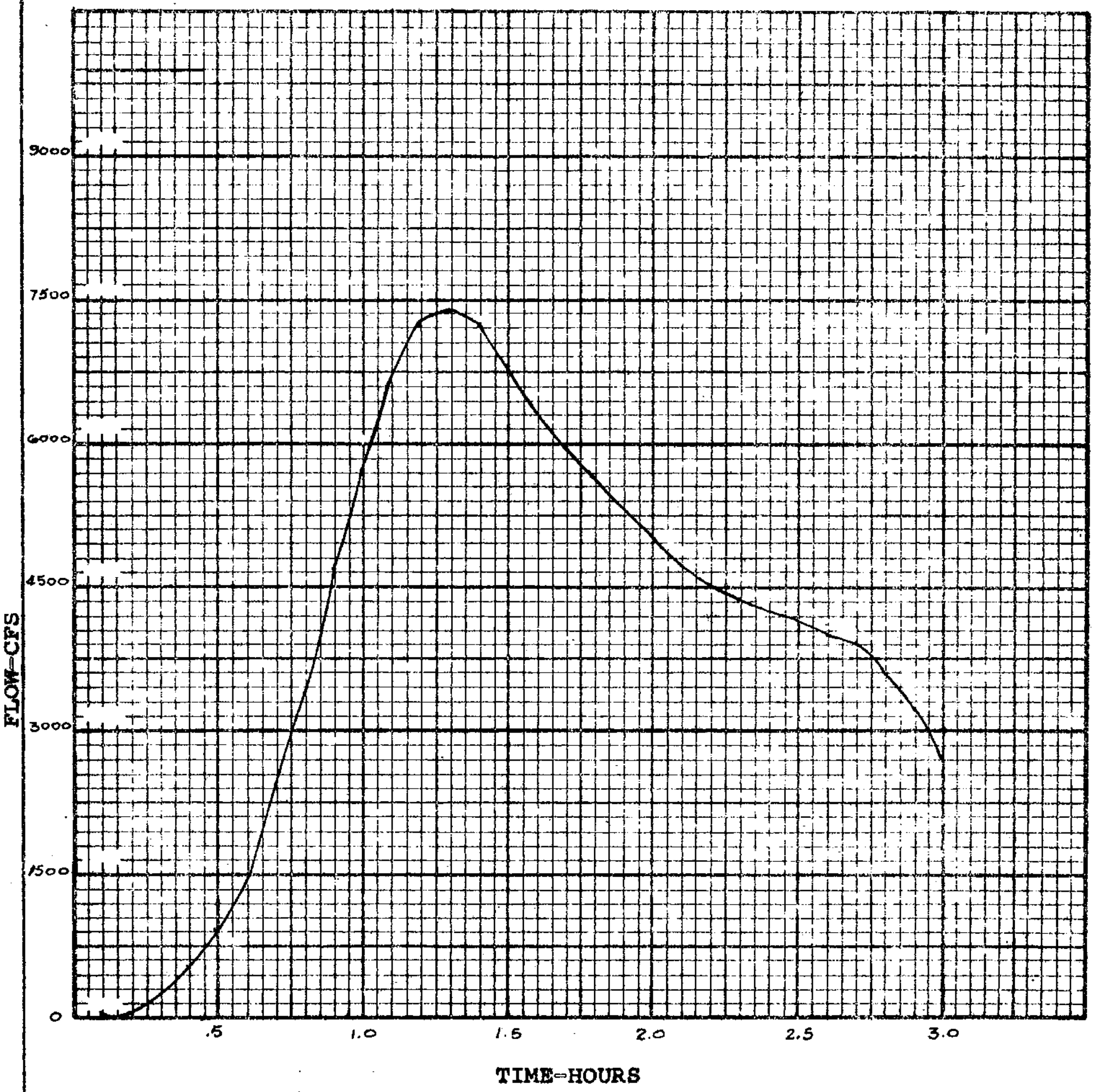
UNTREATED COMBINED HYDROGRAPH AT POINT VII	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



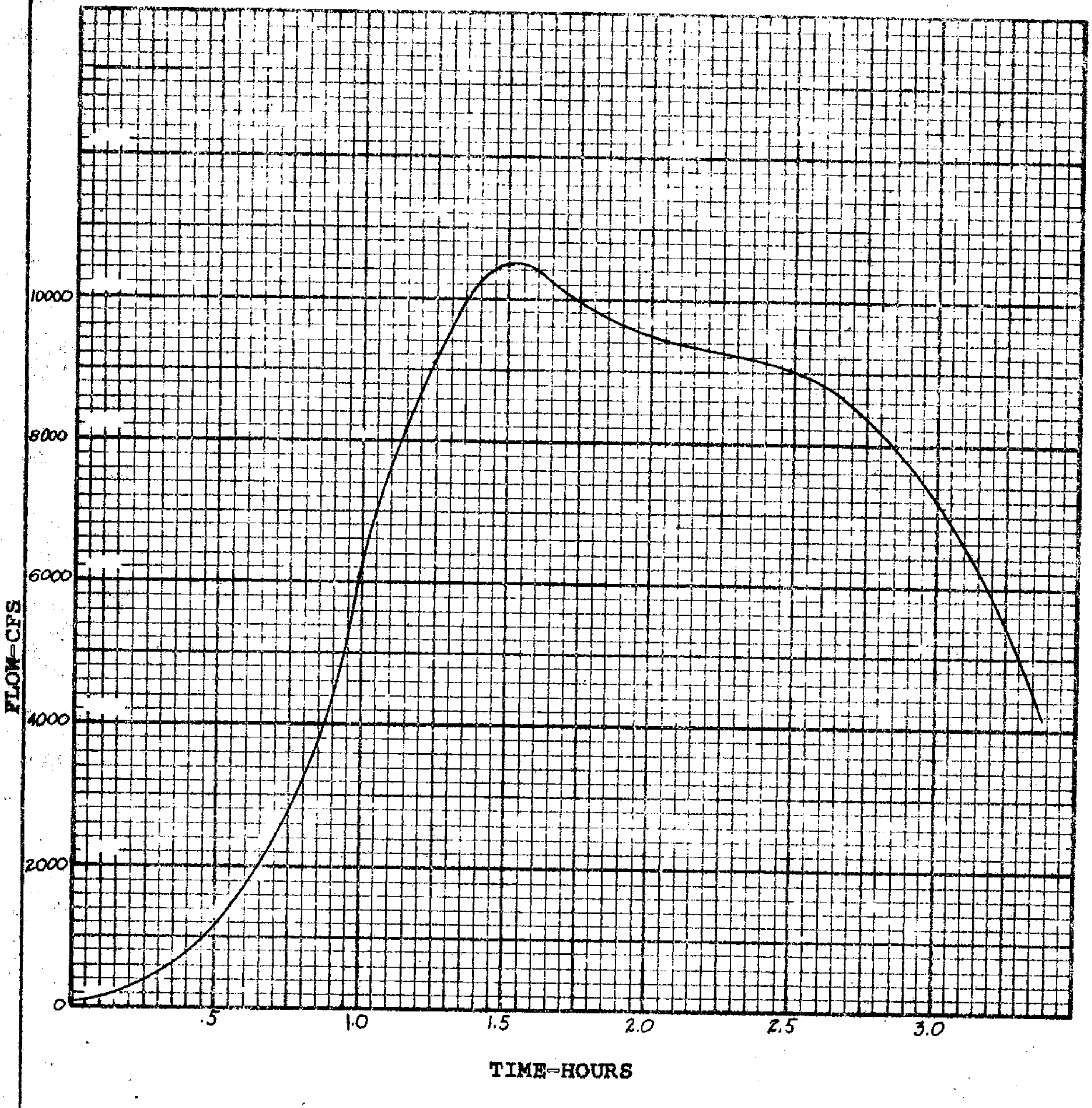
UNTREATED COMBINED HYDROGRAPH AT POINT VII A	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



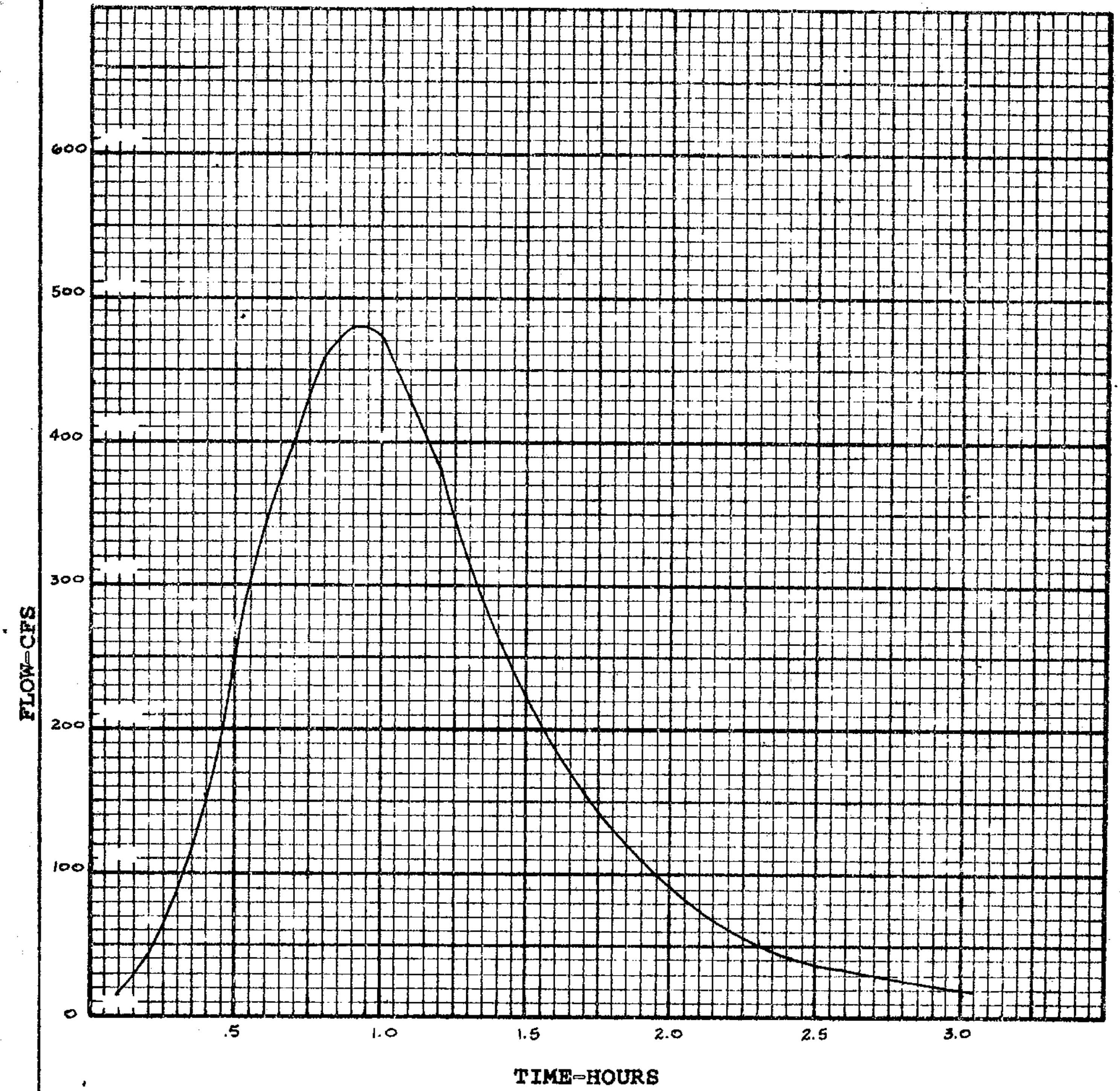
UNTREATED COMBINED HYDROGRAPH AT POINT VIII	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



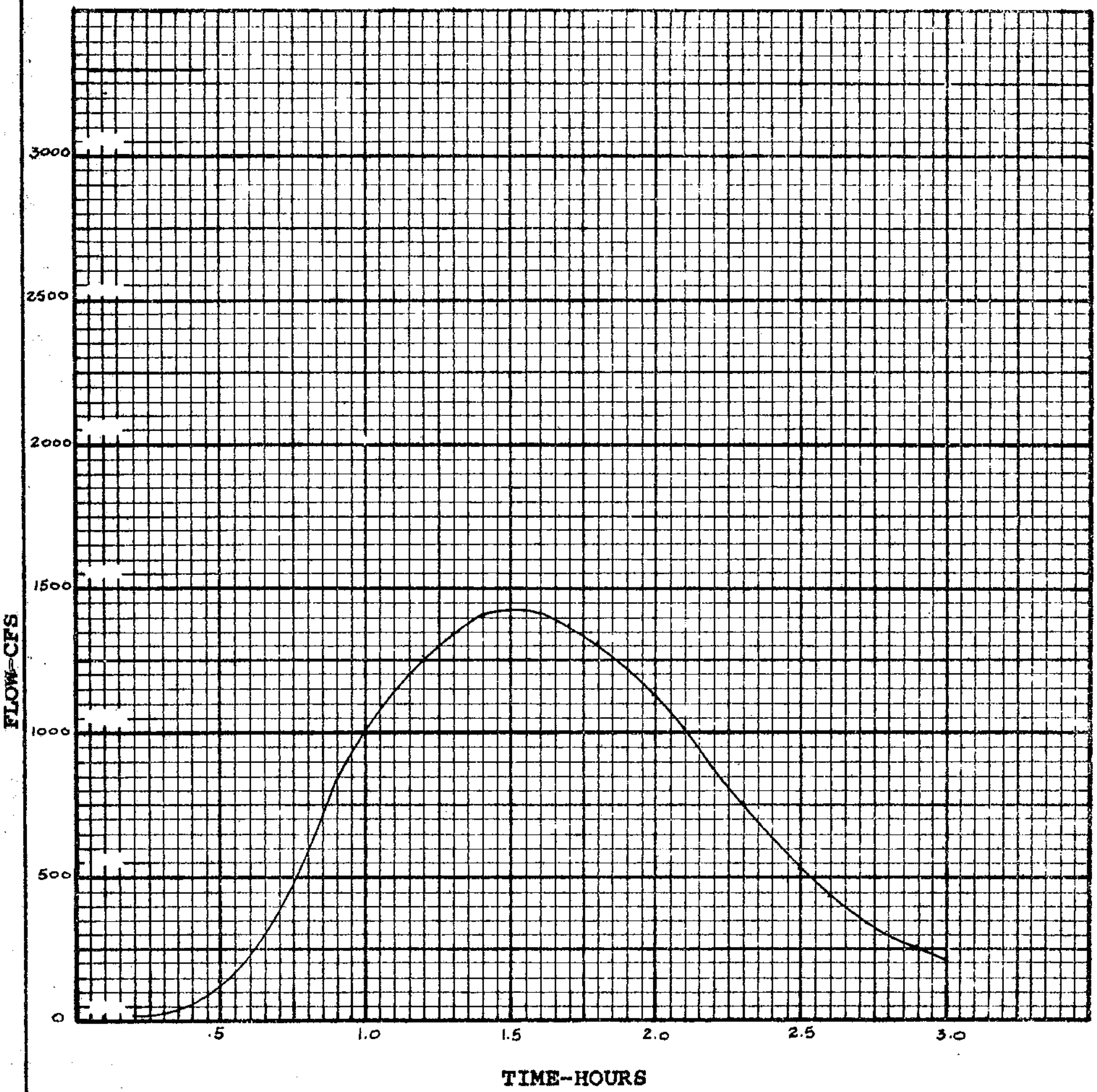
UNTREATED COMBINED HYDROGRAPH AT POINT IX	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



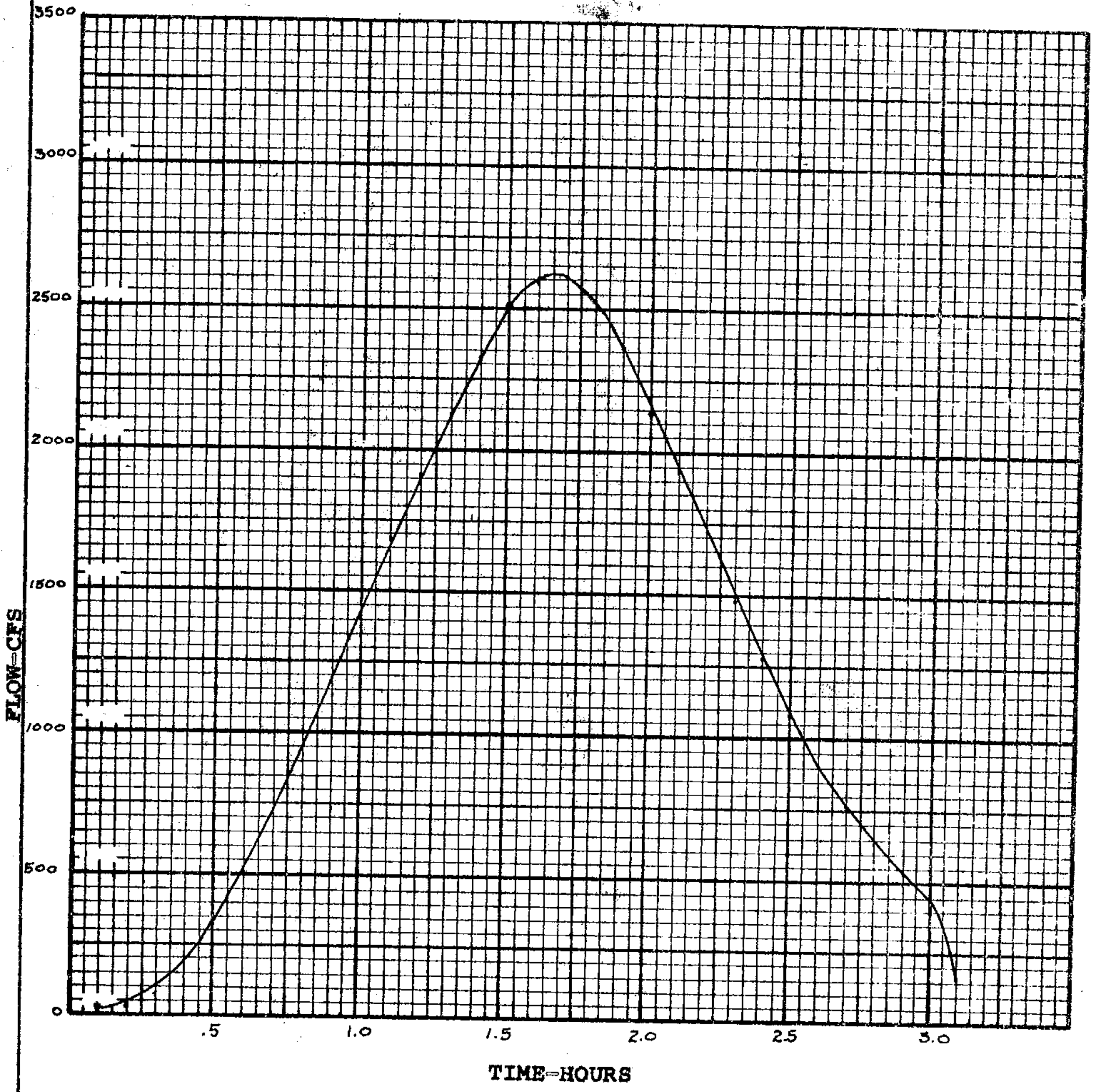
UNTREATED COMBINED HYDROGRAPH AT POINT IX A	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



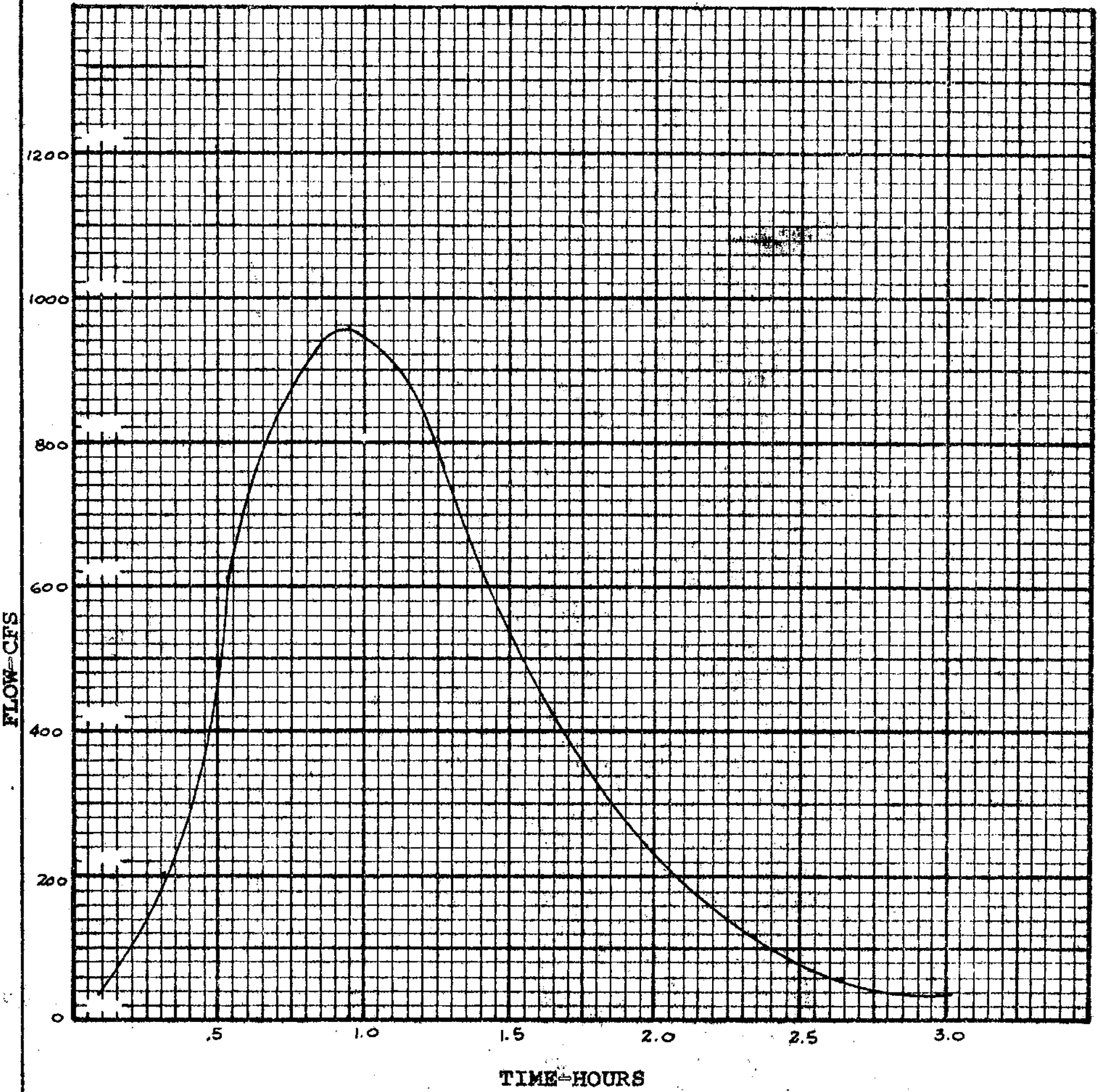
UNTREATED COMBINED HYDROGRAPH AT POINT X	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



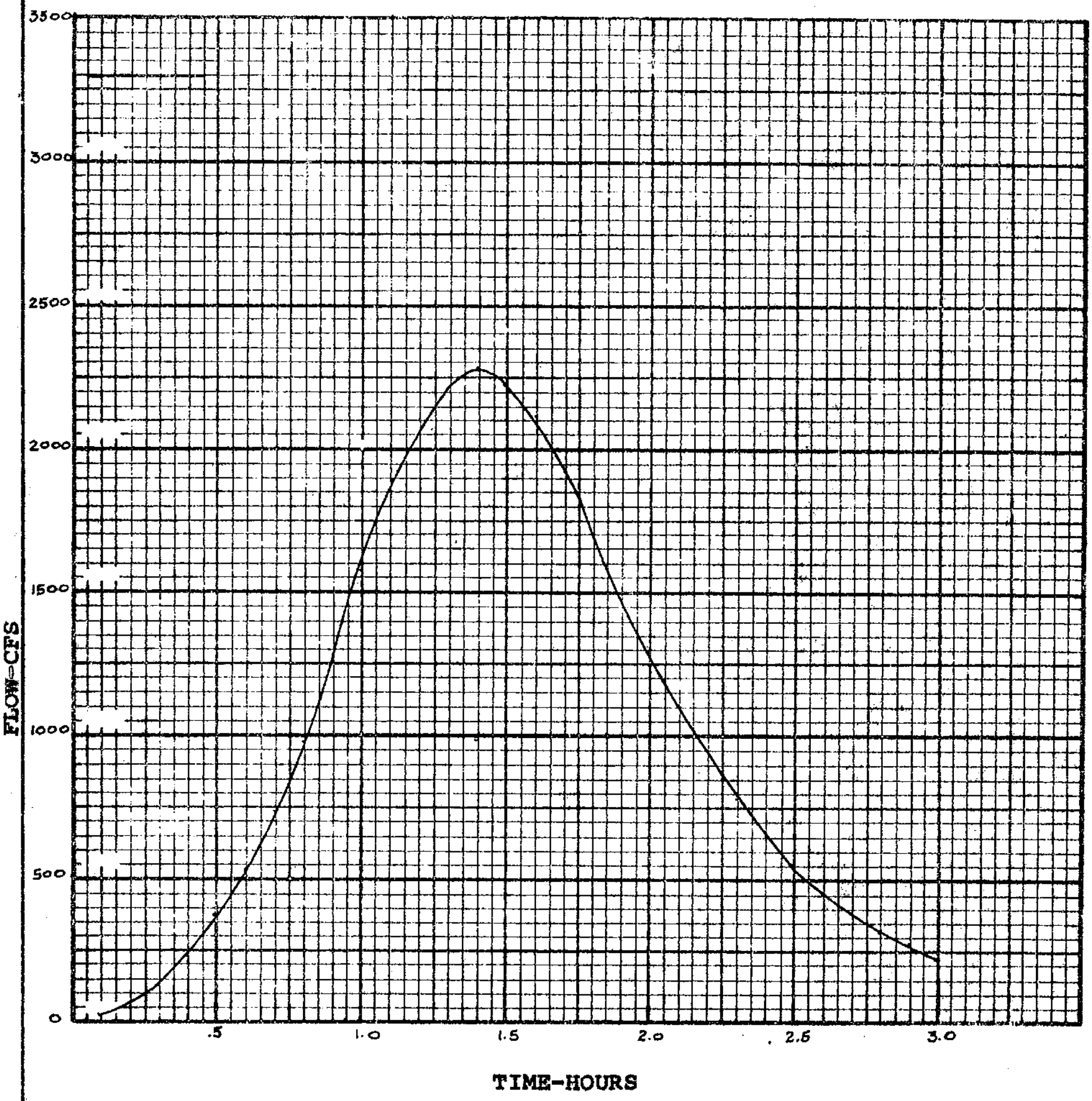
UNTREATED COMBINED HYDROGRAPH AT POINT XI (BASINS K&L)	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



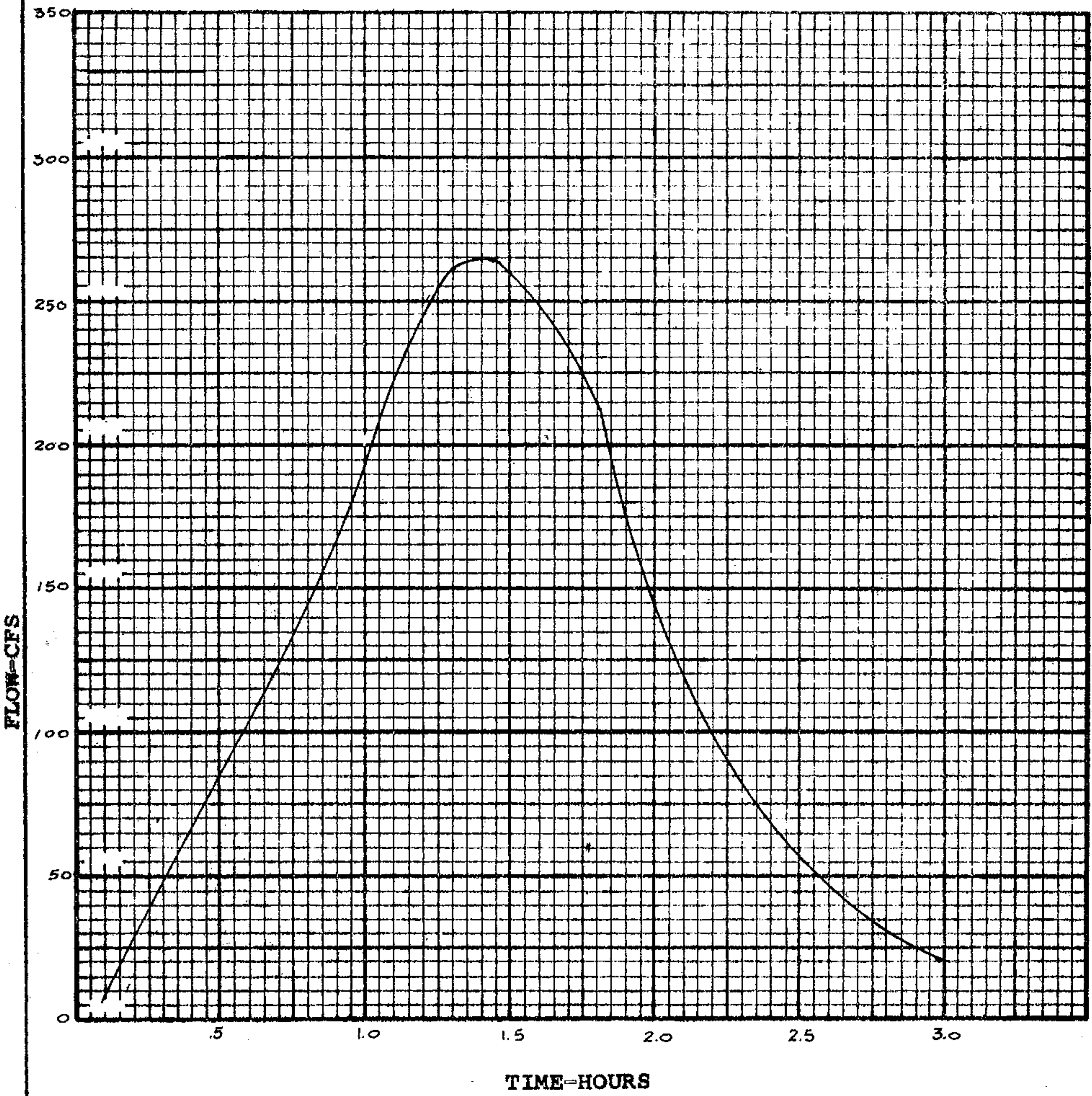
UNTREATED COMBINED HYDROGRAPH AT POINT XI (BASINS N, O, &P)	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



UNTREATED COMBINED HYDROGRAPH AT POINT XII	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO

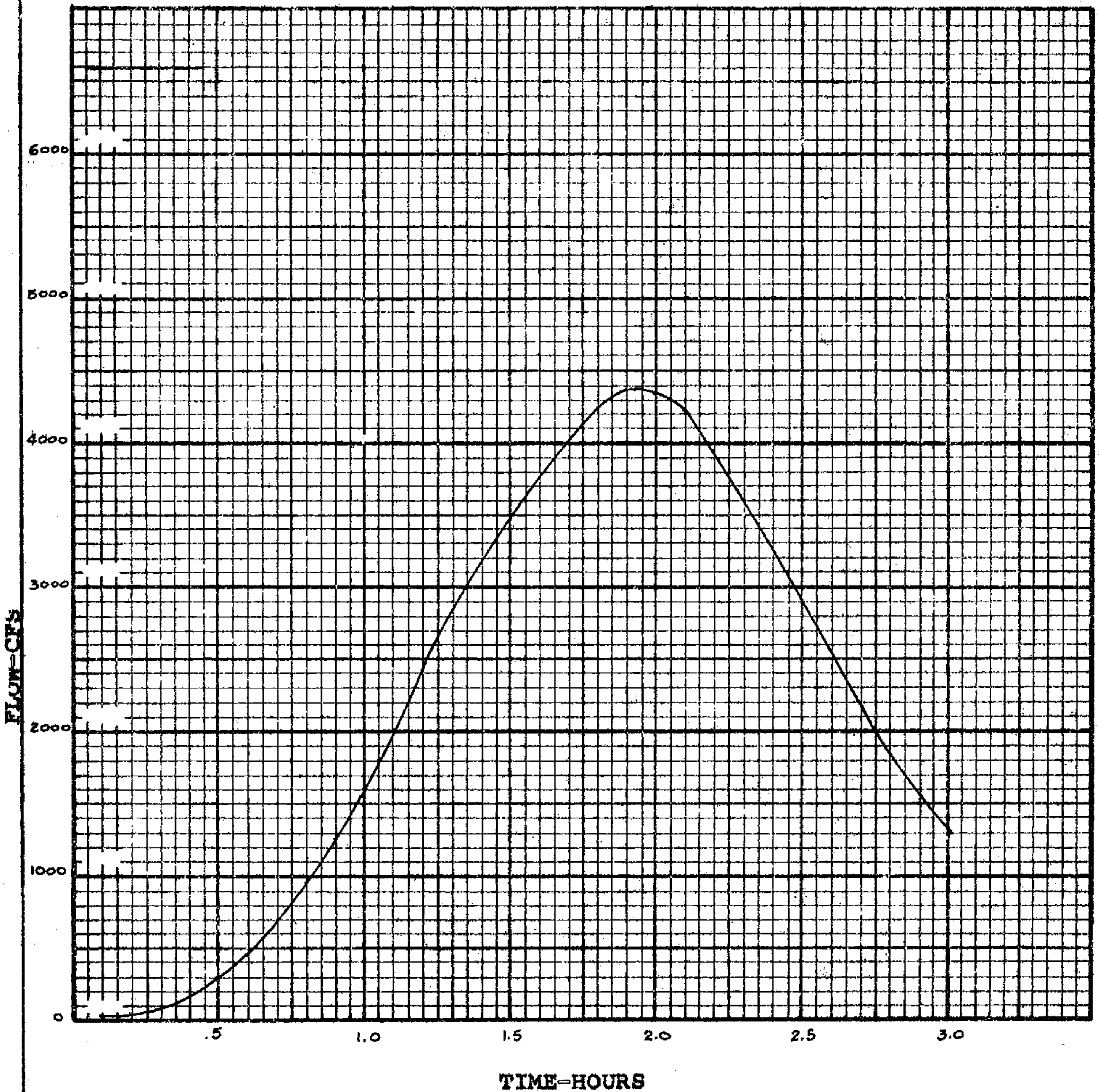


UNTREATED COMBINED HYDROGRAPH AT POINT XIII	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO

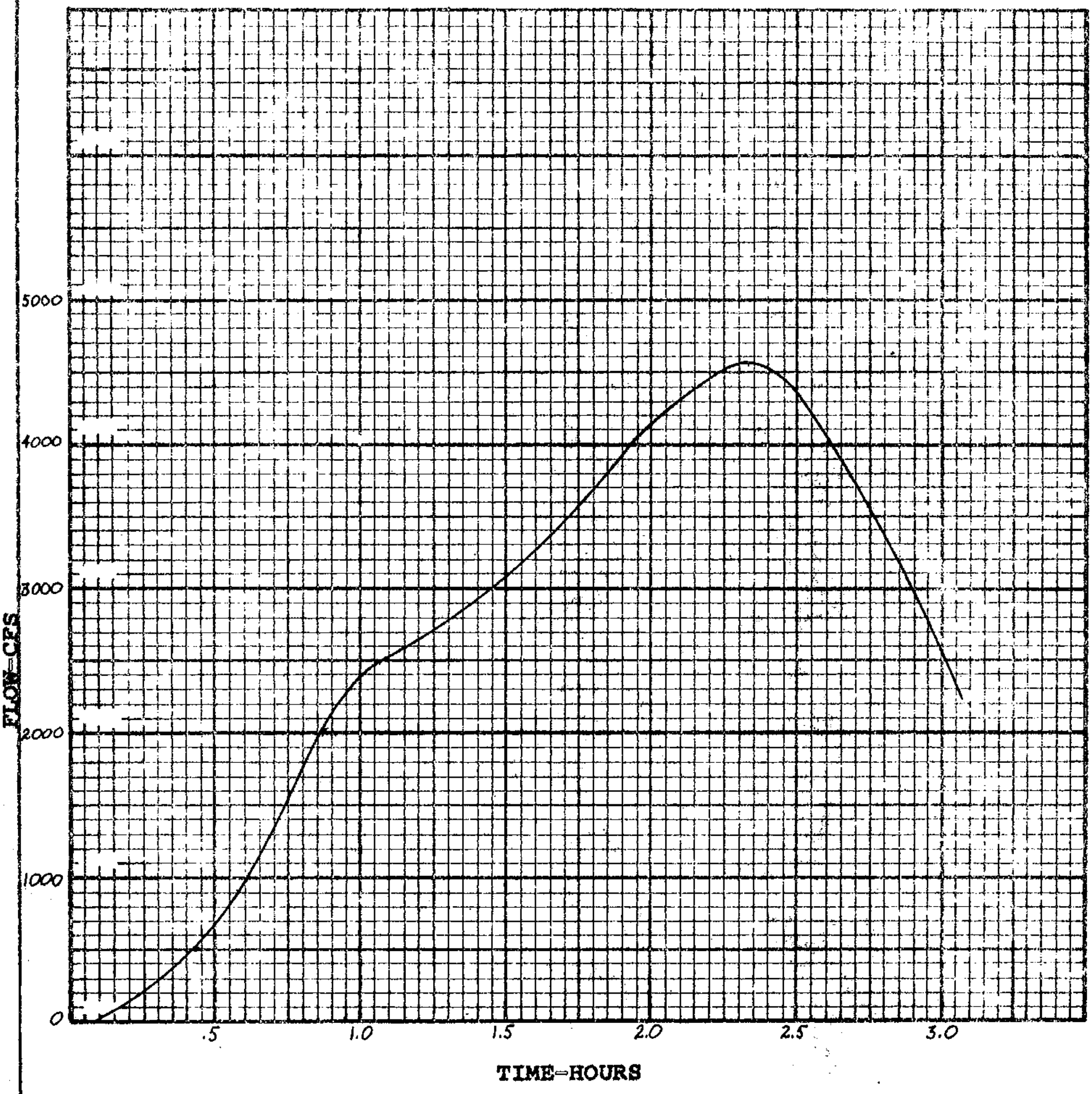


UNTREATED COMBINED HYDROGRAPH AT POINT XIV

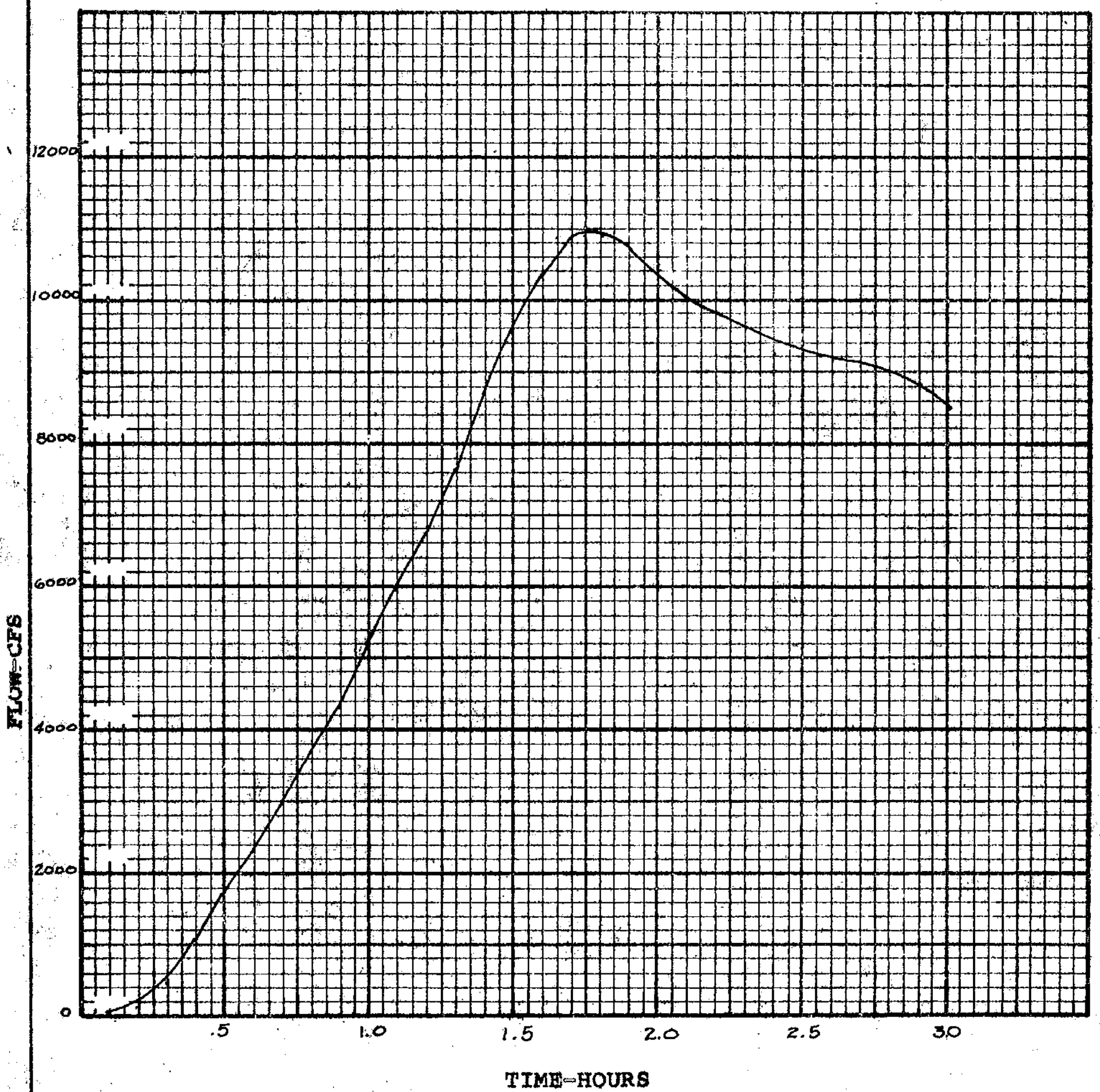
UNITED WESTERN ENGINEERS
COLORADO SPRINGS, COLORADO



UNTREATED COMBINED HYDROGRAPH AT POINT XV	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



UNTREATED COMBINED HYDROGRAPH AT POINT XVI	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO



UNTREATED COMBINED HYDROGRAPH AT POINT XVII	UNITED WESTERN ENGINEERS COLORADO SPRINGS, COLORADO

APPENDIX F:

The hydrographs shown here are based on the same data as those in Appendix E. These, however, reflect the treatment of the Sand Creek channel by proper channeling and the construction of low, "flow through", dams. The dams have the effect of reducing peak flows and lengthening flow periods.

These hydrographs indicate total and consistant channel treatment over the entire basin. They are, thus, maximum flow curves considering a fully developed basin, and a fully controlled channel.