HYDROLOGIC ENGINEERING STUDY

MASTER DRAINAGE BASIN STUDY

Rockrimmon South Drainage Basin

for

THE DEPARTMENT OF PUBLIC WORKS
COLORADO SPRINGS, COLORADO

and

THE DIGITAL EQUIPMENT CORPORATION

OCTOBER, 1976

KARCICH & WEBER, INC.
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HYDROLOGIC ENGINEERING STUDY

OF THE

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Prepared By:

KARCICH & WEBER, INC.

OCTOBER 1976

November 8, 1976

Mr. Dewitt Miller
Director of Public Works
City of Colorado Springs
Colorado Springs, Colorado

Dear Mr. Miller:

Transmitted herewith is the Hydrologic Engineering Study of the Rockrimmon South Drainage Basin in Colorado Springs, Colorado.

This plan has been prepared at the request of Digital Equipment Corporation and the City of Colorado Springs to conform with recently revised changes in land use.

The study includes a hydrologic study of the entire Rockrimmon South Drainage Basin. Included are rainfall-runoff characteristics of the basin, geologic and soil survey information, synthetic hydrographs for peak runoff flows in the channel and recommended facilities together with costs to accomodate the storm runoff. This is the Master Drainage Plan for all proposed development within the basin as presently conceived.

We wish to thank the City of Colorado Springs and the Digital Equipment Corporation for their cooperation in reviewing and commenting on the study during the preparation of this report. We remain available at any time to answer questions or provide specific information relative to this study.

Respectfully submitted,
KARCICH & WEBER, INC.

Matthew F. Karcich

Matthew F. Karcich

MFK:drc

cc: The Digital Equipment Corporation
Dennis Maroney
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ROCKRIMMON SOUTH DRAINAGE BASIN

SCOPE AND PURPOSE:

It is the intent of this report to furnish the basis for an overall plan for placing storm sewers, culverts, detention reservoirs, channel linings, and drainage appurtenances in the Rockrimmon South Drainage Basin as development occurs. It should be a part of the overall plan for stormwater control in the metropolitan area around Colorado Springs.

This study does not establish the exact design details of storm sewers or drainage channels in any definite area, but does establish the general location of required storm drainage structures and their required sizes in accordance with the planned development of the area. Retention and detention facilities were considered as economical measures for reducing runoff peaks.

Existing channels will be reserved for drainage purposes, and encroachments on them will not be allowed. According to the planned development these existing channels will be enhanced and utilized to some extent. Multiple use of drainage facilities has been encouraged. Erosion control and recreational uses of proposed drainage facilities should be considered wherever possible.

Studies of undeveloped basins provide a basis for logical and realtively inexpensive overall storm drainage design. Thus, adequate storm drainage structures may be constructed as subdivisions are developed, thereby minimizing costs and avoiding potential storm damage.

BASIN DESCRIPTION:

Rockrimmon South Drainage Basin is located in the northwest portion of the metropolitan area approximately 6 miles north-northwest from downtown Colorado Springs, east of Wilson Road, and south of the Rockrimmon development. The entire basin lies within the city limits. Figure 1 shows the location of the drainage basin.

The upper most portion of the basin is situated at an elevation of 6890 msl and falls to an elevation of 6174 in a 3.5 mile water course. The Rockrimmon South Drainage Basin is a tributary to Monument Creek and its confluence is located approximately 1/2 mile south of the intersection of Interstate 25 and Monument Creek.

The topography is varied because it occurs at the foothills of the Rampart Range which is a part of the Front Range of the Rocky Mountains. Erosion has created some precipitous slopes in the area. Rock formations are exposed in many areas and shallow soils are evident in many parts of the basin.

CLIMATOLOGICAL SUMMARY:

The average annual rainfall for Colorado Springs is 14.52" as recorded at Peterson Field. Extreme variances in rainfall amounts are experienced throughout the city for individual storms due to varying intensities and limited areal extent of storm systems. Over 80% of the rainfall falls between April 1st and September 30th. Most of this rainfall is in the form of heavy downpours associated with summer thunderstorms.

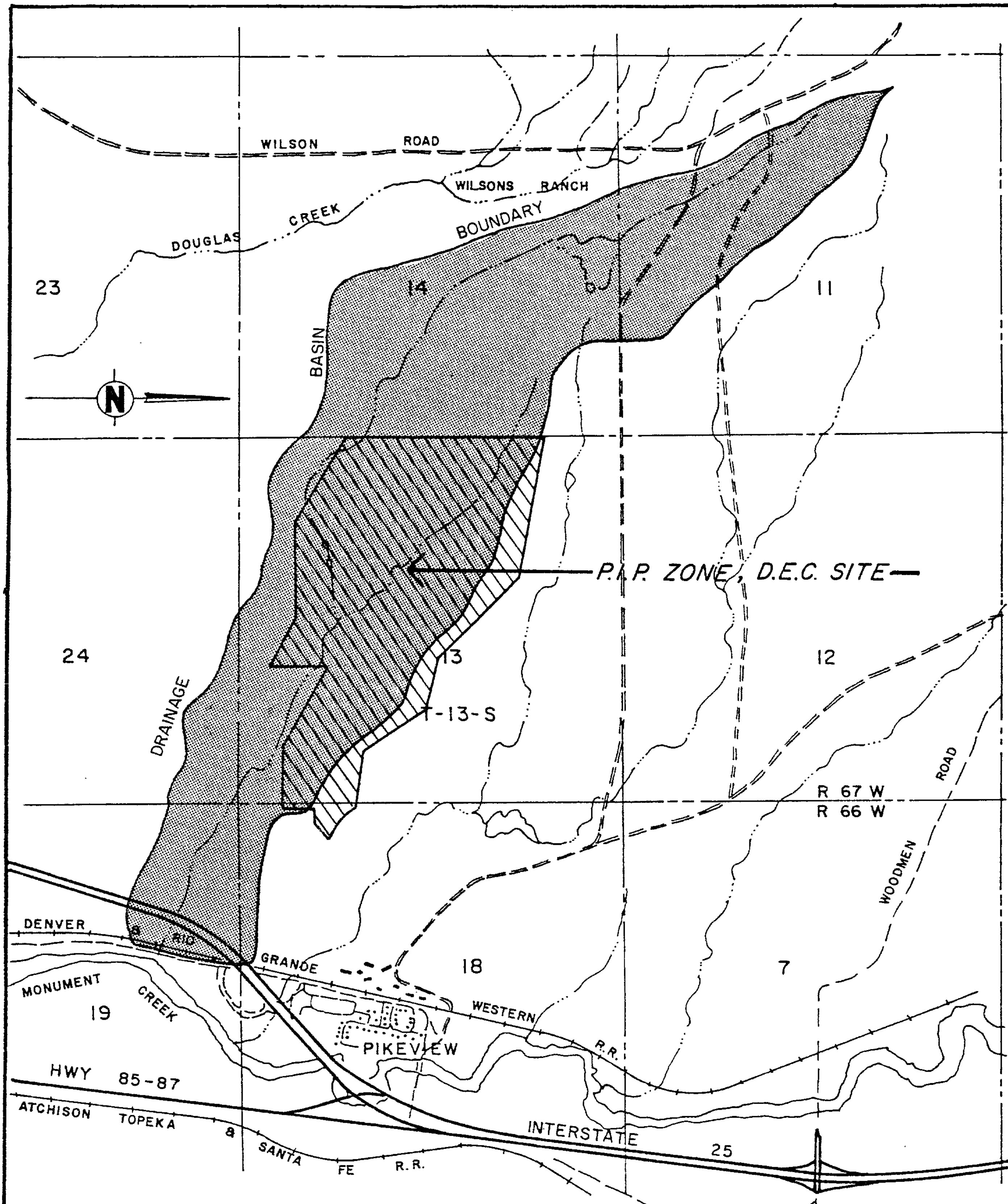


FIGURE 1

VICINITY MAP

ROCKRIMMON SOUTH DRAINAGE BASIN

BASIN GEOLOGY:

Exposed rock outcroppings are of the Laramie and Dawson Formations. The Laramie Formation consists of fine grained sandstones and claystone with stratified coal seams. The Dawson Formation consists of materials eroded from rising mountains to the West. The weathered sandstones and claystone of this formation form montmorillonitic clays which are generally highly expansive when exposed to moisture.

Significant geologic structural variations exist within the basin. The eastern basin exhibits characteristics of a relatively flat geologic structure while rock formations of Pierre Shale in the upper basin along the westerly boundary are severely tilted. The Rampart Range fault runs along the mountain range near the westerly basin boundary.

Valleys and lower slopes of the drainage basin consists of stratified alluvial deposits of varying thicknesses. These silty and clayey deposits of the local Dawson and upper Laramie Formations generally have a high sulfate content and should be investigated when selecting construction materials for drainage facilities. In areas of high sulfate content, corrosion protection should be provided for metal pipe and Type II Cement utilized for concrete structures. Subdrainage should be given careful attention in areas where soil stratification has occurred. Sand lenses interspersed among less pervious materials could serve as the transport conduits for subsurface flows. Structural foundations should not block these flow paths and create subsurface dams.

Drainage within the basin requires critical attention both during and after construction due to the critical nature of surface soils. Existing gullies and surface characteristics show signs of heavy wind and water erosion. A sand and gravel veneer has developed on the surface since most fine material has been removed by wind and water erosion. This "desert pavement" has created a delicate balance between stabilizing forces and erosion potentials. When this surface protection is removed, heavy sheet erosion will occur unless proper control measures are observed both during and after construction. Compatible erosion control plans should be developed with drainage plans and drainage strucutres utilized for both erosion control and flood control purposes. An increase in flow runoff quantities and velocities would increase the possiblity of additional gully erosion. Portions of the basin show signs of past erosion control measures. Terraces, diversions and erosion control dams have been constructed in the past to help stabilize erosive forces.

SOILS SURVEY:

The soils in the basin areas are dark soils of stream terraces with sandy subsoils (Eastonville Series) and some very shallow, common stony or gravelly soils. The northern part has decomposed granites, and the southern part consists of fine grained sands and clays of the Laramie Formation. Some clay will appear in the deeper stratas.

The various soil types found in the Rockrimmon South Drainage Basin are delineated on Figure 2. Soil suitability ratings for indicated perimeters are given in Table 1. Mapping and interpretations are by soil scientists of the USDA-Soil Conservation Service and are given below:

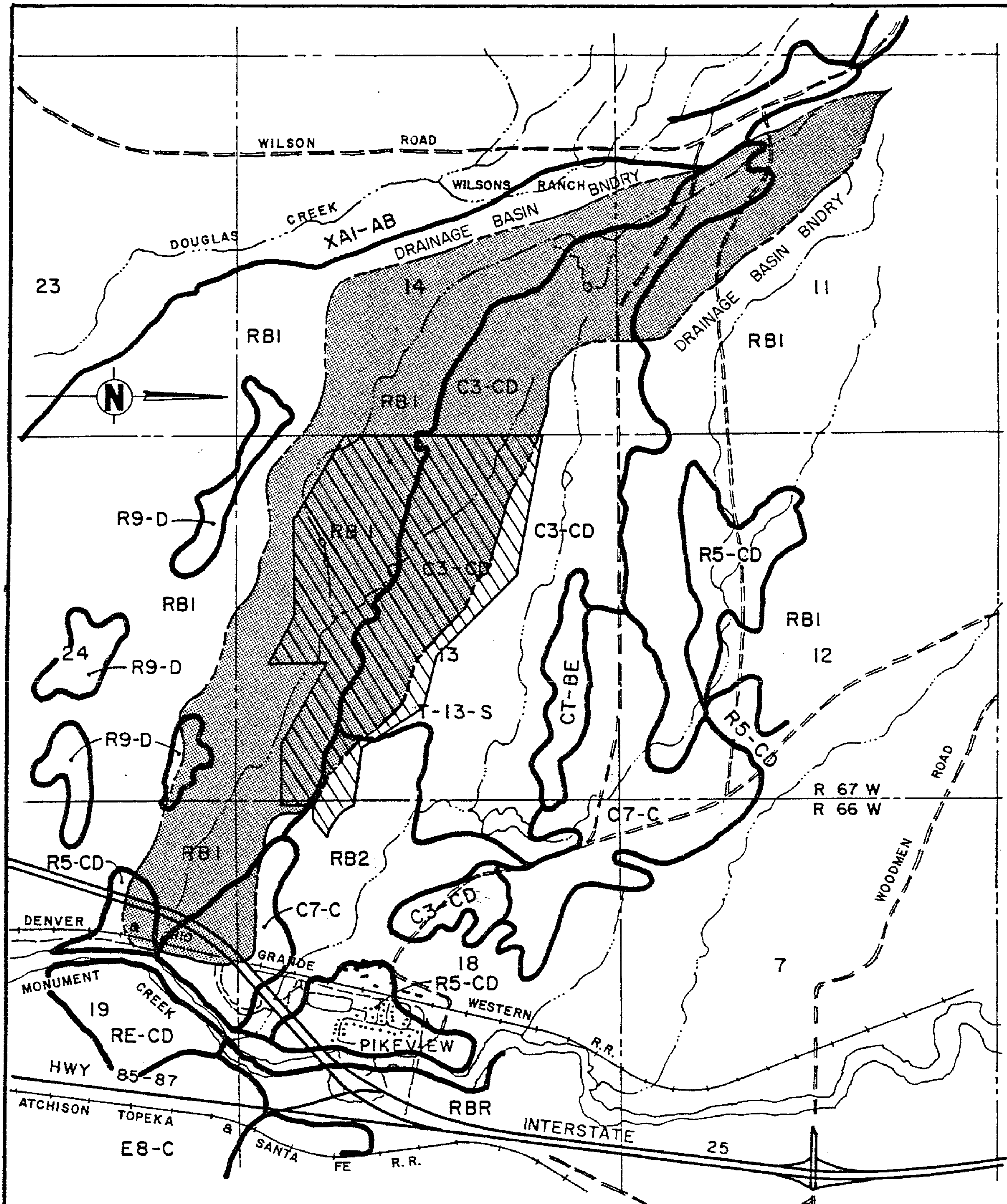


FIGURE 2
SOILS MAPPING

SCALE: 1" = 2000'

ROCKRIMMON SOUTH DRAINAGE BASIN

TABLE I- SOIL SUITABILITY RATINGS FOR SOIL MAPPING UNITS IN THE ROCKRIMMON SOUTH DRAINAGE BASIN (CONTINUED)

Mapping Unit	Series Present	Agriculture Non	Agriculture Irrig	Range	Playground	Campgrounds	Picnic Area
C3-CD	Razor	P	F	Good	S-12,2	S-12,2	S-12,2
C7-C	Cushman	P	F	Good	M-15,1	M-15	M-15
R5-CD	Truckton	F	G	Good	M-S-1	SL	SL
R9-D	Bresser	F	F	Good	S-1	SL	SL
RB1	Stoney Steep Land	P	P	Poor	S-1,2	S-1,2	S-1,2
RB2	Hilly Gr. & Samsil	P	P	Poor	S-1,2	S-1,2	S-1,2

INTERPRETIVE TABLE LEGEND

LIMITATION RATING

S = Severe
M = Moderate
SL = Slight
P = Poor
F = Fair
G = Good
U = Unsuited
VP = Very Poor

FACTOR CODE

1 = Slope
2 = Depth to Bedrock
3 = Flooding or Overflow
4 = Shrink-swell
5 = Seepage
6 = Permeability
7 = Stoniness
8 = Frost Action
9 = Piping
10 = Corrosivity
11 = Slow Percolation
12 = Texture (fine)

FACTOR CODE (CONT.)

13 = Compressibility
14 = Compaction
15 = Dust Problem
16 = Excess Humus
17 = Rapid Percolation
18 = Cut-bank Instability
19 = Drainage - Wetness
20 = Low strength
21 = Thin Soil
22 = Reclamation Hazard
23 = Severe Erosion
24 = Texture (Sandy)
25 = Water Table

TABLE I - SOIL SUITABILITY RATINGS FOR SOIL MAPPING UNITS IN THE ROCKRIMMON SOUTH DRAINAGE BASIN

Mapping Unit	Series Present	Percent Soil Composition	Percent Slope	Hydrologic Group	Erodibility	Septic Tank	Sewage Lagoon	Land Fill (Trench)	Land Fill (Area)	Daily Cover for Land Fill	Roadfill
C3-CD	Razor	85	3-9	D	4	S-2	S-2	S-2	S-2	S-12	P-4
C7-C	Cushman	85	3-5	B	5	M-11	M-17,1	SL	SL	G	M-20
R5-CD	Truckton	85	3-9	B	2	SL	S-17	SL	M-1	SL	G
R9-D	Bresser	85	5-9	B	2	M-1	M-1,17, 16	S-1	SL	G	G
RB1	Stoney Steep Land	85	15+	D	3	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2
RB2	Hilly Gr. & Samsil	85	15+	D	3	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2

Mapping Unit	Series Present	Gravel	Soil	Topsoil	Shallow Excavations	Dwellings Without Basements	Dwellings With Basements	Commercial Buildings	Local Roads and Streets	Ponds and Reservoirs	Embankments
C3-CD	Razor	U	U	P-12,21	S-2	S-4,2	S-4,2	S-4,2,1	S-4,2	S-4,2	S-4
C7-C	Cushman	U	U	G	SL	SL	SL	M-1	M-20	M-17,1	M-20
R5-CD	Truckton	U	P	G	SL	SL	SL	M-1	M-8,1	S-5,1	M-23
R9-D	Bresser	U	P	F-21	SL	SL	SL	M-1	SL	M-17,1	SL
RB1	Stoney Steep Land	U	U	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2	S-1,2
RB2	Hilly Gr. & Samsil	U	U	S-1,2	S-1,2,4	S-1,2	S-1,2,4	S-1,2	S-1,2	S-1,2	S-1,2

Mapping Unit C3:

Razor series consists of well drained light colored, clayey soils. The surface layer, 3 to 6 inches thick, is a clay loam. Subsoil is a clay, 12 to 24 inches in depth, where a calcarious shale occurs. This soil is of high plasticity, has a high shrink swell potential and falls within hydrologic group "D".

Mapping Unit C7:

Cushman series consists of well drained, loamy soils over interbedded sandstone and shale. The surface layer ranges from loam to clay loam and a sandy clay loam 4 to 10 inches thick. The subsoil consists of 15 to 30 inches of clay loam overlying a calcarious loam. Sandstone and shale occurs at a 20 to 40 inch depth. These soils have low plasticity and permeability and fall within hydrologic group "B".

Mapping Unit RB-1:

Stony steep land has slopes from six percent to vertical cliffs. The surface soil is loamy sand or sandy loam at a depth of from 10 to 30 inches over sandstone or shale, with 20 to 30 percent of the area in rock outcrop. This soil is within hydrologic group "D".

Mapping Unit RB-2:

Samsil soils are made up of gravelly, cobbly material over shale. The Samsil series consists of light colored, calcarious, clayey soils of high shrink swell capacity overlying shale at a depth of 20 inches or less. The gravelly, cobbly material is 30 to 70 percent coarse fragments overlying shale at depths of one to thirty feet. This soil is in hydrologic group "D".

Mapping Unit R5:

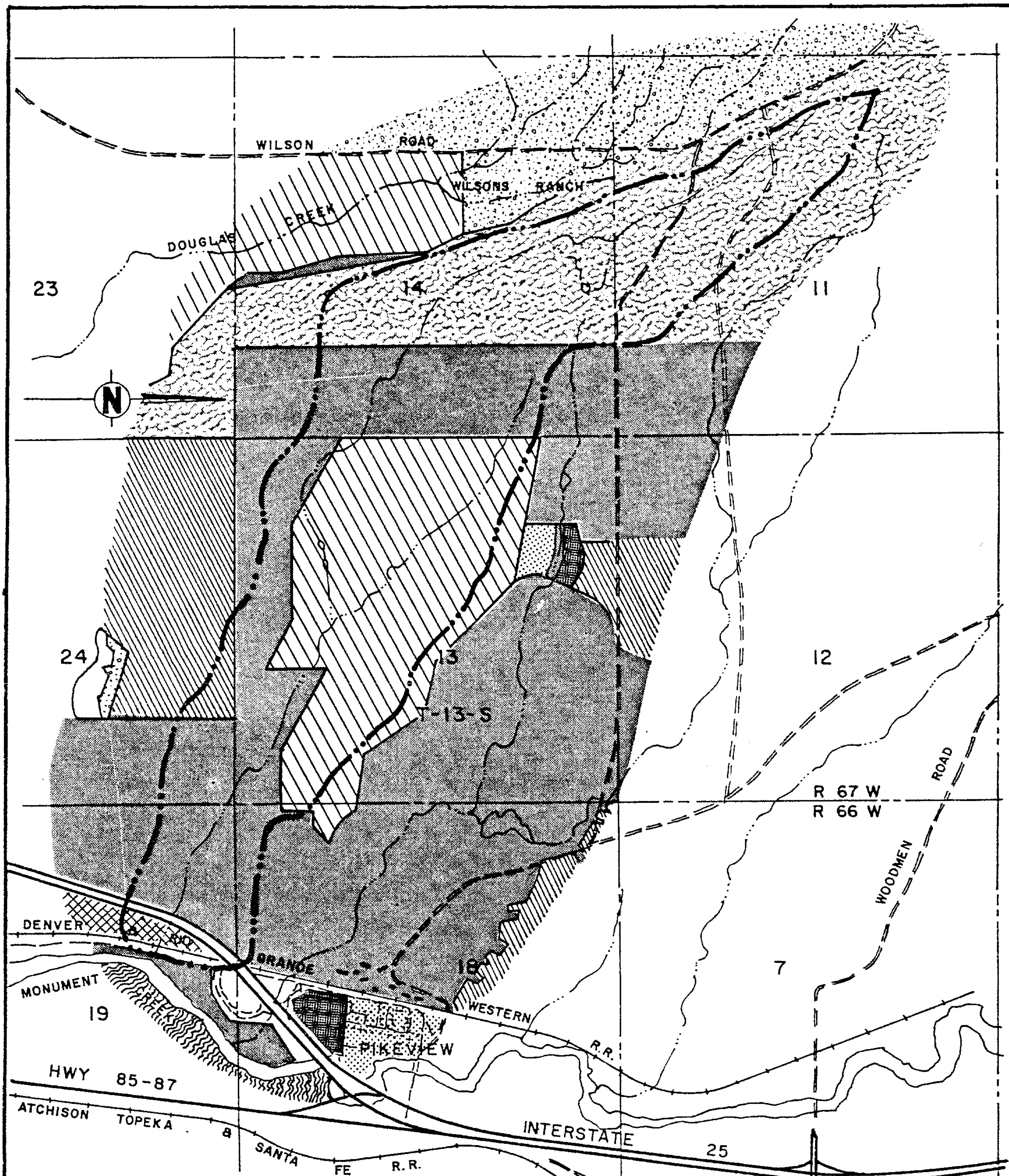
Truckton series consists of deep, dark soils which are sandy loam in texture throughout the profile. The surface layer is 5 to 8 inches thick, the subsoil is 10 to 26 inches thick and the light colored underlying soil usually extends to a depth of 60 inches or more. This soil is moderately permeable, has low plasticity and falls within hydrologic group "B".

Mapping Unit R9:

Bresser series is made up of sandy loam, sandy clay loam and clay loam surface layers. The Bresser soils are underlain by shale at 20 to 40 inches. The soil has a moderate permeability and is subject to gully and sheet erosion. The soil is in hydrologice group "B".

FUTURE BASIN DEVELOPMENT:

Existing zoning is shown on Figure 3. Until recently, the basin was zoned almost entirely for single family residential and garden homes. Only a small portion of the upper basin was zoned PIP-2 as part of the City's Industrial Park. However, approximately 281 Ac. has recently been zoned PIP-1. This area is located



LEGEND (Zoning)

- A........Agriculture
- A-1.....Garden Homes
- R-1.....Single Family Residential
- R-5....Multi-Family Residential
- PBC...Planned Business Park
- PIP....Planned Industrial Park
- M-1....Light Industrial
- DRAINAGE BASIN BOUNDARY
- R.... Single Family Residential

FIGURE 3
EXISTING ZONING MAP
ROCKRIMMON SOUTH
DRAINAGE BASIN
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approximately in the middle of the drainage basin. These changes in land use revises previous drainage basin studies extensively.

The current drainage study projects future development patterns based on information available from city agencies and existing development plans. The projected land use patterns are shown on Figure 4. Extensive amounts of park lands are shown immediately upstream of the PIP-1 zone. These lands are currently under consideration for purchase by the City for future park development. However, for the purpose of this study, runoff was determined assuming residential development in all proposed park areas where terrain would permit such construction.

RUNOFF PATTERNS:

The basin is drained by two well defined channels which have many minor contributing branches. Except after a storm, the entire stream beds are dry at least 90% of the time. The drainage basin is irregular in shape, having very narrow starting and outfall points, and being 0.6 miles in width at its widest point. Drainage of the terrain is generally southeasterly. Due to the steep rocky slopes, the water movement is exceptionally fast. Existing grasses, trees and brush help to control erosion. Some soil conservation work has been accomplished in these areas. Three detention dams exist on natural drainage channels for the purpose of controlling erosion. Terraces have also been used to provide additional erosion protection.

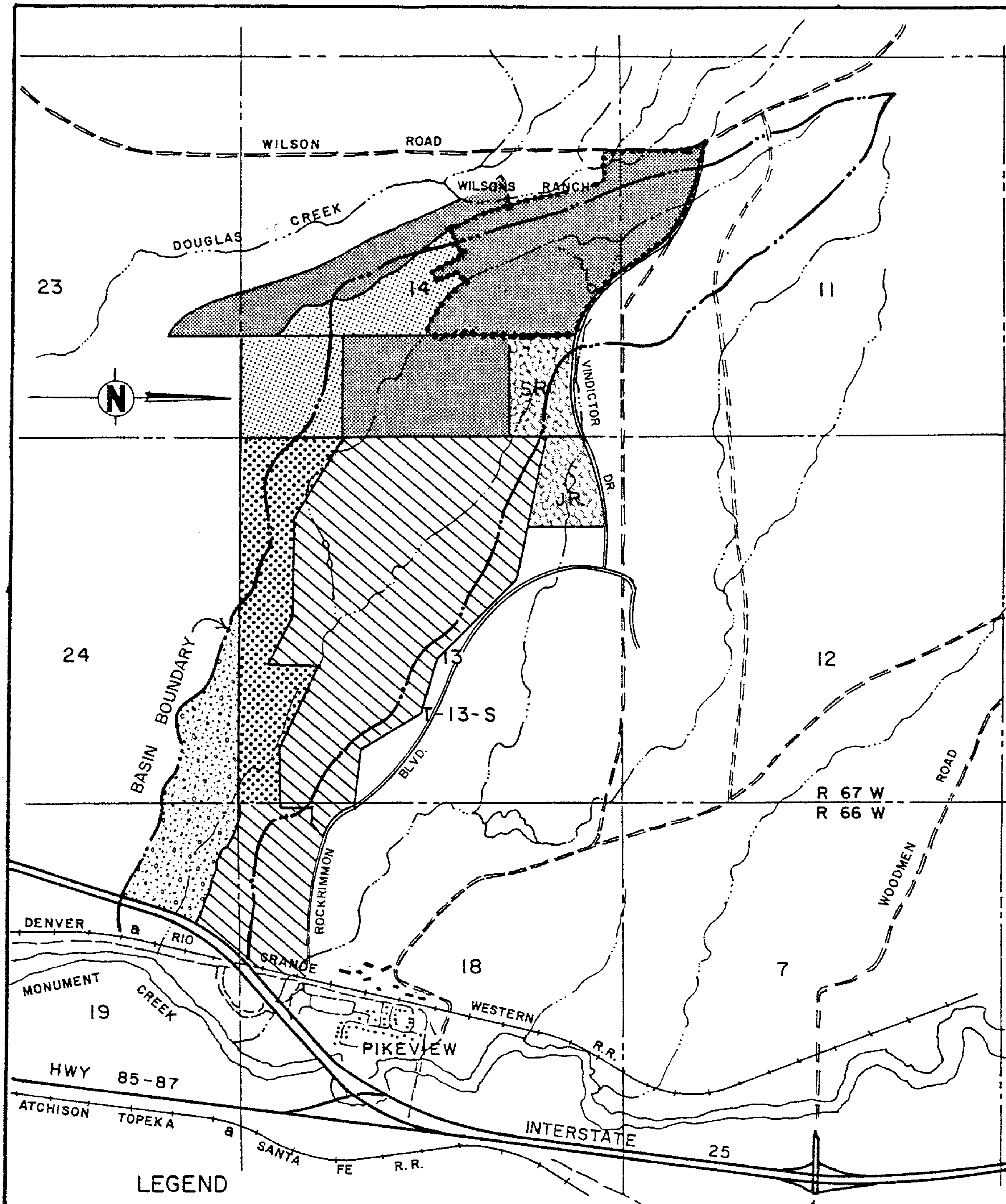
Presently the area is hilly grasslands, forests and rock outcroppings. Runoff peaks for this condition are lower than for the fully developed condition. Since there is no sure way to predict growth of the City of Colorado Springs, it is assumed that the entire basin would be developed according to proposed plans provided in this study. All the stormwater runoff developed in this report are based on the assumption that the entire area has been developed in accordance with Figure 3, "Future Development" and existing development plans. The criteria for design provides for adequate drainage structures that will be large enough to handle the stormwater runoff produced if the entire basin becomes developed as noted on the drawings. Detention and retention facilities are being proposed in the basin to keep future runoff equal to or less than that of existing conditions.

MAIN DRAINAGE CHANNELS:

The most economical method of removing flood runoff from a developed area is to improve and use existing ditches and drainage courses. Initial cost is lower and the ditches are easier to maintain and clean than are pipes or culverts.

Previous studies commissioned by the City of Colorado Springs have recommended a "Drainage Channel" drainage system in other areas. The Drainage Channel System consists of land reserved for drainage flow and for certain drainage structures.

This land should be maintained as a natural ditch and additional grass and riprap used where necessary on curved and other reaches to prevent excessive erosion. Development should be kept out of designated drainage easements and only minor modifications allowed to accomodate some planned phase of development. The natural terrain in the lower reaches of major drainage courses does not allow for development adjacent to the channel due to steepness and numerous rock outcroppings.



LEGEND

- Park (Assumed Res. for Hydrologic Calc.)
- Private Park
- Schools
- P. I. P., Planned Industrial Park
- R-2, 1-2 Family Residential
- Possible Residential Area
- A-1, Garden Homes

SCALE: 1" = 2000'

FIGURE 4
FUTURE DEVELOPMENT
ROCKRIMMON SOUTH
DRAINAGE BASIN

Some erosion control would be desired in the natural channels because channel erosion is basically a function of the specific weight of the fluid, slope of the channel and depth of flow. For seeding, the gully banks should have flat slopes approximating natural conditions and leaving a wide bottom area. Suitable grasses are blue grama, crested wheat, or side oats grama. The seeding should be accomplished in accordance with recommendations and specifications of the U.S. Soil Conservation Service.

Truck dumped riprap will undoubtedly control erosion better than seeding or sodding. Check dams, and drop structures will be used in specified stream reaches to reduce velocities to maintain control of erosion. Several existing retention dams in the basins will be used to provide some erosion control.

On the D.E.C. site,detention and retention reservoirs are planned to improve water quality, reduce peak flows and provide future recreational and natural areas. Flow through the dam is provided by a culvert and an emergency spillway designed to meet state criteria and convey runoff from a 100 year storm. The retention reservoir is intended to be used as water storage for fire protection. No additional retention is contemplated in any other areas.

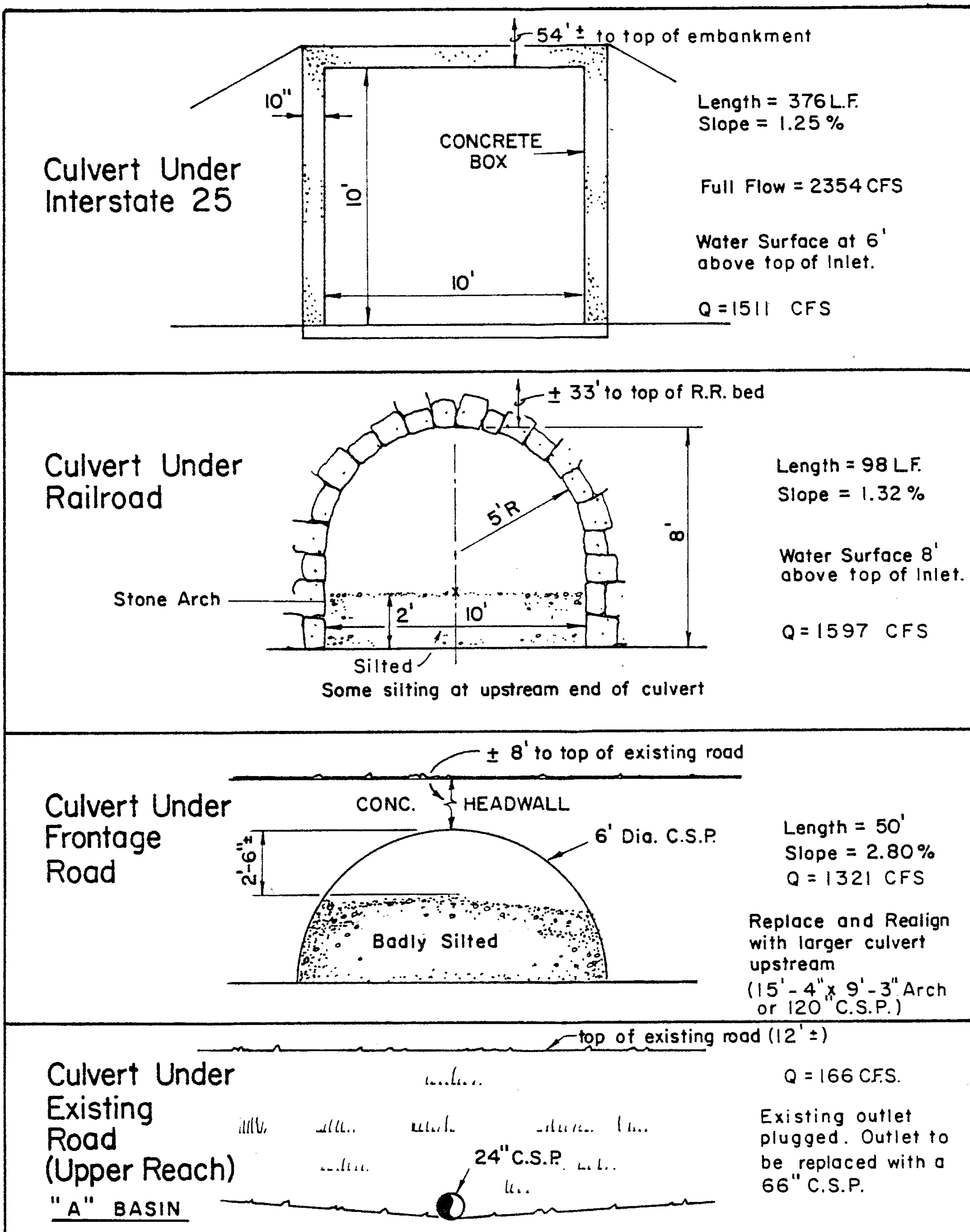
Existing capacities of box culverts under the railroad and Interstate 25 will limit future flow capacities from the Rockrimmon South Drainage Basin. Flow capacities of existing highway and railroad structures will require ponding to pass design flows for the 100 year storm. The existing structure under Cascade Avenue is badly silted and will require replacement with a larger structure designed to pass 100 year peak flows. See Figure 5 for existing structures within the basin.

DETENTION AND RETENTION RESERVOIRS:

Detention and retention reservoirs have been designed to be in compliance with applicable state laws governing erosion control dams. Both the application form and specifications governing construction have been included in the Appendix of this report.

In accordance with state law the detention and retention facilities will meet the following criteria:

1. Facilities will be constructed on watercourses and channels that are normally dry.
2. The embankment height will not exceed 15 feet from the bottom of the channel to the bottom of the spillway.
3. The storage capacity will not exceed 10 Ac-Ft. at the emergency spillway level.
4. Retention reservoirs will retain a maximum of 2 Ac-Ft. of permanent storage.
5. All detention and retention facilities will have an ungated outlet with a minimum diameter of 12" and capable of draining any impoundment in excess of 2 Ac-Ft. within 36 hours.
6. All embankments will be constructed in accordance with specifications provided by the state engineer for erosion control dams.



EXISTING CULVERTS
ROCKRIMMON SOUTH DRAINAGE BASIN
FIGURE 5

STUDY CRITERIA:

Design criteria utilizes recommended design frequencies for minor and major drainage channels. A 100 year return frequency will be used for all major green belt areas where flows in the watercourse exceed 500 cfs, and a 50 year return frequency will be used for the design of minor greenbelts and interior collection systems. Both the "1 hour" and "6 hour" storm durations were used and the most critical design storm used for drainage facility design.

Major and minor detention facilities will be designed in accordance with recommended design procedures of the State Engineer. A 100 year return frequency and a storm duration of 6 hours will be used to design all detention facilities.

METHODOLOGY:

A. Hydrology

Runoff quantities for the Rockrimmon South Drainage Basin have been determined using the Soil Conservation Service Method as described in the SCS Handbook, "Procedures for Determining Peak Flows in Colorado," incorporating "Urban Hydrology for Small Watersheds," Technical Release No. 55, July, 1975.

In the absence of measured data a synthetic hydrograph was adapted to the soil conditions of the Rockrimmon South Drainage Basin.

1. Precipitation-Frequency

Rainfall data was taken from the NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Vol. III - Colorado 1973. The following rainfall data was taken from annual series rainfall data developed for the Colorado Springs area (see Appendix):

1 hr storm - 100 year return frequency - 2.6"
1 hr storm - 50 year return frequency - 2.3"
6 hr storm - 100 year return frequency - 3.7"
6 hr storm - 50 year return frequency - 3.3"

Rainfall criteria for the City of Colorado Springs requires that 3" precipitation be used for a 1 hour storm with a 100 year return frequency.

2. Hydrological Soil Cover Complex

The SCS Method uses the hydrologic soil cover complex as determined by the weighted CN (Curve Number) to characterize the watershed. A soils map is used to classify the hydrologic soil group (Group A has a low runoff potential; Group B, moderate; Group C, slow infiltration; and Group D, high runoff potential). In the Rockrimmon South Drainage Basin, most of the basin is in the hydrologic soil group D. Some small areas are in the hydrologic soil group B. After determining the hydrologic soil group, a curve number is selected for the subarea based on the type of cover and land use characteristics. Then a composite weighted CN is developed for the drainage subarea. Table 2 is a list of the soils complex curve numbers (CN) for land uses that exist or are proposed in the Rockrimmon South Drainage Basin.

TABLE 2

SOIL COMPLEX CURVE NUMBERS

FOR

SELECTED LAND USE

LAND USE DESCRIPTION	HYDROLOGIC SOIL GROUP			
	A	B	C	D
Pasture or Range Land	62-72	71-81	78-88	81-91
Forest Land	25-45	55-66	70-77	77-83
Industrial District	81	88	91	93
Impervious Areas	98	98	98	98
Residential - 1/8 acre or less	77	85	90	92
- 1/4 acre	61	75	83	87
- 1/3 acre	57	72	81	86
- 1/2 acre	54	70	80	85
- 1 acre	51	68	79	84

3. Antecedent Moisture Condition

The antecedent moisture condition (AMC) is based on the precipitation occurring five days preceeding the hydrology study. An AMC II was used in this study. This condition is considered an average moisture condition.

4. Time of Concentration

"Time of Concentration" is the time it takes for runoff to travel from the hydraulically most distant part of the watershed to the point of reference. It is computed by determining the water travel time through the watershed in both overland flow and through drainage facilities. Nomographs from the Corps of Engineers and the SCS were used to determine overland flow time. To determine travel time in facilities, normal depth calculations based on Manning's equation or pipe charts were applied.

5. Runoff

The amount of rainfall that produces direct runoff is called "effective rainfall" and is the runoff entering the drainage facilities during a storm. The difference between rainfall and direct runoff accounts for losses and abstractions.

A combination of a hydrologic soil group (soil), land use, and treatment class (cover) is used to determine the hydrologic soil cover complex. The effect of the hydrologic soil cover complex on the amount of rainfall that runs off is represented by a runoff curve number, referred to as CN. The runoff in inches of rain for various CN's is derived from SCS curves.

6. Peak Discharge

In the Colorado Springs area that is east of the 8000 foot contour elevation, the SCS uses a Type IIA Storm. The Type IIA Storms are typical of the more intense storms that occur over the Colorado Springs area. Based on the Type IIA Storm typical for the Colorado Springs area, a curve relating time of concentration verses peak discharge in cubic feet per second of runoff per square mile per inch of direct runoff has been developed. The curves for 1 hour, 6 hour and 24 hour duration storm are plotted on Figure 6. These curves were developed from synthetic hydrographs using one inch direct runoff and a one square mile basin area.

7. Peak Flow Determination

The SCS Method applied in this study determines the peak flow at a reference point by the following procedure:

1. Determine drainage area (DA) to reference point
2. Determine weighted CN or hydrologic soil cover complex from land use, soil cover, impervious and pervious area information and antecedent moisture condition.
3. Determine direct runoff for the CN.
4. Determine time of concentration.
5. Determine peak discharge for Type IIA Storms of the desired duration.
6. Determine peak flow by multiplying DA x direct runoff x peak discharge.

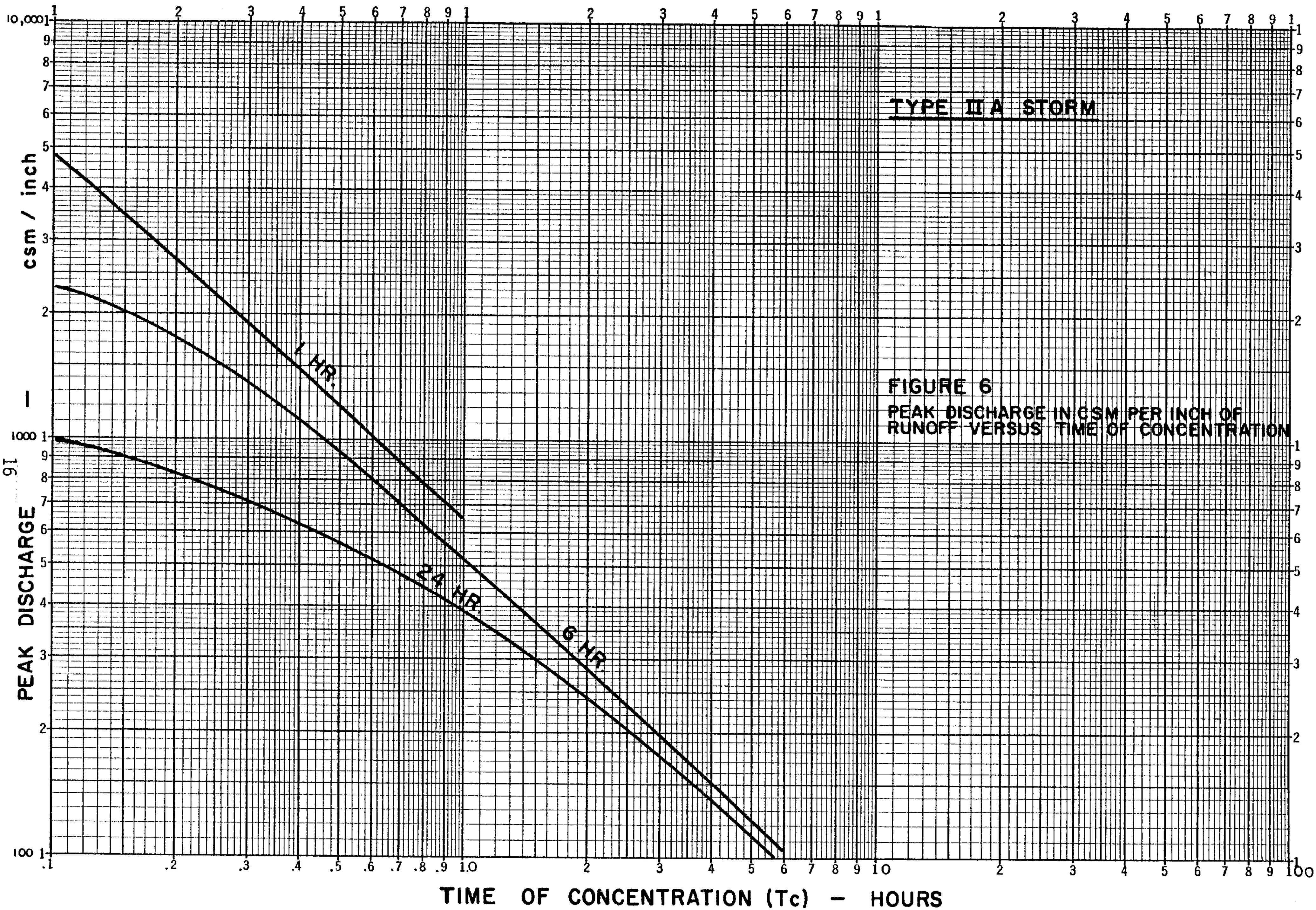


FIGURE 6
PEAK DISCHARGE IN CSM PER INCH OF RUNOFF VERSUS TIME OF CONCENTRATION

The peak flow determination procedure is used for both major and storm sewer hydrology. However, this procedure is limited to peak discharge determination where stream routing is not required.

8. Hydrograph Development

The hydrologic procedures used in developing the hydrographs for the greenbelt system that were used in this study are defined in the SCS National Engineering Handbook Section 4, Hydrology, Chapter 16, Hydrographs. A computer program was used to develop the hydrographs. This program is similar to the portion of the computer program that develops the hydrograph in SCS-TR-20 "Computer Program for Project Formulation -- Hydrology."

These hydrographs are all synthetic and some adjustments may be made when more accurate development conditions are known, and watersheds have been gauged to measure precipitation and subsequent runoff.

9. Stream and Reservoir Routing

The procedure used in routing the hydrographs through the Rockrimmon South Drainage Basin is described as follows:

1. Compute up to 60 ordinates of a hydrograph for the basins.
2. Compute the travel time of the peak flow in the stream reaches.
3. Add the ordinates of the respective time increments of the hydrograph to obtain the combined hydrographs.

This procedure obtains higher peak flows since it ignores the effect of storage in the channels. The computing effects of storage in the channel, which would reduce the peaks was not considered necessary because of the small flows in most of the channels and the costs associated with obtaining accurate channel measurements.

The inflow hydrograph of each reservoir was routed through the reservoir to obtain the outflow hydrograph. The reservoir routing method that was used is the mass curve method. In this reservoir routing method, the storage-discharge relation is used for repeatedly solving the continuity equation, each solution being a step in delineating the outflow hydrograph. The procedure is outlined in the SCS National Engineering Handbook, Section 4, Hydrology, Chapter 17, Flood Routing.

B. Hydrualics

1. Design of Open Channels

Mannings' equation was used to determine channel sections for the open channels in the Rockrimmon South Drainage Basin.

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

Where: Q = Discharge in CFS
n = Mannings roughness coefficient
A = Area of the hydraulic section in ft^2
R = Hydraulic radius, being the area of the hydraulic section divided by the wetted perimeter

S = Slope of the hydraulic gradient in ft/ft

Many trial and error solutions have been avoided by using tables, graphs, and computer programs to obtain solutions.

Also by Mannings' Formula:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

Where: V = Velocity in ft/sec

2. Storm Sewers

The most widely accepted formula for evaluating the hydraulic capacity of nonpressure sewers is the Manning Formula. After the design flows were calculated, pipe or culvert size was obtained by selecting a pipe roughness coefficient and using the natural slope of the land.

Mannings' Formula:

$$Q = VA = \frac{1.486}{n} AR^{2/3} S^{1/2} \text{ ir}$$

$$QS^{1/2} = \frac{1.486}{n} AR$$

Where: Q = Maximum discharge of conduit in CFS
A = Area of flow in conduit in square feet
V = Velocity of flow
n = Mannings' roughness coefficient for conduit lining
R = Hydrualic radius = area/wetted perimeter
S = Slope of conduit in ft/ft

By evaluating the values of $(1.486/n)\ AR^{2/3}$ for various types and shapes of pipes available, a pipe size can be selected for any $Q/S^{1/2}$ value. Under any given flow condition, the area A and hydraulic radius R are constant for a particular size and shape of pipe. Therefore, the hydraulic capacity of a pipe is primarily dependent on n, the roughness coefficient.

However, this trial and error method of calculating pipe sizes is not necessary, since nomographs, tables, graphs and computer programs provide a direct solution.

3. Roughness Coefficient

The following roughness coefficients were utilized.

Type of Structure	n
Natural streams	0.035 to 0.05
Ashphalt lined	.013
Concrete lined	.013
Rock lined	.035
Concrete conduit	.013
Corrugated metal conduits	.024

4. Freeboard Requirements

Freeboard requirements are generally a function of velocity. In high velocity concrete channels, where the velocity exceeds 20 fps, freeboard of 2.0 feet is recommended. In low velocity channels or grass-lined channels, where velocity is less than 20 fps, freeboard requirements are 1.0 foot.

5. Culverts

Culverts under roadways and reservoir dams are designed to flow under inlet control conditions. The maximum head permitted is limited by roadway fill, channel areas or development limits.

6. Spillway Capacity

Spillways are designed in accordance with the requirements of the State of Colorado, Division of Water Resources. Discharge capacities are computed by the formula.

$$Q = 3.3 \text{ L He}^{3/2}$$

Where: Q = Discharge in CFS
L = Length of weir
He= Depth of flow plus velocity head

7. Reservoir Staging

The water surface elevation of the reservoir is determined from stage-storage discharge curves that were used in the reservoir routing method.

CALCULATIONS:

1. Area

Areas used to calculate peak storm flow for the various sub-basins were planimetered from a 1" = 300' scale topographical map. Part of the map has 2 foot countour intervals and the other part has 10 foot contour intervals derived from the U.S.G.S. Colorado Springs Quadrangle. Elevation differences were excerpted directly or interpolated from the contours given on the topographic map to determine time of concentration for the sub-basins.

2. Composite Curve Number

Table 3 sets forth the composite runoff curve numbers that were determined to represent the hydrologic soil group, land use, and treatment class for each subbasin.

3. Peak Runoff Calculations

In order to determine the critical design storm, both the 1 hour storm and the 6 hour storm duration were used to determine runoff quantities. Table 4 shows the

TABLE 3
COMPOSITE RUNOFF CURVE NUMBERS
FOR
MINOR SUB-BASINS

Sub-Basin	Planning Condition	Land Use	Percentage of Sub-Basin	Hydrologic Soil Group	Type of Cover	CN	Composite CN
1A	Existing	Pasture	30	D	50% Pine	79	
		Pasture	70	D	Good Grass	82	81.1
	Future	Natural	30	D	50% Pine	79	
		Residential	70	D	1 Ac lots	84	82.5
2A	Existing	Pasture	40	D	20% Pine	85	
		Pasture	20	D	Good Grass	82	
		Pasture	40	D	10%Oak-Aspen	83	83.6
	Future	Natural	40	D	20% Pine	85	
		Residential	40	D	1/8 Ac lots	92	
		Residential	20	D	1 Ac lots	84	87.6
3A	Existing	Pasture	40	D	Fair Grass	86	
		Pasture	10	D	50% Pine	79	
		Pasture	50	D	50%Oak-Aspen	68	76.3
	Future	Residential	40	D	1/8 Ac lots	92	
		Residential	10	D	1 Ac lots	82	
		Residential	50	D	1 Ac lots	71	80.5
4A	Existing	Pasture	10	D	30%Oak-Aspen	72	
		Pasture	30	D	Fair Grass	84	
		Forest	60	D	60%Oak-Aspen	64	70.8
	Future	Natural	70	D	Existing	70.8	
		Residential	30	D	1 Ac lots	84	74.8
5A	Existing & Future	Forest	45	D	60% Pine	76	
		Pasture	10	D	Fair Grass	84	
		Forest	45	D	60%Oak-Aspen	64	71.4
6A	Existing	Forest	30	D	30% Pine	81	
		Forest	60	B&D	40% Pine	79	
		Pasture	10	D	Fair Grass	84	80.1
	Future	Natural	30	D	30% Pine	81	
		Natural	45	D	40% Pine	79	
		Residential	15	B&D	1/4 Ac lots	87	
		Residential	10	B&D	1 Ac lots	84	81.3
7A	Existing	Pasture	10	B&D	Poor Grass	89	
		Forest	90	D	60% Pine	76	77.3
	Future	PIP	10	D	72%Impervious	93	
		Natural	80	D	60% Pine	76	
		Residential	10	B	1 Ac lots	84	78.5
8A	Existing	Pasture	100	B&D	Poor Grass	89	89
	Future	PIP	100	B&D	72%Impervious	93	93
9A	Existing & Future	Freeway & Open Space	100	B	10%Impervious	78	78
10A	Existing & Future	Roadway & Open Space	100	B	Dirt	75	75

TABLE 3 (CONTINUED)
COMPOSITE RUNOFF CURVE NUMBERS
FOR
MINOR SUB-BASINS

Sub-Basin	Planning Condition	Land Use	Percentage of Sub-Basin	Hydrologic Soil Group	Type of Cover	CN	Composite CN
1B	Future	School	100	D	30% Impervious	90	
		Residential	10	D	1/8 Ac lots	92	
		Natural	50	D	Fair/Poor Grass	86	88.2
2B	Future	Natural	96	D	Fair Grass	84	
		Bldg.&Parking	4	D	Impervious	98	84.5
3B	Future	Pasture	100	D		81	81
4B	Future	Bldg.&Parking	100	D	50% Impervious	90.5	90.5
5B	Future	Bldg., Open Space, Streets	100	D	30% Impervious	88	88
6B	Future	Parking lot	100	D	50% Impervious	90.5	90.5
7B	Future	Open Space	100	D	5% Impervious	84.5	84.5
8B	Future	Bldg., Parking Open Space	100	D	35% Impervious	89	89
B West	Existing	Pasture&Forest	100	D	Fair/Poor Grass		83.6
B East	Existing	Pasture&Forest	100	D	Fair/Poor Grass		84

TABLE 4
SCS HYDROLOGY CALCULATION
100 YEAR - 6 HOUR STORM
PEAK RUNOFF

BASIN	DRAINAGE AREA (Ac)	TIME OF CONCENTRATION (Hr)	"qp" (cms/in)	CURVE NUMBER "CN"	DIRECT RUNOFF (in)	PEAK RUNOFF (cfs)	REMARKS
1A	51.4	.34	1250	81.1	1.88	189	Existing
1A	51.4	.34	1250	82.5	1.99	200	Future
2A	36.8	.28	1420	83.6	2.08	170	Existing
2A	36.8	.26	1500	87.6	2.42	209	Future
3A	139.8	.67	720	76.3	1.53	241	Existing
3A	139.8	.62	780	80.5	1.84	314	Future
4A	76.4	.42	1070	70.8	1.18	151	Existing
4A	76.4	.42	1070	74.8	1.43	183	Future
5A	81.8	.48	960	71.4	1.21	148	Existing&Future
6A	107.5	.50	930	80.1	1.81	283	Existing
6A	107.5	.50	930	81.3	1.89	295	Future
7A	68.6	.41	1080	77.3	1.60	185	Existing
7A	68.6	.41	1080	78.5	1.69	196	Future
8A	42.1	.38	1170	89	2.54	195	Exsiting
8A	42.1	.40	1100	93	2.93	212	Future
9A	14.6	.14	2080	78	1.65	78	Existing&Future
10A	5.4	.11	2250	75	1.45	28	Existing&Future
1B	85.8	.54	870	88.2	2.47	288	Future
2B	31.4	.38	1160	84.5	2.15	122	Future
3B	26.2	.36	1200	81.0	1.87	92	Future
4B	23.9	.24	1580	90.5	2.69	159	Future
5B	8.6	.24	1580	88.0	2.45	52	Future
6B	8.8	.20	1750	90.5	2.69	65	Future
7B	3.0	.06	2300	84.5	2.15	23	Future
8B	44.1	.31	1380	89	2.54	242	Future
B West	203.5	.56	840	83.6	2.08	556	Existing
B East	28.5	.17	1900	84	2.11	179	Existing

peak runoff for each minor sub-basin that is produced from a 6 hour storm with a 100 year return frequency having a total rainfall of 3.7 inches, and Table 5 shows the peak runoff that is produced from a 1 hour storm with a return frequency of 100 years having a total rainfall of 3.0 inches.

From Tables 4 and 5, it can be seen that the 1 hour storm produces a higher peak runoff when the time of concentration is less than 0.3 hours. When the flows under existing conditions were routed to the confluence of Monument Creek, the 1 hour storm produced a peak flow of 1397 cfs while the 6 hour storm produced a peak of 1760 cfs. Being the higher of the two, the 6 hour storm was used for hydraulic calculations. The need to use the 6 hour storm for hydraulic calculation is further emphasized because the 6 hour storm will produce a larger volume of water which will have particular importance in the calculation of reservoirs.

The peak runoff calculations for portions of the minor sub-basins where drainage facilities are proposed are shown in Tables 6 and 7. The 50 year storm return frequency for the 1 hour storm is shown in Table 6 and the 6 hour storm is shown in Table 7. Comparing the results of these tables indicate that the 1 hour storm will produce higher runoff when the time of concentration is less than 0.25 hours. Since most of the basins have a time of concentration that is greater than 0.25 hours, the 6 hour storm was used for hydraulic calculations.

4. Hydrographs

Hydrographs have been prepared under the proposed development conditions for each of the sub-basins. In addition, inflow-outflow hydrographs for the reservoirs have been prepared. They hydrographs are included in the Appendix. The reference points of the hydrographs are at the lowest point in the minor sub-basin. Table 8 summarizes the 100 year flood for major greenbelts routing and Table 9 summarizes the 50 year flood routing for the minor greenbelts.

TABLE 5
SCS HYDROLOGY CALCULATION
100 YEAR - 1 HOUR STORM
PEAK RUNOFF

BASIN	DRAINAGE AREA (Ac.)	TIME OF CONCENTRATION (Hr.)	"qp" (cms/in)	CURVE NUMBER "CN"	DIRECT RUNOFF (in.)	PEAK RUNOFF (cfs)	REMARKS
1A	51.4	.34	1700	81.1	1.33	182	Existing
1A	51.4	.34	1700	82.5	1.42	194	Future
2A	36.8	.28	2000	83.6	1.49	171	Existing
2A	36.8	.26	2130	87.6	1.79	217	Future
3A	139.8	.67	920	76.3	1.03	207	Existing
3A	139.8	.62	980	80.5	1.29	276	Future
4A	76.4	.42	1400	70.8	.75	109	Existing
4A	76.4	.42	1400	74.8	.95	138	Future
5A	81.8	.48	1240	71.4	.78	124	Existing&Future
6A	107.5	.50	1200	80.1	1.26	254	Existing
6A	107.5	.50	1200	81.3	1.34	270	Future
7A	68.6	.41	1440	77.3	1.09	168	Existing
7A	68.6	.41	1440	78.5	1.16	179	Future
8A	42.1	.38	1530	89	1.90	191	Existing
8A	42.1	.40	1480	93	2.25	510	Future
9A	14.6	.14	3650	78	1.13	94	Existing&Future
10A	5.4	.11	4220	75	.96	34	Existing&Future
1B	85.8	.54	1110	88.2	1.84	274	Future
2B	31.4	.38	1520	84.5	1.56	116	Future
3B	26.2	.36	1610	81.	1.32	87	Future
4B	23.9	.24	2300	90.5	2.03	174	Future
5B	8.6	.24	2300	88.0	1.82	56	Future
6B	8.8	.20	2680	90.5	2.03	75	Future
7B	3.0	.06	4800	84.5	1.56	35	Future
8B	44.1	.31	1860	89	1.90	244	Future
B West	203.5	.56	1080	83.6	1.49	512	Existing
B East	28.5	.17	3100	84	1.52	210	Existing

TABLE 6
SCS HYDROLOGY CALCULATIONS
50 YEAR - 1 HOUR STORM
FUTURE PEAK RUNOFF

BASIN	DRAINAGE AREA (Ac)	TIME OF CONCENTRATION (hr)	"qp" (cms/in)	CURVE NUMBER "CN"	DIRECT RUNOFF (in)	"qp" PEAK RUNOFF (cfs)
1A	51.4	.34	1700	82.5	0.88	120
1Aa	24.4	.24	2300	82.5	0.88	77
2A	36.8	.26	2130	87.6	1.19	146
2Aa	8.6	.22	2480	87.6	1.19	40
3A	139.8	.62	980	80.5	0.78	167
3Aa	19.8	.28	2000	92	1.51	93
4A	76.4	.42	1400	74.8	0.53	89
6Aa	2.3	.17	3100	84.5	1.00	11
6Ab	1.0	.16	3280	85	1.02	5
6Ac	1.8	.18	2950	84.5	1.00	8
6Ad	1.2	.16	3280	85	1.02	6
8A	42.1	.40	1480	93	1.59	155
8Aa	10.3	.30	1900	93	1.59	49
8Ab	6.1	.30	1900	93	1.59	29
8Ac	7.6	.34	1700	93	1.59	32
8Ad	17.5	.33	1740	93	1.59	76
8Ae	0.6	.10	4800	93	1.59	7
9A	14.6	.14	3650	78	0.66	55
9Aa	3.6	.10	4800	78	0.66	18
1B	85.8	.61	1000	88.2	1.22	164
1Ba	3.9	.28	2000	92	1.51	18
1Bb	16.3	.28	2000	92	1.51	77
1Bc	35.1	.38	1520	88	1.21	101
2B	31.4	.38	1520	84.5	1.00	75
2Ba	6.1	.25	2200	84	0.97	20
3B	26.2	.36	1610	81	0.80	53
4B	23.9	.24	2300	90.5	1.39	119
4Ba	11.3	.20	2680	85.5	1.05	50
4Bb	5.9	.19	2800	98	2.07	53
4Bc	2.7	.14	3650	95	1.77	27
4Bd	4.0	.16	3280	94	1.68	34
5B	8.6	.24	2300	88	1.21	37
6B	8.8	.20	2680	90.5	1.39	51
7B	3.0	.06	4800	84.5	1.00	23
8B	44.1	.31	1860	89	1.28	164
8Ba	8.2	.20	2680	86	1.08	37
8Bb	5.9	.19	2800	98	2.07	53
8Bc	1.3	.14	3650	88	1.21	9
8Bd	3.4	.16	3280	94.5	1.73	30
8Be	1.9	.15	3450	96	1.87	19
8Bf	4.9	.16	3280	93	1.59	40
8Bg	1.7	.25	2200	86	1.08	6
8Bh	3.1	.19	2800	92	1.51	20

TABLE 6 (CONTINUED)
SCS HYDROLOGY CALCULATIONS
50 YEAR - 1 HOUR STORM
FUTURE PEAK RUNOFF

BASIN	DRAINAGE AREA (Ac)	TIME OF CONCENTRATION (hr)	"qp" (cms/in)	CURVE NUMBER "CN"	DIRECT RUNOFF (in)	"qp" PEAK RUNOFF (cfs)
8Bi	4.8	.18	2950	85	1.02	23
8Bj	0.8	.14	3650	91	1.43	5
8Bk	8.1	.28	2000	85	1.02	26
B West*	203.5	.56	1080	83.6	0.95	326
B East*	28.5	.17	3100	84	0.97	134

* Natural Condition - Peak Flow

TABLE 7
SCS HYDROLOGY CALCULATIONS
50 YEAR - 6 HOUR STORM
FUTURE PEAK RUNOFF

BASIN	DRAINAGE AREA (Ac)	TIME OF CONCENTRATION (hr)	"qp" (cms/in)	CURVE NUMBER "CN"	DIRECT RUNOFF (in)	"qp" PEAK RUNOFF (cfs)
1A	51.4	.34	1250	82.5	1.65	166
1Aa	24.4	.24	1580	82.5	1.65	99
2A	36.8	.26	1500	87.6	2.06	178
2Aa	8.6	.22	1660	87.6	2.06	46
3A	139.8	.62	780	80.5	1.52	259
3Aa	19.8	.28	1420	92	2.45	108
4A	76.4	.42	1070	74.8	1.15	147
6Aa	2.3	.17	1900	84.5	1.81	12
6Ab	1.0	.16	1960	85	1.85	6
6Ac	1.8	.18	1850	84.5	1.81	9
6Ad	1.2	.16	1960	85	1.85	7
8A	42.1	.40	1100	93	2.54	184
8Aa	10.3	.30	1380	93	2.54	56
8Ab	6.1	.30	1380	93	2.54	33
8Ac	7.6	.34	1250	93	2.54	38
8Ad	17.5	.33	1280	93	2.54	89
8Ae	0.6	.10	2300	93	2.54	6
9A	14.6	.14	2080	78	1.35	64
9Aa	3.6	.10	2300	78	1.35	17
1B	85.8	.61	790	88.2	2.11	223
1Ba	3.9	.28	1420	92	2.45	21
1Bb	16.3	.28	1420	92	2.45	89
1Bc	35.1	.38	1160	88	2.10	134
2B	31.4	.38	1160	84.5	1.81	103
2Ba	6.1	.25	1550	84.0	1.77	26
3B	26.2	.36	1200	81.0	1.55	76
4B	23.9	.24	1580	90.5	2.30	147
4Ba	11.3	.20	1750	85.5	1.88	58
4Bb	5.9	.19	1800	98	3.07	51
4Bc	2.7	.14	2080	95.0	2.74	24
4Bd	4.0	.16	1960	94.0	2.64	32
5B	8.6	.24	1580	88.0	2.09	44
6B	8.8	.20	1750	90.5	2.31	56
7B	3.0	.06	2300	84.5	1.81	20
8B	44.1	.31	1360	89.0	2.17	206
Ba	8.2	.20	1750	86	1.92	43
8Bb	5.9	.19	1800	98	3.07	51
8Bc	1.3	.14	2080	88	2.09	9
8Bd	3.4	.16	1960	94.5	2.69	28

TABLE 7 (CONTINUED)
SCS HYDROLOGY CALCULATIONS
50 YEAR - 6 HOUR STORM
FUTURE PEAK RUNOFF

BASIN	DRAINAGE AREA (Ac)	TIME OF CONCENTRATION (hr)	"qp" (cms/in)	CURVE NUMBER "CN"	DIRECT RUNOFF (in)	"qp" PEAK RUNOFF (cfs)
8Be	1.9	.15	2020	96	2.85	17
8Bf	4.9	.16	1960	93	2.54	38
8Bg	1.7	.25	1530	86	1.92	8
8Bh	3.1	.19	1800	92	2.45	21
8Bi	4.8	.18	1850	85	1.85	26
8Bj	0.8	.14	2080	91	2.35	6
8Bk	8.1	.28	1380	85	1.85	32
B West*	203.5	.56	840	83.6	1.74	465
B East*	28.5	.17	1900	84	1.77	150

*Natural Condition - Peak Flow

TABLE 8
SUMMARY OF PEAK RUNOFF
FOR
100 YEAR STORMS

Hydro-graph Point	6 Hour Storm		1 Hour Storm	
	Existing	Future	Existing	Future
1A	189/38.5	200	182/38	194
2A	192	357	187	310
3A	433	628/520	455	560/494
4A	532	611	530	454
5A	604	680	592	516
6AB West	1231	1035	974	828
6AB East	1264	1131	988	976
6A	1499	1379	1161	1228
7A	1618/1551	1511/1448	1224/1173	1357/1300
8A	114	212	106	215
9A	1701/1406	1597/1320	1293/1151	1434/1185
10A	1407	1321	1152	1186
1B		188/214		274/198
2B		259		236
3B		339		288
4B		456/450		415/406
5B		475/465		440
7B		467		442
6B		492		460
8B		242/190		244/185

Note: 189/38.5 = Inflow/Outflow

TABLE 9
SUMMARY OF PEAK RUNOFF
FOR
50 YEAR STORM

Hydrograph Point	6 Hour Future Storm
1A	166
2A	327
3A	565
1B	223/166
2B	222
3B	290
4B	390/380
5B	415/405
7B	406
6B	451
8B	206/158

Note: 223/166 = Inflow/Outflow

COST ANALYSIS

The following cost analysis relates total drainage facility development for the basin. Costs have been delineated for the north and south drainages. Costs allocated to Digital Equipment Corporation (DEC) have been noted for all drainage facilities within their property. Density of future development is highest for the PIP zoning designated for the DEC site. Runoff has been limited to that under existing conditions and thus the higher cost for drainage facilities on the DEC site.

COST SUMMARY

A BASIN:	DEC	-	$ 49,030
	OTHER	-	297,200
	TOTAL	-	$346,230
B BASIN:	DEC	-	$196,700
	OTHER	-	32,480
	TOTAL	-	$229,180
TOTAL COMBINED COST:	A Basin	-	$346,230
	B Basin	-	229,180
	TOTAL	-	$575,410
	Engineering @ 10%	-	57,540
	Contingencies @ 15%		86,310
	Total Rockrimmon South Basin Cost	-	$719,260

DRAINAGE FEE (856 ACRE):	$840/ACRE
TOTAL D.E.C. SITE COST:	$307,160
TOTAL OTHER SITES COST:	$412,100

TABLE 10

COST BREAKDOWN - "A" BASIN (SOUTH DRAINAGE)

BASIN	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1A	66" CSP	100	LF	$ 105.00	$10,500.00
1A	Curb outlet	1	LS	400.00	400.00
1A	2-Catch basins	24	LF	125.00	3000.00
1A	30" CSP	650	LF	34.00	22,100.00
1A	Trapazoidal channel (riprap)	750	LF	27.00	20,250.00
2A	84" CSP culvert	120	LF	130.00	15,600.00
2A	Curb outlet	1	LS	400.00	400.00
2A	Inlet and outlet structures	1	LS	2000.00	2000.00
2A	2-Catch basins	24	LF	125.00	3000.00
2A	36"Ø CSP storm sewer	650	LF	42.00	27,300.00
2A	Trapazoidal channel (riprap)	1100	LF	33.00	36,300.00
3A	4-Catch basins	48	LF	125.00	6000.00
3A	24"Ø storm sewer	350	LF	28.00	9800.00
3A	30"Ø storm sewer	350	LF	34.00	11,900.00
3A	36"Ø storm sewer	350	LF	42.00	14,700.00
3A	42"Ø storm sewer	75	LF	48.00	3600.00
3A	Ripraped-lined swale	35	CY	20.00	700.00
3A	Concrete curb opening	30	SF	2.00	60.00
3A	Riprap drop structures	17	EA	400.00	6800.00
3A	84"Ø CSP culvert	140	LF	130.00	18,200.00
3A	Inlet and outlet structures (energy dissipator)	1	LS	3000.00	3000.00
5A*	Improve spillway and embankments of existing erosion control	1	LS	6000.00	6000.00
5A*	Channelization & Stabilization	456	LF	15.00	6750.00
6A*	7-Drop structures(dumped riprap)	320	CY	27.00	8640.00
6A*	Channel inlet control (dumped riprap)	250	CY	20.00	5000.00
6A*	Embankment protection (dumped riprap)	1320	SY	9.00	11,880.00
6A*	18" CSP	124	LF	1800.00	2230.00
6A*	2-Catch basins	16	LF	125.00	2000.00
6A*	18" CSP	100	LF	18.00	1800.00
6A*	Riprap 2 locations	6	CY	20.00	120.00
6A*	2-Catch basins	12	LF	125.00	1500.00
8A	60"Ø CSP culvert	110	LF	90.00	9900.00
8A	Inlet and outlet structures	1	LS	3500.00	3500.00
8A	Trapazoidal channel (riprap)	1000	LF	20.00	20,000.00
8A	36" CSP	50	LF	42.00	2100.00
8A	42" CSP	50	LF	48.00	2400.00
8A	2-Curb outlets	2	EA	400.00	800.00
8A	2-Catch basins	40	LF	125.00	5000.00
9A	Concrete channel	75	CY	200.00	15,000.00
9A	Riprap energy dissipator	55	CY	27.00	1500.00
9A	Riprap drop structure	37	CY	27.00	1000.00
9A	Riprap embankment protection	200	SY	9.00	1800.00
10A	120" CSP Culvert (15'-4"x9'-3"Arch)	60	LF	210.00	12,600.00
10A	Inlet and outlet protection	1	LS	4000.00	4000.00
10A	Utility relocation	1	LS	5000.00	5000.00
			TOTAL		$346,230.00

*ITEMS ON D.E.C. SITE ($49,030.00)
ITEMS ON OTHER SITES ($297,200.00)

TABLE 11

COST BREAKDOWN - "B" BASIN (NORTH DRAINAGE)

BASIN	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1B*	Catch basin	38	LF	$ 125.00	$ 4750.00
1B*	30"Ø CSP	100	LF	34.00	4080.00
1B*	Curb outlet	1	LS	400.00	400.00
1B*	Gabion drop structures	15	EA	550.00	8250.00
1B*	Grass channel	1500'	LF	10.00	15,000.00
1B	Gabion drop structures	1	EA	550.00	2200.00
1B	Grass channel	400'	LF	15.00	6000.00
1B	3-30"Ø CSP Culvert	480	LF	34.00	16,320.00
1B	Inlet and outlet structures	1	LS	2500.00	2500.00
2B	24"Ø CSP Culvert	80	LF	28.00	2240.00
2B	Inlet and outlet structures	1	LS	1500.00	1500.00
2B&3B	84"Ø CSP Culvert	100	LF	130.00	13,000.00
2B&3B	Inlet and outlet structures	1	LS	2000.00	2000.00
4B	30" RCP	280	LF	24.00	6720.00
4B	Batch basins	34	LF	125.00	4250.00
4B	36" RCP	320	LF	34.00	10,880.00
4B	Reservoir (detention)	1	LS	12,500.00	12,500.00
5B	Reservoir (retention)	1	LS	13,000.00	13,000.00
6B	Check structures	1	LS	700.00	700.00
7B	84"Ø CSP	100	LF	130.00	13,000.00
7B	Inlet and outlet structures	1	LS	3000.00	3000.00
7B	3-Drop structures	144	CY	27.00	3890.00
8B	36"Ø RCP	280	LF	34.00	9520.00
8B	42"Ø RCP	848	LF	44.00	37,300.00
8B	Catch basins	84	LF	125.00	10,500.00
8B	24"Ø CSP	350	LF	24.00	8400.00
8B	Energy dissipator	1	LS	3600.00	3600.00
8B	Reservoir (detention)	1	LS	11,400.00	11,400.00
8B	Outlet structures	10	CY	27.00	270.00
			TOTAL		$229,180.00

*ITEMS ON OTHER SITES ($32,480.00)
ITEMS ON D.E.C. SITE ($196,700.00)

Conclusions

This study was conducted on the Rockrimmon South Drainage Basin to update and revise the previous study of March 1967, by Karcich & Weber, Inc. The current study was prepared using the SCS Method as outlined in "Technical Release 55" and "Procedures for Determining Peak Flows in Colorado". Both the 6 hour and the 1 hour storm durations were used in runoff determination with the most critical storm used for facility design.

The Rockrimmon South Basin contains 856 acres all lying within the city limits of Colorado Springs. The drainage facilities proposed within this report have a current estimated cost of $719,260.00. The new assessment for drainage fees would be $840/acre. This new fee would result in a reduction of $1441/acre from the existing basin drainage fee of $984/acre.

New detention and retention dams have been recommended only within property designated for development by Digital Equipment Corporation. At their request operation and maintenance of these facilities will be the responsibility of Digital Equipment Corporation and the City of Colorado Springs would have no responsibility for maintenance within D.E.C. property.

All detention facilities are designed to accomodate future development with outflows equal to or less than those flows generated in the present natural state. If the proposed development of the DEC site varies from that shown on the master plan, the size of the detention facility can be varied to meet these furture conditions provided the design complies with existing state regulations for erosion control and flood control structures.

Existing topography severely limits the development potential of land adjacent to the primary drainage channels. It is recommended that the major portion of these channels be left in their natural state. The unlined channel will continue to experience some erosion but the cost of fully lining such channels would be prohibitive both from the standpoint of economics and practical development. Construction efforts should be geared to maintain the natural beauty of rock outcroppings and vegetation of the meandering stream channel. Those areas accessible to construction equipment and subject to heavy erosion should be protected with heavy rock riprap. Annual maintenance checks should be made to verify the adequacy of existing measures and additional riprap used where necessary.

Existing and proposed road crossings have been indicated on the master drainage plan. Culverts have been designed to carry design storms under inlet control. In some cases, embankment fills have been considered to act as small detention facilities ponding waters as headwater depths increase to allow passage of flood peaks. Road fills will not be overtopped by design flows and significant peak flow reductions can be achieved in utilizing natural ponding areas upstream of road crossings.

Storm drainage networks have been considered only when runoff flows exceed street capacities indicated by the City of Colorado Springs drainage criteria. Catch basins have been developed under sump conditions to accept storm flows into the drainage systems. Both CSP and RCP have been considered in system layout and design. Pipe costs for CSP have assumed coated pipe for anticipated corrosive conditions.

General Recommendations

1. Erosion control plans should be developed in conjunction with drainage plans and as a prerequisite for all development within the basin.

2. Flood control and erosion control measures should be initiated to check gully erosion and stabilize stream channels where indicated on attached drainage maps.

3. Future runoff flows to be kept at or below runoff generated from existing conditions by slowing runoff and reducing peak flows.

4. Erosion control and channel maintenance be employed on an as needed basis.

5. Reservoirs be maintained on a regular basis to provided for sediment removal.

6. Recommended facilities be installed in accordance with the master plan for the basins. Variations from the plan must be approved by the City of Colorado Springs, Dept. of Public Works, and when necessary the Drainage Board.

7. Encroachment within the flood plain is not to be permitted and all drainage easements preserved and retained with width as noted.

REFERENCES:

1. City of Colorado Springs:

   a. Existing Ordinances, rules, regulations and criteria.

   b. Hydrologic Engineering Study of Rockrimmon North Drainage Basin, United Western Engineers, March, 1973.

   c. Hydrologic Engineering Study of the Rockrimmon North and Rockrimmon South Drainage Basins, Karcich & Weber, Inc., March, 1967.

2. USDA - Soil Conservation Service:

   a. Soil Mapping and Interpretations and Range Studies of the El Paso County.

   b. National Engineering Handbook.
      1. Section 4, Hydrology, January, 1971.
      2. Section 5, Hydraulics
      3. Section 11

   c. Technical Release No. 55

   d. Procedures for Determining Peak Flows in Colorado.

3. USDI - Bureau of Reclamation:

   a. Design of small dams, 1973.

4. USA - Corps of Engineers:

   a. Flood Plain Information, Monument Creek, January, 1971.

5. Denver Regional Council of Governments, Drainage Criteria Manual, March, 1969:

6. NOAA

   a. NOAA, Atlas 2, 1973

   b. Climatalogical Data

7. State of Colorado, Div. of Highways, Roadway Design Manual, May, 1972:

8. State of Colorado, State Engineer, Applicable Laws, Rules and Regulations Pertaining to the Design, Operation and Maintenance of Dams:

9. Soils Reports:

   a. Lincoln Devore - Preliminary Investigations DEC Site.

10. Linsley, Kohler and Paulhus, Hydrology for Engineers, McGraw-Hill, 1964:

11. Linsley & Franzini, Water-Resources Engineering, McGraw-Hill, 1964:

12. King & Brater, Handbook of Hydraulics, McGraw-Hill, 1963:

13. Handbook of Steel Drainage and Highway Construction Products, American Iron and Steel Institute, 1971.

14. Handbook of Concrete Culvert Pine Hydraulics, Portland Cement Association, 1964:

15. Concrete Pipe Design Manual, American Concrete Pipe Association, 1970:

16. Pikes Peak Area Council of Government:

    a. Drainage Criteria Manual, Part 2

    b. Soils Resource Analysis of El Paso & Teller Counties, Colorado, Land Inventory Consultants, Fort Collins, Colorado

** APPENDIX **

WRA-26-72
(10M)

STATE OF COLORADO

DIVISION OF WATER RESOURCES

OFFICE OF STATE ENGINEER

....
County

APPLICATION FOR EROSION CONTROL DAM: ....
Title and Number

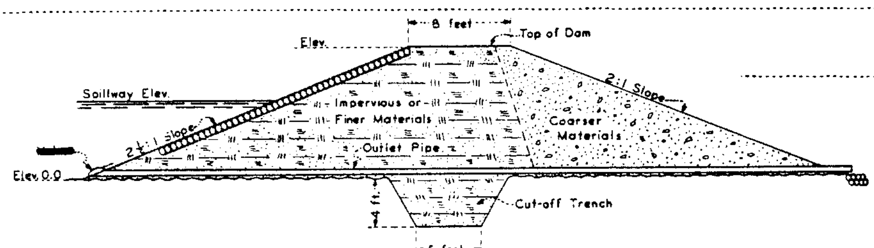
This application and statement is made in conformity with the provisions of the Erosion Control Dam Act of Colorado, Chap. 148-5-30, C.R.S. 1963 as amended.

This application must be accompanied by a filing fee of one dollar, payable to the State Engineer of Colorado.

.... Name of Owner .... P.O. Address

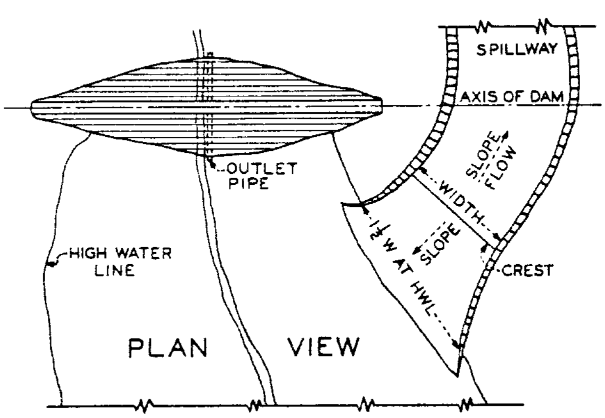
Tank located in the..........Quarter of Section..........., Township..........., Range.......................P. M.
Water course on which tank is located.......................................Trib. to.......................................
Is water course normally dry..............................: Subject to floods.......................................
Approximate area of drainage basin above tank...
Vegetative cover above tank: Cultivated............., Pasture............., Forest............., Brush.............
Topography of drainage basin: Steep............., Medium............., Flat.............
Character of surface formation of drainage basin: Rock............., Rocky Soil............., Soil............
Approximate elevation of drainage basin above sea level ....feet.
Height of top of dam above bottom of water course ....feet.
Height of bottom of spillway above bottom of water course ....feet.
Approximate capacity of tank.................................acre feet, high water line area.....................acres.
Location of spillway with respect to dam...
Bottom width of spillway at narrowest point..................................feet.
Distance of lower end of spillway below dam..................................feet.
Formations in which spillway is located: Rock............., Shale............., Clay............., Earth.............,
or Mixture of Soil and Rock.............
Width of top of dam...................feet. Length of dam...................feet.
Slope of upstream face of dam........... Slope of downstream face of dam...........
Kind and size of outlet pipe ....
Nature of riprap or other protection to be placed over water face of dam ....
....

Give location by section, township and range and size of every other stock tank now constructed in drainage basin in which this tank will be located ....
....



MAXIMUM CROSS-SECTION OF DAM

....
Owner



....
Date of receipt of application

....
Date of approval

....
Number assigned tank

....
STATE ENGINEER

....
CHIEF, Dam Section

STATE OF COLORADO

DIVISION OF WATER RESOURCES

OFFICE OF STATE ENGINEER

SPECIFICATIONS TO GOVERN THE CONSTRUCTION OF A EROSION CONTROL DAM

Preparation of Foundation for Dam—All vegetable matter of every description, including roots to a depth of two feet, shall be removed from the entire area upon which the dam will rest, together with boggy or unstable materials and deposited outside the toes of the dam. The banks of the stream channel shall be dressed to a slope of about 1½:1. A bonding trench, with sloping sides and a bottom width of not less than 5 feet and depth of 4 feet, shall then be excavated beneath the center line of the dam the full length thereof, which trench shall be refilled with the most impervious materials available. The foundation of the dam shall then be lightly plowed lengthwise of the dam, to provide proper contact between the foundation and the dam embankment.

Placing of Dam Embankment—The materials shall be placed in the bonding trench and in the embankment of the dam in layers not exceeding 6 inches in thickness, after which each layer shall be thoroughly compacted by a heavily loaded disc cultivator, a corrugated or sheep's foot roller, the treads of a caterpillar or trucks, or by livestock used in the construction. During the construction period, the top of the embankment shall be maintained as a horizontal plane the full width and length thereof, and no side dumping of materials shall be permitted. The materials shall at all times contain sufficient moisture to provide proper compaction. Puddling of material with water shall not be permitted. No frozen material or large clods or stones shall be incorporated in the dam. The upstream face of the dam shall be constructed with a slope not steeper than 2½:1, and the downstream face on a slope not steeper than 2:1. The crest or top of the finished dam shall be not less than 8 feet in width.

The upstream two-thirds of the dam shall be constructed of the most impervious materials, such as clay loam, or a mixture of clay and sand, and the downstream one-third of more pervious material, such as sand or gravel. The upstream face of the dam shall be adequately protected against wave action by stone riprap, or other suitable materials when required.

Outlet—There shall be located beneath the dam an ungated outlet pipe not less than 12 inches in diameter and large enough to drain within thirty-six hours any impoundment in excess of two acre-feet. Such outlet pipe shall be provided with cutoff collars. The pipe shall be placed in a trench bottomed in stable formation, and shall be completely surrounded with well compacted impervious materials.

Spillway—For the protection of the dam, an adequate spillway shall be constructed around one or both ends of the dam, of sufficient width to provide a capacity to carry the entire discharge from the drainage basin above the dam during periods of unusual runoff. The spillway shall be located in stable formations not easily eroded, and shall extend to a point well downstream from the dam. The following table shall be used to determine the necessary width of spillway to meet the above requirements. The top of the dam at all points shall be not less than 4 feet above the bottom of the spillway.

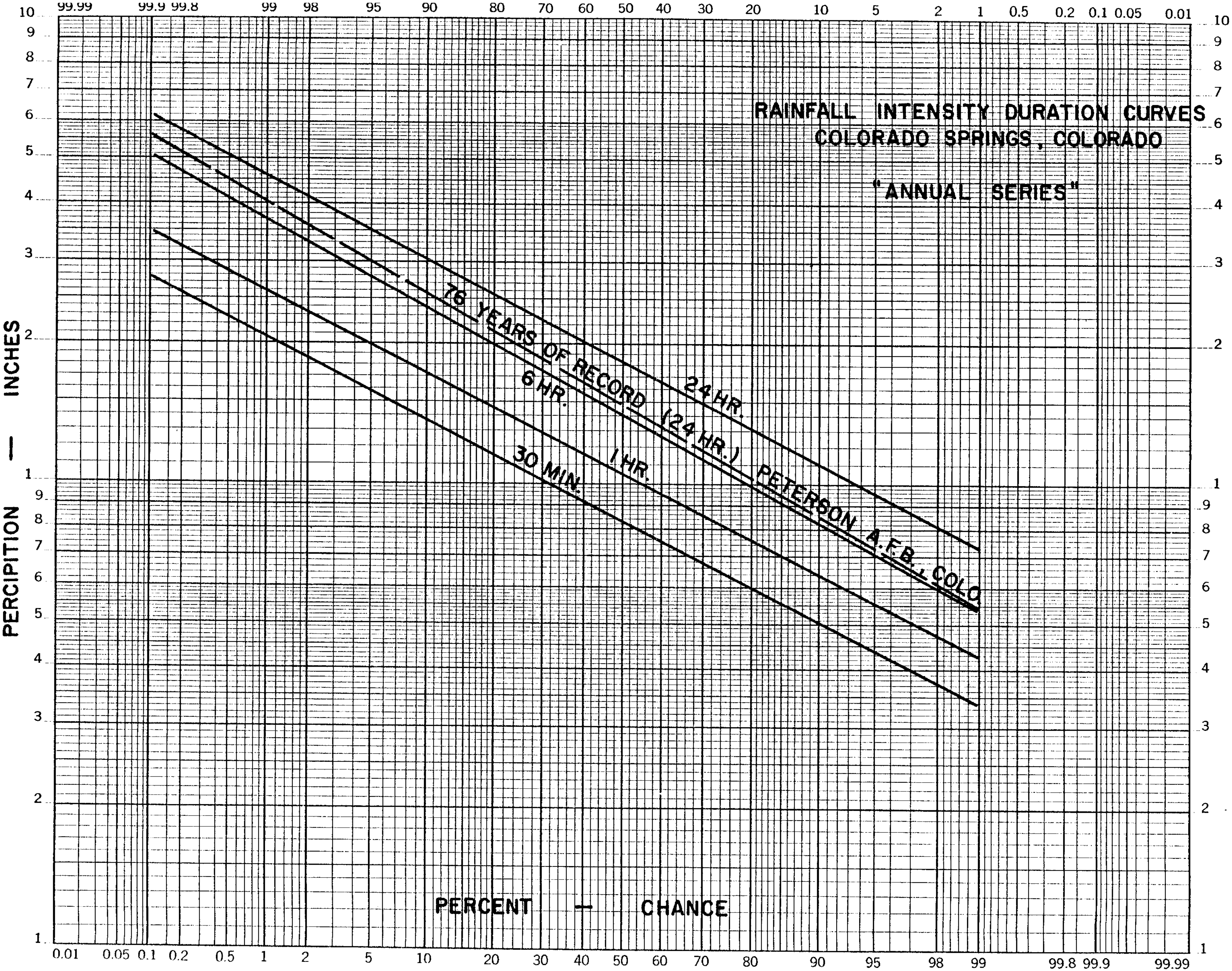
The following table shows the widths of spillways for corresponding drainage areas with an allowance of a minimum freeboard between the maximum high water line and top of dam, of 2.3 feet, and maximum velocities of 3.5 feet per second of time.

AREAS OF LOW RAINFALL INTENSITY		AREAS OF HIGH RAINFALL INTENSITY			
AREA OF DRAINAGE BASIN ABOVE DAM IN ACRES	REQUIRED WIDTH OF SPILLWAY "W" AT NARROWEST POINT IN FEET	AREA OF DRAINAGE BASIN ABOVE DAM IN ACRES	REQUIRED WIDTH OF SPILLWAY "W" AT NARROWEST POINT IN FEET	AREA OF DRAINAGE BASIN ABOVE DAM IN ACRES	REQUIRED WIDTH OF SPILLWAY "W" AT NARROWEST POINT IN FEET
20	8	20	8	400	76
40	9	40	9	450	84
60	11	60	11	500	90
80	14	80	18	550	98
100	16	100	22	600	105
140	21	120	26	700	117
180	25	140	30	800	129
220	29	160	34	900	140
260	33	180	37	1000	150
300	35	200	43	1100	160
350	38	220	46	1200	169
400	42	240	50	1300	178
450	44	260	53	1400	187
500	46	280	57	1500	196
600	51	300	60	1600	203
700	55	320	63	1700	212
800	59	340	66	1800	219
900	62	360	70	1900	225
1000	66	380	73	2000	233

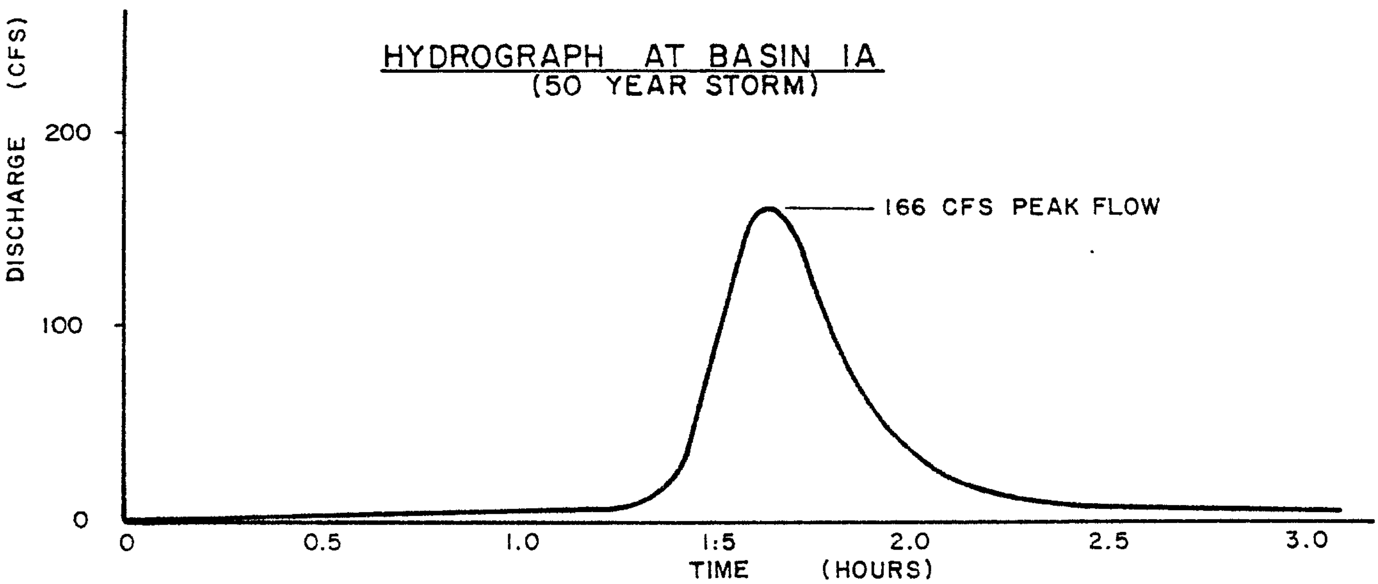
ALL AREAS EAST OF THE CONTINENTAL DIVIDE BELOW AN ELEVATION OF 7000 FEET, ARE CONSIDERED AS BEING IN THE HIGH RAINFALL INTENSITY ZONE.

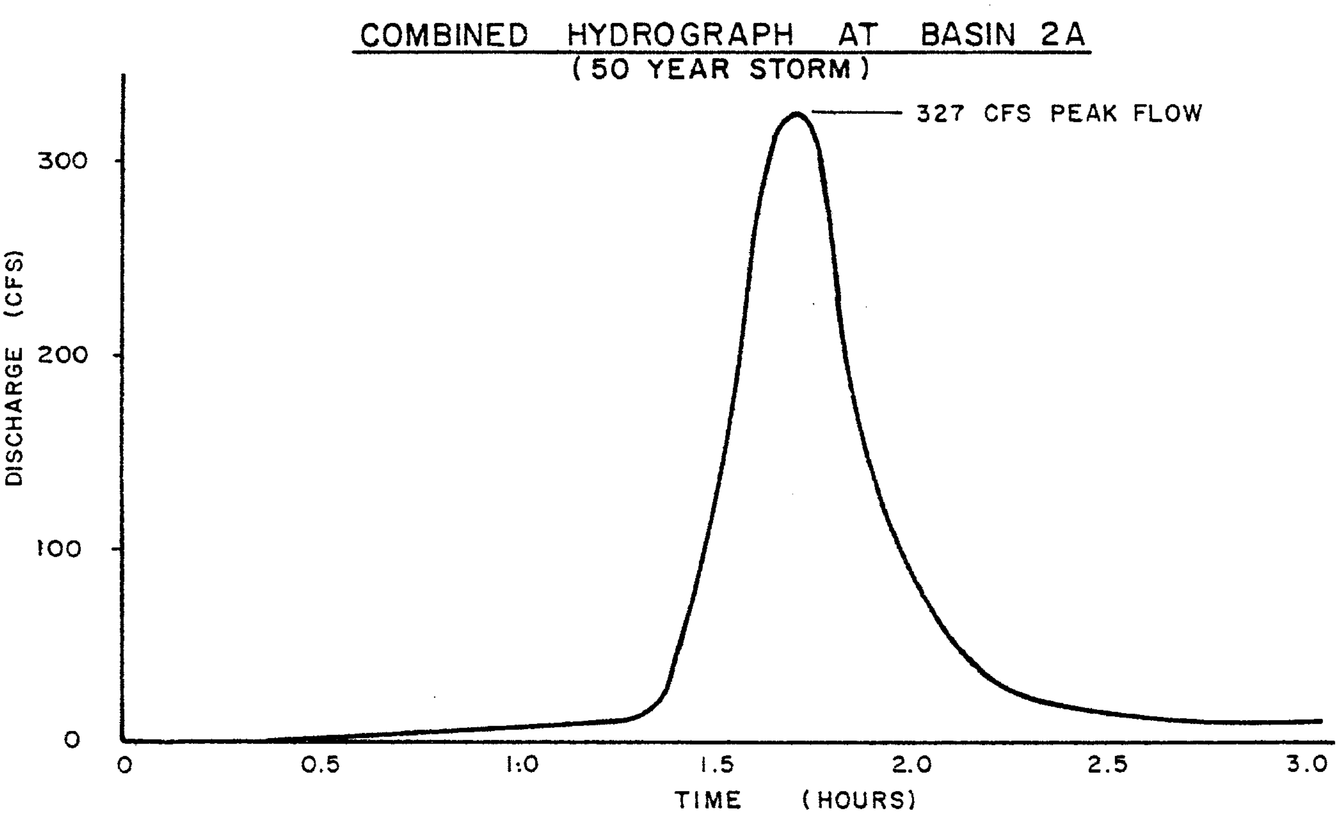
The above spillway widths may be reduced at a point 50 feet below intake, by 25 per cent, where the spillway is located the full length thereof in hard clay or shale, and by 50 per cent when located in hard rock formations, if the slope or grade of the bottom is increased accordingly. The grade for clay and shale formations should be 0.30 foot per 100 feet, and for rock formations 0.90 foot per 100 feet. The width of the entrance to the spillway must in all cases be one-third wider than shown in the table, and the bottom should slope from the lower end of the funnel section, toward the reservoir 1.0 foot in the distance of 50 feet, and the slope downstream should be 0.25 foot in a distance of 100 feet.

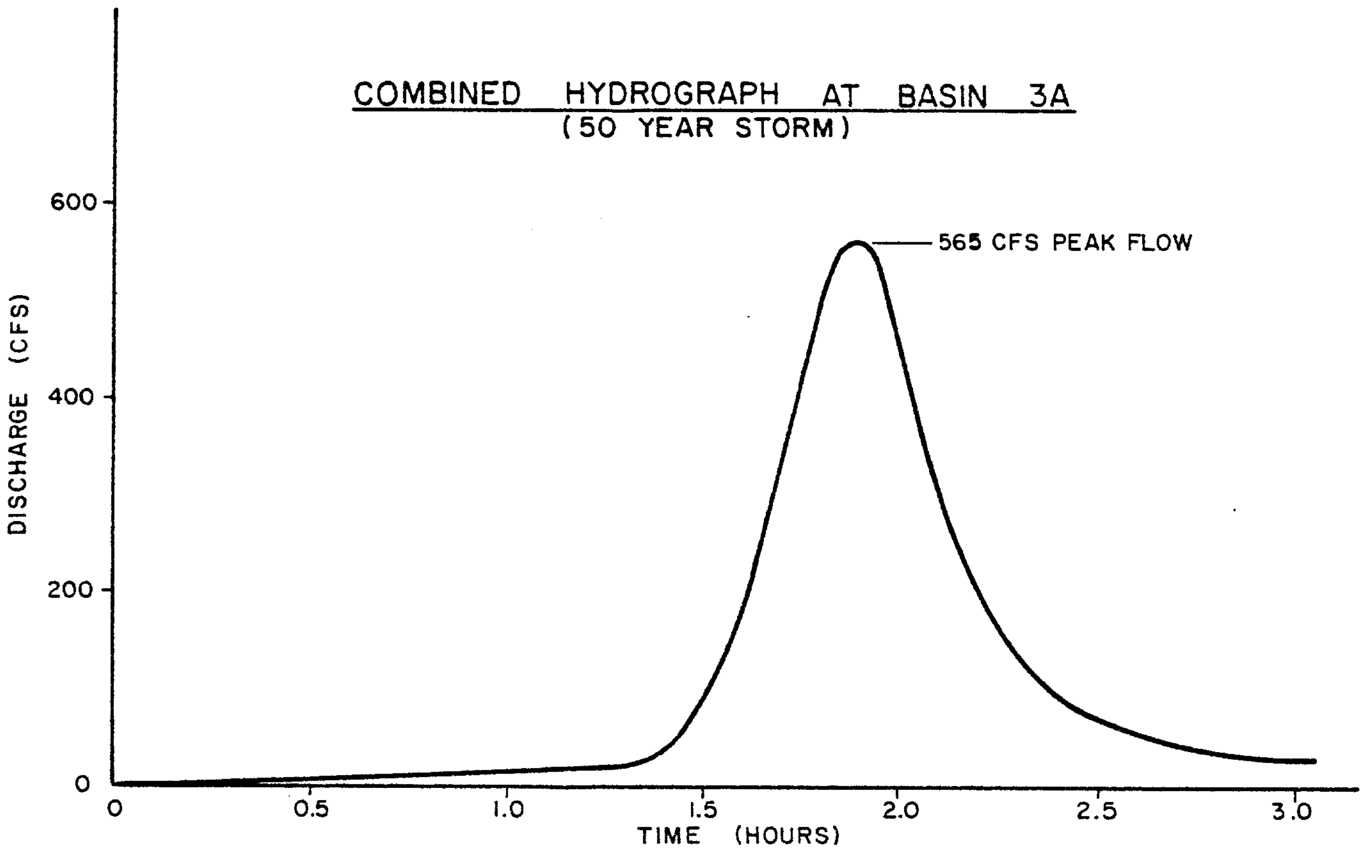
Borrow Pits—Pits, from which materials are taken to build the dam, shall be cleared of all vegetable matter, and no material shall be borrowed within a distance of 50 feet of any part of the dam. Materials excavated from the spillway, when suitable, may be used in building the dam.

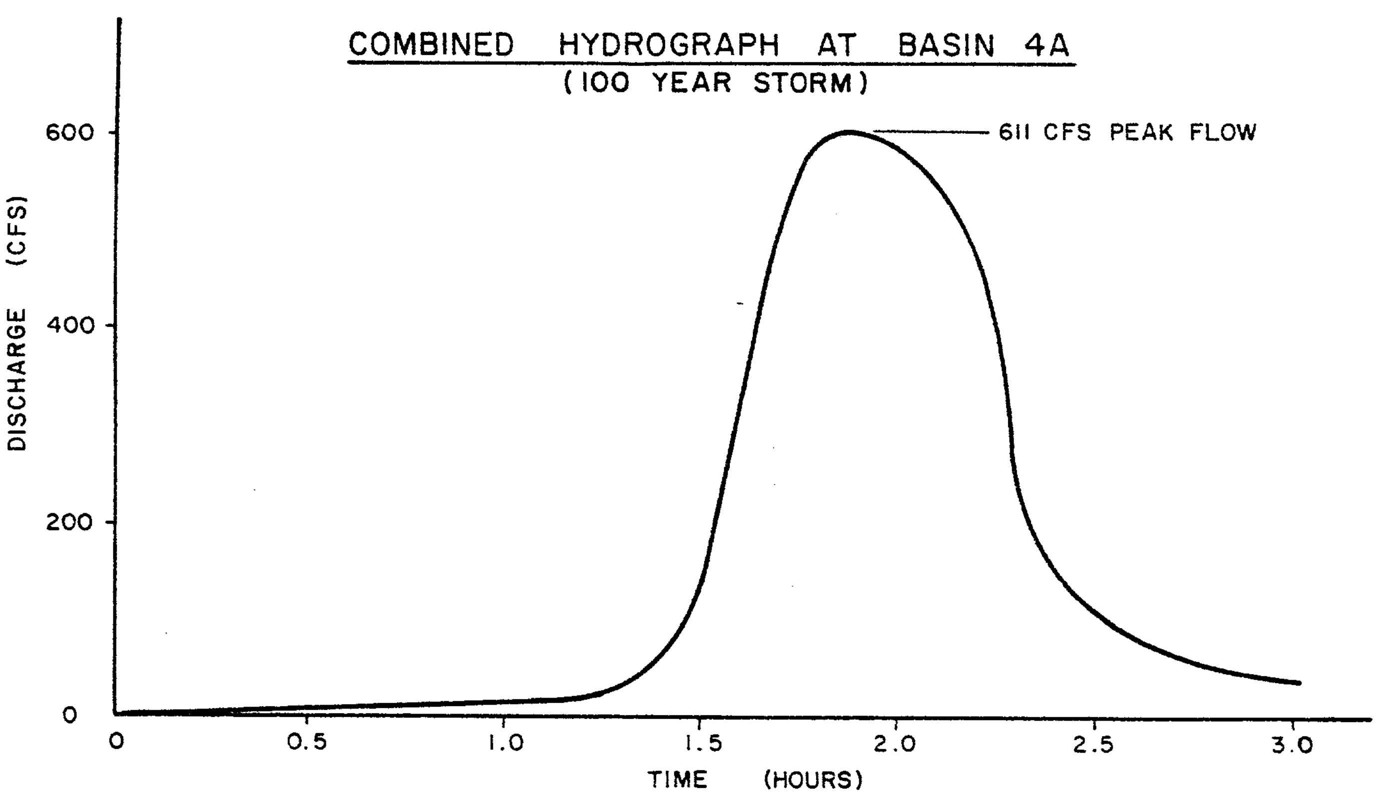


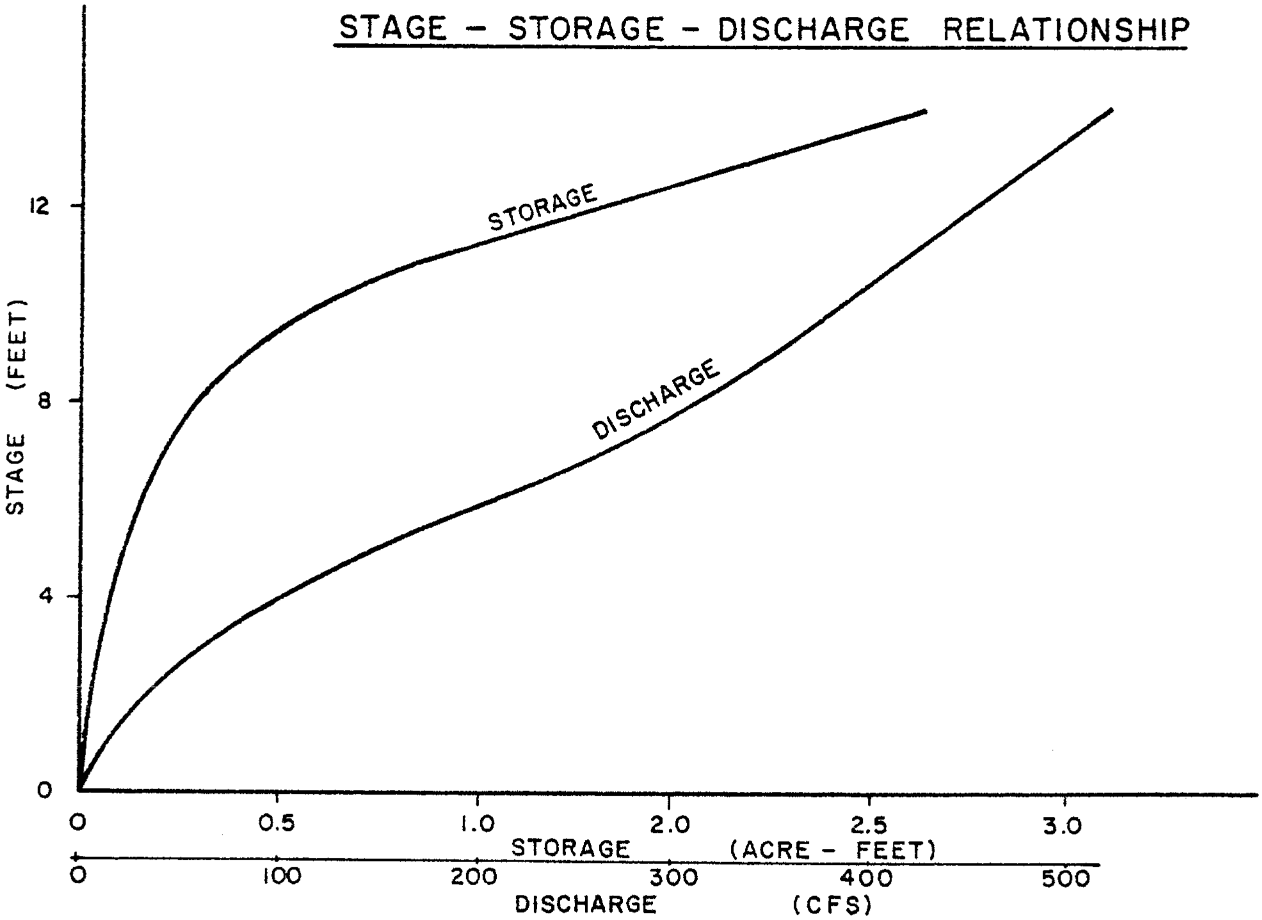
RAINFALL INTENSITY DURATION CURVES
COLORADO SPRINGS, COLORADO
"ANNUAL SERIES"
76 YEARS OF RECORD (24 HR.) PETERSON A.F.B., COLO
24 HR.
6 HR.
1 HR.
30 MIN.
PERCIPITION — INCHES
PERCENT — CHANCE
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99

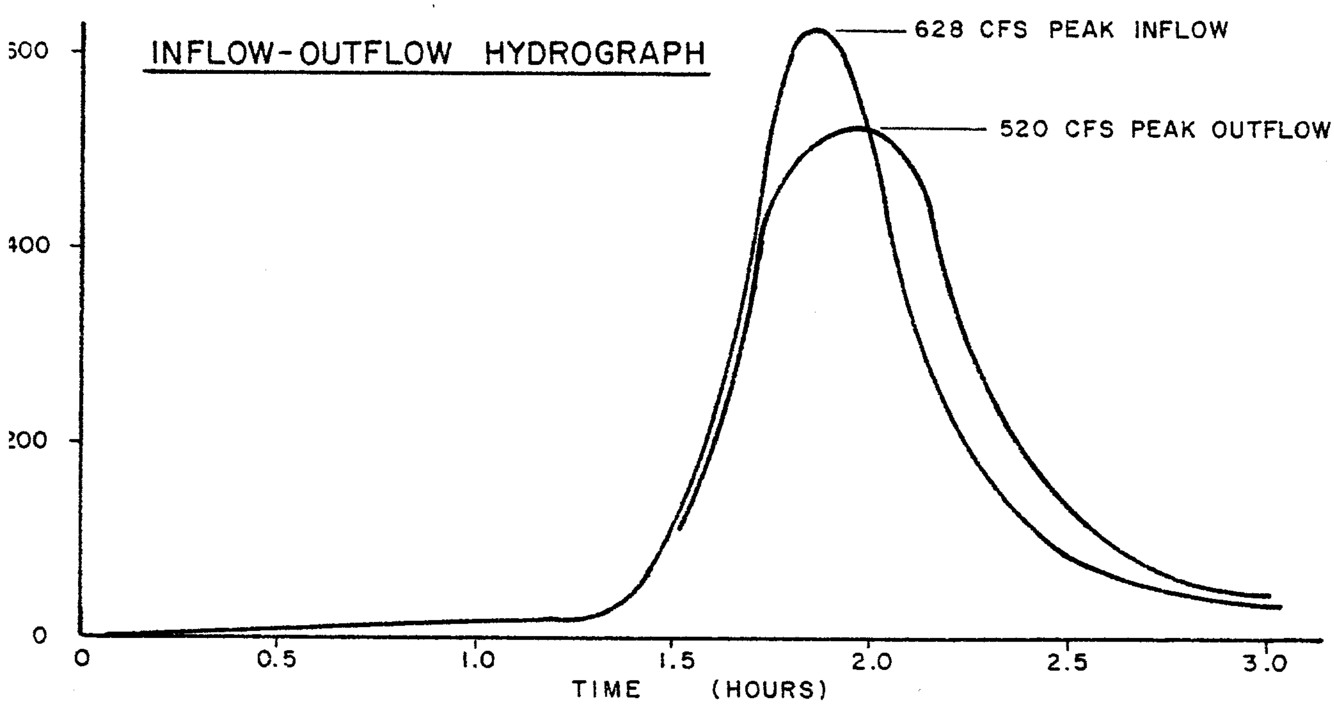

HYDROGRAPH AT BASIN 1A
(50 YEAR STORM)
166 CFS PEAK FLOW
DISCHARGE (CFS)
200
100
0
0
0.5
1.0
1:5
2.0
2.5
3.0
TIME (HOURS)


COMBINED HYDROGRAPH AT BASIN 2A
(50 YEAR STORM)
327 CFS PEAK FLOW
DISCHARGE (CFS)
300
200
100
0
0
0.5
1:0
1.5
2.0
2.5
3.0
TIME (HOURS)

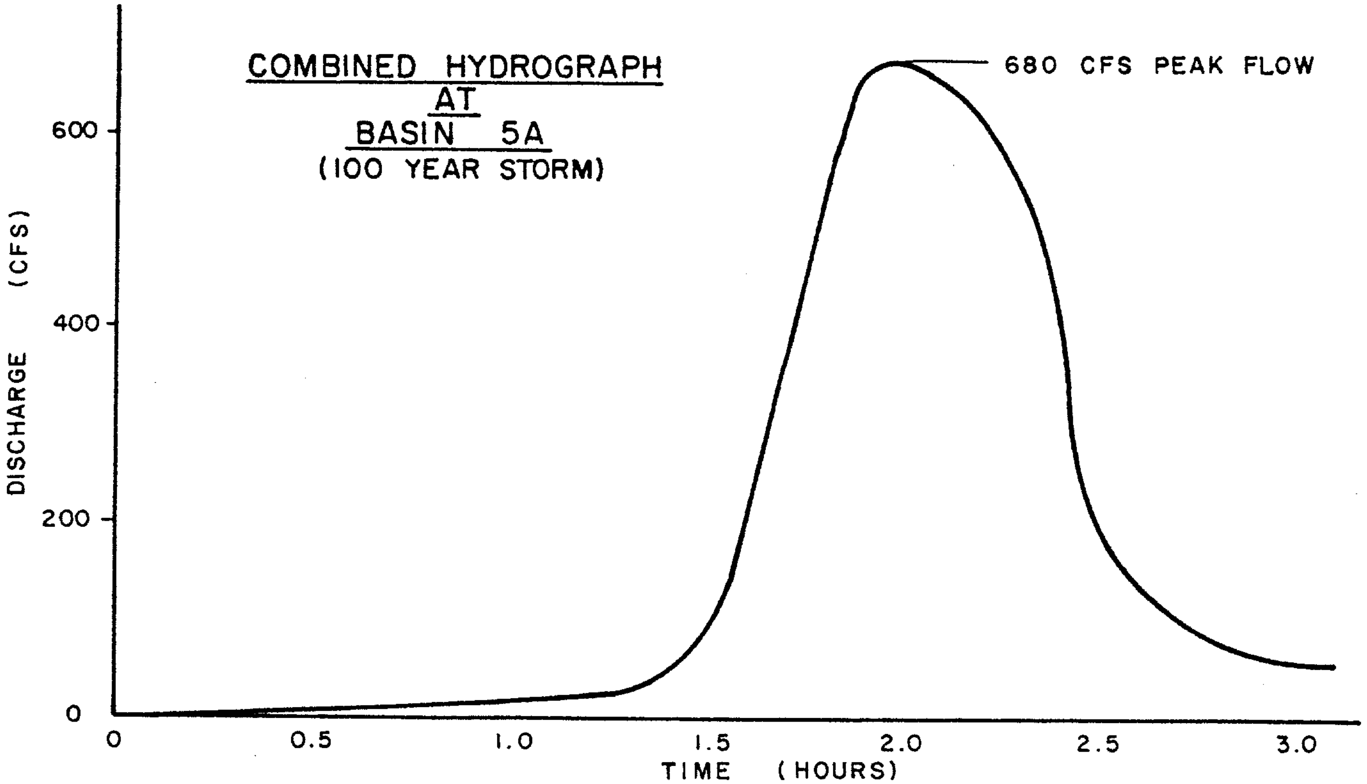

COMBINED HYDROGRAPH AT BASIN 3A
(50 YEAR STORM)
565 CFS PEAK FLOW
DISCHARGE (CFS)
600
400
200
0
0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (HOURS)

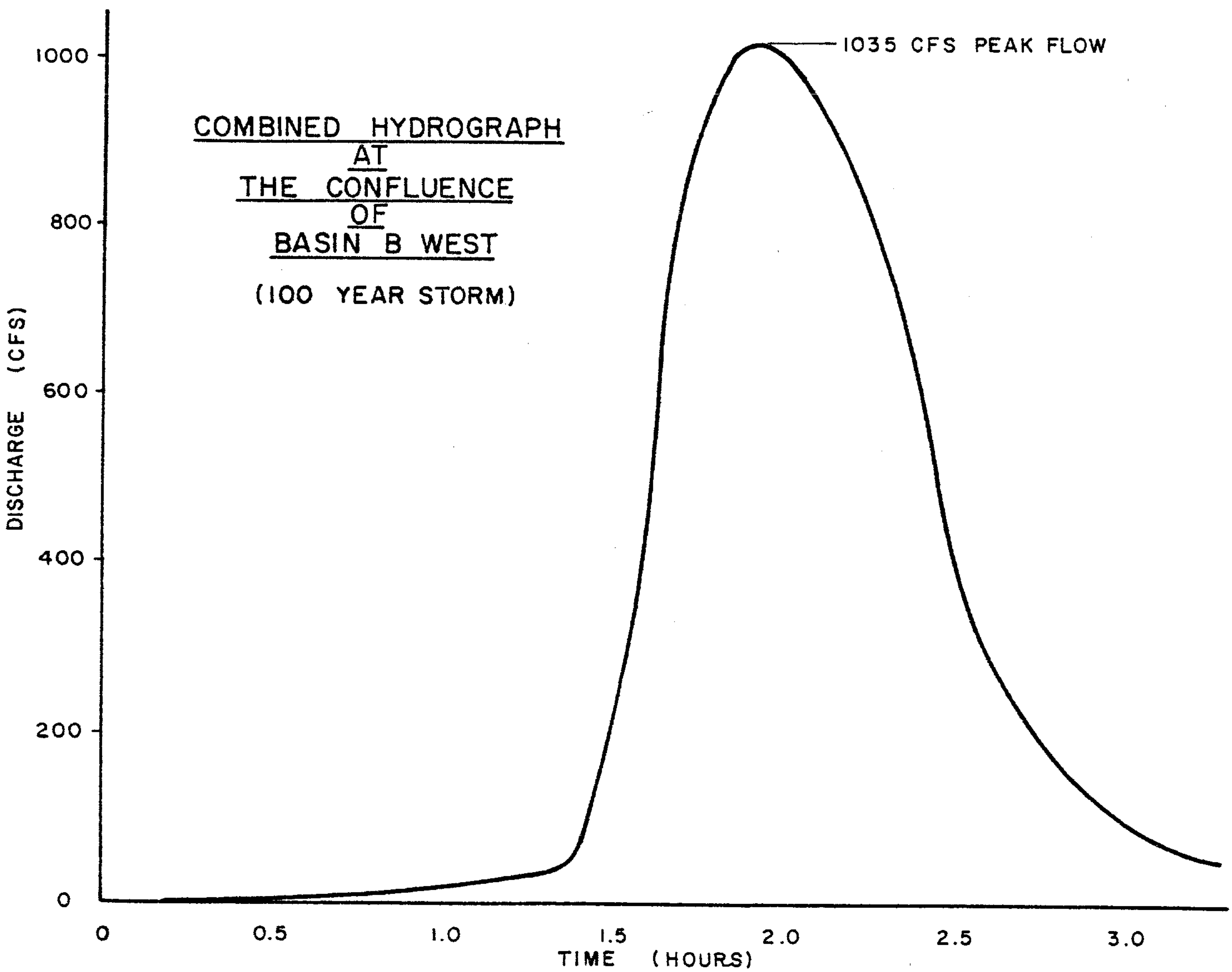

COMBINED HYDROGRAPH AT BASIN 4A
(100 YEAR STORM)
611 CFS PEAK FLOW
DISCHARGE (CFS)
600
400
200
0
0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (HOURS)

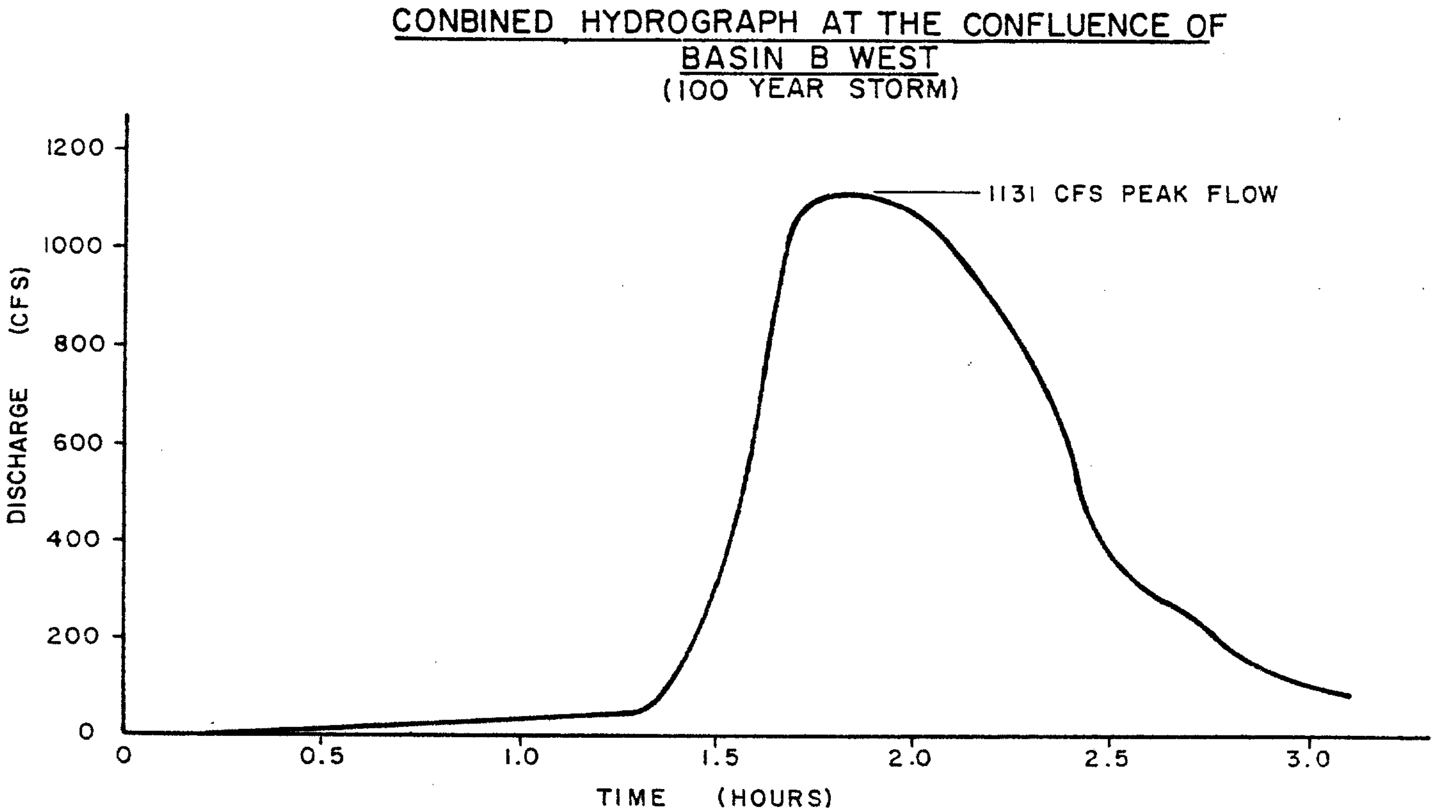


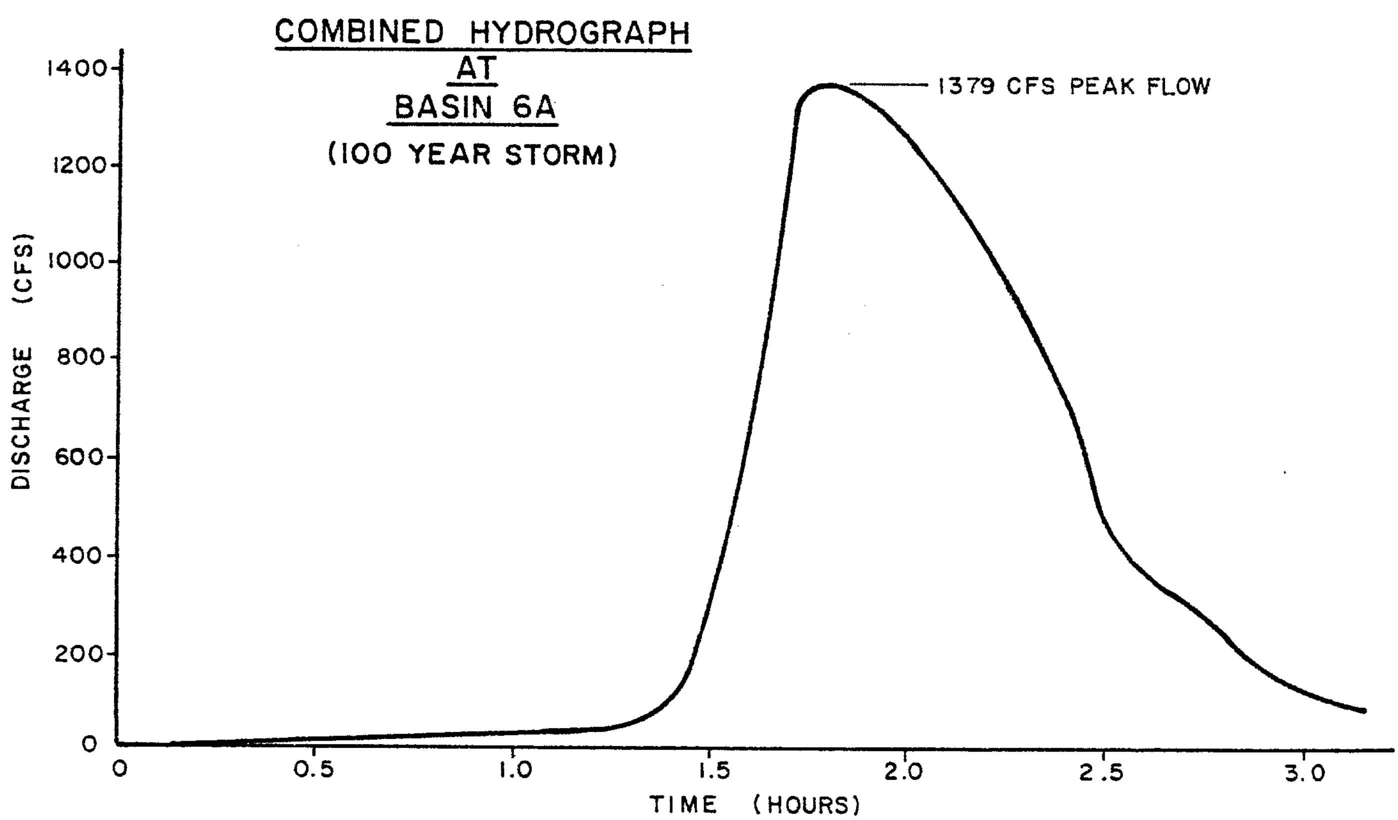


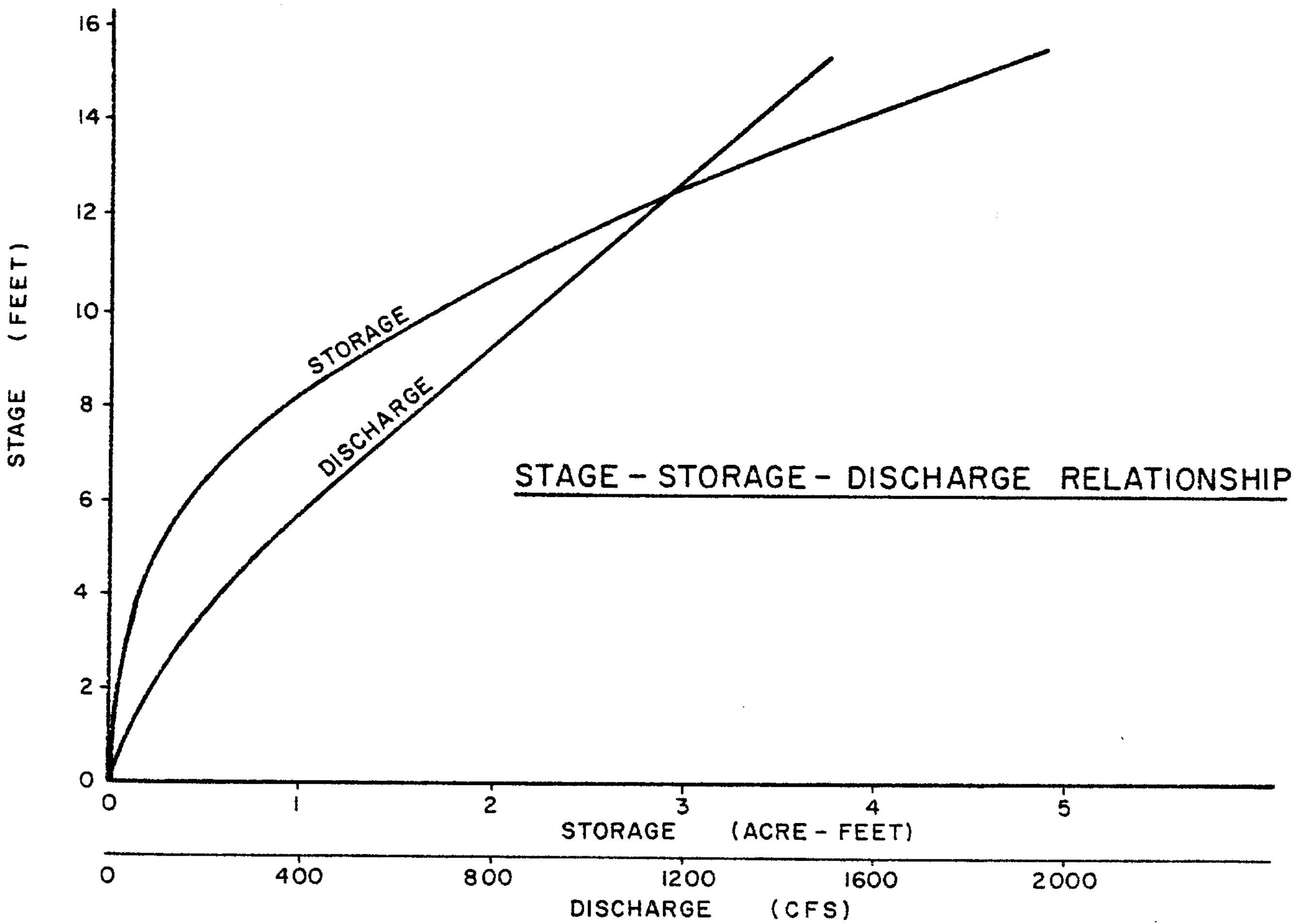
EMBANKMENT PONDING AREA AT BASIN 3A
(100 YEAR STORM)

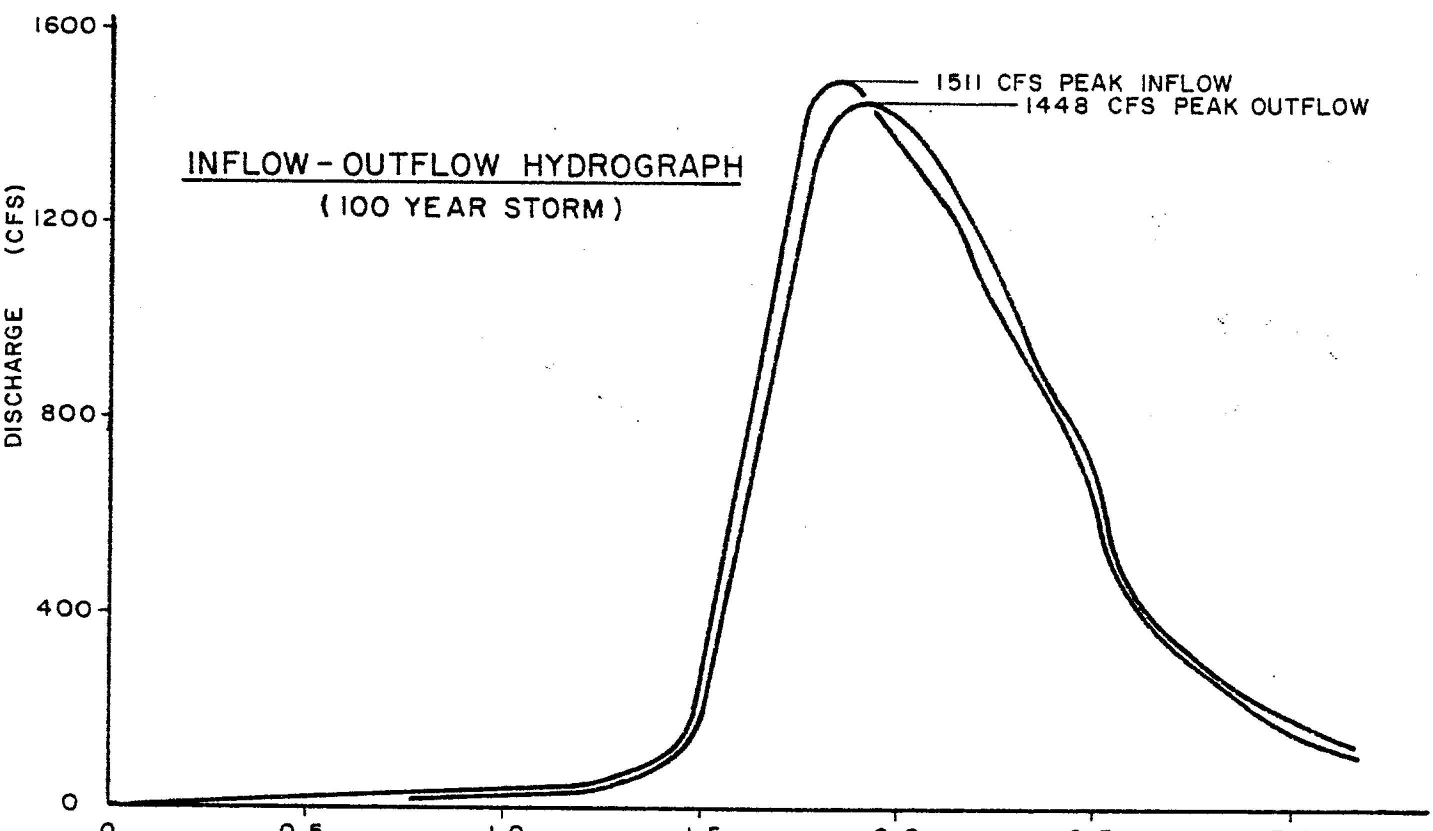

COMBINED HYDROGRAPH
AT
BASIN 5A
(100 YEAR STORM)
680 CFS PEAK FLOW
DISCHARGE (CFS)
600
400
200
0
0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (HOURS)


1035 CFS PEAK FLOW
COMBINED HYDROGRAPH
AT
THE CONFLUENCE
OF
BASIN B WEST
(100 YEAR STORM)
DISCHARGE (CFS)
1000
800
600
400
200
0
0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (HOURS)


CONBINED HYDROGRAPH AT THE CONFLUENCE OF
BASIN B WEST
(100 YEAR STORM)
1131 CFS PEAK FLOW
DISCHARGE (CFS)
1200
1000
800
600
400
200
0
0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (HOURS)

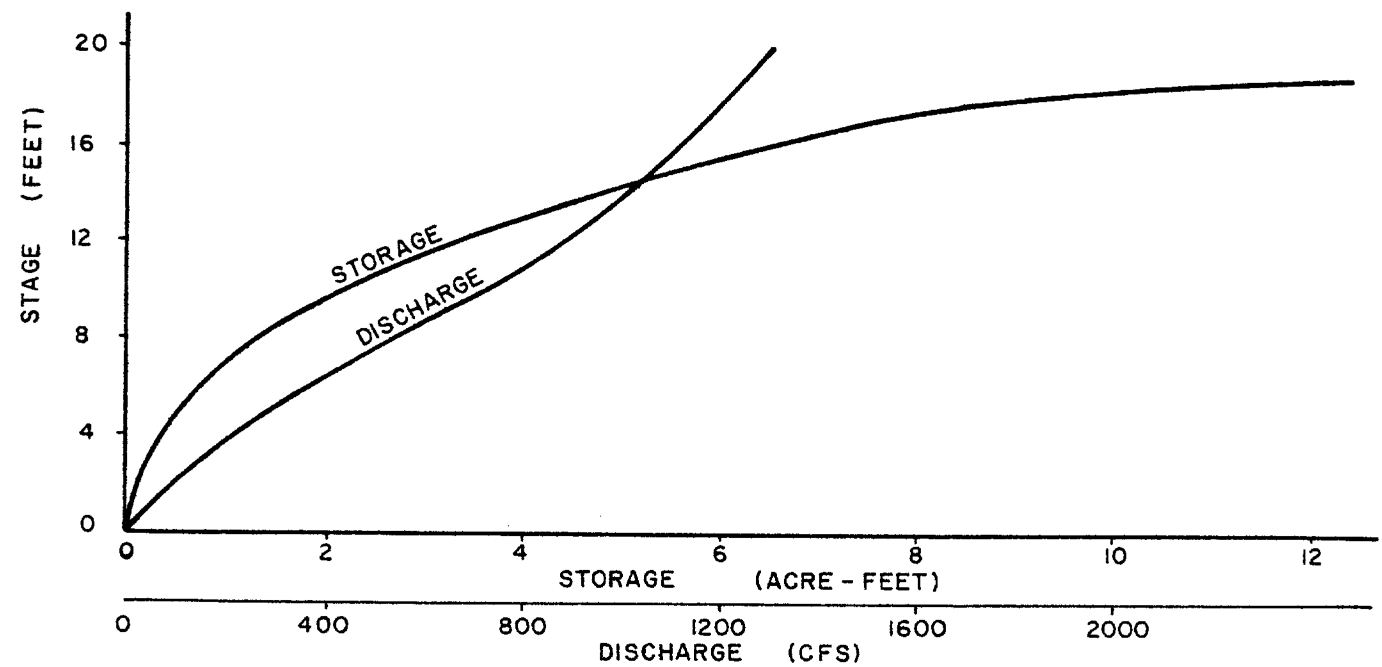

COMBINED HYDROGRAPH
AT
BASIN 6A
(100 YEAR STORM)
1379 CFS PEAK FLOW
DISCHARGE (CFS)
1400
1200
1000
800
600
400
200
0
0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (HOURS)



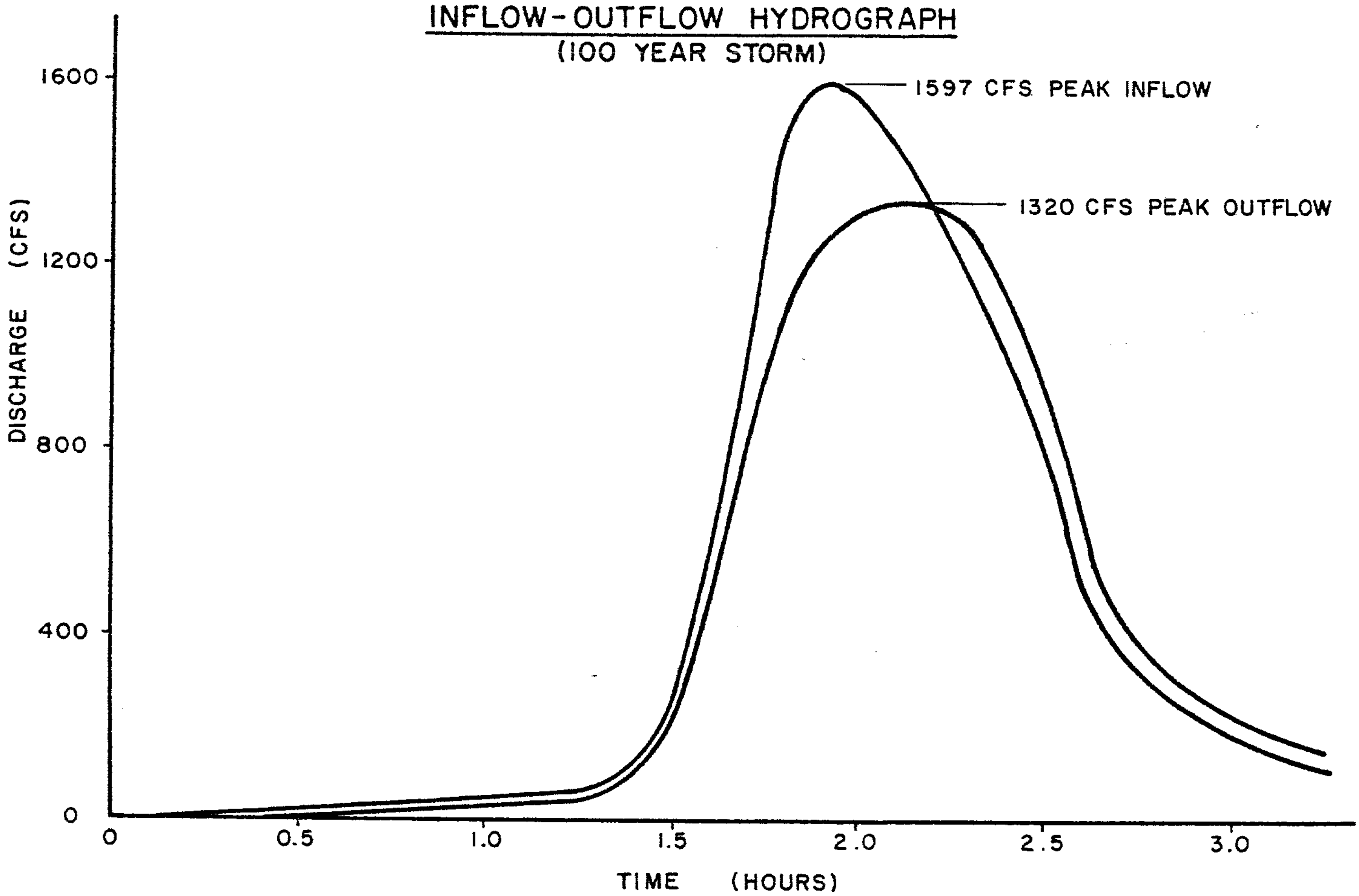


EMBANKMENT PONDING AREA AT BASIN 7A (I-25)

STAGE – STORAGE – DISCHARGE RELATIONSHIP



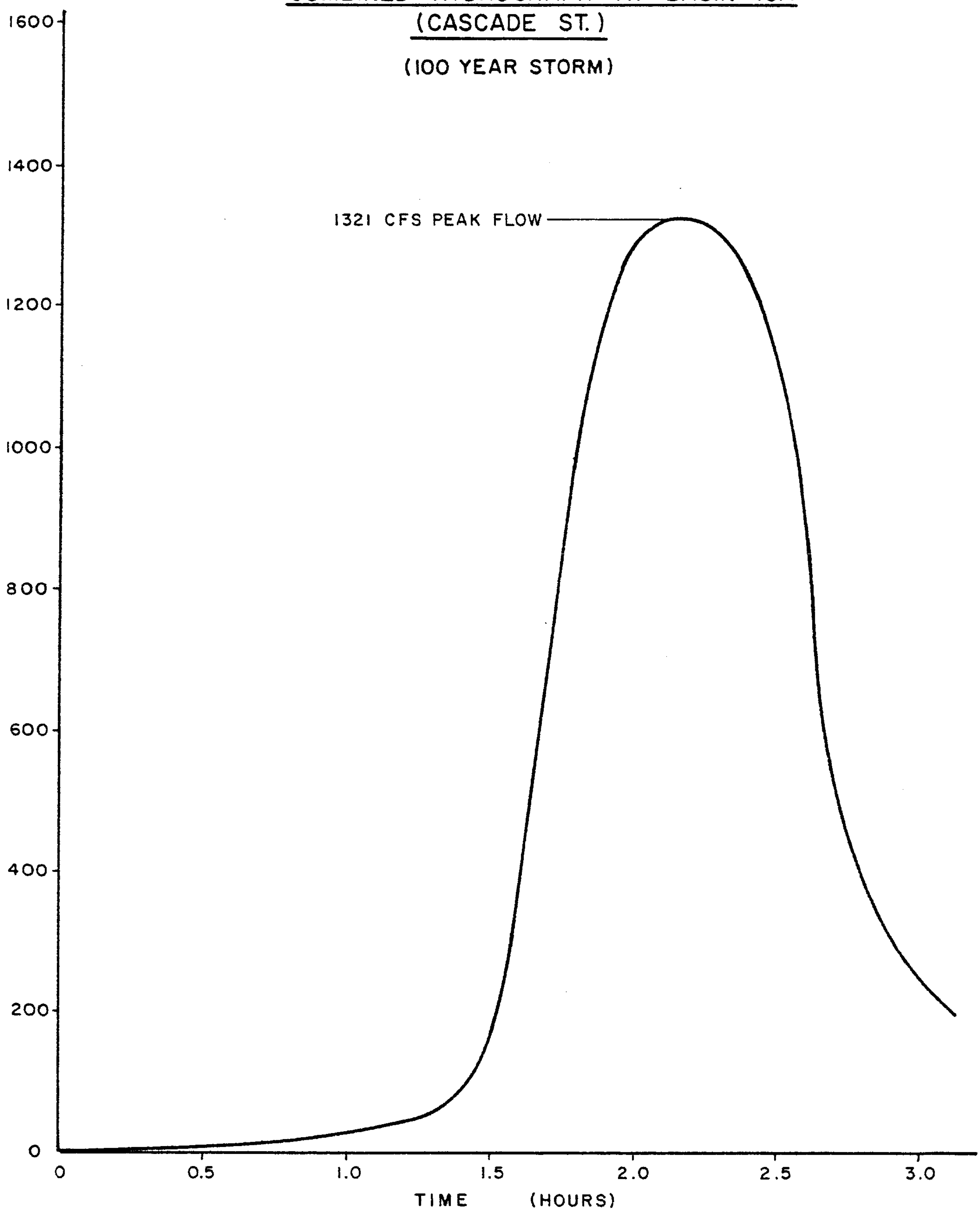
INFLOW-OUTFLOW HYDROGRAPH
(100 YEAR STORM)

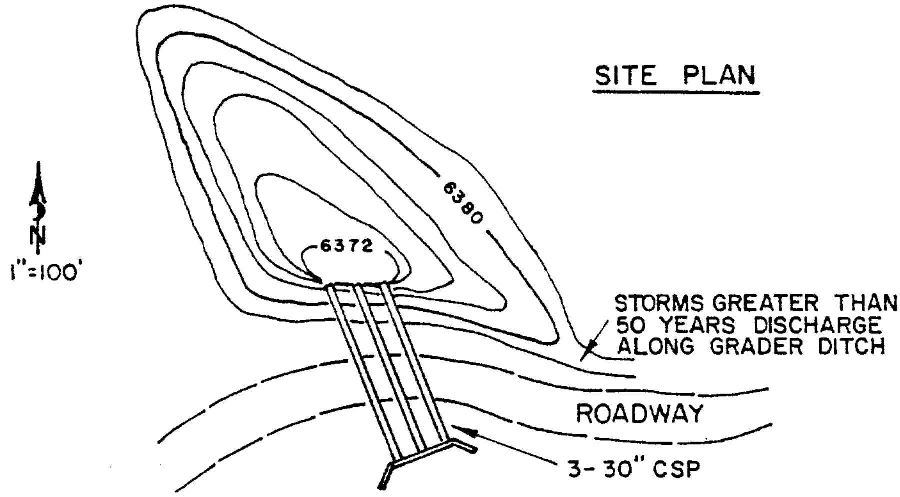


EMBANKMENT PONDING AREA AT BASIN 9A (R.R. BRDG.)

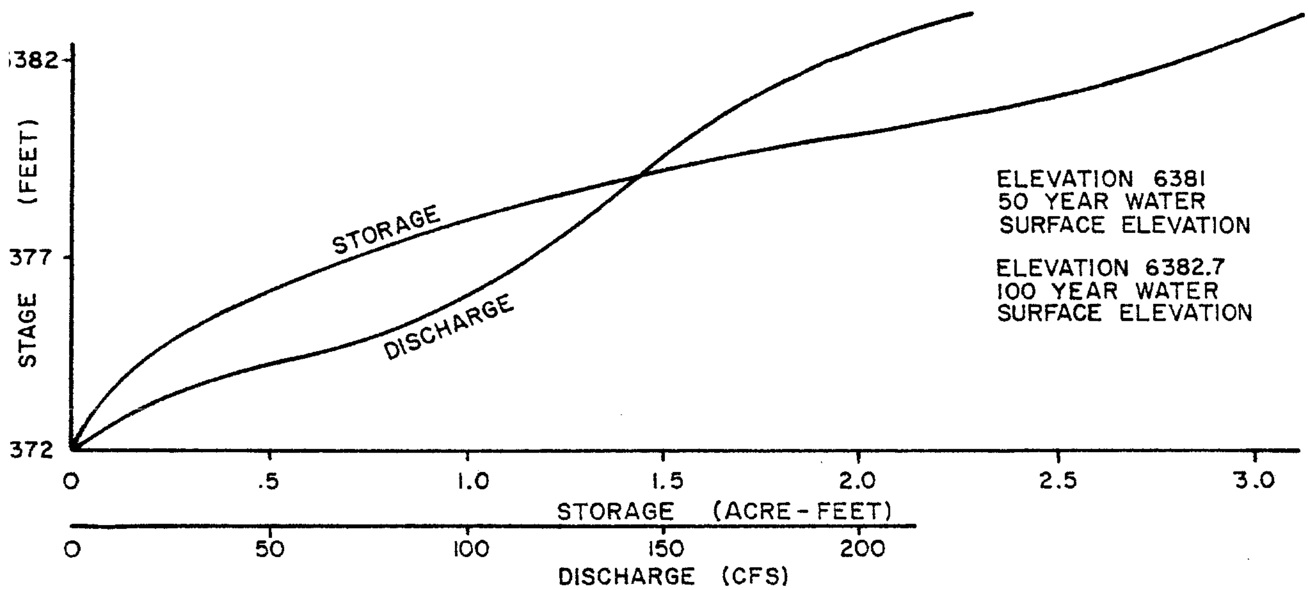
COMBINED HYDROGRAPH AT BASIN 10A (CASCADE ST.)

(100 YEAR STORM)



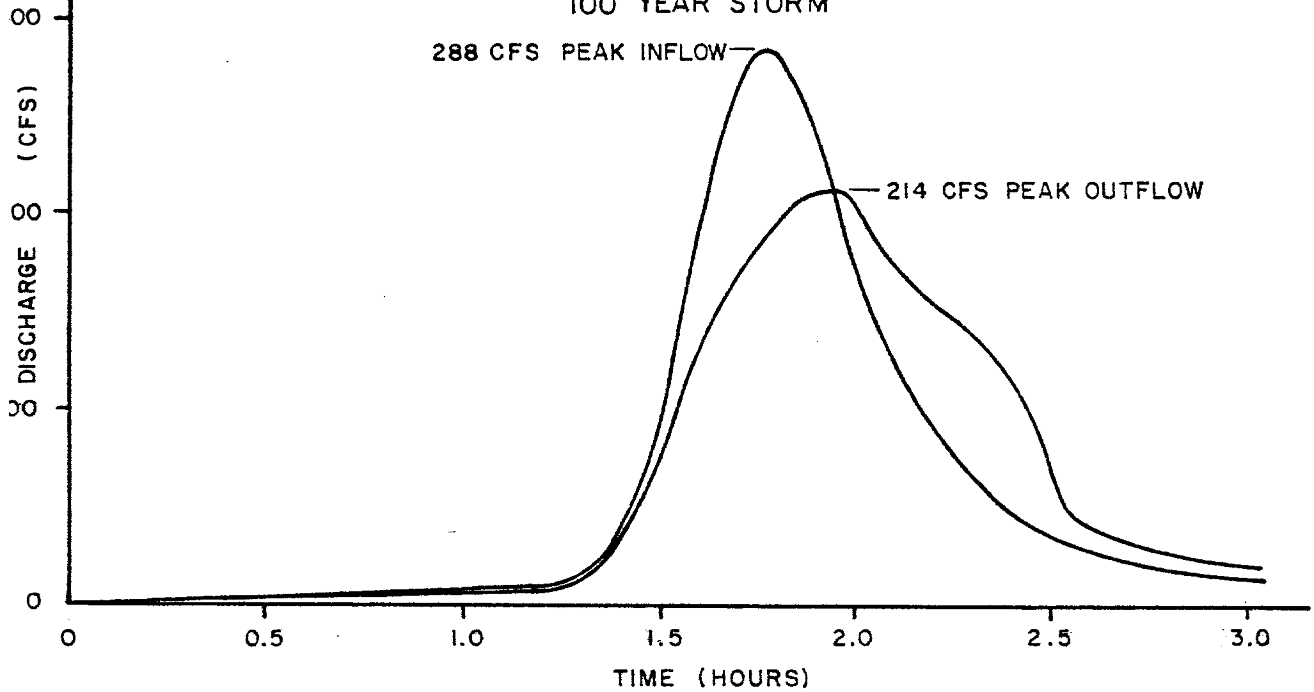


STAGE - STORAGE - DISCHARGE RELATIONSHIP

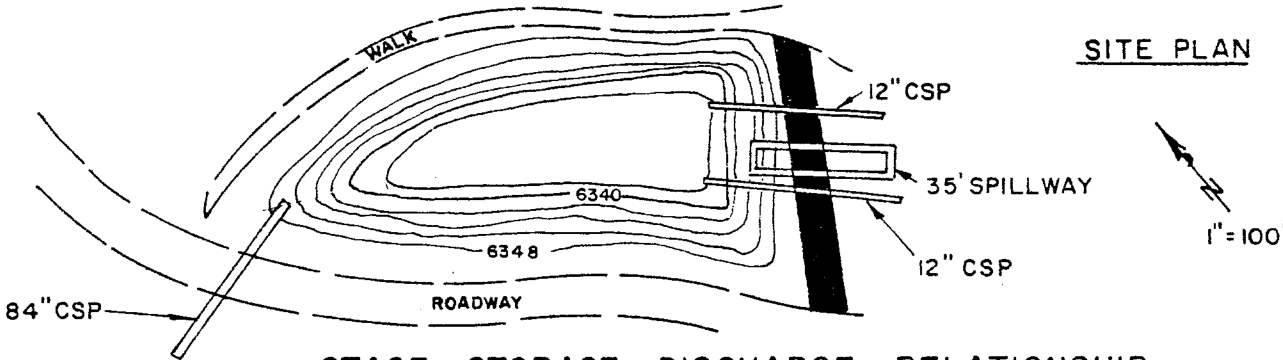


INFLOW - OUTFLOW HYDROGRAPH

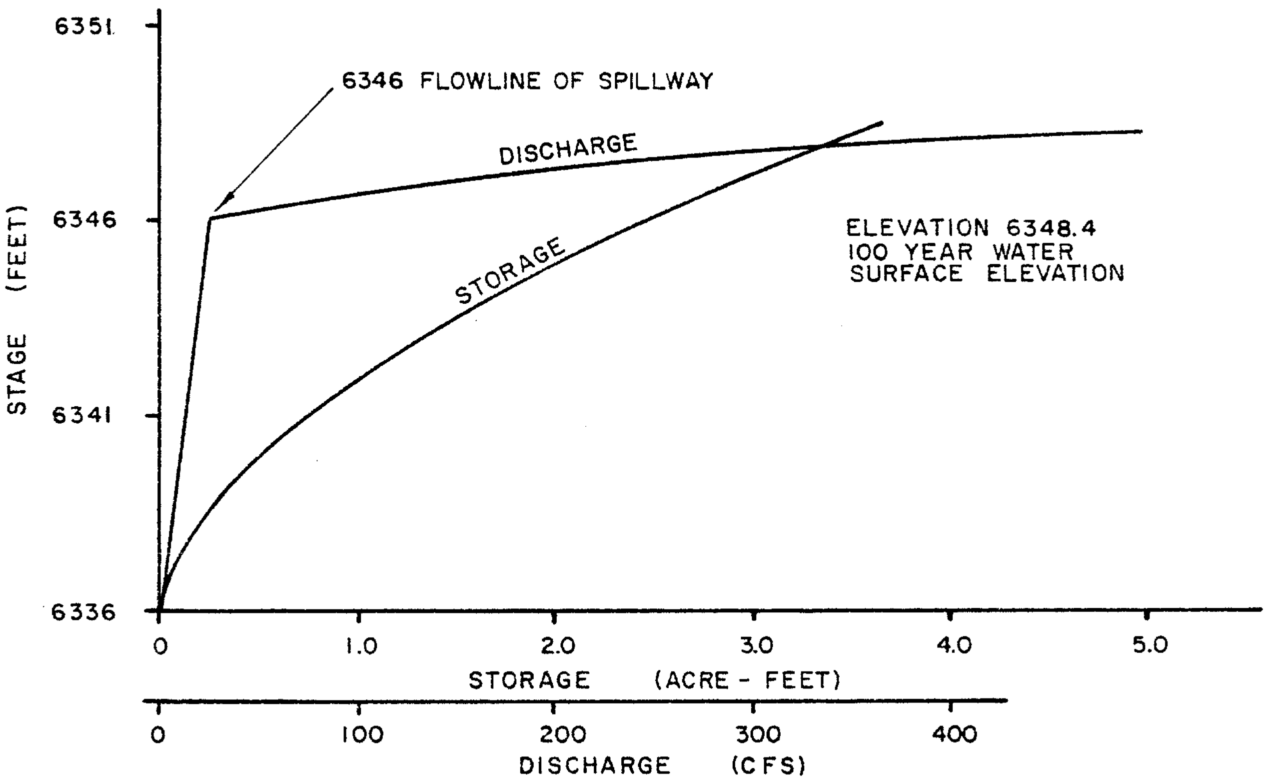
100 YEAR STORM



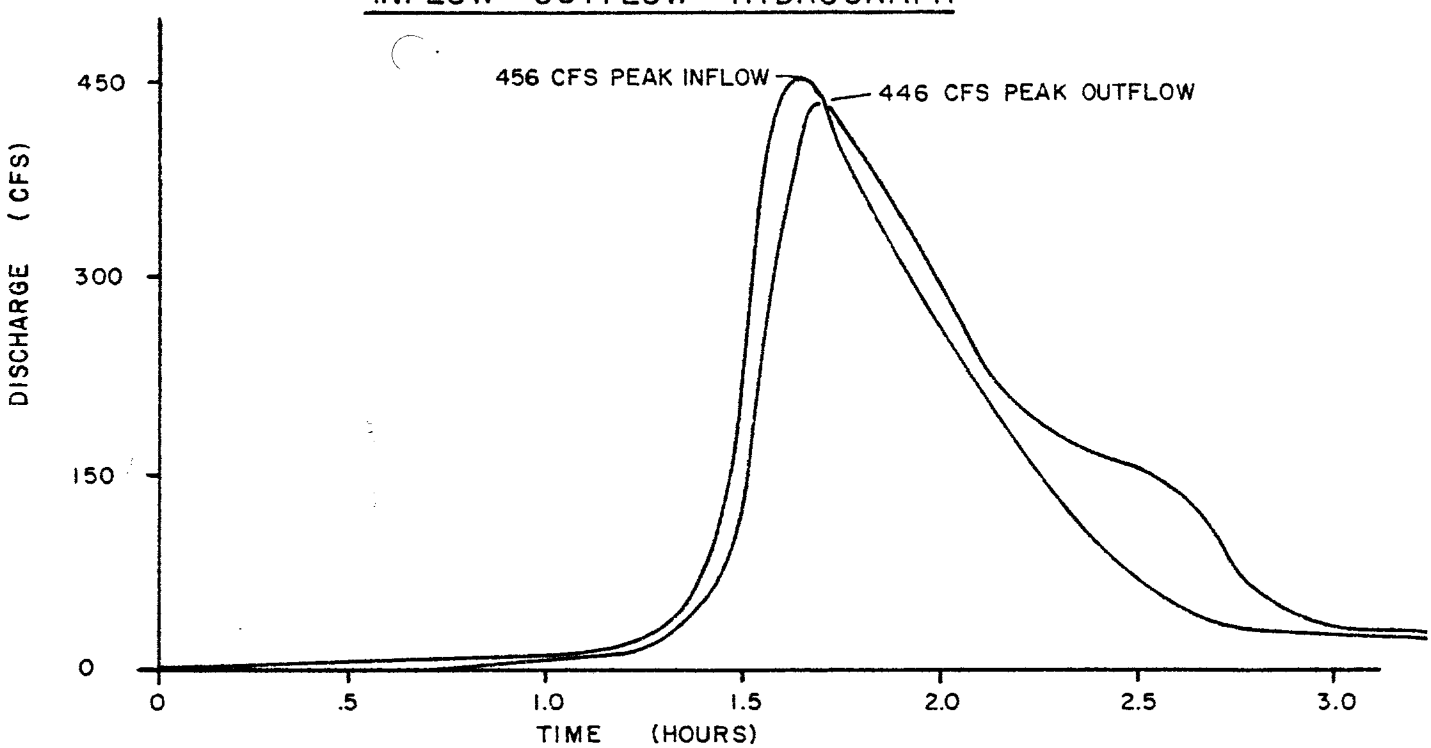
PROPOSED EMBANKMENT PONDING AREA AT BASIN 1B



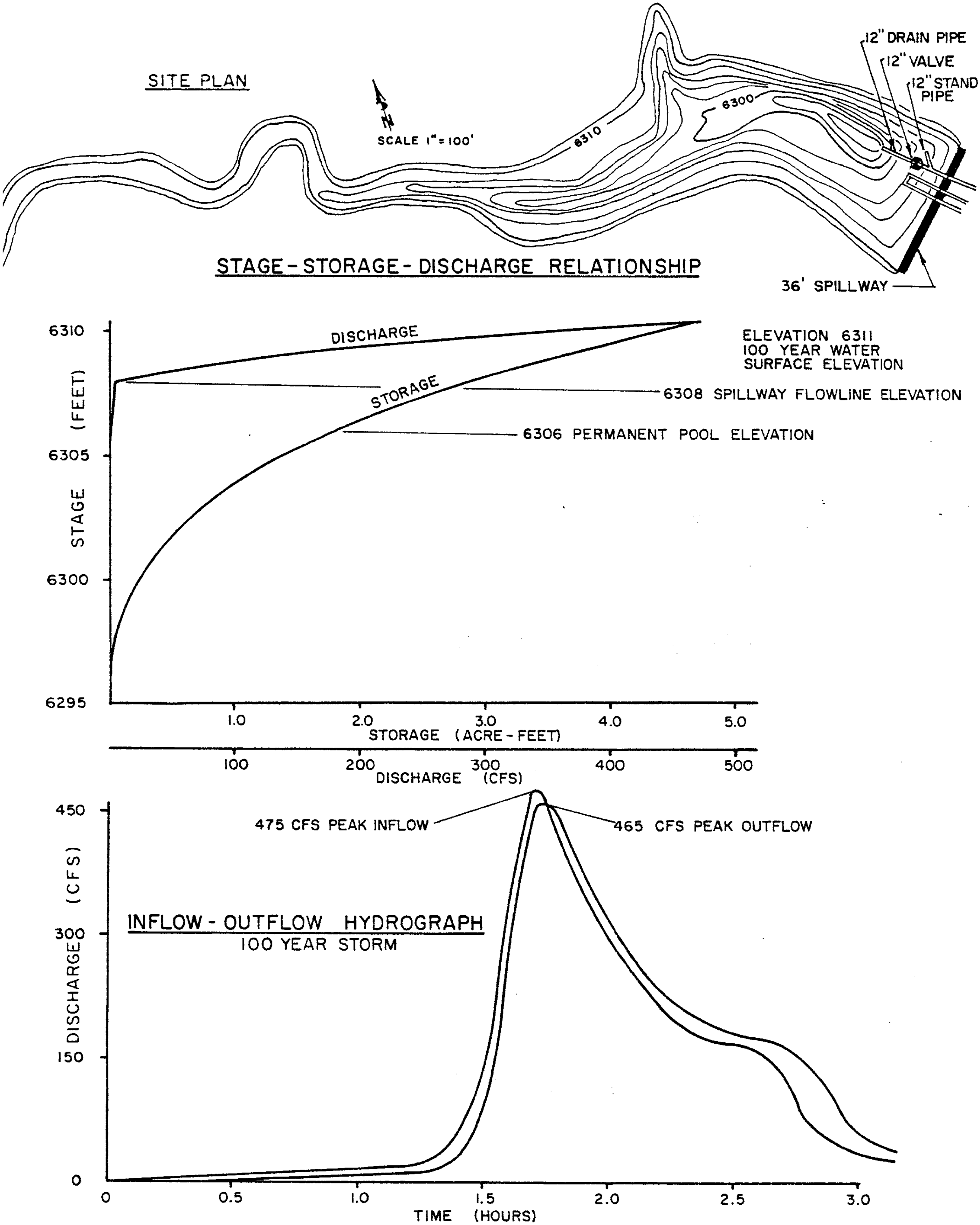
STAGE - STORAGE - DISCHARGE RELATIONSHIP



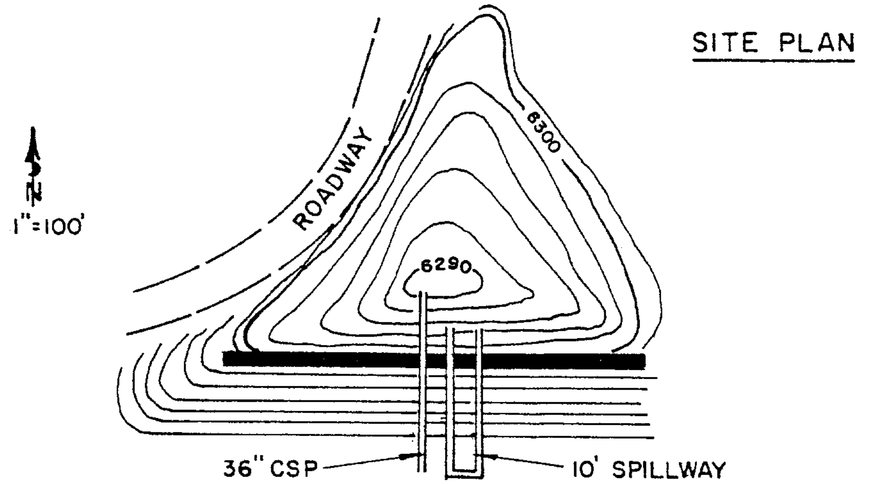
INFLOW - OUTFLOW HYDROGRAPH

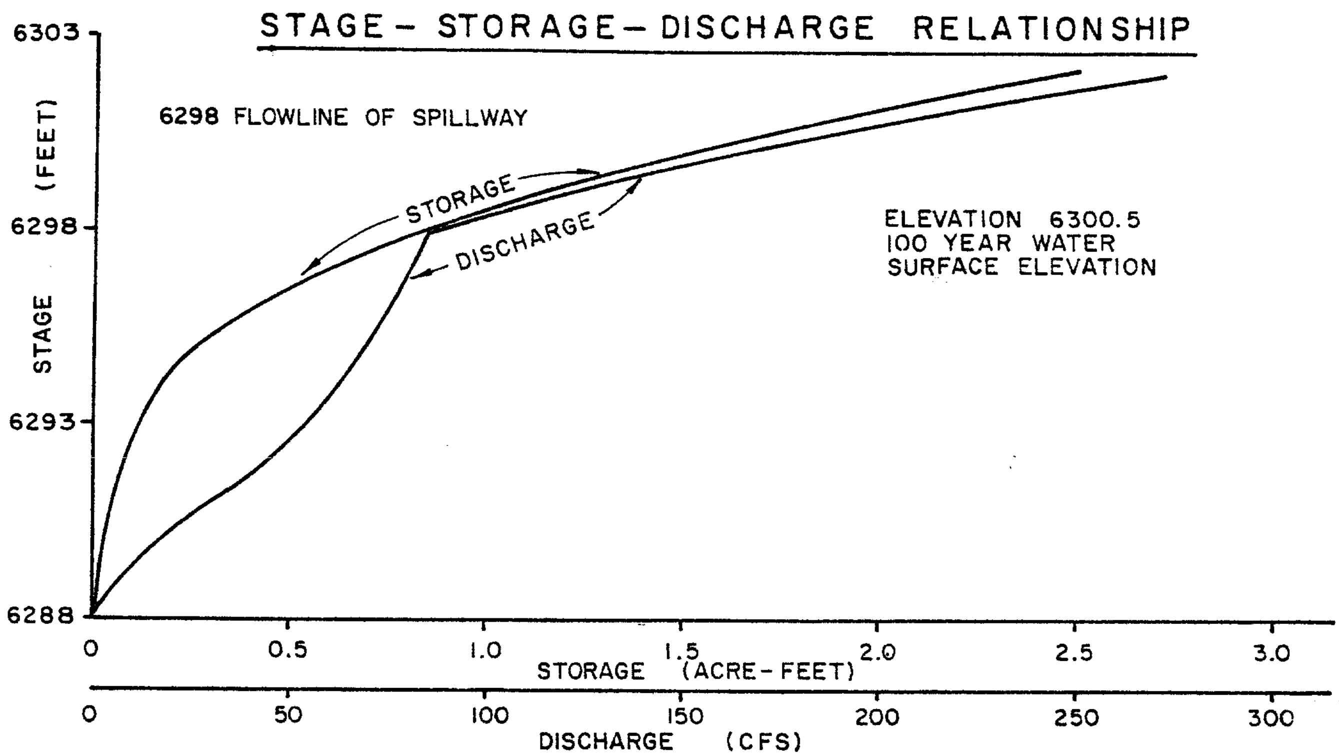


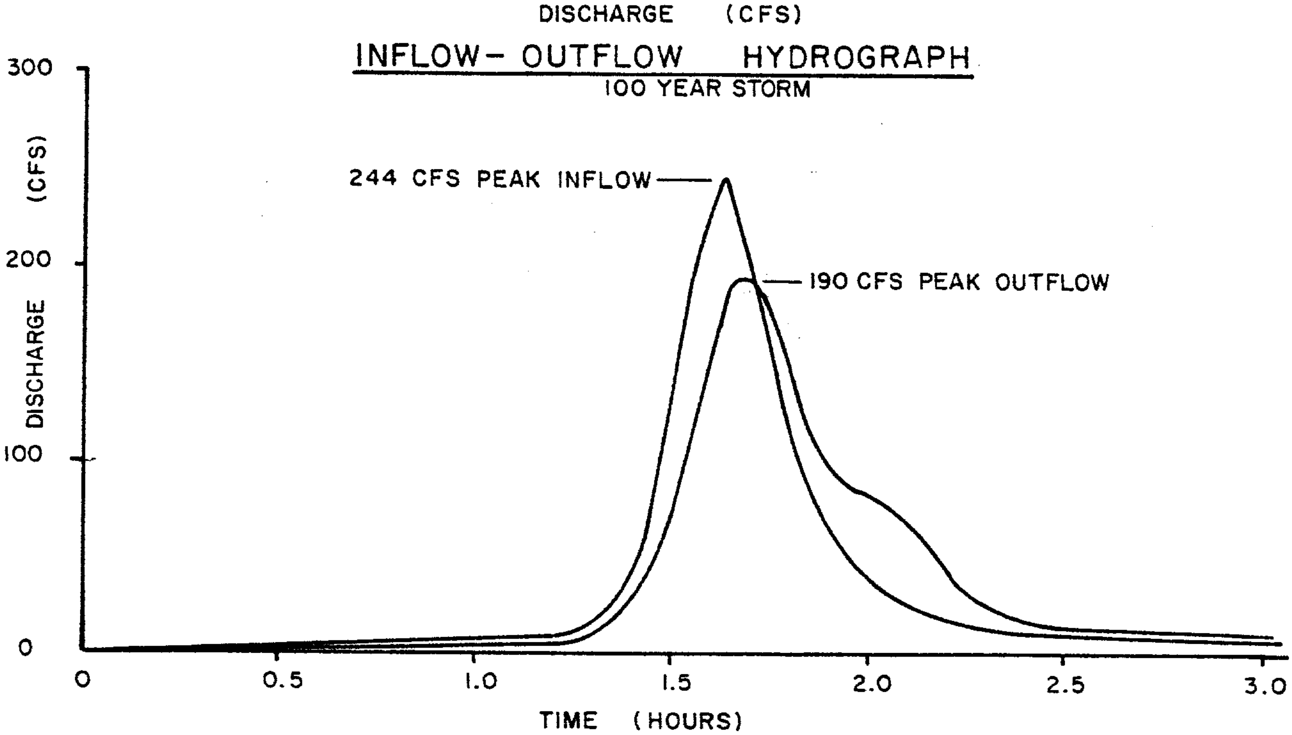
PROPOPOSED DETENTION RESERVOIR AT BASIN 4B



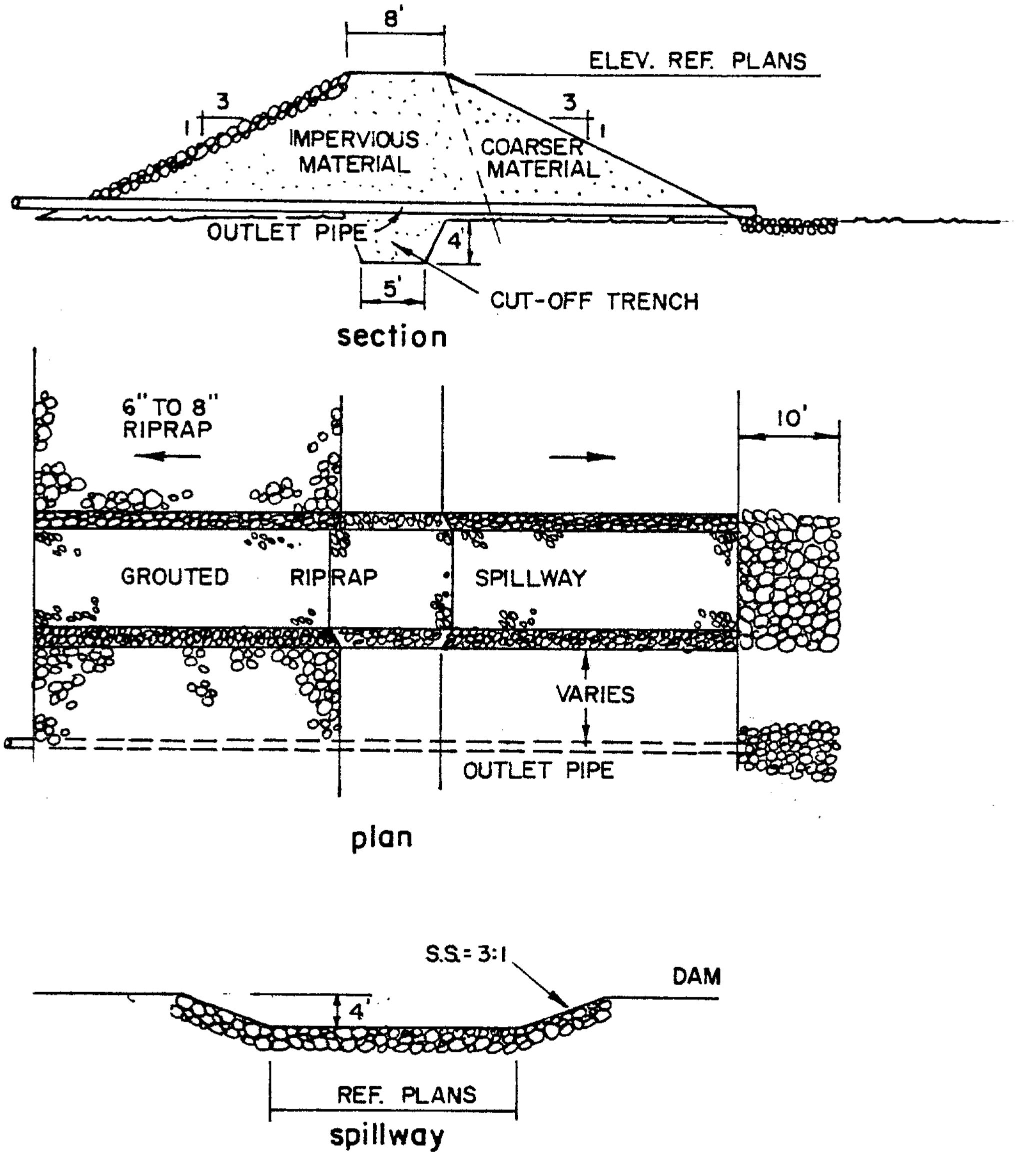
PROPOSED RETENTION–DETENTION RESERVOIR AT BASIN 5B



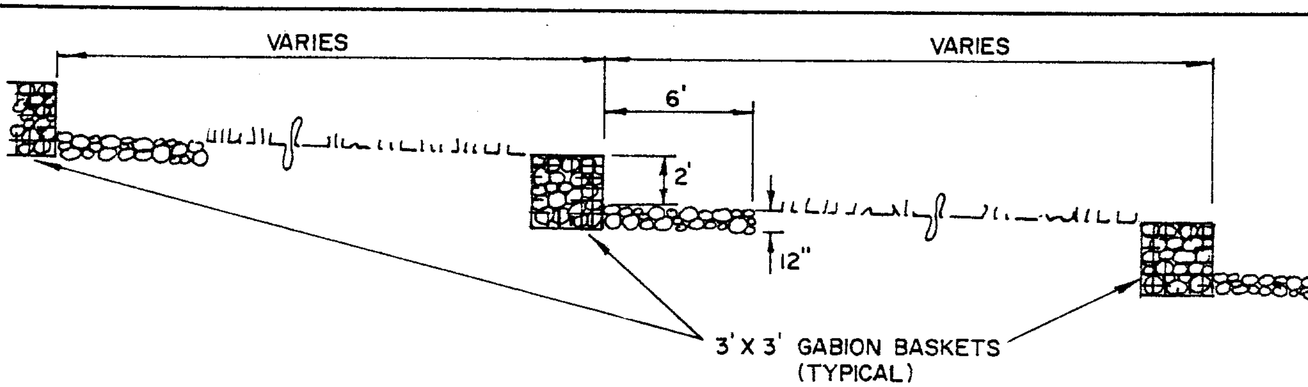




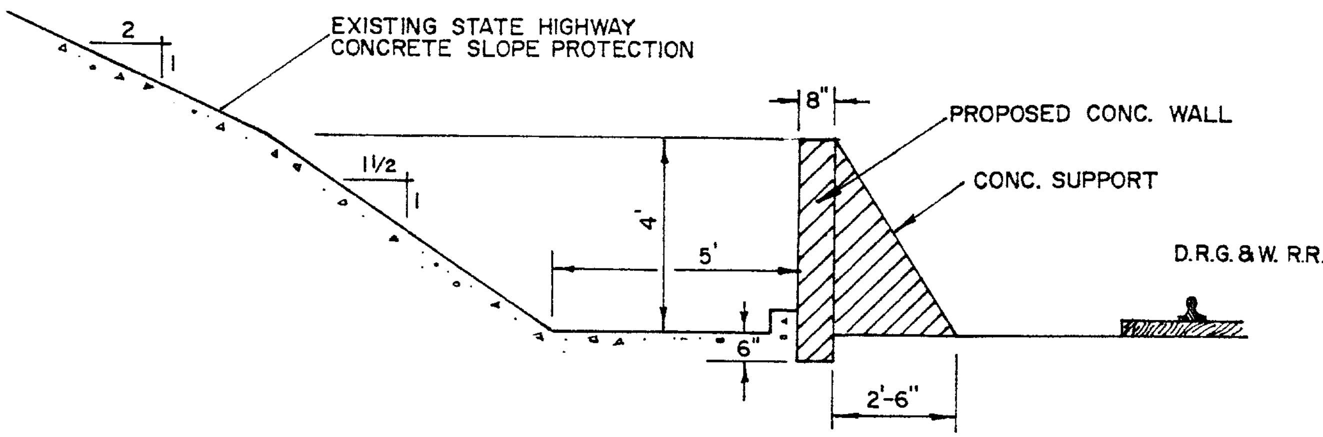
PROPOSED DETENTION RESERVOIR AT BASIN 8B



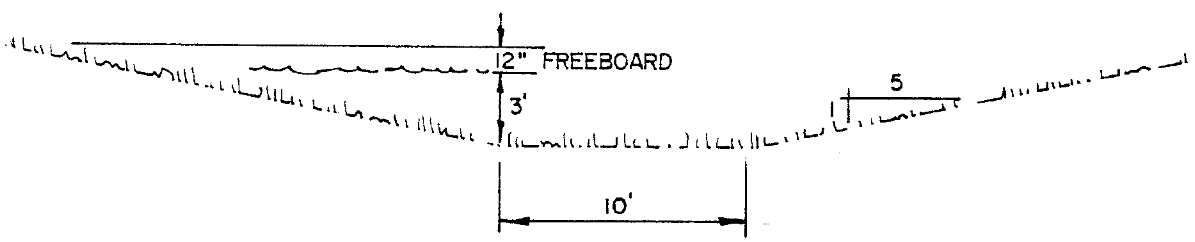
RIPRAP LINED SPILLWAY



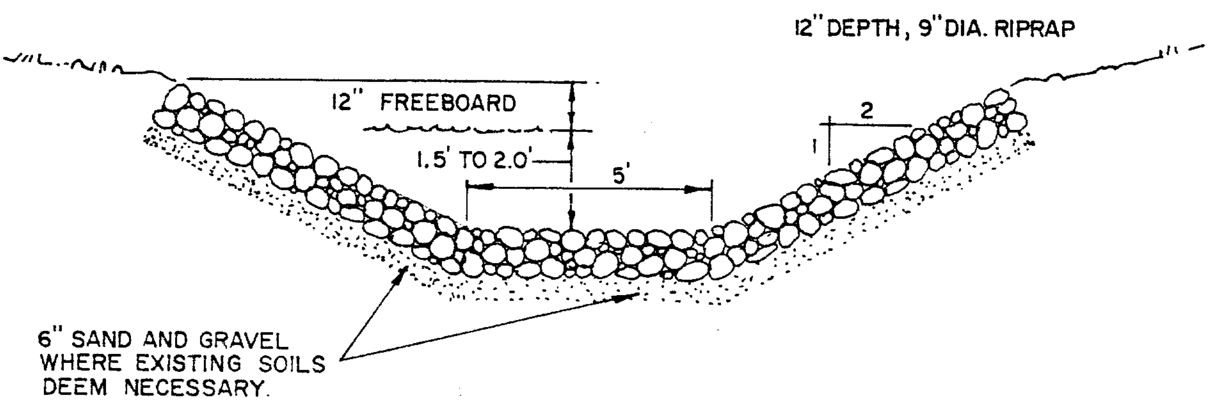
GABION BASKET DROP STRUCTURES



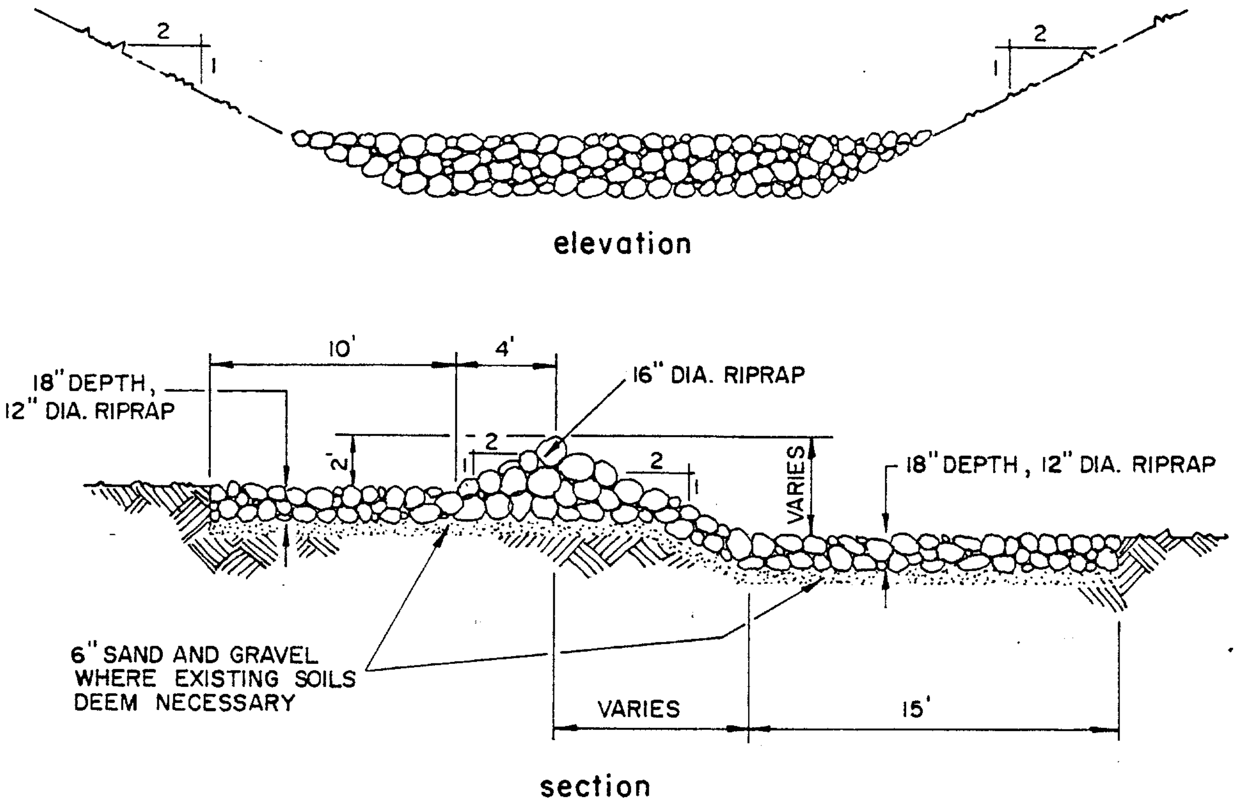
CONCRETE CHANNEL



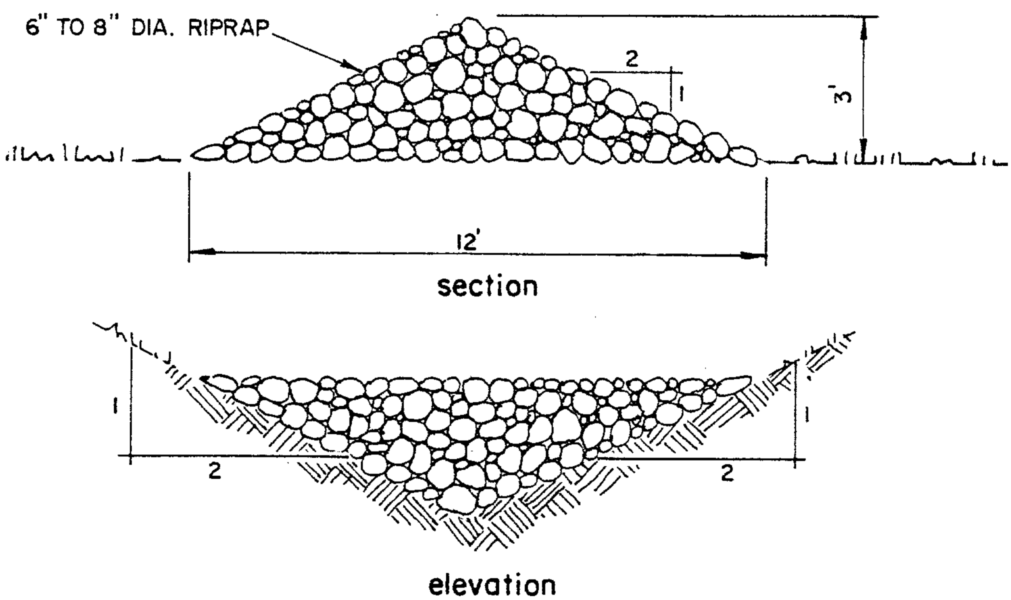
GRASS LINED CHANNEL



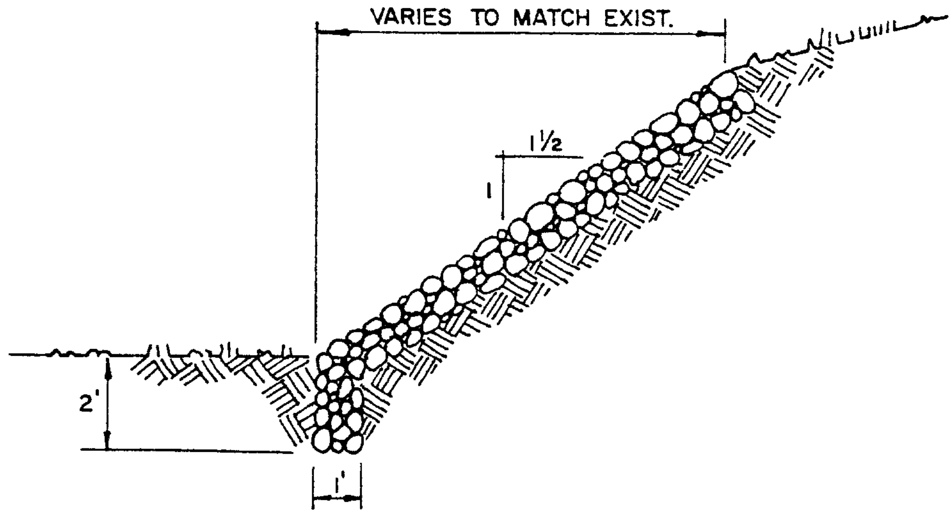
RIPRAP LINED CHANNEL



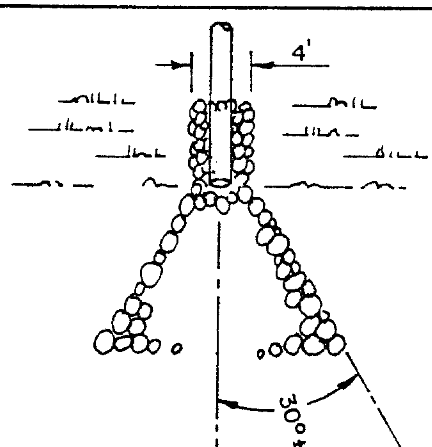
RIPRAP DROP STRUCTURE

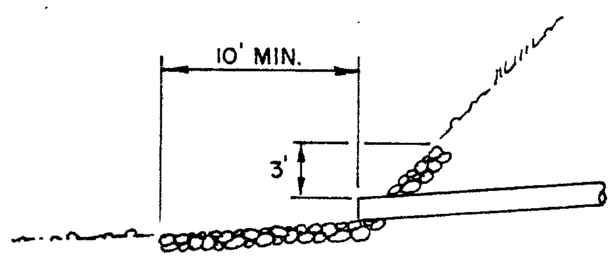


RIPRAP CHECK STRUCTURE



EMBANKMENT PROTECTION





RIPRAP PIPE OUTLET PROTECTION