BOULDER SLOUGH
FLOOD PLAIN STUDY

PREPARED FOR
THE CITY OF BOULDER
BOULDER, COLORADO 80306

PREPARED BY:
MULLER ENGINEERING COMPANY, INC.
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215

PROJECT NO. 8108

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I. INTRODUCTION

This study was initiated by the City of Boulder to assess the potential for and extent of flooding along the Boulder Slough, particularly in the study reach between 24th Street (Folsum) and 47th Street. This assessment was brought about after the change of the flood plain map for Boulder Creek, wherein the area along the Boulder Slough and within the limits of this study, was identified to be free from flooding from the 100-year flood in Boulder Creek. The City wished to determine the potential flood hazard to the Crossroads Shopping Center area and other public and private properties along the slough.

The Boulder Slough was once a flood slough for Boulder Creek. Presently, the slough has been improved to more efficiently carry irrigation waters for the Boulder and Left Hand Ditch and North Boulder Farmers Ditch. Over the years, the slough has been constricted by adjoining developments and road crossings which have restricted the flood flow carrying capability of the slough. A description of the structures located along the slough is provided later in the report.

A previous drainageway planning study of the slough recommended certain improvements to increase the capacity of the slough drainage system. That study was completed in June, 1970, by Wright-McLaughlin Engineers.

The study area and vicinity information are shown in Figure 1. Sheet 1 of 1, in the back pocket, also shows more detail of the general area adjoining the slough.

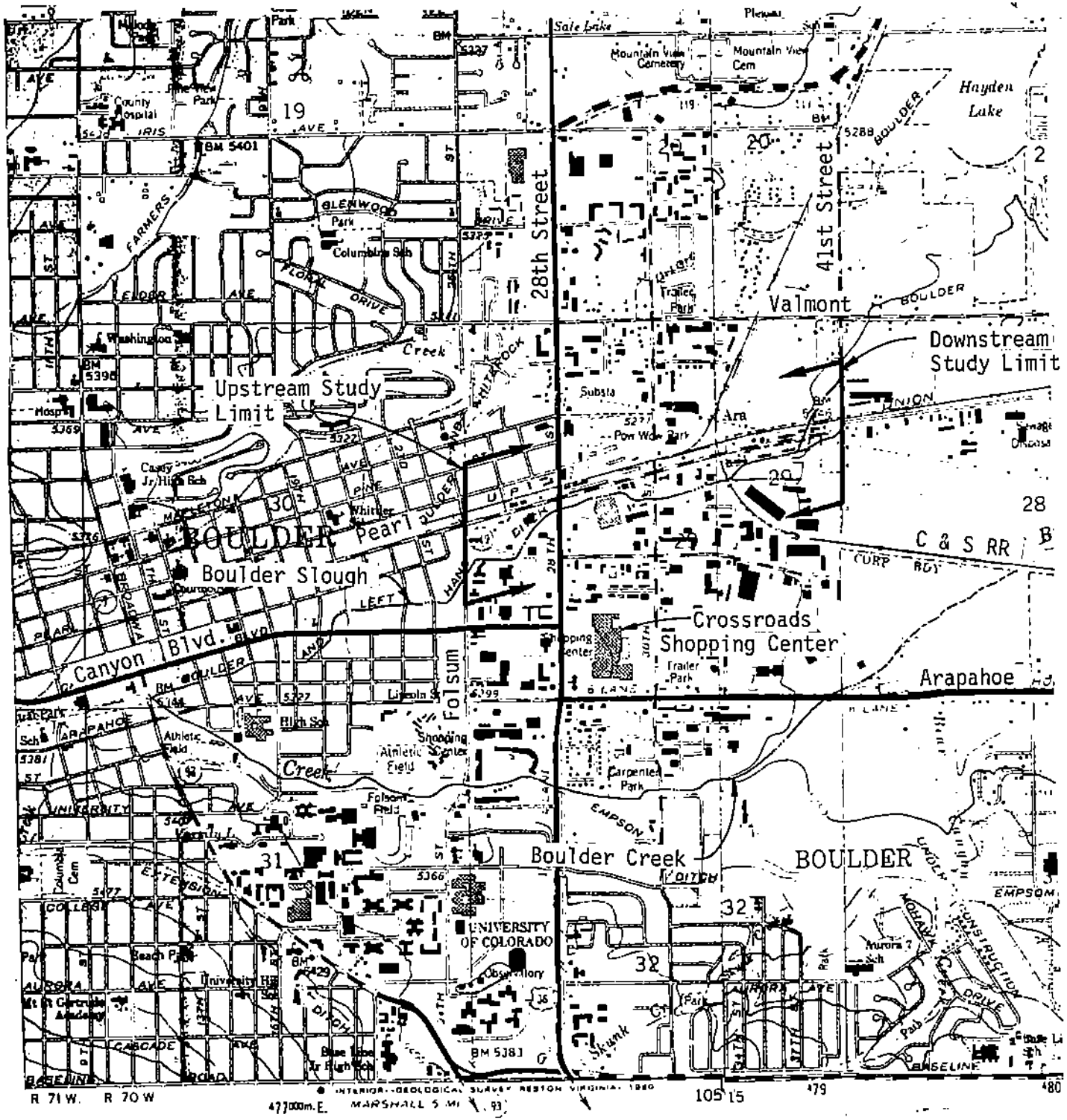


FIGURE 1

BOULDER SLOUGH
STUDY AREA

MEC FILE NO. 8108

II. SCOPE OF STUDY

The study of the Boulder Slough flood plain was based upon topography of the area as prepared in 1970 by Falcon Air Maps. The study area map has been upgraded in certain locations to show buildings which have been built in the study area as of February, 1978. The original mapping was prepared at a scale of 1" = 200', with a 2-foot contour interval. Recent updates of the mapping were prepared by Bell Mapping in Denver.

Site inspections, surveys and measurements were completed by Muller Engineering Company, Inc. to confirm structure sizes, types and conditions. A photo record of the facilities is on file at the office of the engineer. Surveys were made to the extent of measuring elevation differences between slough flow lines and the top of roads or crossing structures. Also, selected cross sections were measured at certain locations. Previous design information, studies and storm sewer maps, pertinent to the study, were obtained from the City.

The flow carrying capacity of structures within the slough were computed based on the field measurements. Also, surface drainage areas tributary to the slough were delineated, based on maps and field inspections, and runoff from those areas based on a 100-year storm event, were computed. Knowing tributary flows to each design point and the hydraulic capacity of each structure, a potentially floodable area could be delineated.

The following sections discuss the specific study analyses and results in more detail.

III. DESCRIPTION OF BOULDER CREEK FLOOD SLOUGH

As mentioned previously, the slough is used as an irrigation channel to transport waters to users north and east of town. As the channel traverses through town, it passes through residential, commercial and industrial areas. In the residential areas, the slough has been pleasantly incorporated into site improvements. Through the commercial and industrial areas, the channel has been enclosed or concrete lined.

Generally three different channel types exist along the slough as described below:

1. Natural channel with variations in depth, cross section, and somewhat irregular side slope. Scattered loose cobbles and coarse gravel exist on the bottom. Trees, bushes and roots exist along the side. Concrete walls are found along some of the reaches where residential development projects have been completed along the bank of the slough.
2. Concrete lined channels with straight alignments and uniform shape.
3. Underground conduits which replace the original slough thalweg.

In addition to the different channel conditions, there are a number of crossing structures along the slough. Of these crossing structures, most are concrete box culverts, while a few are oval metal pipe, elliptical concrete pipe, or circular pipe.

Diversion gates exist along the Slough to permit the slough to function as an irrigation ditch. The gates are used to divert flow from the slough into lateral ditches. Operation of the gates has a significant effect on the ability of the slough to convey flood waters. With gates closed during flood time, certain amounts of water would be forced to flow into the adjoining

bank areas. As the adjoining terrain is relatively flat, shallow flooding may occur and in areas around the gates the water would eventually return back to the slough by means of streets or storm sewers.

This study assumes that during a flood event all of the main channel gates would be opened in order to convey the flood water by utilizing the maximum capacity of the slough. This is characteristic of the condition of the slough during flood periods, which is concurrent with the irrigation season.

Storm sewer lines from adjoining areas are designed to drain storm water into the slough. All the contributing storm water pipes in the study area are shown in Sheet 1 of 1.

A list of the hydraulic structures in the slough between 18th Street and 47th Street is tabulated in Table 1.

TABLE 1

BOULDER SLOUGH

LOCATION OF STRUCTURES

No.	Location	Type/Description	Size (w x d)
1	18th Street	Stone Conc. bridge	15' x 3'
2	19th Street	Conc. box	15' x 3'
3	Canyon Blvd.	Conc. box	20' x 4'
4	Bet. Canyon Blvd. Bldg. (and 22nd St.)	Conc. box	20' x 5.5'
5	Bet. Building & 22nd St.	Conc. box w/gates	2- 4'x'4
6	22nd Street	RCP (oval)	3- 45" x 29"
7	23rd Street	Conc. box	7.5' x 3'
8	Just east of 23rd St.	Conc. bridge	15' x 4'
9	24th Street	Conc. box	11' x 3'
10	Just east of 24th St. and Building	Conc. box	21' x 2.5'
11	Bet. 24th & 26th Sts. (new road)	Conc. box	9' x 3.5'
12	26th Street	Conc. box	12' x 2.5'
13	West of 28th St.	RCP/Storm sewer	48"
14	28th St.	CMPA	148" x 84" (transition to 148"x48" box culvert)
15	Target Store (U/S side)	RCP	2- 66"
16	Target Store (U/S side)	CMP/Storm sewer	24"
17	Target Store (D/S side)	Box w/gate(diversion)	6' x 3'
18	30th Street	Bridge	33' x 5'
19	C & S RR (U/S)	Conc. box	2- 7' x 35"
20	C & S RR (O/S)	Diversion structure	12' x 3' - main channel 24'x1.5' conc. weir - overflow
21	Frontier Ave.	Conc. box	9' x 3'
22	Bet. Frontier Ave. and Pearl St.	Diversion structure	2- 60" x 52" openings
23	Pearl St.	CMPA	60" x 44"
24	47th St.	CMP (oval)	70" x 48"
25	Bet. 25th & 26th Sts.	CMP/Storm sewer	24"
26	30th St. Bridge	RCP/Storm sewer	1- 39", 1- 30"
27	Target Store (D/S side)	RCP/Storm sewer	2- 24", 1- 18"

IV. HYDROLOGY

The Boulder Creek Flood Slough serves mainly as an irrigation ditch. During flood season, it also serves as a drainage channel. The amount of flood water that can be conveyed through the slough depends on 1) the maximum flow rate for irrigation, 2) operation schedule of the control gates along the slough. The Water Commissioner was contacted and reported the maximum irrigation flow rate could range from 60 cfs to 100 cfs. He also indicated there is no particular operational schedule of the gates in the slough. Changes in the gate settings depended on water needs.

The flood flow in the slough is also dependent on how much flood water is tributary from the creek. The official Boulder Creek 100-year flood plain map shows the floodplain to intercept the slough at 18th Street. Thus, the maximum flow diverted into the slough from the Creek could be estimated by analyzing the maximum culvert capacity at the 18th Street crossing, which is calculated to be 225 cfs.

The amount of flow can be treated as a base flow and added to the local 100-year tributary surface flow at each designated design point. If flows are diverted from the slough, the amount of diverted or escaped flow is subtracted from the total flow. Where the storm sewers drain into the slough, an assumed full flow capacity from the sewer pipe has been added to the total flow at the related design point.

The 100-year local developed flows have been calculated using the Rational Formula, $Q = C_f .C.I.A$, where Q = discharge in cfs, C_f = frequency (antecedent moisture) factor; C = runoff coefficient, I = intensity in inch-per-hour, A = drainage area in acres. The 100-year rainfall intensity (I) for the study area was obtained from the publication "Project REUSE", published by the Denver Regional Council of Governments and the Urban Drainage and Flood Control District.

The 100-year time-intensity tabulation is provided in Table 2. Drainage basins which contribute flow into the slough are delineated on available 1" = 200' scale, 2-foot contour mapping (Sheet 1 of 1), which have been verified in the field. Each design point and the calculated surface inflows are tabulated in Table 3.

TABLE 2

100-Year Rainfall Time-Intensity Tabulation
Boulder County
(T. 1 N., R. 70 W.)

Time (Min.)	Intensity (inches/hr)
10	7.65
20	5.50
30	4.35
40	3.55
50	2.90
60	2.50

The calculated 100-year discharges at certain design points is different from predicted discharges in the previous study titled "Pilot Planning Study - Boulder Creek Flood Slough, Vol. III", by Wright-McLaughlin Engineers, completed in June, 1970. That study computed a discharge of 1000 cfs near the lower end of the study area, compared to the estimate of 700 cfs determined in this study. The primary reason for this difference is the earlier study considered that a much larger surface drainage area is tributary to the slough than presently is the case.

TABLE 3

SUMMARY OF CALCULATED INFLOWS

Tributary surface inflows to Boulder Slough
Canyon Blvd. to 47th St.

Design Point & Basin Number	Location	Drainage Area (acres)	100-year surface inflow (cfs)
1*	Canyon Blvd.	3.44	9
2*	22nd Street	14.28	27
3	24th Street	3.00	6
4	26th Street	5.86	41
5	28th Street	8.81	73
6	30th Street	11.72	90
7	C & S RR	23.81	75
8	Diversion east of Frontier Rd.	3.67	9
9	Pearl Street	3.48	6
10	47th Street	2.72	5

* Not shown on Sheet 1 of 1

V. HYDRAULICS

The hydraulic structures and the representative channel configuration and conditions along the study reach were photographed and measured in the field. In order to compute channel capacity, channel cross sections were taken from the available topographic map and approximated by regular sections for each different reach. The natural channel roughness coefficient of 0.040 to 0.045 was selected. A coefficient of 0.20 was used for the concrete channels. These coefficients were selected following a thorough field investigation. Normal depth calculations were used to calculate the flood width and average flood depth along the channel and the overbank areas.

Each crossing structure was analyzed by assuming an inlet control situation. Where flows overtop crossing structures, the broadcrested weir flow formula, $Q = CLH^{3/2}$ was used to estimate the weir flow depth on top of that crossing.

Flow rates were determined at each design point by adding the base flow to the surface inflow and the flow from the storm sewer inflows. The diverted or escaped flows were subtracted from the total inflow at the various design points. A summary of the capacities for each crossing and the routed flow rates at each design point are provided in Tables 4 and 5. The plotted 100-year water surface profile along the study reach is shown in Sheet 1 of 1.

TABLE 4

HYDROLOGY SUMMARY

Design Point	Base Inflow (cfs)	Surface Inflow (cfs)	Flow from Storm Sewer (cfs)	Total Inflow (cfs)	Total Diverted Outflow (cfs)	Total Outflow (cfs)	Remarks
1	225	9	-	234	-	234	
2	234	27	-	261	50	211	Irrigation diversion
3	211	6	-	217	30	187	Irrigation diversion
4	187	41	17	245	17	228	Street overflow
5	228	73	90	391	-	391	
6	391	90	134	615	-	615	
7	615	75	-	690	200	490	Railroad diversion
8	490	9	-	499	268	231	Spillway diversion & 20% of Frontier Rd. overflow
9	231	6	-	237	115	122	Irrigation diversion
10	122	5	-	127	-	127	

TABLE 5

STRUCTURE CAPACITIES AND CALCULATED FLOWS

No.	Location	Structure	Calculated* Maximum Capacity (cfs)	Calculated Flow Rate Thru Structure (cfs)	Calculated Overflow (cfs)	Calculated Total Outflow (cfs)	Remarks
1	18th Street	Stone & concrete bridge	225	225	-	225	
2	19th Street	Conc. box	225	225	-	225	
3	Canyon Blvd. (DP-1)	Conc. box	460	234	-	234	
4	Building (bet.Canyon Blvd. & 22nd St.	Conc. box	740	234	-	234	
5	Bet. Building & 22nd St.	Conc. box w/gates	184	184	-	184	50 cfs diverted to north
6	22nd Street (DP-2)	RCP (oval)	165	165	46	211	
7	23rd Street	Conc. box	180	180	31	211	
8	Just east of 23rd St.	Conc. bridge	345	181	-	181	30 cfs diverted to south
9	24th Street (DP-3)	Conc. box	286	187	-	187	
10	Just east of 24th St. and Building	Conc. box	441	187	-	187	
11	Bet. 24th & 26th Sts. (new road)	Conc. box	261	187	-	187	
12	Bet. 25th & 26th Sts.	CMP/Storm sewer	17	17	-	17	
13	26th Street (DP-4)	Conc. box	228	228	17	228	17 cfs overflow to north
14	West of 28th Street	48" RCP/Storm sewer	90	90	-	90	

TABLE 5

STRUCTURE CAPACITIES AND CALCULATED FLOWS

No.	Location	Structure	Calculated* Maximum Capacity (cfs)	Calculated Flow Rate Thru Structure (cfs)	Calculated Overflow (cfs)	Calculated Total Outflow (cfs)	Remarks
15	28th Street (DP-5)	CMPA	700	391	-	391	
16	Target Store (U/S side)	CMP/Storm sewer (24")	17	17	-	17	
17	Target Store (U/S side)	2 - RCP (66")	600	408	-	408	
18	Target Store (D/S side)	Box w/gate(diversion)	90	90	-	90	
19	Target Store (D/S side)	3- RCP/Storm sewer	42	42	-	42	
20	30th St. Bridge	2- RCP/Storm sewer	75	75	-	75	
21	30th Street (DP-6)	Bridge	1881	615	-	615	
22	C & S RR (U/S)(DP-7)	Conc. box	560	490	200	690	200 cfs diverted to south
23	C & S RR (D/S)	Spillway structure	243	243	-	243	247 cfs diverted into main slough
24	Frontier Ave.	Conc. box	135	135	108	243	
25	Bet. Frontier Ave. & Pearl St. (DP-8)	Diversion structure	115	115	-	130	115 cfs diverted to north
26	Pearl Street (DP-9)	CMPA	110	110	12	122	
27	47th Street (DP-10)	CMP (oval)	110	110	17	127	

*Based upon inlet control with headwater depth at road crossing elevation.

VI. FLOODPLAIN DESCRIPTION

The 100-year floodplain for the Boulder Creek Flood Slough is described in the following paragraphs.

1. 24th Street to 26th Street

Flood flows are confined in the concrete-lined channel which passes under the building near the east side of 24th Street. Flows will also pass through the bridge just east of that building.

Once the flow passes through the bridge, overbank flows would occur due to the limitations of the culverts located at 25th and 26th Streets. Estimated flow depths on the overbank area is less than one foot, based upon the mapped contours. About 17 cfs would overtop the crossing at 26th Street and flow to the north along the 26th Street. Those flows would pond midway between Walnut and Pearl and be drained by the existing storm sewer. If depths become too great, shallow flooding will occur to the east across the Woolco parking lot and return to the slough at 28th Street.

2. 26th Street to 28th Street

Through this reach, the slough is enclosed in a 570-foot, 12 x 2.5-foot concrete box culvert with the exception of a short length of open ditch between the end of the box culvert and 28th Street. A 48-inch reinforced concrete pipe drains storm water into the slough near the west side of the 28th Street crossing. The 28th Street crossing has a maximum culvert capacity of 700 cfs. Therefore, the calculated 100-year total inflow of 391 cfs would easily pass through the culvert without creating flooding problems. Some shallow flooding may occur around the open ditch. Also, the parking lot area east of 26th Street could have some sheet flow due to possible overtopping flows from 26th Street. The flood depth in the above-mentioned flood areas are estimated to be less than one foot.

3. 28th Street to 30th Street

From the east side of 28th Street, the Boulder Flood Slough is enclosed in two 66-inch concrete pipes which daylight at the northeast corner of the Target Store. At this point, special structures control channel flows, directing discharges in the main slough channel and into a special pond east of the store, which also spills into the main channel, approximately 300-feet west of 30th Street. Flooding may occur outside of normal channel banks near the diversion structure but will return to the main channel section upstream of 30th Street.

No 100-year flood flows would escape from the slough area in this reach.

4. 30th Street to Colorado & Southern R.R.

The estimated flow at 30th Street is 615 cfs or approximately one-third the hydraulic capacity of the existing bridge. Storm sewers drain into the slough from the north and south at the 30th Street bridge. Downstream of 30th Street, the 100-year flow exceeds the normal channel capacity, however, no flows are lost from the main slough section.

At the railroad, the existing concrete box structure has a calculated capacity of 490 cfs compared to an estimated 100-year flow of 692 cfs. During a 100-year event, flows will pond upstream of the embankment, flooding the adjoining, low-lying buildings, and will spill to the southeast near 33rd Street, and over the railroad tracks into the warehouse area to the east.

The flow spilling to the southeast, on the west side of the tracks, will spread out between the buildings into a shallow flooding condition, and would likely drain to Boulder Creek along the south side of the tracks.

5. Colorado & Southern R.R. to 47th Street

Downstream of the railroad crossing, the flood slough channel splits from the irrigation ditch. This is accomplished by a concrete spillway

structure which controls the channel flows that are contained in the irrigation ditch. With higher flow stages in the structure, flood flows are diverted from the main channel and into the broad, flat slough section, north of the warehouses. The diversion structure will pass approximately half the flood flow into the slough and the other half into the irrigation ditch.

The Frontier Road crossing on the irrigation ditch will divert additional waters from the concrete irrigation channel into the slough.

Further downstream on the ditches, the Pearl Street and 47th Street culverts have limited capacities which may cause minor overflows on those streets. The flooding at those crossings is dependent on the amount of water which may be diverted north in the North Boulder Farmers Ditch.

The main slough area will be flooded to shallow depths on the order of 1- to 2-feet, or less.

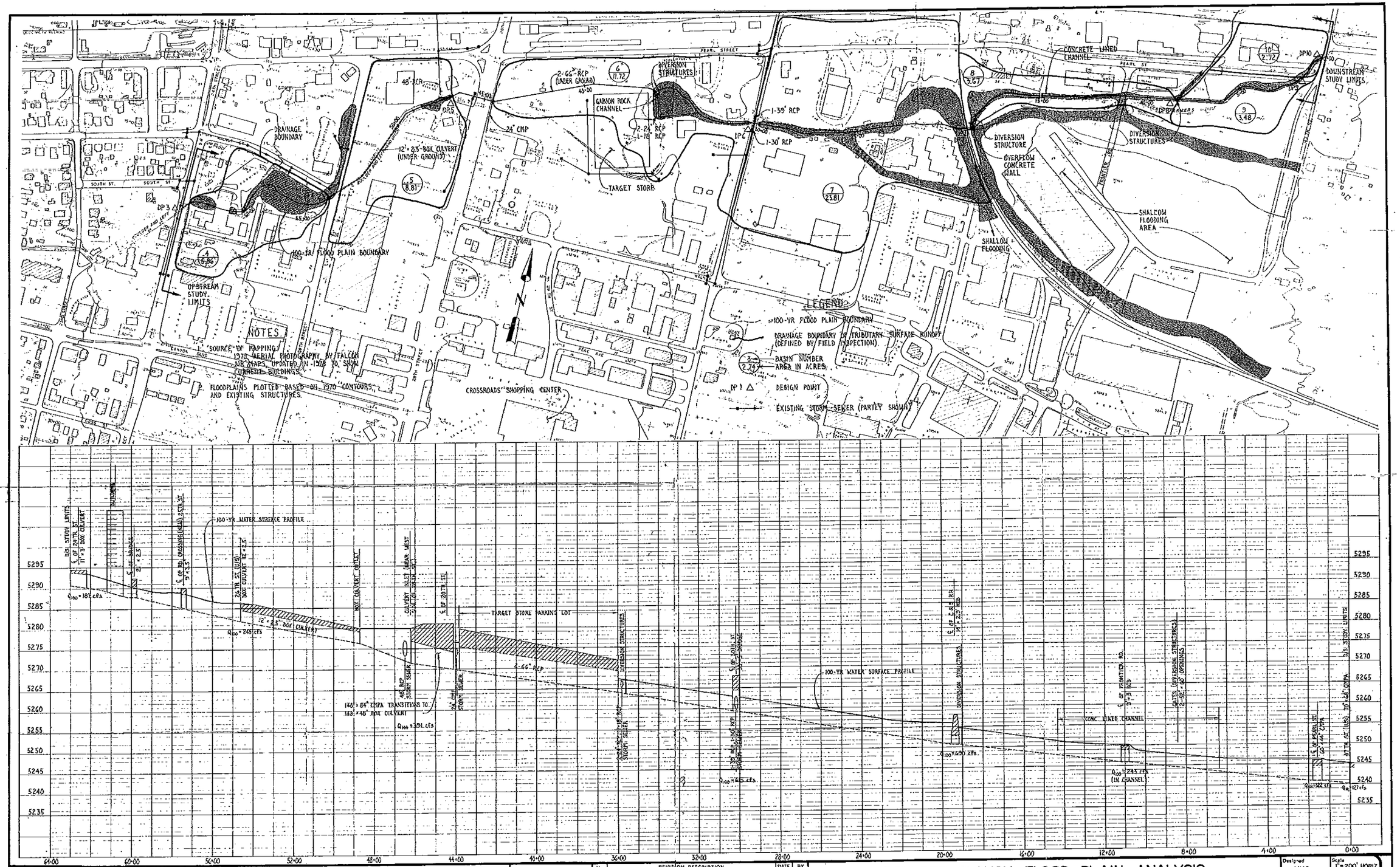
VII. SUMMARY

The following summary and conclusions can be drawn following this study:

1. The slough originates from Boulder Creek and serves as an irrigation facility as well as a storm water drain, and thus will be subject to receiving flood waters from the creek during a period of flooding or heavy rains.
2. The slough traverses an area of relatively flat terrain from Boulder Creek to 47th Street and thus does not have a large tributary area from which surface water runoff is received.
3. Many structures have been built to cross the slough limiting the hydraulic capacity and the ability to convey high flood flow rates.
4. The newer structures built to convey slough flows, generally east of 28th Street, are of an adequate capacity to pass the 100-year flow.

5. Presently, the only location identified within the limits of this study, where flood flows would escape from the slough into an adjoining drainage basin, is directly upstream of the Colorado & Southern R.R., near 33rd Street, where flows will be diverted to the east and south along the tracks.

6. No flood flows are diverted to the Crossroads Shopping Center from the Boulder Slough.



MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 232-9343

No.	REVISION DESCRIPTION	DATE	BY

BOULDER SLOUGH FLOOD PLAIN ANALYSIS

24TH. ST. TO 47TH. ST.

PLAN AND PROFILE

CITY OF BOULDER, COLORADO

Designed: YHC	Scale: 1"=200' HORIZ. 1"=10' VERT.
Drawn: JHK	Date: 8-12-81
Checked: LAM	Job: 8108
Approved for construction	Sheet: 1 OF 1