PRELIMINARY
DRAINAGE
REPORT FOR
MONTEBELLO DRIVE SANITARY
SEWER IMPROVEMENT DISTRICT
COLORADO SPRINGS, COLORADO

Drexel Barrell

Engineers/Surveyors
Incorporated

Boulder,
Colorado Springs

4840 Pearl East Circle
Suite 114
Boulder, Colorado 80301

303 442 4338

PRELIMINARY
DRAINAGE
REPORT FOR
MONTEBELLO DRIVE SANITARY SEWER IMPROVEMENT DISTRICT
COLORADO SPRINGS, COLORADO

PREPARED FOR:

THE CITY OF COLORADO SPRINGS
CITY ENGINEERING DIVISION
30 S. NEVADA ST., SUITE 403
COLORADO SPRINGS, CO 80901

PREPARED BY:

DREXEL BARRELL
4840 PEARL EAST CIRCLE
SUITE 114
BOULDER, CO 80301

DATE: January 12, 1989
REVISED: June 5, 1989
January 12, 1990

CE-3745

(0035R.BWT)

CITY OF COLORADO SPRINGS
The "America the Beautiful" City
DEPARTMENT OF PUBLIC WORKS **CITY ENGINEERING DIVISION (719) 578-6606**
30 S. NEVADA SUITE 403 P.O. BOX 1575
COLORADO SPRINGS, COLORADO 80901

February 6, 1990

Mr. John Common
Drexel Barrell
4840 Pearl East Circle
Suite 114
Boulder, CO 80301

RE: DRAINAGE REPORT FOR MONTEBELLO DRIVE SANITARY SEWER S.I.D.

Dear John:

Upon review of the revised Preliminary Drainage Report for Montebello Drive Sanitary Sewer Design which you sent me on January 18, 1990, it is my determination that this report satisfies the requirments as set forth in the Scope of Services for this contract and is complete and satisfactory for its intended purpose. The report is dated "Revised January 12, 1990".

This letter shall be evidence of the City's acceptance of this report. When the time comes, you will provide us with the appropriate number of copies. In the meantime, please send me two copies with this letter included at the begining of the text portion of the report.

Sincerely,

David R. Lethbridge

David R. Lethbridge
Subdivision Land Specilist

DRL/le

xc: Gary R. Haynes, City Engineer
Chris Smith, Subdivision Administrator

f-dl02L

TABLE OF CONTENTS

REFERENCES

1. "Pulpit Rock, Drainage Basin Plan, for the City of Colorado Springs" prepared by R. Keith Hook & Associates, Inc. in March 1968.

2. "Drainage Report, Erindale Heights Filing No. 10" prepared by Abbott & Jacobsen Engineering Services, September 11, 1974.

3. "Drainage Report & Plan, Triple - J Subdivision Filing No. 2" prepared by Leigh Whitehead & Associates in November 1984.

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5. "Drainage Report for Berkshire Plaza Subdivision" prepared by H.J. Kraettli & Sons; Inc. July 7, 1980.

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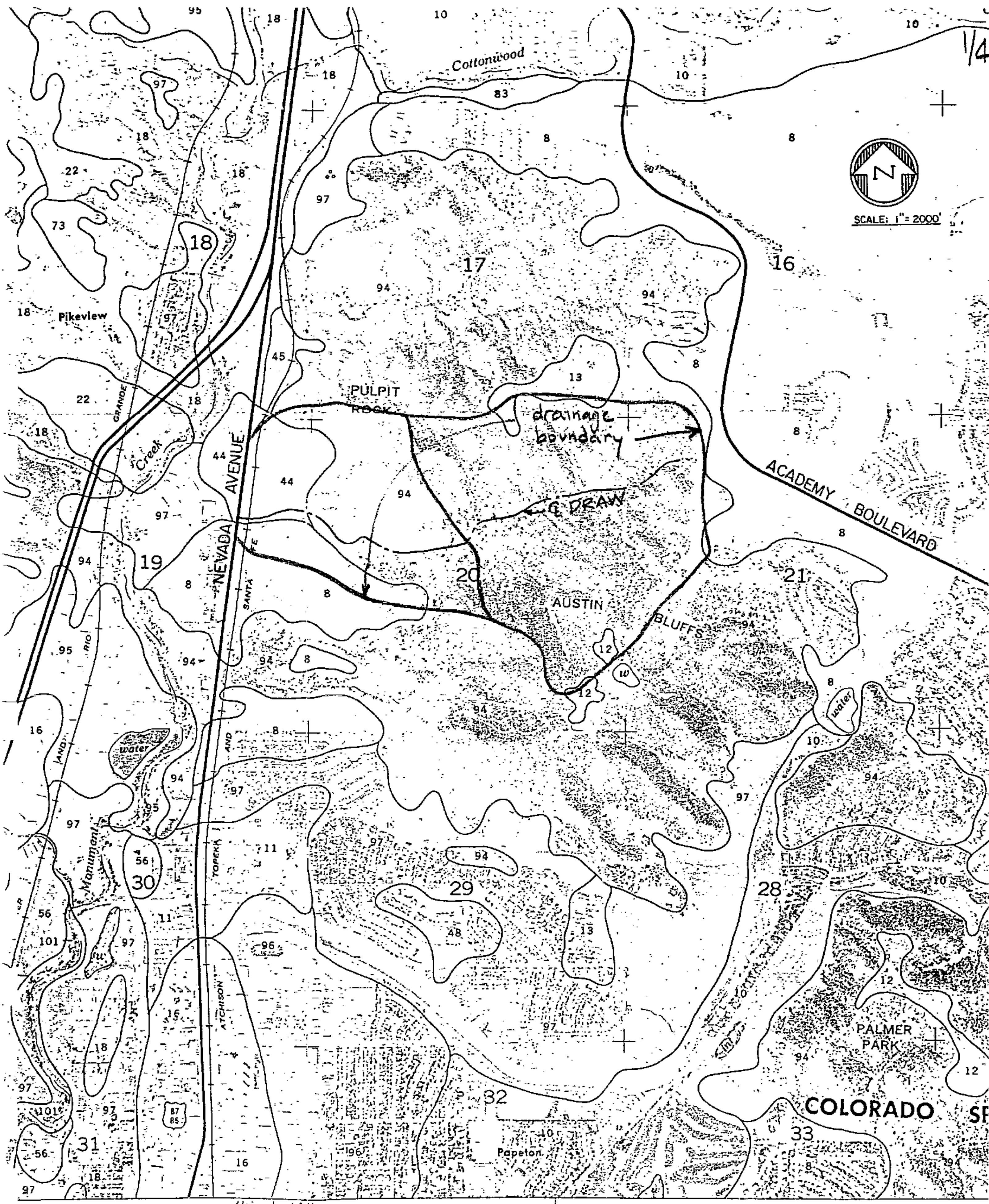
7. "Engineering Study and Revision of The North Shook's Run - Templeton Gap Drainage Basin, Colorado Springs, Colorado" prepared by Lincoln DeVore in September 1977.

8. "Soil Survey of El Paso County area, Coloraddo, United States Department of Agriculture, Soil Conservation Service, in cooperation with the Colorado Agricultural Experiment Station" issued 1981.

9. Project Formulation - Hydrology (1982 Jersion) Technical Release Number 20. (U.S.) Soil conservation Service, Washington, D.C.

10. "Preliminary Geotechnical Investigation, Houck Estate Property, Colorado Springs, Colorado" prepared by CTL/Thompson, Inc., March 9, 1983.



(Joins sheet 16)

66 W.

SCS SOILS MAP

Ref. 11

6-14

SOIL LEGEND

SYMBOL	NAME
1	Alamosa loam, 1 to 3 percent slopes
2	Ascalon sandy loam, 1 to 3 percent slopes
3	Ascalon sandy loam, 3 to 9 percent slopes
4	Badland
5	Bijou loamy sand, 1 to 8 percent slopes
6	Bijou sandy loam, 1 to 3 percent slopes
7	Bijou sandy loam, 3 to 8 percent slopes
→ 8	Blakeland loamy sand, 1 to 9 percent slopes
9	Blakeland complex, 1 to 9 percent slopes
10	Blendon sandy loam, 0 to 3 percent slopes
11	Bresser sandy loam, 0 to 3 percent slopes
12	Bresser sandy loam, 3 to 5 percent slopes
13	Bresser sandy loam, 5 to 9 percent slopes
14	Brussett loam, 1 to 3 percent slopes
15	Brussett loam, 3 to 5 percent slopes
16	Chaseville gravelly sandy loam, 1 to 8 percent slopes
17	Chaseville gravelly sandy loam, 8 to 40 percent slopes
18	Chaseville-Midway complex
19	Columbine gravelly sandy loam, 0 to 3 percent slopes
20	Connerton-Rock outcrop complex, 8 to 90 percent slopes
21	Cruckton sandy loam, 1 to 9 percent slopes
22	Cushman loam, 1 to 5 percent slopes
23	Cushman loam, 5 to 15 percent slopes
24	Cushman-Kutch complex, 3 to 12 percent slopes
25	Elbeth sandy loam, 3 to 8 percent slopes
26	Elbeth sandy loam, 8 to 15 percent slopes
27	Elbeth-Pring complex, 5 to 30 percent slopes
28	Ellicott loamy coarse sand, 0 to 5 percent slopes
29*	Fluvaquentic Haplaquolls, nearly level
30	Fort Collins loam, 0 to 3 percent slopes
31	Fort Collins loam, 3 to 8 percent slopes
32	Fortwingate-Rock outcrop complex, 15 to 60 percent slopes
33	Heldt clay loam, 0 to 3 percent slopes
34	Holderness loam, 1 to 5 percent slopes
35	Holderness loam, 5 to 8 percent slopes
36	Holderness loam, 8 to 15 percent slopes
37	Jarre gravelly sandy loam, 1 to 8 percent slopes
38	Jarre-Tecolote complex, 8 to 65 percent slopes
39	Keith silt loam, 0 to 3 percent slopes
40	Kettle gravelly loamy sand, 3 to 8 percent slopes
41	Kettle gravelly loamy sand, 8 to 40 percent slopes
42	Kettle-Rock outcrop complex
43	Kim loam, 1 to 8 percent slopes
→ 44	Kutch clay loam, 3 to 5 percent slopes
45	Kutch clay loam, 5 to 20 percent slopes
46	Kutler-Broadmoor-Rock outcrop complex, 25 to 90 percent slopes
47	Limon clay, 0 to 3 percent slopes
48	Louviers silty clay loam, 3 to 18 percent slopes
49	Louviers cobbly clay loam, 5 to 40 percent slopes
50	Manvel loam, 3 to 9 percent slopes
51	Manzanola clay loam, 0 to 1 percent slopes
52	Manzanola clay loam, 1 to 3 percent slopes
53	Manzanola clay loam, 3 to 9 percent slopes
54	Midway clay loam, 3 to 25 percent slopes
55	Nederland cobbly sandy loam, 9 to 25 percent slopes
56	Nelson-Tassel fine sandy loams, 3 to 18 percent slopes
57	Neville fine sandy loam, 3 to 9 percent slopes
58	Neville-Rednun complex, 3 to 9 percent slopes
59	Nunn clay loam, 0 to 3 percent slopes
60	Olney sandy loam, 0 to 3 percent slopes
61	Olney sandy loam, 3 to 5 percent slopes
62	Olney and Vona soils, eroded
63	Paunsaugunt-Rock outcrop complex, 15 to 65 percent slopes
64	Penrose-Manvel complex, 3 to 45 percent slopes
65	Perrypark gravelly sandy loam, 3 to 9 percent slopes
66	Peyton sandy loam, 1 to 5 percent slopes
67	Peyton sandy loam, 5 to 9 percent slopes
68	Peyton-Pring complex, 3 to 8 percent slopes
69	Peyton-Pring complex, 8 to 15 percent slopes
70	Pits, gravel
71	Pring coarse sandy loam, 3 to 8 percent slopes
72	Pring coarse sandy loam, 8 to 15 percent slopes
73	Razor clay loam, 3 to 9 percent slopes
74	Razor stony clay loam, 5 to 15 percent slopes, clay loams
75	Razor-Midway complex
76	Rizozo-Neville complex, 3 to 30 percent slopes
77	Rock outcrop-Coldcreek-Tolman complex, 9 to 90 percent slopes
78	Sampson loam, 0 to 3 percent slopes
79	Santanta loam, 0 to 3 percent slopes
80	Santanta loam, 3 to 5 percent slopes
81	Santanta-Neville complex, 3 to 8 percent slopes
82	Schamber-Razor complex, 8 to 50 percent slopes
83	Stapleton sandy loam, 3 to 8 percent slopes
84	Stapleton sandy loam, 8 to 15 percent slopes
85	Stapleton-Bernal sandy loams, 3 to 20 percent slopes
86	Stoneham sandy loam, 3 to 8 percent slopes
87	Stoneham sandy loam, 8 to 15 percent slopes
88	Stroupe-Travessilla-Rock outcrop complex, 9 to 90 percent slopes
89	Tassel fine sandy loam, 3 to 18 percent slopes
90	Terry sandy loam, 1 to 8 percent slopes
91	Terry-Razor complex, 3 to 20 percent slopes
92	Tomah-Crowfoot loamy sands, 3 to 8 percent slopes
93	Tomah-Crowfoot loamy sands, 8 to 15 percent slopes
X→ 94	Travessilla-Rock outcrop complex, 8 to 90 percent slopes
95	Truckton loamy sand, 1 to 9 percent slopes
96	Truckton sandy loam, 0 to 3 percent slopes
97	Truckton sandy loam, 3 to 9 percent slopes
98	Truckton-Blakeland complex, 9 to 20 percent slopes
99	Truckton-Bresser complex, 5 to 20 percent slopes
100	Truckton-Bresser complex, eroded
101*	Ustic Torrifluvents, loamy
102	Valent sand, 1 to 9 percent slopes
103	Valent sand, 9 to 20 percent slopes
104	Vona sandy loam, 1 to 3 percent slopes
105	Vona sandy loam, 3 to 9 percent slopes
106	Wigton loamy sand, 1 to 8 percent slopes
107	Wiley silt loam, 1 to 3 percent slopes
108	Wiley silt loam, 3 to 9 percent slopes
109	Yoder gravelly sandy loam, 1 to 8 percent slopes
110	Yoder gravelly sandy loam, 8 to 25 percent slopes

* Broadly defined units.

Ref. 11

TABLE 14.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
Blakeland: 8	0-11	Loamy sand	SM-SC, SC	A-2	0	95-100	90-100	40-60	15-30	15-30	5-10
	11-60	Loamy sand, loamy coarse sand, sand.	SP-SC, SM-SC	A-2	0	95-100	80-100	35-60	5-25	20-25	5-10
Kutch: 44, 45	0-5	Clay loam	CL	A-6, A-7	0-10	90-100	80-100	80-100	70-80	30-50	20-30
	5-28	Clay, clay loam	CH, CL	A-7	0-5	90-100	80-100	80-100	75-95	45-60	20-35
	28-36	Extremely shaly clay loam.	GC	A-2	0-10	20-30	10-20	10-20	5-15	45-60	20-35
	36	Weathered bedrock.	---	---	---	---	---	---	---	---	---
Travessilla: [1]94: Travessilla part	0-11	Sandy loam	SM	A-2, A-4	0-10	75-100	60-95	50-65	15-40	---	NP
	11	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Rock outcrop part.											

Blakeland #8 = Hydrologic group A

Kutch #44 = Hydrologic group C

Travessilla #94 = Hydrologic group D

Ref. 11

4/4

Project Montebello - Soils	Job № E-34756

Client C Springs	By BWT	Date 12/12/88

Houck Estates-all soils ref # 8

94 Travessilla - Rock outcrop complex
8-20% slope, sandy loam
hydrologic group D
hard bedrock 6-20" deep

note: rational method C parameters
2.6 du/Ac → say 1/3 Ac
6 du/Ac → 1/8 Ac
research & dev. → light industrial
open space, minor amt of rock outcrop, scrub oak,
some underbrush, future paths → use $C_{10} = .35$
$C_{100} = .55$

Ref. II

Project Montebello - Individual Basin Calc	Job Nº E-3475C

Client C Springs	By BWT	Date Dec '88

Basin K 7.2 Ac

200'	@ 2%	sht flow	10
600'	@ 6%	street flow	1
300'	@ 5%	streetflow/pipe	1

land use	C_{10}	C_{100}	CN_2	CN_{24}
res 2.6 du/Ac	.6	.7	94	86

$Q_{10} = .6(4.3)\,7.2 = 19$ cfs

$Q_{100} = .7(6.6)\,7.2 = 33$ cfs

A

2

Project	Job №
Montebello - Individual Basin	E-3475C

Client	By	Date
C Springs	BWT	Dec '83

Basin L 12.3 ac.

300' @ 5% sht. flow
500' (44'V) say 700' @ 6% street flow
500' @ 5% street flow/pipe

land use	C_{10}	C_{100}	CN_2	CN_{24}
res. 2.6 du/Ac	.6	.7	94	86

Q_{10} = .6 (4.3) 12.3 = 32 cfs
Q_{100} = .7 (6.6) 12.3 = 57 cfs

A

3/

Project Montebello - Individual Basin	Job Nº E-3475C

Client C Springs	By BWT	Date Dec '88

Basin J. 11.0 Ac

300' @ 10% C = .6 sheetflow T = 8 min

450' @ 10% say street 750' @ 6%

assume 14 fps & assume T = 1 min

700' @ 5% open channel

say 8 fps T = 2 min

total T = 11 min

land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
res. 2 du/Ac	11.0	.45	.55	94	85

$Q_{10} = .45 (4.5)(11) = 22$ cfs

$Q_{100} = .55 (6.7)(11) = 41$ cfs

A

Project: Montebello - Individual Basin	Job No: E3475C
Client: C Springs	By: BWT — Date: Dec '88

Basin I 55.3 Ac

	Time (min)
300' @ 10%	8
300' @ 10% assume street flow	1
600' @ 10% natural channel use 12 fps (may be pipe)	1
900' @ 3.5% use 8 fps	2
	12 min

%	land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.39	res. 9 du/Ac	21.7	.65	.75	97	92
.61	res 2.6 du/Ac	33.6	.5	.6	94	86
			.55	.67	95.2	88.3

Q_{10} = .55 (4.3) 55.3 = 131 cfs

Q_{100} = .67 (6.6) 55.3 = 245 cfs

A

5/

Project	Montebello - Individual Basin		Job №	E-3475C
Client	C Springs	By BWT	Date	Dec '88 rev

Basin N - 55.1 Ac ✓ w/ P 58.5 Ac

	Tc
300' @ 8% school / Park	8
750' @ 6% street flow use 14 fps	1
2400' @ 6-7% use 10 fps	4
	13 min

%	- land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.11	school / Park -	6.4	.35	.6	93	84
.61	res. 2.6 DU/Ac -	35.5	.5	.6	94	86
.18	res 9 DU/Ac (avg)	10.7	.65	.75	97	92
.04	neighborhood facilities -	2.5	.75	.80	98	93
.06	res 2.6 du/Ac (P)	3.4	.5	.6	94	86
			.52	.64	94.6	87.1

Q_{10} = .52 (4.2) 55.1 = 120 cfs

Q_{100} = .64 (6.3) 55.1 = 222 cfs

Basin P 3.4 Ac Tc = 10 min

assume Q_{10} = .6 (4.6) 3.4 = 9.4 cfs

assume Q_{100} = .7 (7.0)(3.4) = 16.7 cfs

A

Project	Job №
Montebello - Individual Basin Calc	E-3475C

Client	By	Date
C Springs	BWT	Dec '83

Basin H

550' @ 20%

16

land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
openspace	6.8	.35	.55	93	84

Q_{10} = .35(3.8) 6.8 = 9.0 cfs

Q_{100} = .55(5.7) 6.8 = 21 cfs

A

7

Project	Montebello - Individual Basin		Job №	E-3475c
Client	C Springs	By BWT	Date	Dec 88

Basin G 50.3 Ac

		Tc
300' @ 8% sheet flow		8
250' (40'h) say 700 @ 6% street	14 fps	1
2200' @ 7% nat. channel	10 fps	4
		13

%	Land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.46	res - 2.6 du/Ac	23.3	.5	.6	94	86
.44	open space	22	.35	.55	93	84
.1	res 6 du/Ac	5	.65	.75	97	92
			.45	.59	93.9	85.7

Q_{10} = .45(4.2) 50.3 = 95 cfs

Q_{100} = .59 (6.3) 50.3 = 187 cfs

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Project: Montebello - Individual Basin			Job No: E-3475C
Client: C Springs	By: BWT	Date: Dec' 93	

Basin F 3.7 Ac

300' @ 15% sht flow 8

600' @ 25% nat. channell 12+ fps $\frac{1}{9}$

%	land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.19	res. 2.6 du/Ac	.7	.5	.6	94	86
.81	openspace	3.0	.35	.55	93	84
			.38	.56	93.2	84.4

Q_{10} = .38 (4.7) 3.7 = 6.6 c/s

Q_{100} = .56 (7.2) 3.7 = 15 c/s

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DREXEL, BARRELL & CO. LAND SURVEYORS CIVIL ENGINEERS

Project: Montebello - Individual Basin

Job №: E·3495C

Client: C Springs

By: BWT

Date: Dec 88

Basin C 13.5 Ac

300' @ 17%	sht flow (openspace)		8
1000' @ 1.5%	nat. channel	10 fps	2
			10

%	land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.55	res. 3 du/Ac	7.4	.65	.75	.97	92
.18	research/dev	2.5	.7	.8	98	93
.27	open space	3.6	.35	.55	93	84
			.58	.71	96.1	90.0

Q_{10} = .58(4.6)13.5 = 36 cfs

Q_{100} = .71(7.0)13.5 = 67 cfs

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Project: Montebello - Individual Basin Calc	Job No: E-3475C
Client: C Springs	By: BWT · Date: Dec '93

Basin B 4.9 Ac

	Tc
300' @ 17% res.	7
700' @ 19% nat. swale	1
	8

%	land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.10	open space	.5	.35	.55	98	93
.06	res. 8 du/Ac	.3	.65	.75	97	92
.84	research /dev.	4.1	.7	.8	93	84
			.66	.77	93.7	85.4

Q_{10} = .66 (5.0) 4.9 = 16.2 cfs

Q_{100} = .77 (7.5) 4.9 = 28 cfs

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Project Montebello - Individual Basin	Job Nº E-3475C

Client C Springs	By BWT	Date Dec 88

Basin D 11.5 Ac

	Tc
150' @ 5% sht flow (res.)	11
150' @ 20% sht flow (open space)	6
450' @ 33% nat channel	1
350' @ 10% nat channel	1
	19

%	land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.77	open space	8.8	.35	.55	93	84
.23	res. 2.6 du/Ac	2.7	.5	.6	94	86
			.38	.56	93.2	84.5

Q_{10} = .38 (3.5) 11.5 = 15 cfs

Q_{100} = .56 (5.2) 11.5 = 33 cfs

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Project Montebello		Job Nº E-3475C
Client C Springs	By BWT	Date Dec '88

Basin M 61.6 Ac

	Tc
300' @ 10% res.	9
600' @ 28% nat. channel	1
2150' @ 6-7% nat. channel/pipe? (10fps)	4
	14

%	land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.20	research/dev	12.3	.7	.8	98	93
.70	open space	43.3	.35	.55	93	84
.07	res. 2.6 du/Ac	4.2	.5	.6	94	86
.03	school/Park	1.8	.35	.6	93	84
			.43	.61	94.1	85.9

$Q_{10} = .43(4.0)61.6 = 106$ cfs

$Q_{100} = .61(6.1)61.6 = 229$ cfs

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DREXEL, BARRELL & CO. | LAND SURVEYORS CIVIL ENGINEERS | 13

Project Montebello	Job № E3475C

Client C Springs	By BWT	Date Dec '88

Basin A 11,3 Ac

300' @ 43% openspace 8

600' (58'V) 100' street flow @6% 4fps 1

9

%	Land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
,08	open space	.9	.35	,55	93	84
.92	research/dev	10,4	.7	,8	98	93
			.64	.78	97,6	92,3

Q_{10} = .64 (4,7) 11,3 = 34 cfs

Q_{100} = ,78 (7,2) 11,3 = 63 cfs

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Project Montebello - Individual Basin Calc		Job Nº E-3475C
Client C Springs	By BWT	Date Dec 88

Basin Q 39 Ac

	Tc
300' @ 10% sheet flow	8
700' (120V) @ 17% nat. channel	1
800' @ 4% street 10fps.	2
	11

950' @ 5% nat. channel/pipe?

%	Land use	Ac	C_{10}	C_{100}	$CN_{(2)}$	$CN_{(24)}$
.05	res 6 du/Ac	1.8	.65	.75	97	92
.05	res 2.6 du/Ac	2.0	.5	.6	94	86
.14	research/dev.	5.5	.7	.8	98	93
.76	zoned R 2 du/Ac	29.7	.45	.55	94	85
			.5	.6	94.7	86.5

$Q_{10} = .5\ (4.5)\ 39 = 88$ cfs

$Q_{100} = .6\ (6.7)\ 39 = 157$ cfs

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Project Montebello - Individual Basin	Job № E-34756
Client C Springs	By BWT / Date Dec 83

Basin R 14.7

	Tc
300' @ 10% sheetflow	8
700' (160'V) @ 22% nat channel	1
2000' @ 6% street flow (14 fps)	3
	12

land use	C_{10}	C_{100}	$CN_{100}(2)$	$CN_{100}(24)$
all res 2 du/Ac	.45	.55	94	85

Q_{10} = .45(4.3)14.7 = 28 c/s

Q_{100} = .55(6.6)14.7 = 53 c/s

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Project: Montebello - Individual Basin
Job Nº: E-3475C
Client: C Springs
By: BWT
Date: Dec 88

Basin E 26.3 Ac

800' @ 30% openspace	11
200' @ 20% sht flow	3
250' (40 V) 700' @ 6% st. flow (14 fps)	1
100' @ 20% pipe flow (20 fps)	1
	16

%	land use	Ac	C_{10}	C_{100}	CN_2	CN_{24}
.43	open space	11.2	.35	.55	93	84
.57	research/dev	15.1	.7	.8	98	93
			.55	.69	95.9	89.1

$Q_{10} = .55(3.8)26.3 = 55$ cfs

$Q_{100} = .69(6.8)26.3 = 124$ cfs

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Project: Montebello - Individual Basin	Job № E-3475C

Client: C Springs	By: BWT	Date: Dec '88

Basin Summary Sheet

see sht E 2/2 for calibration

									C/A		SCS	
%	point	Basin	Ac	C_{10}	C_{100}	CN_2	CN_{24}	T_c	Q_{10}	Q_{100}	Q_{10}	Q_{100}
.02	1	K	7.2	.6	.7	94	86	12	19	33		
.03	2	L	12.3	.6	.7	94	86	12	32	57		
.03	3	J	11.0	.45	.55	94	85	11	22	41		
.14	4	I	55.3	.55	.67	95.2	88.3	12	131	245		
.15	5	N	58.5	.52	.64	94.6	87.1	13	120	222	193	324
.02	6	H	6.8	.35	.55	93	84	16	9	21		
.12	7	G	50.3	.45	.59	93.9	85.7	13	95	187		
.01	8	F	3.7	.38	.56	93.2	84.2	9	6.6	15		
.03	9	C	13.5	.58	.71	96.1	90.0	10	36	67		
.01	10	B	4.9	.66	.77	93.7	85.4	8	16	28		
.03	11	D	11.5	.38	.56	93.2	84.5	19	15	33		
.17	12	M	61.6	.43	.61	94.1	85.9	14	106	229	195	329
.03	13	A	11.3	.64	.78	97.6	92.3	9	34	63		
.10	14	Q	39	.5	.6	94.6	86.5	11	38	157		
.04	15	R	14.7	.45	.55	94	85	12	28	53		
.07	16	E	26.3	.55	.69	95.9	89.1	16	55	124	82	137
			387.9	.50	.63	94.6	86.3					
			388			95	86					

A

Project	Job №
Montebello - Individual Basin Calc	E-34756

Client	By	Date
C Springs	BWT	Dec 88

@ point 16 from pnt 5 $L = 2600'$ @ 3.5%

if channel 7fps / 6.2 min or total $T_c = 19$ min

if pipe 20fps / 3 min or 16 min

— use pipe @ $T_c = 16$ min

— $Lag = .6T_c$

$= .6(16) = 9.6$ min

1.3 — $P_{10-2} = 2.1$ inch

$P_{10-24} = 3.1$ in

$P_{100-2} = 2.64''(1.156) = 3.05''$

$P_{100-24} = 4.5$ in

— $I_a = ?$

$$S = \frac{1000}{CN} - 10$$

for $CN = 95$ $S = .53$

for $CN = 86$ $S = 1.6$

$I_a = S(.2)$

for 2 hr $I_a = .2(.53) = .11$

for 24 hr $I_a = .2(1.6) = .3$

- $Q = ?$

$$Q = \frac{(P - .2S)^2}{P + .8S}$$

A

Project	Job №

Client	By	Date

- 10 yr 2 hr

$$Q = \frac{(2.1 - .2(.53))^2}{2.1 + .8(.53)} = 1.6''$$

- 10 yr 24 hr

$$Q = \frac{(3.1 - .2(1.6))^2}{3.1 + .8(1.6)} = 1.8''$$

- 100 yr 2 hr

$$Q = \frac{(3.05 - .2(.53))^2}{3.05 + .8(.53)} = 2.5''$$

- 100 yr 24 hr

$$Q = \frac{(4.5 - .2(1.6))^2}{4.5 + .8(1.6} = 3.0''$$

- $D = .133\,t_c = .133(16) = 2.1$ use $D = 5$ min

$$t_p = \frac{D}{2} + .6\,t_c = \frac{5}{2} + .6(16) = 12.1 \text{ min} \doteq .20 \text{ hr}$$

$$Q_p = \frac{484\,A\,Q}{t_p}$$ unit hydrograph

$A = 388$ Ac ≈ .61 sq mi

$$Q_p = \frac{484(.61)(1)}{.2} = 1476.2$$

$$\left.\begin{array}{l} Q_{10-2} \\ Q_{10-24} \\ Q_{100-2} \\ Q_{100-24} \end{array}\right\}$$ See TR 20 Output

A

Project Montebello- Individual Basin	Job Nº E-34756

Client C Springs	By BWT	Date Dec 88

Point flows / Rational method for upper end

point	Basins (add)	Ac (accum.)	C_{10}	C_{100}	Tc	I_{10}	I_{100} in/hr	Q_{10} cfs	Q_{100}
2	K,L	19.5	.6	.7	12	4.3	6.6	50	90
3	J	30.5	.55	.65	13	4.2	6.3	70	125
4	I	85.8	.55	.66	13	4.2	6.3	198	357
5	N	144.3	.53	.64	13	4.2	6.3	321	582

@ pnt 4 $CN_{24} = 87$

A

Project Montebello - Individual Basin	Job Nº E-3475C

Client C Springs	By BWT	Date Dec 83

zoning west of site west to Nevada
mostly R estate residential 7 20,000 □
PBC-1 (200 x 1300') planned business Center
@ Nevada

Basin Z 212 Ac

land use	Ac	CN_2	CN_{24}
res. (soil D) 2du/Ac	140	94	85
commercial (soil C)	6	98	94
res (soil C) 2du/Ac	35	91	80
res (soil B) 2du/Ac	31	85	70
			82

Tc Basin Z

300'	@ 10% res.	7
1500'	nat. channel say (2.5%) 7 fps	4
4000'	nat. channel @ 2% 7 fps	10
		21 min

A

DREXEL, BARRELL & CO. LAND SURVEYORS CIVIL ENGINEERS 2C

Project: Montebello - Individual Basin
Job No: E-3475C
Client: C Springs
By: BWT
Date: Dec 88

Generic Channel Characteristics
Open channel (grass)

n = 0.05	D = .3	Q = 9 cfs	V = 3 fps
S = .05	.9	64	5
B = 10'	1.2	110 Dc = 1.3	6
Z = 4			
@ n = .025	.2	9	4
	.5	50	8
	.7	77	9
S = .01	@ D = 1'	89	4
n = .035	2	301	5.8
B = 20	3	630 Dc = 2.7	7.3
Z = 3	4	1086	8.5
	5	1676 Dc = 4.7	9.6
	5.5	2025	10.-
@ S = .006	1	100	3.6
n = .03	3	680 2.5 Dc	6.7
B = 25	5	1779 Dc =	8.9
S = .03	1	95	7.3
n = .03	3	767 Dc = 3.9	13
B = 10'	5	2232 Dc = 6.6	17
Z = 3'			
n = .025	1	114	8.8
combichannel	3	921 Dc = 4.3	16.1
	5	2678	21
	4	1665	19
n = .03	3	500	5.2
S = .004	4	878 Dc = 3.1	6.1
B = 20 Z = 4	5.5	1679	7.3

A

DREXEL, BARRELL & CO. LAND SURVEYORS CIVIL ENGINEERS

Project Montebello - Individual Basin

Job Nº E-34756

Client C Springs

By BWT

Date Dec '88

Generic channels
Grass-lined channels

V max = 5 fps
Z = 4:1
n = .04

B = 20'	D = 4	Q = 737	V = 5
@ S = .5%	4.5	933	5
	5.	1157	6
	5.5	1408	6
	6.0	1688	6.4
	6.5	2000	6.7
	7.0	2343	7.
@ B = 25'	4	861	5
	5	1335	6
	5.5	1616	6.3
	6.0	1930	6.6
@ D = 30'	3.5	768	5
	4	988	5.5
	5	1516	6
	6	2171	6.7

A

Project Montebello - Individual Basin			Job Nº E-34756
Client C Springs	By BWT	Date Dec '88	

Generic Channels
Grass con't

change S = .4%

B = 25'	D = 4	Q = 771	V = 4.7
	5	1194	5.3
	4.5	970	5
	5.5	1446	5.6
	6.0	1725	5.9
	6.5	2033	6.1
B = 35	6	2161	6.1

conc tricklechannel

@ S = .004%	D = 2	227	7
B = 10	2.5	343	9
Z = 2	3.5	653	11
	4.5	1073	13
	1.5	135	6.9
	1.0	66	5.5
	.5	20	3.7
B = 12 Z = .01	1.3	104	6.6
	1.5	130	7.1
	1.7	158	7.6
	1.9	137	8.1
	2.1	218	8.5

A

Project
Montebello - Individual Basin

Job №
E-3475C

Client
C Springs

By
BWT

Date
Dec '88

conc. channel - Generic

S= ,03	D= 1	Q= 70	V= 10
n= ,02	1,4	137	12,6
B = 5'	2,3	363	16,4
z = 2	2.75	522	18,1
	3,2	717 Dc=5'	19,7
	4,1	1220	22,5
	5	1890 Dc=5'	25
S = ,02	1,4	112	10,3
	3,2	585	16
	5	1343	20,6
	1,0	95	13,
	1,5	202	17
S= ,05	2	354	20
	3	808	24,5
	4	1493	29
	5	2440	33
S = ,03	1	98	14
n = ,015	2	366	20
	3	835	25
	4	1541	29
B = 10'			
	2,5	706 Dc=4.	18,8
	3,5	1341 Dc=5,7	22,5

A

Project: Montebello - Historic

Job №: E-3475C

Client: C Springs

By: BWT

Date: Dec 88

rev May 89

All basins excluding Z

A = .61 sq mile

CN open space = 84

Tc

1000' @ 7% @ C = .45 overland flow 17 min

2400' natural channel @ 6-7% @ 16 fps 3 min

2900' natural channel @ 3% @ 14 fps 4 min

24 min

Tc = or .4 hr

All Basins

A = .94 Ac

CN = see below (open space)

Tc add

3500' natural channel @ 2% or 12 fps .08 hr

or Tc = .48 hr

ref pg 21 Appendix A

CN = [140 Ac (84) + 41 Ac (79) + 31 Ac (69)] ÷ 211

= 81

A

DREXEL, BARRELL & CO.

LAND SURVEYORS
CIVIL ENGINEERS

1/2

Project	Job №
Montebello TR 20	E-3475

Client	By	Date
C Springs	BWT	Dec '88

stream routing
determination of m & X from TR20 User's manual

assume $B = 25$
$S = .006$
$n = .03$

from figure H-1 $X = .45$

assume $D = 5.5'$ $D/B = .2$ @ w ℄ 100 YR
$Z = 3$
$A = 228^{□}$

from figure H-2 $m = 1.57$

assume $D = 4'$ $D/B = .16$
$A = 148^{□}$

from figure H-2 $m = 1.575$

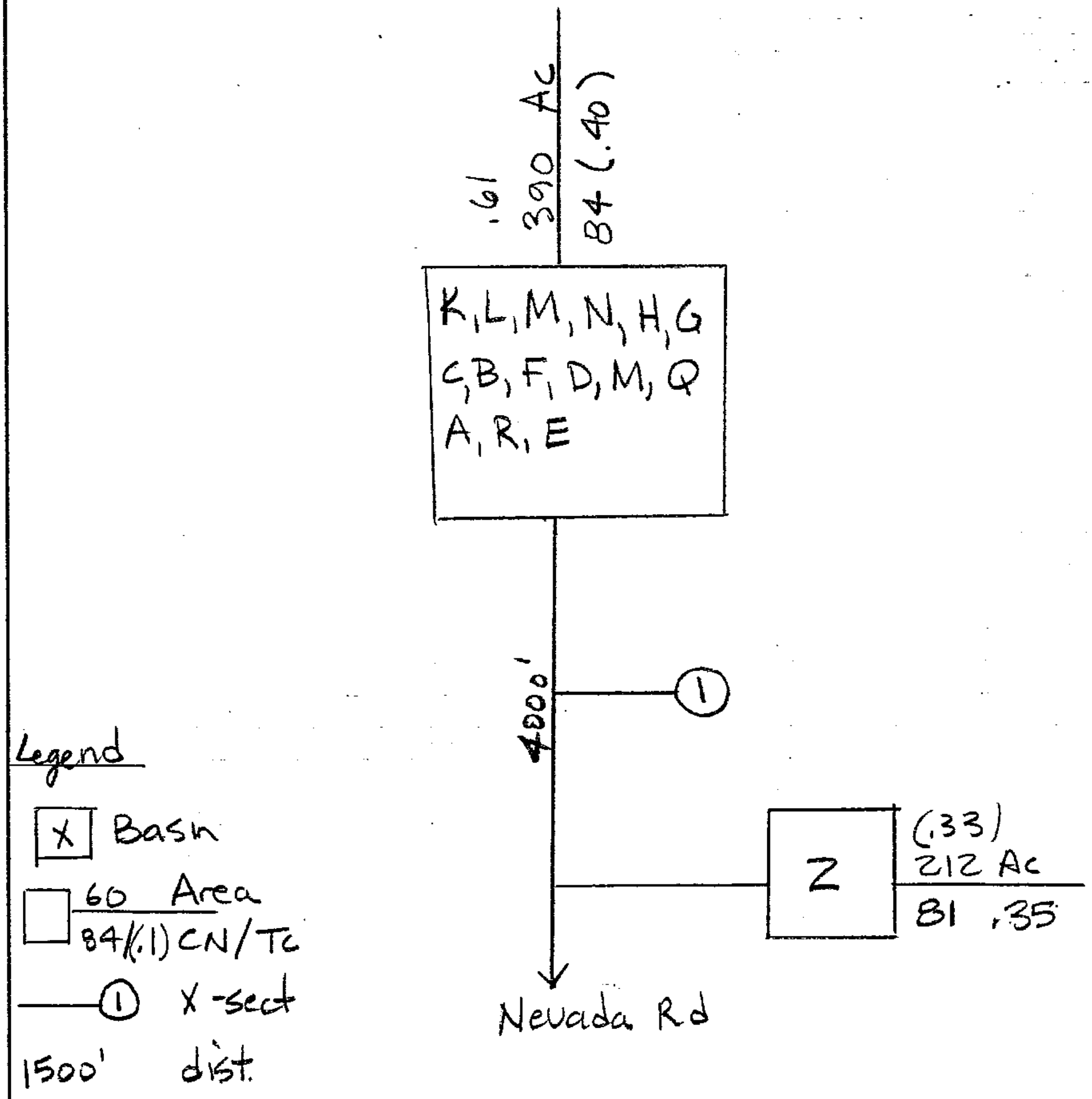
A

1700 38TH STREET (303) 442-4338
BOULDER, COLORADO 80301

740 WOOTEN RD. #108 (303) 591-5151
COLORADO SPRINGS, COLORADO 80915

Project Montebello TR20			Job No E-3745C
Client C Springs	By BWT	Date June '89	

TR 20
Flow chart
Historic



B

TR20 Historic Condition 1/2

Input Data

```
                  ******************80-80 LIST OF INPUT DATA FOR TR-20 HYDROLOGY*****************

                  JOB TR-20                     FULLPRINT          SUMMARY
                  TITLE    MONTEBELLO SAN SEWER
                  TITLE    EXISTING CONDITIONS
                   5 RAINFL 7              0.2500
                   8          0.0000      0.0005      0.0015      0.0030      0.0045
                   8          0.0060      0.0080      0.0100      0.0120      0.0143
                   8          0.0165      0.0188      0.0210      0.0233      0.0255
                   8          0.0278      0.0320      0.0390      0.0460      0.0530
                   8          0.0600      0.0750      0.1000      0.4000      0.7000
                   8          0.7250    . 0.7500      0.7650      0.7800      0.7900
                   8          0.8000      0.8100      0.8200      0.8250      0.8300
                   8          0.8350      0.8400      0.8450      0.8500      0.8550
                   8          0.8600      0.8638      0.8675      0.8713      0.8750
                   8          0.8788      0.8825      0.8863      0.8900      0.8938
                   8          0.8975      0.9013      0.9050      0.9083      0.9115
                   8          0.9148      0.9180      0.9210      0.9240      0.9270
                   8          0.9300      0.9325      0.9350      0.9375      0.9400
                   8          0.9425      0.9450      0.9475      0.9500      0.9525
                   8          0.9550      0.9575      0.9600      0.9625      0.9650
                   8          0.9675      0.9700      0.9725      0.9750      0.9775
                   8          0.9800      0.9813      0.9825      0.9838      0.9850
                   8          0.9863      0.9875      0.9888      0.9900      0.9913
                   8          0.9925      0.9938      0.9950      0.9963      0.9975
                   8          0.9988      1.0000      1.0000      1.0000      1.0000
                   9 ENDTBL
                   5 RAINFL 8              0.08333
                   8          0.000       0.020       0.057       0.139       0.289
                   8          0.539       0.659       0.715       0.758       0.796
                   8          0.828       0.860       0.892       0.924       0.956
                   8          0.988       1.013       1.032       1.051       1.070
                   8          1.089       1.108       1.127       1.144       1.157
                   9 ENDTBL
                   5 RAINFL 9              0.08333
                   8          0.000       0.010       0.040       0.086       0.166
                   8          0.306       0.556       0.696       0.776       0.838
                   8          0.888       0.928.      0.968       1.008       1.028
                   8          1.048       1.060       1.072       1.084       1.096
                   8          1.108       1.120       1.132       1.144       1.156
                   9 ENDTBL
                   6 RUNOFF 1 001       6 0.61      84.         0.40        1 1   1   1
                   6 REACH  3 001   6   5 4000.     0.45        1.57        1     1   1
                   6 RUNOFF 1 002       6 0.33      81.         0.35        1 1   1   1
                   6 ADDHYD 4 002   6 5 7                                   1 1   1   1
                     ENDATA
                   7 INCREM 6              0.1
                   7 COMPUT 7 001   002    0.0         3.1         1.0         7 2  01  10

                    ENDCMP 1
                  7 COMPUT 7 001   002   0.0         4.5         1.0         7 2  01  99
                    ENDCMP 1
                  7 COMPUT 7 001   002   0.0         2.1         1.0         8 2  01  10
                    ENDCMP 1
                  7 COMPUT 7 001   002   0.0         3.05        1.0         9 2  01  99
                    ENDCMP 1
                    ENDJOB 2
                 0********************************END OF 80-80 LIST*******************************
                 1
```

B

2/2

TR20 Historic Condition
Basin Results

```
SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
                  (A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH
                   A QUESTION MARK(?) INDICATES A HYDROGRAPH WITH PEAK AS LAST POINT.)

SECTION/    STANDARD                RAIN  ANTEC  MAIN          PRECIPITATION                                        PEAK DISCHARGE
STRUCTURE   CONTROL    DRAINAGE  TABLE  MOIST  TIME   -------------------------  RUNOFF   -----------------------------------------
   ID       OPERATION    AREA      #    COND  INCREM  BEGIN   AMOUNT  DURATION   AMOUNT   ELEVATION   TIME       RATE       RATE
                       (SQ MI)                 (HR)    (HR)    (IN)     (HR)      (IN)      (FT)      (HR)       (CFS)      (CSM)


   ALTERNATE    1   STORM   10 Year     24 hour
+
 XSECTION   1  RUNOFF     .61      7      2     .10      .0     3.10    24.00     1.60       ---       6.11      698.88     1145.
 XSECTION   1  REACH      .61      7      2     .10      .0     3.10    24.00     1.60       ---       6.26      635.26     1041.
 XSECTION   2  RUNOFF     .33      7      2     .10      .0     3.10    24.00     1.39       ---       6.09      346.17     1049.
 XSECTION   2  ADDHYD     .94      7      2     .10      .0     3.10    24.00     1.52       ---       6.19      901.99      959.

   ALTERNATE    1   STORM   ~~99~~  100 Year   24 hour
+
 XSECTION   1  RUNOFF     .61      7      2     .10      .0     4.50    24.00     2.81       ---       6.10     1260.71     2066.
 XSECTION   1  REACH      .61      7      2     .10      .0     4.50    24.00     2.81       ---       6.23     1197.33     1962.
 XSECTION   2  RUNOFF     .33      7      2     .10      .0     4.50    24.00     2.54       ---       6.08      650.62     1971.
 XSECTION   2  ADDHYD     .94      7      2     .10      .0     4.50    24.00     2.72       ---       6.17     1723.94     1834.

   ALTERNATE    1   STORM   10 year     2 hour
+
 XSECTION   1  RUNOFF     .61      8      2     .10      .0     2.43     2.00     1.06       ---        .72      419.48      687.
 XSECTION   1  REACH      .61      8      2     .10      .0     2.43     2.00     1.06       ---        .90      360.69      591.
 XSECTION   2  RUNOFF     .33      8      2     .10      .0     2.43     2.00      .89       ---        .70      189.26      573.
 XSECTION   2  ADDHYD     .94      8      2     .10      .0     2.43     2.00     1.00       ---        .85      507.65      540.

   ALTERNATE    1   STORM   ~~99~~  100 year   2 hour
+
 XSECTION   1  RUNOFF     .61      9      2     .10      .0     3.53     2.00     1.96       ---        .80      994.77     1630.

 XSECTION   1  REACH      .61      9      2     .10      .0     3.53     2.00     1.96       ---        .94      928.70     1522.
 XSECTION   2  RUNOFF     .33      9      2     .10      .0     3.53     2.00     1.73       ---        .77      486.10     1473.
 XSECTION   2  ADDHYD     .94      9      2     .10      .0     3.53     2.00     1.88       ---        .91     1326.34     1411.
1
```

B

Project: Montebello TR 20

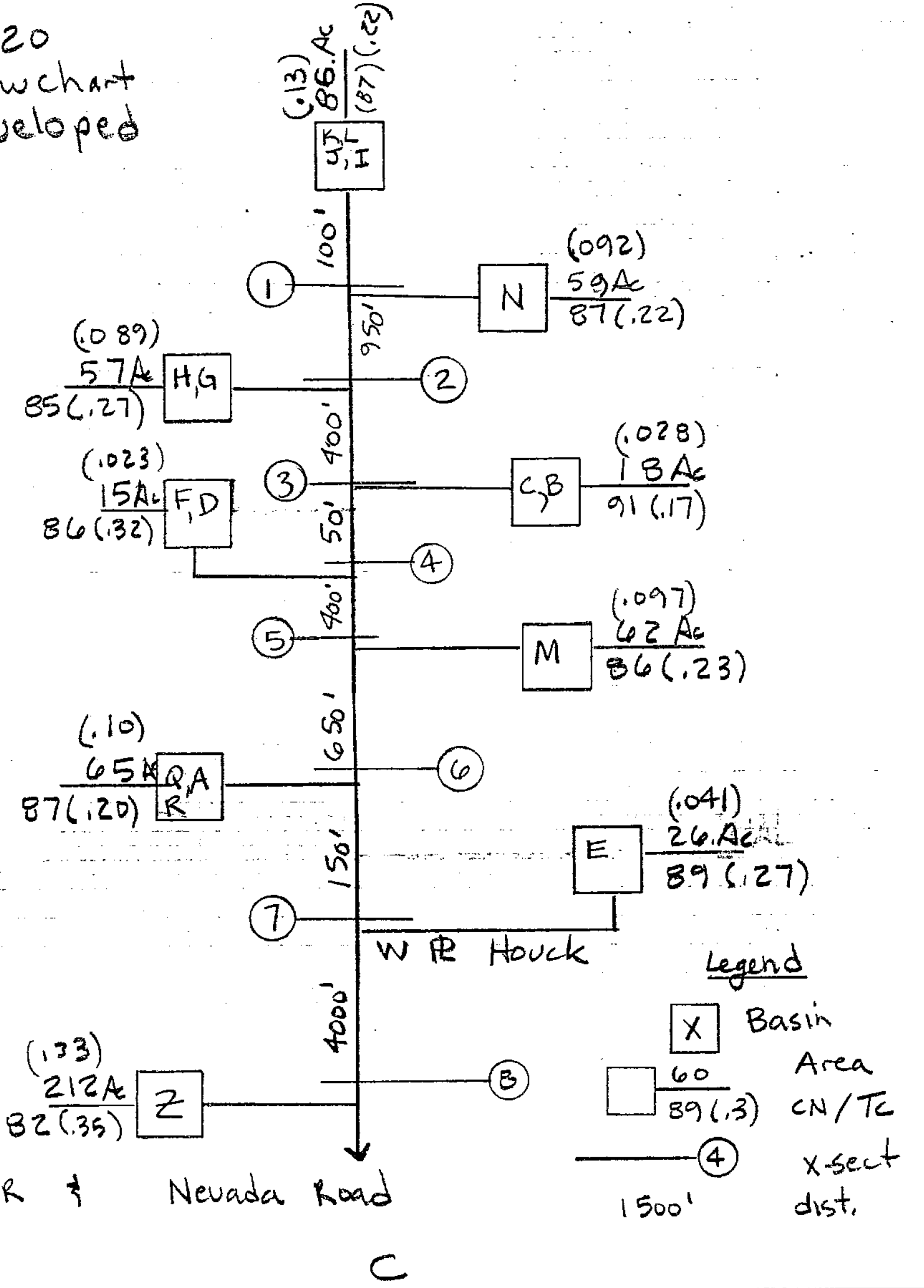
Job No: E-3475C

Client: C Springs

By: BWT

Date: Dec '88

TR20 Flowchart Developed



1/5

TR 20 Developed Condition

Input Data

```
********************80-80 LIST OF INPUT DATA FOR TR-20 HYDROLOGY********************

JOB TR-20                         FULLPRINT          SUMMARY
TITLE     MONTEBELLO SAN SEWER
TITLE     EXISTING CONDITIONS
 5 RAINFL 7             0.2500
 8          0.0000      0.0005      0.0015      0.0030      0.0045
 8          0.0060      0.0080      0.0100      0.0120      0.0143
 8          0.0165      0.0188      0.0210      0.0233      0.0255
 8          0.0278      0.0320      0.0390      0.0460      0.0530
 8          0.0600      0.0750      0.1000      0.4000      0.7000
 8          0.7250      0.7500      0.7650      0.7800      0.7900
 8          0.8000      0.8100      0.8200      0.8250      0.8300
 8          0.8350      0.8400      0.8450      0.8500      0.8550
 8          0.8600      0.8638      0.8675      0.8713      0.8750
 8          0.8788      0.8825      0.8863      0.8900      0.8938
 8          0.8975      0.9013      0.9050      0.9083      0.9115
 8          0.9148      0.9180      0.9210      0.9240      0.9270
 8          0.9300      0.9325      0.9350      0.9375      0.9400
 8          0.9425      0.9450      0.9475      0.9500      0.9525
 8          0.9550      0.9575      0.9600      0.9625      0.9650
 8          0.9675      0.9700      0.9725      0.9750      0.9775
 8          0.9800      0.9813      0.9825      0.9838      0.9850
 8          0.9863      0.9875      0.9888      0.9900      0.9913
 8          0.9925      0.9938      0.9950      0.9963      0.9975
 8          0.9988      1.0000      1.0000      1.0000      1.0000
 9 ENDTBL
 5 RAINFL 8             0.08333
 8          0.000       0.020       0.057       0.139       0.289
 8          0.539       0.659       0.715       0.758       0.796
 8          0.828       0.860       0.892       0.924       0.956
 8          0.988       1.013       1.032       1.051       1.070
 8          1.089       1.108       1.127       1.144       1.157
 9 ENDTBL
 5 RAINFL 9             0.08333
 8          0.000       0.010       0.040       0.086       0.166
 8          0.306       0.556       0.696       0.776       0.838
 8          0.888       0.928       0.968       1.008       1.028
 8          1.048       1.060       1.072       1.084       1.096
 8          1.108       1.120       1.132       1.144       1.156
 9 ENDTBL
 6 RUNOFF 1 001       6 0.13       87.         0.22        1 1   1   1
 6 REACH  3 001   6   5 100.       0.45        1.57        1     1   1
 6 RUNOFF 1 002       4 0.092      87.         0.22        1 1   1   1
 6 ADDHYD 4 002   5 4 7                                    1 1   1   1
 6 REACH  3 002   7   5 950.       0.45        1.57        1     1   1
 6 RUNOFF 1 003       6 0.089      85.         0.27        1 1   1   1
 6 ADDHYD 4 003   6 5 7                                    1 1   1   1
```

C

2/5

TR 20 Developed Condition

Input Data

```
*********************80-80 LIST OF INPUT DATA (CONTINUED)*********************

6 REACH  3 003   7   5 400.          0.45         1.57         1      1   1
6 RUNOFF 1 004       6 0.028         91.          0.17         1 1    1   1
6 ADDHYD 4 004   6 5 7                                         1 1    1   1
6 REACH  3 004   7   5 50.           0.45         1.57         1      1   1
6 RUNOFF 1 005       6 0.023         86.          0.32         1 1    1   1
6 ADDHYD 4 005   6 5 7                                         1 1    1   1
6 REACH  3 005   7   5 400.          0.45         1.57         1      1   1
6 RUNOFF 1 006       6 0.097         86.          0.23         1 1    1   1
6 ADDHYD 4 006   6 5 7                                         1 1    1   1
6 REACH  3 006   7   5 650.          0.45         1.57         1      1   1
6 RUNOFF 1 007       6 0.1           87.          0.2          1 1    1   1
6 ADDHYD 4 007   6 5 7                                         1 1    1   1
6 REACH  3 007   7   5 150.          0.45         1.57         1      1   1
6 RUNOFF 1 008       6 0.041         89.          0.27         1 1    1   1
6 ADDHYD 4 008   6 5 7                                         1 1    1   1
6 REACH  3 008   7   5 4000.         0.45         1.57         1      1   1
6 RUNOFF 1 009       6 0.33          82.          0.35         1 1    1   1
6 ADDHYD 4 009   6 5 7                                         1 1    1   1
  ENDATA
7 INCREM 6             0.05
7 COMPUT 7 001   009   0.0           3.1          1.0          7 2  01  10
  ENDCMP 1
7 COMPUT 7 001   009   0.0           4.5          1.0          7 2  01  99
  ENDCMP 1
7 COMPUT 7 001   009   0.0           2.1          1.0          8 2  01  10
  ENDCMP 1
7 COMPUT 7 001   009   0.0           3.05         1.0          9 2  01  99
  ENDCMP 1
  ENDJOB 2
0*******************************END OF 80-80 LIST*******************************
```

c

3/5

TR 20 Developed Condition

—Basin Results —

SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
(A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH
A QUESTION MARK(?) INDICATES A HYDROGRAPH WITH PEAK AS LAST POINT.)

SECTION/ STRUCTURE ID	STANDARD CONTROL OPERATION	DRAINAGE AREA (SQ MI)	RAIN TABLE #	ANTEC MOIST COND	MAIN TIME INCREM (HR)	PRECIPITATION			RUNOFF AMOUNT (IN)	PEAK DISCHARGE			
						BEGIN (HR)	AMOUNT (IN)	DURATION (HR)		ELEVATION (FT)	TIME (HR)	RATE (CFS)	RATE (CSM)
ALTERNATE 1 STORM 10 year 24 hour													
XSECTION 1	RUNOFF	.13	7	2	.05	.0	3.10	24.00	1.63	---	6.03	214.30	1648.4
XSECTION 1	REACH	.13	7	2	.05	.0	3.10	24.00	1.63	---	6.03	214.30	1648.4
XSECTION 2	RUNOFF	.09	7	2	.05	.0	3.10	24.00	1.63	---	6.03	151.66	1648.4
XSECTION 2	ADDHYD	.22	7	2	.05	.0	3.10	24.00	1.63	---	6.03	365.95	1648.4
XSECTION 2	REACH	.22	7	2	.05	.0	3.10	24.00	1.63	---	6.08	363.19	1636.0
XSECTION 3	RUNOFF	.09	7	2	.05	.0	3.10	24.00	1.48	---	6.05	127.24	1429.7
XSECTION 3	ADDHYD	.31	7	2	.05	.0	3.10	24.00	1.59	---	6.07	485.01	1559.5
XSECTION 3	REACH	.31	7	2	.05	.0	3.10	24.00	1.59	---	6.07	485.01	1559.5
XSECTION 4	RUNOFF	.03	7	2	.05	.0	3.10	24.00	1.96	---	6.00	55.54	1983.5
XSECTION 4	ADDHYD	.34	7	2	.05	.0	3.10	24.00	1.62	---	6.06	534.75	1577.4
XSECTION 4	REACH	.34	7	2	.05	.0	3.10	24.00	1.62	---	6.06	534.75	1577.4
XSECTION 5	RUNOFF	.02	7	2	.05	.0	3.10	24.00	1.55	---	6.07	32.31	1404.7
XSECTION 5	ADDHYD	.36	7	2	.05	.0	3.10	24.00	1.61	---	6.06	566.97	1566.2
XSECTION 5	REACH	.36	7	2	.05	.0	3.10	24.00	1.61	---	6.06	566.97	1566.2
XSECTION 6	RUNOFF	.10	7	2	.05	.0	3.10	24.00	1.55	---	6.03	151.64	1563.3
XSECTION 6	ADDHYD	.46	7	2	.05	.0	3.10	24.00	1.60	---	6.05	716.67	1561.4
XSECTION 6	REACH	.46	7	2	.05	.0	3.10	24.00	1.60	---	6.05	716.67	1561.4
XSECTION 7	RUNOFF	.10	7	2	.05	.0	3.10	24.00	1.63	---	6.02	167.58	1675.8
XSECTION 7	ADDHYD	.56	7	2	.05	.0	3.10	24.00	1.60	---	6.04	883.43	1580.4
XSECTION 7	REACH	.56	7	2	.05	.0	3.10	24.00	1.60	---	6.04	883.43	1580.4
XSECTION 8	RUNOFF	.04	7	2	.05	.0	3.10	24.00	1.78	---	6.04	69.77	1701.7
XSECTION 8	ADDHYD	.60	7	2	.05	.0	3.10	24.00	1.62	---	6.04	953.19	1588.6
XSECTION 8	REACH	.60	7	2	.05	.0	3.10	24.00	1.61	---	6.14	865.28	1442.1
XSECTION 9	RUNOFF	.33	7	2	.05	.0	3.10	24.00	1.28	---	6.09	365.07	1106.3
XSECTION 9	ADDHYD	.93	7	2	.05	.0	3.10	24.00	1.49	---	6.12	1220.39	1312.3
ALTERNATE 1 STORM ~~99~~ 100 year 24 hour													
XSECTION 1	RUNOFF	.13	7	2	.05	.0	4.50	24.00	2.79	---	6.02	355.28	2732.9
XSECTION 1	REACH	.13	7	2	.05	.0	4.50	24.00	2.79	---	6.02	355.28	2732.9
XSECTION 2	RUNOFF	.09	7	2	.05	.0	4.50	24.00	2.79	---	6.02	251.43	2732.9
XSECTION 2	ADDHYD	.22	7	2	.05	.0	4.50	24.00	2.79	---	6.02	606.71	2732.9
XSECTION 2	REACH	.22	7	2	.05	.0	4.50	24.00	2.79	---	6.07	605.75	2728.6
XSECTION 3	RUNOFF	.09	7	2	.05	.0	4.50	24.00	2.61	---	6.04	221.29	2486.5

1

C

4/5

TR20 Developed Condition

Basin Summary

```
SECTION/    STANDARD              RAIN  ANTEC  MAIN          PRECIPITATION                                          PEAK DISCHARGE
STRUCTURE    CONTROL    DRAINAGE  TABLE MOIST  TIME   -------------------------  RUNOFF   ------------------------------------------
   ID       OPERATION     AREA      #   COND  INCREM  BEGIN   AMOUNT  DURATION   AMOUNT   ELEVATION   TIME       RATE       RATE
                        (SQ MI)                 (HR)   (HR)    (IN)     (HR)      (IN)       (FT)     (HR)       (CFS)      (CSM)

    ALTERNATE   1  STORM  09  100 year   24 hour
+   ----------------------------
XSECTION   3  ADDHYD    .31       7      2     .05     .0      4.50    24.00      2.74       ---      6.06      824.76     2652.0
XSECTION   3  REACH     .31       7      2     .05     .0      4.50    24.00      2.74       ---      6.06      824.76     2652.0
XSECTION   4  RUNOFF    .03       7      2     .05     .0      4.50    24.00      3.10       ---      5.99       87.48     3124.3
XSECTION   4  ADDHYD    .34       7      2     .05     .0      4.50    24.00      2.78       ---      6.05      906.48     2674.0
XSECTION   4  REACH     .34       7      2     .05     .0      4.50    24.00      2.78       ---      6.05      906.48     2674.0

XSECTION   5  RUNOFF    .02       7      2     .05     .0      4.50    24.00      2.70       ---      6.06       55.70     2425.2
XSECTION   5  ADDHYD    .36       7      2     .05     .0      4.50    24.00      2.77       ---      6.05      962.14     2657.8
XSECTION   5  REACH     .36       7      2     .05     .0      4.50    24.00      2.77       ---      6.05      962.14     2657.8
XSECTION   6  RUNOFF    .10       7      2     .05     .0      4.50    24.00      2.70       ---      6.02      255.71     2636.2
XSECTION   6  ADDHYD    .46       7      2     .05     .0      4.50    24.00      2.76       ---      6.04     1217.74     2653.0

XSECTION   6  REACH     .46       7      2     .05     .0      4.50    24.00      2.76       ---      6.04     1217.74     2653.0
XSECTION   7  RUNOFF    .10       7      2     .05     .0      4.50    24.00      2.80       ---      6.01      279.16     2791.6
XSECTION   7  ADDHYD    .56       7      2     .05     .0      4.50    24.00      2.76       ---      6.03     1496.88     2677.8
XSECTION   7  REACH     .56       7      2     .05     .0      4.50    24.00      2.76       ---      6.03     1496.88     2677.8
XSECTION   8  RUNOFF    .04       7      2     .05     .0      4.50    24.00      2.98       ---      6.03      114.45     2791.5

XSECTION   8  ADDHYD    .60       7      2     .05     .0      4.50    24.00      2.78       ---      6.03     1611.32     2635.5
XSECTION   8  REACH     .60       7      2     .05     .0      4.50    24.00      2.77       ---      6.16     1516.55     2527.6
XSECTION   9  RUNOFF    .33       7      2     .05     .0      4.50    24.00      2.34       ---      6.08      674.58     2044.2
XSECTION   9  ADDHYD    .93       7      2     .05     .0      4.50    24.00      2.62       ---      6.14     2140.76     2301.9

    ALTERNATE   1  STORM  10  year   2 hour
+   ----------------------------
XSECTION   1  RUNOFF    .13       8      2     .05     .0      2.43     2.00      1.25       ---       .56      156.32     1202.4
XSECTION   1  REACH     .13       8      2     .05     .0      2.43     2.00      1.25       ---       .56      156.32     1202.4
XSECTION   2  RUNOFF    .09       8      2     .05     .0      2.43     2.00      1.25       ---       .56      110.62     1202.4
XSECTION   2  ADDHYD    .22       8      2     .05     .0      2.43     2.00      1.25       ---       .56      266.94     1202.4
XSECTION   2  REACH     .22       8      2     .05     .0      2.43     2.00      1.25       ---       .62      260.02     1171.3

XSECTION   3  RUNOFF    .09       8      2     .05     .0      2.43     2.00      1.12       ---       .60       82.26      924.3
XSECTION   3  ADDHYD    .31       8      2     .05     .0      2.43     2.00      1.21       ---       .62      341.88     1099.3
XSECTION   3  REACH     .31       8      2     .05     .0      2.43     2.00      1.21       ---       .62      341.88     1099.3
XSECTION   4  RUNOFF    .03       8      2     .05     .0      2.43     2.00      1.55       ---       .51       51.07     1823.9
XSECTION   4  ADDHYD    .34       8      2     .05     .0      2.43     2.00      1.24       ---       .61      377.17     1112.6

XSECTION   4  REACH     .34       8      2     .05     .0      2.43     2.00      1.24       ---       .61      377.17     1112.6
XSECTION   5  RUNOFF    .02       8      2     .05     .0      2.43     2.00      1.19       ---       .64       20.94      910.3
XSECTION   5  ADDHYD    .36       8      2     .05     .0      2.43     2.00      1.24       ---       .61      397.92     1099.7
XSECTION   5  REACH     .36       8      2     .05     .0      2.43     2.00      1.24       ---       .61      397.92     1099.7
XSECTION   6  RUNOFF    .10       8      2     .05     .0      2.43     2.00      1.19       ---       .57      106.05     1093.3

XSECTION   6  ADDHYD    .46       8      2     .05     .0      2.43  C  2.00      1.23       ---       .60      490.49     1086.0
```

TR 20 Developed Condition 5/

— Basin Summary —

```
SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
                  (A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH
                   A QUESTION MARK(?) INDICATES A HYDROGRAPH WITH PEAK AS LAST POINT.)

SECTION/    STANDARD                RAIN  ANTEC  MAIN          PRECIPITATION                              PEAK DISCHARGE
STRUCTURE   CONTROL     DRAINAGE   TABLE  MOIST  TIME   --------------------------  RUNOFF    -----------------------------------
  ID        OPERATION    AREA        #    COND  INCREM  BEGIN   AMOUNT  DURATION  AMOUNT   ELEVATION  TIME      RATE       RATE
                        (SQ MI)                  (HR)   (HR)     (IN)     (HR)     (IN)      (FT)     (HR)     (CFS)      (CSM

 +
     ------------------------------
  XSECTION   6  REACH       .46      8     2     .05     .0      2.43     2.00     1.23       ---       .60     498.49     1086.

  XSECTION   7  RUNOFF      .10      8     2     .05     .0      2.43     2.00     1.25       ---       .55     125.02     1250.
  XSECTION   7  ADDHYD      .56      8     2     .05     .0      2.43     2.00     1.23       ---       .59     611.10     1093.
  XSECTION   7  REACH       .56      8     2     .05     .0      2.43     2.00     1.23       ---       .59     611.10     1093.
  XSECTION   8  RUNOFF      .04      8     2     .05     .0      2.43     2.00     1.39       ---       .59      51.41     1253.5

  XSECTION   8  ADDHYD      .60      8     2     .05     .0      2.43     2.00     1.24       ---       .59     662.59     1104.
  XSECTION   8  REACH       .60      8     2     .05     .0      2.43     2.00     1.24       ---       .72     540.62      901.0
  XSECTION   9  RUNOFF      .33      8     2     .05     .0      2.43     2.00      .95       ---       .68     206.90      627.
  XSECTION   9  ADDHYD      .93      8     2     .05     .0      2.43     2.00     1.14       ---       .71     743.98      800.0

   ALTERNATE    1   STORM   100 year     2 hour
 +
     ------------------------------
  XSECTION   1  RUNOFF      .13      9     2     .05     .0      3.53     2.00     2.20       ---       .64     324.43     2495.6
  XSECTION   1  REACH       .13      9     2     .05     .0      3.53     2.00     2.20       ---       .64     324.43     2495.6
  XSECTION   2  RUNOFF      .09      9     2     .05     .0      3.53     2.00     2.20       ---       .64     229.59     2495.6
  XSECTION   2  ADDHYD      .22      9     2     .05     .0      3.53     2.00     2.20       ---       .64     554.02     2495.6
  XSECTION   2  REACH       .22      9     2     .05     .0      3.53     2.00     2.20       ---       .70     551.37     2483.6

  XSECTION   3  RUNOFF      .09      9     2     .05     .0      3.53     2.00     2.04       ---       .68     185.20     2058.4
  XSECTION   3  ADDHYD      .31      9     2     .05     .0      3.53     2.00     2.16       ---       .69     734.12     2368.5
  XSECTION   3  REACH       .31      9     2     .05     .0      3.53     2.00     2.16       ---       .69     734.12     2368.5
  XSECTION   4  RUNOFF      .03      9     2     .05     .0      3.53     2.00     2.56       ---       .59      92.51     3303.9
  XSECTION   4  ADDHYD      .34      9     2     .05     .0      3.53     2.00     2.19       ---       .69     804.99     2374.6

  XSECTION   4  REACH       .34      9     2     .05     .0      3.53     2.00     2.19       ---       .69     804.99     2374.6
  XSECTION   5  RUNOFF      .02      9     2     .05     .0      3.53     2.00     2.12       ---       .72      46.01     2088.5
  XSECTION   5  ADDHYD      .36      9     2     .05     .0      3.53     2.00     2.18       ---       .69     850.02     2348.
  XSECTION   5  REACH       .36      9     2     .05     .0      3.53     2.00     2.18       ---       .69     850.02     2348.1
  XSECTION   6  RUNOFF      .10      9     2     .05     .0      3.53     2.00     2.12       ---       .65     226.94     2339.6

  XSECTION   6  ADDHYD      .46      9     2     .05     .0      3.53     2.00     2.17       ---       .68    1068.71     2328.3
  XSECTION   6  REACH       .46      9     2     .05     .0      3.53     2.00     2.17       ---       .68    1068.71     2328.3
  XSECTION   7  RUNOFF      .10      9     2     .05     .0      3.53     2.00     2.20       ---       .63     257.66     2576.6
  XSECTION   7  ADDHYD      .56      9     2     .05     .0      3.53     2.00     2.18       ---       .67    1318.19     2358.1
  XSECTION   7  REACH       .56      9     2     .05     .0      3.53     2.00     2.18       ---       .67    1318.19     2358.1

  XSECTION   8  RUNOFF      .04      9     2     .05     .0      3.53     2.00     2.38       ---       .67     103.23     2517.9
  XSECTION   8  ADDHYD      .60      9     2     .05     .0      3.53     2.00     2.19       ---       .67    1421.42     2369.0
  XSECTION   8  REACH       .60      9     2     .05     .0      3.53     2.00     2.19       ---       .78    1247.45     2079.1
  XSECTION   9  RUNOFF      .33      9     2     .05     .0      3.53     2.00     1.81       ---       .76     519.59     1574.5
  XSECTION   9  ADDHYD      .93      9     2     .05     .0      3.53     2.00     2.05       ---       .77    1770.53     1903.8
1
```

C

DREXEL, BARRELL & CO.
LAND SURVEYORS
CIVIL ENGINEERS

Project	Montebello
Job No	E-3745C
Client	C Springs
By	BWT
Date	May '89 revised June '89

Comparison & Summary (historic) developed

	w Rd cfs		Hour	AMC	Storm	Nevada Rd cfs		
use →	(1261)	1611	24	2	100	(1724)	2141	← use
		2048	2	3	100		2693	
	(995)	1421	2	2	100	(1326)	1771	
use →	(699)	953	24	2	10	(902)	1220	← use
	(419)	663	2	2	10	(508)	744	

D

1/2

Project	Job No
Montebello - Calibration	E-34756

Client	By	Date
C Springs	BWT	Dec '88

rev. June '89

Comparison of computed flows - SCS vs Rational

Basin (Ac)	flow(cfs) rational	storm	flow(cfs) SCS	% increase
N	120	Q_{10}	152	27
N (58.5)	222	Q_{100}	251	13 –
M (61.6)	106	Q_{10}	152	43
M	229	Q_{100}	255	11 –
E (26.3)	55	Q_{10}	70	15
E	124	Q_{100}	115	-7 –
FD	22 (flows added)	Q_{10}	33	50
FD	48 "	Q_{100}	56	17 –
HG	104 "	Q_{10}	128	23
HG	208 "	Q_{100}	222	7 –
K,L,J,I (86)	198	Q_{10}	214	8
KLJI	357	Q_{100}	355	— -
K,L,J,I,N (144)	321	Q_{10}	364	15
K,L,J,I,N	582	Q_{100}	604	4 -

- use 25% increase for design purposes (10yr)
- use 6% increase for design purposes (100yr) above rational method

E

DREXEL, BARRELL & CO. LAND SURVEYORS CIVIL ENGINEERS 2/2

Project: Montebello - Calibration	Job Nº: E-3475C
Client: C Springs	By: BWT Date: Dec 88

Final Calibrated Basin Summary Sheet for former Rational Method

Basin	Basin cfs Q_{10}	Basin cfs Q_{100}	Accum cfs Q_{10}	Q_{100}
K	24	35		
L	40	59	64	84
J	28	43	92	127
I	163	260	(SCS)→ 214	355
N (SCS)	→ 152	251		
H	11	22		
G	119	198		
F	9	16		
C	45	70		
B	20	29		
D	19	41		
M (SCS)	152	255		
A	43	67		
Q	110	166		
R	35	56		
E	69	131		
P	12	18		

E

Project Montebello - Facilities Design	Job № E-3745C
Client C Springs	By BWT Date June '89

Index for Facilities design (F)

F

Project	Job №
Montebello - Facilities Design	E-3745c

Client	By	Date
C Springs	BWT	June '89

Size storm sewer east end basin. $n = .013$

Basin K rd @ 2% min Q_{10} = 24cfs
by mannings use 24" RCP

Basin L rd @ 2% min Q_{10} = 40cfs
by manning use 30" RCP

Basin KL rd @ 3% min Q_{10} = 64cfs
by mannings use 30" RCP

Basin KLJ rd @ 4% min Q_{10} = 92cfs
by mannings use 36" RCP

Basin PKLJ rd @ 4% min Q_{10} = 104cfs

F

Project: Montebello - Facilities Design
Job No: E-37456
Client: C Springs
By: BWT
Date: June 89

size storm sewer laterals
by inlet control - note: beveled edges used
slope tapered would not be cost effective

- Basin I Q_{10} = 163 cfs Q_{100} = 260 cfs
  use 66" RCP HW/D = 1.0 10year & 1,3 100year
- Basin NP Q_{10} = 152 cfs Q_{100} = 251 cfs
  use 66" RCP same as above
- Basin HG Q_{10} = 128 cfs Q_{100} = 222 cfs
  use 60" RCP for HW/D = 1 10year & 1,5 100year
- Basin D Q_{10} = 19 cfs Q_{100} = 41 cfs
  use 30" RCP HW/D = ,9 for 10year & 1,6 100year
- Basin CB Q_{10} = 55 cfs Q_{100} = 88 cfs
  use 42" RCP for HW/D = 1 10year & 1,5 100year
- Basin FD Q_{10} = 33 cfs Q_{100} = 56 cfs
  use 36" RCP for HW/D = ,9 10year & 1,4 100year
- Basin M Q_{10} = 152 cfs Q_{100} = 255 cfs
  use 66" RCP same as above
-

F

Project Montebello - Facilities Design	Job № E-3745C

Client C Springs	By BWT	Date June 89

section 1 300 L.F.

S = 5% road

Q = 355 cfs 100 yr & 214 cfs 10 yr

by mannings use w/ n = .013

54" RCP

by inlet control

w/ HW/D = 1 for 214 cfs 72" RCP

for 72" RCP V = 30 fps @ .43 full

for 66" RCP V = 30 fps @ .5 full

use 66" RCP

F

Project Montebello Facilities Design
Job Nº E3745C

Client C Springs
By BWT
Date June 89

section 2 500 L.F

S = 5% (road)

Q = 606 cfs (100 yr) 364 cfs 10 yr

inlet control use 90" RCP

mannings use 66" RCP

use 84" RCP / 7×6 / 8×5 box
$47/1 (not avail) $174/1

@ n = .015

V = (fps) 30 30

d = (ft) 3 2.6

F

Project Montebello - Facilities Design	Job Nº E-3745C
Client C Springs	By BWT Date June '89

section 3   600 L.F.

S = 2.5% to 5% (road)

Q = 825 cfs (100 YR)   486 cfs 10 YR

inlet control for 10 X 6 box

430 cfs for Hw/D = 1

mannings use .84'   (8x5 box)

use 9X6 box

@n=.015	S=5%	S=2.5%
V=	32	25
d=	3	3.8

F

1/

Project Montebello Facilities Design		Job Nº E-3745C
Client C Springs	By BWT	Date June '89

Section 5 460 LF

$S = 1\%$ to 2.4% (road)

$Q = 963$ cfs - 100 YR 567 cfs - 10 YR

by mannings @ 1% 102" RCP (10×6 box)

Inlet control for 10×8 box @ HW/D = 1 Q = 580 cfs

use 10×7 box

n = .015	S = 2.4%	S = 1%
V = (fps)	25	19
d = (ft)	3.7	5.2

F

Project	Job №
Montebello Facilities Design	E-3745C

Client	By	Date
C Springs	BHT	June '89

Section 6 600 L.F

rd S = 1% Q_{100} = 1218 cfs Q_{10} = 717 cfs

10' x 8' high box

by inlet control HW/D = 1 at 630 cfs

10' x 9' box @ HW/D = 1 Q = 780 cfs

@ 1218 cfs HW/D = 1.5

by mannings @ 1% 108" RCP or 10'x7' box

use 10 x 8 box

n = .015

V = (fps) 20

d = (ft) 6.2

F

DREXEL, BARRELL & CO. **LAND SURVEYORS CIVIL ENGINEERS**

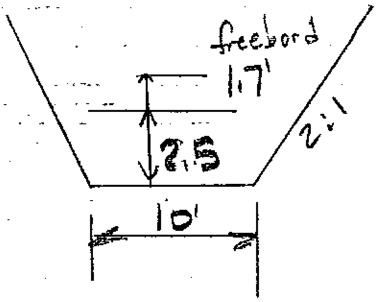
Project Montebello - Facilities Design	Job Nº E-3475C

Client C Springs	By BWT	Date Dec 88

① Length = 100' 5 % 458 cfs

storm sewer 72" RCP

channel



@ 1 %

grass lined channel

@ S = .5% Bottom width = 15'

z = 4 n = .04

D = 3.5' V = 4.7 fps

F

Project Montebello - Facilities Design	Job Nº E-3475C

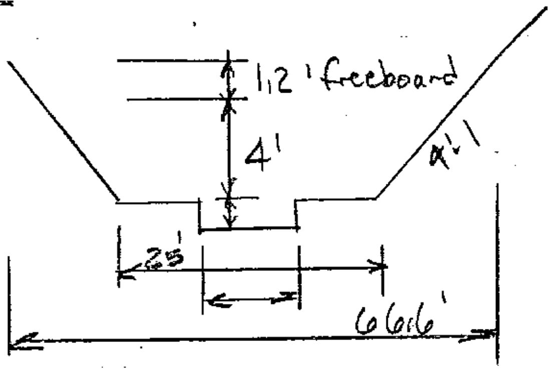
Client C Springs	By BWT	Date Dec 88

② Length = 900   2.5 %   728 cfs

storm sewer alternate   9x5/9x6 Box culvert

channel

1) grass

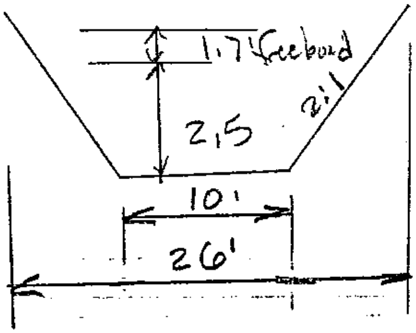


concrete
trickle channel
10%
73 cfs

V = 5 fps @ .5 %

5 drops 3.6' high
(every 180')

2) conc



V = 21 fps @ 2 %

1 drop 4.5 high

F

Project: Montebello - Facilitie's Design

Job Nº: E-3475C

Client: C Springs

By: BWT

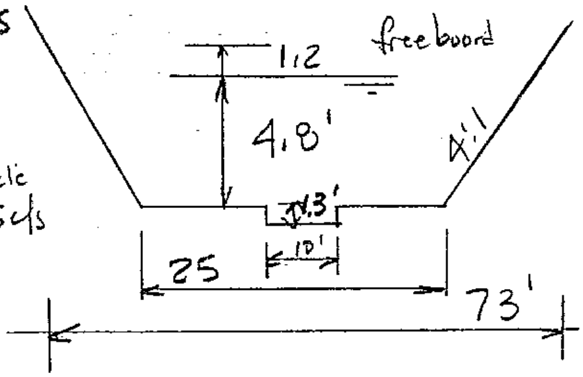
Date: Dec 88

③ Length = 550' 2.5% 1050

<u>Storm Sewer Alternate</u> 9x6 or 9x7 Box colvert

<u>Channel Alt</u>

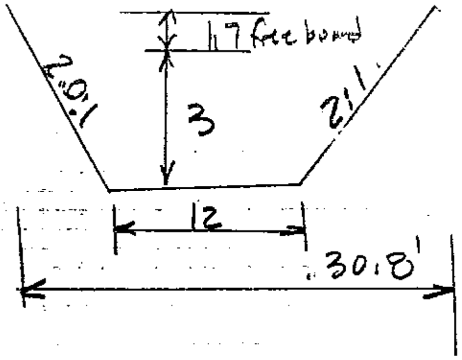
1) grass



conc trickle
10% 105cfs
V= 7fps

V = 5.2 fps
S = .4%
need drops = 12'
say 3-4' drops @ 180'

2) concrete



V= 20 fps @1.5%
5.5' drop

F

Project Montebello - Facilities Design	Job Nº E-3475C

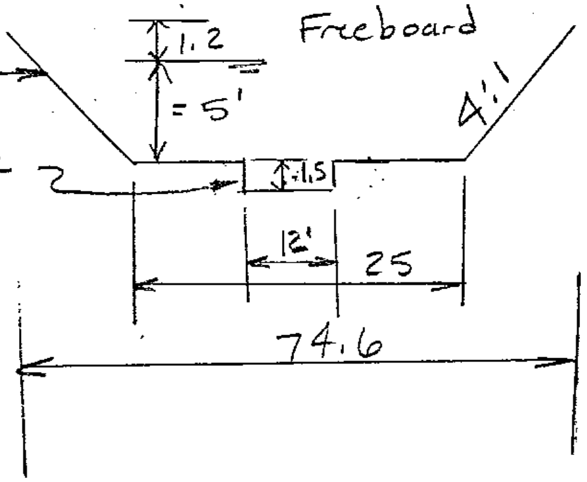
Client C Springs	By BWT	Date Dec '88

⑤ & ④ Length = 490'± 3% 1217cfs

<u>storm sewer alt.</u> 9x7 or 9x8 Box culvert

<u>channel alt.</u>

) grass



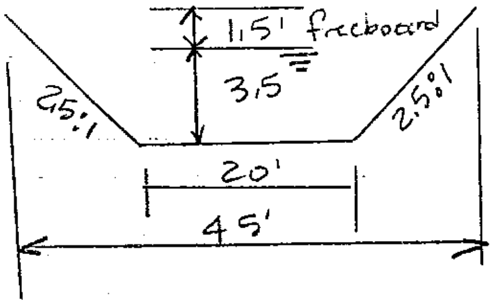
conc trickle
10%
121cfs
V = 7fps

V = 5.3fps

S = .4%

need 13' of drops say 3 - 4.5' drop every 163'

2) riprap
NG



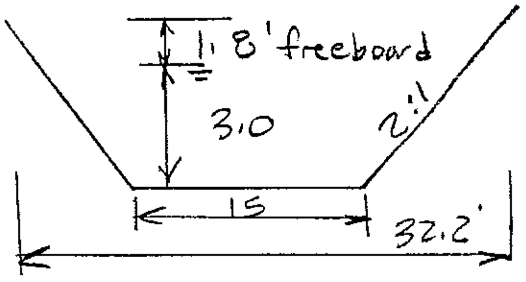
V = 12fps S = 2.0%

1' - 5' drop

Dc = 4'

supercritical

3) concrete



V = 20fps S = 1.5%

2 - 3' drop

Dc = 4.7'

supercritical

F

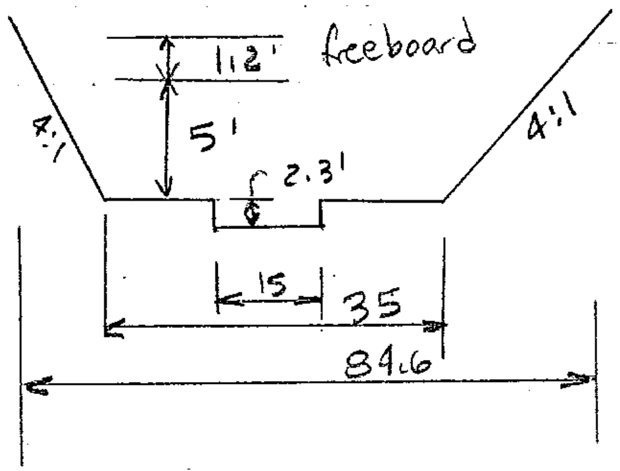
Project: Montebello - Facilitie's Design
Job Nº: E-3475C
Client: C Springs
By: BWT
Date: Dec '88

⑥ Length = 650' 2.5% 1514 cfs

storm sewer alt 9x8/9x9 Box culvert

channel

1) grass

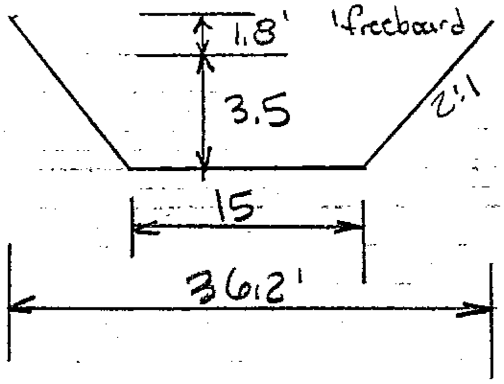


conc trickle channel
Q= 315 cfs
V= 9 fps

V = 5.5 @ .4%

14' drop
or 4 @ 3.5'
@ 160'

2) concrete



V = 20 fps @ S = 1.2%

3 - 3' drop

F

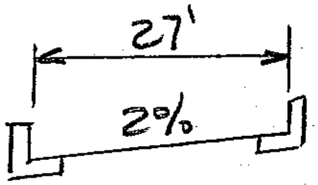
Project Montebello Facilities Design	Job No E-3475C

Client C Springs	By BWT	Date Dec '88

Street Capacity

minor storm

assume $S = 3\%$



- max spread = 20'
- no curb overtopping

fig. 7-3

$D = .4'$

$Q = 25\,\text{cfs}$

find min. area for $Q = 25\,\text{cfs}$

$Q = CIA$ @ $T_c = 5\,\text{min}$ $I_{10} = 6\,\text{in/hr}$

$C = .9$

$$A = \frac{25}{6(.9)}$$

$= 4.6$ Ac per inlet

F

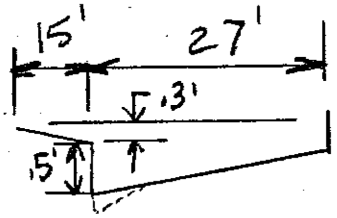
Project Montebello Facilities Design	Job Nº E-3475C

Client C Springs	By BWT	Date Dec 88

Street capacity

major storm

1/2 rd section



- depth @ gutter < 12"
- no inundation of bldg.

$n = .015$

$A = 17^{\#}$

$P = 43 \quad R^{2/3} = .54$

$Q = 1.49 \; A R^{2/3} S^{1/2} / n$

$Q = 1.49 (17) .54 (.17) / .015$

$Q = 158$ cfs

F

Project Montebello Facilities Design		Job Nº E-37454
Client C Springs	By BWT	Date Dec 88

size inlets - generic

Fig. 7-9

$d = .5'$ $T = 25'$ $S_x = .02$ $Q = 38$ c/s

$S = 3$ % assumed

$d_w = .46' = S_x (T-2)$

use <u>20' inlet</u> for $Q/Q = 45\%$ or P.U. ~17 c/s

for <u>north side</u> Montebello

Q_{10} total = 54 (A) + 23/4 (D) + 13 (H) + 31 (J) = 104 c/s

∴ use $\frac{104}{17}$ or 6 inlets

try also @ s = 2.%

@ Q = 10 c/s T = 15' fig 7.2

$L_i = 17'$ $Q/Q = .65$ or $Q_{pu} = 6.5$ c/s

$L_i = 30'$ $Q/Q = .8$ $Q_{pu} = 8$ c/s

for <u>south side</u> Montebello

Q_{10} total = 22 (E) + 22 (B) + 56 (C) + 13 (P) = 113 c/s

∴ use $\frac{113}{17} = 7$ inlets

17 c/s req's 24" RCP

F

Project Montebello Exist. Nevada Rd culvert		Job Nº E-37456
Client C Springs	By BWT	Date rev. June '89

Nevada Rd culvert

L = 136.5' 12' wide X 10'

INV. IN = 226.11 INV. out = 218.76

19' WW's @ 45° on east end, none on w.

2' sand @ w. end

RR. culvert

12' wide x 13.1' high w/ R=6' arch

INV. in(e) 6227.43, out(w) = 6226.35

sand (e) 28.3 sand(w) 28.7

17' WW

ck inlet control Nevada Rd culvert

HW avail = 39.4 - 26.11 = 13.3' or $\frac{HW}{D}$ = 1.33

for 100 yr flow = 2141 cfs Q/B = 178

actual HW/D = 1.9

no allow. cross flow for arterial

Q capacity = 1560 cfs Q/B = 130

need addition box for 581 cfs

or 8' high X 6' wide or 10' high X 5' wide @ HW/D = 1.3

note historic Q_{100} = 1261 cfs

G

DREXEL, BARRELL & CO. LAND SURVEYORS CIVIL ENGINEERS

2/2

Project Montebello	Job № E3745C

Client C Springs	By BWT	Date June 1989

ck inlet control RR culvert

assume 12' wide X 11' high box

HW/D avail = 1.3 Q = 2141 cfs

Q/B = 145 Q = 1740 cfs cap.

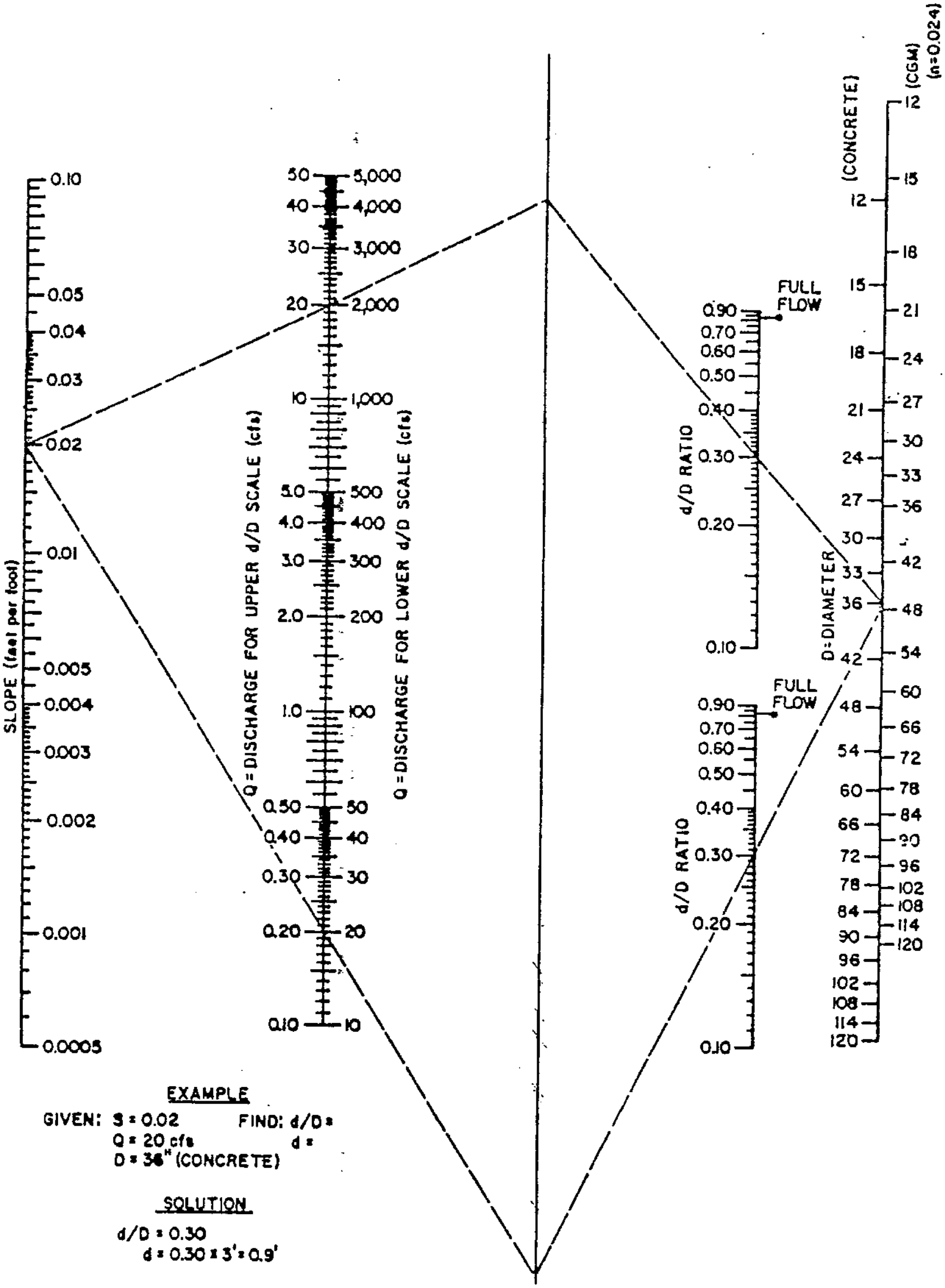
need additional box for 401 cfs

8' high x 5' wide

G

APPENDIX H

Miscellaneous Charts, Tables used in preparation of preliminary report



EXAMPLE

GIVEN: S = 0.02 FIND: d/D =
Q = 20 cfs d =
D = 36" (CONCRETE)

SOLUTION

d/D = 0.30
d = 0.30 × 3' = 0.9'

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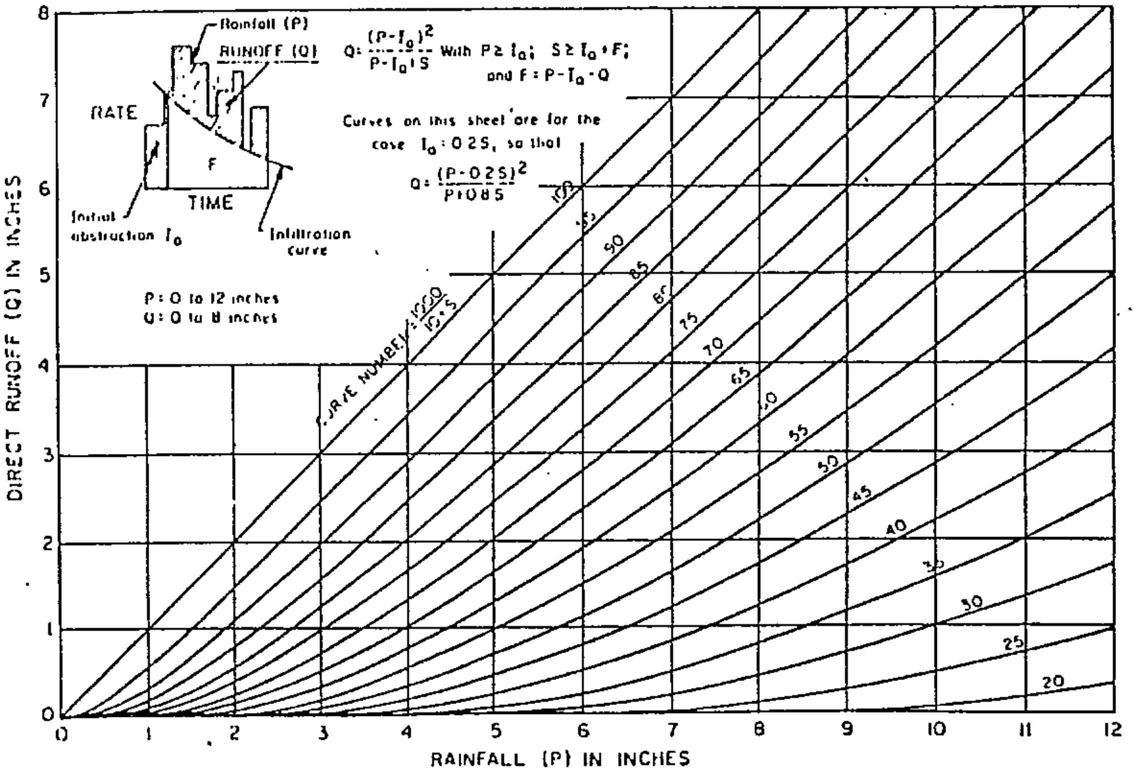
Uniform Flow for Pipe Culverts

Date
OCT. 1987

Figure
8 - 1



REFERENCE : Mockus, Victor; Estimating direct runoff amounts from strom rainfall: Central Technical Unit, October 1955, Soil Conservation Service

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Drainage Criteria Manual

Graphical Relationship Among Precipitation, Curve Numbers, and Direct Runoff

Date
OCT. 1987

Figure
5-8

TABLE 5-3

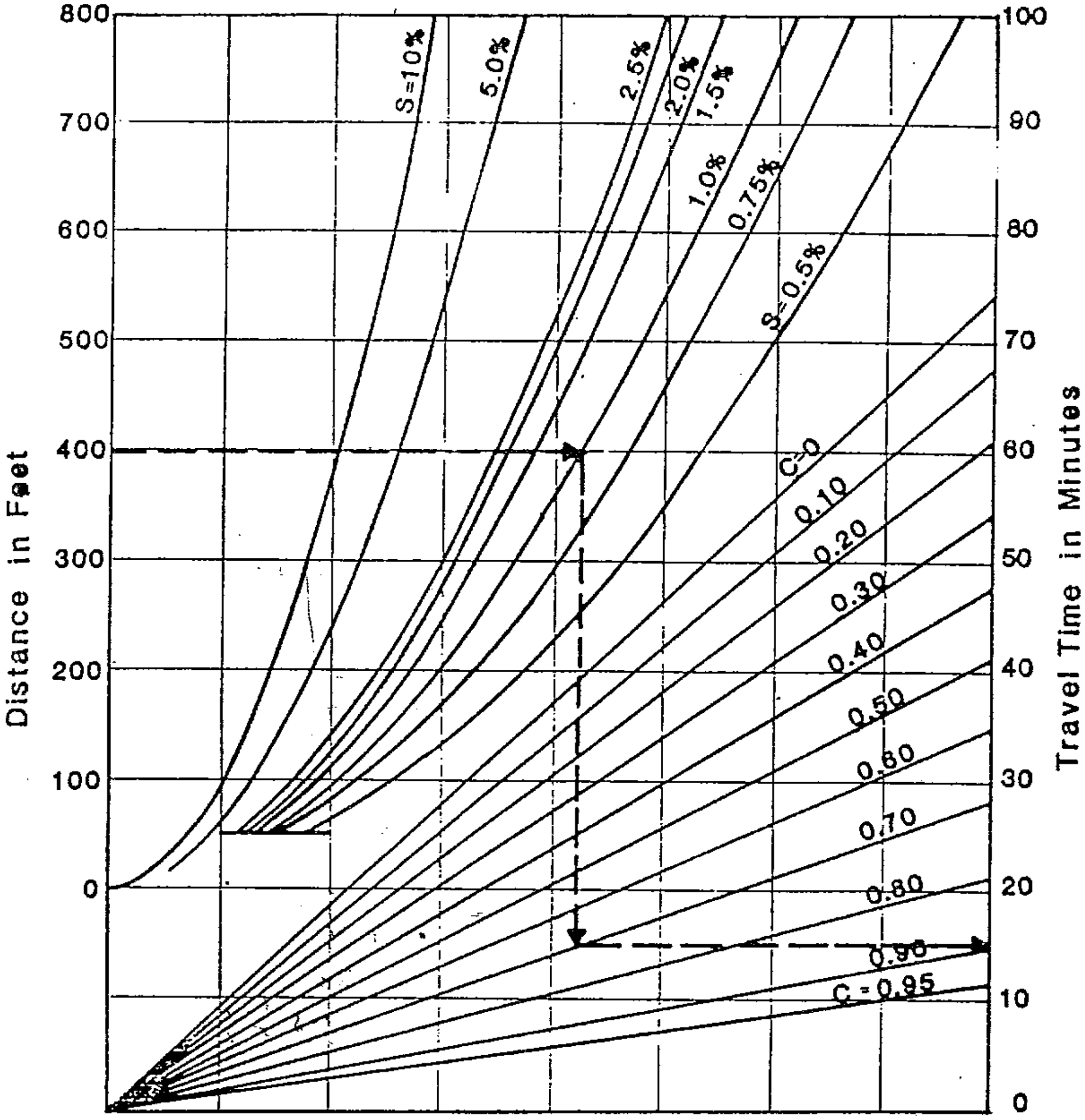
STANDARD SCS 24-HOUR, <u>TYPE IIA</u> CUMULATIVE RAINFALL DISTRIBUTION FOR TR-20 INPUT

Minute Intervals				
15	30	45	60	Hour
0.0005	0.0015	0.0030	0.0045	1
0.0060	0.0080	0.0100	0.0120	2
0.0143	0.0165	0.0188	0.0210	3
0.0233	0.0255	0.0278	0.0320	4
0.0390	0.0460	0.0530	0.0600	5
0.0750	0.1000	0.4000	0.7000	6
0.7250	0.7500	0.7650	0.7800	7
0.7900	0.8000	0.8100	0.8200	8
0.8250	0.8300	0.8350	0.8400	9
0.8450	0.8500	0.8550	0.8600	10
0.8638	0.8675	0.8713	0.8750	11
0.8788	0.8825	0.8863	0.8900	12
0.8938	0.8975	0.9013	0.9050	13
0.9083	0.9115	0.9148	0.9180	14
0.9210	0.9240	0.9270	0.9300	15
0.9325	0.9350	0.9375	0.9400	16
0.9425	0.9450	0.9475	0.9500	17
0.9525	0.9550	0.9575	0.9600	18
0.9625	0.9650	0.9675	0.9700	19
0.9725	0.9750	0.9775	0.9800	20
0.9813	0.9825	0.9838	0.9850	21
0.9863	0.9875	0.9888	0.9900	22
0.9913	0.9925	0.9938	0.9950	23
0.9963	0.9975	0.9988	1.0000	24

TABLE 5-2

STANDARD SCS 24-HOUR, TYPE II RAINFALL DISTRIBUTION FOR TR-20 INPUT

Minute Intervals				
15	30	45	60	Hour
0.0020	0.0050	0.0080	0.0110	1
0.0140	0.0170	0.0200	0.0230	2
0.0260	0.0290	0.0320	0.0350	3
0.0380	0.0410	0.0440	0.0480	4
0.0520	0.0560	0.0600	0.0640	5
0.0680	0.0720	0.0760	0.0800	6
0.0850	0.0900	0.0950	0.1000	7
0.1050	0.1100	0.1150	0.1200	8
0.1260	0.1330	0.1400	0.1470	9
0.1550	0.1630	0.1720	0.1810	10
0.1910	0.2030	0.2180	0.2360	11
0.2570	0.2830	0.3870	0.6630	12
0.7070	0.7350	0.7580	0.7760	13
0.7910	0.8040	0.8150	0.8250	14
0.8340	0.8420	0.8490	0.8560	15
0.8630	0.8690	0.8750	0.8810	16
0.8870	0.8930	0.8980	0.9030	17
0.9080	0.9130	0.9180	0.9220	18
0.9260	0.9300	0.9340	0.9380	19
0.9420	0.9460	0.9500	0.9530	20
0.9560	0.9590	0.9620	0.9650	21
0.9680	0.9710	0.9740	0.9770	22
0.9800	0.9830	0.9860	0.9890	23
0.9920	0.9950	0.9980	1.0000	24



REFERENCE : **Wright – McLaughlin Engineers, Urban Storm Drainage Criteria Manual, Vol. 1, Denver Regional Council of Governments, Denver, Co. 1977**

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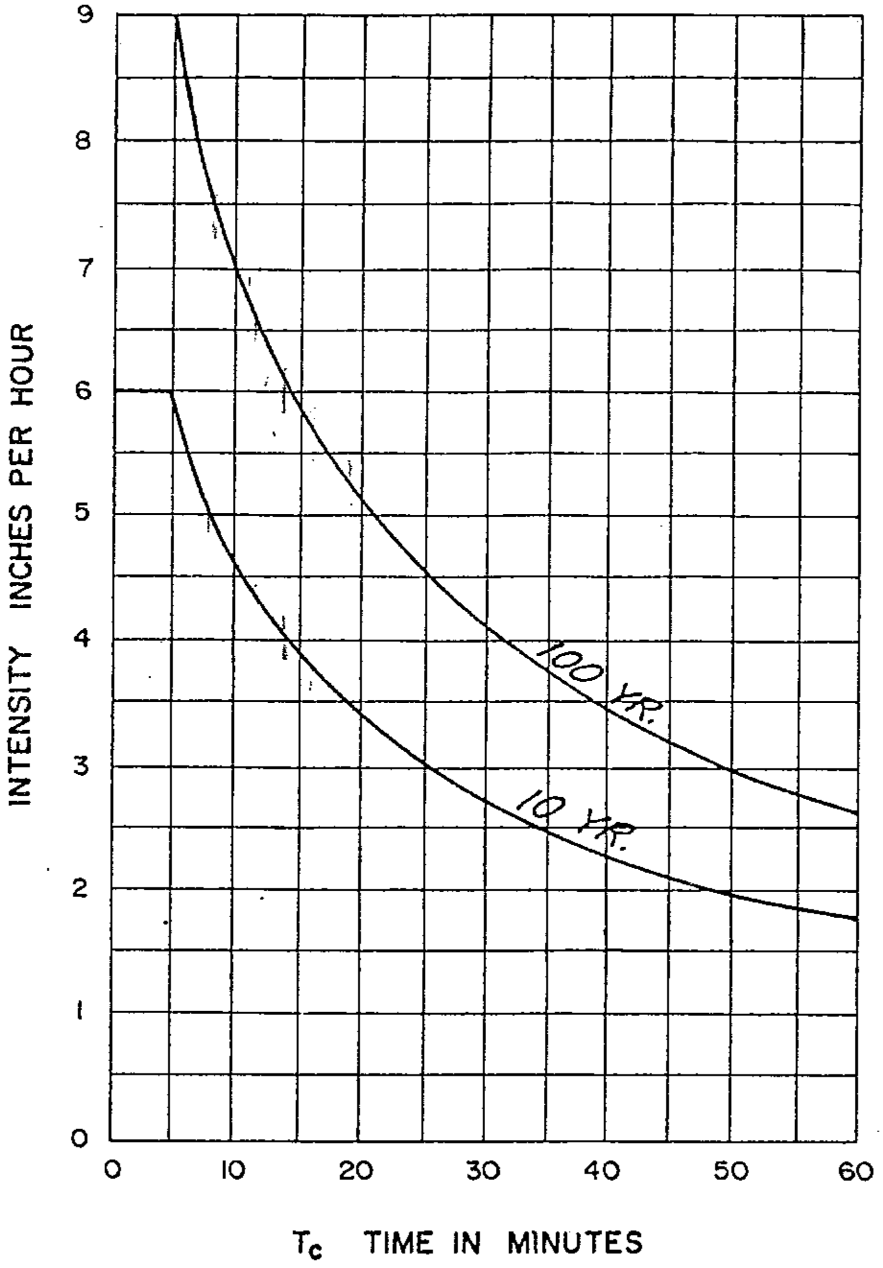
Figure
5-2

Overland Flow Curves



RE: Based upon Pikes Peak area council of governments/
areawide urban runoff control manual.

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Drainage Criteria Manual

Storm Rainfall
Time Intensity-Frequency Curves

Date
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Figure
5 - 1

NOTE: THIS TABLE TO BE USED FOR 24-HOUR STORM ONLY.

TABLE 5-5
RUNOFF CURVE NUMBERS FOR HYDROLOGIC SOIL-COVER COMPLEXES URBAN AND SUBURBAN CONDITIONS 1/

(For Antecedent Moisture Condition II)
(From: U.S. Department of Agriculture,
Soil Conservation Service, 1977)

Land Use		Hydrologic Soil Group			
		A	B	C	D
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
Good condition: grass cover on 75% or more of the area		39*	61	74	80
Fair conditon: grass cover on 50% to 75% of the area		49*	69	79	84
Commercial and business areas (85% impervious)		89*	92	94	95
Industrial districts 72% impervious)		81*	88	91	93
Residential:2/					
Acres per Dwelling Unit	Average % impervious3/				
1/8 acre or less	65	77*	85	90	92
1/4 acre	38	61*	75	83	87
1/3 acre	30	57*	72	81	86
1/2 acre	25	54*	70	80	85
1 acre	20	51*	68	79	84
Paved parking lots, roofs, driveways, etc.		98	98	98	98
Streets and roads:					
paved with curbs and storm sewers		98	98	98	98
gravel		76*	85	89	91
dirt		72*	82	87	89

1/ For a more detailed description of agricultural land use curve numbers, refer to in the National Engineering Handbook (U.S. Dept. of Agriculture, Soil Conservation Service, 1972).

2/ Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

3/ The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

* Not to be used wherever overlot grading or filling is to occur.

NOTE: THIS TABLE TO BE USED FOR 2-HOUR STORM ONLY.

TABLE 5-7
RUNOFF CURVE NUMBERS FOR HYDROLOGIC SOIL-COVER COMPLEXES URBAN AND SUBURBAN CONDITIONS 1/

(For Antecedent Moisture Condition III)
(From: U.S. Department of Agriculture, Soil Conservation Service, 1977)

Land Use			Hydrologic Soil Group			
			A	B	C	D
Open spaces, lawns, parks, golf courses, cemeteries, etc.						
Good condition:	grass cover on 75% or more of the area		59*	78	88	91
Fair conditon:	grass cover on 50% to 75% of the area		69*	84	91	93
Commercial and business areas (85% impervious)			96*	97	98	98
Industrial districts 72% impervious)			92*	95	97	98
Residential:2/						
Acres per Dwelling Unit		Average % impervious3/				
1/8 acre or less		65	89*	94	96	97
1/4 acre		38	78*	88	93	95
1/3 acre		30	75*	86	92	94
1/2 acre		25	73*	85	91	94
1 acre		20	70*	84	91	93
Paved parking lots, roofs, driveways, etc.			99	99	99	99
Streets and roads:						
paved with curbs and storm sewers			99	99	99	99
gravel			89*	94	96	97
dirt			86*	92	95	96

1/ For a more detailed description of agricultural land use curve numbers, refer to in the National Engineering Handbook (U.S. Dept. of Agriculture, Soil Conservation Service, 1972).

2/ Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

3/ The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

* Not to be used wherever overlot grading or filling is to occur.

TABLE 5-4
RUNOFF CURVE NUMBERS FOR HYDROLOGIC
SOIL-COVER COMPLEXES--RURAL CONDITIONS
(Antecedent Moisture Condition II, and $I_a = 0.2\ S$)
(From: U.S. Dept. of Agriculture,
Soil Conservation Service, 1977)

NOTE: THIS TABLE TO
BE USED FOR 24-HOUR
STORM ONLY.

Land Use	Cover Treatment or Practice	Hydrologic Condition	Runoff curve number by Hydrologic soil group			
			A	B	C	D
Fallow	Straight Row	----	77	86	91	94
Row crops	Straight Row	Poor	72	81	88	91
	Straight Row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Cont. and terraced	Poor	66	74	80	82
	Cont. and terraced	Good	62	71	78	81
Small grain	Straight Row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Cont. and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes 1/ or rotation meadow	Straight Row	Poor	66	77	85	89
	Straight Row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Cont. and terraced	Poor	63	73	80	83
	Cont. and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		----	59	74	82	86
Roads (dirt) 2/		----	72	82	87	89
(hard surface) 2/		----	74	84	90	92

1/ Close-drilled or broadcast
2/ Including right-of-way

TABLE 5-1

RECOMMENDED AVERAGE RUNOFF COEFFICIENTS AND PERCENT IMPERVIOUS

LAND USE OR SURFACE CHARACTERISTICS	PERCENT IMPERVIOUS	"C" FREQUENCY 10 A&B*	10 C&D*	100 A&B*	100 C&D*
Business					
Commercial Areas	95	0.90	0.90	0.90	0.90
Neighborhood Areas	70	0.75	0.75	0.80	0.80
Residential					
1/8 Acre or less	65	0.55	0.65	0.65	0.75
1/4 Acre	40	0.50	0.60	0.60	0.70
1/3 Acre	30	0.40	0.50	0.55	0.60
1/2 Acre	25	0.35	0.45	0.45	0.55
1 Acre	20	0.30	0.40	0.40	0.50
Industrial					
Light Areas	80	0.70	0.70	0.80	0.80
Heavy Areas	90	0.80	0.80	0.90	0.90
Parks and Cemeteries	7	0.30	0.35	0.55	0.60
Playgrounds	13	0.30	0.35	0.60	0.65
Railroad Yard Areas	40	0.50	0.55	0.60	0.65
Undeveloped Areas					
Historic Flow Analysis-Greenbelts, Agricultural	2	0.15	0.25	0.20	0.30
Pasture/Meadow	0	0.25	0.30	0.35	0.45
Forest	0	0.10	0.15	0.15	0.20
Exposed Rock	100	0.90	0.90	0.95	0.95
Offsite Flow Analysis (when land use not defined)	45	0.55	0.60	0.65	0.70
Streets					
Paved	100	0.90	0.90	0.95	0.95
Gravel	80	0.80	0.80	0.85	0.85
Drive and Walks	100	0.90	0.90	0.95	0.95
Roofs	90	0.90	0.90	0.95	0.95
Lawns	0	0.25	0.30	0.35	0.45

* Hydrologic Soil Group

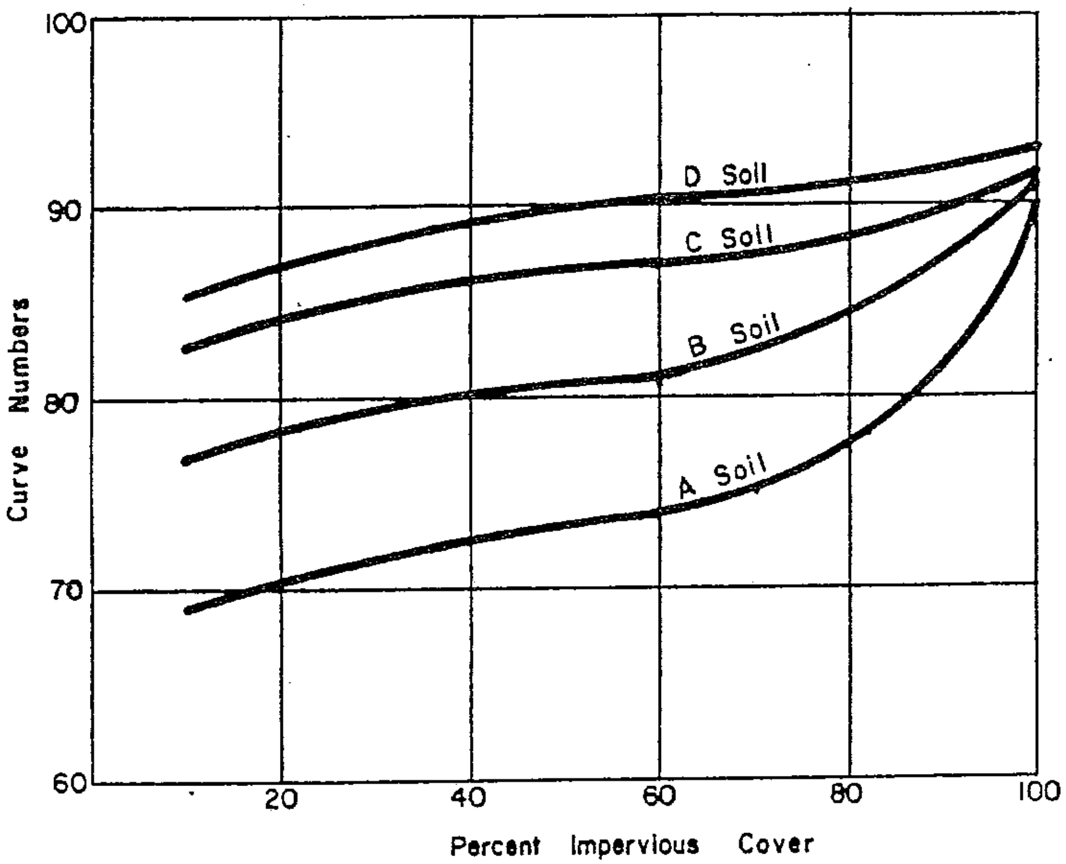
TABLE 5-6
RUNOFF CURVE NUMBERS FOR HYDROLOGIC SOIL-COVER COMPLEXES--RURAL CONDITIONS

(Antecedent Moisture Condition III, and $I_a = 0.2 S$)
(From: U.S. Dept. of Agriculture,
Soil Conservation Service, 1977)

NOTE: THIS TABLE TO BE USED FOR 2 HOUR STORM ONLY.

Land Use	Cover Treatment or Practice	Hydrologic Condition	Runoff curve number by Hydrologic soil group			
			A	B	C	D
Fallow	Straight Row	----	89	94	97	98
Row crops	Straight Row	Poor	86	92	95	97
	Straight Row	Good	83	90	94	96
	Contoured	Poor	85	91	93	95
	Contoured	Good	82	88	92	94
	Cont. and terraced	Poor	82	88	91	92
	Cont. and terraced	Good	79	86	90	92
Small grain	Straight Row	Poor	82	89	93	95
		Good	80	88	93	95
	Contoured	Poor	80	88	92	94
		Good	78	87	92	93
	Cont. and terraced	Poor	78	86	91	92
		Good	77	85	90	92
Close-seeded legumes 1/ or rotation meadow	Straight Row	Poor	82	89	94	96
	Straight Row	Good	76	86	92	94
	Contoured	Poor	81	88	93	94
	Contoured	Good	74	84	90	93
	Cont. and terraced	Poor	80	87	91	93
	Cont. and terraced	Good	70	83	89	91
Pasture or range		Poor	84	91	94	96
		Fair	69	84	91	93
		Good	59	78	88	91
	Contoured	Poor	67	83	92	95
	Contoured	Fair	64	77	88	93
	Contoured	Good	15	55	85	91
Meadow		Good	50	76	86	90
Woods		Poor	65	82	89	93
		Fair	56	78	87	91
		Good	43	74	85	89
Farmsteads		----	77	88	92	94
Roads (dirt) 2/		----	86	92	95	96
(hard surface) 2/		----	88	93	96	97

1/ Close-drilled or broadcast
2/ Including right-of-way



URBAN HYDROLOGIC SOIL COVER COMPLEX
& ASSOCIATED CURVE NUMBERS

REFERENCE : Pikes Peak Area Council of Governments Areawide Urban Runoff Control Manual

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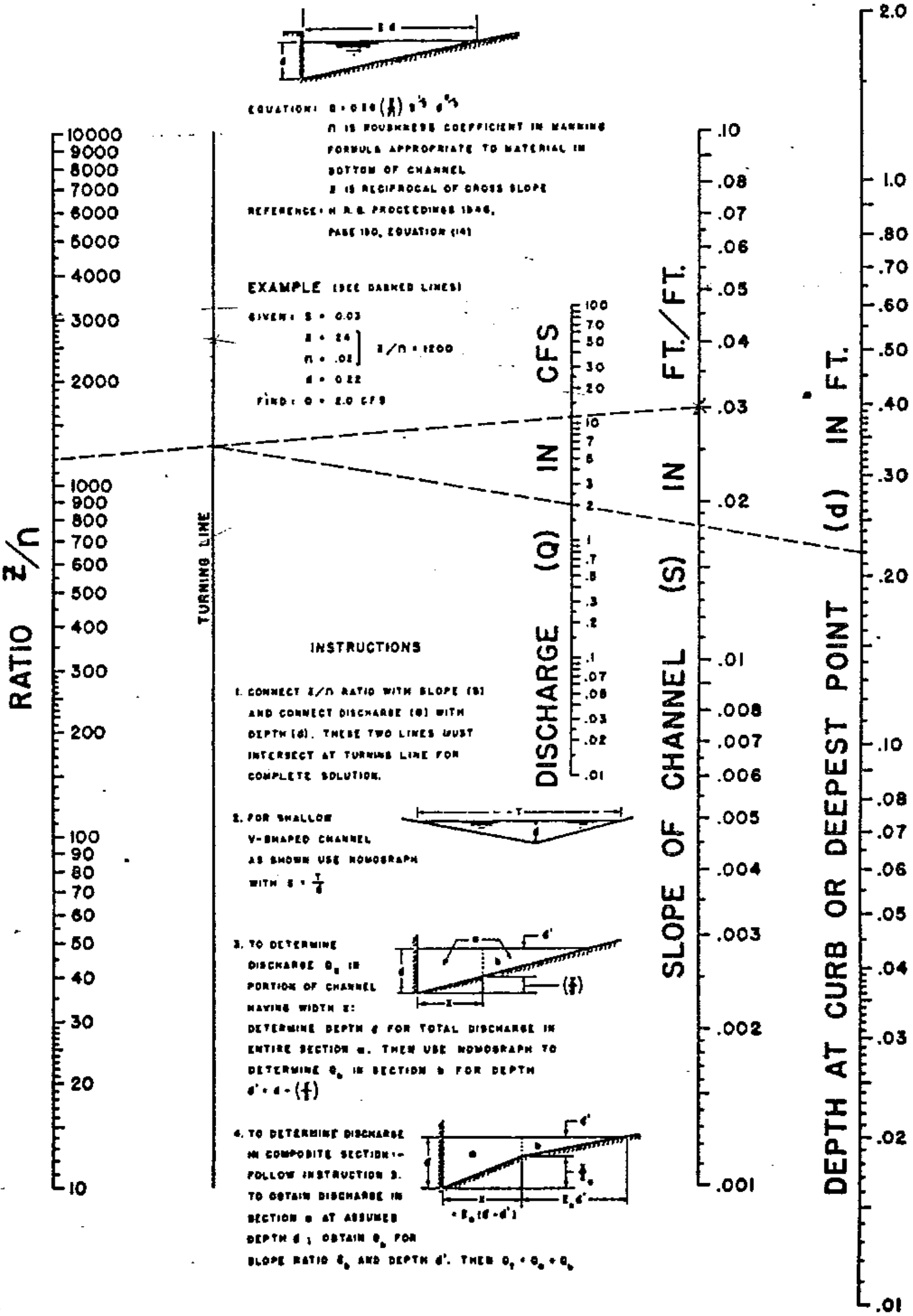
Drainage Criteria Manual

Urban Hydrologic Soil Cover
Complex and Associated Curve Numbers

Date
OCT. 1987

Figure
5-7



EQUATION: $Q = 0.56 \left(\frac{z}{n}\right) S^{1/2} d^{8/3}$

n IS ROUGHNESS COEFFICIENT IN MANNING FORMULA APPROPRIATE TO MATERIAL IN BOTTOM OF CHANNEL

z IS RECIPROCAL OF CROSS SLOPE

REFERENCE: H. R. B. PROCEEDINGS 1946, PAGE 150, EQUATION (14)

EXAMPLE (SEE DASHED LINES)

GIVEN: S = 0.03

$\left.\begin{array}{l} z = 24 \\ n = .02 \end{array}\right]$ z/n = 1200

d = 0.22

FIND: Q = 2.0 CFS

INSTRUCTIONS

1. CONNECT z/n RATIO WITH SLOPE (S) AND CONNECT DISCHARGE (Q) WITH DEPTH (d). THESE TWO LINES MUST INTERSECT AT TURNING LINE FOR COMPLETE SOLUTION.
2. FOR SHALLOW V-SHAPED CHANNEL AS SHOWN USE NOMOGRAPH WITH $z = \frac{T}{d}$
3. TO DETERMINE DISCHARGE Q_x IN PORTION OF CHANNEL HAVING WIDTH x: DETERMINE DEPTH d FOR TOTAL DISCHARGE IN ENTIRE SECTION a. THEN USE NOMOGRAPH TO DETERMINE Q_b IN SECTION b FOR DEPTH $d' = d - \left(\frac{x}{z}\right)$
4. TO DETERMINE DISCHARGE IN COMPOSITE SECTION:- FOLLOW INSTRUCTION 3. TO OBTAIN DISCHARGE IN SECTION a AT ASSUMED DEPTH d; OBTAIN Q_b FOR SLOPE RATIO z_b AND DEPTH d'. THEN $Q_T = Q_a + Q_b$

11-15-68

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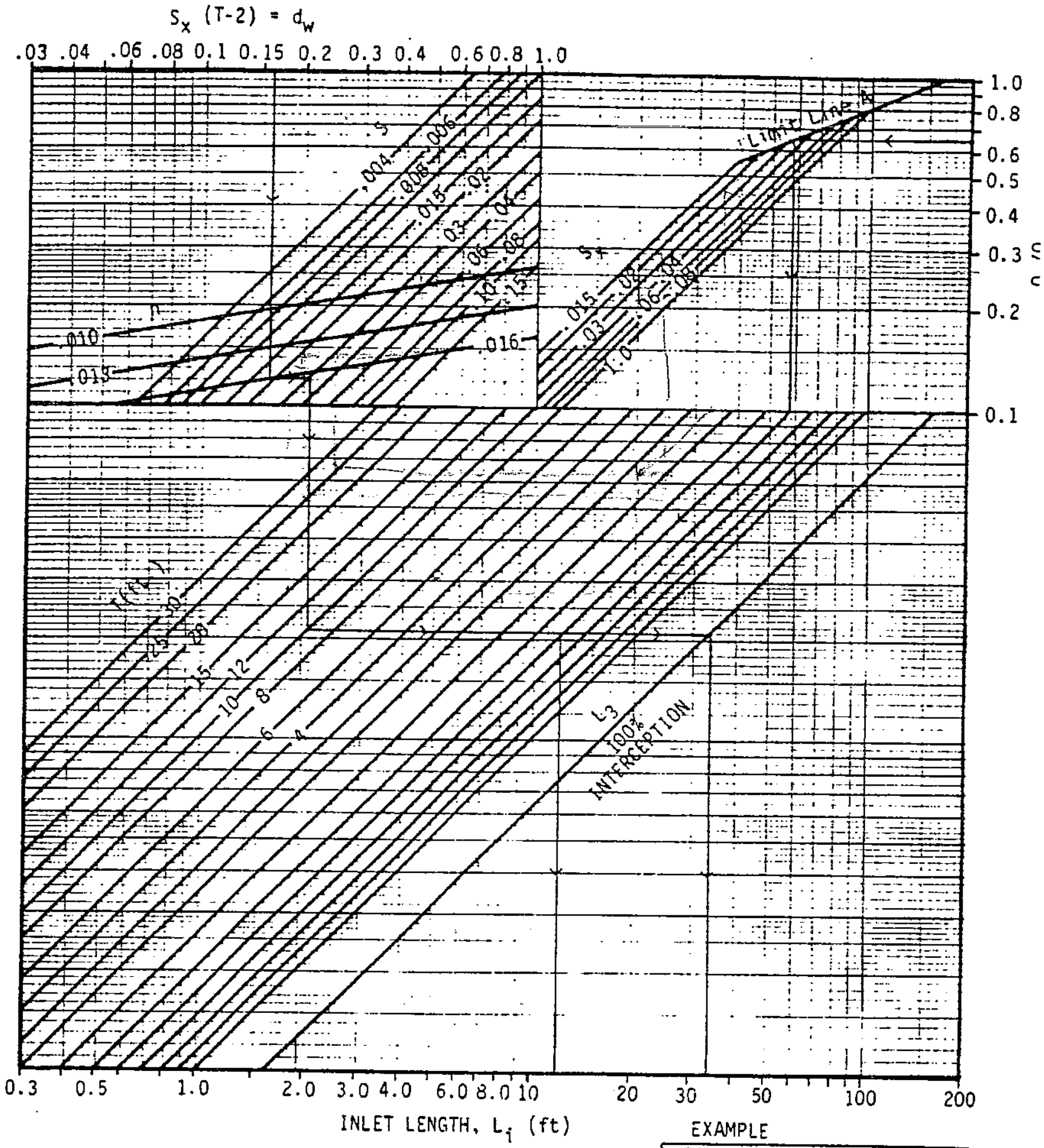
NOMOGRAPH FOR FLOW IN TRIANGULAR GUTTERS.

Date
OCT. 1987

Figure
7 - 2



This chart assumes, w=2 ft.,a = 2" and h=6in.

REFERENCE :

Izzard, Carl. f., Report presented at the Annual Meeting of the National Transportation Board, January 1977; Simplified Method For Design of Curb-opening Inlets

EXAMPLE

Given — S_x = 0.02 ft/ft
T = 10 ft.
S = 0.03 ft/ft

Find — L_i = 11.8 ft L_i = 34 ft.
Q_i/Q= 0.65 Q_i/Q=1.0

Standard Curb-Opening Inlet Chart

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Date
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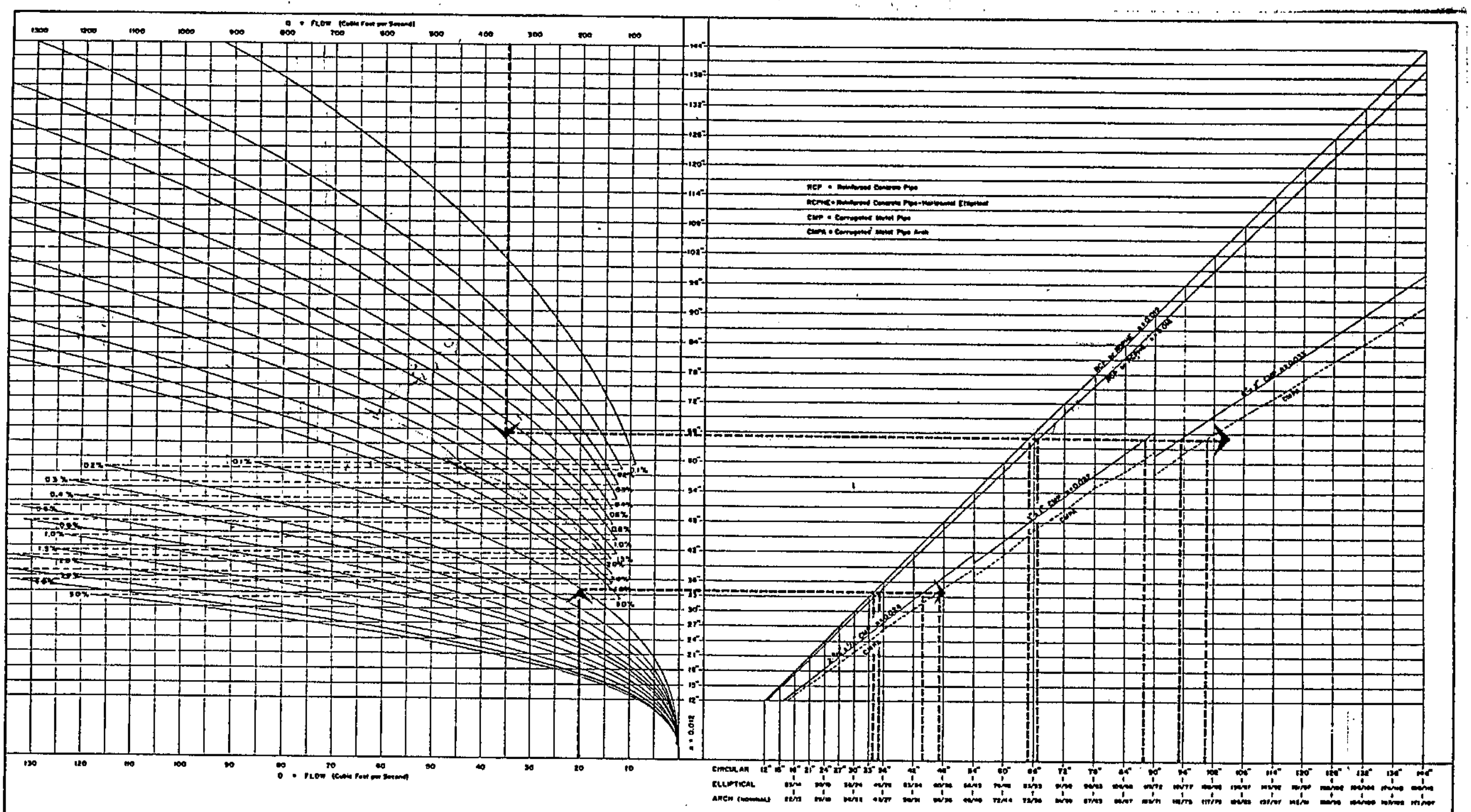
Figure
7 - 9



STORM CONDUIT SIZING CHART

MANNING FORMULA

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

FLOWING FULL CONDITION where:

Q = FLOW (Cubic Feet per Second)
A = AREA (Square Feet)
R = HYDRAULIC RADIUS (Feet)
s = SLOPE (Feet per Feet)
n = FRICTION FACTOR (Manning)

HYDRAULICS

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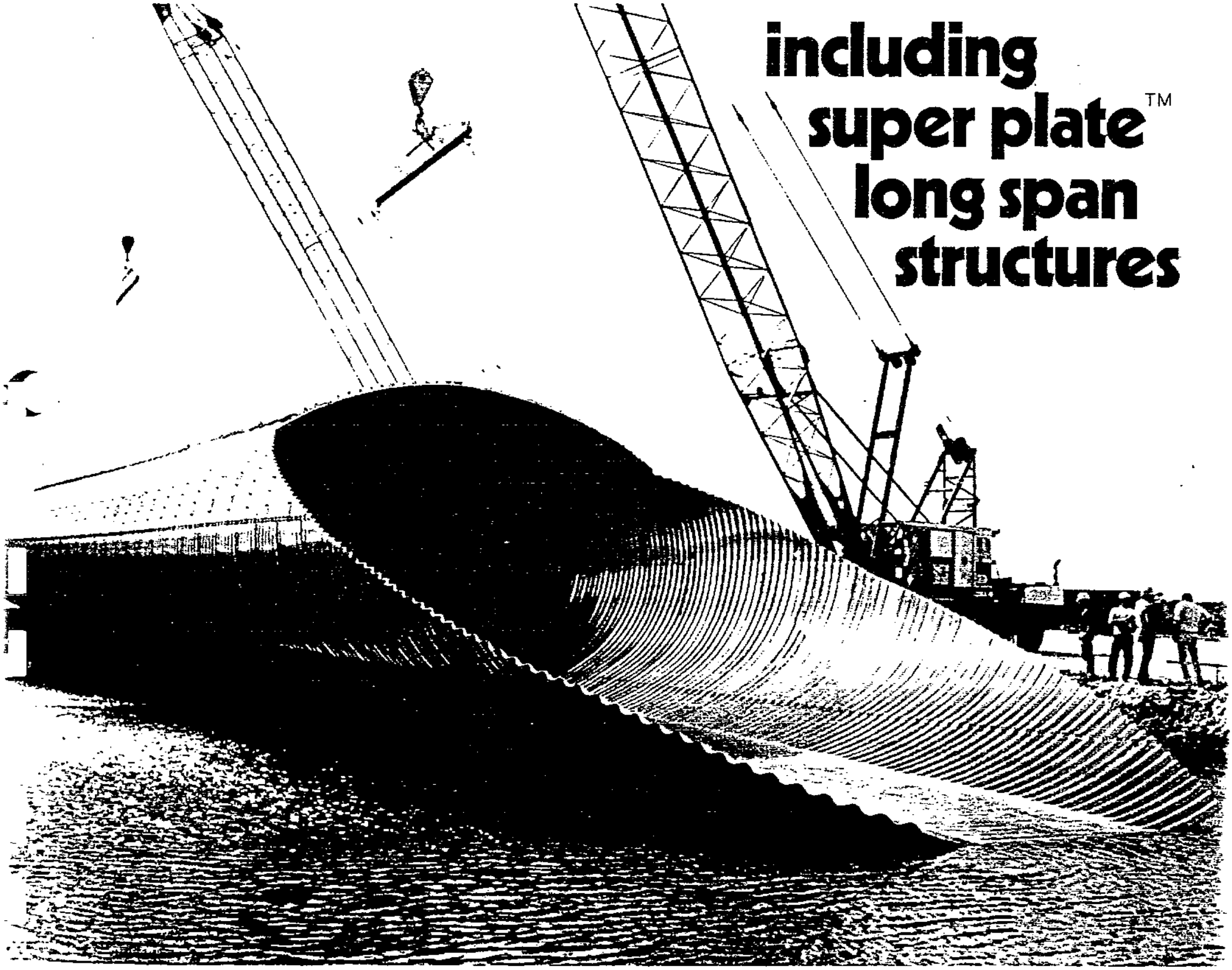

"King of the Culverts" is the apt description of this Super Plate™ structure installed to permit a two-lane crossing of Black Creek in Dade County Florida. Light weight of aluminum simplified assembly and made possible this single-lift positioning. The structure utilized advanced, computer-assisted design procedures pioneered by Kaiser Aluminum.

I

Aluminum is compatible with concrete. There is an initial reaction with fresh concrete. However, within a day or so, the reaction ceases and further corrosion will not occur. Early set admixtures should not be used. Grout should be nonmetallic, non shrink material and should contain no corrosion promoting agents.

Abrasion resistance

In the mid 60's it was observed that the ductile properties of aluminum allowed the culvert surface to be moved or "peened" rather than removed under erosive and moderately abrasive condition. These observations prompted a four year research effort to confirm the energy levels at which metal removal would occur, and more importantly, rates of such removal translated into culvert service life.

The research culminated with the preparation of a technical paper presented by The Aluminum Association to the Highway Research Board in January 1969, entitled "The Mechanisms of Abrasion of Aluminum Alloy Culvert, Related Field Experiences and a Method to Predict Culvert Performance" by A. H. Koepf. It is an excellent treatment of the subject in that it effectively correlates mathematical hypothesis with numerous field observations. A copy of the paper is available upon request. Specific conclusions drawn were as follows:

- Degree of abrasion is a function of bed load flow energy, mass and velocity.
- Metal removal is insignificant when mean pipe water velocities do not exceed 20 ft/sec and bed load is limited to 2 inch round rock size.
- Metal removal up to .002 inches/year may be expected when mean pipe water velocities are in the order of 20 to 25 ft/sec and rock sizes are limited to 4".
- There was general uniformity of performance for similar terrains, bed load, and cumulative flow times. While there was some surface peening, there was no observed metal loss due to sand or very small rock bed loads, even when the flows were high.
- The total cycle causing metal loss of aluminum due to erosion-corrosion has been observed by the author to differ markedly from the cycle causing metal loss from galvanized steel culvert. Galvanized steel exposed to an abrasive flow follows an erosion-corrosion-erosion cycle. The abrasive material removes the relatively soft zinc and exposes the steel surface below at a rate that depends on the severity of flow; iron oxide is then formed, only to be removed by further abrasive flow. This mechanism of corrosion-erosion attack causes steady rates of wastage of steel culvert inverts. The surface hardness of steel was observed to resist the abusive action of larger rocks under severe conditions of flow moderately well. The wastage rate is governed more by the corrosion portion of the erosion-corrosion cycle than the abrasion only. The progressive erosion-corrosion cycle proceeds in all types of abrasive flow including sand and gravel.
- In cases where water may be corrosive, wastage would increase.

A method of predicting performance of aluminum corrugated drainage pipe was developed from this study. Peak energy curves were converted into a service life chart. The spread in expected service life is due in large part to wide differences in metal thickness (16 Ga. to 8 Ga.) that are commonly used.

With these recommendations an experienced engineer can predict performance by evaluating the channel to be drained in the immediate proximity to the upstream entrance to a pipe and estimating what maximum rock size can be expected to reach and pass repeatedly through the pipe. He must consider slopes, soil types, and rainfall patterns.

Hydraulic adaptability

In the usual applications for structural plate or super plate, inlet control will be common, although outlet control should be checked. To aid your hydraulic analysis, Kaiser Aluminum has developed inlet and outlet control nomographs specific to aluminum structural plate pipe and pipe arch. For arch structures with contrete or natural inverts, nomographs have been developed by Dr. James R. Barton and Dr. A. Woodruff Miller, Civil Engineering professors at Brigham Young University, at Provo, Utah. They are based on research reports by John L. French and H. G. Bossy, and are similar to nomographs found in Hydraulic Engineering Circular No. 5. All nomographs may be obtained upon request from any of the sales offices listed on inside back cover.

Design assistance is available for inlet control design of horizontal ellipse, low, and high profile arches. Outlet control will best be performed using backwater calculations. Conduit frictional resistance can be approximated using the 1966 report by the Corps of Engineers entitled "Resistance Coefficients for Structural Plate Corrugated Pipe". The formula, referenced on page 19 of that publication, was used to compute roughness coefficients "n" for bolted structures.

$$n = \frac{0.039}{D^{.074}}$$

where D = diameter of pipe in feet

For closed conduit shapes the total circumference can be converted to an equivalent diameter to obtain D.

Some economies in size can be achieved when the installation is on a steep slope by depressing the inlet to attain some of the benefits of improved culvert inlets. See Hydraulic Engineering Circular number 13 for further information. Arches with a smooth invert can provide improved capacity through roughness coefficient improvement.

A note about special designs

The following sections include fundamental data for application, design and installation of aluminum structural plate. However, not every project can be accommodated by this data. Consequently, Kaiser Aluminum has available skilled and experienced technical personnel to assist your projects with their knowledge and computer programs. For this assistance, call your nearest Kaiser Aluminum Drainage Products sales office or your nearest independent culvert fabricator or distributor offering Kaiser Aluminum Drainage Products. Sales offices are listed on the inside back cover.

Title No. 52-18

Erosion Resistance of Concrete in Hydraulic Structures*

Reported by ACI Committee 210

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SYNOPSIS

Attention is given mainly to the physical erosion of concrete in hydraulic structures resulting from particles carried by flowing water and from pitting resulting from cavities forming and collapsing in water flowing at high velocities. Disintegration of concrete by chemical attack as may occur in hydraulic structures is also discussed.

Materials, mix proportions, and construction procedures which will make concrete more resistant to erosion are presented. Means of improving concrete resistance to chemical disintegration are also discussed.

INTRODUCTION

This report is concerned mainly with the physical erosion of concrete in hydraulic structures resulting from particles carried by flowing water and from pitting resulting from cavities forming and collapsing in water flowing at high velocities. Disintegration of concrete by chemical attack as may occur in hydraulic structures is also discussed. Other types of disintegration are beyond the scope of this report.

In general, erosion resistance of concrete increases as the strength of the concrete is increased. Materials and methods which tend to increase the strength of concrete at the surface, or throughout the mass, also increase erosion resistance. However, the best concrete that can be made will not withstand the forces of cavitation or severe abrasion for a prolonged period. Materials, mix proportions, and construction procedures which will make concrete more resistant to erosion are discussed. Means of improving concrete resistance to chemical disintegration are also discussed.

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*Received by the Institute Apr. 27, 1955. Title No. 52-18 is a part of copyrighted JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, V. 27, No. 3, Nov. 1955, *Proceedings* V. 52. Separate prints are available at 50 cents each. Discussion (copies in triplicate) should reach the Institute not later than Mar. 1, 1956. Address 18263 W. McNichols Rd., Detroit 19, Mich.

This report in form and substance as here submitted was approved unanimously by the committee as listed above.

†Deceased.

I

EROSION BY CAVITATION

Vapor bubbles will form in running water whenever the pressure at a point in the liquid is reduced to its vapor pressure in accordance with the following relationship:

$$P - \frac{V^2}{2g} C = V_p$$

where

P = apparent absolute pressure, ft of water
$V^2/2g$ = velocity head, ft
C = coefficient depending upon the shape and/or roughness of the surface boundary
V_p = vapor pressure of water at given temperature, ft of water, absolute

These vapor bubbles flow downstream with the water and upon entering an area of higher pressure collapse with great impact. When water vapor is compressed, the pressure of the vapor will increase until the vapor becomes saturated; then suddenly with very small increase in pressure the vapor will condense into a liquid state. The liquid occupies much less space than the vapor from which it was condensed, thus leaving a cavity. The collapse of these cavities has been termed "implosions," the opposite of "explosions," but is similar in effect. Repeated collapse of such cavities on or near the surface of the concrete will cause pitting. Pitting due to cavitation is readily recognized from the holes or pits formed, which are distinguished from the smoother worn-appearing surface caused by sand, silt, or rocks carried by the flowing water.

Boundary irregularities and shape cause local reductions in pressure when water flows past them at high velocity. When the size and nature of the irregularity and the flow velocity are such that reduced pressure is equal to the vapor pressure of water, cavitation will occur. Damage from cavitation is not common in open conduits at water velocities below 40 ft per sec. Fig. 1

Fig. 1—Pitting in Parker Dam gate pier below gate slot. Note pitting in metal of gate guide. This type of pitting is common and has occurred near the control gates on other structures. Maximum velocity was 50 ft per sec

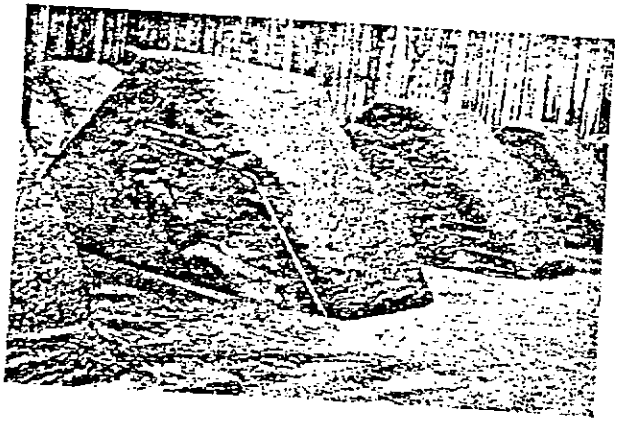

Fig. 2—Pitting in concrete baffles in the Bonneville Dam stilling basin after 17 years of heavy service. The arrow indicates the direction of the high velocity water during each seasonal flood. The attrition on baffles was progressive and had reached a point, when they were repaired in 1955, where hydraulic conditions in the stilling basin were adversely affected by reduction in the efficiency of the baffles

shows the damage which resulted at Parker Dam for a maximum velocity of about 50 ft per sec. Fig. 2 shows damage to concrete baffles in the Bonneville Dam stilling basin after 17 years of service. Velocities ranged from 60 to 70 ft per sec. Concrete in closed conduits has been pitted by cavitation at velocities as low as 25 ft per sec where the air pressure was reduced by the sweep of the flowing water. Fig. 3 shows such damage in a conduit below a control gate, produced at a velocity of about 25 ft per sec. At higher velocities the forces of cavitation are sufficient to erode away large quantities of high-quality concrete and to penetrate through thick steel plates in a comparatively short time. Concrete in spillways and outlet works of many high dams has been severely damaged by forces of cavitation. In closed conduits the liquid can be made more compressible by introducing air into the flowing water near the point of disturbance, and the forces resulting from collapsing vapor bubbles can be reduced.

The best means, however, of protecting concrete from forces of cavitation is the elimination of these forces, whenever possible, by design and construction procedures which will produce smooth, uniform flow in the hydraulic structure. Abrupt changes in slope and curvature, particularly adverse changes which tend to allow the flow to pull away from the concrete surface, should be avoided, and care should be exercised to obtain a smooth surface

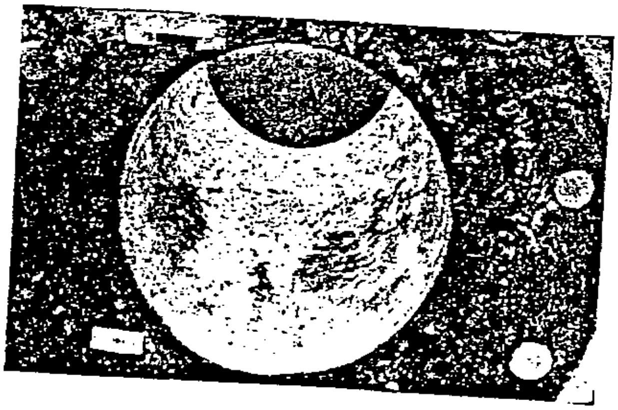

Fig. 3—Pitting in 6-in. ID mortar lined pipe below control gate—velocity about 25 ft per sec

free from irregularities. An example of damage, on the inclined face of Grand Coulee Dam, resulting from poor alignment below a place where the forms had sprung out of line is shown in Fig. 4. There are a number of examples where the bottom of inclined tunnels, spillway buckets, stilling pools, and piers and crests just downstream from gate guide slots have been damaged by forces of cavitation, and these locations need special attention in design and construction. Computed cavitation-free designs are often so conservative that their costs are prohibitive. In such cases hydraulic model studies may be used to arrive at acceptable designs with due regard to cost.

The sloping faces of overflow spillways have not been damaged by cavitation where reasonable care has been taken to produce surfaces of sound concrete without irregularities. Small voids or "bug holes" which occur on formed surfaces are not necessarily objectionable, but obstructions which protrude above the plane of the surface will result in pitting downstream from the obstruction.

Concrete is comparatively strong in compression and there are many tests and experiences which show that dense concrete can withstand the impact of a jet of water hitting it at velocities as high as 100 ft per sec without damage at the point of impact. Damage has occurred in some cases as a result of water impact, and it is indicated that such failures may be due to the pressures built up in the pores of the concrete which are sufficient to cause failure in the concrete in tension at points of reduced pressure. For this reason it is desirable to use dense concrete having an impermeable surface when it will be expected to withstand the impact of water flowing at high velocities.

Fig. 4—View looking up spillway face of Grand Coulee Dam showing pitted area at elevation 990 below place where form sprung out of line during construction

EROSION BY ABRASION

Erosion of concrete by silt, sand, gravel, and other solids can be as severe as that caused by cavitation. Fig. 5 shows erosion caused by movement of sand and gravel by eddy currents in the bucket of Grand Coulee Dam. Stilling basins which are not self-cleaning in which rocks and sand collect are eroded by the movement of solids by eddy currents in the pool, and concrete over which large quantities of sand and gravel are transported by floods may be seriously eroded.

Concrete in the invert of the 20-ft diameter, 1300 ft long tunnel at Anderson Ranch Dam was worn away to a depth of about 3 in. while it was used for diverting the flow of the river for 43 months during construction of the dam.

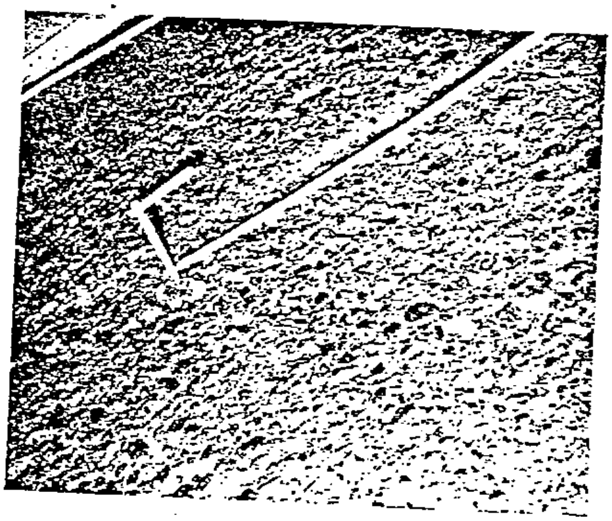

Fig. 5 — Surface of dewatered bucket of Grand Coulee Dam showing condition of surface eroded by sand and gravel

The water carried large quantities of silt, sand, and gravel during the spring runoff, and when the tunnel was unwatered the invert was covered to a depth of several feet with such material. The wear was fairly uniform on all types of aggregate and the exposed surfaces of the larger aggregate were smooth and flat. Some of the 1:2 dry-packed mortar patches in this tunnel were completely eroded away, and in general the mortar patches were eroded more than the surrounding concrete. Maximum velocity of the water in the tunnel was about 30 ft per sec. The new low-slump concrete which has been installed in this tunnel and subjected to high velocities of relatively clear water since it was converted to an outlet tunnel, shows only slight wear. Similar erosion was experienced in the diversion tunnels of Hoover Dam prior to their conversion to outlet and spillway tunnels. There are many cases where the concrete of dams and tunnel linings has been damaged by erosion during the construction period, and this possibility should not be overlooked in design considerations.

Fig. 6* shows that the comparatively low bottom velocity of 5 ft per sec is capable of moving rock particles as large as 4 in. in diameter. Apparently, the rate of erosion is dependent on the quantity, shape, size, and hardness of the particles being transported, the velocity of the water, and the quality of the concrete. Concrete-lined irrigation canals which usually carry small quantities of solids show no appreciable erosion after years of service for velocities as high as 6 ft per sec.

Where it is expected that the conduit will carry solids or that abrasion will result from solids and eddy currents, the concrete should be of the highest quality, because abrasion resistance increases as strength of the concrete is increased. It is not necessary to be as particular about alignment and surface smoothness where only abrasion is expected and where the velocity of the water will not exceed 40 ft per sec.

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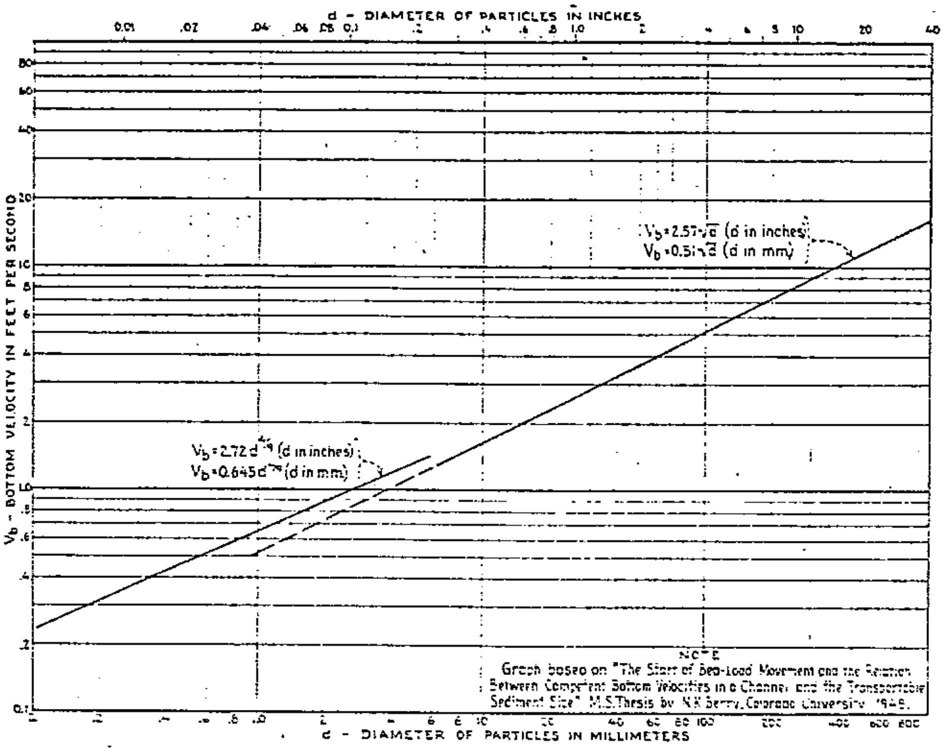
*From "The Start of Bed-Load Movement and the Relation between Competent Bottom Velocities in a Channel and the Transportable Sediment Size," by Norendra Kumar Berry, University of Colorado, 1948.



NOTE
Graph based on "The Start of Bed-Load Movement and the Relation Between Competent Bottom Velocities in a Channel and the Transportable Sediment Size" M.S. Thesis by N. K. Berry, Colorado University, 1948.

Fig. 6—Relation between competent bottom velocity and transportable sediment size

EROSION BY CHEMICAL ATTACK

The compounds present in set portland cement are attacked by water and many salt and acid solutions, though fortunately in most instances the action on an impermeable mass of hardened portland cement paste is so slow as to be unimportant. There are, however, certain conditions to which concretes may be exposed producing reactions which become serious.

One of the compounds formed when cement and water combine is hydrated lime, which is readily dissolved by water and more aggressively dissolved by pure mineral-free water as is found in some mountain streams. Dissolved carbon dioxide is contained in some fresh waters in sufficient quantity to make the water slightly acid and add to its aggressiveness. Serious attacks by fresh water, partly on concrete surfaces, but more markedly in defective (porous or cracked) parts of interior concrete of conduits have been reported in Scandinavian countries. In America there are many instances where the surface of the concrete has been etched by fresh water flowing over it, but serious damage from this cause is uncommon. A review of raw water in many reservoirs throughout the United States, published in V. 3 of the *Transactions of the Fourth Congress on Large Dams*, indicates a nearly neutral condition for most of these waters.

The main concrete corrosion problem in a sewer is chemical attack by sulfuric acid in the crown of the sewer. Sanitary sewage (domestic house sewage derived principally from dwellings, business buildings, institutions, and the like, which may or may not contain some groundwater, surface water, storm water, and a small proportion of industrial waste liquid) generally fluctuates slightly above and below a pH of 7.0, averaging out as neutral. Such sewage does not attack concrete. However, conditions of temperature, sewage concentration, and velocity of flow may be such that sulfur-bearing materials in sewage are converted to hydrogen sulfide gas by bacteria reposing in the silt or scum in the sewer. If sewage flows very slowly or is stagnant, the rate at which hydrogen sulfide is generated may exceed the rate at which it can be oxidized by the oxygen dissolved in the sewage and hydrogen sulfide gas may emerge into the atmosphere above the sewage. Before hydrogen sulfide gas can do any damage to the sewer crown it must come in contact with moisture on the crown where, under certain conditions, it is converted to sulfuric acid. Although information is available which should enable the engineer to design, construct, and operate a sewer so that the development of sulfuric acid is practically eliminated, it is not always possible to accomplish this, and corrosion of concrete sewer pipe from this acid is a serious problem in some cities.

No portland cement concrete, regardless of what may be its other ingredients, will long withstand water of high acid concentration. Where strong acid corrosion is indicated, an appropriate surface covering or treatment should be used. Replacement of a portion of the portland cement by a suitable pozzolan in amounts up to 30 percent will improve the resistance of concrete to weak acid attack.

Sulfates of sodium, magnesium, and calcium frequently encountered in the "alkali" soils and groundwaters of the western United States attack concrete aggressively. The sulfates react chemically with the hydrated lime and hydrated calcium aluminate in the cement paste to form calcium sulfate and calcium sulfoaluminate, which is accompanied by considerable expansion and disruption of the concrete. Concrete containing cement low in tricalcium aluminate (C_3A) is highly resistant to attack by sulfate-laden soils and waters. Whenever the sulfate (as SO_4) in the water is above 1000 ppm, a sulfate-resisting cement low in C_3A should be used. Use of a suitable pozzolan for replacement of Type I or Type II cements (which are usually relatively high in C_3A) in amounts approximating 30 percent will improve the sulfate resistance of the concrete. Rich mixes are more resistant to sulfate attack than lean ones.

MIX PROPORTIONS AND MATERIALS

It has been conclusively demonstrated that resistance of concrete to forces of cavitation and abrasion increases with increased compressive strength of the concrete. It is recommended that when the structure will be subjected to forces of cavitation or abrasion the mix be proportioned for a strength of at least 6000 psi. Where sulfate attack is expected, the water-cement ratio of the concrete should be held below 0.45 by weight. The ACI Committee 613 report* gives information on mix proportions, and the report of ACI Committee 614† gives information on measuring, mixing, and placing of concrete.

Cement

The type of portland cement is of little importance from an abrasion and cavitation-resistance standpoint, provided adequate compressive strength is obtained at the desired time. Cements low in tricalcium aluminate (such as Type V) are much more resistant to sulfate attack than cements high in this compound. No portland cement is resistant to acid attack.

Pozzolans

Pozzolans are siliceous materials, natural or artificial, which, though not cementitious in themselves, contain constituents that will, at ordinary temperatures, combine with lime in the presence of water to form compounds which have low solubility and possess cementing properties. Suitable pozzolans, when used to replace a portion of the portland cement in the concrete, combine with the lime liberated during the hydration processes to form a more stable product. Usually concrete is made more impermeable through addition of a finely divided pozzolan. Pozzolans improve the resistance of concrete to leaching and weak acid attack and to sulfate attack where they replace portions of cements relatively high in tricalcium aluminate. Concrete in which a portion of the cement has been replaced by a pozzolan usually develops strength slower than a concrete made with straight portland cement and this should not be overlooked where abrasion is expected soon after placing the concrete.

Aggregates

It has been demonstrated that the larger particles of aggregate are plucked out or pushed out of the concrete by the forces of cavitation more easily than the smaller particles. It is indicated, therefore, that the maximum size aggregate should be limited to ¾ in. where cavitation might occur. The aggregate should be sound, but its hardness is not of as great importance as in the case of abrasion where the aggregates resist abrasion after the layer of mortar has been eroded away. Good bond is more important than hardness in the case of cavitation.

In the case of abrasion, the aggregates are not pulled out of the matrix, but are worn down by solids carried in the flowing water. An aggregate which will resist wear is desirable in this instance, and the fine and coarse aggregate should preferably contain not more than 2 percent of soft particles. Aggregates are more resistant to chemical attack than cement paste, and any

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*ACI Committee 613, "Recommended Practice for Selecting Proportions for Concrete (ACI 613-54)," ACI JOURNAL, Sept. 1954, *Proc.* V. 51, pp. 49-64.

†ACI Committee 614, "Recommended Practice for Measuring, Mixing and Placing Concrete (ACI 614-42)," ACI JOURNAL, June 1945, *Proc.* V. 51, pp. 625-650.

aggregate which meets the usual specifications should be suitable where this is the main consideration.

Entrained air

Entrained air, obtained either by use of an air-entraining cement or an admixture, greatly improves the workability of concrete and its resistance to weathering. For the same cement content the strength of richer mixes is reduced slightly by air entrainment. But, in spite of this reduction in strength, use of entrained air in the proportions listed in "Recommended Practice for Selecting Proportions for Concrete (ACI 613-54)," is recommended wherever freezing and thawing is expected. Entrained air also improves the resistance of concrete to sulfate and acid attack under some exposure conditions; due apparently to improved impermeability.

Slump

Concrete for structures should be as dry as can be adequately placed, but in no case should the slump be over 3 in. Dry-tamped concrete used in machine-manufactured pipe should be on the moist side for best results.

FINISHES AND FINISHING

The formula given previously in this report shows that as the depth of water over the surface is increased the tendency toward formation of cavities in the water is decreased. Nevertheless, where water velocities of more than 40 ft per sec are expected, the concrete should be built to accurate alignment and evenness of surface. Abrupt irregularities caused by displaced or misplaced form sheathing, lining or form sections, or by loose knots in forms or otherwise defective form lumber, should not exceed ¼ in. parallel to the direction of flow and ⅛ in. at right angles to the direction of flow. Gradual irregularities which can be measured by a 5 ft long template should not exceed ¼ in. For formed surfaces of open, overflow-type spillways, irregularities may be increased to twice the size of those listed. For velocities above 100 ft per sec, irregularities should be reduced to half the size of those listed above.

Forms may be made of steel, wood, aluminum, or any other material which will give the desired smoothness and alignment. Green lumber should not be used because, in addition to shrinkage and warping which may occur, the tannic acid in the lumber may soften the surface of the concrete.

Forms should be removed at the earliest practicable time so that curing may proceed without delay and necessary repairs or surface treatment done while the concrete is still green and conditions are most favorable for good bond. The ACI Committee 604 report* gives information on form removal during cold weather. Offsets and bulges should be removed by grinding to specification limits.

The concrete of unformed surfaces should contain just sufficient mortar

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*ACI Committee 604, "Proposed Recommended Practice for Winter Concreting," ACI JOURNAL, Oct. 1955, *Proc.* V. 52, pp. 113-130.

to avoid the necessity for excessive floating. If the mix is wet and oversanded, an excess of water and fine material will be brought to the surface and the result will be a layer of inferior mortar having a high water-cement ratio with a tendency to dust, craze, crack, and possibly separate from the mass beneath. Working of the surface in the various finishing operations should be the minimum necessary to produce the desired finish. The first step in the finishing operation is the leveling and screeding of the concrete to produce an even and uniform surface. This is followed by floating, which should not be started until some stiffening has taken place in the surface of the concrete and the moisture film or "shine" has disappeared. The floating should work the concrete no more than necessary to produce a surface that is uniform in texture and free of screed marks.

From an erosion standpoint, floated surfaces are of sufficient smoothness for velocities less than 40 ft per sec. For high velocities the surface should be smoothed by steel troweling. Steel troweling should not be started until after the moisture film and "shine" have disappeared from the floated surface and after the concrete has hardened enough to prevent an excess of fine material and water from being worked to the surface. Steel troweling should be performed with firm pressure such as will flatten the sandy texture of the floated surface and produce a dense, uniform surface. Dense, impermeable surfaces are more resistant to impact by high-velocity jets than porous ones. Through use of absorptive forms or the vacuum process on flat surfaces, the denseness and strength of the surface of concrete can be increased above that which can usually be obtained by proper placing and finishing methods. These processes remove water from the surface of the concrete while it is still in the plastic state. Concrete surfaces can be protected from forces of cavitation and abrasion by rubber-like coatings (see "Resistance of Concrete and Protective Coatings to Forces of Cavitation," by W. H. Price and G. B. Wallace, ACI JOURNAL, Oct. 1949, *Proc.* V. 46, pp. 109-120). Tests have also shown that metallic aggregate greatly improves the resistance of concrete surfaces to erosion and pitting as a result of cavitation.

Precast concrete pipe is manufactured in a number of different ways, such as by placing and vibrating concrete in vertical forms as in any wall, by tamping and packing relatively dry concrete as in the packerhead and tamped processes, by spinning plastic mortar or concrete in a horizontal form, and by spinning, vibrating, and rolling relatively dry concrete in a rotating horizontal form. Conduits are also lined by various processes of applying and smoothing mortar on the inside surface of the conduit. There is considerable difference in density and strength of the surface concrete produced under the different methods and by different manufacturers under the same method due to variations in materials, consistency, and curing employed. It is recommended, therefore, after it has been decided what surface is desirable for the conditions of the job, that a process and procedure which will obtain this surface be specified. Specifications of the American

Society for Testing Materials and the American Water Works Assn. for concrete pipe and mortar-lined steel pipe are given in the bibliography.

CURING

Proper hydration of the cement to form hard and durable concrete requires that the concrete be maintained in a moist condition for a suitable period, usually 14 days. Usual procedure for accomplishing this is to keep the exposed surface continuously (not periodically) wet by spraying, ponding, or by covering with earth, sand, or burlap maintained in a wet condition. Moist curing should start as soon as forms can be loosened or removed. Curing of unformed concrete should start immediately after the concrete has taken its initial set. Under certain conditions it is desirable to cure concrete by applying to the exposed surfaces a sealing compound designed to restrict evaporation of the mixing water. An effective compound, properly applied and maintained for at least 28 days, will, under most conditions, retain enough moisture for adequate curing. A white-pigmented compound has been found to be especially suitable for hot weather curing, as it considerably decreases the heat which would be absorbed from direct sunlight.

Although attention to curing requirements is important at all times, it is especially so in hot dry weather because of the greater danger of crazing and cracking. Concrete as deposited should have a temperature of not more than 90 F because it has been shown that strength and durability of concrete decreases as the placing temperature is raised. Concrete placed in cold weather should be protected from freezing in accordance with the ACI Committee 604 report.

REPAIRS OF ERODED AREAS

Where concrete has been damaged by erosion it is almost certain that the repaired section will be damaged also unless the cause of the erosion is removed. The best concrete made will not withstand the forces of cavitation or severe abrasion for a prolonged period. It may be more economical, however, to replace the concrete periodically than to reshape the structure to produce streamlined flow or to eliminate the solids causing abrasion. Furthermore, it may be undesirable to streamline those portions of the structure designed to dissipate energy such as dentated sills and other types of obstructions to the flow of water placed in stilling basins of spillways. Such sills should be made of the best possible concrete.

In repairing concrete it is necessary that attention be paid to many details, because experience has demonstrated that repairs that are carelessly made later become defective and have to be replaced. All damaged concrete and loose and broken particles should be removed. Where the thickness of section permits, holes to be repaired should be enlarged to a minimum depth of 6 in. with a minimum area of ½ sq ft in reinforced and 1 sq ft in unreinforced concrete. There should be a clearance of at least 1 in. around each exposed reinforcing bar; they should not be left partially embedded. The top edge of the hole in walls at the face of the structure should be cut to a fairly horizontal line. If the shape of the eroded area makes it advisable, the top of the cut may be stepped down and continued on a horizontal line. In all cases in walls or floors it is desirable to make a square edge by cutting around the area to be repaired with a concrete saw prior to chipping out the area to be repaired.

It is extremely important that the concrete to be repaired be thoroughly cleaned by wet sandblasting, followed by washing with an air-water jet. The holes should be kept continuously wet for not less than 12 hr prior to placing new concrete. Cavities should be free of any water at the time of placing and preferably should be surface dry. The replacement concrete should have a slump as low as is consistent with thorough vibration and good placement.

Where velocities above 40 ft per sec are encountered, the repaired areas should be made smooth. It may be necessary to grind them after they have hardened.

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For such discussion of this paper as may develop please see Part 2, December 1956 JOURNAL. In *Proceedings* V. 52 discussion immediately follows the June 1956 JOURNAL pages.